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5G NETWORKS BASED ON SOFTWARE DEFINED NETWORK

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***Abstract*- A software-defined network (SDN) based 5G architecture that utilizes three controllers to improve network performance is proposed in this paper. The controllers are responsible for managing functions related to access mechanism, core connectivity, and network transport. The proposed architecture aims to address solutions for the challenges of traditional 5G networks such as scalability, flexibility, and resource allocation. The paper investigates two networks: 5G without SDN and 5G with SDN. The performance of these networks is evaluated by simulation tests using OMNeT++. The results show a considerable improvement in performance measures such as throughput, packet error rate (PER), and energy consumption. Under favorite test conditions, improvements of 46%, 88% and 94%, in throughput, PER, and energy consumption are achieved. The main finding of the paper is that the proposed SDN-based 5G architecture with multi-controllers is a promising arrangement to overcome the challenges of 5G networks.**

keywords: **5G, SDN, energy consumption, throughput, packet error rate, and QoS.**

I. Introduction

5G technology continues to evolve while the integration of software-defined networking (SDN) with 5G is becoming increasingly important. SDN can provide a centralized control plane that can enables network administrators to manage network services, flows, and policies through centralized software-based decisions [1]. SDN provides a high degree of flexibility and programmability, allowing network administrators to tailor their networks to the needs of specific applications and workloads. New potential and difficulties for SDN are created by the introduction of 5G technology. SDN offers several benefits to wireless mobile networks, including centralized network control, dynamic network provisioning, enhanced network security, simplified network management, and improved quality of service (QoS) [2]. By enabling centralized control of the network, SDN can improve network efficiency, reliability, and availability, while its dynamic provisioning capabilities allow for efficient resource utilization and improved scalability [3]. Additionally, the creation of network policies and rules in SDN can enhance network security, while providing a common interface for network management simplifies the management of wireless mobile networks. Finally, by dynamically adjusting QoS, SDN can improve the user experience for wireless mobile networks, adapt to changing traffic demands, enhance network performance, and provide a better user experience [4] [5].

The importance of 5G networks lies in its ability to bring significant improvements in data speeds, latency, capacity, reliability, and enablement of new applications and services. 5G offers faster data speeds than previous generations of wireless network technology, with peak data rates of up to 20 Gbps [6]. This translates into quicker downloads and uploads of content, and immersive experiences like virtual reality and augmented reality. In comparison with 4G, 5G provides lower

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latency, higher capacity, allowing it to support more devices and data traffic, which is essential as more devices become connected to the Internet of Things (IoT) [7]. This will enable new applications like smart cities and industrial automation. Finally, 5G enables a wide range of new applications and services that were not possible with previous generations of mobile networks. These include things like remote surgery, smart factories, and autonomous vehicles. Overall, the importance of 5G in networks lies in its ability to transform the way we live, work and communicate, through faster data speeds, lower latency, higher capacity, improved reliability, and enablement of new applications and services.

Integrating SDN with 5G can bring numerous benefits to the performance of the network [8]. This is particularly important in 5G networks, which require greater flexibility and scalability to handle the massive amounts of data generated by connected devices and applications [9]. Secondly, SDN can enhance network security which can help to prevent cyber threats and reduce the risk of data breaches, which is essential in 5G networks. SDN can optimize network performance, reduce latency, and improve throughput. The present work investigates the combination of SDN with 5G to improve the network performance.

The remaining parts of the paper are organized as follows: Section-I covers the literature review where similar works are mentioned. Section-III deals with the system model used in the simulation and the considered tools. The results of the simulation and their related discussion are presented in Section-IV. Finally, Section-V gives the concluding remarks.

II. Literature Review

The followings provide an overview of related researches: In [10] the authors used an OMNeT++-based simulation framework for evaluating the performance of distributed SDN controller architectures. In this paper they presented the OpenFlow OMNeT++ Suite, which enables the simulation of distributed SDN controller architectures within the OMNeT++ framework. The results show how the control plane may be impacted by partitioning, instance location, and service times. HyperFlow achieved a better efficiency in the investigated scenario.

The work in [11] aimed to provide a general point of view to the 5G networks with SDN, and discussed the different technologies that can be used to enable these networks such as Network Functions Virtualization (NFV), multiple radio access technology (Multi-RAT), device-to-device (D2D) communication. The work also addressed different challenges of control and orchestration like: cost reduction, better performance, energy efficiency. The authors demonstrated how 5G system orchestration and control were implemented to successfully coordinate and leverage the full potential of 5G technology.

