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PAPER

Software Defined Network Based Next Generation Mobile Communication Network Architecture

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ABSTRACT

As mobile networks and network speeds become more prevalent, the demand for marketing strategies increases. The operators are thinking about this, and the development of 5G communication networks is one of their main concerns. As the need for higher transmission speeds increases, 5G networks face challenges of scalability and adaptability. The next-generation mobile network (NMCN-SDN) architecture proposed in this study is based on Software-Defined Networks (SDN). A new network model called computer-defined networking allows for dynamic network definition and programming. A network simulator is created to examine the efficiency of the built infrastructure under different network conditions, including throughput, latency, and resource consumption. In this paper, the comparison of end-to-end latency between the standard communication architecture and the proposed NMCN-SDN architecture is done. The results show that the proposed architecture has less space in various conditions compared to existing communication architectures in various conditions.

KEYWORDS

Software-Defined Networks (SDN), mobile communication, 5G, end-to-end latency, throughput, resource utilization

1 INTRODUCTION

In future network configurations, it will become increasingly difficult to maintain effective network management as communication networks grow [1]. In addition, as carrier services and communication technologies evolve, new ideas and approaches to network management emerge. It tries to change the existing network infrastructure to add new technologies, services, and mobile applications. All these developments have a significant impact on the business strategies of network providers [2]. Operators must plan for the costs of adding new services, upgrading existing infrastructure, or expanding network designs.

All these things are becoming more expensive because consumers want more convenience and power [3]. Therefore, network planning and design decisions must

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take cost estimates into account. In this context, network managers should be able to test the proposed processes using systematic methods that can repeat the tests. The evaluation of new network ideas must be thoroughly tested before adopting a protocol or putting a system into production [4]. A test environment usually involves testing systems in a laboratory environment to ensure that the project meets initial requirements or to convince network administrators that new network technology has significant benefits.

With the trend in network architecture shifting from network-centric to client-centric, the new concepts of software defined network (SDN) and network function virtualization (NFV) are two potential disruptive strategies for the future generation of internet and mobile communication [5]. Unfortunately, the existing radio access network environment is essentially heterogeneous, with technologies such as LTE, Wi-Fi, and W-CDMA separated from one another. Thus, we believe that the SDN architecture has the potential to enable new radio infrastructure sharing in next-generation mobile communication networks. The traffic volume and large mobile terminals for the future mobile Internet will expand by orders of magnitude in the next few years, ushering in the era of big data.

Software defined network divides the control plane of a network into a single unit and keeps the data plane and control plane apart. Network flexibility is increased by separation and centralization, which also reduces the network's capital expenditure (CAPEX). By using SDN ideas, network operators can meet the requirements of different applications, and the 5G network can better adapt to changing requirements [6]. An SDN controller can dynamically control data layer switches using open standards such as OpenFlow [7].

