WHITE PAPER NEUTROON:

Multi-tenant management framework for future 5G neutral and private infrastructures

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Sumary

1. Motivation

Traditional cellular network deployments have been championed by Mobile Network Operators (MNOs), who own tower sites, deploy the Radio Access Network (RAN) nodes, the Mobile Core, and the transport network connecting the RAN nodes to the Mobile Core. The same approach is being followed for the initial 5G deployments that typically comprise the installation of a 5G active antenna collocated with a 4G tower site. The 5G antenna radiates at 3.5 GHz (bands B42 or B43) with a carrier bandwidth around 100 MHz and is configured in Non-Standalone (NSA) mode, which means that a complementary 4G carrier is still required to carry the signaling connection from the 5G device. This model is suited to urban environments where a high density of 4G radio sites exists, and hence the higher frequency used in 5G (3.5 GHz versus 1.8 GHz or 2.6 GHz in 4G) can still be used to provide ubiquitous coverage.

The aforementioned deployment model is however not suitable to provide widespread 5G coverage and it might fall short to address some of the major 5G vertical use cases, such as Industry 4.0, where factories are usually located in suburban areas, Cooperative and Connected Automated Mobility (CCAM), which require 5G coverage across main transport roads, and Future Railways Mobile Communication Service (FRMCS), requiring 5G coverage along railways paths. Addressing these vertical sectors will require novel deployment models, including new approaches to RAN sharing or directly involving the vertical actors in the 5G network deployment.

Regulators are reacting to the needs of the vertical sectors and a framework for 5G spectrum licenses for private networks has been put in place in several EU countries including Germany, France and Sweden. In Germany the auctions for private 5G spectrum in the 3.7 GHz – 3.8 GHz band officially launched in November 2019[1] . The need for further consolidation in the RAN sharing market also appears visible with the last movements in the telco market where tower companies are acquiring cell sites from MNOs[2] .

The previous trends lay out opportunities for future 5G deployment strategies where private networks and active network sharing will play a key role. To deliver on this vision two challenges need to be addressed. First, future 5G private network operators do not have the same operational expertise as traditional MNOs, hence they need advanced management tools that allow their existing IT personnel to effectively operate 5G infrastructure. Second, RAN sharing strategies today are static, with long-term agreements reached among MNOs. In a future where a plurality of new actors will make use of 5G networks, novel management technologies are required that enable neutral host operators to easily share their 5G infrastructure across tenants in a dynamic manner, i.e. “as a Service”, while providing SLA guarantees. **Neutroon** is an innovative management software for 5G networks that has been designed to address the previous challenges.

2. Market Landscape

2.1 Standardization

The growing interest in private networks has triggered the creation of a study item in Non-Public Networks (NPNs) within 3GPP[3] which has identified a set of use cases for NPN distinguish between standalone NPNs and NPNs integrated with the public mobile network, i.e. where some components of the NPN are offered by a slice of the public 5G network. Along these lines, in order to enable the request of 5G slices tailored to a specific vertical the GSMA defined a Generic Slice Template (GST)[4] that is currently being refined in 3GPP.

The 5G Alliance for Connected Industries and Automation[5] (5G-ACIA) is an industry alliance representing the OT and telecommunication sectors. 5G-ACIA has a working group on spectrum and operating models looking at the concept of private networks, at the need of private spectrum for Industry 4.0 applications and consolidate Industry 4.0 requirements towards 3GPP.

Open-RAN Alliance[6] (O-RAN) is an industry alliance pushed by the main MNOs worldwide that targets an opening of the RAN ecosystem to include smaller hardware and software vendors providing dedicated RAN components. Towards this goal, O-RAN is defining additional interoperable interfaces in the radio access network beyond those defined in 3GPP. O-RAN is expected to trigger the appearance of radio white boxes powering future 5G networks, which will play a key role in future private and neutral 5G networks.

2.2 Market analysis

The transition to 5G is expected to generate profits for network, infrastructure, and equipment vendors but it is still in the "building" phase. Hence, in order for 5G to become a great opportunity it wil have to take care of the following challenges:

- Providing ubiquitous 5G coverage requires a higher density of antennas compare to 4G (small-cell deployment cases).
- Given the sector's high debt and the difficulty to boost revenue little leeway of increasing incomes, MNOs are looking to seem to prefer deleverage instead of before doing further capex investments[7].
- In order to restructure balance sheets, some MNOs are divesting moving some of their antenna assets to tower companies, or even creating their own spin-offs[8].

