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SDN and NFV in 5G: Advancements and Challenges

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Abstract: The next generations of mobile networks have up the expectations and have prompted an entirely new technique in the networking future. This study gives optimal solutions that meet all the existing requirements enclose Software Defined Network (SDN) and Network Function Virtualization (NFV) in mobile networking. The major contribution of this research analysis is that it is a resource for literature reference for researchers and engineers because it gives and compares the most basic present solutions and consequently the future directions. In this paper, the main features of SDN & NFV are sum up as fundamental alternatives contributing to succeed the goals set by 5G. The essential needs and demanding situations faced through these solutions and consequently the most useful applications of the combination of SDN with NFV are defined. Finally, the main conclusions of this research and suggestions for possible future work in the field are described

Keywords- SDN, NFV, 5G, mobile networks

I. INTRODUCTION

The advent of the next generation of cellular networks has rendered the demands of the novel, extra advanced and scalable technology an imperative requirement. Mobile customers are extraordinarily augmenting not only because of the reality that the wide variety of personal devices is increasing, however also because of(device to device(D2D) communication methods, the internet of things (IoT)), that add data overhead, increase the data rate, raise the capacity demands and boom the needs for coverage. Although several forms of cellular networks will dominate in the 2020's, there are also many demanding situations, like extenuating power consumption in devices and base stations, better resource allocation, higher data rates, ensuring lower round-trip times, reducing all costs, optimization of mobile management policies, scalability, elasticity and agility[23].Although until currently decentralized architectures were considered secure and efficient leading to increasingly decentralized models, the augmenting network traffic advocates in choose of adopting a centralized manner of control. A central structure offers essential advantages, such as optimum frequency presentation and accomplished mobility management policies.Software Defined Networking (SDN) is not only a means of meeting the 5G demanding goals, but additionally offers an opportunity technique to face the main mobile network issues. There is not much work in the field of reviewing the sevenfold necessary studies including SDN and NFV, even though there is much research is possible in applicable scenarios for implementing the technologies. The survey [16] summarizes the most significant facts about SDN and includes several other research and testing in this area. A framework for cellular SDN is provided thoroughly in [7].The primary objective of this paper is to summarize the main features of SDN and NFV. The survey [16] summarizes the maximum essential information about SDN and includes numerous other studies and testing within the discipline. Open network running system (ONOS) is the vastly well-known and vital SDN controller. Its ultra-modern releases (from Emu and beyond) introduce the primary office re-imagined as a data center (CORD). The subsequent launch of NFV is the Brahmaputra, goes to be mixed with those releases.

The rest part of this paper is established as follows: in Section II the main demanding situations SDN & NFV should meet are listed. In section III literature review of previously, solutions and upcoming solutions in the mobile SDN cases are presented. In section IV there is a comparison and contrast of the suggested mobile solutions. In section V the predicted evolution within the domain inside the subsequent years is printed, the paper is concluded and some ideas for future research work are listed.

II. REQUIREMENTS & CHALLENGES

In this section, the main requirements and obstacles that have been raised are summarized. Fig 1 describes the concept in the already presented SDN architectures, such as [12] and [16], which are based on decoupling the data and control layers. The infrastructure layer includes commodity switches. The control layer includes a cluster of controllers. The application layer includes application and network appliances.

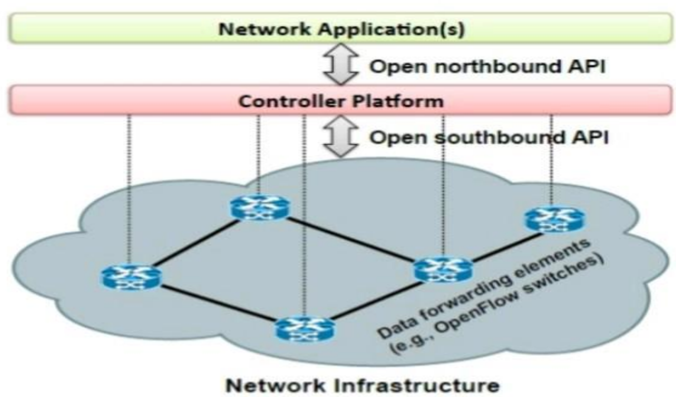

Fig 1 The general concept of SDN architectural model.[25]