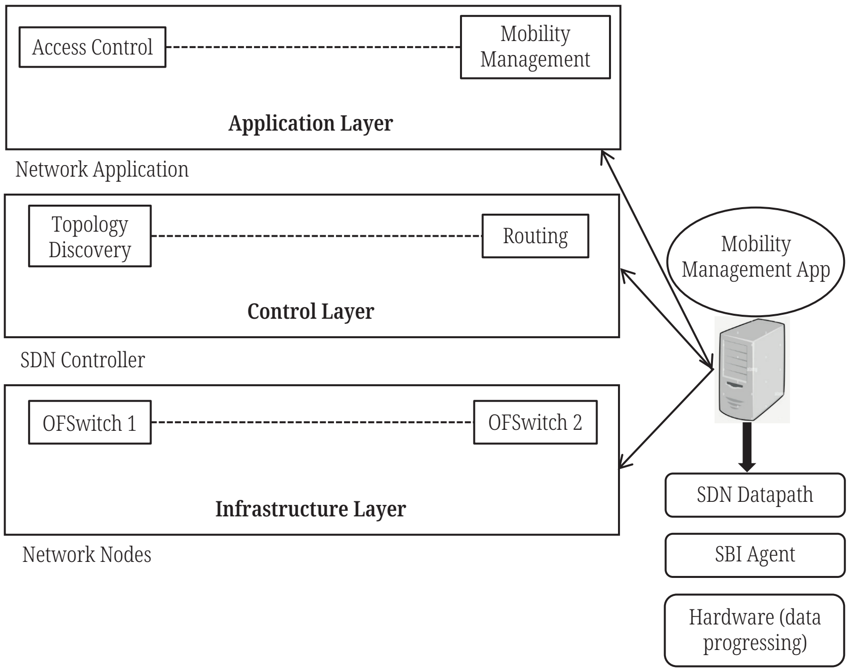

Fig. 1. Functional design of a software defined network

Regarded as an essential paradigm for managing standard IP networks, which are renowned for their intricacy and difficult administration, software-defined networking is acknowledged. Direct programmability, agility, central management, and open standards adoption describe the SDN architecture. SDN has been invented to enhance the programmability of connection solutions supplied by 5G beyond (B5G) and 6G networks, facilitating the adaptive direction and control of network traffic flows to acquire the best feasible profits. Thus, SDN provides efficient and dynamic programmable B5G/6G networks, enabling delicate coordination and control of applications and functions.

In new-generation mobile networks, it overcomes the gap between facility provisioning and QoE (quality of experience) administration by developing a virtualized control plane that is responsible for making smart management decisions for network operations [8]. For multimedia applications that are time-sensitive, SDN can offer context-aware QoE management, guaranteeing network integrity, dependability, and lower latency.

2 LITERATURE REVIEW

In [9], an SDN-based 5G core architecture was proposed to improve network management and flexibility. This paper explains the first methods of embedding and transmission in cellular networks. A proposed SDN-based 5G architecture is presented, along with a comparison of two processes in the 5G architecture. A network simulator built in Python is used to determine the performance of both a conventional 5G architecture and a proposed design. Various simulations were performed considering many variables to evaluate the performance in terms of endpoint delay, controller throughput, and controller resource consumption and to identify potential bottlenecks.

[10] Proposed an SDN controller-based intelligent wireless network architecture for next-generation wireless networks. To handle different RATs, it is chosen to employ virtual RATs with the same interface set and protocol stack. SDNC was created to improve connection synergy and help with radio access resource allocation. Consequently, the overall latency is reduced and the handover procedure is enhanced. Moreover, they present a novel SH technique to minimize different types of backhaul faults and enhance the robustness and stability of NWNs. Finally, they verify that their idea meets the stringent NWN handover latency requirements.

[11] Focused on significantly improving the quality of service. Software defined networking networks will be the foundation for their architecture. Their complex effectiveness is evaluated using a statistical approach that takes particular values for scalability, performance, and packet delay into account to meet Quality of Service criteria for system implementation. To assess the suitability of the suggested approach, software-based switches are used to simulate overlay networks. The findings indicate that employing IP networks with substantial traffic flows and a lot of network hardware makes using SDN more effective.

[12] Suggested a blockchain-enabled distributed security framework using edge cloud and software-defined networking. Dynamic network traffic flow management is provided by the SDN-enabled gateway. This management helps identify suspicious network traffic flows and reduces security assaults by obstructing suspicious flows. The outcomes demonstrate that the suggested security architecture can successfully and efficiently address the data confidentiality issues brought about by the combination of edge cloud, blockchain, and SDN paradigms.

In [13], a convergent SBA (cSBA) is used to divide the access, control, and data planes. Mobile communication networks have moved towards a service-based architecture with great flexibility to satisfy the highly flexible demands of vertical applications, made possible by technologies such as SDN and Network Function Virtualization. Converged services, cognitive solutions architecture, and effective service-based interfaces are all necessary for an enterprise cSBA to be implemented successfully. A comparison of monolithic structure and cSBA function is presented as the study's conclusion.

3 METHODOLOGY

A new next-generation mobile communication network (NMCN) architecture based on SDN is proposed. Figure 2 shows the proposed architecture, which includes all control-plane network tasks in addition to the SDN controller. Authorization and management function (AMF), session management function (SMF), project control function (PCF), and unified management data management (UDM) are some of the network functions used in this system. These applications can communicate north of the SDN controller. The user plane function (UPF) is implemented as an SDN switch and connects it to the southbound interface controller using the OpenFlow protocol. SDN controllers are used here to control the data plane and locate flow controllers in switches, including UPF and gNBs data plane switches. Since this structure is controlled by a centralized controller, it has the advantage that the user interface is flexible and easy to control [14–15].

The data plane's nodes demand fewer resources when the controller's task is dispersed, while the controller itself requires more. Studying robustness, latency, and performance is necessary to guarantee that SDN networks operate well. These characteristics are influenced by the quantity of requests received, the number of managed switches, their degree of connectivity to the controller, and the controller's query processing speed. Therefore, when developing new implementations and expanding the design of current networks, careful consideration of network scalability—which is based on the concepts of SDN, latency, and productivity must be given.

