Mobility Management in 5G Network on the Efficiency Hierarchical State of Slicing

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Research Article

Keywords: 5G, Mobility Management, Slicing, Two-Tier Pattern, Connectivity

Posted Date: October 10th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2135964/v1

Additional Declarations: No competing interests reported.

Mobility Management in 5G Network on the Efficiency Hierarchical State of Slicing

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Abstract

Performing quality of service thanks to mobility management in network slicing such as seamless handover brings new challenges. Wherefore, to build and manage a ***5G*** network, that cope and exceeds the emerging requirements of a full-scale range of users. Massive wireless data traffic from different application scenarios. Need, to transform it into a set of logical networks of a shared infrastructure. To configure and connect end-to-end anytime, anywhere, regardless of the access channels characteristics. To attend a defined business purpose and comprise all the required network resources. In this study, we discuss the background and related work in network slicing. Then, we present a framework for ***5G*** network slicing mobility management, a versatile model based on a two-tier pattern. Handled by the massive wireless data traffic from different application scenarios. Keeping into consideration that depends on the design parameter $\boldsymbol{P^B}$ blocking probability for homogenous models, and the generic value radii R = (r max) as the minimum communication range required in the heterogeneous models. To achieve a configurable balance between power saving and latency in ***5G*** mobility management.

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1 Introduction

To ensure that the user mobility patterns match with the coverage and availability of the resources allocated to the slice, we introduce the concept of slice

mobility [7]. Where, the scope of this article is to define, that a network slice is an end-to-end (E2E). A logical network operates from a common basis (physical or virtual) network, fully isolated, with independent control and mobility management. Flexible programmable to cope service level agreements (SLA) of a specific service. Being that, the mobility support for network slicing is optional for some specific network slices [8]. For example, network slices serving industrial control do not need mobility management functions due to the fixed position of devices (mMTC). Despite, network slices do need mobility management to differ in their mobility requirements [6]. E.g, the mobility requirement of the mobile broadband (eMBB) slice is different from the slice for automated driving services. The mobility of low latency communication services, shared by a group of moving devices, e.g, autonomous vehicles that share sensor data, are a main example of these cases. Furthermore, a network slice can help a communication system to improve energy efficiency and resource utility and satisfy flexibility requirements imposed by the wide variety of business services through adopting technologies. Accordingly, we propose a two-tier resource allocation scheme [5] for the network slicing paradigm to achieve the highest resource utility as illustrated in $Fig.1$.
Motivation and contribution:
Since we have a very limited number of scenarios to generalize. And our study is a case where the event in an SC (Small Cell) might borrow channels from the umbrella MC (Macro Cell) [9, 14]. Wherefore, based on this observations, the contributions of this article are:

- The introduction of several slice mobility patterns to optimally manage and use slices with their allocated resources.
- The definition of several key slice mobility triggers and user equipment (UE) grouping methods to enable efficient slice mobility needed for the described slice mobility use cases.
- The review of service migration capabilities needed for slice mobility inside one homogenous infrastructure and can be applied to heterogeneous load scenarios as well i.e. spectrum licensed and unlicensed.

Hence, we present our 5G network slicing framework based on our previous work.

The rest of the paper is organized as follows. We introduce the Related Work on Network Slicing and Mobility Management in Section II. Concept of Slice Mobility in Section III. Scenarios and Mobility Models in Section IV. Followed by Network Model and Assumptions in Section V. Then, Numerical Evaluation: Adaptation to Large Scale in Section VI. Technical Method and Results are illustrated in Section VII. The contribution ends, with a final discussion of the results obtained followed by a conclusion, and future work are reported in Section VIII.