SDN refers to software defined networking architecture where:

- Data and control planes decoupled from one another.
- Data planes at forwarding devices managed and controlled remotely by a "controller".
- Well-defined programming interface between control and data planes.
- Applications running on controller manage and control underlying data plane.[24]

Firewalls are virtually deployed renovate which are linked to the SDN wireless and mobile cases and the needs of NFV presented[6] are summarized in Table 1.It is important to standardize the control and provision future needs of resources and achieve offering dynamic control not only by statistical development and real time data. Viewing a large part of the network, contributes in enhancing the assignment and routing capabilities [23]. It also endue performance degradation control policies, requirements in protection and security issues and alternative applicable scenarios in case the controllers get out of order. 5G and beyond networks are based on ultra-dense deployments. It is compulsory to succeed in providing denser cellular infrastructures, magnify the available bandwidth, exploring Multiple Input Multiple Output (MIMO) solutions collecting network state, specifying the behavior of the network, updating the network configuration [23]. The open flow protocol and the wireless networking abstractions contribute to this direction, namely the light virtual access point, resource pool, interference map [20]. Ultimately, the originator end up evaluating the indicated resource management, querying and interference tracking. There is an preface of some basic terms for IP mobile networks. They analyze the procedure of exchanging IP datagrams. There is also an extract of the main mobile IP challenges, such as security, triangle routing and handover. It depict the OpenFlow implementation based on registration processes, packet processing and the controller application. It educe that this research activity enforces seamless networking mobility and improves QoE [19].Review [18] describes a base station and a core network virtualization. The most important motivations of using the NFV are analyzed. For NFV cases, the virtualized and non virtualized mobile core network should coexist according to[18].The challenges and performance degradation effects are avoided in the network by the SDN and are specially controlled by the ONOS project in the mobile 5G [5].

TABLE 1 . The main requirements and challenges linked to the SDN & NFV

REQUIREMENTS	SDN	NFV
Control	Standardization of the control interfaces. Protection of commercial business operating schemes. Measures to avoid performance degradation. Maintenance of information of the controlling network-big data development	Seamless control and provisioning. Real-time and dynamic provisioning. Creation of network granularity policies. Maintenance of information of the controlling network-big data development.
Reliability	Seamless connectivity and fast connection recovery. Security requirements in EPC and RAN. Security and reliability of the transport and data network. Equilibrium among performance, security and flexibility.	The high complexity of 5G (technologies, devices, IoT). Seamless and high-quality connectivity. Virtualization of terminal points. Security concerns (same physical medium).
Scalability	Support of technology and device heterogeneity. Controller messages with performance and survivability (low packet loss levels) Optimization of flow rules-better network slicing.	Carrier-grade scalability and robustness. Acceleration of implementation. Openness and interoperability, global reach and cross administration
Cost efficiency	Reduce CAPEX & OPEX	Reduce equipment costs (CAPEX) and operational costs (OPEX).
Energy efficiency	Reduce power consumption.	On demand allocation of resources, and efficient utilization of network resources.

Security	Firewall, access control, DOS attack detection/ mitigation, traffic anomaly detection.	Micro-segmentation is a security technique that enables fine-grained security policies to be assigned to data center applications, down to the workload level. Many data center virtualization technology vendors, including Cisco, Nuage, and VMware have been touting the benefits of micro-segmentation as an advantage of network virtualization.
Reason of being	Separation of control and data, centralization of control and programmability of network.	Relocation of network functions from dedicated appliances to generic servers.
Formalization	Open networking forum(ONF)	ETSI NFV working group

III. PROPOSED SOLUTIONS OF MOBILE SDN/NFV

In this section, the main aspects of previously and upcoming existing solutions in the mobile SDN cases are presented.