Examples of network functions are the SMF, PCF, authentication server function (AUSF), network segment selection function (NSSF), AMF, and UDM. This is on the control plane. Additional components consist of user equipment (UEs), data networks (DNs), user platform functions (UPFs), application functions (AFs), radio access networks ((R)ANs), or next generation RAN (NG-RAN), and user equipment.

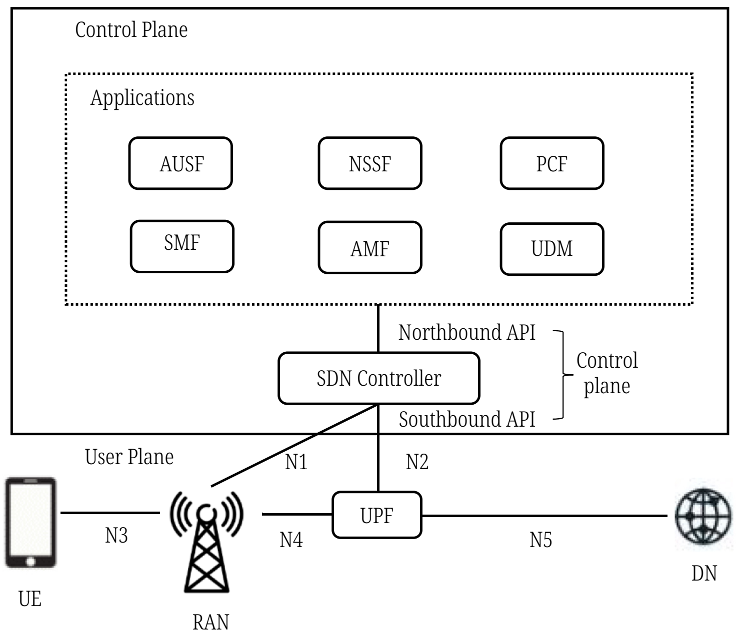

Fig. 2. Proposed architecture

The software-defined networking paradigm allows the database and management plane of a network to remain separate. SDN does this by removing traffic tasks from progressing devices such as switches and routers and putting these tasks into the SDN controller. Network management may be made simpler, and network content can be integrated by integrating the management plane into an entity. These guidelines are known as flow rules, and they are kept in a table known as the flow table by each progress item. An indicator of forwarder performance is this flowchart. The OpenFlow communication protocol is utilized when the SDN controller and the forwarding device connect across the southbound interface.

End-to-end latency (L) can be represented as the sum of propagation latency (L_{Prop}), transmission latency (L_{trans}), queuing latency (L_{queue}), and processing latency (L_{proc}).

$$L = L_{Prop} + L_{trans} + L_{queue} + L_{proc} \tag{1}$$

Where, $L_{Prop} = \frac{d}{s}$ (d is the distance and s are the signal propagation speed)

$L_{trans} = \frac{l}{r}$ (l is the packet length and r are the data rate)

L_{queue} and $L_{proc} = \frac{n}{s}$ (n is the packets and s are the service rate)

Throughput is defined as the amount of data transferred successfully per unit of time.

$$Throughput\ (T) = \frac{Total\ data\ transferred}{Total\ time} \tag{2}$$

Total data transferred could be calculated by summing up the data transmitted successfully during the simulation period. Total time is the total simulation time.

Resource utilization (U) can be represented as the ratio of the time the link is active to the total time.

$$U = \frac{Active\ time}{Total\ time} \tag{3}$$

Active time is the total time the link is transmitting packets during the submission.

Registration procedure: The registration procedure is called the initial application procedure in the proposed work. First, the UE requests registration to the RAN, which is forwarded to the corresponding AMF after being selected from the RAN [16]. The registration request sent by the RAN to the controller is forwarded to the AMF application, because in this case the AMF acts as an application in the controller. If the UE is unable to provide the subscription unidentified identifier (SUPI), the AMF application sends an ID Request message to the UE to obtain the SUCI. The AMF selects the AUSF to initiate the UE authentication procedure. After completing the registration, the AMF sends a registration confirmation message to the UE and the global unique title (5G-GUTI).

Handover procedure: In this way, the source and destination gNBs are connected to a single UPF. In other words, UPF divided by gNB. The target next-generation radio access network (T-NG-RAN) sends a handover request to the SDN operator request (AMF), indicating that the user has moved to a new home cell. You must make an offer. The SMF then sends a segment change request to the UPF to change the PDU segment requested by the T-NG-RAN. When a PDU segment is changed, the UPF responds with a change control message. After the route change, the UPF sends a stop signal to the source NG-RAN (S-NG-RAN) to indicate the route change, and then the UPF starts sending link traffic to the T-NG-RAN. When this process is complete, the AMF sends an acknowledgment (ACK) of the routing request to the T-NG-RAN and sends a message to the S-NG-RAN to release resources and confirm the completion of the handover process.

