An architecture of 5G based on SDN NV wireless network

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Article Info

Article history:

Received Sep 20, 2018
Revised Dec 21, 2018
Accepted Jan 12, 2019

Keywords:

5G
Future network
HetNet
NV
SDN

ABSTRACT

The unexpected increase demand growth of broadband traffic, rapid advancement in networking and internet technology led to the growth in Internet-connected devices to sensor networks, and machine type communication devices. These increases bring more challenges in network capacity and connectivity. The use of the new 5G technology continues to address these challenges by providing high data rates, low latency, and more mobility with highly and densified HetNe deploment. This densified network brings new challenges to service provisioning in future networks based on the recent network paradigm innovations, Network Virtualization and Software Defined Networking to cope with massive broadband connectivity and enhancement of capacity, flexibility, and scalability. This study sets out to present the key features and requirements for 5G HetNet, SDN and NFV. The results of this study generally justify the challenges and how to integrate them into future wireless networks through a proposed 5G-based SDN-NV wireless network architecture to enable best network performance and resource management.

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1. INTRODUCTION

The rapid advance in networking and internet technology, and due to enormously raised demand broadband traffic provides enabled a wide variety of applications along with various requirements concerning network services. Based on Cisco’s network visual index state there has been a marked increase in the data traffic which is estimated to rise at a compound annual rate of 60 % by 2020, a tenfold increase over 2014, by 2021 the mobile data traffic is estimated likely to growth by eightfold when compared to 2015 [1].

Recent 4G cellular systems should come upon challenges because of rapid advancement in mobile traffic increasing volumes and diversity of services. The explosive development of smart mobile devices enabled ubiquitous mobile internet access, intensive traffic social applications, sensor networks, and cloud-based services. Also, to accommodate newly developed modern advanced technologies such as the Internet of Things (IoT), Device to Device (D2D) and Machine-type Communications (MTC), both communication industry, and academicians have started to search for new cellular communication networks and standards beyond 4G. Sufficiently great endeavor has been devoted to designing Next-generation Wireless Networks (NWNs) [2-3].

The new generation of mobile internet communication which termed as the fifth-generation (5G) mobile wireless communication technology. It developed based on Long-Term Evaluation (LTE 4G) that can be deployed to cope with explosive traffic requirements. Moreover, 5G is expected to lead the communication technology to satisfy the information requirements of the human communities by interconnecting the wireless world without having difficulties. So far 5G architecture is yet evolving specification of isolated slices operation and management to deal with the issues to achieve such goals for the future networks. It brings new specifications that need to be highlighted. Firstly, by using a densified 5G Heterogeneous Network (HetNet) which comprises various small cells with multiple Radio Access Technologies (RATs) such as WiFi, WiMAX, LTE, 3G, GPRS, etc., can provide a solution where massive broadband is expected to x 1000 data rate with low latency and higher capacity demand. Secondly, improvement of the spectral efficiencies through reconfigurable technologies such as the Cognitive Radio (CR) and advanced antenna systems [4-5]. Thirdly, a technique is to develop a new architecture for mobile internet networks that serves to obtain an autonomous communication and different integrated protocols, such as Software-Defined Networking (SDN) and Network Virtualization (NV). These advancements which are characterized by distinct segregation of the control and data and planes are promising the introduction of programmability, flexibility, and more comfortable netwrok management. The concept of Network Function Virtualization (NFV) has been introduced to enable the virtualization of network resources components. Furthermore, this massive deployment of HetNet SDN brings in unpredictable interference, frequent handovers, along with backhauling complications. In general, to acquire the desired 5G performance, flexible HetNet management and Quality of Service (QoS) aware, with optimum resource allocation have become essential [6].

The primary goal of this work is to address and highlight the 5G features and requirements for future networks. Therefore, it focuses on analyzing and justifying the 5G HetNet integrated into the SDN network architecture as a reference model through the proposed decentralized approach that should be fulfilled through innovative mobile network architecture design. Further, several concepts and ideas for 5G service delivery on how to use open networks efficiently have been discussed. On the other hand, the mobile network architecture needs to be evaluated about enormously exploring the prospective of new modern advances as well as becoming more flexible and scalable to accommodate several services and applications.

