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Research paper

5G mobile networks based on SDN concepts

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Abstract

With The rapid growth of mobile networks data and the emergence of the new services and applications, Mobile operators should provide a several solutions to cope with the challenges of the next 5G mobile networks and to reduce costs. For these reasons, SDN was proposed to be one of the key technology trends that will facilitate the required architectural agility needed in the next 5G mobile networks.
Software Defined Networking (SDN) is the highly promising technology to provide innovation and enforce the main drivers in 5G mobile networks such as flexibility, suability, service–oriented management and to reduce costs by the softwarization of the 5G Core networks functions.
Thus, there is an immediate need to study the fundamental architectural principles of SDN, and to analyze the integration and application scenarios of this architecture into the next 5G mobile networks. In this paper, we present a survey on the most relevant research works on SDN concepts and SDN integration in mobile networks. We propose a SDN-based architecture for 5G mobile network; we give an overview of SDN requirements and challenges for SDN integration in 5G, we address the benefits of IPv6 over SDN in 5G and finally we provide the benefits of SDN integration in 5G mobile networks.

Keywords: *SDN; Core Networks; 5G; Virtualization; Open Flow.*

1. Introduction

The exponential growth of data traffic ,connected devices, and the reduction of latency and costs are considered as major challenges for the future mobile communication networks[1].This growth is based on the new mobile services and applications ,such as mobile games ,mobile videos and location-based check –in services [2]. The afore-mentioned challenges cannot easily be addressed without radically changing the current 4G architecture [2] and their components. To achieve this gaol, cellular operators investigate the possibility of commodity hardware implementations in order to exploit the benefits of cloud technology by means of the SDN and virtualisation [3].
In recent years, there are growing interests in both academia and industry to apply SDN to the next generation of mobiles networks 5G .The main motivation behind this is the potential for simplification of network management ,enabling new services , SDN may help cellular operators to supporting higher traffic and to reduce operational costs through programmable interfaces [2].
Furthermore, the integration of SDN and network function virtualisation (NFV) in 5G mobile networks will minimize the changes in network elements,it will response to traditional network architecture limitations and will introduce centralized management and higher programmability in 5G .
Current standardizations and specifications of SDN are focussed to define networks the fine-grained quality of service (QoS) over the network architecture . In this area ,the SDN will provide the possibility of enhancement of the Quality of experience (QoE) for delay-sensitive and jitter-sensitive applications such as cloud gaming ,It will simplify flow management and QoS provisioning by controlling the movement of network functions, storaging of popular content [4] and controlling QoE in 5G network .SDN will help also operators to make use of the unified, less complex ,less expansive and adjustable configuration of the network behaviour [4].
According to the Open Networking Foundation that is non-profit industry consortium guiding the progress of SDN and the standardisation of SDN architecture elements such as Open Flow protocol and SDN controller, the SDN will take place in different contexts and areas in the future mobile networks such as modern networks, data Center enterprise , carrier networks and domain-cantered deployment and operation [5] .This paper will give an overview of the 5G perspectives based on SDN paradigms and address the main benefits of SDN in term of security ,flexibility and QoS .

2. Related works of SDN

In recent years, there has been growing interest in SDN and its profits. This growth was driven by the fundamental role that will be played and challenging issues that are expected to be addressed by SDN at the next 5G mobiles networks .In this way , the ideas behind SDN was built on many previous efforts through several studies and research works that have pointed out this importance of SDN.
At the first , SDN definitions, Concepts, and terminology was discussed in several previous works [6-9] .The basic definition of SDN and its important paradigms was given in [9] as network with decoupled control and data planes .In 1998, the authors of the [10] paper, shows how the network programmability can be achieved without changing the global network architecture . They address also the role of network programmability in providing

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advanced control of the networks. The Authors approach in [10] paper was based on the Tempest framework that offer the possibility to create virtual private networks and to split forwarding and control plane toward the ATM networks. In [11], the authors give an overview of key principals and architectural components of SDN as seen by the Open Networking Foundation (ONF). In [12], the authors give a survey on the SDN concepts and they address the benefits of SDN while considering a limited number of surveyed networks.