2 Related Work

The management of different applications with contradictory requirements on a common infrastructure can be performed via separated network slices. Since, slicing the network will allow to configure own network outline and define specific functions for each case, while sharing the same infrastructure [15]. For example, slicing will allow allocating only the necessary functions and reserve resources on the entire path of the communication, allowing the network configuration to be tailored for each case. With the help of NFV [12]. The objective is to virtualize as many functions as possible [2, 3]. Some works have been done toward the use of smart clustering techniques for distributed NFV-based networks [4]. Another example scenario for applying the QoS slicing is given in [1]. And in this a scenario [6] consists of a future $5G$ network operator offering differentiated types of services depending on the specific use case. Thus, the scenario is a combination of these use cases, each one with its specific requirements, and the operator has to provide service and management for all of them jointly. In addition, the authors discuss building a multi-tenant and multi-service end-to-end $5G$ mobile network architecture using NFV, and network slicing in the $5G$ NORMA project. As well, Ericsson and NTT DOCOMO successfully showed a dynamic $5G$ network slicing proof of concept (POC) on June $9, 2016$. Very recently, Huawei with the other three enterprises released a network slicing white paper. They discuss several key technologies such as network management system, the dedicated core (DCOR) feature supports the operator to deploy multiple dedicated core networks by sharing a common Public Land Mobile Network (PLMN). Furthermore, some frameworks for virtualizing wireless networks have been proposed in the last years. As a MATILDA project, proposed a highly modularized OSS for managing the different components of the whole $5G$ infrastructure; this OSS can work with the fundamental Convergence Layer to manage network slices. Also, provides NFV MANO functionality; however, their OSS/BSS is not structured according to what 3GPP defined [3]. Besides that, A flexible $5G$ network architecture is proposed in to support the coexistence of heterogeneous services and to quickly create services [15]. The authors propose to use NFV in the architecture to realize the sharing of resources by different services and orchestrating resources automatically [6, 12, 13].

3 Concept of Slice Mobility

A network slice consists of computing and storage resources, associated with virtual networks, possibly composed of multiple virtual sub-network segment [1, 15]. Moreover, the slice itself may need to adjust its resource allocation, adding more resources or freeing unused ones. These requirements lead us to the definition of the concept of slice mobility. Depending on the type of services they are using are generally triggered by the mobility of a group of end-users [8]. However, The mobility of users is a particular feature of wireless networks that brings new challenges to slicing. Not only because mobility generates variations in link capacity and performance, or because it makes the number of users on a network vary significantly, but also because it adds management complexity. Since, Wireless networks have to deal with the management of user mobility, transact handovers and assure QoS despite the location of the user [1, 14]. New problems are introduced when allowing user mobility in a sliced network. In this case, not only a user will change the BS or AP it is connected to, but also it could change of slice. Then, handover mechanisms to move a user across slices are necessary. As slices may be owned by different entities and can belong to totally independent virtual networks [9, 13].

3.1 Mobility Management in 5G

Mobility management is composed of two main parts, handover and location management protocols. The major challenges are to provide omnipresent wireless access abilities, maintain the quality of service, and seamless mobility management for terminal communication devices in networks. To cope with requirements such as scalability, traffic management, seamless mobility, resource management, etc. Therefore, novel approaches and methods are needed [1, 15].

3.2 Infrastructure Scenario

In this paper, we propose a new paradigm slice allocation scheme with a two-tier pattern [5, 9] to overcome the traditional network slicing pattern. Since in real deployments it is common to find scenarios with multiple BSs or APs belonging to the same access network. Then, resource allocation and isolation on a multi-cell (multi-AP) network need a consideration. Deploying slices sharing multiple BSs or APs can bring new issues such as load unbalance between slices. For instance, sharing the spectrum could be accomplished considering some load estimation mechanism. Then, resource assignment to each slice inside each cell could be more accurate. As we already mentioned, slicing can be done at different levels, namely, from application and flow slicing to hardware and spectrum slicing.

