5G Challenge Response

2/10/2021

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Challenge Structure & Goals

I. How could a Challenge be structured such that it would take advantage of DOD's role as an early U.S. Government adopter of 5G technology to mature the open 5G stack ecosystem faster, encourage more participation in open 5G stack development including encouraging new participants, and identify any roadblocks to broader participation?

An open invitation to the industry to join an alliance of strategic developers, government, academia, and regulatory compliance experts targeted on the development, implementation and interoperability test and certification of open and agile 5G network components. The alliance would consist of groups focused on the following:

1. The 5G compliant RAN including Software Designed Radio (SDR)
2. The 3GPP complaint 5G Core network functions.
3. The 5G compliant open stack network.
4. Compliant end User Equipment (UE).
5. Spectrum allocation for open networks.
6. Cyber security
7. A neutral workforce management program to facilitate an integrated deployment, ***NOC, and training platform that will lead to national and international deployment of open 5G networks. (See SLA "Narrative for the 5G Challenge")***
8. Monetization (with relative thresholds) – Temporary Patents – Data Exchange bargaining – open market for purchasing bandwidth over the network.

A) The DOD would serve as the head sponsor of the alliance with direct support from the NTIA and US Department of Commerce.
B) During the first phase the alliance would address the following:

1. Identification of all applicable software development items.
2. Development of a roadmap from definition to certification for each develop item including the following.
    - Definition/Refinement of each open development item and associated APIs.
    - Development a timeline for each open item
    - Designate all working groups with members needed to address the various functions.
    - Establish a spectrum allocation team that would work to acquire spectrum for using the 5G open networks and coordinate with the FCC and other government bodies from other countries.
    - Establish a steering committee that would represent the government, academia, and private sector to oversee the overall development, test, and certification process.

C) In the second phase the alliance would focus on development and address the following

- Establish and maintain the overall schedule.
- Identify and then facilitate gate reviews.
- Establish the certification, interoperability, and approval/homologation process for all open development items.
- Establish the compliance and regulatory requirements in coordination with regulatory bodies.
- Refine the technical characteristics of each development item.
- Determine the regulations and laboratory tests which will be necessary for certification.

D) In the third phase the alliance would focus on testing and deployment and would address the following

- Work with alliance members on reducing barriers to entry, especially for smaller firms, associated with the defense acquisition process.
- Identification/development of laboratory/test beds for certification and interoperability testing.
- Commence certification and interoperability testing.
- Develop the workforce platform to Re-patriate 50k to 75k US jobs for Veterans and facilitate national and international deployment. ***(See SLA "Narrative for the 5G Challenge")***

E) How could a Challenge be structured to focus on the greatest impediments to the maturation of end-to-end open 5G stack development?

- During the initial phase of the project a risk assessment will be conducted identifying those development items with the highest risk.
- Once the high-risk development items and long lead processes are identified a risk assessment and analysis will be performed on each and processes put in place to avoid and/or mitigate each risk.
- An automated testing plan would be created in order to test high risk function points in the network. Automated testing would be mandatory for vendors and the results of these test would be accessible to key DoD staff.

F) What should be the goals of a Challenge focusing on maturation of the open 5G stack ecosystem? How could such a Challenge be structured to allow for the greatest levels of innovation? What metrics should be used in the assessment of proposals to ensure the best proposals are selected?

- The salient goals must focus on the development of a truly open 5G network from core, network, service functions to the UE in the shortest time possible.
- To accomplish this, see "***Enabling 5G Network Automation Over AWS with RIFT"***
- A minimum SLA would be established for each portion of the network for each vendor required

G) How will the open 5G stack market benefit from such a Challenge? How could a Challenge be structured to provide dual benefit to both the Government and the open 5G stack market?

- There are many common challenges facing the private and public sector extending broadband services into underserved and unserved rural areas. Namely the cost of extending fiber infrastructure, the resistance by incumbent players to make the investment, and the closed nature of today's 5G networks. A shared cost of new infrastructure builds with local, state, and federal government departments, utilization of an open 5G stack network, and utilization of open 3GPP complaint 5G Core network functions in the cloud would make it feasible for both incumbent and new carrier entrants to provide services to unserved and underserved customers.
- Selected, more aggressive state Departments of Public Services, such as Vermont, could be added to the alliance to bring their experience and bring synergy to this Challenge. Many states are now developing their 10 Year Telecom Plans and the focus is on bringing 100 Mbps symmetrical service to every customer by 2024. The solutions will include extended fiber builds into more rural areas supporting 5G wireless service in the last mile.
- Open 5G Market: Vendors would be able to list pricing for specific network services based on the amount of bandwidth passing through the network. For instance, Software providers would charge a rate based on the amount of bandwidth passing over either their software or cloud infrastructure while hardware providers could do the same. This would allow Vendors to monetize portions of the infrastructure and allow smaller Vendors to enter the space by focusing on and being able to monetize a specific aspect of the 5G Network infrastructure. If there are multiple providers in a specific segment of the market (for instance multiple hardware providers), 5G service providers could pick and choose which vendors they want to use for specific portions of the network, which is not possible given interoperability standards and automated testing that would show which portion of the network failed (and often times how).
- Subsidies would be provided for under-served areas, opening up new markets that were previously financially unsustainable to incumbent operators and new entrants.
- Open 5G vendors would benefit from its relationship with other vendors and benefit from interoperability while being fairly compensated for their involvement via the Open 5G Bandwidth market

II. Incentives and Scope

A) What are the incentives in open 5G stack ecosystem development that would maximize cooperation and collaboration, promote interoperability amongst varied open 5G stack components developed by different participants, and mature desired featured sets faster with greater stability?

- Two factors would promote cooperation and collaboration. First, developers taking an active role in the alliance will be first to market with their products. Second, strictly enforcing certification and interoperability testing will make it paramount for all developers interested in future DOD business to take an active role. Third, by forcing interoperability and certification testing a 5G open network will attract smaller, more innovative developers and operators.
- Subsidies provided by government funds will open up new markets to Open 5G that previously were financially disadvantageous to enter into. Incumbent Operators would benefit in that they have a boarder market to server while new entrants will have new "greenfield markets" to enter into where Incumbent 5G Operators may have limited or no current infrastructure.
- The 5G Bandwidth market will allow vendors to focus on their core offering without requiring them to be a one stop shop for the entire network. This will allow smaller more agile and specialized firms to collaborate on the project without having to reach a scale large enough to be a one stop shop, they will also not have to own the end customer since the 5G Network would be open architecture, which allows for smaller, more agile and more innovative entities to enter the market with a lower threshold requirement for startup capital.
- Open Architecture with interoperability standards would also allow for new technologies to be developed by Niche software and hardware startup companies that may be able to obtain new funding more easily as investors become interested capitalizing on the new 5G Open Market / Open Network.
- Existing AI tools should be leveraged to assist new entrants in determining which markets would have the highest ROI for entry. These same tools should be used by Government agencies in helping determine what subsidies should be provided to ensure coverage in underserved markets.

B) Could a Challenge be designed that addresses the issues raised in previous questions and also includes test and evaluation of the security of the components?

- Security requirements would be addressed throughout the network development cycle from the backhaul, 3GPP core, to the UEs.
- Security would be made a paramount part of the certification testing described in I. See "Enabling 5G Network Automation Over AWS with RIFT" for detail.

C) 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?

- Specific database structures maybe required to increase the ease of interoperability.
- Software vendors would need to build Open API's with adequate documentation to allow for interoperability.
- Automated testing and 5G Open Network standards will be required in order to regulate and maintain interoperability.
- Existing AI tools should be leveraged to determine what infrastructure gaps pre-exist within the 5G market in the United States.

D) 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?

- TBD

E) 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 portions of the control and user functions in a 3GGP core network need to be addressed.
- An agile, open RAN that can be utilized in various spectrums and bands depending on where deployments could take place and easily homologated.
- A Software Defined Radio that can be easily upgraded to meet future 6G, 7G technology and beyond.

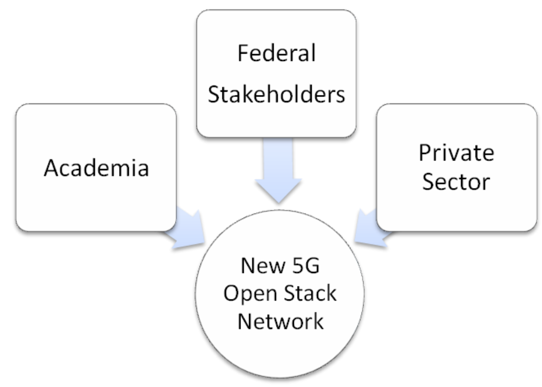
End of Section

Narrative for 5G Challenge

New 5G Open Stack Network for the Public Sector

Introduction: Neutral Workload Management Platform for 5G & Cloud Edge

Deployment of a Hybrid Cloud workload management platform for user neutral access to deploy testing and training resources delivered by Educators, DoD Contractors, Federal Agencies and Non-Profits. (pg2)

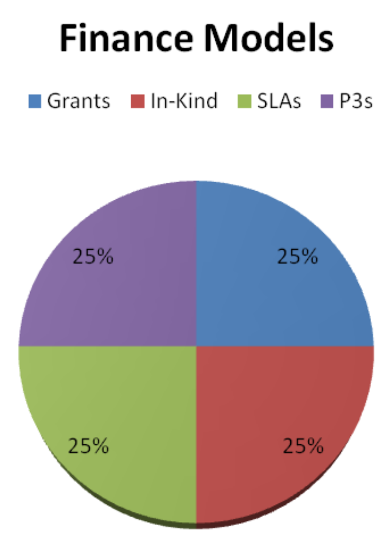


Defined Goals:

- Deploy a Small Cell 5G Open Stack Network for DOD/DOC
- Acquire, Train, and Deploy a 5G Workforce for Infrastructure Support
- Leverage Select Federal Agencies for Deployment
- Engage Private Sector Contributors to the Model
- Introduce a New DOD Revenue Model (JOBPODs) to support long term growth
- Re-patriate 50K to 75K US Jobs for Veterans by 2025

Federal 5G Stakeholders

- US Department of Defense
- National Telecommunications and Information Administration, U.S. Department of Commerce



Contributing Federal Agencies and Programs

- US Department of Labor
- Federal Communications Commission
- Chief of Workforce Management Directorate Chief, Cyber Excepted Service Branch
- Office of Transition and Economic Development Veterans Benefits Administration
- U.S. DOD 5G to Next-G Initiative
- DOD SkillBridge, STEM, SMART, CTE and VetTech

SLA Labs Finance Models are 100% Leveraged Project Funding

- SLA Revenue from Managed IT Agreements by SLA Labs= 25%
- DOD In-Kind Contribution = 25%
- Federal Grants = 25%
- Private Public Partnerships In-Kind Contribution (P3s) = 25%

Non Profit Project Contributors

- SLA Labs & Neo Networks
- National Urban League
- The Wireless Infrastructure Association

Proposed Test Sites Phase I: Establishing the 5G Coalition = 50% of the Finance Model

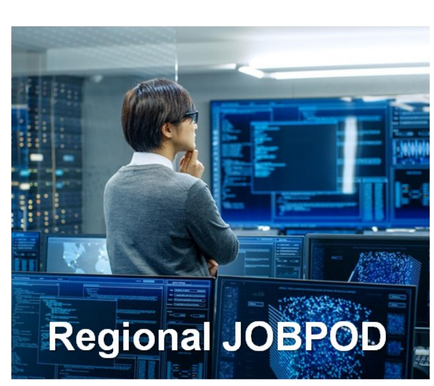
The following list of test sites have been chosen for their strategic value proposition to meet funding requirements, leverage the academic research base & train workforce with military site proximity. The metrics used for selection is predicated on the funding model requirements for H1Bs grants to engage academia and FCC Rural Broadband grants for infrastructure. Each site having a strategic investment value for private /public partnerships.