This paper addresses and analyses the key features and methods of implemented a promising paradigm for future networks from the literature. It is structured into various sections. Section two provided a brief overview of 5G networks features and their future directions. Section three summarised related works based on a proposed architecture for the 5G HetNet. This paper also discussed the critical technical challenges brought by SDN and NFV in section four. Moreover, section five presented a proposed of an open densified 5G HetNet based on SDN and NV network architecture. Then, finally, the paper closed with a conclusion drawn from the research findings.

2. 5G NETWORK FEATURES AND FUTURE DIRECTIONS

The next generation or 5G networking expected to be probably be built around people, as well as things. It targets the needs to deliver low-latency, high flexibility, high capacity networks for supporting the estimated increase in mobile data traffic, and seamless mobility. Moreover, the 5G structure should be multi-tier, including overlay coverage with enormous devices connectivity, through small cells deployment to supply the dedicated higher capacity to homes, enterprises, plus urban hotspots and to meet high data rates and traffic offloading. Thus, it can allow mobile operators to significantly lower their Capital Expenditure (CapEx) and Operational Expenditure (OpeEx) cost. Also, to support hyperconnectivity, a combination and integration of multi-RATs into intelligent clustering and relaying techniques, all contribute to providing applications with various QoS and provisioned services to anyone and anything at any time and anywhere [7]. The massive number of devices connections should lower end to end latency challenge. Correspondingly, to support the heterogeneity of devices and service demands in a scalable and efficient method. Henceforth, 5G should not only enhance the link efficiency by employing innovative technologies but also require a higher flexible and scalable architecture for adapting numerous situations [8].

An increase in network capacity is needed to meet the demand forecasted for 2020. Therefore, achieving the preceding requirements and challenges defined for 5G networks aim to improve the spectral efficiency as well as optimize resource utilization plus support the predicted traffic masses [4]. It requires the implementation of a new network paradigm and the deployment of a densified network architecture providing a new generation of dynamic radio access networks. That will be beneficial in many ways; introduces numerous tasks including interference management, network administration and management, and resource allocation for the development of future wireless systems [9-10].

A densified heterogeneous network is recognized as one of the crucial technologies for the 5G wireless communication networks which have enabled essential capabilities to achieve the needed capacity demand and data rate. It consists of dense and dynamic Radio Access Networks (RANs) and several different sized low power small cells with different applications. Several attempts and efforts presented and investigated architecture for future 5G backhaul networks. These efforts analyzed the essential requirement and significant features of 5G architecture which might be utilized to obtain higher output capacity and better QoS in high data traffic scenarios [11].

Unfortunately, this massive deployment of such a multi-layer 5G HetNet caused many current problems such as interference, frequent handovers, congestion and extensive backhauling. These problems have been attracting considerable interest by many researchers. However, all can be well exploited if 5G cellular networks employ joint scheduling or using a proper radio resource and power control approaches. Additionally, traffic offloading and the load balancing, among flexible air interface and the multi-RAT schemes are however able to improve the network capacity by enhancing the effectiveness of a network resource (i.e., multi-standards systems) [10].

3. RELATED WORKS

Recently, many articles related to our work have proposed solutions, addressed and dealt with challenges within current LTE networks. They focused on coping with some difficulties in the 4G core networks and 5G by adopting SDN design principles. However, certain methods cannot meet emerging new demands, because such conceptions are based upon the current 4G-EPC design.

Hence, control and data planes separation along with resource-efficient network virtualization with distributed accommodative traffic classifier can deliver a highly flexible architecture. This architecture can boost the revolutions for a collaborative hardware forwarding infrastructure and software networking algorithms. A new redesign of SDN network architecture called SoftAir was introduced in [12] to deliver the highest spectrum performance via cloud-based collaborative baseband processing. It encourages the convergence of HetNet through open and technology independent interfaces. It additionally improves energy efficiency in the dynamic scaling of computing capacity of the softly defined base stations (BS).