A. Literature review of previously solutions

1) The EPC in SDN solutions is virtually deployed. The NFV concept will be used for the case of EPC so that the network operates in a virtualized way. The idea takes advantage of all NFV assets including scalability, lower costs etc. According to [12] and [14] EPC provides substantial applications:
   - Implementation of virtualized mobile gateways, S-GW,P-GW.
   - Creation of mobility management policy.
   - Network management & network components management.
   - Band splitting in cloud cases & management of cloud nodes.

2) **OpenRadio**: [4] describes the programmable data plane in wireless systems and its possible implementation in today's mobile networks. Firstly, there are several analyses including the cell-based optimization, the coexistence of heterogeneous and alternative types of cells and the application of specific wireless services. It introduces programming abstractions, such as modular declarative interface, information plane, state machine model and deadlines. Finally, it refers to the challenges of the OpenRadio and suggests a designing policy.

3) **OpenRAN:** [21] introduces an OpenRAN approach via virtualization. The suggested overall protocol is divided in the SDN controller, in the wireless spectrum resource and the cloud computing resource protocol. It also induces four levels of virtualization: application, cloud, spectrum and cooperation. It concludes that controllers and programmable schemes achieve routing and bandwidth allocation and several flow priorities.

4) **SoftRAN:** [9] introduces the dense network management. The authors design the SoftRAN (Software defined RAN) combined with a coupled control plane in dense networks. It introduces the base station abstraction, the SoftRAN, the controller architecture and the refactoring of the control plane. It ends up indicating the feasibility of RAN.

5) **NetShare**: [17] operates as the manager of shared resources and is introduced as a way of reallocating the existing resources of base stations and multiple entities in an existing network. Netshare isolates entities and highly utilizes the resources of an entity. The resource allocation is based on distribution, strict isolation, network heterogeneity and per base station reservation.

6) **ONOS**: [5] analyzes the SDN based on ONOS and the motivation linked to wireless transport networks. MCORD (Mobile CORD) is the mobile ONOS CORD and is available for experimentation since the Emu release of ONOS.

7) **Software Defined Cellular Network (SDCN)**: [14] includes fundamental answers in the already augmenting demand, namely flexible policies, scalability, commodity switches, remote control of base stations. Several controller applications are directing traffic throughout middle boxes, monitoring network controlling and billing, providing seamless subscriber mobility and QoS, accessing control policies, offering virtual cellular operators and managing inter-cell interference. Last but not least, slicing several resources, such as bandwidth, topology, traffic, device CPU and forwarding tables important for efficient resource allocation.

8) **Cellular SDN (CSDN**): [15] focuses on resilient policies on client attributes, scalability through local agents, flexible switch patterns and actions and network virtualization on subscriber attributes. There are also various CSDN applications such as flexible client policies, scalability for local agents, flexible switch patterns and virtualization of the client attributes. The SDN architecture induces logically centralized control, programmability and high abstraction levels [10]. The background study is based on inter-cell interference management and mobile traffic management. SDN and NFV are capable of providing intelligent services and dynamic resource allocation. The virtualized network in SDN architectures include several functions, designing considerations in the forwarding and control plane [7]. Practical questions are considered when it comes to centralized vs distributed data collection, data processing, decision making and user privacy. Future work is summarized as being a combination of CSDN with Big Data.

9) **Wireless SDN (WSDN**): [6] introduces a wireless SDN architecture. The virtualization of various functions and mechanisms of the network infrastructure are analyzed alongside with other vital issues, such as sharing, virtualizing core servers, dynamic energy policies. SDN, OpenFlow, CAPWAP and reconfigurable wireless devices are defined. Virtualization matters, QoE-aware network operations, network access selection and mobility control are established.