In Europe, high competition among MNOs hinders substantial revenue increases, and there are still not many 5G use cases with a clear positive ROIAs a solution to all these challenges threads and in order to boost the deployment of 5G, MNOs believe that the sharing of RAN active elements will increase in thenext years[9].

The aforementioned reasons benefit tower companiesthat are booming in the corporate arena with recent mergers, acquisitions and demergers that let us glimpse a mid-term future where sharing active RAN equipment among MNOs will become mainstream, as it happens in the computation domain with Amazon Web Services, Microsoft Azure and other cloud platforms.

In this scenario, Neutroon is positioned as a key enabler for the management of future 5G infrastructures. Neutroon will redefine the management agreements making them much more dynamic and allowing detailed monitoring and control, providing to MNOs the required SLA guarantees. On top of this, tailored invoicing linked to the allocated resources of each operator will simplify the management of the tower company assets considerably.

3. Introducing Neutroon

3.1 Design principles

Neutroon is an end-to-endmanagement platform for integrated 5G infrastructures composed of three segments: 1) a Radio Access Networks (RAN) segment, 2) an Ethernet transport network segment, and 3) a Compute segment.

Neutroon adheres to the following design principles:

- *Hard slicing of infrastructure resources:*

  Built for multi-tenancy, and subject to the capabilities of the underlying hardware, Neutroon provides the ability to isolate physical resources in the RAN, Transport and Compute domains for a particular tenant. A **Neutroon Chunk** is an amount of virtual RAN, Transport and Compute resources assigned to a particular tenant, while a **Neutroon Slice** is a collection of such chunks, interwined with the network services that run on top of them.

- *Integrated management of 5G services:*

  A **Neutroon Service** is an integrated 5G service defined as: i) a virtual multi-technology radio slice that allows the customers of a tenant to connect to the tenant's service, ii) a set of virtual network or application functions hosted in the Neutroon compute resources, and iii) a dedicated transport network service connecting the virtual radio slice with the tenant's network or application functions.

- *Multi-tenancy:*

  Neutroon is designed with multi-tenancy in mind. Thus Neutroon distinguishes the role of the infrastructure operator and the role of the tenant. The Infrastructure operator is allowed to configure the physical infrastructure and to define infrastructure chunks that are assigned to different tenant. Tenants are allowed to instantiate integrated 5G services on compilations of their allocated chunks.

3.2 Neutroon Architecture

Figure 1 describes the internal Neutroon architecture highlighting the following functional elements:

The Neutroon Northbound Interface (NBI): Adopting the REST paradigm the *Neutroon NBI* allows the infrastructure provider to configure the physical infrastructure and to provision Neutroon Chunks and Slices. It also enables Neutroon tenants to provision Neutroon Services. A front-end service or a Machine Learning framework are the typical consumers of the Neutroon NBI.

Virtual Infrastructure Manager: It virtualizes the compute, RAM and storage resources available in a Neutroon compute domain. Neutroon uses OpenStack Ocata[10] as VIM, but other virtualization frameworks will be included in the future.

Service Orchestrator: Neutroon uses Open Source MANO (OSM)[11] to orchestrate network or application services instantiated over the VIM within a Neutroon Compute domain.

RAN Controller: Neutroon features a custom-built RAN controller that enables the deployment of virtual Wi-Fi and LTE services. RAN