As the basic evolution of native flexibility and programmability in mobile networks, SDN is seen as the main solution to integrate the virtualisation and cloud paradigms in the 5G core networks. In this direction, there are several papers that discussing the SDN integration in mobile networks .The [13] paper surveys the current approaches and solutions for adopting SDN/Openflow in LTE/EPC architectures and then introduces a new Openflow-enabled EPC (OEPC) architecture. In addition, the paper provides detailed analyses of five procedures that commonly occur in LTE/EPC architectures, and the analyses are further elaborated with the separation of the control and data planes and the support of extended Openflow protocol. [14] proposed an OpenFlow-based control plane for LTE/EPC architecture.

In [15],authors provides analysis of virtualisation technologies that offer different architectural scenarios in order to meet 5G requirements and to achieve flexible 5G network architectures .[2] provide an overview and encompasses the previous research works on SDN and virtualisation solutions toward 4G mobile networks architecture.

The implementation of SDN concepts and its spreading into 5G core networks and 5G segments such as the mobile Backhaul network was discussed in many previous works and research efforts .In [1] ,authors propose SDN-based design for the next 5G core networks and they address the benefits and challenges of the integration of SDN in 5G backhaul .For [16] , the mobile backhaul network will be enhanced by the integration of programabilty and virtualisation which will provide the possibility to share the network resources between the different mobile operators.

IPv6 will be critical protocol for 5G mobile network scenarios , with combining IPv6 and SDN , operators will be able to provide better management and scalability to 5G architecture .In this regard ,integration, unification and the benefits of IPv6 toward SDN have been dealt in several works. The authors [17] discuss the main architectures of SDN and illustrate how IPv6 can be deployed and integrated in SDN technologies using OpenFlow mechanisms. Authors address also the operations and deployment scenarios of IPv6 over SDN networks. [18] proposed a novel, software defined approach to address the challenges of transitioning from IPv4 to IPv6. The propose approach unifies the variety of IPv6 transition mechanisms. Combine the existing IPv6 protocol and the SDN to provide the smarter and reliable network communication architecture.

In order to present and study the 5G benefits mobile networks, [19-22] many works are done on 5G network architectures and concepts regarding the software network perspective. Authors of these papers address the basic technologies that are expected to play relevant role in the 5G packet core Design such as MobileFlow. Bernadosn this manner, et al. [20] describe a multi-operator wireless network architecture for the next generation by combining SDN, NFV, and quality of experience. They illustrate with a number of representative use cases the benefits from the adoption of the proposed architecture, which is detailed in terms of modules, interfaces and high-level signaling.Yazici et al. [21], and Trivisonno et al. [22] discuss the benefits of SDN ,NFV and cloud technologies in routing, mobility, and flexible assignment in the next 5G access networks .In this stage , authors advocate an all-SDN network architecture with hierarchical network control and management capabilities wich will provide service differentiation and higher flexibility for 5G systems.

In [22] paper, Authors propose a novel plastic architecture for the advanced 5G network infrastructure by harvesting latest advances of SDN, network functions virtualisation and edge computing. The goal of this novel architecture is to improve functional and performance requirements of new 5G services and devices. [23] discusses a reference architecture, open APIs for SDN ,SDN uses cases and detailed requirements on each standard interface. In [12], S. Tomovic, M. Pejanovic-Djurisic and I. Radusinovic, explain key reasons for transition to SDN based mobile networks and briefly describe several proposals of design scenario. [25] present a model based on network calculus framework to describe the functionality and model the behavior of an SDN switch and SDN controller. Focusing on bounds and worst case scenario, network calculus compliments the classical queuing theory.an analytical model of the interaction between SDN switch (es) and SDN controller is analysed.