State	Site Designation	Miltary Sites	Partner Colleges	Partner HBCUs	HBCU Rank
Maryland	Super Regional	Fort Meade	University of Maryland*	Bowie State & Morgan State	3 & 5
Georgia	Regional	Fort Gordon	Augusta Technical	Payne College	7
North Carolina	Regional	Fort Bragg	NC State, Shaw University	North Carolina A&T State University	1
Alabama	Regional	Redstone Arsenal	JF Drake CC	Alabama A&M University	4
Florida	Micro	Elgin AFB	Tallahassee CC	Florida A&M	6
Virginia	Regional	Norfolk Naval Station	Old Dominion	Norfolk State University	7
Georgia	Micro	Robins AFB	Middle GA State	Fort Valley State University	9
Georgia	Micro	Dobbins AFB	Kennesaw State	Spelman College	14
Florida	Micro	Homestead AFB	Miami Dade CC	Florida Memorial	15
Texas	Regional	Ellington Field	Houston CC	Prairie View Houston	29

SLA Labs Hybrid Workload NOC Platform = 25% of Finance Model Detailed PG-3

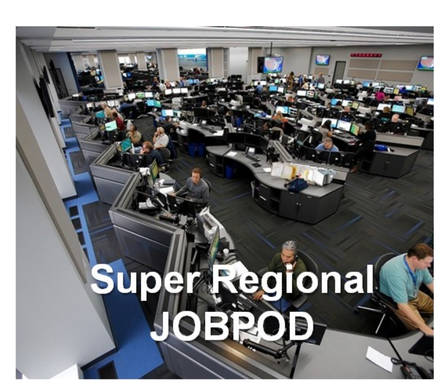
25 Workstation Hybrid NOC

- $65K Year Facility Allotment
- $350K Annual Training Allotment
- $250K Annual Economic Payback



50 Workstation Hybrid NOC

- $100K Year Facility Allotment
- $550K Annual Training Allotment
- $500K Annual Economic Payback



100 Workstation Hybrid NOC

- $135K Year Facility Allotment
- $750K Annual Training Allotment
- $1M Annual Economic Payback

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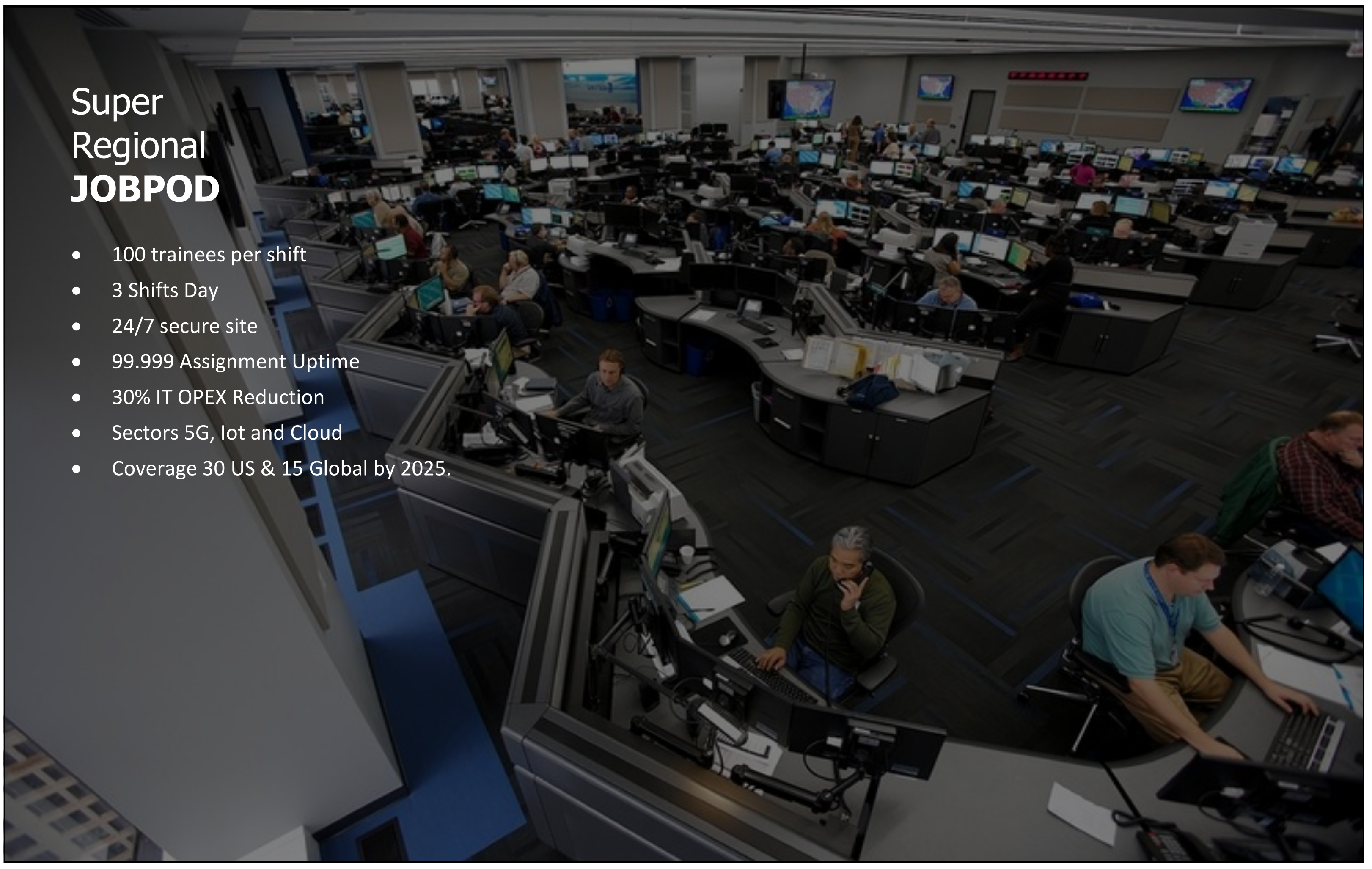


Mission Statement: SLA Labs deploys Hybrid NOCs as a new work-learn platform *AKA: JOBPOD* to support workforce engagement and infrastructure deployments through IT CO-OPs. Partners include employers from 5G, Cloud, Cloud Edge, Cyber Security and Iot sectors working closely with City, State and Federal Government stakeholders for mutual work – learn outcomes. JOBPODs are self sustaining repurposed NOCs (Network Operating Centers) supplemented by private sector IT workloads repatriated from off-shore competitors and deployed as a new training platform for veterans and underserved students. Public Sector funding by Department of Labor H1B grants support workforce engagements & FCC Rural Broadband grants support 5G infrastructure deployments for P3s established by SLA Labs.

JOBPODs perform live workload training & testing assignments on a neutral 24/7 platform that support mission critical infrastructures in a private / public sector environment.

JOBPODs are leveraged to support 5G, Broadband and Cloud infrastructure deployments at a cost savings of 30% to 50% below market CAPEX & OPEX when deployed through SLA Labs P3s.

Private Sector Partners: 5G, Broadband, Cloud, Cloud Edge, and Iot sectors are represented.

Market Verticals: SaaS (Software as a Service), IaaS (Infrastructure as a Service), CMMS (Computerized Maintenance Management Service), PaaS (Platform as a Service), MBSE (Model Based Systems Engineering), DCIM (Data Center Infrastructure Management) and BMS (Building Management Systems) .

Principals: SLA Labs (non-profit), Private and Public Sector Partners

Existing Business Training Units: Customer Service & Dispatch, Escalation Management, Help Desk, Managed IT, Network Engineering, Service Delivery, Software Testing and Human Resource Development.

Proposed NEW Testing Units to Meet DOD Directives: Cyber Security, Hypersonics, Missile Warning, 5G Communications, Quantum Information Science, Micro Nuclear Reactor, Autonomy, Artificial Intelligence

JOBPOD Types: Micro (25*), Regional (50*) & Super Regional (100*). *# of trainees per 4-8 hours shift.

Facility Requirements: JOBPOD facility requirements range from 1,500-5,000sf with 25-100 work stations with meeting area and secure space / network access.

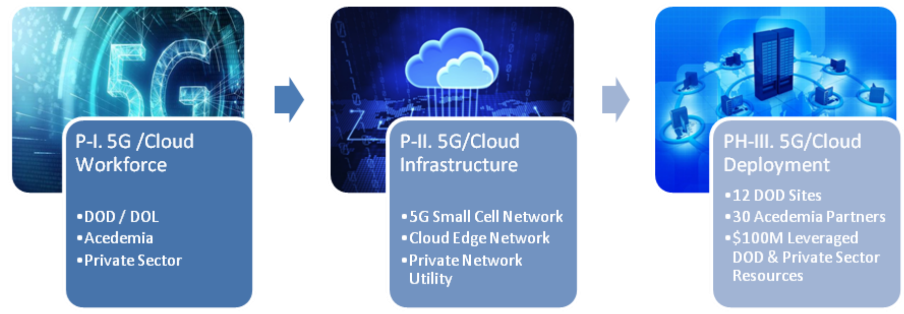
The Private/Public Engagement: 50% of IT Training CO-OP Funding is Established by SLA Labs Acquisition of Government Grants & Opportunity Zone Incentives for deployments. 50% of IT Training CO-OP Funding is Established by SLA Labs Subsidized IT Assignments with Private Sector Partners.

Public Sector Partners: Higher Learning**,** City, State, County and Federal Stakeholders.

SLA Labs Provided Services: SLA Asset Management including but not limited to: IT CO-OP management & administration, training supervision, training curriculum development, private sector engagement, OPEX & CAPEX admin, marketing and business development.

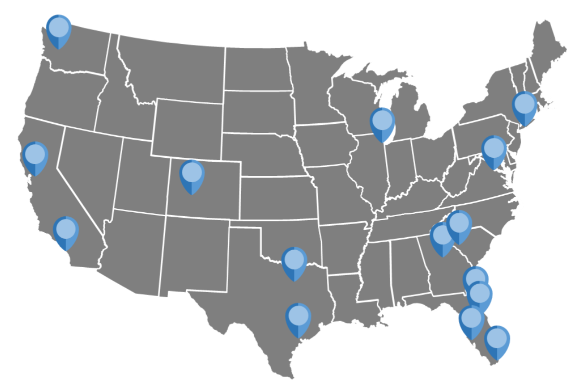
JOBPODs by the Numbers: Grant amounts $1M to $10M per site, annual community payback value proposition up to $1M per site for jobs created, 30% to 50% reduction in OPEX and CAPEX for infrastructure deployments in 5G/Cloud and Broadband sectors.

