Secure Healthcare: 5G-enabled Network Slicing for Elderly Care

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***Abstract*—While the research and advancements in 5G progresses, the focus of its application is shifting towards the industry and different verticals. The healthcare sector is also where 5G directs its promise to accomplish the requirements for smart hospitals, assisted living, elderly care etc. In sequence of fulfilling that capability, the healthcare needs to be provided a safe, secure, reliable and robust infrastructure for handling tasks. For that purpose, in this paper we provide an insight in the existing limitations in the healthcare sector for elderly care, presenting a fashionable solution that encompasses actual 5G network slicing techniques and innovations.**

Keywords-5G, network slicing, virtualization, healthcare, 5G security, elderly care

I. Introduction

The axiom of 5G ascends in numerous spheres in the industry, enticing the interest of investors, engineers, professionals and individuals alike. The aptitudes of 5G are broad and include several, but not limited to, extravagances such as: reduced latency, higher bandwidth, cheaper implementations [1], as well as inclusion of the upcoming world of Internet of Things (IoT) [2]. The Internet of Things are aiming to become a crucial component of voluminous areas such as: production and industrial domains, automotive and transportation, law enforcement and military, smart infrastructure as well as smart healthcare etc. To utilize what is promised by 5G, IoT will need to respect specific rules in order to be ameliorated by its vacant resources, as well as particular protocols in the use case they are intended for [3].

The certain application of devices can have detrimental modelling influence of what the 5G is going to become in terms of infrastructural display. For example, a wearable device (i.e. a smart-watch) will have different purpose for a doctor issuing it to a patient as a monitoring device, rather than a wearable for an individual, casually monitoring his heartbeat during sport activity. Thereby, the same device, which will become part of a certain IoT network, will need specific environment to which it will perform the activity it is envisioned for. Consequently, the privacy level is not very important for the person monitoring his heartbeat, whereas for preserving the doctor-patient confidentiality, it will be of utmost importance. Thus, in 5G the concept of *network slicing* is introduced, a novel approach for stipulating network segments, acclimatizing them to the conditions of the situation [4]: different security levels, diverse network performance, various latency, distinct reliability etc. [5]. One phone attached to two divergent network slices will experience two different performance levels, as well as access to different services [6].

Through network slicing, 5G aims at fulfilling the promise of satisfying the requirements of different verticals [7]. One of the most challenging demands is impending from the industrial IoT applications, where hundreds and even thousands of sensors, actuators, measuring devices and monitoring utensils should in an orchestral manner be an effective asset for simplifying production-related operations [8]. Alongside accommodating these devices’ requirements in terms of network resources, 5G contemplates also security-related issues that may transpire from such setups. In a more heterogeneous environment, the incidence of a security breach increases, i.e. a setup such as the healthcare, where privacy of users is the principal concern [9, 10]. A typical smart healthcare scenario may involve adaptation of devices that the users already have, for the specific need. In case of elderly care, where most elderly people live alone and lack the supervision of a person as well as physical presence, such smart devices may be critical in determining the future of the concerning individual. The designated healthcare professional will need an adequate level of security privileges in order to be able to provide sufficient degree of help in cases of peculiar incidents. This opens the door for questions of privacy, identity protection as well as personal data safety [11].

To handle these issues, the 5G network needs to be able to delineate a network slice for the healthcare provider with appropriate security levels and directives, as well as Quality of Service (QoS) [11]. For that reason, in this paper we introduce the concept of a network slice for the elderly care segment of the healthcare sector, for whose achievement a virtualized 4G EPC network core is integrated with a 5G concepts of User-plane and Control-plane separation, introducing additionally functional splits of the radio frontend for efficiently steering the Software-Defined Networking platform and providing ample Virtual Network Function (VNF) / Container Network Function (CNF) accordingly [12]. Consequently, the network slice should be flexible and customizable according to surfacing requirements. Last but not least, we conclude with the fact that this type of architecture should also be supplemented with additional privacy protection mechanisms and assets.