10) **SDN Mobile Cloud**: [11] offers important benefits in wireless communications alongside with novel applications, that stem from SDN. There is a consideration of several challenges of combining SDN with ad-hoc networks and a heterogeneous architecture is proposed.

11) **Mobile Extension of SDN (MeSDN**): [12] summarizes the possible mobile cloud requirements. MSDN should be used at the enterprises to cover the augmenting demands of the visitors in using the network. The proposed architecture describes the flow manager, the roles of the local and the global controllers. There is also a reference in MeSDN applications, such as App-aware End to End (E2E), QoS, network blemish diagnosis, WLAN Virtualization, 4G cellular networks. It oneself pTDMA (pseudo-Time Division Multiple Access), a type of pseudo TDMA, analyzing scheduling principles, downlink control, power saving, prototype implementation, such as architecture, threats, evaluation. The vital challenges are presented, among which are: millisecond level synchronization, driver buffering delay and 802.11 beacons.

12) **Ultra-dense deployments based on SDN**: A network model and some control functions are presented, in which the controllers are divided into two possible categories based on optimization approaches. For long-term optimization, the technique is deployed in dedicated hardware, while for short-term ones only cover some base stations [2]. There is a presentation of some controller applications, such as mitigation LTE, WLAN optimization, LTE access selection, power cycling and offloading. The main security dangers in 5G, such

as interference, backhauling, inconsistent security, and high complexity, due to augmenting a number of devices, are described thoroughly. The exact applicability of SDN in mobile networks is analyzed alongside with the fact the constant handovers raise security issues in 5G. In order to avoid these problems, 5G is suggested to be implementing using SDN capabilities, handover mechanisms and privacy protection [8].

13) **SDN & NFV in 5G** [23]: The overall SDN mobile architecture based on today's LTE networks is explained.

The above solutions are not enough to achieve the demanding goals of 5G and some concept are also missing which is important in the architecture of 5G with SDN & NFV. The separation of control and user plane, as introduced through software-defined networking (SDN), will also impact the 5G mobile network, which may similarly split functionality and provide corresponding interfaces. Beside the radio access and core network, the transport network will play a key role in 5G to flexibly and dynamically address the wants of future mobile networks. In order to support the desired flexibility, a unique packet-based network is needed. Three main types of interface are envisioned: packetized CPRI, next-generation fronthaul interface (a new useful split inside RAN), and backhaul. In order to address these interfaces, traffic class ideas are going to be introduced. Furthermore, to expeditiously support network slicing by the transport network too, the ideas and systems of SDN and network function virtualization (NFV) will be supported by the transport network, e.g. by separating the control and data planes through common packet-based data path abstraction. This unified data and control plane interconnects distributed 5G radio access and core network functions, hosted on in-network cloud infrastructure. The 5G transport network will consist of integrated optical and wireless network infrastructure. The proposed architecture of 5G with NFV & SDN focus on physical infrastructure having radio access network, transport network, and the core network.