Phase I. Workforce: Rather than outsourcing the costs associated with 5G deployments, SLA Labs approach is different. Our team will identify partner resources that can be leveraged to make up to 100% of deployment costs for a DOD owned private 5G network. First our team looked at DOD resources for workforce engagement and identified (5) existing DOD workforce programs to be leveraged for this purpose. They are DOD SkillBridge, STEM, CTE, SMART and VetTech. When combined with SLA Labs Hybrid NOC workforce model, the DOD could stand up a long term self sustaining workforce solution to build out national ***5G and Cloud*** networks while meeting Department of Defense 5G Requirements. These are ***1. Promote technology development, 2. Asess, mitigate, and operate through 5G vulnerabilities, 3. Influence 5G standards and policies, and 4. Engage partners.*** ****1 & *2****



Phase II. Infrastructure: Next our team looked at Federal resources that can be leveraged for a DOD owned 5G infrastructure build out. SLA Labs has identified two key federal agencies that meet infrastructure requirements, they are the DOL and FCC. Both federal agencies share the same DOD mission to expand 5G access to underserved communities and expand 5G nationwide. The DOL currently supports 5G workforce development by providing private/public access to H1B grants and the FCC currently provides private/public access to infrastructure funding for 5G through Rural Broadband Grants. When combined with SLA labs 5G deployment model up to 100% of the infrastructure costs can be leveraged when those deployments are used to stimulate investment from private & public partnerships.

Phase III. National Deployment: SLA Labs has identified 12 military sites, 30 Community Colleges, $100M in leveraged DOD and Private Sector resources for a DOD owned private 5G network. In addition, SLA Labs sampled 3 DOD contracts from December 2020 and identified $1.1M of leveraged resources from DOD Partners to support a 5G deployment.



SLA Labs centerpiece for 5G deployments is the **Hybrid NOC (Network Operating Center)** repurposed as a work-learn environment and funded with repatriated off-shore IT workloads and deployed as a new training platform for veterans. Working with DOD SkillBridge, STEM, CTE, SMART and VetTech, SLA Labs will introduce a Hybrid NOC as a DOD pilot in Maryland with 12 remote-in sites to be brought on line nationally in phase 1.

Proposed sites for a Hybrid NOC are Joint Base Andrews, Fort Meade and Aberdeen Proving Grounds in Baltimore. Fort Meade can be adopted right away with the University of Maryland and both are located in federal opportunity zones for P3's. SLA Labs maintains a teaching partnership for 5G at the University of Maryland and is associated with the WIA https://wia.org/industry-initiatives/education/ who received a DOL Grant 2/19/2020. The WIA has a DOL recognized apprenticeship program and was key partner on the SLA Labs team that submitted the Shaw University H1B workforce grant application for the City of Raleigh & NC State P3 submitted on Nov 12th 2020. Our team also identified two HBCUs in Baltimore Opportunity Zones, Morgan State https://www.morgan.edu/scmns with Computer Science & STEM programs that meet DOL guidelines for workforce deployment in Maryland. Bowie State is outside the opportunity zone next to Fort Meade but close to Annapolis MD.

Key Takeaways for 5G / Cloud / Cloud Edge Deployments During Current Economic Conditions

In an age of Covid the US has been forced to acknowledge its weaknesses in the economy and communications infrastructure changing forever the way we learn and work. As a result new opportunities emerged for remote learning, remote working and telehealth but at what cost? New remote working and learning habits have forced an accelerated time table to stand up new 5G networks and prepare the skilled workforce to maintain its infrastructure. In response, private and public sectors have a renewed focus on infrastructure investments to take swift and decisive actions to accommodate growth.

Why does the largest US Employer (DOD) have a problem attracting the Best IT Talent Available? A number of factors affect demand for skilled IT new hires. A shrinking US talent pool for high growth sectors. A lack of marketable skill sets by new hires entering the workforce. Pay scales not meeting US talent demand standards. Increased pressure from well funded private sector employers to outbid the DOD for the best talent the US has to offer.

Combating the IT workforce shortage also means taking back IT jobs that are off shored by US Employers. In an effort to save money and prop up the bottom line, 68% of US companies have been off shoring IT jobs for years with unintended consequences. Short sighted US Employers gain profits but hand over control of their IT infrastructure and open themselves up to unintended security breeches, what's the solution?

Why Does a Hybrid NOC Make Sense for the DOD? A Hybrid NOC...

- Produces supplement resources required to operate DOD SkillBridge, STEM, CTE, SMART and VetTech programs.
- Manages repatriated off-shore IT workloads as a new income source and training platform for veterans.
- Supports IT workloads on an independent network dedicated to 5G, Cloud and Iot projects transitioning from private / public sector testing phase to DOD service phase.
- Offers private sector partners a domestic workload management solution on a DOD co-hosted platform to replace off-shore competition for domestic IT workload management.
- Sustains a domestically trained veteran workforce meeting the IT manpower needs of the DOD.
- Provides an incentive for DOD recruits to obtain a work-learn experience through a DOD/College infused career path over a college only career path.

Source Material: SLA Labs is providing for discovery a detailed review of the business training units (links) that will be deployed at each location to execute veterans' transitions from their existing service to their engagements in the private sector. Each business unit is a self sustaining operation that engages veterans in one hour of instruction and up to seven hours of workload management during any eight hour shift. Instruction is provided remotely by public sector partners and workload assignments secured by SLAs (Service Level Agreements) with private sector partners. SLA Labs maintains oversight of business unit operations 24/7/365 with on-site network engineering staff engaged in the execution of private sector workload management.

A. DOD IT CO-OP for 5G Cloud Cyber Project Delivery ***https://drive.google.com/file/d/1XbhphVUr4CxEPOW5hpEiJcmRsvtIDdHw/view?usp=sharing***

B. Proposed Business Units as Workforce Solutions: ***https://drive.google.com/file/d/1f-XnVizQ17oFRgzq-jEmSXUAoWImnxQd/view?usp=sharing***

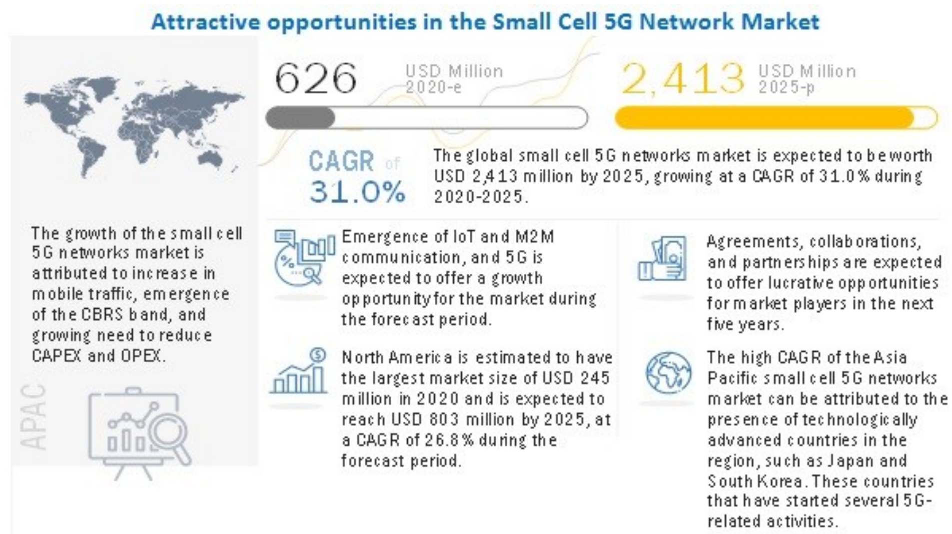
1. DoD 5G Strategy, https://www.cto.mil/wp-content/uploads/2020/05/DoD_5G_Strategy_May_2020.pdf.

2 National Strategy to Secure 5G, https://www.whitehouse.gov/wp-content/uploads/2020/03/National-Strategy-5GFinal.pdf.

Making a Case for Small Cell 5G

The small cell 5G network market size is expected to grow from USD 626 million in 2020 to USD 2,413 million by 2025, at a Compound Annual Growth Rate (CAGR) of 31.0% during the forecast period.

Small cells are low-power base stations that are used to improve network coverage and network capacity, helping end users to bolster their wireless connectivity. These cells are mostly deployed over indoor and outdoor environments to deliver rapid data services to customers. The small cell network would play a pivotal role in 5G networks. Currently, 5G telecom operators are more focused on deploying small cell under low-frequency band for delivering improved bandwidth services to customers. In the later stage of 5G deployment post-2021–2022, the adoption of small cell network for mmWave would be expected to increase, as operators are expected to massively deploy small cell solutions for Internet of Things (IoT) and Machine-to-Machine (M2M) communications.



e: estimated; p: projected

https://www.marketsandmarkets.com/Market-Reports/small-cell-market-216204568.html0

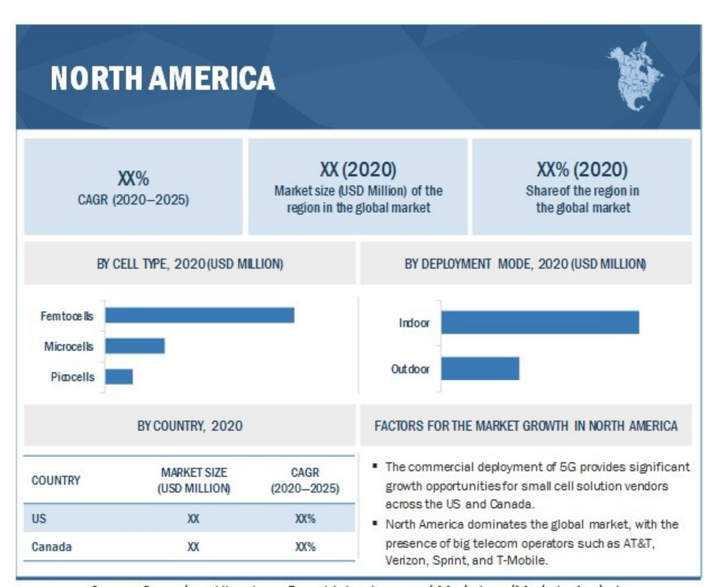
Driver: Emergence of citizens broadband radio service band The CBRS band is the key component driving the small cell 5G network market. The band offers a tremendous new spectrum resource that can be allocated for indoor mobile networks. The use of CBRS spectrum band for indoor frees up valuable licensed spectrum which would otherwise have to be allocated for indoor use. It also eliminates the possible co-channel interferences between macro and indoor networks. CBRS small cell enables multi-operator support and offers cost-effective mobile coverage solution for third-party neutral host providers and large enterprises. CBRS small cell network simplifies network integration efforts and is able to enhance the user experience as compared to Wi-Fi offloading.

Restraint: Poor backhaul connectivity The major backhaul challenge that mobile network operators had to deal with up to 5G network includes ultralow latency of ~1 Millisecond (ms) (roundtrip) connectivity requirements. Small cells are deployed at high rate network congestion places or where macrocells coverage is poor, and backhaul and power are usually not available. Radio backhaul is one of the potential solutions for this issue, but unit size reduction and throughput testing is a must for the small cell deployment, which may result in increased deployment cost. Unavailability of an alternative backhaul solution creates a significant barrier for the proper deployment and working of small cells. Thus, to overcome such issues, service providers must have a strong service delivery process that is reliable and flexible to terminate backhaul services in a variety of non-traditional locations, such as billboards, telephone poles, and sides of buildings. To tackle the backhaul connectivity problem, denser small cell deployment is required under 5G network, and over a period of time if the issue of poor backhaul is not resolved then vendors may need to find alternative backhaul options such as Wi-Fi and next-generation satellites to satisfy service expectations.