3.3 The Resource Allocation Problem

The main issue is how to assign resources to the different slices. For the wireless scenario, the resource allocation problem considers what the resources are and how they are modeled can vary depending on the standpoint. Some works have studied the resource allocation problem from the traffic perspective. An important fraction of the study is the blocking probability and signaling load trade, typically in a two-tier network where terminals move at different speeds [9]. Our work is related to this several works on resource allocation between operators in which the operators take no decision at all, and it is the infrastructure owner who allocates resources among the operators to maximize some sort of network utility [8]. Each decision influences and is influenced by each other decisions. Additionally, the allocation of resources to the individual slices and their real-time management can be implemented with the support of Software-Defined Networking (SDN) and Network Function Virtualization (NFV) approaches, hence with management and orchestration (MANO) functions, and in particular with a resource orchestrator (RO). Virtual Infrastructure Manager (VIM), VIM is responsible for managing the NFVI resources including computing, storage, and network. These resources are transformed from hardware resources to virtual resources via a virtualization layer Fig.1. Moreover, network slicing needs to coexist and cooperate with traditional technologies, evolved from LTE/LTE-A systems. In order to achieve, connection between physical radio equipment and radio equipment controller [1].

4 Scenarios and Mobility Models

In response to business needs. It is advisable to start with just a few, static slices and then increase the number of slices and the level of dynamicity in terms of orchestration and adaptability later on. [2, 3, 15] as illustrated in $Fig.1$.

Besides that, network slicing increases the complexity of network management, especially in the context of large numbers of network slices. Thus, it is critical to find automated management and orchestration solutions. So far, there is not a standardize vision about the exact form and scope of network slice management and orchestration (MANO) [2, 3, 15]. To enable automated and flexible slice management, the concept of network services developed by the ETSI NFV group can be reused. Based on the current technology trend, it is natural that the existing NFV MANO framework [12] is leveraged to manage and orchestrate $5G$ network slices. Therefore, the management of network slices may be performed at two levels, which are inter-slice management and intra-slice management. Inter-slice management is performed by the slice orchestrator while intra-slice management is implemented by running a virtual manager function as a part of the slice [5, 9].

4.1 Intra Slice and Type of Cells

We assume cells with the shape hexagonal is been used [9, 10]. A single base station serves more than one cell since antennas can radiate over circular sectors of, for instance, 60 or 120. Small cell is an umbrella term for low-power and low-cost radio access nodes that operate in both licensed and unlicensed spectra and have a range of several meters to several hundred meters.

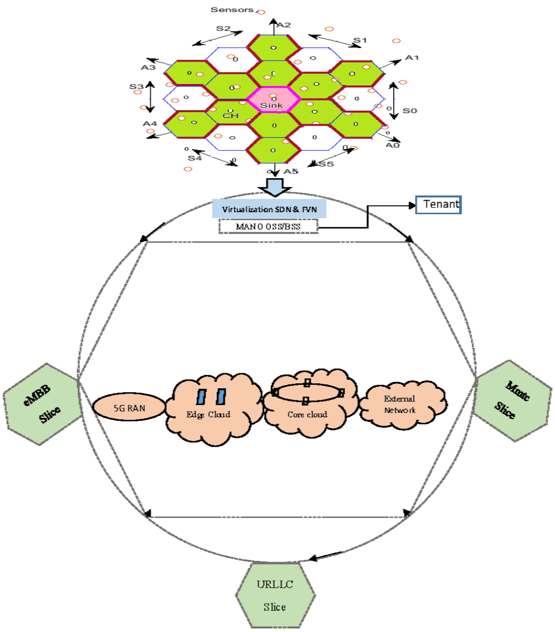

Fig. 1: Infrastructure Slicing Network 5G Shared

4.2 Inter Slice

We consider the homogeneous case where all MCs are statistically identical and independent. The model is more general and can be applied to heterogeneous load scenarios as well. As aforementioned, macrocells are hexagonal in shape, between 1 and $40Km$. [9, 10, 14]. The network constituted by the (BSs) overlaid by the small cell base stations (SBSs). Traditional macro cell as well as small cell networks each of them constituting a network tier, and captures the single-tier (i.e, homogenous) cellular network as a special case [11, 13].

5 Network Model and Assumptions

The resources can be used on-demand by network slices, which enhances the network resource utilization.