In [12] the researchers presented an in-depth analysis and current solutions for 5G network slicing using SDN and NFV. First, they discussed the 5G service quality and commercial needs. Next, they described the 5G network softwarization and slicing paradigms. Second, they offered an introduction to the technical enablers for 5G network slicing, such as SDN, NFV, cloud/fog computing, network hypervisors, virtual machines, and containers. Thirdly, they conducted a thorough analysis of several commercial activities and projects hastening the adoption of SDN and NFV in order to hasten 5G network slicing. This study discussed potential difficulties and future opportunities for 5G network slicing research.

In [13], the researchers proposed a Network Slicing (NS) architecture for 5G networks that enhanced the QoS. This

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architecture depends on SDN and NFV to guarantee the QoS for different applications. It is based on the separation of 5G network into three different parts: the Transport Network (TN), Core Network (CN), and radio access network (RAN) to be able to have three types of NS each with different resources. The performance evaluation showed that the suggested QoS framework could route unique flows into unique Open vSwitch (OVS) queues, allocate network resources for distinct NS types, and deliver reliable E2E QoS to users based on predefined QoS needs.

The work in reference [14] presented the performance evaluation of a network with 5G network based on multi-controllers that runs the OpenFlow and Open Shortest Path First (OSPF) protocols. Video and ping traffic tested Packet Error Ratio (PER) and time jitter as QoS metrics. An improvement of 60% across two QoS metrics, namely PER and jitter were experienced when SDN-based controllers is used

The research efforts mentioned above were concentrated on using SDN and 5G networks to address performance challenges including PER and time jitter. In this paper the utilization of SDN with multiple controllers when combined with 5G was investigated. In addition to consider throughput and PER measures, the work here investigated the consumed energy, the average time delay, and time jitter covering a variety of test conditions and parameters.

III. THE SYSTEM MODEL

In traditional computer networks, networking devices such as switches and routers have integration between the control plane and the data plane. Based on preset configurations and criteria, these devices decide how data is routed and how it should be delivered. Traditional networks are less flexible to new network services or changing traffic patterns. Each device is manually configured by network managers, and any changes need manual intervention and frequently cause network problems. Because network management is distributed among several devices, it is difficult to create centralized controls. Additionally, limited network visibility, particularly in big networks, can make monitoring and troubleshooting difficult. Software defined network (SDN) separates the control plane from the data plane. It presents a centralized controller that controls data routing and administers network resources and gives network administrators the ability to create and implement policies. SDN simplifies the network administration and perform automatic centralized control. Because SDN networks are flexible, it's easier to implement new services and adjust to changing traffic patterns. Software allows for modifications, negating the requirement for manual device setting. SDN increases the agility and cost-effectiveness of network hardware by abstracting it. It makes it possible for businesses to employ commodity hardware for switching and routing. Improved network visibility via SDN makes it simpler to monitor and to resolve network problems.

The system simulation model in this paper consists of two networks. Each network covered three scenarios. In both network models, four mobile base stations are assumed with ten users (or user equipment UEs) being connected to each base station. In the first network, the mobile 5G network is connected to the core network as shown in Fig.1. The second network is SDN based network consisting of three controllers, six OpenFlow switches (OF_Switchs) and server as shown in Fig.2. Both networks are built using OMNeT++ version 5.6.2, SimuLTE version 1.1.0 and OpenFlow version 1.3.4. All traffic coming from the cells should pass through the packet gateway (PGW) and then to the core network. The PGW functions as a packet router (transmitting packets to and from external IP networks). In addition, it assigns IP addresses to all UEs

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and applies various rules for IP traffic from users, such as packet filtering. UEs are positioned either 200 or 400 meters away from the Evolved Node B (eNodeB) of its assigned base station.

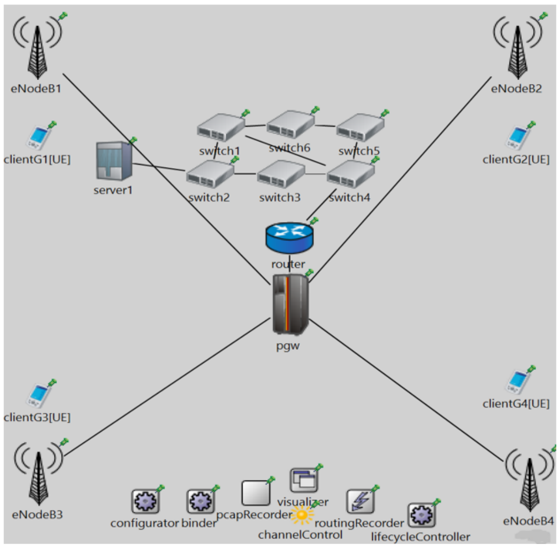

Figure 1: First simulated network (without SDN).