Opportunity: Emergence of 5G: The small cell market is driven due to emerging 5G technology and its increasing deployment rate. The high speeds and low latencies of 5G networks lend themselves to the small cells 5G network market. Next-generation wireless networks will be essential to solve the issue of mobile traffic congestions. Supporting policies have been drawn by the governments across the globe to assist industry in R&D and strive for 5G commercialization. China is expected to implement 5G technology for a multitude of life transforming applications from 3D video to immersive media and audio quality due to its ultrahigh data rates, enhanced capacity, and reduced latency. China is planning to reach 576 million 5G connections by 2025, almost 40% of 5G connections globally. Small cells are a perfect fit into 5G revolution as they provide increased data capacity and assist service providers in reducing the overall cost by eliminating expensive rooftop systems and installations or rental costs. The small cell 5G network also helps to improve the performance of mobile handsets, as it transmits at lower levels, which effectively lowers the power of cell phones and substantially increases their battery life.

Indoor segment to constitute a larger market size during the forecast period: The indoor segment is expected to be in high demand, due to their wide range of functionalities, such as high indoor network connectivity and improved network coverage. The deployment of indoor small cells is more due to the major deployment of small cells in public places, such as stadiums, shopping malls, college campuses, and residential buildings. The 5G indoor small cells market space is expected to grow significantly during the forecast period, as people spend most of the time indoor and they are unsatisfied with their indoor cellular connection performance. According to the telecom operator, Ericsson, people spend 90% of their time indoor and 60% of the users are unsatisfied with their indoor cellular connectivity.

Among radio technologies, the 5G NR standalone segment to grow at a higher CAGR during the forecast period 3rd Generation Partnership Project (3GPP) has completed the specification for the 5G New Radio (NR) non-standalone technology, which would be rollout in the early 2019 and the 5G NR standalone version is expected to be available by 3rd or 4th quarter of 2019. 5G NR standalone solutions are expected to be more effective than 5G NR non-standalone solutions. 5G NR standalone solutions are expected to have various new in-built capabilities. In the early phase of 5G deployment, small cell deployment for 5G NR standalone segment is expected to be in a niche stage and projected to grow exponentially during the forecast period.



Source: Secondary Literature, Expert Interviews, and MarketsandMarkets Analysis

North America to account for the largest market size during the forecast period. The global small cell 5G network market by region covers 5 major geographic regions, namely, North America, Asia Pacific (APAC), Europe, Middle East and Africa (MEA), and Latin America. North America is estimated to account for the largest market size during the forecast period. North America is an eminent leader in adopting advanced technologies. Operators across North America are expected to deploy small cell solutions on their 5G mobile infrastructures; for example, AT&T, Verizon, Sprint, and T-Mobile have shown positive approach toward commercializing 5G networks. These operators have signed billion-dollar deals with network equipment providers, such as Nokia, Samsung, Ericsson, Huawei, and ZTE, to build up their 5G network infrastructure.

Enabling 5G Network Automation Over AWS with RIFT

Introduction The next generation of mobile services promises support for all uses, from smart appliances to interactive, high-resolution gaming. The ultimate vision of 5G not only provides frictionless delivery of traffic in terms of bandwidth, latency, and scalability, but also frictionless delivery of the service itself, from the moment of customer request to the availability of the service.

This combined vision of instant-on, bespoke mobile networks at scale can be achieved only through a combination of technologies that provide:

- Top-to-bottom automation of service fulfillment, from the service provider's customer portal to the infrastructure layers.
- End-to-end automation that works across multiple technology domains and locations, from Radio Access Network (RAN), Transport, and Core, to private, public, and edge clouds.
- Automated management of the 5G service, to maintain high performance and availability, and to ensure the customer's Service Level Agreements (SLAs) are met.

Yet challenges remain in the realization of this vision. While it is possible to build catalogues of applications and network functions and launch them in the cloud, many network functions today are still virtual machine (VM)-based, and not built with cloud ready techniques in mind. The service-based nature of 5G slices and the evolutionary characteristic of the 5G architecture requires service providers to design and build networks of applications and network functions that span VM-based and container based clouds in various locations, to meet the customer's service, coverage, and performance needs.

AWS and RIFT can overcome these challenges and help to realize the vision. AWS provides various types of cloud services and application programming interfaces (APIs) which enable the design of cloud-native network functions and micro services applications. AWS can provide single pane of glass unified management tools, including DevOps and CI/CD pipeline, to effectively operate these network functions and applications. However, it is a common requirement in the telecommunications (telecom) industry to have an orchestrator/manager application that meets industry standards. AWS provides the building blocks for programmable operation and automation pipelines.

RIFT is a company that bridges the IT and network domains through the development of RIFT.ware™, a next-generation, model-driven, standards-compliant network functions virtualization (NFV) automation and orchestration product with carrier-grade capabilities. RIFT.ware provides an environment to automate the on boarding and life cycle management of multi-vendor 5G network slices across any cloud environment and technology domain.

RIFT.ware also streamlines the operation of these slices through Closed Loop Day 2 operations, which include zero-touch, end-to-end network service management such as auto scaling or self-healing. (Day 2 operations usually means ongoing configuration change and update after Day 0 deployment and Day 1 configuration.)

Together, AWS and RIFT.ware form an ideal infrastructure for end-to-end automated management and operation of 5G slices. The RIFT.ware solution is a multi-standards automation solution that enables end-to-end service orchestration across hybrid clouds.

RIFT.ware's standards-based APIs and models are built according to TM Forum, Internet Engineering Task Force (IETF), European Telecommunication Standards Institute (ETSI), and 3 rd Generation Partnership Project (3GPP) specifications to enable integration with operations support system/ business support system (OSS/BSS) for deployment of 5G, Software-Defined Networking in a Wide Area Network (SD-WAN), and multi-access edge computing (MEC) across cloud types and locations. This is to create end-to-end services by chaining cloud deployments across the WAN, and to enable standards-based 5G slice and slice SLA management.

As a multi-standard, compliant, open-source product, RIFT.ware is designed to eliminate vendor lock-in through multi-domain orchestration of any use case across any cloud at any site. RIFT.ware is designed to reduce operating expenses (OPEX) by providing a single pane of glass into the 5G slice operating environment. Designed as a product and not a loose toolset or framework, RIFT.ware also increases service velocity through the incorporation of standards-compliant templates and built-in integrations to the service provider OSS/BSS and NFV ecosystem.

In the following sections, we examine how AWS Services and tools, coupled with RIFT's RIFT.ware Orchestration and Automation suite, can automate a service provider's 5G offerings, and achieve the goals of 5G slice deployments.

AWS Services and RIFT.ware for Management and Orchestration

As described in a previous whitepaper called 5G Network Evolution with AWS, one of the most common challenges of CSPs in the era of NFV and 5G is Management and Orchestration (MANO) defined by ETSI Industry Specification Group (ISG) NFV across all networks and infrastructure resources, as well as end-to-end service configuration. In the case of the 5G mobile network, network slicing is leveraged to create a dedicated network for enterprise and specific service use cases. This means that orchestration will have to solve another layer of complexity. In the referenced paper, three different options for implementing the orchestration layer for 5G networks have been explored:

- AWS native management and orchestration
- Extended orchestration using AWS tools
- Application-based orchestration by API interworking The third approach provides the MANO layer on AWS by deploying RIFT.ware as Service Orchestrator, NFV Orchestrator (NFVO), and Generic Virtual Network Function Manager (VNFM) into the AWS platform, and integrating with AWS as a Virtualized Infrastructure Manager (VIM) through the native AWS APIs.

It is also beneficial to leverage AWS Services natively, and develop using container services, such as Amazon Elastic Container Services (Amazon ECS) and Amazon Elastic Kubernetes Service (Amazon EKS), AWS App Mesh, server less (AWS Lambda), and Amazon API Gateway, as well as Continuous Integration / Continuous Delivery (CI/CD) DevOps tools. This approach results in the creation of an orchestrator that is fully built based on microservice-based flexible architecture. This is a critical aspect, because the complexity of the 5G orchestration tool will continue to increase as new service cases get added. Microservice-based architecture will ensure that the orchestrator can be further developed and enhanced in an agile and flexible manner. RIFT.ware RIFT's RIFT.ware is a carrier-grade Orchestration and Automation platform that delivers management and life cycle automation of virtual network services, applications, and functions with scale. Designed specifically for deployment of service provider use cases,

RIFT.ware simplifies the day-to-day operations of network functions, and the composition and management of complex network services. RIFT.ware is a cloud native, modular, and scalable system that is capable of providing orchestration and automation services according to the following common architectures:

- 3GPP Slice Management Functions: Communication Service Management Function (CSMF), Network Slice Management Function (NSMF), Network Slice Subnet Management Function (NSSMF)
- ETSI NFV Management and Orchestration (MANO)
- TM Forum Open Digital Architecture – Service Orchestration and Domain Orchestration
- Open Network Automation Platform (ONAP)

- ETSI Open Source MANO (OSM) – Service Orchestration and Resource Orchestration
- MEF 55 – Lifecycle Services Orchestration Reference Architecture

RIFT.ware's orchestration modules provide full virtual service, virtual function, and virtual network life cycle management and automation, enabling service providers to rapidly onboard, deploy, manage, and automate an end-to-end service spanning multiple clouds and locations in a standards-based, repeatable manner. RIFT.ware's open interfaces and plugin-driven architecture enable operators to deploy multi-domain services to satisfy multiple markets, including:

- 5G network slices and network slice subnets
- Multi-site enterprise virtual private network (VPN) and SD-WAN
- Multi-access edge computing

The multi-tenant nature of RIFT.ware provides secure separation of access based on the service provider's internal organizational boundaries, suppliers, and customers. To enable distributed RIFT.ware deployments in the service provider's private cloud or in the AWS Cloud, RIFT.ware provides integration with the service provider's single sign on (SSO) system to ensure security.

To ensure high availability and reliability, RIFT.ware is architected to run over Amazon EKS, including the use of stateless worker tasks and task resiliency mechanisms to ensure restarts in the case of local fault events, or load-balanced, state synchronized multi-AZ resiliency. Coupled with Elastic Load Balancing service and placement in different AWS Regions and Availability Zones (AZs), RIFT.ware provides recovery even from a total AZ outage.

As a high scale, low footprint automation engine, RIFT.ware's deployment overhead is low. Coupled with the economies of scale of the AWS Cloud, such as the ability to scale, right sizing, capacity on demand, and the removal of hardware ownership and obsolescence issues, RIFT.ware on AWS provides significant cost of ownership benefits for service providers.

Key Concepts of the 5G Architecture

5G networks are intended to provide connectivity and data processing services tailored to a variety of business use cases, from Augmented Reality / Virtual Reality (AR/VR), to Internet of Things (IoT) and Industrial Internet of Things (IIoT), to connected cars. To address the disparate requirements brought by these use cases, 3GPP has rearchitected the 5G network to utilize the best practices of cloud software.

Cloud Native Control Plane and Service-based Architecture

In a continued evolution step from 4G, 5G networks further separate the user plane functions from the control plane. This enables the control plane to evolve into cloudnative, stateless functions that yield benefits in resiliency and elasticity. The control plane has been rearchitected into a service, mesh-like architecture known as the Service Based Architecture (SBA). A benefit of the SBA is reliance on HTTP as the carriage protocol, which makes the 5G control plane far less network sensitive, requiring a simple IP network instead of a specific point-to-point topology.

User Plane Separation

Separation of the User Plane Function (UPF) from the remainder of the 5G functions has benefits not only to the control plane, it also allows the user plane to be distributed closer to the edge, where latency and backhaul bandwidth become less of a concern. This enables 5G architectures to scale better to interactive, high-bandwidth applications such as gaming and augmented reality.