To achieve the promising characteristics of SoftAir, a new decentralized control approach. It was adapted for mobility management to increase the effectiveness of network resource utilization and decrease signaling cost compared with LTE networks. The essential management tools, including mobility aware and control traffic balancing, was investigated in a new SDN architecture (SoftNet) [13]. This new SDN architecture based on the core network and a unified RAN, where the network defined by software provide a flexible and scalable system that can dynamically enable/disable related virtual network functions.

A smart wireless network configuration for NWNs based on SDN using interface virtual RATs was designed to achieve overall low handover latency between heterogeneous networks. SDN controller was proposed to maintain the allocation of radio access resources and optimize internetworking coordination utilizing RATs interface set and standard protocol stack to deal with Het-RATs [14].

A contributed works have been undertaken in the cloud computing combined with 5G heterogeneous networks. These works investigated the challenges that allow cellular networks to perform a higher spectral efficiency, cooperative resource management together with the smarter controlled networks. The performance was achieved by replacing conventional RAN with cloud-based C-RAN to cope with the new requirement of 5G networks [15]. Added, further work in [16] carried out the necessity for fog computing through arguing in which cloud computing undoubtedly introduces undesirable latency and backhaul bottlenecks which is not suitable for location-based service provisioning via the decentralized method.

Accordingly, the deployment of multiple controllers to fulfill the optimal goal for a given SDN management is a research issue. Although the controller performs logically centralized control of network infrastructure, network policies, and data flow. It considered as a single point of failure for network reliability and cause network outage due to an unexpected change in traffic. Recently, many articles discussed this challenge causes propagation latency. It implies to determine the right number of controllers (single or multiple depending upon the size of the network) to be installed and their location within the network. The authors in [17] proposed a high-available controller arrangement which enables the deployment of high availability control plane for establishment networks. While in [18], they considered the suitable dynamic controller placement problem in network designing phase, which it depends upon the physical network topology, switch weight and the delay from switches to controller together. Also, in [19] authors addressed the problem of latency within controllers and their associated switches. They proposed a method of divided up a network into subnetworks and run controllers in those subnetworks through the deployment of distributed control architecture. Furthermore, to elevate the propagation latency and bottlenecks in controller deployment in such a high densified 5G based SDN network. Many proposed methods such as Kandoo in [20] and [21] gave a promising solution to the above problems.

Although there still exists many challenging problems for the distributed control plane. However, a few works have been undertaken in the combined of 5G heterogeneous networks with based SDN distributed multi-control architecture. We believe that this combination can enhance the scalability, flexibility and overall network performance.

4. 5G HETEROGENEOUS NETWORK BASED ON SDN AND NV

The revolutionary direction for ultimate mobile communications that are driving toward 5G and NMN require more flexible, scalable and reconfigurable ability of various network parts to meet the new services and massive traffic demand which are brought by the future requirement. The vision is to bring unique high performance to deliver high mobility network beside efficient dense heterogeneous platform for improvement of capacity, reliability, availability, and scalability [22]. For example, the major challenges facing the current network is the need to adopt new standards and new services to end users without reconfiguration of the legacy closed network. As a result, the migration toward an innovative unified access network architecture, encompassing several technologies and intended to provide and integrate a new generation of dynamic and flexible radio access networks for the 5G core network. Considering the advantages of SDN and NFV, the challenges faced by the current network configurations cannot be settled without a criterion transfer towards NWNs. That way can be realized by SDN paradigm shift toward cloud computing combined with 5G heterogeneous networks.

This new paradigm is known as Software Defined Network (SDN), with Network Virtualization (NV), and cloud computing technologies. Driven by These technologies are aimed to promote the network capabilities from dedicated hardware to virtual, and programmable devices accomplished on the shared service layer. The following section discusses the technical challenges of SDN and NV along with the future direction for managing physical infrastructure resources and virtual service functions [23].

