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Mobility Management Architecture in Different RATs Based Network Slicing

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***Abstract*—Network slicing is an architectural solution that enables the future 5G network to offer a high data traffic capacity and efficient network connectivity. Moreover, software defined network (SDN) and network functions virtualization (NFV) empower this architecture to visualize the physical network resources. The network slicing identified as a multiple logical network, where each network slice dedicates as an end-to-end network and works independently with other slices on a common physical network resources. Most user devices have more than one smart wireless interfaces to connect to different radio access technologies (RATs) such as WiFi and LTE, thereby network operators utilize this facility to offload mobile data traffic. Therefore, it is important to enable a network slicing to manage different RATs on the same logical network as a way to mitigate the spectrum scarcity problem and enables a slice to control its users mobility across different access networks. In this paper, we propose a mobility management architecture based network slicing where each slice manages its users across heterogeneous radio access technologies such as WiFi, LTE and 5G networks. In this architecture, each slice has a different mobility demands and these demands are governed by a network slice configuration and service characteristics. Therefore, our mobility management architecture follows a modular approach where each slice has individual module to handle the mobility demands and enforce the slice policy for mobility management. The advantages of applying our proposed architecture include: i) Sharing network resources between different network slices; ii) creating logical platform to unify different RATs resources and allowing all slices to share them; iii) satisfying slice mobility demands.**

***Keywords*—5G Network; Network slicing; Long-Term Evolution (LTE); WiFi; Software Defined Networking (SDN); Network Function Virtualization (NFV); Mobility Management; IP-Flow; Data offloading.**

I. Introduction

The growing proliferation of smart device connectivity and applications have meant that the traditional cellular network infrastructure and networking protocols are not sufficient to manage the tremendous data traffic generated, considering a different level of resource allocation and traffic flows in Radio Access Networks (RAN) and core networks. The future network, 5G, appears as a promising solution offering a higher capacity and efficient network connectivity than a current cellular network. Moreover, 5G network architecture enables to integrate different Radio Access Technologies (RATs), such as 5G, LTE, WiFi. 5G system designed based on the concept of software defined network (SDN) and network functions virtualization (NFV) to visualize physical network resources. SDN and NFV empowers 5G architecture for slicing virtual network resources to many network slices. Therefore, the concept of network slicing has been identified as a multiple logical networks where each network independently operates on a common physical network [1]. Each network slice works independently and virtually represents end-to-end network. Moreover, slicing architecture allows multiple network slices to operate simultaneously.

Nowadays, it is common that a user has more than one type of wireless connectivity interfaces working on the same device. Thus, todays network isbecoming more and more common to have heterogeneous RATs environment, such as WiFi, LTE and 5G networks. Therefore, it is important to provide a network slicing capability to manage different RATs on the same logical network as a way to mitigate the spectrum scarcity problem and to enable a slice to control its users across different access networks. For instance, according to the Office of Communications of U.K (Ofcom) [2] there is around 81% of mobile consumers using WiFi network at some point, thereby network operators consider a WiFi network an important player as a method to offload mobile data traffic.

In this paper, we propose a mobility management architecture in network slicing where each slice can manage its users across heterogeneous radio access technologies such as WiFi, LTE and 5G networks. In this architecture, each slice has a different mobility demands and these demands are governed by a network slice configuration and service characteristics. Therefore, our mobility management architecture follows a modular approach where each slice has individual module that handles the mobility and enforces the policy of mobility management of a slice.

Several benefits of applying our proposed architecture are: i) Sharing network resources between different network slices; ii) creating logical platform to unify the resources of different radio access technologies and allows all slices to share the resources; iii) satisfying slice mobility requirements by enforcing a policy of slice mobility taken into account the network slice configuration and service requirements.

The rest of the paper is organized as follows. In Section II, we describe the network slicing architecture. Section III presents our mobility management architecture. The seamless connectivity of different RATs in Network Slicing is presented in section IV. Different use cases are discussed in section V. Section VI presents some of the related works in mobility management for network slice. Conclusion follows in section VII.