SLA-driven Network

A major effort in 5G networks is the standardization of Slice Templates for describing the type of 5G network to create. The Generic Network Slice Template (GST) specified by the GSMA, is a list of attribute-value pairs that indicate the location, characteristic, behavior, and type of service expected of a 5G slice. When filled out with values, the GST, now known as the NEtwork Slice Type (NEST), describes the SLA requirements of the 5G slice. Standardization of the GST enables service providers to clearly indicate the requirements of the network slice to each entity responsible for the components of that slice even across departmental and enterprise boundaries, ensuring the SLA of the end-to-end slice.

5G Service Management Layers

5G slice management is hierarchical in nature. When coupled with NFV, 5G slice management and ETSI NFV neatly form a series of "as-a-Service" layers with open APIs to automate the life cycle of each layer

- Infrastructure as a Service (IaaS) provides raw resources such as compute, storage, and networks.
- Platform as a Service (PaaS) provides base infrastructure services, such as OS and networking, to host cloud native 5G functions. While Kubernetes logically belongs in the PaaS layer, it also provides automation capabilities for managing the life cycle of cloud native network functions, so it spans both the PaaS and Network Functions Virtualization as a Service (NFVaaS) layers.
- NFV as a Service (NFVaaS) provides the capability to automate deployment of end-to-end network services. This layer is used by the service providers' network operations teams for day-to-day operations automation. Internally, the NFVaaS layer is further sub-divided

- **NFV Orchestrator (NFVO), which provides Network Service life cycle management.**
- **VNFM, responsible for VM-based Virtual Network Function (VNF) life cycle management.**

- 5G as a Service (5GaaS) provides APIs for creation and management of end-toend network slices. The 5G slice management functions, CSMF, NSMF, and NSSMF, are contained within this layer. The role of the 5GaaS layer is to interact with the service providers' OSS/BSS layer and translate the customer facing requirements, which includes the customer SLAs into operational commands that can be realized at the NFVaaS layer.

AWS and RIFT as a 5G Platform

5G as a Service (5GaaS) provides APIs for creation and management of end-toend network slices. The 5G slice management functions, CSMF, NSMF, and NSSMF, are contained within this layer. The role of the 5GaaS layer is to interact with the service providers' OSS/BSS layer and translate the customer facing requirements, which includes the customer SLAs into operational commands that can be realized at the NFVaaS layer.

5G enables service providers to deploy new services to their customers, tailored to each customer's individual requirements. The evolution of the 5G architecture addresses all modern use cases, from connectivity for a massive scale Internet of Things to interactive audio/video applications. Realizing such use cases requires service providers to deal with the new architectural challenges posed by 5G services, including:

- The ability to automatically and rapidly deploy new services
- The ability to place these services in a manner that best serves the use cases in terms of performance, availability, and proximity
- The ability to ensure that the service fulfills the customer's requirements and expectations

To achieve these goals, service providers must be able to automate the processes required to deploy 5G network services from OSS/BSS to the IaaS layer, and must be able to place and connect both VM-based and cloud native network functions on different VIMs to support Control and User Plane distribution. This means that resources must be available in a variety of disparate locations. These network functions and network services must be continuously monitored and automatically adjusted to scale according to network and customer demand, or heal in the case of failures.

While standards bodies such as TM Forum, 3GPP, and ETSI have invested in specifications for deployment automation in the service provider domain, these specifications focus on private cloud deployments, and often overlook the many benefits of the public cloud. AWS Services, such as Amazon Elastic Compute Cloud (Amazon EC2), Amazon ECS, and Amazon EKS, can augment the service provider's private cloud by providing additional resources for placement of 5G services. AWS Outposts offers a consistent, managed, low-latency service using the service provider's on premises resources.

Properly utilizing AWS Services such as AWS Cloud Formation, The AWS Cloud Development Kit (AWS CDK), or Amazon API Gateway requires an automation solution that can bridge the gap between a service provider's standards and the public cloud, enabling 5G services to be automatically deployed from the OSS/BSS and span VM, containers, public, and private cloud.

Deploying 5G Services on AWS

The end-to-end nature of 5G slices demands a system capable of automating the deployment of components across a variety of technology, geographic, and administrative domains. This automation should foster reusability, maintainability, and adaptability. If it does not, service deployment times will suffer, and the deployment itself will be fragile and hard to adapt to new service changes.

Network connectivity is vitally important in 5G networks. While its significance is understood in the transport connectivity between RAN and Core, the role of the network is often overlooked in use cases such as geographic resiliency, or in inter-NF or interslice subnet connectivity, which may span multiple sites and even cloud types (VM and container).

Finally, it must be possible to integrate 5G slice management with the service provider's existing OSS/BSS, to ensure the service can be ordered, monitored, and managed from a customer perspective.

The 5G Service Lifecycle

The journey of constructing a 5G service starts with the basic building blocks of the service; specifically, the individual Virtual or Containerized Network Functions (CNF) that comprise the 5G network service. With RIFT.ware, any supplier's 5G NF, be it RAN, Core, or Transport, can be onboarded to or constructed using RIFT.ware's Network Function Composer UI and the resultant Network Function Descriptor (NFD) stored in the RIFT.ware NF catalog

For cloud native NFs, this process is even simpler, as the Helm chart can be imported via a single click and automatically converted into an ETSI-compliant Containerized Network Function Descriptor (CNFD)

Creation of the NFD enables operators to easily manipulate the NF, by dragging and dropping any NFD in the RIFT.ware catalog. Operators can create an entire topology of NFs simply by connecting these NFs into multi-vendor, multi-domain network services

The ability to create service chains via a drag-and-drop UI is especially important for 5G network functions and service provider NFs in particular, because many NFs require multihomed Pods and optimized input/output (I/O) for user plane packet forwarding and/or redundancy purposes in an AWS Region

The resultant network function and network service templates created through the design time process are cloud-agnostic templates that can be placed on any cloud type (private or public) or location (Figure 8). Each template can be customized at instantiation time through a simple input file containing parameters such as names of placement groups, IP address pools, and Domain Name System / Dynamic Host Configuration Protocol (DNS/DHCP) servers, to tailor the deployment for site or use case specific parameters. This enables the NF and NS templates to be reused across service provider use cases, from enterprise 5G to massive Internet of Things (mIoT) deployments.

Prior to deployment, the NS template can be put through a CI/CD pipeline to test the functionality and determine its operational characteristics. This stage is crucial to 5G service deployments, as the 5G function and the resultant service is tested against the desired 5G NESTs supported by the service provider. Characteristics examined may include:

- Performance curves, such as throughput or sessions per second with varying sizes and numbers of CPU, memory, and storage
- Latency characteristics
- Resiliency characteristics, including recovery times and placement requirements for local and geographic redundancy
- Optimization parameters, such as use of Single-Root I/O Virtualization (SR-IOV) and/or Data Plane Development Kit (DPDK) and effect on latency and performance

After the behavior of the NF is understood, the service provider may choose to fine-tune the CNFD/Virtual Network Function Descriptors (VNFD) for deployment by modifying the model to include:

- Key Performance Indicator (KPIs) information, to enable RIFT.ware to monitor performance and health of the NF
- Scaling or healing policies triggered by the KPIs
- Initial scaling size for the NF
- Placement rules, such as EC2 placement groups, host aggregates, affinity/antiaffinity, and security groups
- Optimization rules, such as need for DPDK, SR-IOV, security and encryption assist, which are of particular importance to User Plane functions

These attributes are encoded in the models to enable repeatable deployments. As many attributes can be parameterized for run-time customization, these models may be used even if deployed in different locations (such as AWS Outposts vs. a Region where user plane function is deployed on Outposts for local breakout, and control plane functions are in a Region to enable centralized management and operation), cloud form factors (such as MEC platform / Universal customer premises equipment (uCPE) vs. data center), and cloud capabilities (such as availability or absence of SR-IOV). Use of an abstract model allows a "low code" approach to cloud deployments, which reduces the time needed to put the NFs into service, and reduces risk.

A similar approach is used for construction of the service. Using RIFT.ware, service providers can drag and drop NFs into the RIFT.ware Service Composer pane to create Network Service Descriptors (NSD) containing both CNFs and VNFs. The CNFs and VNFs are connected using Virtual Links (VLs) to form service chains. At instantiation time, RIFT.ware interacts with the VIM and networking layers to enable placement of the NFs on any cloud and any site, and ensures the connection between NFs is made regardless of whether connectivity is between CNFs and VNFs or across clouds. Due to the portability of the NSD, the entire NSD may be inserted to a CI/CD pipeline for testing and fine-tuned afterwards, in the same manner as the NFD.

The NSD model is particularly useful in the 5G orchestration to support control plane/user plane (CP/UP) separation. As previously discussed, a key goal of 5G is to support interactive, high-bandwidth applications such as gaming and augmented reality. By distributing the UP NFs closer to the edge, latency can be mitigated and traffic can be broken out locally instead of being backhauled, allowing bandwidth to be used more efficiently.

This type of deployment requires coordination between different technology domains including:

- Ensuring the UP NFs are placed on capable hosts that support high bandwidth, low latency applications through use of DPDK, SR-IOV, and similar technologies.
- Ensuring the container cluster supports multi-homing, an essential requirement of UP NFs. • Ensuring the NFs are chained together to form the correct service topology. This is particularly important for UP NFs which have multiple interfaces.
- Ensuring the network connectivity supports the necessary latency and bandwidth required for a distributed, multi-site deployment.

To support these requirements, the candidate AWS placement locations in the form of EC2, ECS, or EKS accounts that meet these criteria are added into RIFT.ware as VIM accounts or Container-as-a-Service (CaaS) accounts. Once added, all VIM and CaaS accounts are available as virtual data center resources which can be selected during NSD instantiation, to be used by that NSD for placement of NF workloads

Once the NF descriptors, NS descriptors, and VIM/CaaS accounts have been created, the entire instantiation process can be automated through a combination of RIFT.ware and AWS capabilities, such as the interworking between ETSI NSD, CNFD, and AWS CloudFormation Templates and AWS APIs:

1. As part of the NS instantiation process, a VIM or CaaS account is selected for each constituent VNF and CNF in the NS. These locations are selected based on serving area, latency requirements, and other attributes. The selection may be completed manually or programmatically via the RIFT.ware northbound SOL 005 API.
2. As part of the NS instantiation process, the NS deployment requirements are gathered from the NSD model. For example, in the case of a distributed deployment where the UP may be located on an AWS Outposts instance and the CP is located at the service provider data center, RIFT.ware will:
   a. Create and provision the necessary L3 access points for the NFs each location, as directed by the Virtual Link Descriptor (VLD) model within the NSD.
   b. Create and provision the L3 WAN connectivity between sites through interfacing with the network controllers at each site.
3. RIFT.ware then creates the inter-NF virtual links (networks), attaching these to the access points created in step 2.
4. As part of the instantiation process of each constituent NF, the optimization and placement policies such as multi-homing, EC2 placement groups, SR-IOV, DPDK, and affinity / anti-affinity are determined from the NF descriptor models.
5. Using the requirements in step 4, a suitable cluster is located for placement of the NF. If a suitable cluster is not located, RIFT.ware constructs a CloudFormation Template tailored to the NF's requirements, and creates a cluster to host the optimized NFs.
6. RIFT.ware places the NF into the selected VIM or CaaS account and creates the intra-NF networks. For cloud-native NFs, this is achieved via the Amazon ECS or EKS APIs, which are used to fully instantiate and manage the CNF. Day 0 configuration is also applied at this stage.
7. Following instantiation, RIFT.ware applies Day 1 configuration to the NF.
8. RIFT.ware attaches the NFs to the inter-NF VLs created in step 3.
9. RIFT.ware then configures the NFs with service level configuration, such as ensuring each NF knows the IP address of other NFs in the service, or knows the identity of the geo-redundant pair.