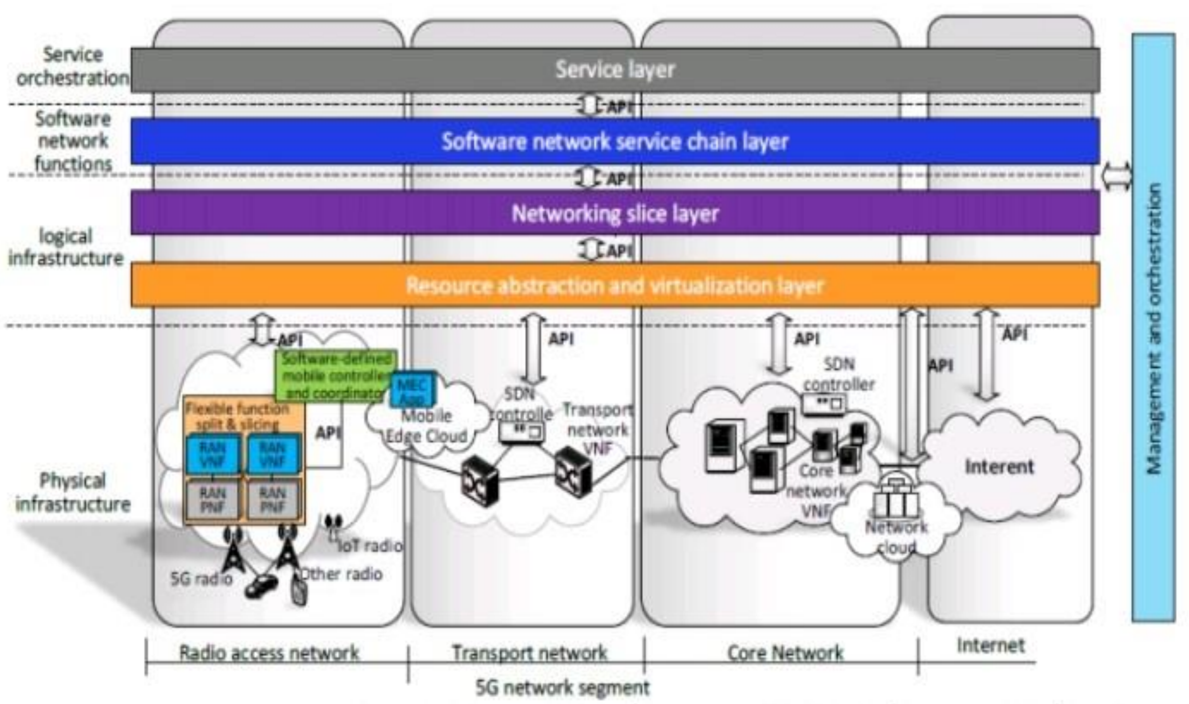

Fig 2 the architecture of 5G with SDN & NFV

This architecture is also not appropriate because softwarization and programmability concept is missing. This concept is important in 5G with SDN & NFV. So, softwarization and programmability framework of 5G is explained further.

In network softwarization architecture the main 5G network segments are Radio Networks, Fronthaul & Backhaul Networks, Aggregation and Core Networks, Network Clouds, Mobile Network and enabling technologies like Mobile Edge Networks, Service/Software Networks, Software-Defined Cloud Networks, Satellite Networks, IoT Networks. The natures of this proposal are referred as separate planes. In separately defined, the planes are not completely independent: main terms in each plane are relates to the main terms of other planes in the architecture. The framework is separated in these major terms which are Application and Business Service Plane, Multi-Service Management Plane, Integrated Network Management & Operations Plane, Infrastructure Softwarization Plane, Control Plane and Forwarding/Data Plane.

The proposed architecture for network softwarization and programmability is presented in Figure 2, where each plane is explained.