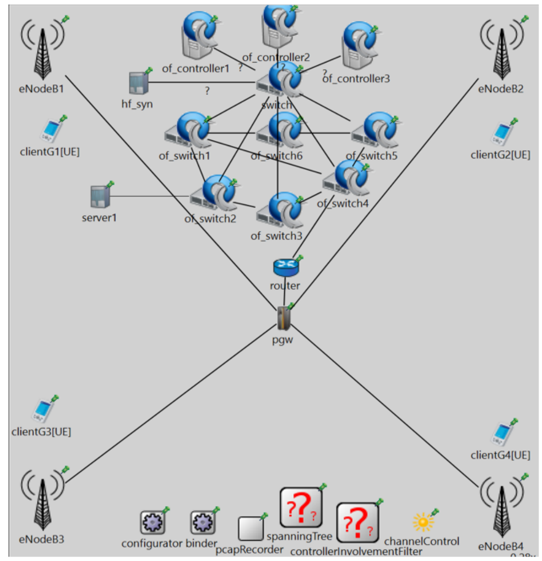

Figure 2: Second simulated network (with SDN).

The application used by the UEs is UDPBasicApp and the server is UDPSink. The packets are sent from the UEs to the server via PGW all the way to the switches and then to the server. Traditional network devices use a distributed forwarding approach, where each device independently determines the next hop for a packet based on locally stored routing tables. In contrast, SDN devices use a centralized controller to manage forwarding decisions. When a packet arrives at an SDN-enabled switch (OF_Switch), it is inspected and classified based on pre-defined policies or rules. The switch then sends a message to the centralized controller to request forwarding instructions. The controller examines the packet and determines the appropriate next hop based on network conditions and policies. It then sends instructions back to the switch. In the second network OF_Switch#1 and 2 assigned to Controller#1, OF_Switch#3 and 4 assigned to Controller#2, and OF_Switch#5 and OF_Switch#5 and 6 assigned to Controller#3.

IV. Simulation Results and Discussion

The assumed two networks are simulated and tested to evaluate their performance. There are three scenarios in each network depending on the packet transmission rate per second. Namely, 10, 100, 1000 UDP packets per second are used. The packets are originated from the client toward the target server. The first two of these cases are fixed UE at distance of 200 and 400 meters away from eNodeB. Others are dealt with mobility speed of UE, covered speed of 1, 50, and 100 m/sec. Table I shows the main simulation parameters considered in the tests. Different performance measures are then performed for the suggested networks with and without SDN. The throughput performance is shown in Fig.3, while the

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Packet Error Rate (PER) performance is shown in Fig.4. Further, energy consumption performance, average delay, and average time jitter performance are shown in Figs. 5 to 7, respectively.

TABLE I
The simulation parameters.

Parameter	**Values**
Application	UDP Basic Application
No. of bytes per packet	100
No. of packets per second	10, 100 and 1000
No. of controllers	3
Area	1600x1600 m^2
UE mobility	Fixed and mobile
UE speed	1m/s, 50m/s and 100m/s
Distance from UE to eNodeB	200 m and 400 m
Type of base station	Urban Macrocell
Carrier frequency	2.4 GHZ

