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# Software-defined networking based network virtualization for mobile operators

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ABSTRACT

Software-defined networking (SDN) paradigm provides many features including hardware abstraction, programmable networking and centralized policy control. One of the main benefits used along with these features is core/backhaul network virtualization which ensures sharing of mobile core and backhaul networks among Mobile Operators (MOs). In this paper, we propose a virtualized SDN-based Evolved Packet System (EPS) cellular network architecture including design of network virtualization controller. After virtualization of core/backhaul network elements, eNodeBs associated with MOs become a part of resource allocation problem for Backhaul Transport Providers (BTPs). We investigate the performance of our proposed architecture where eNodeBs are assigned to the MOs using quality-of-service (QoS)-aware and QoS-unaware scheduling algorithms under the consideration of time-varying numbers and locations of user equipments (UEs) through Monte Carlo simulations. The performances are compared with traditional EPS in Long Term Evolution (LTE) architecture and the results reveal that our proposed architecture outperforms the traditional cellular network architecture.



## 1. Introduction

Developing new innovative solutions within current network infrastructure with respect to today's requirements is becoming difficult every day due to high complexity of networks [1]. It should be noted that even though the mobile technology is advancing rapidly, data transmission has been performed through the same backhaul since second generation of mobile technologies which is still valid in current Long Term Evolution (LTE) systems. With the advancements in LTE-Advanced and small cell technologies, backhaul of Mobile Operators (MOs) is expected to be similar to data centers with mesh network topologies. Taking into account these facts, the currently deployed network architecture of Evolved Packet System (EPS) used in LTE presents several drawbacks. Constantly deploying the infrastructure network equipments at high capacity is both costly and inefficient for MOs. With respect to this, virtualizing the currently on demand network infrastructure owned by infrastructure owners, Backhaul Transport Providers (BTPs), is crucial. Therefore, managing the dynamic network traffics resulting from users of MOs and handling the possible complex Service Level Agreements (SLAs) between MOs and BTPs via dynamic slicing becomes more important. However, current infrastructure deployment solutions cannot enable such virtualization option for MOs due to lack of proper usage of recent technological advancements in network

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virtualization. Therefore, MOs and BTPs are looking for new innovative solutions in order to overcome the increasing demands of these network dynamics [2].

Recent developments such as Software-defined networking (SDN), which is initially implemented using OpenFlow protocols, provides powerful and simple approaches to manage complex networks by creating programmable, dynamic and flexible architecture, abstraction from hardware and centralized controller structure. In addition to SDN, network virtualization has become one of the major recent innovations that can also provide flexible and scalable logical infrastructure to every organization. In respect to this, network virtualization with SDN is an important paradigm that ensures the efficient usage of network resources. It can provide several features such as sharing of resources by breaking down the larger ones into multiple virtualized pieces, isolation of resources for better monitoring of data privacy and interference-free network access among users, aggregation for combining smaller resources into a single virtual resource, dynamism for fast deployment and reliable scalability in order to deal with the users' mobility, ease in resource management for debugging, testing and rapid deployment purposes [3]. On the other hand, developing appropriate scheduling mechanisms for resource allocation plays a fundamental role and help to meet quality-of-service (QoS) requirements of applications used by MOs' users. Depending on the application types (voice-over-IP (VoIP), video conferencing, streaming media etc.), the requirements differ, however, they can be mapped to common parameters such as minimum guaranteed data rate, transmission delay, jitter and packet loss rate. Therefore, combining the advantages of SDN for network virtualization with appropriate scheduling algorithms under the consideration of those QoS parameters for dynamic resource allocations plays a key role in satisfying the demands of users associated with MOs as well as of BTPs.

### 1.1. Related works

Before the introduction of SDN, traditional QoS providing approaches such as Integrated Services (IntServs) [4] and Differentiated Services (DiffServs) [5], had been standardized. However, there have been several drawbacks of these approaches. IntServ, a fine-grained traffic control architecture, is only applicable for small scale networks. DiffServ, on the other hand, is coarse-grained and applicable for larger networks, but it can only provide predefined/static 64 different classes of traffic to be differentiated since DiffServ routers forward the packets based on 8−bit DS field in the Internet Protocol (IP) header [5]. This makes it hard for DiffServ to fine tune the QoS of separate flows. For example, the limit of DS field can be reached when four tenants each with sixteen application traffic types exists in the system. On the other hand, SDN can enable fine-grained tuning (e.g. rules defined per flow) based on the specific application or user needs without restrictions. Therefore, approaches utilizing more scalable techniques such as SDN can provide better QoS guarantees for big networks that have large coverage areas as in the case for MOs.

New cellular network architectures based on SDN paradigm have also been extensively investigated in the literature [6–12]. In [6], SDN architecture with four extensions to controller platforms, switches and base stations is proposed for cellular networks. The proposed SDN architecture helps to simplify the design and management in order to address major limitations of today's cellular network architectures. A novel architecture, namely SoftCell, supporting fine-grained policies for cellular core network is proposed in [7] with the usage of packet classification on access switches that are next to the base stations and aggregation of traffic along multiple dimensions. In [8], software-defined based mobile network architecture that increases the operator's innovation potential is presented and validated by testbed implementation. [9] provides techno-economic analyses of two network scenarios which are software-defined non-shared and virtualized shared networks as well as comparisons with traditional networks. In [10], the authors point out applications of network function virtualization (NFV) and SDN while minimizing the transport network load overhead against several parameters (i.e., delays, number and placement of data centers etc.) as the function placement problem and aim to model and provide a solution for LTE mobile core gateways. [11] examines several implementation scenarios of SDN in mobile cellular networks and SDN's contributions to inter-cell interference management, traffic control and network virtualization domains are explained. SoftRAN [12] abstracts all base stations in a local area as a virtual big base station that is managed by a centralized controller to perform load balancing, resource allocation, handover etc. while considering global view of the network. Moreover, although network sharing in the context of relationship between third parties (e.g. Mobile Virtual Network Operators (MVNOs), vertical players) and MOs has been widely discussed, most of the related works are in the context of economic advantages, business requirements and operational benefits that network sharing can introduce [13–16]. Recently, The 5th Generation Partnership Project (5GPP) has proposed some vertical use cases when envisioned 5G architecture (which can be owned by different entities such as mobile, transport or cloud infrastructure providers) provides infrastructure slices over the same physical infrastructure [17]. None of these approaches, however, consider the opportunity of applying both virtualization of mobile core/backhaul and as a consequence dynamic assignment of available evolved Node-Bs (eNodeBs) to different MOs based on their traffic demands which come basically from their respective user equipments (UEs) using various scheduling algorithms. This can be especially achieved by designing a SDN-based shared EPS architecture for multiple MOs with a virtualization controller that is subject to instructions from BTP.

Many vendors such as Cisco, VMware, Big Switch, NEC etc. provide different approaches to network virtualization which are critical for infrastructure providers [18]. Additionally, different network virtualization technologies have been studied in the literature [19–22]. In [19], the authors have classified different network hypervisors based on centralized and distributed architectures at the top level classification criterion and a second-level classification is executed based on the hypervisor execution platform. Technologies including OpenVirteX [20] and FlowVisor [21] act as the transparent proxy between

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