The 5G mobile networks should also support mechanisms for traffic differentiation and should achieve the end-to-end Quality of Service (QoS) requirements for incoming 5G applications .In fact , and in order to assure a higher QoS management , Several efforts and works has defended the idea of integrating SDN and its performance in future mobile networks as the effective solutions for enshrining QoS end-users. . In [26], authors address motivations literature in OpenFlow-enabled SDN networks, they organize the related works according to flow in which QoS can benefit from the concept of SDN. The authors of [27] presents the QoSFlow proposal in order to improve the flexibility of QoS control in SDN networks .Delay estimation in SDN networks using Queue model was discussed in [28]. The architecture proposed in [29] exploits the capability of OPenFlow in providing performance requirements for different applications.

3. 5G perspectives and architecture based on SDN concepts

The Software Defined Networking (SDN) is highly promising technology to provide innovation and enforce the main drivers in 5G mobile networks such as flexibility, scability and service-oriented management. It will be the basic key technology trends that will facilitate the required architectural agility needed in the next 5G mobile networks.

To achieve this goal , SDN will facilitates network configuration and management by pushing all control tasks to a centralized controller in 5G cloud-based wireless architecture .SDN paradigms will introduce high level of programmability and will provide the tools and functions to manipulate the massive data in expected 5G use cases.

The basic SDN definition has come from the standard compus network project OpenFlow, when researchers began to consider a network with programmable hardware devices and the centralisation of control and management [24] functions, which enables abstraction of low level networking functionalities into virtual services. This can be presented in the SDN architecture as the separation of the data plane from the control plane and by introducing novel network control functionalities [30].In this way, the control plane is represented as a centralized controller that maintains network-wide dynamics and enables network-wide management [31].

In the SDN architecture, the network controller maintains the intelligence of the entire network .On the other hand, Data plane is distributed to multiples switches and routers [32] that offer simple flow forwarding or routing based on flow entries generated by the control plane [31]. the controller calculates per-flow based routing path to provide QoS ,security and higher management resources capabilities .Furthermore ,SDN introduces an open Application programmability interfaces (API)between the decoupled planes Fig.1 ,wish offers a programmable network and provide flexibility to network operation and speeds the deployment of new innovations and services such as Openflow[33], ForCES [34] and PCE [35] [2].This promise programmability can open interesting opportunities in 5G mobile networks [36].The Openflow [37] is defined by the Open Networking Foundation (ONF) as the first standard protocol in southbound interface between the data and control plane of SDN architecture [38] [39]. It is broadly accepted as the dominant SDN protocol used in interface between the network controller and network devices [40].However , there are other protocols that can represent an alternative to OpenFlow in southbound SDN interface [41] [42] such as the ForCES and PCE protocols defined by IETF .A novel southbound SDN protocols are actually under development and testing .

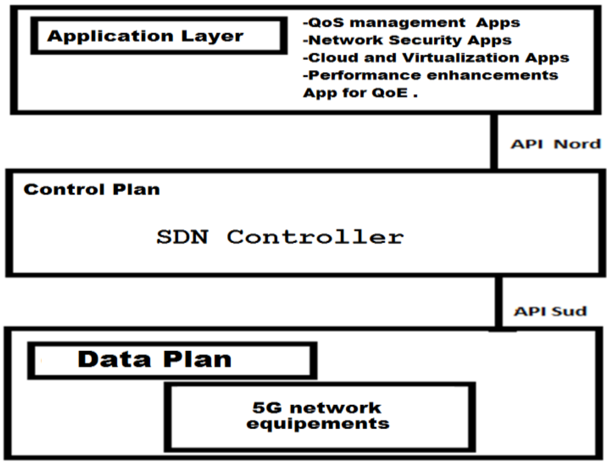

Fig. 1: 5G Plans Based on SDN Concepts.