4.1. The Software Defined Network

Currently, SDN is an expansion of the traditional allocated networks strategy based mostly on extremely particular hardware executing standardized protocols in coexistence with legacy networking devices. The basic configuration of SDN is depicted in Figure 1. Through this architecture, the mobile network functions which in the control plane are decoupled from the data forwarding planes. This segregation enables programmability and reconfiguration of the network with centralized network administration control without the requirement of independent access or network reconfiguration. The controller could communicate with switches or virtual data plane devices through the OpenFlow protocol. Besides, SDN is configured using software to offer great flexibility in its structure, efficient network management and a significant reduction in CapEx and OpeEx for both network service providers and data centers. Also, the SDN configuration concerns the high availability of services with performance, and scalability. Through its well determined separate architecture, the SDN is split into the layered structures: Data-layer, a control layer, and application layer [24].

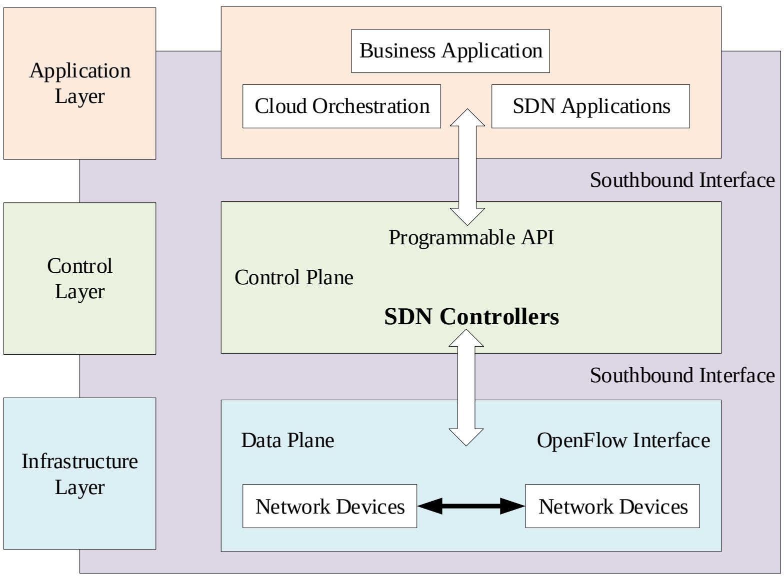

Figure 1. SDN basic architecture

4.1.1 Data Layer

One of the crucial layers of this architecture is data-layer which consists of both switching (hardware) and virtual (software) network devices. These devices are forwarding traffic (packets) according to flow rules identified by protocols, such as OpenFlow which is redirected by the controller.

4.1.2 Controller

The controller monitors and abstracts interoperation of network applications. Allows centralized control of the devolving traffic forwarding depending on the inputs from protocols which operate using applications of the control plane. At the same time, it sets up the communication channel for switches to facilitate automated network and control management. Several controllers can coincide in the network to control multiple enabled switches of SDN to establish many to many relationships. These entries are delivered as instructions to the switching infrastructure via the formed channel.

4.1.3 Application Layer

It relates the network services and end-user business applications which use abstractions provided by the control layer to implement SDN network applications and services for new user experiences.

4.1.4 Interface

The standard interfaces used in SDN networks is southbound and northbound. The southbound is the control-resource interface, which connects between controller and user data planes to the physical user-plane establishments in the RAN. This interface enables efficient virtualization of the accessing network. The northbound is the interface between the SDN controller and the application layer. To speculate, SDN assures many advantages are involve improved network service performance, simplified and enhanced network control as well as flexible and efficient network management [23], [25].

4.1.5 Openflow as Technology

OpenFlow is a standard interface protocol from Open Networking Foundation (ONF) which its first version was released in 2011. This protocol is main approaches to realize communication between the control layer and forwarding infrastructure layer in SDN architecture. Besides, various protocols running in SDN controller, but mostly is open flow which is considered as a standard protocol used with SDN. The interoperability characteristic of the OpenFlow framework of traffic flow based on network traffic and resource allocation allows the incorporation of heterogeneous devices commonly. Also, it simplifies the operation of multiple supplier infrastructures and increases network functionality to enable the decoupling of the control plane from the data plane in networks. Moreover, OpenFlow can be implemented on both sides of the interface devices and controller. As a result, it allows the networking hardware to provide a control which attaches to the network to design and direct the forwarding control and dynamically C-RAN [26].