II. Network Slicing Architecture

Different network slices work on top of shared infrastructure, which is constructed of common hardware resources such as network functions virtualization infrastructure (NFVI). Also it could work on the dedicated hardware such as network entities in the RAN. Each network slice is realized by a number of network functions NFs, which are either physical or virtual, depending on the slice functionality. These network functions are controlled by SDN where the network can be classified into control plane (CP) and user plane (UP).

Despite the NFV and SDN concepts being completely deferent, they are highly complementary to each other. NFV can work as a virtual SDN controller (network function) to run on the Cloud. This allows to move the SDN controllers to the optimal locations in the Cloud. On the other hand, SDN provides logical connectivity between virtual network functions (VNFs) to optimize network traffic engineering [3].

End-to-end slices are sharing of resources of the CN and RAN. For example, in the RAN domain, the shared NFs include monolithic and distributed base stations. In the CN, they share different virtual network function (VNF) instances including mobility management and home subscriber server (HSS). According to 3GPP standards [4], there are three solution groups of common functionality of the network slice as illustrated in Fig. 1. Group A is depicted by deploying a common RNA and independent CN slices such that each network slice handles a user, and its mobility management, sessions and subscription. Group B assumes that all network slices are on a common RAN where mobility and subscription are shared between slices, while other functionality handles the network slice. Finally, group C assumes fully shared RAN and a common CN control plane, but CN user plane is under a dedicated slices control.

III. Mobility Management Architecture

Todays network operators are facing many issues such as increasing mobile data traffic volume, congestion in users dense area and the need for expanding the current network coverage area. Therefore, it is becoming more and more important to find suitable solutions to overcome these issues. The data offloading solutions appear as promising solutions to solve these networking issues. There are many mechanisms for offloading mobile data traffic such as capping user data, device-to-device data offloading and using complementary network to offload mobile data (e.g.,WiFi network). According to [5], wifi network is one of the key players in data traffic

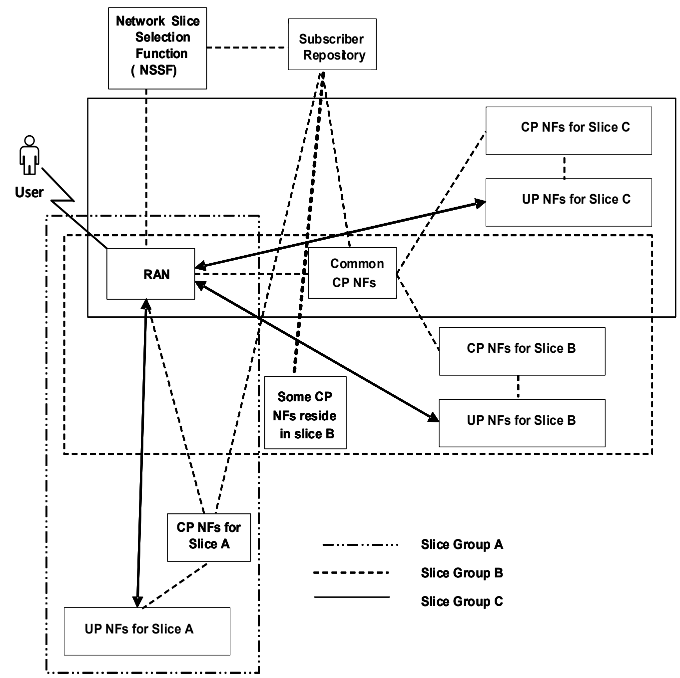

Fig. 1. LTE Network slice architecture with different groups of network functions (NFs).

where 20% of data in the outdoor environment comes from wifi network, while 60% of data in indoor environment is landing in WiFi network. Therefore, cellular network operators consider WiFi network as a complimentary network to offload mobile data.

