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# Enhancing 5G network performance through effective resource management with network slicing

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**ABSTRACT**

The immense growth of mobile networks leads to versatile applications and new demands. The improved concert, transferability, flexibility, and performance of innovative network services are applied in diversified fields. More unique networking concepts are incorporated into state-of-the-art mobile technologies to expand these dynamic features further. This paper presents a novel system architecture of slicing and pairing networks with intra-layer and inter-layer functionalities in 5th generation (5G) mobile networks. The radio access network layer slices and the core network layer slices are paired up using the network slicing pairing functionalities. The physical network elements of such network slices will be logically assigned entities called softwarization of the network. Such a novel system architecture called network sliced softwarization of 5G mobile networks (NSS-5G) has shown better performances in terms of end-to-end delay, total throughput, and resource utilization when compared to traditional mobile networks. Thus, effective resource management is achieved using NSS-5G. This study will pave the way for future softwarization of heterogeneous mobile applications.



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## 1. INTRODUCTION

Mobile networks are in dynamic progress over some time to gratify the new-fangled demands for improved performance, transportability, springiness, and resource management of innovative network services. 5th generation (5G) mobile networks espouse state-of-the-art networking architecture to meet the ongoing needs of modern life [1]. 5G mobile networks afford enormous scheme functionalities with high-speed data transfer, less end-to-end delay, enhanced dependability, and state-of-the-art experience in internet of things (IoT) applications [2]. The telecommunication regulatory authorities and the research fraternity are putting vast exertions into developing a novel model called the softwarization of 5G mobile networks. Multiple latest concepts, like software networks, network function virtualization, are integrated to meet newer service requirements. The stage-wise network transformation for the softwarization of mobile networks is presented in Figure 1.

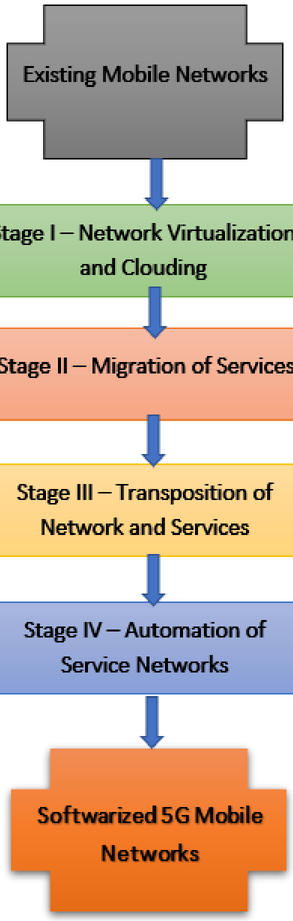


Figure 1. Softwarization of 5G mobile networks

The establishment of 5G mobile networks is explained in four stages towards achieving softwarization [3]. In stage 1, recitals, including software-defined networks and network function virtualization, are designed, leading to network virtualization and clouding. In stage 2, migration of services, including wide area network establishment of software-defined networks and cloud management, is established. In stage 3, the transposition of the network and services, including end-to-end orchestration of network elements, are furnished. In stage 4, automation of service networks, including network slicing and edge computing of multi-access technologies, are developed. In the architecture, the obstinate rigid mobile networks are visualized as dynamic and elegant software-based applications [4]. These design vicissitudes are beneficial to real-time industry applications and end-user requirements. This will also lead to the engenderment of novel service models and innovative value chains that impact cultural and social conduct.

Based on the functionalities and the operational convenience, the system architecture of 5G mobile networks is separated into multiple functional layers: the business process, control, and infrastructure. The concept of network softwarization empowered the capability to characterize the 5G mobile network as an encrusted structure designed analogous to software-defined networks [5]. The system architecture of 5G mobile networks supports various heterogeneous applications of mobile devices and various internet of things (IoT) applications. The network-connected elements, including base stations, switches, hubs, and routers, are connected to the infrastructure layer. In contrast, all the network control modules and decision support units are positioned in the control layer. Application service requests are initiated at the business process layer, which is communicated to the control layer and translates into service control instructions. Each layer associates and communicates with the adjacent layer, and at the same time, all the layers are operationally synchronized with the end-to-end management and establishment interface [6]. Optical transport networks and other backhaul access technologies function in the infrastructure layer. Various configuration setup procedures and network operating systems are performed in the control layer. Functional service-level applications, enterprise, and other third-party applications function in the business process layer. An anti-phishing system was proposed to immediately remove features from the uniform resource locator and utilize four classification techniques: decision tree, K-nearest neighbor, support vector machine, and random forest [7]. The system is necessarily a global positioning system and a global system for mobile telecommunications technology. The vehicle's position on the ground is decided utilizing Google Maps [8]. Mobile phones and smartphone software that exhibit sensor data and alarms of falls have also been introduced. It admits a web interface. To raise the sensor node service life, the pressure in the center element essentially utilizes a full-strength, flexible solar-oriented sensor [9]. To increase the central ingredient life of the wearable sensor, the pressure in the center ingredient mostly utilizes a full-strength flexible solar-oriented sensor with the effect of a superior method similar to maximum power point tracking [10].

