Comments in Response to "5G Challenge Notice of Inquiry"

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This white paper is our response to the 5G Challenge Notice of Inquiry issued by NTIA – RIN 0660-XC049. This paper contains three parts. In the first part we briefly describe the research activities of our team towards open solutions in networking. The second part describes a few research challenges that we have identified in achieving advanced open mobile networking solutions such as 5G. The third part suggests a few steps that could facilitate the creation of ecosystems aimed to accelerating the design, development, and adoption of complete solutions for open 5G.

Part 1: Research Activities in Open Networking at the OpNeAR Lab at UT-D

Our interest in open networks and systems is broader than just the radio component in 5G. We believe that the promised advantages of 5G and beyond technologies can only be harvested by fully leveraging a holistic ecosystem of *many modules and domains* that must be well integrated together. Fig. 1 provides a simple block diagram that shows the key modules of the envisioned ecosystem as they have been implemented at UT-D. It must be noticed that each module shown in Fig.1 could be replaced by a number of equivalent modules depending on the technology that one wishes to leverage.
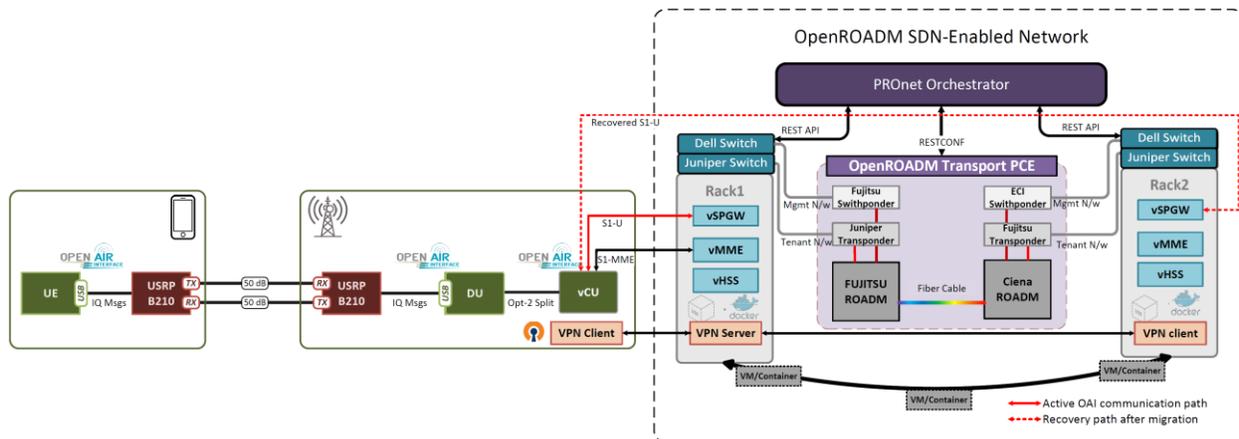

Fig. 1: Mobile network ecosystem comprising a number of open source software packages and open standard interfaces.

The modules shown in Fig. 1 have been chosen because of their open-source mission. Open Air Interface (OAI) provides radio protocol stack software packages that one can run on commercial radio hardware (USRP B210 is the example shown in Fig. 1) and conventional compute servers. OpenROADM on the other hand provides the open interfaces for the fiber optics equipment that is deployed in the fronthaul and backhaul of the 5G infrastructure. For high flexibility and ease of configuration the various software modules (including the radio protocol stack) must be virtualized and/or containerized through open platforms like OpenStack and Kubernetes. Our research

mission is to have these open software solutions run concurrently, well integrated and orchestrated by a software module that we developed, which is referred to as PROnet Orchestrator [1] in Fig. 1. Public live demonstrations of parts of the system shown in Fig. 1 have been presented recently [9-13].

Part 2: Open Challenges in Achieving Fully Functioning Open 5G Solutions

1. **Support for Accelerated Hardware.** Virtual RAN (vRAN) and Cloud RAN (cRAN) architectures consider the software defined and virtualization of the Radio Access Network (RAN) components. Many 5G use-cases run well on pure CPU platforms, but as bandwidths increase and advanced antenna systems are deployed, x86 cores struggle to keep up due to the throughput, latency and power consumption constraints. Hardware acceleration will play a vital role in the heavy computational resource blocks such as IFFT, channel coding schemes in the RAN physical layer. GPUs and FPGAs offer the acceleration platform that delivers performance and programmability without sacrificing the "COTS" of x86 architecture [2,3]. However, there are currently no open solutions available that enable to fully exploit the advantages of the hardware accelerators in the RAN module.