II. Related Work

The composition of this paper represents the work achieved in the Secure 5G4IoT Lab at the Oslo Metropolitan University in Norway, where an early testbed [13] was established as a platform-precursor for research in the fields of 5G networks, IoT furtherance and security-related issues in the equivalent. The initial testbed was founded on introduction of virtualized 4G core-network, namely the open-source research from the OpenAirInterface community in the venture towards 5G [14]. Alongside establishing of a 5G platform, the Secure 5G4IoT Lab focuses also on research in the field of cybersecurity and protection of 5G-related entities such as: mobile users, IoT and smart devices, enterprise and personal constituents etc. Their applications can be broad and therein the utilization of the same is shifted towards a possibility for the healthcare sector, particularly in the sphere of elderly care. Nevertheless, the platform needs to consider variety of considerations such as: appropriate security and granularity in its control, flexibility to support various scenarios due to the unpredictability and the nature of the work [15], ease of implementation with minimal interaction etc. For that purpose, we introduce a network slice concept for the elderly care.

A. *Requirements for Elderly Care*

In this period of shifting demographics, the modern human civilization worldwide is experiencing a change in population distribution by age. The number of elderly people is increasing and the availability of young people to sustain society and care for the elderly is on the decline [16]. According to the United Nations, "*Globally, the population aged 65 and over is growing faster than all other age groups. According to data from World Population Prospects: the 2019 Revision, by 2050, one in six people in the world will be over age 65 (16%), up from one in 11 in 2019 (9%). By 2050, one in four persons living in Europe and Northern America could be aged 65 or over. In 2018, for the first time in history, persons aged 65 or above outnumbered children under five years of age globally. The number of persons aged 80 years or over is projected to triple, from 143 million in 2019 to 426 million in 2050"* [17].

These facts alone are speaking highly of the need for technology-assisted care and mechanisms to support the deficiency of personnel for elderly care. Private services that encompass elderly care are expensive, and many people are unable to afford the same. However, the potential that resides within 5G for smart-home and smart-healthcare can alleviate the sharp requisite for succor in the elderly care domain.

B. *Core Networking*

For achieving network slicing, the 5G core (5GC) should be instigated because the architectural differences with the 4G antecede a need for more granular control over network function policies [18]. Namely, 5G will support differences in the control-plane and user-plane functions, where a policy control function is introduced (PCF) [19], as well as network slice selection function (NSSF) [20]. As indicated in Figure 1. , the 5G core is a service-oriented architecture, therefore the particularity is increased and accordingly the possibilities broadened [4, 18].

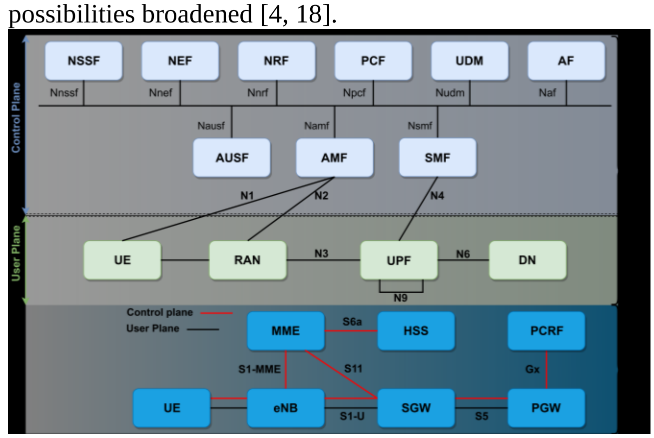

Figure 1. 5G and 4G core reference architectures (courtesy of 3GPP) [18]

For provisioning of network-related control and automation, a specific framework based on Software-Defined Networks is required. There are numerous SDN controllers with different capabilities and performances [21], which can be used in accordance to the need for achieving network slicing in 5G.

In the Secure 5G4IoT Lab, the testing of the core networking is performed in a private OpenStack cloud [22], exploiting the open-source capabilities of various tools such as OpenDaylight SDN controller [23], Docker container environment [24], Kubernetes orchestration [25] and automation as well as the OpenAirInterface deployment of a

4G Evolved Packet Core (EPC) according to the reference architecture from Figure 1. [26].