Like the NF models, a model-driven approach to network service deployments enables a low-code, low-maintenance, and repeatable deployment across cloud locations and types, enabling the distributed, high-performance deployments required by 5G services.

End-to-end Architecture for 5G Service Deployment on AWS
A primary goal of 5G networks is the automated deployment of 5G slices based on direct customer request, through a marketplace or similar mechanism. Unlike application marketplaces, which typically involve the deployment of a single application in one site, a distinguishing characteristic of 5G slices is that they require a coordinated launch of multi-vendor applications across several sites, they require the networking of these applications in a specific topology.

Another attribute of 5G slices is the level of guarantees expected of a carrier-grade service. Items like latency and availability are vital in 5G, so placement of NFs in specific locations and zones to ensure proximity, accessibility to networking resources, and fault isolation is key to meeting the service level requirements of 5G.

The ETSI NFV specifications are mainly focused on automating tasks related to network operations, such as the creation of resources to support applications, and the chaining of applications to support Network Services. The APIs presented by ETSI are inherently resource and deployment focused, and speak in terms of compute, memory, storage, and IP addresses. While these APIs are ideal for specifying detailed placement and connectivity, they lack information regarding customer intent, such as gold, silver, and bronze level, use case, and service area. To achieve the goal of automated deployment through a marketplace-like mechanism, it is necessary to receive customer requests that specify the intent, and translate these into instructions suitable for deployment.

TM Forum has invested heavily in creating a set of APIs specifically to address the problem of customer intent. The TM Forum Open APIs allow service providers to specify attributes that are more meaningful to the end customer, such as service tier described in a higher level, abstract terms such as gold, silver, or bronze, or SLA terms such as availability characteristics.

While TM Forum Open APIs provide the missing piece for the customer APIs, these APIs are very generic and contain no 5G slice semantics, which can lead to proprietary behavior that complicates the integration between OSS/BSS and other customer systems to the 5G complex. To ensure openness, 3GPP has defined a set of functions complete with models and APIs, to standardize the handover from the customer layer (OSS/BSS) to the resource layer (ETSI NFV).

As shown in Figure 3, 5G slice management functions act as the intermediary layer between the OSS/BSS and the ETSI NFV layer. Figure 10 shows the slice management architecture as defined in ETSI GR NFV-EVE 012. 3GPP slice management functions provide a key translation step from TM Forum APIs to ETSI APIs. In conjunction with the GSMA defined NEST template, the 3GPP functions enable deployments of SLA-driven 5G networks automatically from customer to resource.

The NEST Template

NEST templates define how a network slice is to be created, by describing the SLAs the slice is intended to fulfil, plus high-level instructions that determine the placement of the slice. Attributes in the NEST enable the customer to communicate the use case (enhanced Mobile Broadband (eMBB), mIoT, Ultra-Reliable Low-Latency Communication (URLLC)), performance, scalability, and location in mobile network terminology, which in turn enables the service provider to determine the resources required to fulfil that service.

For example, consider the "Area of service" attribute in the NEST. Based on the service provider's knowledge of the geographic locations corresponding to the public land mobile network (PLMN) ID and Tracking Areas being requested, this attribute can be used to locate a data center, an AWS Region, or an AWS Outposts instance on which to place certain NFs. This information can then be conveyed to the RIFT.ware NFVO via the SOL 005 reference point for instantiating the network service (NS). Similar attributes in the NEST can also be used to determine NS and NF sizing, optimization parameters, and network connectivity.

NEST and the Slice Management Functions

The role of the NEST is key for ensuring correct instantiation of the 5G service. While it is possible to instantiate any 5G NF or even NS (5G or otherwise) directly through the TM Forum APIs alone, the NEST specifies the SLAs expected by the customer. The role of the 5G Slice Management Functions is to correctly map, decompose, and transform between TM Forum APIs and data models to ETSI APIs and data models.

- The CSMF selects a NEST based on the customer service request received from OSS, using TM Forum Open APIs. The APIs used, for example, TMF641 "Service Order", and fields within the API such as the Service Specification Relationship are used to select the NEST template to use. The NEST is then communicated to the NSMF as a Service Profile using 3GPP APIs.
- The NSMF receives the Service Profile. Based on the Service Profile (NEST), the NSMF further decomposes the slice into slice subnets, and requests allocation of each subnet with the selected NSSMF using the 3GPP Slice Profile.
- The NSSMF's role is to transform the Slice Profile into ETSI APIs, by mapping the NEST fields into SOL 005 instructions. This mapping is performed by RIFT.ware using a transformation engine that allows the Service Profile to select AWS Region, VIM (Outpost or AWS instance), placement parameters, and Cloud Formation Templates, based on the service provider's CI/CD results and other considerations such as location and networking availability and capability. The NSSMF then requests deployment of the slice from the RIFT.ware NFVO using SOL 005 APIs.

As each service provider has unique deployment conditions such as type and location of data centers, services, suppliers, and capabilities, RIFT provides a simple yet flexible mechanism for supporting model transformations and selection of VIMs, suppliers, and services in the RIFT.ware 5G Slice Management functions. This mechanism supports slices and slice subnets across clouds, chaining together the NFs placed on Service Provider data centers, the AWS Region, and AWS Outposts.

Closed Loop SLA Control

Because the NEST template and 5G Slice Management as a whole is highly tailored towards SLA management, it is vitally important that the SLA of the end-to-end slice be continuously monitored and adjusted around changing demands and/or outages. For this reason, AWS and RIFT have partnered to provide a Closed Loop SLA control mechanism, to enable the 5G slices to autonomously and automatically scale, heal, and adapt to changing network conditions. Utilizing RIFT.ware's auto-scaling and auto-healing framework plus Amazon CloudWatch analytics functionality, AWS and RIFT provides an end-to-end service assured slice management solution.

RIFT is a leading innovator in Closed Control Loop Automation, providing a suite of advanced capabilities that allow service providers to automate Day 2 operations using intelligent, policy-based triggers and operator-designed, model-driven responses.

RIFT.ware's ETSI-compliant data models contain built-in attributes for application layer KPI from VNFs and CNFs. For cloud-native applications, in which large numbers of worker tasks may be placed on widely dispersed VMs, application layer KPIs such as sessions per second, processing latency and the like are far more indicative of NF performance and congestion over infrastructure-level KPIs such as CPU or memory utilization percentage.

These application layer KPIs, or monitoring parameters, can then be aggregated to form policies that trigger life cycle management actions when a threshold is crossed. Such actions may include healing actions such as restarting tasks or VMs, or scaling a NS/NF via RIFT.ware's Autoscaling Framework.

RIFT.ware's Autoscaling Framework works with the NS/NF life cycle management workflows to ensure that new capacity (VMs/VNF and Containers/CNF) are added and removed seamlessly from service, with minimal impact to upstream and downstream systems, and to ensure even load distribution across all available capacity (Figure 13). The Autoscaling Framework uses the RIFT.ware's built-in life cycle management workflows to automate all aspects of scaling a multi-NF network service, including:

- Instantiations of scaling groups consisting of one or more NFs based on the policy trigger
- Configuration of all new NFs
- Rebalancing load across all NFs
- Busy-out of user sessions, in the case of scale-in
- Reprogramming any load balancers in the network service

RIFT.ware's support of open standards-based APIs and data models also enables simplified integration with the service provider's service assurance system, and Amazon CloudWatch for bridging anomaly event detection, which can provide more complex analytics and artificial intelligence / machine learning (AI/ML)-based triggers in a nonreal time fashion. To support this scenario, RIFT.ware exports the entire virtual topology, including all cross-layer correlation data to the analytics system, which can then be combined with telemetry obtained from CloudWatch to trigger intelligent policy-based actions.

Using Amazon CloudWatch and RIFT.ware, service providers can create complex use cases such as:

- Automated instantiation of new Slice Subnet in response to degradation of user experience
- Automated recovery during loss of Slice Subnet
- Proactive scaling based on capacity planning trends
- Reactive scaling due to outages based on pre-determined disaster recovery plans

Through Amazon CloudWatch, advanced ML-based analytics can be used to drive Closed Loop automation for 5G networks in a rapid, repeatable, efficient manner.

5G Use Cases

5G Slice Deployment Automation

Automation of 5G deployments requires automation across all layers of the 5G orchestration stack. AWS Services and tools, coupled with RIFT's RIFT.ware Orchestration and Automation suite, provide top-to-bottom automation of 5G services.

AWS programmable services related to IaaS and PaaS orchestration and management, such as AWS Lambda, AWS Config, CloudFormation, Step Function, and CDK, can help design and realize network slicing at the optimal resource level, while RIFT's RIFT.ware service orchestration and automation solution can be used to design, deploy, and manage slices, slice subnets, and other network services by providing standardsbased APIs and functions to the service provider.

RIFT's RIFT.ware Orchestration and Automation suite provides ETSI NFV service (NFVO) and VNF (VNFM) level components. As a use-case, agnostic, standards-based ETSI NFV orchestration suite, RIFT has demonstrated the on boarding and life cycle management of nearly 100 VM-based and containerized cloud native Network Functions from over 40 different vendors. Using the RIFT.ware NF and Service Composer components, service providers can rapidly onboard new NFs and design carrier-scale end-to-end services using a drag-and-drop UI that facilitates multi-site hybrid cloud deployments and geographically redundant, high-performance, optimized network services. The RIFT.ware automation suite also makes use of AWS Services and tools, such as Cloud Formation Templates, to automate the creation of clusters in the AWS Cloud to support the deployment.

To enable 5G-specific automation for the creation and management of 5G slices, RIFT has introduced the RIFT.ware Slice Management Automation suite to automate the reception of customer service orders, fulfillment of these orders into a deployed end-to-end network service on AWS infrastructure, and continuous monitoring and Closed Loop life cycle management for automated SLA management.

CI/CD Pipeline The automation capabilities described in the previous section can also be used to drive CI/CD pipelines in order to create predictable, carrier-grade services. A well-established CI/CD process enables service providers to characterize, and in some cases, predict NF and NS behavior, which is essential to ensuring that the service, once released, is able to fulfill the SLAs in the customer's requested NEST.

The best CI/CD processes make use of automation tools to ensure repeatability of the process, and closely mimic the conditions under which the service is to be deployed. Using a combination of AWS and RIFT automation, service providers can accurately reproduce deployment environments in a sandbox

With its rich, standards-based APIs, RIFT.ware can be incorporated into the service provider's existing automation frameworks such as Jenkins or Robot Framework, to drive automated deployment of network functions or network services into a sandbox environment using AWS developer tools, bookend the NF/NS with test harnesses or traffic generation tools, and fully configure the service as a final step for automation tests or deployment.

Conclusion

AWS and RIFT provide capabilities for you to deploy and leverage 5G infrastructure globally, to attain scalability, elasticity, and high availability. Customers are using AWS, AWS Partner Network (APN) Partners, and open-source solutions to host mobile workloads on AWS. This has resulted in reduced cost, greater agility, and a reduced global footprint. For partner solutions, AWS has the broadest and strongest partners in the ecosystem, available through AWS Marketplace and the APN Partner Central for each part of the stack presented in this paper. The reference architectures and best practices provided in this whitepaper can help you successfully set up 5G workloads on AWS and optimize the solutions to meet end user requirements, all while optimizing for the cloud. AWS extends its cloud beyond Regions to the distributed edge. This provides CSPs with a choice between AWS Outposts (to implement cloud native user plane) or Outposts and AWS Wavelength to host MEC applications and latency sensitive workloads. Additionally, management and orchestration, as well as network slicing, can be deployed cost effectively, following cloud-native architectures and with an easy path to use AI/ML capabilities to create predictive and self-healing networks.