One of the most important aspects of 5G network is the capability for managing heterogeneous infrastructure, where it creates unified programmable platform based on abstracting different RANs as depicted in Fig. 2. The abstraction platform unifies all RATs resources and it is shared by different network slices where each slice has the capability to control its users in different access networks such as 5G, LTE or WiFi. As shown in the figure, the mobility management is centrally controlled by a mobility manager (controller). The mobility manager works based on modular approach, where each slice has its modular unit reside in the controller. Thereby, each module enables the mobility management of a dedicated slice to support different operations, such as resource optimization and data offloading between different access networks and so on.

The general fundamental requirements of offloading data between any networks are:

- Seamless connectivity between two networks such as LTE and unlicensed network (WiFi).
- A common interface of multi-connectivity in the users mobile device for available networks (offloading networks).
- Considering latency mechanisms to minimize the

effectiveness of delay of current service during the offloading procedures, e.g. short path mechanism [6].

Different abstraction parameters are considered for network offloading where these parameters are distinct according to different access networks and most of these abstraction parameters come from physical network resources. Below, we provide brief definitions of potential parameters for abstraction, depending on the network interface [7].

- As mentioned earlier, the abstraction parameters depends on RAN-T. For example, wifi network parameters include Received Signal Strength Indicator (RSSI), frequency bandwidth, power transmission, etc. whereas the LTE network abstraction parameters include Quality of service Class Identifier (QCI), Physical Resource Block (PRB), Reference Signals Received Power (RSRP), Reference Signal Received Quality (RSRQ), etc.
- Available bandwidth is an important parameter where it represents the amount of radio resources available at a RAN node. Many factors affect bandwidth availability such as current Quality of Service (QoS) satisfaction requirements, channel capacity and backhaul network load.
- Spectral efficiency represents the capability of how many bit rate can be transmitted over a current transmission bandwidth (in bps/Hz).
- Node capacity, which represents a composition of available bandwidth and spectral efficiency.

In the Next section, we disscus the seamless mobility management between different access networks, for exmple, we consider the seamless connectivity between LTE and WiFi networks.

IV. Seamless Connectivity of Different RATs in Network Slicing

In heterogeneous network environments, where a user moves between different access networks, the operator always would like to have the control of his clients in different access networks in order to introduce better quality of services (QoS) and enhance user experience (QoE). In this work, we introduce a network slicing architecture in order to provide offloading of user flows between different access networks but under the same slice control. In our architecture, we have an abstraction layer that includes different logical shared resources of heterogeneous RAN networks. All network slices share this layer to assign resources to their users in different RANs.

In order to seamlessly assign a user to a certain slice, there is a controller in each slice that manages users in the slice and assigns a number to each user (ID-Slice). ID-Slice represents a slice identification for a user within the slice, meaning that

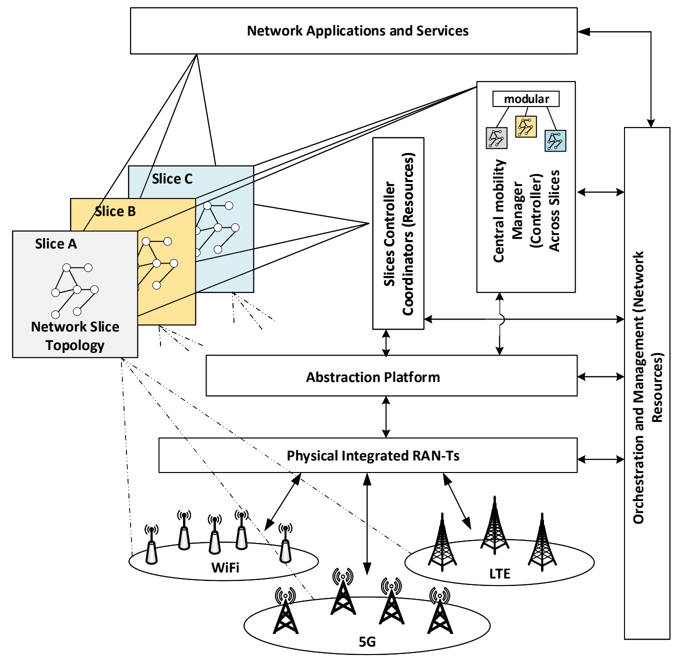

Fig. 2. Mapping logical abstraction RAN-Ts between different network slices.

whenever a user switches into different RANs and it has ID-Slice, this helps to identify the slice to which the user belongs.