4.2. Network Virtualization and Abstraction

Wireless virtualization is an emerging technology that is coping with the growing demand of varies networking services. It enables multiple virtual network operators (VNOs) to serve over and share the same infrastructure while improving backward compatibility access networks (by applying Ethernet and integration platform as IP protocol). Also, the concept of network function virtualization NFV of radio resources is to utilize infrastructure resources to meet service requirements. However, the simplicity of VNs specific configuration is accomplished as the impact of network element abstraction and high isolation of physical resources [27]. Both SDN and NFV based on abstraction, but they focus on the plane and layer dimensions. Because of the SDN and NFV features, interchange benefit can be gained between them.

Therefore, SDN confirmed the quality of the network traffic and the delivery of NFV's virtualized functions. Besides, NFV intends to facilitate the virtualization of network services and functions, like a cellular core function. So, by using SDN's control plane services, with NFV, the behavior of both the traffic and the network can be easily programmed by network administrators in a centralized way and become much efficient and flexible without demanding independent accessing and configuring either regarding the network's hardware device [24].

In recent years, the operators of network and providers for infrastructure service are required minimizing the operating costs while guaranteeing the best QoS. So many researches were conducted on proposed a new shareable network infrastructure that integrates SDN and wireless network virtualization (WNV) with many accesses control protocol (OpenFlow platform), to support multi-tenant virtual SDN networks and slice data plane layer. Regarding the vision of 5G and HetNet wireless, both the SDN with NV they provide efferent network management. It significantly improves the resource utilization, gains the network innovations, and offers customized services. Thus, it enhances network service provisioning and QoS, especially, in cell layers and RAN configuration [28].

One of the most important challenges in 5G network infrastructure and driving factor for software virtualization is slicing. In slicing where radio access network could produce either any VN or network slice along with core network resources or virtualized air interface. Alternatively, included all simultaneously, to provide end-to-end (E2E) network slicing. This concept is realized over 5G/SDN to enable flexibility especially for HetNet network density with different quality of services requirement without interference among them. However, NFV is considered as useful tool using on the extension of RANs through the implementation of network slicing to realize flexibility and accommodate different applications (different RANs and RATs) in 5G HetNet [29].

4.3. Resource and Management Utilization

Resource management and spectrum sharing based on the abstraction of resources in a heterogeneous network environment has become a critical issue, especially in wireless network virtualization. In which SDN control plane utilized to manage resources in virtualized networks efficiently and how to assign the isolated resources to the various convergence of different wireless networks and operators. As a result, it requires more efficient and optimal resource management and coordinated control procedures within the heterogeneous platform way [30]. Considerable research has shown, particularly, the interference and coordinated radio resource management (CRRM) schemes on the top of resource allocation through proper configurations. The software-defined design can adapt to diverse communication paradigms and provides transmission reliability regarding QoS guarantees via the optimum control of the design and the development of the CRRM for the 5G cellular network [31].

Many works and technology direction in the design for a 5G network looking for to obtain virtual wireless links and achieve end-to-end (E2E) virtual networks by aggregating all the physical resources from different radio access techniques, through mapping virtual functions to physical resources. Furthermore, as the cloud concept is extending, the SDN enabled cloud fog interoperation architecture mostly reduces latency and jitter compared to the standalone cloud solution using decentralized control node methods. Fog computing offers on-demand services and applications close to devices, dense geographical distributed and low-latency responses, resulting in more user experience and redundancy in case of failure [32].

5. PROPOSED 5G HETNET BASED SDN AND NV ARCHITECTURE

The development of future network architecture aims to improve the spectral efficiency through the design of a flat network to provide flexibility, enhance coverage, offload traffic, and delivers more management. Also, the 5G cellular network is expected to utilize a wide variety of technologies and standards to handle the increasing integration of networks. This approach can be achieved through the best driving solution architecture for 5G networks targeting to address programmability, proper management, and control for the 5G HetNet. However, such existing system with the dense deployment and the control plane which still relies on either RAN or in the core network (CN), suffers from inflexibility, scalability and performance concerns for a vast network. Therefore, this work presents and emphasizes the development of an efficient open densified 5G HetNet [33].