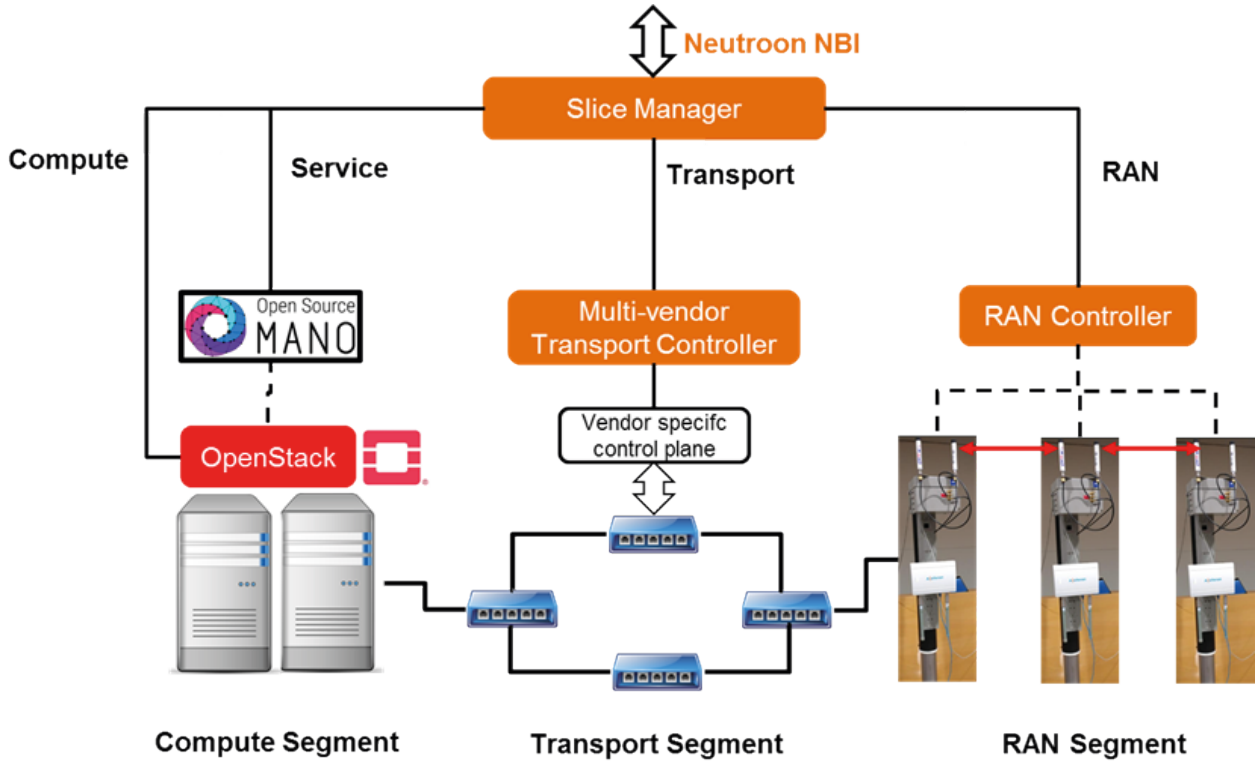

Figure 1. Neutroon Architecture

vendors can be integrated within Neutroon using a NETONF/YANG plugin. Upcoming releases of Neutroon will support instantiation of on demand services over 5GNR infrastructure.

Multi-vendor Transport Network Controller: Neutroon uses a multi-vendor Transport Network Controller to manage the deployment of on-demand transport services connecting the OSM Network Service with the virtual wireless access networks. Specific transport adapters are used to control transport technologies from different vendors, without impacting the rest of Neutroon components.

Neutroon Slice Manager: The Neutroon Slice Manager orchestrates the provisioning of Neutroon Chunks, Slices, and Services interacting with VIM, the Transport Controller and the RAN Controller. The Neutroon Slice Manager aggregates telemetry from the various RAN, transport and compute domains and offers an integrated telemetry end-point for each Neutroon Chunk, Slice, and Service. The Neutroon Slice Manager adopts a plugin based designed to enable the integration with other NFV orchestrators in addition to OSM.

3.2.1 Supported hardwarevendors

Neutroon has been demonstrated with various device vendors in the RAN, Transport and Compute domains.

RAN domain (Cellular): Neutroon has been used to deploy dynamic LTE services using Accelleran[12] small cells. A Neutroon LTE service is composed of a custom PLMNID in the small cell (up to 5 PLMNIDs are supported) and an associated virtual Evolved Packet Core (EPC) instantiated in the Neutroon compute domain. Several vEPC functions have been validated to be compatible with Neutroon including nextEPC[13], free5GC[14] and Attocore[15] .

RAN domain (Wi-Fi): Neutroon can provision Wi-Fi services using any Wi-Fi AP equipped with an embedded Linux distribution, such as Ubuntu or OpenWRT. A reference Wi-Fi device implementation for Neutroon is available that features up to three Qualcomm 802.11ac radio modules. This reference implementation provides joint access and backhaul services and hard slicing of Wi-Fi airtime radio resources.