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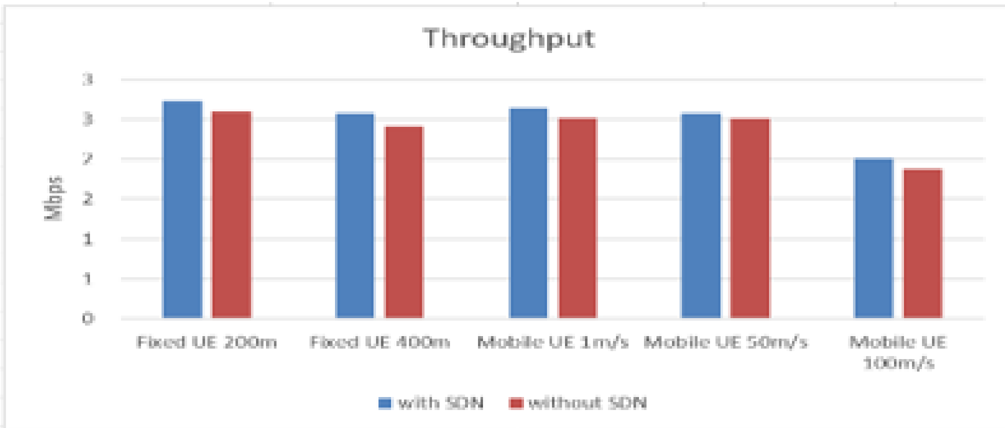
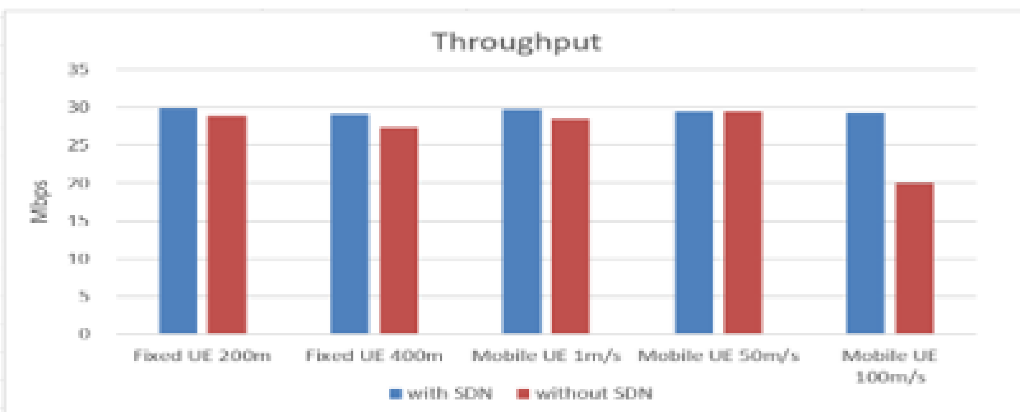
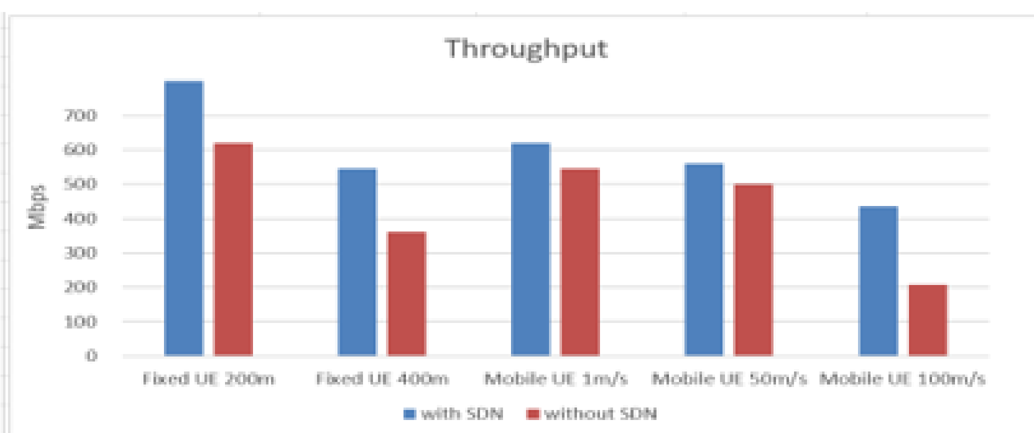


A- 10 packets/sec.



B- 100 packets/sec.



C- 1000 packets/sec.

Figure 3: Throughput performance.