Let us consider LTE and WiFi networks to illustrate a user seamless connectivity within a network slice. In the traditional LTE network, a network operator holds a user flows (bearers) setup. In the same manner, our proposal encompasses a slice operator that enables a slice operator to setup a user IP-flows. Moreover, the slice controller, during the setup tags an ID-Slice for each flow. In the same context, we assume that a slice operator takes care of the flow admission control to ensure that each flow gets enough resource requirement for QoS guarantee.

In our work, we consider that a UE device has the capability to use both interfaces (LTE and WiFi). Fig. 3 illustrates the logical connection between network elements. The P-GW works as an IP anchor, which does all the IP-flow admissions. Another node called Wireless Access Gateway (WAG) implements the necessary functions in the WiFi network. The routing is done between the P-GW and WAG by the LTE-WiFi Controller Flow (LWCF). It takes care of all the signaling between the P-GW and WAG to tunneling the UE flow mobility from the LTE to the WiFi and vice versa. When a UE changes his network coverage location from LTE to WiFi, the slice controller coordinator assigns a new AP that has enough resource. At this point, all information of the AP is held by the abstraction platform. Note that all UE information and status are held by the slice controller (e.g., IP addresses, port addresses, OpenFlow rules and ID-Slice which is the same as SSID). In the case of any change in the

UE locations, the slice controller tells the WAG to update the binding tables in the LWCF. One Home Address (HoA) has a number of Care of Address, which may be assigned in the binding cache table. In addition, there is another table called the flow-binding table, which specifies the type of traffic route to a corresponding CoAs. Both tables are sorted with respect to the priorities. The highest prioritized entry is at the top. They are linked together over the Binding Identity (BID) fields. If any item is missing in one of the tables, the highest priority binding entry is used by default. Finally, the novelty of the presented architecture is that seamless individual flows can be implemented for any of the interfaces (LTE and WiFi) under a specific slice.

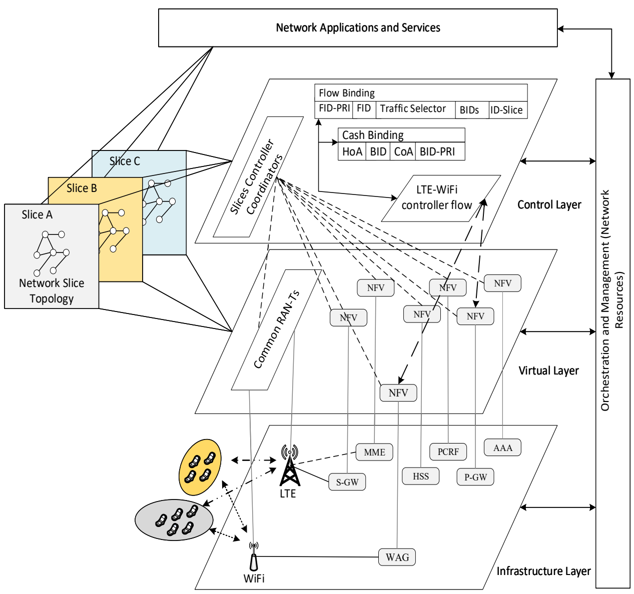

Fig. 3. Logical connection LTE-WiFi network slicing.