5.1 Handovers Decision

The key element of mobility management is the handover procedure, which generally utilizes well-established metrics for the handover decision: The handover procedure is initiated when the quality of the transmission in progress worsen according to a certain threshold [14]. Handovers can be classified as intra handover and inter-handover. By intra-handover it is included the change of a radio resource within the same cell that is driving the event running. By inter-handover it is incorporated the action to shift from an old radio resource to a new one that is associated with a new base station [9]. To evaluate the signaling load it might be of interest to determine the distribution of the random variable number of handovers executed by the event [9]. That is the probability that an event executes k handovers, for $k \geq 0$, before it terminates, either successfully or being forced to terminate.

5.2 Grouping Attributes

The geographical environment and cell geometry, and cell residence time depend on other movement-related parameters such as speed and trajectory of the user. These parameters, among others, are related to mobility models [8, 14]. Currently, they are classified into two types:
Traces and synthetic. Traces are mobility patterns that are captured from the observation of realistic human trip movements in daily life behaviors. Wherefore, ETSI Technical Specification defines three classes of slices and service types (SST). The first class refers to slices suitable for the performing of $5G$ enhanced mobile broadband (eMBB). The second class refers to slices appropriate for the handling of ultra-reliable low latency communications (URLLC). The third class refers to slices appropriate for the managing of massive IoT (mIoT). Several slices of the same class can coexist on one infrastructure [11, 13] .

5.3 System Model: Versatile Model

A traffic model was proposed to analyze two-tier cellular networks where MCs overlay hundreds of small cells. However, the traffic carried by systems without small cells depends on the number of resources allocated to the macrocell base stations, and is less dependent on the mobility scenario. We consider the service area of given several operators covered by a set of MCs (macro cell). Where each MC contains multiple non-overlapping SCs that are fully overlaid by the MC. We consider the homogeneous case where all MCs are statistically identical and independent. Thus, a handover is carry out to update the the receiving signal, balance the load, reduce the cost, and minimize energy consumption.

Table 1: Mobility Speed Table

Mobility	E[V](km/h)	to E[V](km/h)
Stationary	0	
Pedestrian	0	10
Vehicular	10	120
High speed vehicular	120	500

6 Numerical Evaluation: Adaptation to Large Scale

Carried traffic:

Being that, $5G$ systems should provide users with seamless high-data-rate services anytime and anywhere.

Therefore, as an example of the versatility of the proposed model [9]:
We compare the traffic carried by the system in two different network scenarios, one with SCs deployed (WSC) and one with no SCs deployed (NSC). An MC overlaying SCs, or just the MC. To set up a fair comparison, we maintain the same mobility pattern in WSC and NSC, and in addition, we use an equivalent load from the loading perspective, the equivalence is defined in terms of the global QoS is perceived by users of both network scenarios. Then, the following classes of mobility are defined:

7 Technical Method and Results

For the comparative evaluation, we define three extreme mobility scenarios:

i) High mobility at MC and low at SCs (HM-LS)

ii) Low mobility at MC and high at SCs (LM-HS)

Note that the mobility pattern of users changes according to the cell (location) at which the terminal is residing at. That is, terminals with an ongoing event attached to the SC will exhibit a low mobility pattern ($\mu_r^s \leqslant \mu^d$), as SCs will mainly support indoor traffic. On the other hand, terminals attached to the BS of an MC will exhibit higher mobility ($\mu_r^m \geqslant \mu^d$). Where, μ^d, μ_r^m and μ_r^s are event duration rate, MC residence rate, and SCs residence rate respectively. Also, attaching fast-moving terminals to SCs might be a bad application, due to the high signaling load [9, 10].

The generic computation for this case, applying the equations follow[9, 14]:

$$\mu = 2/\sqrt{3} \quad 2E[V] \ / \ \Pi \ \ R \tag{1}$$

For simplicity, we set $\mu^d = 1$, and for a large system with $F = 200$ SCs.

Also, λ_m^n and λ_s^n are MC, SCs new event arrival rate respectivly.