Transport domain: Neutroon supports the provisioning of dedicated paths over an Ethernet transport network using VLAN to signal dedicated label switched paths. Neutroon can manage any transport network element offering an OpenFlow 1.3 interface, such as Dell[16] or EdgeCore[17] switches, or mm-wave wireless transport devices from BluWireless technologies[18]. Traditional Ethernet vendors can be integrated leveraging NETCONF and the available YANG models.

Compute domain: Neutroon can be used to manage compute resources that are virtualized using OpenStack. This means that all commodity hardware that is compatible with OpenStack (preferably hardware that can support RedHat or CentOS Linux as an operating system) is suitable for being used as the compute infrastructure of Neutroon[19].

Neutroon continues to integrate new device vendors in the RAN, transport and compute domains, setting as short-term priorities the support of 5GNR vendors in the RAN and high end

3.2.2 Examples Neutroon Services

To illustrate the concept of a Neutroon Service, Figure 2 depicts two exemplary Neutroon Services instantiated over a common 5G infrastructure. Each Neutroon Service consists of a RAN segment, i.e. virtual WiFi Access Points radiating a service specific SSID and virtual eNBs radiating a service specific PLMNID, a transport service that in this case is a service specific VLAN, and a compute segment consisting of a virtual EPC associated with the per-service PLMNID and an application virtual function (VM-A or VM-B). Inside the green and purple boxes, we can see the logical topology representing each service.

Although not explicitly shown in Figure 2, Neutroon Chunks could be used to limit the physical resources, e.g. compute nodes, transport network links, or physical interfaces in the RAN, available to each Neutroon Service.