III. Facilitating 5G Connectivity

By means of successful virtualization, the EPC core constituents were examined and their potential for deploying in containerized environment proven [13, 26]. This fabricates the basis for utilizing the capability of Software-Defined Networking to construct adjustable network functions, which can be tailored according to the need of specific units (such as per-user basis, group or a sector, i.e. healthcare). For the purpose of researching the virtualization potential, the 4G EPC was deployed in the cloud and tested accordingly in different scenarios (Figure 2. [13, 15, 26-28].

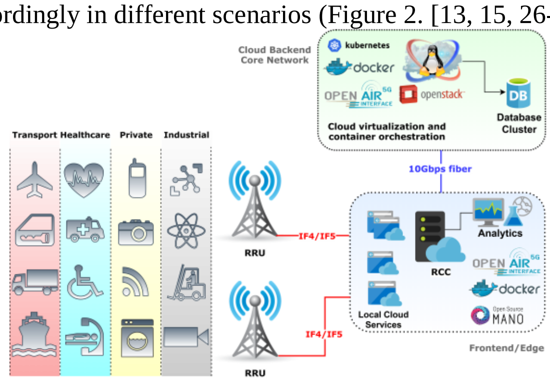

Figure 2. Secure 5G4IoT Lab 5G deployment infrastructure [11]

For connection to the core network, we employ an eNode-B (eNB) base-station (Figure 2. , founded on a Software-Defined Radio from National Instruments, explicitly, Universal Software-Defined Radio Peripheral (USRP) B210 as a Remote Radio Unit (RRU) [29]. The USRP B210 was successfully tested on two 4G LTE bands 3 and 7 (1800 MHz and 2600 MHz, respectively). Connectivity with the 4G LTE network is demonstrated using generic mobile phones as User Equipment (UE) with self-programmed SIM cards for authentication, as well as Wi-Fi to 4G gateways [30]. This scenario incorporates integration between the radio frontend and the core network in a C-RAN (Cloud-Radio Access Network) model [26, 30].

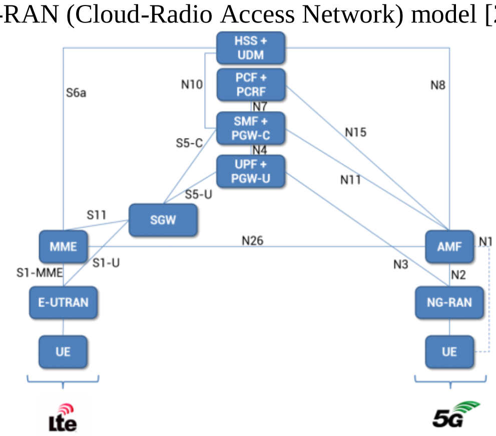

Figure 3. Non-roaming architecture for interworking between 5GS and EPC/E-UTRAN (courtesy of 3GPP) [18]

In the effect towards a fully-operational 5G connectivity, an interworking strategy is introduced between the EPC and 5GC, according to the requirements from 3GPP [18] (as represented in Figure 3.) [26, 28]. Furthermore, the interworking between the virtualized core and a Wi-Fi fronted was demonstrated, allowing for a transparent and simple inclusion of Wi-Fi capable devices into the 5G network, i.e. for smart-home deployments [27].

IV. Adaptable Network Slicing

Network slicing in 5G has to abide to specific requirements before becoming achievable. To be exact, the core network needs to have the User-plane function separated from the Control-plane function for the purpose of providing packet routing/forwarding, header manipulations, Quality of Service, billing system and policy control. Different metrics are also required (latency and QoS) in order for the isolation/separation functions to ensure adequate performance per-slice. An implementation of a software-based VNFs (Virtual Network Functions) can be achieved with using a generic server machine with more than 200 Gbps throughput and approximate 70 micro-seconds latency with 60% CPU usage [31]. In the 5G4IoT Lab, we proposed a comparable model for local connection of a Distributed Unit to a Cloud Radio Access Network (Centralized Unit) through Thunderbolt-3 interface, although the achievement of the same is feasible using fiber optic links [30].