Hence, the equations for carried traffic $\mathrm{T}_C(Erlangs) are:$

$$T_m^c = \lambda_m^n(1 - P_m^B)(1 - P_m^f t) \ / \ \mu^d \tag{2}$$

$$T_s^c = \lambda_s^n(1 - P_m^B)(1 - P_s^f t) \ / \ \mu^d \tag{3}$$

$$T_s^c * = \lambda_s^n(P_m^B - P_s^L)(1 - P_S^f t*) \ / \ \mu^d \tag{4}$$

$$T_C = T_m^c + F(T_s^c + T_s^c *) \tag{5}$$

Where, P^{ft} global forced term probability. P_m^{ft} MC forced termination probability. P_s^{ft} SCs forced term probability. P_s^{ft*} SCs forced term probability channel in MC.

Thus, we adjust the offered load to achieve $\mathrm{P}_m^B \approx 1\% \ and \ P_s^B \in [2,4]\%$.

The number of resources in each scenario applying the equations follow is [13]:

$$N_{Phr} = \mu * AvgPacketSize/d_{Phr} \tag{6}$$

Where, μ is the residence rate, d_{Phr} is data rate per user on top of the slice, and N_{Phr} is a number of physical resources.
Since, network slicing aims at sharing the same physical infrastructure. However, in the above works, it is not detailed how these values N_{Phr} it extracted for each slice, knowing that each slice type has its own features and requirements. In this paper, our contribution is presented to avoid this hole by improving the study.

Accordingly, we can illustrate the traffic in several scenarios with a numerical example $Fig2$. And the system parameters are defined and extracted from the tables of [9, 10].

Hance, we can verify that in the mMTC there is almost no high mobility traffic in either case WSC or NSC. On the other hand, in eMMB and uRLLC there is high mobility traffic in none of the WSC and NSC cases unless in HM, as can be seen in $Fig.2$. The traffic carried by systems without small cells depends on the number of resources allocated to the macrocell base stations and is less dependent on the mobility scenario as well-known in the last

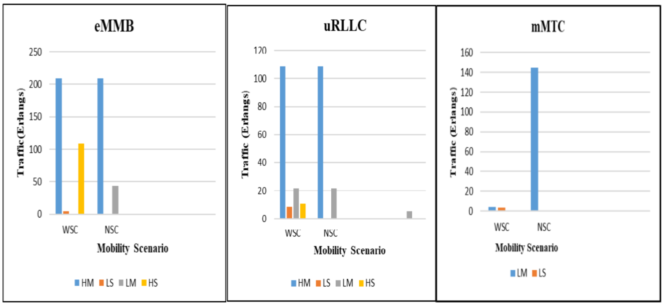

Fig. 2: Traffic in eMBB, URLLC and mMTC Scenarios

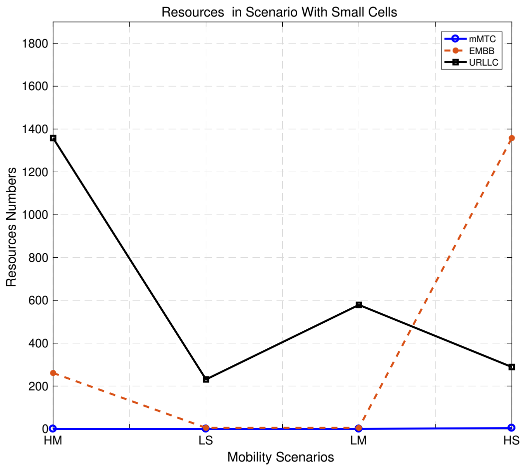

Fig. 3: Resources Scenario with Small Cells

$section.5$ as seen in $Fig.2$. As aforementioned above in $Section.3$, e. i. The slice itself may need to adjust its resource allocation $Fig.3$. The procedure followed for the adjustment gives priority to the setting of P_m^B. Note that in some scenarios it is not possible to set values for P_s^B even close to 1% , particularly for moderate to high SC mobility rates. In these scenarios, an important fraction of SC initiated event will perform a handover to the MC. Then, to achieve that $P_m^B \approx 1\%$, a higher SC load could have been offered, provided that the MC was configured with more channels [9].

iii) Hybrid mobility.