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Acronyms

- 3GPP — 3 rd Generation Partnership Project
- 5GaaS — 5G as a Service
- AI — Artificial Intelligence
- API — Application Programming Interface
- APN — AWS Partner Network
- AR — Augmented Reality
- AZ — Availability Zone •
- CaaS — Container as a Service
- CI / CD — Continuous Integration / Continuous Delivery
- CNF — Containerized Network Function (or Cloud-native Network Function)
- CNFD — Containerized Network Function Descriptor
- CP — Control Plane
- CSMF — Communication Service Management Function
- CSP — Communications Service Provider
- DHCP — Dynamic Host Configuration Protocol
- DNS — Domain Name System
- DPDK — Data Plane Development Kit
- eMBB — enhanced Mobile Broadband
- ETSI — European Telecommunication Standards Institute
- GSMA — GSM (Global System for Mobile Communications) Association Amazon Web Services Enabling 5G Network Automation Over AWS with RIFT 27
- GST — Generic Network Slice Template
- IaaS — Infrastructure as a Service
- IETF — Internet Engineering Task Force
- I/O — Input / Output
- IoT — Internet of Things
- IIoT — Industrial Internet of Things
- ISG — Industry Specification Group
- KPI — Key Performance Indictor
- MANO — Management and Orchestration
- MEC — Multi-access Edge Computing
- mIoT — Massive Internet of Things
- ML — Machine Learning
- NEST — NEtwork Slice Type
- NF — Network Function
- NFD — Network Function Descriptor
- NFV — Network Functions Virtualization
- NFVaaS — Network Functions Virtualization as a Service
- NFVI — Network Functions Virtualization Infrastructure
- NFVO — Network Functions Virtualization Orchestrator

- NSSMF — Network Slice Subnet Management Functions
- NFVFaaS — Network Functions Visualization as a Service
- ONAP — Open Network Automation Platform
- OSM – Open Source MANO Amazon Web Services Enabling 5G Network Automation Over AWS with RIFT 28
- OSS/BSS — Operation Support System / Business Support System
- PaaS — Platform as a Service • PLMN — Public Land Mobile Network
- PNF — Physical Network Function
- RAN — Radio Access Network
- SBA — Service Based Architecture
- SD-WAN — Software-Defined Networking in a Wide Area Network
- SLA — Service Level Agreement
- SR-IOV — Single Root I/O Virtualization
- SSO — Single Sign-on
- uCPE — Universal Customer Premises Equipment
- UP — User Plane
- UPF — User Plane Function
- URLLC — Ultra-Reliable Low-Latency Communication
- VIM — Virtualized Infrastructure Manager
- VL — Virtual Link
- VLD — Virtual Link Descriptor
- VM — Virtual Machine
- VNF — Virtual Network Function
- VNFD — Virtual Network Function Descriptors
- VNFM — Virtual Network Function Manager
- VR — Virtual Reality

End of Section

The Community 5G Network (Open Access by NEO Networks)

Neo Networks Open Access: Neo Networks' Open Access solution provides wireless service providers, advanced and emerging wireless providers and Smart City and IoT technologies with accelerated access to and use of the pubic rights of way and the mission critical vertical infrastructure needed to host their amazing new technologies.

One Time and Annual Revenues: Neo's Open Access program creates and preserves vital, nontaxpayer revenues collected from right of way use fees, existing and newly placed pole rents, attachment fees, ground space, electric service connections, conduit, and wireless site leases generated as a function of Neo's network real estate marketing efforts.

High Value Revenue Streams are Highly Leverageable: Due to their long contract terms (typically 10 years initial lease terms with automatic 5-year renewals) combined with the credit worthiness of the tenants (Verizon Wireless, AT&T Mobility, T-Mobile, Sprint, Dish, Google, Amazon and Microsoft, others), these newly created annual revenues are valued as discounted Tower Cash Flows ("TCF") annuities in high demand by private equity firms (monetizable at multiples of 16 to 18 time EBITDA) or may be levered and securitized to collateralize long term, low interest debt (levered multiples ranging between 7.5 and 8.5 times EBITDA).

Revenue Use Cases: The revenues collected may be used for any lawful purpose with collected revenues distributed as directed by the right of way trustee or infrastructure owner. Transportation agencies often re-invest their portion of the annual revenues for many different purposes including: purchase of road and highway maintenance and repair equipment, supplemental operating costs or allocated to the general fund for reinvestment directly into road and bridge construction and repairs. Local government agencies may apply the revenues towards government operations, education, humanitarian, healthcare, public safety, law enforcement and emergency services. Also, they may create the funding needed to support unbudgeted wireless and broadband technologies such as cost free / low cost municipal wi-fi, community owned fiber optic networks, private LTE, crime prevention and deterrence and the full complement of Smart City technologies.

Value Proposition: Open Access is offered by Public / Private Partnership to all public sector agencies with discretionary authority over the occupation and use of the public and utility rights of way as a 100% cost free, risk free, success-based business model.

Compensation and Revenue Profile: Neo's unique business model revolves around the collection of applicant-paid, non-recurring (pass through) fees, annualized revenue sharing and margins on services related to the performance of mandatory make ready work and optional applicant services.

Infrastructure Investment: Neo invests ourselves in every community that we support, we invest our capital in telecommunications infrastructure and services that are crucial to host commercial wireless and broadband technology and we share the revenue we collect with our public sector partners crafting the ideal win-win scenario for all stakeholders.

Neo Neighborhood Networks was developed to help unserved and underserved Counties, Cities, Villages and Towns provide high quality, low cost wireless technology and broadband solutions as an alternative to far more costly services offered by incumbent wireless, traditional telco and CATV cable broadband or to bring these critical services to those in need.

Synergies: Combining Neo's Open Access program with our Neighborhood Networks program creates synergies that align with every communities Digital Inclusion plan.

Planning for Self-Reliance: Public sector agencies throughout the US are realizing their reliance on incumbent wireless and broadband service providers limits the availability, coverage, quality, performance and affordability of wireless and wireline connectivity. Understanding that the current business case for 5G further limits the providers' ability to deploy outside the urban and dense urban core and the cost of 5G service will be beyond the limits of affordability for many low and moderate income families, communities are looking for creative ways to fund and operate networks independently from the traditional service provider paradigm.

Practical Alternatives: State and local government and transportation agencies are now better able to plan, design and build wireless and fiber optic networks to bridge the digital divide due to several important advantages: 1) billions of dollars in state and federal grants and funds have been allocated for wireless and broadband expansion into rural and underserved markets, 2) significant quantities of RF spectrum has been made available and 3) the cost and operation of public W Fi and Private LTE networks has decreased over time.

Sustainability: Historically, public Wi Fi and community owned fiber networks that have been deployed have struggled to sustain operation, due in large part to the lack of revenue necessary to provide the continuous funding required to operate, maintain, upgrade and replace degraded facilities and obsolete technology.

Community Contributions of Access, Assets and Infrastructure: The active participation, support and contribution of existing fiber, rooftops, street lights, traffic signals and rights of way needed to deploy and expand the network are essential elements of success of the Neighborhood Networks collaboration.

Capital Funding: Leveraging the availability of state and federal grants and opportunity zone funding, initial capital planning includes applying for and receiving funding sufficient to capitalize the network build out and support operations for a 3-year maturation lifecycle.

Direct Network Revenues: Pre-sales, sales, and marketing program designed to develop and qualify the ongoing revenue profile to drive the completed network to a self-sustaining state.

Smart Cities Built on Existing Infrastructure: Neo Networks Open Access, Asset Management, and Marketing program attract wireless carrier and private sector technology and broadband investment by letting the service providers know your Smart City welcomes wireless technology and is open for business.

Right of Way Revenues: Vertical infrastructure and rights of way have the potential to generate high value, (non-taxpayer) annual recurring revenues and non-recurring fees and charges for the local community. Open Access creates annual and one-time fees and charges for the participating PSA's understanding that the revenues collected would be reinvested directly into the Neighborhood Networks program.

Annual Pole Rents and Recurring Revenues Valued as Tower Cash Flow ("TCF"): Commercial lenders and private equity value annual recurring revenues on a level equivalent to traditional discounted cell tower cash flows due to their long (5 to 10 year) initial contract terms, automatic 5- year renewals, and 2% annual rate escalators, resulting in durable, annual recurring revenues for 25 to 30+ years on average.

Annual Cash Flows May Be Monetized or Securitized to Leverage Low-Interest Debt: Traditional tower cash flows current trade at a value between 34 to 36 times EBITDA while discounted tower cash flows from small cells may be monetized, commonly trading between 18 to 22 times EBITDA or securitized to leverage low-interest debt facilities are debt leverage ratios routinely ranging between 7.5 to 8.5

Factoring Measurable Savings from Annual Budgets: Post-implementation, the completed Neighborhood Networks enable measurable savings resulting from reduction or elimination of paid wireless subscription services, broadband connections, wireless data services, traditional telecommunications, electric service usage, law enforcement, court and incarceration costs. These savings would be factored and reinvested as committed funds to the Neighborhood Networks program until the initial capital investment is recovered and the direct network revenues support sustained operation thereby validating the revenue profile.

Capitalization Strategy: State and federal grant monies are practical in the near term for providing the funds to build and operate wireless and broadband networks, however, the dimension of these funds is limited and not sufficient to support all communities with a demonstrable need. The unique approach contemplated for the Neighborhood Networks program is to build the business and use case through a collaboration between MCAS, Michigan City, La Porte City, and La Porte County. The completed network, operating model and revenue profile that creates the prototypical case study promoted as a benchmark of digital inclusion, self-reliance, and sustainability.

Paving the Way to Private Investment: Financial results, repeatability, and value created will derisk and qualify future networks as investable entirely within the private equity and lending markets and allowing for state and federal grant conversion to low interest or interest-free term loans that would provide an evergreen or revolving funding source for unserved and underserved communities nationwide.

COMPANY PROJECTS/ACCOMPLISHMENTS To date, the company has not performed services or completed projects for the Department of Defence. Representative examples of previously completed projects that correlate directly to this RDI include our Open Access program that has been implemented for the Roads Commission for Oakland County, MI and our current Neighborhood Networks pilot in process with the Michigan City Area Schools in Michigan City, IN. Sprint PCS– Roads Commission for Oakland County – Mini-Macro Pilot Project Proven Business Model: Our Open Access program is currently in place and operational with the Roads Commission for Oakland County, MI, Wayne County, MI and the Cities of Romulus, Roseville and Muskegon Heights, MI and the company is now offering our proven infrastructure and asset management and marketing solution to public sector agencies nationwide. RCOC Case Study Example: Reflected in our case study, following the Roads Commission for Oakland County's adoption of our Open Access program, Neo Networks marketing and leasing efforts converted a 16 site build out into a 260 site build out as a turn key project deployed under a contractual arrangement with Sprint PCS. Marketing Success: The marketing effort resulting in a direct revenue increase from $320 per year to over $440K per year in gross revenues and $250K per year retained revenue for the Roads Commission. Traffic signal pole access was administered under an initial 5-year lease Term with four (4) automatic 5-year renewals and annual escalator of 2%. As a result, the Roads Commission will collect over $8M in non-taxpayer revenue over the lease Term which represents a 76,000% increase in gross revenue and 46,000% increase in net retained revenues and based on our forecast, represents less than 5% of potential revenues collected as additional 4G and 5G sites are added.