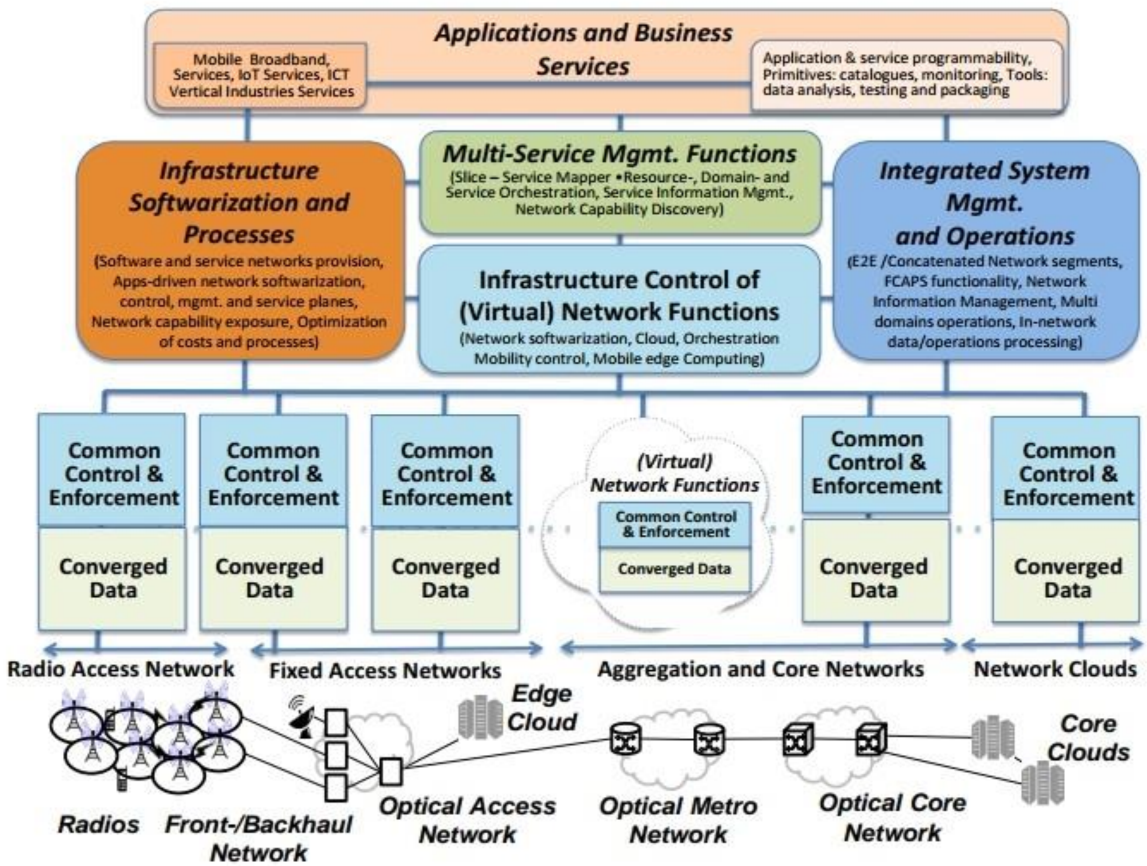

Fig 3 Network softwarization and programmability framework

The following are key system-differentiating functions of the network softwarization and programmability framework:[26]

- **5G Converged Data Plane functions**
- **5G Infrastructure Softwarization Plane functions**
- **Network of (virtual) function**
- **Network architecture can evolve and change**

This network softwarization and programmability framework is based on the following separation in distinct planes:

Application and Business Service Plane – Defines and implements the business processes of the services along exclusive value chains. Provide mobile broadband services, IoT services and ICT vertical industries services. Responsible for application & service programmability like catalogues, monitoring, tools: data analysis, testing and packaging.

Multi-Service Management Plane – The functions and interfaces in this plane are used to set up and manage groups of network instances or nodes. Functions of this plane are slice- service mapper, service orchestration, service information management and network capability discovery.

Integrated network management & operations plane- Enables the creation, operation and control of dedicated management functions operating on top of a 5G E2E. Responsible for E2E/ concatenated network segments, FCAPS functionality and multi domain operations etc.

Infrastructure softwarization plane- enables the provisioning and operation of software and service networks. Features of infrastructure softwarization plane are software and service network provision, App- driven network softwarization, control management and service planes, network capability exposure and optimization of costs and processes.

Infrastructure control plane- The collection of functions responsible for controlling one or more network devices. Responsible for network softwarization, cloud, orchestration mobility control and mobile edge computing.

Forwarding plane/ data plane- The collection of resources across all network devices responsible for forwarding traffic.

IV. COMPARISION OF SDN & NFV SOLUTIONS

In this section, there is a comparison between the two main technologies deployments. The main significant studies combine the two achievement and contribute in outlining the future directions in the field.