The coexistence of URLLC with other services, notably eMBB, is unavoidable in succeeding network deployment. In the smart-plant scenario where a number of automated machines communicate URLLC traffic using unlicensed spectrum, there might exist other users generating other types of traffic, for instance eMBB, and transport it over the same unlicensed channel as URLLC [11, 13]. Hence, the generic computation for this case, applying again the equations follow [9, 14]:

$$f_m(k) = \begin{cases} \alpha_{mL} + \sum_s \alpha^*_{ms} f^*_s(1)), k = 1. \\ \sum_r \alpha_{mr} f_r(k-1) + \sum_s (\alpha_{ms} f_s(k-1) + \alpha^*_{ms} f^*_s(k)), k > 1. \end{cases}$$

(7)

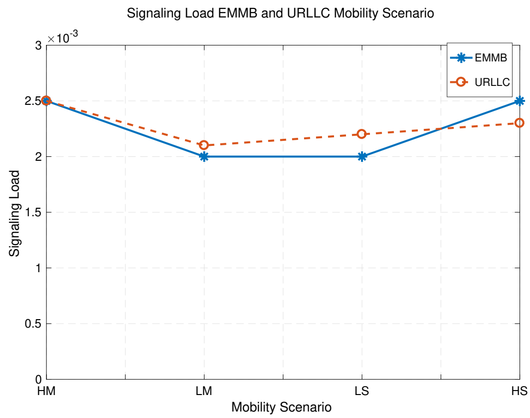

Fig. 4: EMMB and URLLC Signaling Load in Mobility Scenarios

By S the set of SCs that are overlaid by MC_m *and* $\text{s} \in S$. As well as M the set of MCs that are neighbors of MC_m, $\text{r} \in M$.

Then, we can illustrate the traffic in several scenarios with a numerical example *Fig.*4 And the system parameters are defined and extracted again from the tables [9, 10]. As we can note, the results show that the signaling load is very low in the cases of LM and LS traffic mobility scenarios, i.e. There are free resources that can be used to alleviate the load in other cases, with energy and handovers efficiency. On the other hand, the slicing can be performed efficiently. Starting from physicals infrastructures to achieve the virtuals, handled by orchestrator resources (RO) with less cost energy.

8 Conclusion and Future Works

In this paper, we first introduce the relevant background for network slicing technology. Also, the implementation of end-to-end network slices over $5G$ networks has been discussed. We have proposed a network slicing framework consisting of a hierarchical resource management system. Framework for $5G$ network slicing, Versatile Model. We introduce a logical architecture for network-slicing-based $5G$ systems and present a scheme for managing mobility between different access networks, as well as a joint power and subchannel allocation scheme in spectrum-sharing two-tier systems. Then, we defined three extreme mobility scenarios applied to homogeneous and widespread to heterogeneous models that concern sharing licensed and unlicensed spectrums. Which are governed by load traffic and energy consumption, i.e tailoring a generic value radii R = (r max) as the minimum communication range required. Finally, as challenges of network slicing and future research directions. We propose, that the accuracy of the model, should be improved in scenarios when open access policies are deployed. Then, the works can be outspread and able to adapted as well as performed depending on the traffic load using reinforcement learning.

Acknowledgments

I thank the scientific advice of my Professor.

Funding sources

The author declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflicts of Interest

The author declare no conflict of interest.

Consent for publication

Yes

Index Terms:

- WSNs Wireless Sensor Networks.

- (MANO) Management and Orchestration.
- (mMTC) Massive Machine Type Communications.
- Io T Internet of Things.
- VIM Virual Infrastracture Manager.
- OSS Operations Support Systems.
- NFV Network Functions Virtualization.
- (CHs) Cluster - heads.
- BS Base Station.
- PB Blocking Probability.
- VM Virual Manager.
- CN Core Network.
- AP Access Point.
- R Radius.
- k Number of Handovers,

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