V. Use Case Scenarios

Future mobility network (i.e. 5G system) is considered as a big challenge in terms of variety of user devices and applications that generate a huge data volume. In this work, a mobility management focuses on link continuation. The link connection properties are changing during a movement between different base stations and access points, which are attached to the users device. The data session has to continue during mobility, where there are two methods of session continuity (seamlessness) either through the fixed IP address or coping with a current attached point address change.

The different request of mobility cannot be handled by a single solution. Therefore, our architecture has many modules to adapt to different network configurations according to the service or slice requirements (this type of approach is called mobility on demands). At this point, the main challenge is how to identify the actual demands in accuracy with respect to selecting appropriate solution of mobility to fit a scenarios demands. Different criteria have to be taken in to consideration when selecting the solution such as the end device specification and the surrounding environment (e.g. the smartphone in the dense area or sensor attached to car). Furthermore, the network condition should be taken into consideration (e.g., the load of neighbor access points, different access technologies or QoS parameters).

Taking into account aforementioned requirements of mobility, different available scenarios could be identified where a user device needs to offload from a current cellular network (e.g., LTE) to the WiFi network. These scenarios are different from each other depending on the current user services. User may have one or more connection flows representing different services. Consequently, in case of offloading user into WiFi network, it is either offloading all user flows or selecting some of them. Selective flows provide better user experience with services that are sensitive to delay such as online gaming. Therefore, such services have higher priority to stick with a cellular network rather than offloading to WiFi, while services such as FTP download can be offloaded to WiFi because it is not sensitive to delay when switching to WiFi.

Today, network operators pay attention to WiFi network as a complimentary network to deploy to offload their data network and extend their customer services such as voice over WiFi (VoWiFi) and video over WiFi. In the context of Voice over LTE (VoLTE), the VoWiFi is a complimentary service of VoLTE, both of them utilizing IMS voice specification where the voice is delivered based on the IP protocol. The seamless offloading scenario is possible between LTE and WiFi and vice versa. Similarly, video over WiFi follows the video over LTE (ViLTE) in the IMS technology.

The scenarios provided above can be deployed in many real-life situations. For example, when a user is in a region where there is no cellular coverage and that user needs make a call, such as London tube. Also, in the case where a customer exceeds a monthly subscription bundle, the operator with VoWiFi may be avoided such as customers from of extra charging service.

VI. Related Work

5G network has attracted many research interests in academia especially when the concept of network slicing is considered. The authors in [8] introduced mobility management mechanism considering a low latency services in network slice. The authors optimised the selection of mobility anchor during the attachment procedure between the edge nodes. In [9], the authors proposed a unified approach to mobility and routing management that offers connectivity management as a service (CMaaS). This approach was designed based on the SDN network architecture with hierarchical network control capabilities to allow different levels of network performance. In [10], the handover mechanism of LTE network was redesigned to trigger decision scheme based on the grey system theory. This handover mechanism can be applied to the railway communication system to provide less co-channel interference for passengers in carriages. A comparison study of mobility management mechanisms in very high dense network areas was discussed in [11]. In [12], a mobility management architecture in network slice was developed based on the SDN and NFV technologies to offer seamless user traffic in heterogeneous access networks.

This paper presents how the SDN technology could be applied in cellular network in order to control mobility in the context of next generation network (5G). The proposed mobility management architecture follows a modular approach where each slice has individual module to handle the mobility demands and enforce the policy of mobility management of a slice. The advantages of applying our proposed architecture includes: i) Sharing network resources between different network slices; ii) creating logical platform to unify different RATs resources and allowing all slices to share them; iii) satisfying slice mobility demands.

VII. Conclusion

In this paper, we have presented a logical mobility management architecture for network slicing based future 5G system. The control mechanisms have been discussed to unify resources of different RATs through the logical abstraction platform. Based on the modular approach, we have shown how each network slice is linked with the module, which is responsible for the mobility management of the slice. Moreover, we have introduced different use case scenarios of data offloading in cellular network.

In the future, network simulations (using e.g. OMNET++) will be conducted to evaluate our propose architecture of network slicing in different mobility scenarios.

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