The base station, switch, and controller service expenses are denoted by λ_{bs}, ρ_{sw}, and ρ_c, respectively. We first review the registration request parsing model. The whole base station arrival rate is given below:

$$\lambda_{bs} = \pi + ((1 - \rho_{sw}) \times \pi_{sw}) \tag{4}$$

$$\lambda_{bs} = Initial\ Arrival + Arrival\ from\ switch$$

The overall intensity of the switch arrival is given as

$$\lambda_{sw} = \rho_{bs} \times (\pi + ((1 - \rho_{sw}) \times \pi_{sw})) + \rho_c \times (\rho_{sw} \times (\pi_{sw})) \tag{5}$$

$$\lambda_{sw} = Arrival\ from\ Base\ station + Arrival\ from\ controller$$

Although the total intensity of arrival at the controller is provided as

$$\lambda_c = \rho_{sw} \times \lambda_{sw} \tag{6}$$

$$\lambda_c = Arrival\ from\ switch$$

4 RESULTS AND DISCUSSION

This study investigates several critical elements in mobile networks and determines their levels in order to run simulations. Packet distribution times and node processing times are important variables. The different components and their levels are explained in the paragraphs that follow. First, we examine the processing times for several network nodes, such as the base station, OpenFlow switch, and SDN controller that have been published in the literature. The SDN controller has a processing time of less than 0.5 milliseconds.

The network's propagation delay is the next crucial component in the simulation. The backbone network and the radio access network may be hundreds of kilometers apart. The radio access network and the edge have links set up with a 0.1 ms delay in our experiment. The defined core-to-edge coupling ranges from 0.5 ms to 1 ms, contingent upon the specific simulation scenarios. Every link is regarded as a 10 Gbps link. The various simulation parameters and their values that can be found in the literature are compiled in Table 1.

Table 1. Simulation parameters

Parameters	Values
Switch processing time (μsec/requests)	10 μs, 25 μs, 40 μs, 75 μs, 140 μs
BS processing time (msec/requests)	1 ms, 0.6 ms
SDN controller processing time (msec/requests)	0.1 ms, 0.2 ms
Propagation delays (ms)	1 ms for 200 km, 0.5 ms for 100 km, 0.1 ms for 20 km

As shown in Figure 3, the end-to-end latency for registration requests is different between Scenario 1 and 2 when the arrival rates range from "0.5 to 330" requests per second. In scenario 1, at low arrival rates, the delay starts at about 6.9 seconds.

This indicates that it handles lighter loads better. In contrast, scenario 2 results in a longer initial delay of about nine milliseconds and a lower arrival rate. As the data arrival rates increase, both conditions show an increase in time, indicating bottlenecks or bottlenecks.

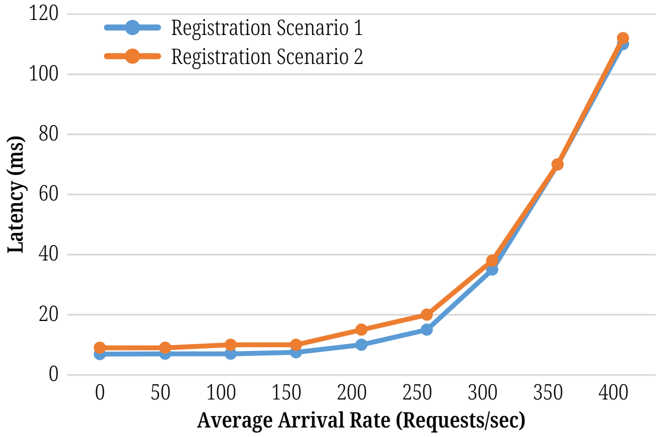

Fig. 3. End-to-end latency for registration requests

If there are more than 250 requests per second, this phenomenon becomes more pronounced, leading to longer waiting times for both conditions. In particular, scenario 2 shows a steady increase in latency compared to scenario 1, suggesting that scenario 1 is better optimized for scalability under high load conditions. This observation shows the importance of considering initial and expansion latency when designing or selecting a logging system, as Scenario 1 holds up better than low latency under variable load conditions.