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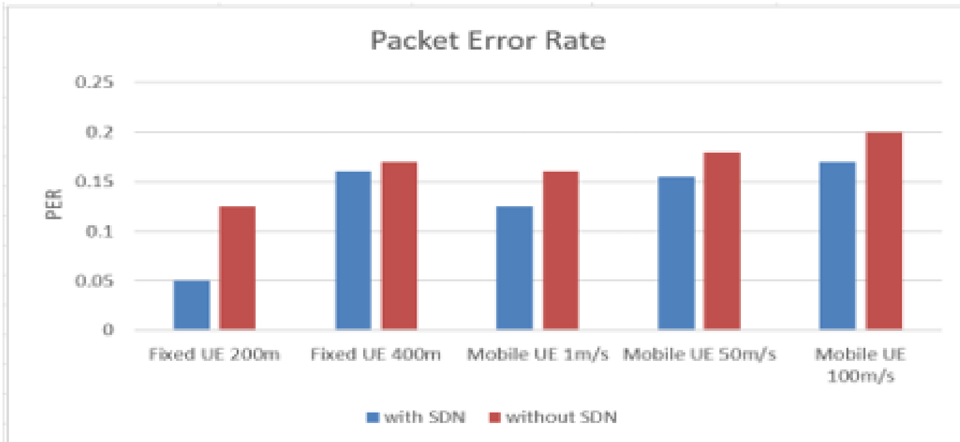
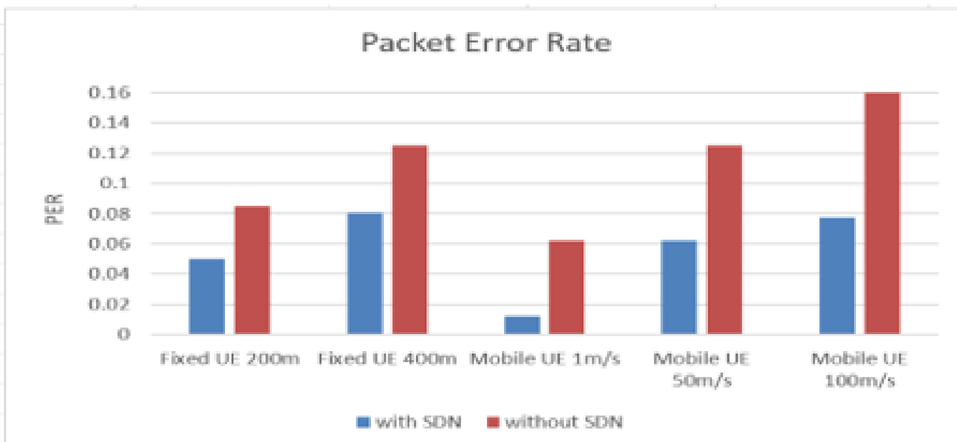


A- 10 packets/sec.



B- 100 packets/sec.

C- 1000 packets/sec.

Figure 4: PER performance.

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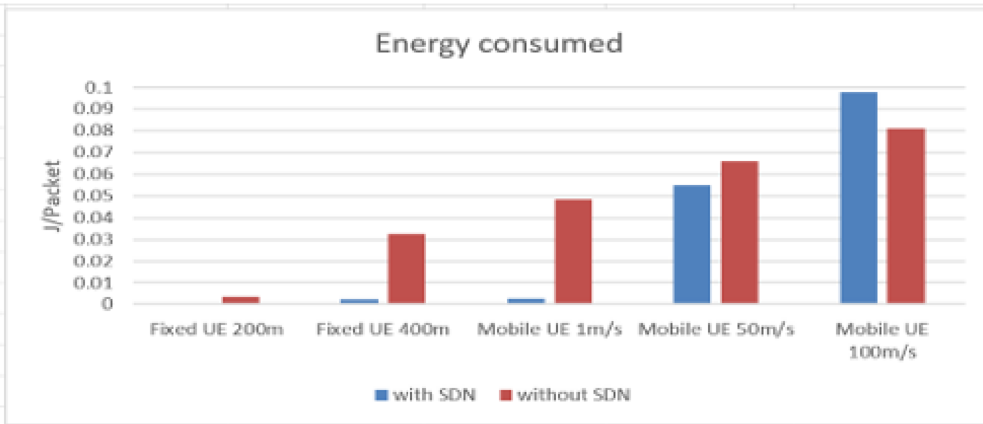
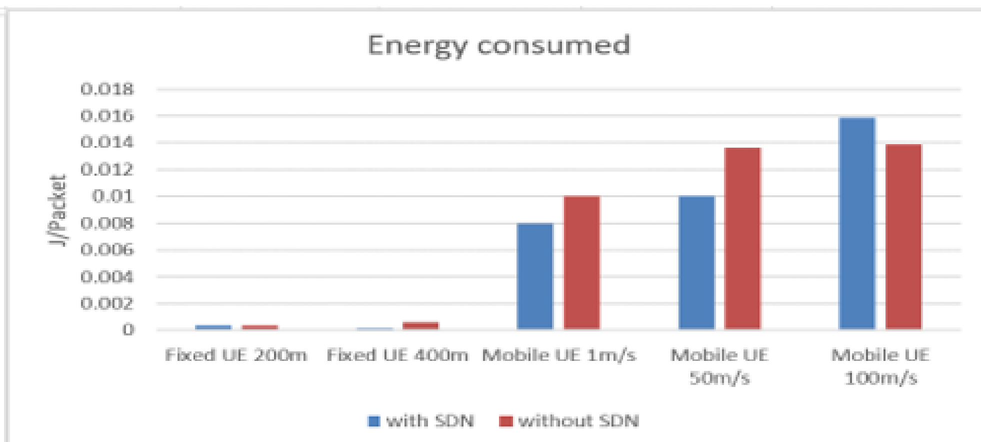
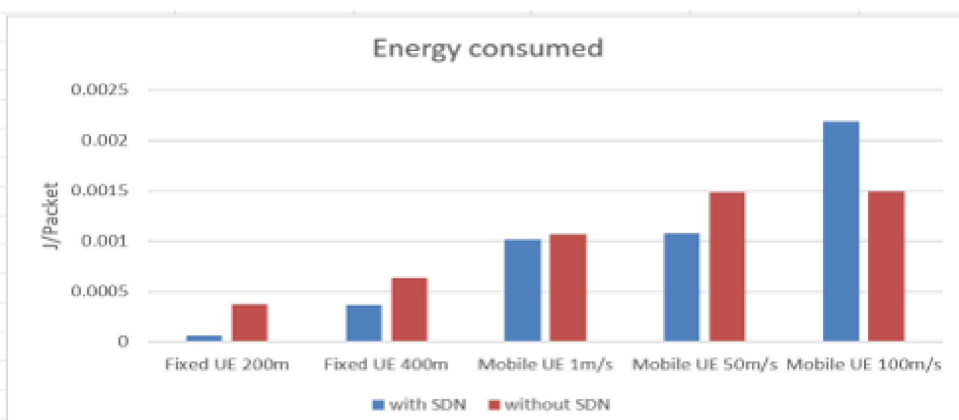