This architecture also aims to identify a suitable tool to orchestrate network elements. Hence, both centralized and distributed architectures in control level are considered to improve the scalability of the network. Also, this proposed model emphasizes mainly in the architecture to optimize the underlying network. It also formulates an efficient network for the future direction of the 5G. It targets to use a standard platform in a way that to control and enable unified abstraction of heterogeneous infrastructures with distributed control functions with under layer controller for capacity and data rate and reduce latency.

Therefore, this 5G HetNet multi-layer network infrastructure should allow virtualization. This visualization is primarily leading to reduce CapEx and OpeEx savings regarding cost-effective multi-vendor selections, and maintenance operations as well. Moreover, providing programmability and flexibility allows the network to adapt the traffic changing and demands through a suitable facilitating the management and information sharing among heterogeneous networks.

Applying SDN/NV network architecture is considered a solution by integrating the heterogeneous backhaul and fronthaul networks with a cloud-based configuration and combining multiple radio access technologies (multi-RATs). The primary consideration in the new architecture is cloud radio access network (C-RAN) as a mechanism to offer a solution for traditional RANs disadvantages such as limited capacity, insufficient expendability and low utilization. Likewise, applying C-RAN to enable separation of remote radio heads (RRHs) from baseband processing unites (BBUs) in RAN through forwarding links. It provides a solution for small cell dynamic deployment in LTE through appropriate coordination for interference and advances resource management. All resources serve and aggerate in BBU where the baseband tasks are processed in a centralized manner. So, many works have been conducted in this area; different architectures apply SDN and NFV in 5G by mean of cloud RAN concept. However, using a logically centralized controller with distributed agents can enhance the network capacity, an end to end latency, flexibility, and scalability and to support different architecture, as well as other performances [34-35]. As a result, it can enable enhancing the performance of the network and optimal utilization of resources.

5.1. Design and Deployment

In this section, a detailed description of the proposed framework is provided along with the main component of the proposed architecture based on the three dominant Software-defined paradigms for wireless networks as shown in Figure 2.

5.1.1 Physical Layer

It is an infrastructure layer responsible for data processing and traffic forwarding according to the controller. It consists of heterogeneous multi-layer network of small cells, distributed architecture of C-RANs, and a combination of multiple radio access technologies (multi-RATs). As well, it connects a massive number of edge/access devices with different applications. These core network devices are required to connect geographically and randomly distributed across the network centers.

This framework optimizes the network performance by aggregates all physical resources and multilayer network into a group of subnetworks (clusters) and virtual networks with different topologies. By this approach, a high bandwidth link with different protocols and coordination concept was characterized to meet the 5G network requirement. Also, to run on the same hardware of the wireless platform to support different kind of services for different RATs. However, it is expected from this proposed architecture to be generic enough to support other RAN technologies. Also, to endure multiple future cellular networks and go through cloud limitation by considering decentralized control functions to go through solving backhaul problems and low latency.

5.1.2 Control Layer

As separating the control plane from the underlying physical infrastructure, the control layer is at the top of the infrastructure layer. It provides core network abstraction and maintains the set of network control functions such as routing, traffic, and controls all network interfacing and mobility management. According to Figure 2, we have two levels of control, the SDN centralized orchestration controllers and distributed controllers.