With SDN concept, the infrastructure is separated into the specialized devices used to access applications and network services .The network is considered here as a set of logically independent virtual entities .This flexibility will promote innovation in the joint mobility ,routing and data management.It offers direct access to the forwarding plane and network devices

In SDN architecture , the OpenFlow protocol is used to define data structures ,messages and procedures , to describe all the physical and logical elements within a data path and to ensure [31] traditional functions of control plane ,such as modifying packets, managing the routing table and managing the different flows.It support also the IPv6 essential features including access control, quality of service and tunnelling through vpn and Ipsec. OpenFlow-based SDN technologies enable IT to address the high-bandwidth, dynamic nature of today's applications, adapt the network to ever-changing business needs, and significantly reduce operations and management complexity.Furthermore , the controller communicates with OpenFlow switches using the OpenFlow protocol running over the Secure Sockets Layer (SSL) in order to resolve security problems in the SDN based mobile network.

In 5G mobile networks, The controller will use Openflow protocol to communicate with 5G core devices, to maintain networks topologies, set new flows ,and collect network-wide statistics in order to offer QoS requirement Fig.1 .Thus ,5G switches and routers will use Openflow protocol to differentiate flows and forward them according to flow entries

Furthermore and according to ITU-T, SDN will introduce several level of services security into 5G network architecture such as Data integrity, Data confidentiality, authentication and access control .Within this regard, SDN will enhance security in the next 5G mobile networks. In addition , with the use of OpenFlow protocol in 5G mobile networks, the network will collect the maximum of characteristics parameters that describe the flow features [43] and select the important parameters that affect the QoS of each flows .The OpenFlow will use these parameters in order to build classification models and to achieve high QoS .

The next 5G core networks will be highly flexible, scalable and will support higher degree of programmability and automation. For this reason, the 5G core networks will be cloud-based environment. Seen as the next virtualization-based EPC architecture (vEPC) for the next 5G networks Fig.2 ,The 5G SDN-based Core Networks will introduce virtualization, and will provide innovative solutions, with more of a focus on the intelligence inherent for 5G network , also SDN will drive the feeds and speeds of data in 5G networks and will dynamically provide network connectivity services.

The implementation of SDN in 5G core networks will give a remote ability to manage the behaviour of network devices by pushing dynamically the change of device configuration and management.

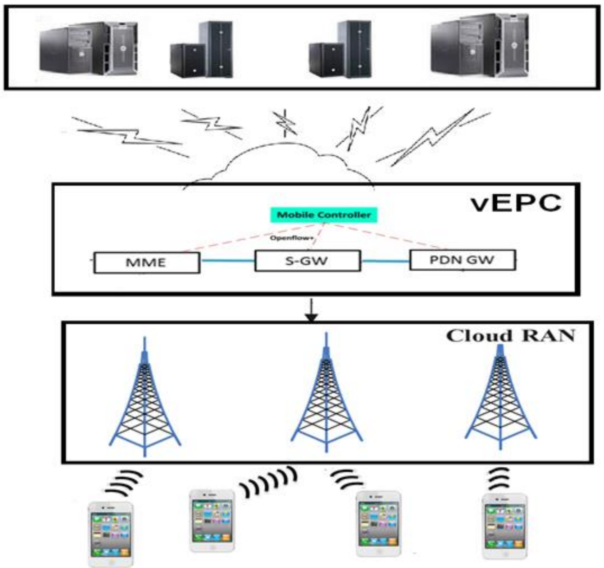

Fig. 2: SDN-Based Architecture for 5G Network.