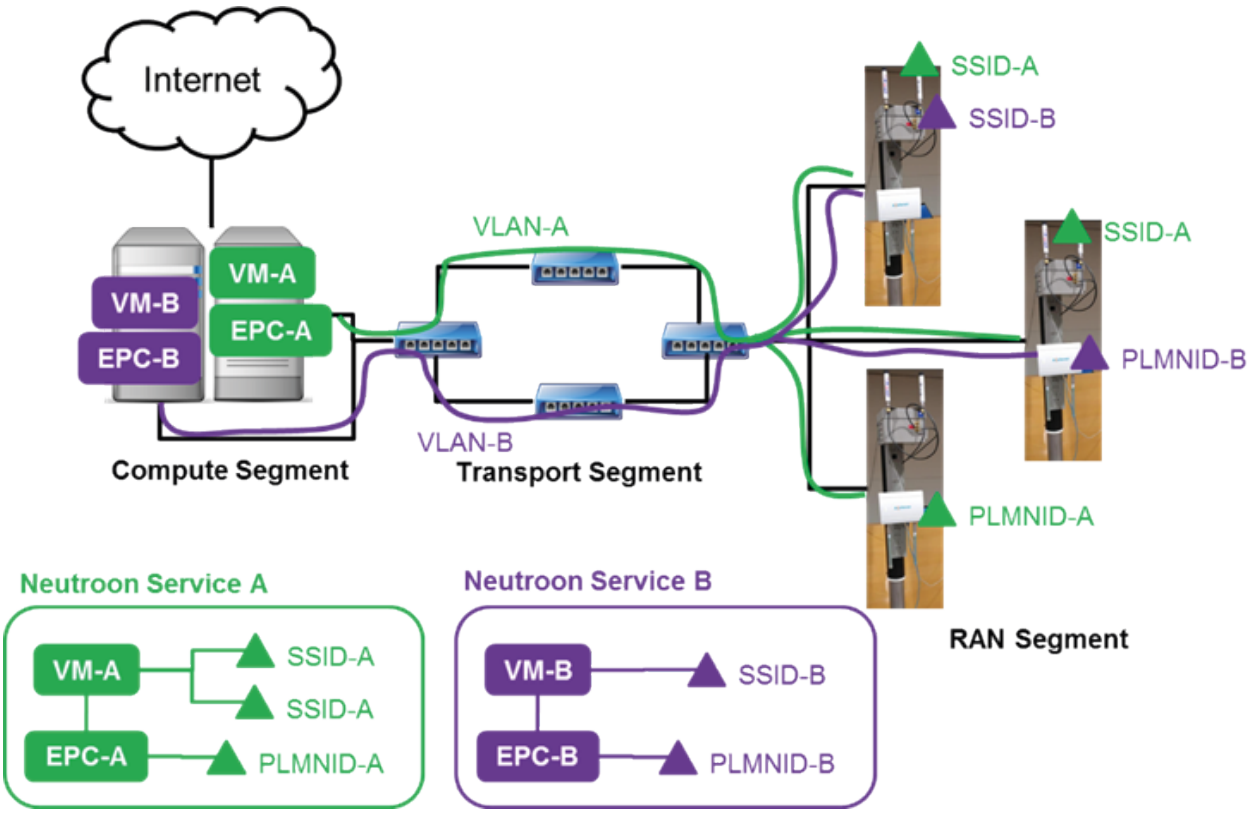

Figure 2. Example of Neutroon Services

4. Neutroon Success Stories

Neutroon has been developed by i2CAT[22] within the framework of several H2020 projects under the 5GPPP initiative[23] funded by the European Commission. We describe next several Neutroon success stories developed within these projects.

4.1 Multi-tenant small cell and edge computing deployment in Barcelona to support on-demand vertical services

The H2020 5GCity project[20] implements has successfully demonstrated its vision of neutral hosting using Neutroon as the keya component of its architecture to control a city testbed. Figure 3 depicts the 5GCity deployment in Barcelona, with details of the on-street and edge elements in the 22@ district.

On top of this infrastructure, Neutroon is capable of generating on-demand slices for each tenant composed of both RAN (LTE and Wi-Fi), as well as compute (edge and main DC) resources. Using a dedicated dashboard that interacts with the Neutroon NBI tenants can instantiate Neutroon Services on top of their Neutroon Slices to support different types of use cases. The dynamically deployed Neutroon Chunks, Slices, and Services can give end users access to the tenant's services within few minutes. Note that the use of multi-RAT within a single Neutroon Service is possible and that services can be deployed wherever the tenant sees it better suited: if a service requires low delays, functions can be placed in the edge; if a lot of storage is required, the main DC is the better option, where resources are less restricted (see an example service depicted in purple in Figure 3).

The 5GCity project demonstrated how a Neu-

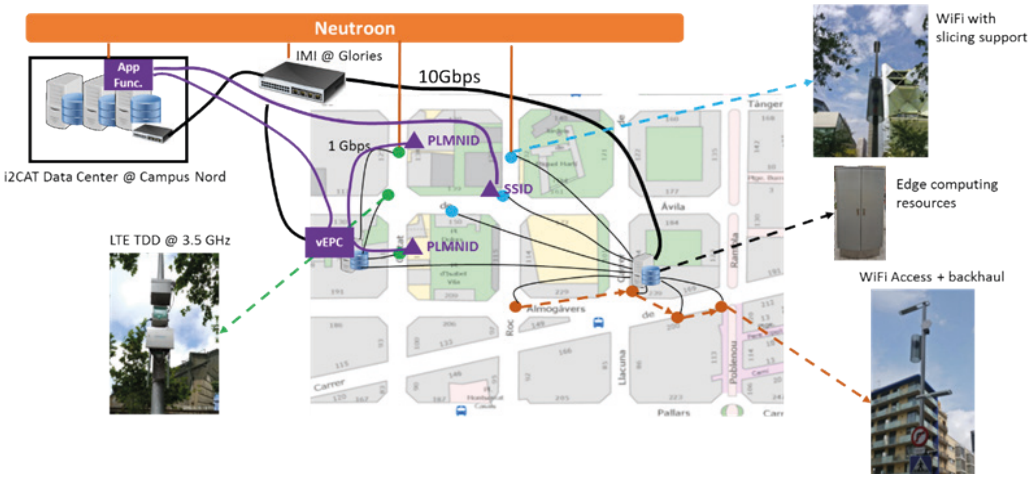

Figure 3. City-wide testbed controlled by Neutroon

troon Service can be deployed on demand to support a remote production use case from Barcelona TV[21]. Nowadays reporters covering remote events are equipped with a camera connected to a remote production backpack that connects to multiple cellular networks simultaneously in order to increase the probability of having enough quality during the transmission of the event. Instead, leveraging the capabilities of Neutroon, the 5GCity project presents a novel value proposition to media verticals, where a vertical specific SIM card is used in the remote production backpack that is used to connect to a dedicated LTE network that is deployed in a matter of minutes by the Neutroon operator just before the event and provides exclusive access to the remote production backpacks. Thus, using Neutroon the Barcelona TV can enjoy the Quality of Service delivered by a dedicated network even when covering crowded events such as concerts or demonstrations. After the event coverage finishes the Neutroon Service, including the dedicated LTE resources, is released and all the network capacity is available for general access user again. Figure 4 describes the elements involved in the Barcelona TV use case in 5GCity.