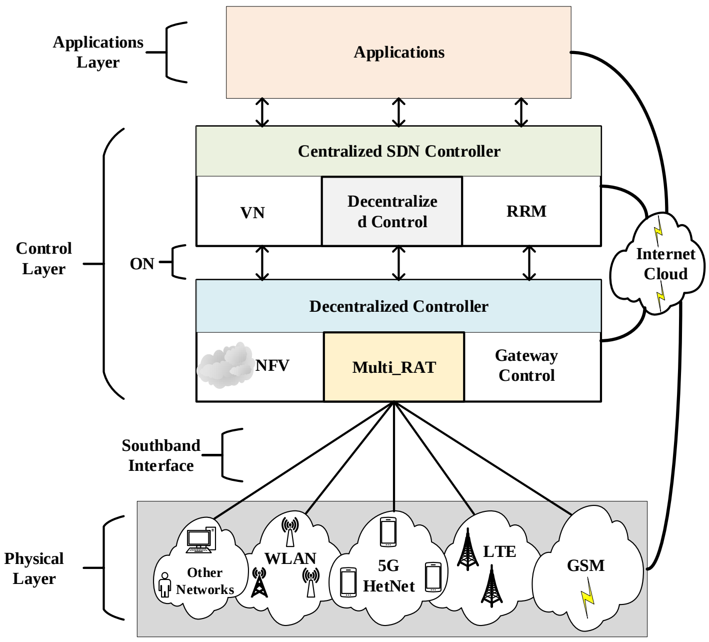

Figure 2. Proposed 5G HetNet based on SDN architecture

They are required to cope with this type of network and to manage such densified architecture. Both controllers that in the control layer and subnetworks expected to deliver substantial scalability and flexibility. All physical resources throughout several substances of an extensive network are aggregated with the SDN controller in a centralized approach by this centralized method; it can provide Softwarization for backbone network infrastructure. They are also required to coordinate the switches traffic routing according to traffic demand and plane and by this way decrease the latency between controllers and their related switches and lead to provide high scalability and flexibility, to reduce the propagation latency between controllers and their associated switches.

5.1.3 Centralized Controller

It distributes control functions across the multiple cluster controllers and them using OpenFlow protocol to communicate with under layer network each one controls a segment of the network, coordinates and manages the utilization of network resources, and underlays infrastructure data network. Relying on a global network view and it could be able to support mobility, the controller must hold the decision of facilitates optimization of resource scheduling between entities in subnetworks.

5.1.4 The Distributed Controller

This controller is placed in those subnetworks which are grouped in (clusters), each one has its local control plan for each base station and decision-making policy. This distributed controller redirected the flow of traffic to a centralized controller, according to traffic demand and depending on available resources of the network that are available for scheduling in each base station using an open flow protocol. This offloading technique can significantly reduce the signaling overhead and the cost, especially for indoor users and achieve network scalability.

By deploying these C-RANs in subnetwork layer, then each local controller could allocate a different channel and provide optimal resource allocation. It enables more management for radio resources, and interference, as well as congestion and energy efficient consumption. Hence the concept of abstraction and NFV practically has been addressed.

5.1.5 Interfaces

From SDN's point of view, the necessary interfaces are; southbound, northbound interfaces, and API for upper layer interface. These interfaces perform data forwarding and control functions. The interfaces utilized in the backhaul segment are the integration of technologies (e.g., fiber-optic and microwave) while that applied together with topologies (e.g., ring structure, daisy chain) as same as traditional LTE network. However, from the above, by using the distributed control architecture with positively the impact of a bottleneck in wide area network and latency over network performance of SDN, efficient and flexible network control can be achieved, which potentially enhances network performance. This proposed architecture needs more investigation and performance evaluation using simulation tools for future work.

6. CONCLUSION

Overall, this paper reviewed the key features and requirement of 5G HetNet architecture. As the 5G is expected to be built around people and things, the increase in mobile data traffic should have low latency, high flexibility, and high capacity networks. On the other hand, the paper identified and discussed the technical challenges of SDN and NVs along with the future direction for managing physical infrastructure resources and virtual service functions. The shift towards NWNs can solve the issues that face the current NW by using the advantages of both SDN and NFV. Also, the integration of 5G HetNet architecture has been presented to provide flexibility, scalability and more network management that can tackle the technical issues associated with SDN.

Moreover, a cluster-based 5G HetNet architecture with the decentralized control was proposed to provide an efficient resource management for the 5G based in SDN/NV structure. Also, the method has been projected to provide an efficient resources allocation optimization for the future direction of the 5G. Therefore, an open densified 5G HetNet using SDN/NV is presented as a suitable tool to orchestrate network elements. Both centralized and distributed architectures in control planes are considered to optimize the underlying network. A detailed description of the proposed framework architecture was shown in this work. This proposed model is expected to be generic to support RAN and endure cellular networks through cloud limitations by decentralized control functions and enable best network performance and resource management.

ACKNOWLEDGEMENTS

This work was financially supported by the Organization for Women in Science for Developing World (OWSD) and Swedish International Development Cooperation Agency (SIDA) under grant No. 3240291613.

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