A- 10 packets/sec.



B- 100 packets/sec.



C- 1000 packets/sec.

Figure 5: Energy consumption performance.

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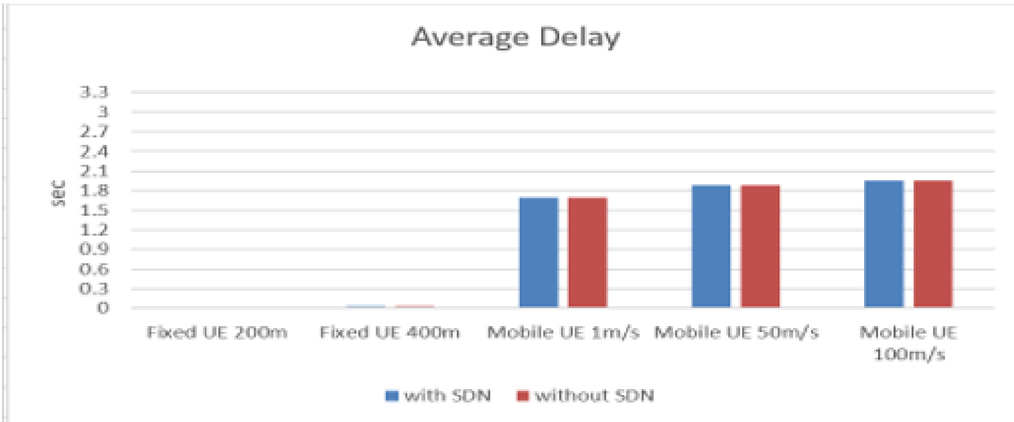
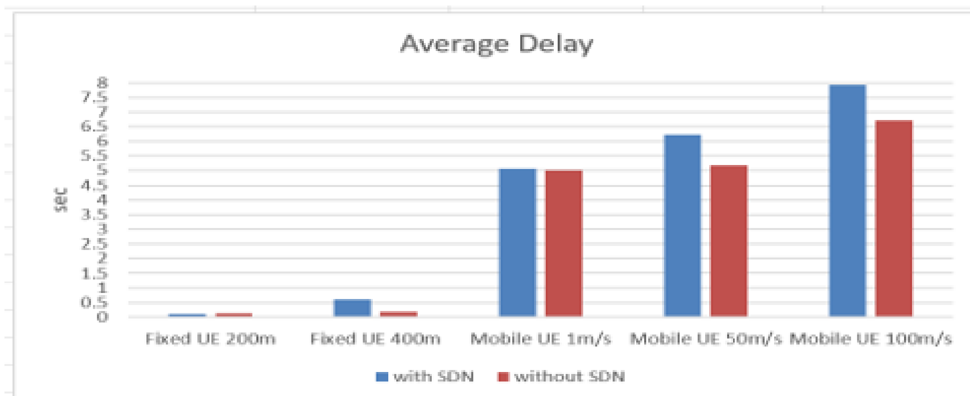
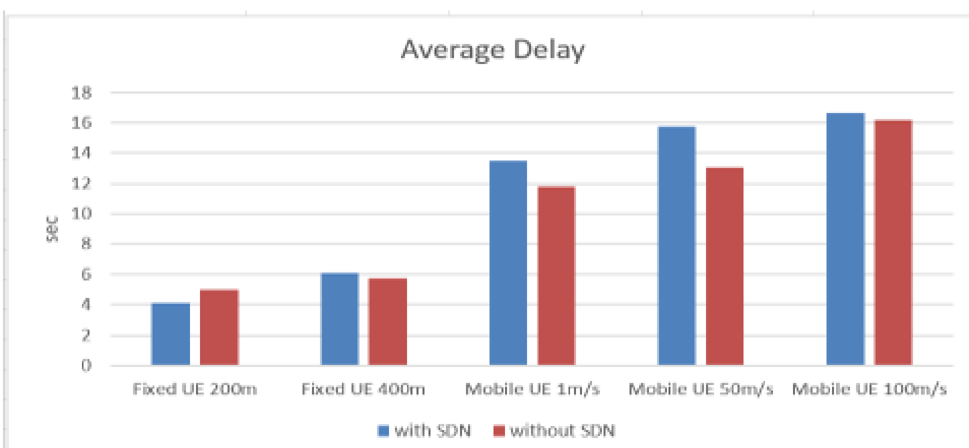