4.2 Ad-hoc deployment of wireless networks in the Bristol stadium fan-zone

The Neutroon RAN Controller has been used to support the deployment of ad-hoc connectivity services in the fan-zone of the Ashton Gate stadium in Bristol, UK, within the H2020 5G-PICTURE project[24].

During match days fans gather outside the stadium enjoying a variety of services such as food stands and concerts. Most venues cannot over-provision network and compute resources to handle the peak loads that occur during match days. Hence, venues require flexible management systems that allow to allocate the available network resources where and when they are most needed. Similar to the Barcelona TV use case, the Neutroon RAN Controller was used to provision guaranteed Wi-Fi access capacity to reporters providing live coverage for the events in the fan-zone. Reporters were equipped with standard mobile devices with Wi-Fi connectivity and used the Watchity service to record and stream live content. Figure 5 depicts the deplo-

Figure 4. BarcelonaTV use case in 5GCity powered by Neutroon

yment in the Ashton Gate fan zone, comprising a portable compute domain and three Neutroon integrated access and backhaul Wi-Fi devices (c.f. Section 3.2.1). The "s3" device connects to the compute domain and acts as gateway to the network, whereas device "s1" covers the VIP access and device "s2" the general access. Two dedicated wireless backhaul links are setup between "s1", "s2" and "s3". Using Neutroon a High Priority (HP) and Low Priority (LP) chunks are deployed covering the "s1-s3" and "s2-s3" links. Both chunks instantiate a Wi-Fi service (SSID) radiated by "s1" and "s2", which is used by any authorized device in the fan zone. Access control at the Wi-Fi access points is used to ensure that all devices connect only through the low priority WiFi service. In order to guarantee the QoS of the reporter's streaming service, a dedicated video identification function (VNF) is deployed in the compute domain, which identifies the Watchity[25] streaming traffic. Upon identifying the streaming traffic, the Neutroon RAN Controller moves the reporter's device to the high priority chunk ("s1"), thus providing a dedicated access and backhaul link to serve this traffic.

4.3 Dynamic wireless Slicing to support emergency services

Neutroon has also been used to provide dynamic airtime resource allocation for emergency services within the framework of the H2020 5GESSENCE project[26]. Said demonstration showcased the orchestration of common cloud and radio resources between public safety and commercial users, while guaranteeing the prioritised and high-quality access required by first responders.
For this purpose, Neutroon was integrated with an alarm management system developed within the 5G-ESSENCE project. The left part of Figure 6 depicts the demonstration setup where three Intel NUC computers were used to emulate a NFV MANO data center instantiating a Network Service that delivers Mission Critical Push-to-Talk (MCPTT) functionality. The Neutroon RAN Controller is deployed in a separate Intel NUC device and controls two Wi-Fi access points providing the radio access to public safety and general users. The system provided a default wireless slice allocating 25% of the radio resources for the public safety users and 75% of the radio resources for