The throughput at the controller during the registration process is depicted in Figure 4. It demonstrates that, as would be predicted, the throughput at the controller increases linearly as the arrival rate does. The lines in this figure depict the entry of registration requests under various circumstances. The y-axis displays the throughput in requests per second, ranging from zero to 1200, while the x-axis displays the number of requests, ranging from zero to 600. Access initially climbed from zero to 300 requests, suggesting that you are receiving adequate handling for the rise in load. The system performs exceptionally well, reaching its maximum output of roughly 1000 requests per second after 300 requests.

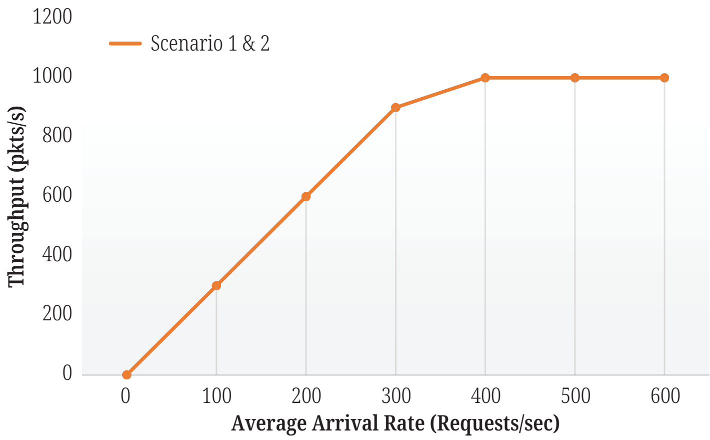

Fig. 4. Throughput

The system's capability is indicated by the 1000–600 requests per second that come in after this point. Congestion suggests that the system is not able to process more requests without experiencing a decrease in performance. Understanding this behavior is important in system design and optimization to improve production efficiency.

Figure 5 shows SDN controller resource usage for different methods in all scenarios. The processing time of the SDN controller was set to "0.2 ms" in all scenarios. This processing time translates into a capacity of 5000 requests per second.

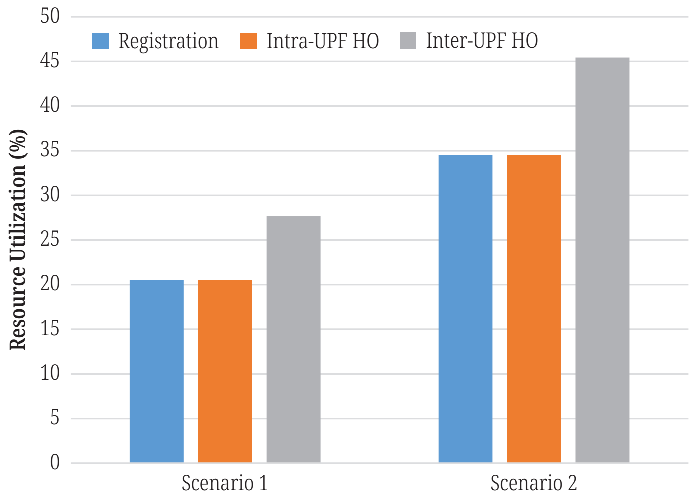

Fig. 5. Resource utilization at software defined network controller

In case 1, UPF uses 20.5% of its resources for internal registration and delivery procedures. The resources used for inter-UPF transmission are 27.66%. In scenario 2, 45.44% of resource utilization is documented in inter-UPF handover and 34.53% in intra-UPF handover. We can infer from this study that the base station is where the architecture's bottleneck is. This is a result of the base station's longer processing time compared to other nodes. Additionally, the controller's maximum resource usage is 45%. The findings demonstrate that, in comparison to previous architectures described in the literature, our suggested architecture has reduced end-to-end latency during the recording and transmission operations. It also achieves the high performance and utilization of resources needed to achieve mobile communications.

5 CONCLUSION

This paper proposed a SDN based next-generation cellular network to address the scalability and flexibility of 5G networks. The proposed NMCN SDN design uses SDN principles to provide a dynamic, flexible, and cost-effective network. Extensive simulations are used to evaluate the resource consumption, throughput, and end-to-end latency of the proposed design. Comparing the NMCN-SDN design with the existing network topology, it can be seen that there are significantly fewer end-to-end registration and transmission processes. Scenario 1 best illustrates the system's ability to handle higher volumes of arrivals with excellent scalability and low latency under extreme loads. The entire performance of the SDN controllers is decided by important factors such as processing power and time by a study on resource use. Increased resource consumption for transmission activities into and out of the UPF is depicted in scenario 2. The proposed NMCN-SDN system improves future mobile networks and considers the system's access, length, and management of resources. This model utilizes a centralized SDN controller that separates the control plane from the data plane and provides improved resource allocation and availability to meet non-5G requirements.

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