A- 10 packets/sec.



B- 100 packets/sec.



C- 1000 packets/sec.

Figure 6: Average delay performance.

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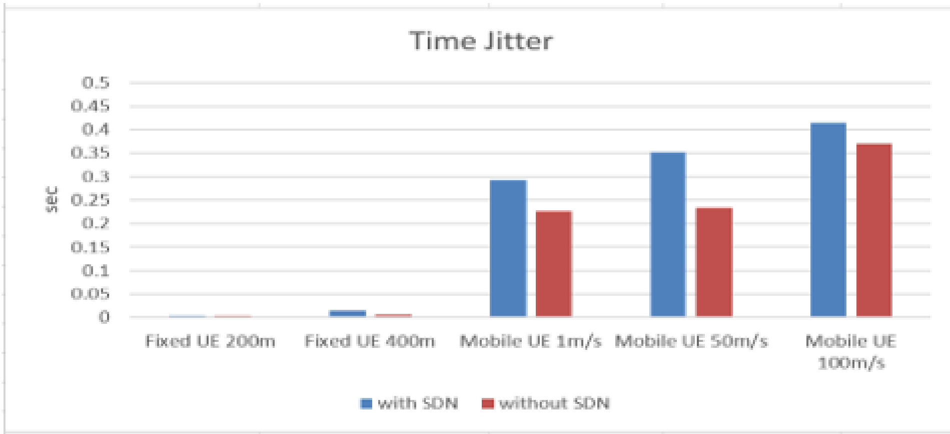
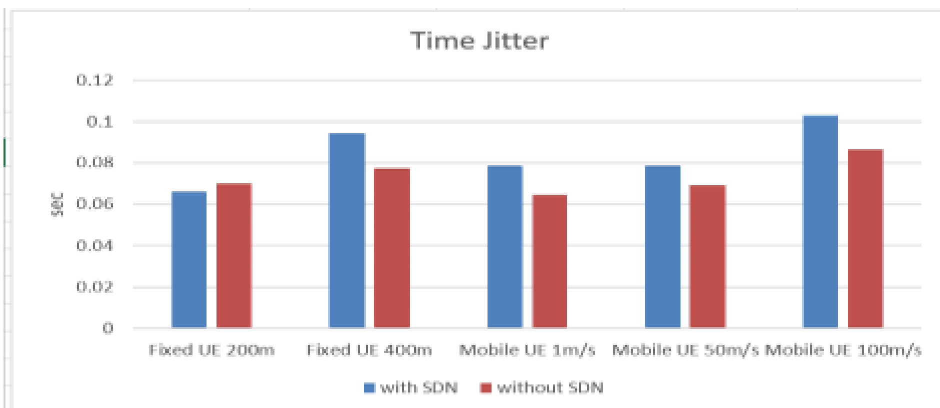
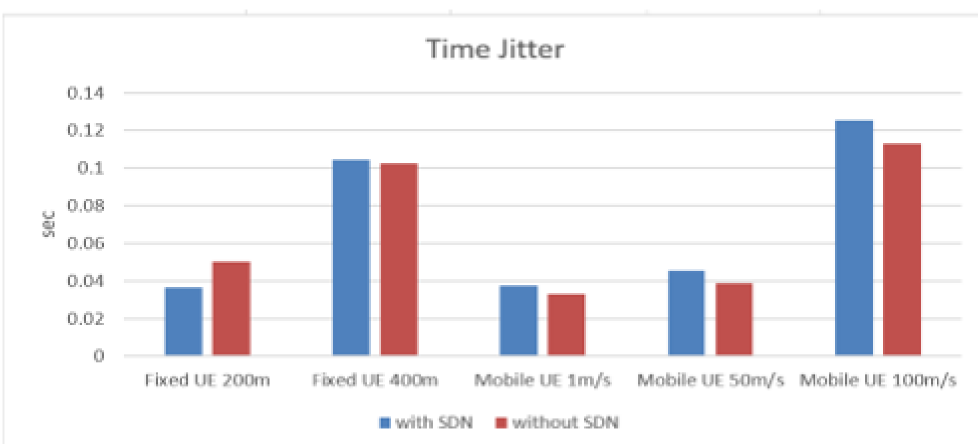