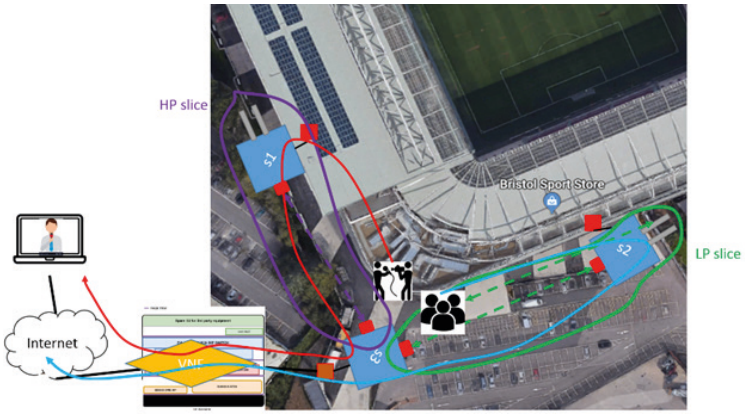

Figure 5. Neutroon control of WiFi slices in Bristol

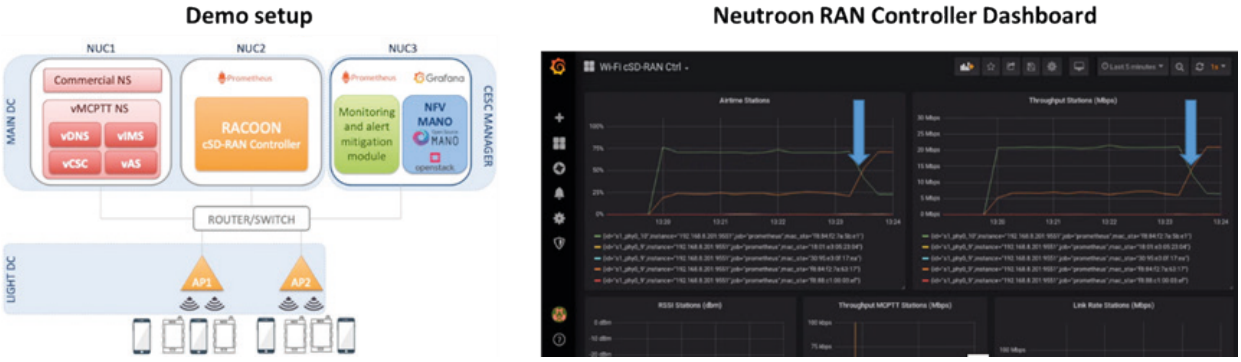

Figure 6 - Neutroon Wireless Slicing demonstrated in BAPCO

the general users, as it can be shown in the right part of Figure 6, where we see the radio airtime and throughput for the public safety (orange line) and general users (green line) slices. The MCPTT mission critical service was integrated with the Neutroon NBI so that emergency alarms raised by the MCPTT logic triggered a resource reallocation in the radio access using Neutroon, in order to increase the resources of the public safety slice (orange line) and decrease the resources of the general use slice (green line). The blue arrow in the right part of Figure 6 depicts the seamless radio resource reallocation among the emergency and general slices enabled by Neutroon. This demonstration was showcased in the BAPCO annual conference and exhibition, the reference event in critical communications and public safety, held in Newcastle UK in November 2019[27].

5. Neutroon Roadmap

This white paper describes the first release of Neutroon, which i2CAT continues to develop. The following features are currently in the roadmap for 1H2020:

- Support of new RAN vendors including 5GNR.
- An integrated telemetry framework, based on Prometheus[29], gathering compute, transport and RAN telemetry associated to a specific Neutroon Chunk, Slice or Service.

6. Conclusions

This white paper introduces Neutroon, a novel software developed by i2CAT to manage in a holistic manner private and neutral 5G infrastructures composed of compute, transport and RAN segments. Neutroon aims at lowering the entry barrier of vertical sectors to operate in an effective manner public and private 5G infrastructures, and to empower neutral host operators to enhance the flexibility of current RAN sharing agreements towards the vision of providing 5G networks “as a Service”.

In this scenario, Neutroon is positioned as a key enabler for the management of future shared 5G infrastructures. Neutroon will redefine the management agreements making them much more flexible, economically efficient and allowing a fully detailed monitoring and control providing to MNOs the required SLA assurance. All this control will allow a tailored invoicing linked to the allocated resources of each operator so that the management of the tower assets will be simplified and improve.

With its Neutral Host Platform, Neutroon also lowers CAPEX and, to some extent, OPEX. It enables a true 5G as a Service: '5GaaS'.

Incumbents, public operators and private operators will have new means of expanding their business and winning new revenue by delivering premium on-demand services focused on the requirements of customer segments, such as high network performance in key buildings, factories or areas or to meet specific industrial, regulatory or compliance needs. This approach has the potential to reach new customer segments and generate substantial extra revenue for a mobile operator [A 15% premium customer segment, increasing of their consumption of 3% each, makes an incremental revenue flow of 45% for the mobile telco[28]], where customer needs cannot be met with single, one-size-fits-all networks.

Contact

If you are interested in having more information about Neutroon, or having access to a demonstration please contact us at:

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8. Annex

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