2. **Support for Virtualization and Live Migration of Network Functions.** We consider another potential challenge related to the Network Function Virtualization (NFV) of the 5G network. Mobile Network Operators (MNO) can reduce their operational cost and the need for excessive over-provisioning of network resources by using both commercial off-the-shelf (COTS) hardware and Network Function Virtualization (NFV) instead of using dedicated network appliances. One of the challenges in this scenario, i.e, COTS based virtualized platform, is to achieve the required carrier grade Service Level Agreement (SLA) in the virtualization platform that supports NFV. It is believed that the NFV compute platform must utilize the fullest features such as (live) migration, snapshot, and rebirth to ensure that the SLA requirements are met in terms of security, reliability, and total cost of ownership. Live migration is the process of migrating the Virtual Network Functions (VNFs) from one host to another while guaranteeing zero or minimal impact to the connectivity service offered to the mobile network users. Being able to live migrate, VNFs offer significant advantages in the areas of Load Balancing, fault handling and power/cost optimization [5]. Container based 5G network solutions offer better advantage than the VM with its smaller footprint and greater network security [4]. But the current open-source container migration software (CRIU) has certain limitations [6] to support the radio stack.

3. **Support for Open Controllers.** Similarly, in the Open RAN (O-RAN) architecture, the RAN Intelligent Controller (RIC) plays an important role in controlling and optimizing use of RAN elements and resources via fine grained data collection (both real and non-real time collection). The O-RAN group has defined technical specifications for the interface options, for example the A1 interface (the interface between Non-RT RIC and Near-RT RIC), the E2 interface (the interface between Near-RT RIC and the RAN components) [7]. The RIC module along with the interfaces is in the development stage, with some packages being already open, while others are not. For instance, the OAI software has started the E2 interface support feature (open) to

integrate with the RIC module (not fully open). An entire open system with the RIC integration is then a critical enabling factor to foster efficient research on the Artificial Intelligence (AI) and Machine Learning (ML) workflow. In addition, as emphasized earlier, hardware accelerators play a primary role in the RIC module with its ML flow [8] and its openness is highly desirable in the research community.

4. **Support for Dynamic Split.** In the 3GPP 38.801, the functional split concept is introduced with eight possible options that are going to be standardized. Each option separates the stack layers into the Central Unit (named Base Band Unit (BBU) in the current RAN) and the Distributed Unit (called Remote Radio Head (RRH) in the current RAN). Fig. 1 shows that Option 2 and Option 7 splits are enabled in the UT-D testbed. To provide more flexibility and scalability of the next generation RAN (NG-RAN), there is a strong requirement to integrate the control of functional splits. With this challenge, flexible open platforms should enable dynamic reconfiguration of the functional split by exploiting NFV and SDN controllers.

5. **Support for Multi-Domain Resource Orchestration.** As demonstrated by our team [10], the openness in the optical fiber fronthaul and backhaul layers helps achieve effective resiliency and fault tolerance in the 5G infrastructure. Together with the dynamic split described above, multi-domain orchestration across RAN and optical/transport domain can provide significant flexibility and advantages.

Part 3: Suggestions for Creating Productive Ecosystems

Based on our experience working on open network technologies and software packages we have concluded that the following activities could help create productive ecosystems, which in turn could facilitate and significantly accelerate the development and adoption of open network technologies.

1. **Creation of Open Labs.** Interoperability is an essential aspect in any modern network solution. In achieving open 5G stack solutions it will be important to conduct baseline testing of the solutions developed by the various parties against the adopted standard interfaces. Interoperability validation and testing will be constantly required between modules that are part of the same domain (for example the modules of the 5G protocol stack). In addition, interoperability between the various domains involved (see Fig. 1) will also be required to ensure that virtualization of the radio software modules will be properly achieved and supported by the fiber network and compute infrastructure. Identifying non-profit organizations that can carry out these important interoperability tasks is going to be of the essence.

2. **Organize public demonstrations.** Publicly demonstrating newly developed functionalities and continuous progress of the open design and development efforts is going to be important to induce confidence in the community and also attract new potential players to join the ongoing efforts. The UT-D team has conducted a number of public live demonstrations [11-13] in close collaboration with a number of partners from industry. These demonstrations – which made use of commercial products offered by multiple vendors that successfully work together using the OpenROADM MSA standard – received considerable attentions and helped gain momentum in specific open networking activities concerning the fiber optic network

infrastructure. Expanding these life demonstrations to include radio open solutions, and possibly showcase interoperability across domains will help make an even stronger case for open 5G and beyond stack solutions.

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