A- 10 packets/sec.



B- 100 packets/sec.



C- 1000 packets/sec.

Figure 7: Average time jitter performance.

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The following highlights the main findings of the paper with related discussions:

- Improvement in throughput performance is achieved when using SDN in all considered scenarios. An improvement in throughput by about 46% is obtained when the UEs are mobile with moving speed of 100m/s and packet transmission rate of 100 packets/s. SDN allows intelligent routing decisions, thus minimizing unnecessary hops and reducing the chances of congestion resulting in improved throughput as shown in Fig.3.

- Using SDN with 5G gives better PER performance due to the rerouting implied by the SDN controllers when congestion is taken place. Thus, reducing the packet error rate in all test conditions. As shown in Fig.4, the best obtained improvement obtained in two cases: when UEs are mobile at speed of 1 m/s with 100 packets/s and 1000 packets/s with percentage improvements of 76% and 88%, respectively.

- Regarding the energy performance issue, the test conditions showed that the use of SDN reduces the energy consumption for fixed and relatively slow UE moving speed (1 m/s with 10 packets/s) by about 94% as shown in Figure 5. At higher speed (100 m/s), the network with SDN consumed more energy, where extra moving speed requires both faster beam tracking of the base station and higher consumed energy by UE.

- For the case of using SDN controllers, the average delay and time jitter showed better performance when the UEs are located at 200 m distance from the base station. The use of extra network devices in SDN case resulted in slight increase in average delay and time jitter. Further, the larger the distance and UEs moving speed, the larger the average delay and time jitter of the network. However, the reduction of average delay and time jitter is relatively small (less than 20% for time delay and 25% for time jitter) as shown in Figs.6 & 7.

- Clearly, for the simulation parameters shown in Table I, the best overall performance using SDN with 5G network occurred when considering fixed UE with distance of 200 m to eNodeB, or/and UEs speed of 1m/s and 50m/s for all cases of packet transmission speeds.

V. CONCLUSIONS

The integration of SDN with 5G technology is presented here using multi SDN controllers. Such arrangement can assist in overcoming the main 5G challenges. A typical test conditions and parameters for the tested networks are considered in the simulation. Different areas, UEs moving speeds, and transmission rates are considered in the simulation tests. Two networks are considered: 5G without SDN and 5G with SDN. The results showed a considerable improvement in performance factors such as throughput, packet error rate (PER), and energy consumption. The best overall performance using SDN with 5G network occurred when considering fixed UEs with relatively small distance to the base station or/and UEs with least moving speeds independent of packet transmission rates. The main finding of the paper is that the proposed SDN-based 5G architecture is a promising arrangement to overcome the challenges of traditional 5G networks.

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CONFLICTS OF INTEREST

The author declares no conflict of interest

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