In summary, the 5G based SDN architecture will have the following features:

- Directly programmable: Using a programmable control framework through controllers the SDN integration will achieve network intelligence with higher dynamic control of 5G devices.
- Open: SDN Controllers will be able to interoperate with several Openflow devices, which will offer better possibilities of a multi-vendor technologies in 5G network environment.
- Agile: Network operators can dynamically configure,manage, and optimize network resources and adjust traffic flows to meet changing needs quickly via dynamic and automated SDN programs.
- Abstraction: SDN services are abstracted from the underlying network technologies in order to increase portability.
- IPv6 deployment over SDN in 5G areas
- The deployment of IPv6 over SDN 5G mobile architecture will have the potential to enhance the network design, construct and operate networks to achieve more efficient business network agility[17] and will be an ideal mechanism for supporting the unification of the current transitional protocols

Combining the IPv6 and SDN provides the features listed as follows:

- Scalability: IPv6 SDN can provide flexibility in how the network can be used and operated. Services developers, either users or operators will have more selections and freedom for their service creation development cycles without vendor lock-in increasing quicker time to market, minimizing the costly dependence on vendors.
- Operational Savings: IPv6 SDN can lower operating expenses with open source platform with easy configuration and lower network construction costs.
- Better management: IPv6 SDN architecture alters the outdated methods of manual configuration, offering speedy provision connections in a computerized manner through separation and abstraction. IPv6 SDN can simplify IP address management and provide a secure environment for end node needs.

4. 5G QOS assurance with SDN

One of the main challenges of SDN integration in the next 5G mobile networks is to provide QoS performances and user satisfaction by the use of OpenFlow Contoller .The QoS improvements using OpenFlow and SDN are focused on routing functionalities and novel mechanisms that will be integrated in 5G routing equipment .The benefits of SDN toward 5G QoS include also the resource and queue management ,Quality of Experience (QoE)-aware schemes , automatic network monitoring mechanisms, Cloud-based QoS provisioning and applying QoS policies .In 5G based SDN architecture , The controller will have the capabilities to collect QoS informations and will be able to automate ,scripting and programming 5G devices to achieve higher QoS with much less cost .SDN Centralization of operations and mechanisms will allow also 5G routing equipement to select the traffic path for QoS end to end achievement .

5. SDN benefits for 5G

SDN and OpenFlow initiate new challenges, as questions of scalability and performance.Regarding SDN architecture; a single controller can control several network elements and can achieve higher performance

- Automated administration: With the SDN concepts, the 5G networks will be able to identify suitable changes, and how to handle these change automatically.
- SDN improve the usage of wireless resources and increase the satisfaction of users.
- Providing QoS requirements for 5G applications : Combining SDN and 5G will have the potential to address the QoS parameters requirements for each types of data flows .
- SDN will be the key technology for the QoE management and provisioning function in 5G mobile networks [QoS5G2].
- SDN can offer flexibility and complete information that support decision making such as offloading routing, energy efficiency and spectrum allocation.
- SDN will help to make use of the unified, less complex, less expansive and adjustable configuration of the network behaviour.
- Ability to provide an abstraction of the physical network infrastructure.
- Provide a seamless migration based on operator needs with a relevant cost reduction.
- The flexibility offered by the centralized approach of SDN can foster innovation in the joint mobility, routing and data management.
- Lower cost by simplifying network configuration and management.
- Service providers can provide more value-added services to customers Innovation in software can accelerate service delivery.
- OpenFlow-based SDN offers a highly secure and manageable environment: Dynamic and flexible adjustment of security policy is provided under SDN.
- Interoperability with other vendors interfaces.
- SDN will provide solutions to the limitations of multi-hop wireless networks [45] and to store data at the edge network to reach the required high capacity of 5G systems.

6. Conclusion

The integration of cloud and virtualisation through SDN and NFV in the next 5G mobile networks architecture will be the higher enhancement for the transition from the 4G to 5G in order to meet the future needs of 5G networks. In this paper, we present SDN concepts such as network programmability, SDN architecture elements and OpenFlow protocol and we will provide an overview of the vision on the future 5G networks based on SDN core paradigms. Furthermore, we discuss the IPv6 deployment over SDN in 5G and how this combination of IPv6 and SDN in 5G environment will provides scalability, flexibility and better management. Next, we address a several benefits of applying Software Defined Networking (SDN) to 5G and finally we give a brief a survey of 5G QoS improvements via SDN.

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