TABLE II: Comparison of mobile SDN/NFV solutions

CATEGORY	SDN	NFV
Motivation of deployment	SDN is deployed in order to decouple the control and the data plane and provides network controlling and programmability.	NFV is an abstraction of network functions.
Abstraction	SDN provides an abstraction model of the forwarding plane and separates it from control plane using open APIs.	Abstraction levels provided by the NFVs should be standardized.
Types of virtualization	One of the most well-known protocols used by SDN controllers is OpenFlow, however, it isn’t the only SDN standard, despite some using “SDN” and “OpenFlow” interchangeably.	NFV is a virtualization of network services.
Mobility management	It is valuable for controlling traffic classes and forming several flow space partitioning rules.	The virtualization methods contribute to better mobility management, the creation of policies and deployment of a billing system.
Heterogeneity	Supporting combination of different technologies and types of cells.	Heterogeneous solutions are supported.
Efficient handover policies	It is important to standardize innovative radio resource management functionalities.	Important to standardize the resource management.
Cost efficiency and software based implementation	Network Address Translation (NAT), firewalls should be virtually deployed.	Functions should be virtually deployed.
Open source	SDN is built on the concept of open source.	NFV is built on the concept of open standards.

Location	SDN controllers are located at the data center	NFVs are located in service provider networks
Technology readiness level(TRL)	TRL is a method for ranking the maturity levels of a technology. It scales from 1 to 9 and represents the existence of basic technological research in the field and the system launching and operation respectively.	some of the suggestions are close to implementation, while others are in a more immature level.
Applicability	Applicable scenarios will provide scalable and reliable solutions and will cover most of the mobile network demands.	It is also vital to prove their applicability through testing and evaluation procedures.
Prototypes	SDN is prototyped for the wired case and there are several suggestions for the mobile and wireless cases	There is not a prototype for NFV

SDN is located at the data center, whereas NFVs are located in service provider networks. SDN applications are linked to cloud orchestration and network management, on the other hand, NFVs are mostly linked to particular network components, such as firewalls, gateways, content delivery network(CDN). Although SDN and NFV are two extremely different technological suggestions, their combination offers benefits in favor of succeeding high network efficiency and performance. As referred to [7] all radio resource management functionalities are included. The corresponding virtual Evolved Packet Core (EPC) functionalities are thoroughly described. In [6] virtualization methods are linked to the implementation of different overlay networks. They are responsible for NAT firewalls and implement cellular core functions. On the other hand, the solution helps to reduce the CAPEX and OPEX for a provider and the time for implementing a new service.

V. CONCLUSIONS & FUTURE DIRECTIONS

In this section, possible future directions in the domain of SDN and the particular suggestion are explained and are formed in future research activity. The combination of SDN and NFV promise a different concept of networking deployments as long as the main challenges presented are faced. In general this research summarizes the existing SDN and NFV solutions for the mobile case with an insight in 5G networks. This paper is able to inform scientists of the latest trends in the domain and also consists a very strong tool, as it reviews several important studies in this particular domain. In the future, an architecture combining the SDN and NFV is going to be presented as a new future activity and how based on both a more optimized mobile network architecture will be succeeded and will cover the demands and needs of future mobile users. The primary goal of the authors is to test and evaluate a possible SDN architecture and also the architecture of 5G combining the key role of SDN & NFV. In this section, possible future directions in the domain of SDN and the particular suggestion are explained and are formed in future research activity. The combination of SDN and NFV promise a different concept of networking deployments as long as the main challenges presented are faced. In general, this research summarizes the existing SDN and NFV solutions for the mobile case with an insight in 5Gnetworks. This paper is able to inform scientists of the latest trends in the domain and also consists a very strong tool, as it reviews several important studies in this particular domain. In the future, an architecture combining the SDN and NFV is going to be presented as a new future activity and how based on both a more optimized mobile network architecture will be succeeded and will cover the demands and needs of future mobile users. The primary goal of the authors is to test and evaluate a possible SDN architecture and also the architecture of 5G combining the key role of SDN & NFV.

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