Turn Key Services: The turn key services included Neo Networks performing the site acquisition, architectural and engineering drawings, managing the zoning, planning and permitting process, construction, turn up, test and optimization of a 260-site build.

Proven Siting Policy and Digital Processes: In addition to the favorable revenue impact, the policy and digital application and approval process that was implemented reduced the overall planning and permitting lifecycle from an average of 12 to 18 months to less than 3 days and the carriers option to request turn key services resulted in an average engineering, construction, turn up test and optimization duration from an average of 6 to 9 months to less than 60 days. The project was completed in February of 2020.

Results: 100% of Sprints sites were deployed safely on RCOC traffic signal poles located in key intersections throughout Oakland County, improving both coverage and capacity of their 4G network. The entire project was completed accident free, with each site being delivered within 60 days of Sprints execution of the lease exhibit and receipt of equipment. Interestingly, the original 16 sites that Sprint had planned prior to our leasing the them traffic signal poles were sites that had been active with another unsuccessful service provider for over 4 years.

Ideal Win – Win Scenario: As an after-action review, Sprints deployment cost was reduced by over 40% and their total operating expense was reduced by nearly 50%, inclusive of the pole rents. The success of this pilot prompted Sprint to direct us to other communities including Wayne County, resulted in a national Master Lease agreement with AT&T and a 200-site letter of intent from Verizon Wireless.

Michigan City Area Schools – Neo Neighborhood Networks Pilot

Neighborhood Networks Pilot Progress:

The Neighborhood Networks program was developed in January of 2020 (pre-pandemic) and is being implemented for the Michigan City Area School district in Michigan City, Indiana. Less than 60 days into the development phase, the infrastructure mapping, network designs, technology and hardware selection process is complete. Neo has also applied for and received an initial GEER's grant allocated from the State of Indiana's allocation of CARES Act funds and have secured an initial $600K grant that will provide dedicated broadband connections to approximately 50% of the 2400 MCAS students and their families. Phase 1 of the project is scheduled to complete prior to YE 2020, with phase 2 and 3 schedule to complete prior to the end of Q121.

Appropriation of State and Federal Grants: In the aftermath of the Covid-19 pandemic, an estimated $60.5B in Federal, State, private and institutional grants and interest free loans are being made available to support various broadband connectivity initiatives with the bulk of those funds to Additional state and federal grants are in process and the deployment of the network is scheduled to begin in October of 2020. Recently introduced legislation that if enacted into law, would allocate an additional $100B for broadband connectivity in rural, unserved and underserved areas.

EXPERIENCE The team at Neo Networks has over 35 years of progressive experience in fiber optic network design, engineering, project management, implementation, and operations and over 20 years of experience building and deploying indoor and outdoor small cells and fiber fed, distributed network architectures. Neo Networks is and remains the first mover in an emerging industry that provides high value, dark fiber network deployment and management, wireless and network real estate development, marketing and management services geared toward accelerating and streamlining right of way and infrastructure access to the mutual benefit of wireless carriers and the local jurisdictions. The Neo Networks team has an exceptional track record of designing and building fiber optic networks, cellular and PCS networks and microcellular architectures including traditional internet service provider ("ISP"), wireless internet service provider ("WISP"), indoor and outdoor, fiber fed distributed antenna systems ("DAS") and small cell networks throughout hundreds of municipalities spanning 40 US States and 2 Canadian Provinces. Our leadership and management team has designed and constructed over 10,000 route miles of fiber optic networks, designed thousands of outdoor DAS networks, and implemented over 40,000 small cell sites within the public and utility right of way. Our core competencies include public sector infrastructure and asset marketing and management, fiber optic and applied wireless technology and their associated business and use cases. Neo Networks is broadly considered to be North America's leading subject matter experts in relation to advanced and emerging fiber and wireless technology, deployment economics, business and use cases and highly proficient in federal ("FCC") regulatory and state legislative policy. After nearly 40 years designing, building, owning and operating fiber and wireless networks and 20 years specializing in the commercial deployment of wireless technology in the public and utility rights of way, Neo Networks is the only company in America putting our expertise, knowledge and experience to work for the benefit of the communities we serve.

UNDERSTANDING Providing affordable internet broadband services in unserved and underserved low income areas is a mission imperative for thousands of communities nationwide and is being viewed as an abject necessity and a matter of national security. While the easy solution may be to simply open the public and utility rights of way to allow any fiber or wireless service provider to deploy in these areas a no cost, the practical issue is the elimination of cost is simply not enough to encourage commercial investment in unserved and underserved areas and public sector agencies are realizing that solving this problem requires taking matters into their own hands. Ultimately, commercial service providers will continue to neglect these areas. Waiting for the incumbents to solve the problem is simply not a viable option, and neither is funding the development of their network. Similar to other municipalities and transportation agencies own or control access to taxpayer owned assets and infrastructure capable of generating hundreds of millions of dollars in annualized revenues, only a fraction of which is currently being realized. Neo's solution is to combines accessing to state and federal grant funds with revenues created by actively marketing and monetizing City and DOT owned and controlled assets and infrastructure with network revenues and measurable savings factored from the annual budget to enable the City to build, own and operate a network capable of permanently bridging the digital divide.

LIDAR AND ARCGIS (ESRI) Neo's GIS, data and analytics capabilities include LIDAR as a professional service and proficiencies with ARCGIS, MapInfo, IBWave (In building wireless design), Kiema (outdoor RF modeling and predictive analysis) and the full suite of MS office software including MS Project and Primavera used for project reporting and trend analysis. Our in-house GIS expert is Brian Webster. Previously, Brian was responsible for the broadband mapping initiatives in New York and Illinois and will play a key role in the mapping the unserved, underserved and low-income areas of the City of Dallas as a means of qualifying for state and federal grants. Todd Melby is Neo's Director of Customer Programs. Prior to joining Neo Networks, Todd previously served as Central Region Director of RF Engineering for Sprint PCS and will be responsible for all RF modeling and predictive analysis, spectrum management, turn up, test and optimization activities. In addition to the off the shelf products, Neo has developed and implement our own, proprietary software platform branded as NeoNetWerx.com. NeoNetWerx.com is our on-line, network real estate, multiple listing service software that continuously promotes and markets our managed portfolios throughout the carrier ecosystem and enables the user to select, reserve and initiate the lease process digitally. NeoNetwerx version 2.0 is currently scheduled for release in early Q121 with embedded workflows, task management and digital processing of small cell applications and approvals designed to manage the FCC shot clock and virtualize the entire acquisition, zoning, planning and permitting process.

LEVEL OF INTEREST Neo Networks is uniquely positioned to provide the optimal financial and technical solution and is genuinely interested in partnering with the DoD on this most important goal. Properly implemented and executed, the receipt of grant funding, the DoD adoption of our Open Access program and dedication of the DoD's share of the revenue will provide the overwhelming majority of the funding to construct and operate a network without reliance on the incumbent service providers or investment from within the private sector. Our goal is to highlight the DoD as the innovator and the first to solve an unsolvable problem.

BEST VALUE

NETWORK OVERVIEW Advanced Network Architectures encapsulate a number of wireless and fiber optic network technologies, leveraging a "tool box" approach to problem solving with equipment and architecture selection based on local conditions. Fiber: While fiber optic networks offer near limitless capacity and are virtually future proof, the cost of construction and operation, in particular in Tier 1 and Tier 2, lower income, dense urban / urban areas and Tier 3 and Tier 4 suburban and rural communities has generally proven to be financially non-viable for the vast majority of the commercial landline, cable, wireless and broadband service providers (collectively "Carriers"), stranding millions of lower income and rural Americans in the digital desert. Wireless: In recent years, the availability of unlicensed and light licensed spectrum, advanced protocols and the availability of low-cost equipment has helped to position wireless broadband technology as is a viable alternative to fiber. Unlike fiber that can take years to deploy and is capital intensive to construct, wireless technologies can be deployed in a matter of weeks or months, are far less capital intensive to deploy but considerably more costly to operate, maintain, repair and upgrade as wireless technology evolves. Wireless Broadband Business Case: Historically, the business case for wireless broadband has been limited to local wireless internet service providers ("WISP") due to the protracted timeframes to realize a return on capital investment ("ROI") and ROI latency combined with the elevated annual network operating burdens have created financial barriers to entry and limited the widespread proliferation including their deployment in unserved and underserved areas and low income communities.

Proposed Network Solution: While solutions may vary from area to area, our solution involves a hybrid wireless network consisting of Wi Fi 6e with customer premise equipment for static and pedestrian users and Private LTE over CBRS spectrum to provide nomadic and mobile data capability. Backhaul includes the use of existing City owned fiber, aggregated dark fiber and build to suit fiber where the cost is qualifiable in tandem with and wireless and fixed wireless in the mid band, micro wave and millimeter wave bands.

Upgrade Migration to Fiber: Initial subscriber usage patterns and network congestion will dictate the timing and affordability of an upgrade migration to fiber for backhaul and last mile laterals where service levels and take rates justify the investment. At this time, wireless and fixed wireless equipment can be re-deployed to serve additional subscribers as the network evolves over time.

Spectrum: Initially, the network contemplates the use of unlicensed and light licensed spectrum in the 2.4 GHz, 3.5 GHz, 5 GHz and 6 GHz to 11 GHz bands for subscriber traffic and wireless backhaul. Ample amounts of unlicensed spectrum is also available in the high band 60 GHz to 90 GHz bands and will also be integrated to provide a wireless alternative to fiber backhaul.

COST AND BENEFIT Our program takes a very logical and programmatic approach to deliver a blended solution of fiber and wireless technologies critical in a cost effective and rapid delivery of broadband. Equally important, our program markets and generates new revenues to self-fund needed programs. Section 5 provides a Solution Summary and Proposal Outline including business terms.

SUPPLIER DIVERSITY Our outsourced, supply chain partnerships have been forged over 3 decades and include a highly diversified, virtual bench of WBE, MBE, VBE and DAVBE certified contractors. Neo Networks remains committed to our supplier diversity program and policy directing our network investments, creating local jobs and aligning with qualified local firms.

End Of Section

Contributors to the Response

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Mark J. Miller Program Director, 34 years of telecommunications expertise with Smart City initiatives; served as COO of Edge Communications; senior-level positions in the national cell backhaul program for Comcast and FiberTower; national 3G network deployment for Nextel de Brazil

Anita Taff-Rice Legal and Regulatory Affairs; Co-founder FreeBand Technologies; Founder of iCommLaw and has twenty years of experience in the technology and telecommunications industries; expertise includes domestic and international technology, regulatory, public policy, intellectual property, network deployment and mobile content issues

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Scott Wierson Accomplished C level executive and advisor with more than 35 years helping both startups and Fortune 500 Global/International telecom, wireless, cable and internet service operators improve operations and successfully develop and implement new technology. Presently working with Tuskegee University as expert witness regarding litigation related to optical network design, IT technology, services, and operations. In addition, Scott has worked for the Vermont Department of Public Service on several regulatory projects since 2007. He helped the Department to assess the readiness of new market entrants to take over operations of the Incumbent Local Exchange Carrier and subsequent request to change the way service quality would be reported. Presently Scott is helping the department evaluate compliance of carrier petitions for funding to extend services to rural underserved customers