In addition, we implement an orchestration mechanism of container network function using Kubernetes [25] with Calico BGP plugin [32], as well as a NSSF and PCF 5G network slicing mechanism based on the FlexRAN open-source project [33]. Nevertheless, this mechanism is tested on the 4G EPC core, dissected into modules and deployed in OpenStack cloud, as represented in Figure 4. [30].

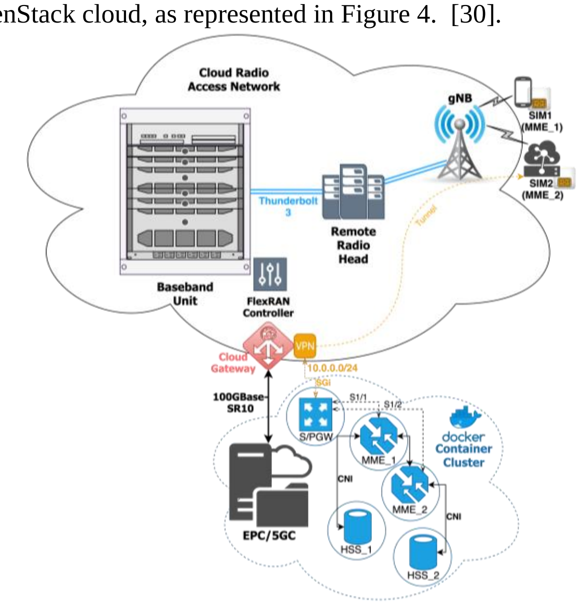

Figure 4. Secure 5G4IoT Lab deployment of a 5G C-RAN network supported by Thunderbolt-3 [30]

V. FUTURE WORK

Providing a network slice for the healthcare vertical was successfully achieved in the work of the Secure 5G4IoT Lab at the Oslo Metropolitan University [11], although further testing and adaptation for the 5GC is required. The Policy Control Function and Network Slice Selection Function are proprietary constituent of the 5G Core [18-20], and thereby an implementation follows as an interworking coexistence between the 4G EPC and 5GC. Introducing the OpenDaylight SDN controller [23], the flow control and Quality of Service can be accordingly adjusted for the requirements of the slice that are going to be established in parallel for the smart-healthcare slice for elderly care. Furthermore, the radio frontend remains to be tested in the spectrum over 6 GHz, specified for the 5G systems, as well as mmWave technologies [34]. This will allow for much broader spectrum of devices to be employed.

The adaptable network slicing for the healthcare vertical is an environment with extensible high security requirements and thus should be supplemented with multiple layers of security. The isolation and policy access definition on the base of a network slice is not sufficient and additional mechanism are required. For that purpose, in the testbed we introduced an Identity Provider system (IdP), which aims towards achieving strengthened security of devices authenticating in the 5G network [35, 36], specifically, providing an Identity Federation [37]. As the heterogeneity of 5G networks increases in parallel with the number of devices, the attack vectors are becoming more complex and thus the devices demand additional protection. Detecting and preventing attacks may be decisive factor between the success and failure of an infrastructure. Correspondingly, a machine learning platform is required that is based on artificial intelligence, and which can perform anomaly detection [38] in such heterogeneous environment while automating the enforcement of actions that aim towards stopping potential attacks and preventing compromising of personal users' data.

VI. CONCLUSION

The mechanism of deploying a network slice for the healthcare vertical was successfully explained and tested. The 4G EPC core slowly transcends towards the dissected 5GC and opens the possibility towards enactment of individualized Quality of Service control and policy enforcement at the network and application layer. Nevertheless, the procedure for instituting dynamically-allocated resources for the slice are not yet clear and therefore, this specific area requires more research and investigation. Furthermore, elaborating a use case for elderly care requires specification and more details in order to customize the 5G slice according to the specific requirement, which includes also security-related issues that need to be covered.

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