A slicing network can improve efficiency and offer various 5G services through a virtual network. Network slicing can separate the 5G physical network [11]. Radio resource management in 5G new radio featuring network slicing during a mixed integer linear program [12]. Network slicing represents an important concept proposed in 5G networks to maintain the requirements articulated by a service generation. network slicing creates chances for service providers and virtual network operators, appropriating them to run their virtual, self-governing functions on a shared structure [13]. An efficient packet-based scheduling mechanism for data traffic via 5G slicing with two function modes enhances the 5G cloud resource utilization and offers a competent separation of the 5G slices [14]. The dynamic resource allocation method improves resource allocation, enhances service capacity, and meets the necessary service quality of the several tenants [15]. An optimal resource allocation is demonstrated using an adaptive channel bandwidth option to calculate service quality requirements and traffic aggregation priority. It improved the efficiency of licensed radio resources by improving the long term evolution (LTE) frame formation process and minimizing signal traffic distribution [16].

## 2. METHOD

Implementing the proposed architecture provides manifold connectivity and acquaintances in disseminated and consolidated network platforms. Such networking mechanisms are used to accomplish distinct degrees of access management and enrich interface communication between base stations. Network capabilities of the imminent 5G mobile networks will be ascending to meet the versatile requirements in a corporate environment. So, the functionalities of access and core networks need to be further boosted to meet the growing demands. The system architecture of the 5G mobile networks has adapted for effective resource management in terms of end-to-end delay, total throughput, and resource utilization using network slicing and softwarization.

### 2.1. Network slicing in 5G networks

Network slicing in 5G mobile networks is established by integrating virtualization and softwarization of self-governing logical networks on the identical physical network substructure [17]. An individual network slice is a secluded end-to-end network personalized to accomplish varied necessities entreated by a specific application. Multiple service level agreements can be met with the pivotal role functionalities of network slicing in softwarization of 5G mobile networks. This leads to deploying supple and ascendable network slices over the shared network architecture [18]. From an industrial application model viewpoint, each network slice is controlled by a virtual network operator. The telecom service provider tenancies its logical functionalities to the virtual operator, segmenting the fundamental physical infrastructure [19]. Based on the accessibility of the allotted resources, the service provider can independently organize various adapted network slices to meet the requirements of specific applications. Softwarization in 5G networks to sustenance functionalities such as improved mobile coverage and dependable low-latency data transfer has transfigured the industry standards [20]. The pseudo-code for network slicing in 5G mobile networks is explained in Table 1.

Implementing this algorithm and the defined mathematical expressions will allow us to effectively manage resources using network slicing in 5G networks. The algorithm dynamically allocates resources based on network slice requirements, resulting in improved network performance, reduced delay, increased throughput, and optimized resource utilization. Additionally, integrating machine learning algorithms enables proactive resource allocation adjustments based on predicted traffic patterns, enhancing the network's performance.

Table 1. Pseudo code for network slicing in 5G mobile networks

| Sl. No | Pseudocode |
|---|---|
| 1 | Define network slicing parameters:<br>$Bandwidth\ (B)$<br>$Latency\ (L)$<br>$Availability\ (A)$ |
| 2 | Collect network data:<br>Traffic patterns<br>Resource usage |
| 3 | Determine network slice requirements:<br>The bandwidth requirement for a specific network slice (*B_slice*)<br>Latency requirement for a particular network slice (*L_slice*)<br>Availability requirement for a particular network slice (*A_slice*) |
| 4 | Slice the network based on requirements:<br>Allocate bandwidth for the network slice:<br>$Bandwidth\ Allocation = (B \times B\_slice)/(Total\ Network\ Slice\ Bandwidth\ Requirements)$<br>Allocate latency for the network slice:<br>$Latency\ Allocation = min(L, L\_slice)$<br>Allocate availability for the network slice:<br>$Availability\ Allocation = A\_slice$ |
| 5 | Monitor network performance and adjust resource allocation as necessary:<br>Calculate end-to-end delay:<br>$End - to - End\ Delay = t\_receive - t\_send$<br>Calculate total throughput:<br>$Total\ throughput = (Number\ of\ bits\ transmitted)/(Total\ time\ taken)$<br>Calculate resource utilization:<br>$Resource\ Utilization = (Total\ used\ bandwidth)\ /\ (Total\ available\ bandwidth)$ |
| 6 | Use machine learning algorithms to predict future traffic patterns and adjust resource allocation preemptively:<br>$Traffic\ Prediction = f(Traffic\ Data)$<br>Resource Allocation Adjustment:<br>If Traffic Prediction indicates an increase in traffic, allocate additional resources to meet the predicted demand |
| 7 | Mathematical Expressions:<br>Bandwidth Allocation:<br>$Bandwidth\ Allocation = (B\ x\ B\_slice)/(Total\ Network\ Slice\ Bandwidth\ Requirements)$<br>Latency Allocation:<br>$Latency\ Allocation = min(L, L\_slice)$<br>Availability Allocation:<br>$Availability\ Allocation = A\_slice$<br>End-to-End Delay:<br>$End - to - End\ Delay = t\_receive - t\_send$<br>Total Throughput:<br>$Total\ throughput = (Number\ of\ bits\ transmitted)/(Total\ time\ taken)$<br>Resource Utilization:<br>$Resource\ Utilization = (Total\ used\ bandwidth)/(Total\ available\ bandwidth)$ |

## 2.2. Effective resource management using network slicing

There have been several studies on managing resources effectively in future mobile technologies. This includes increasing the network capacity to enhance the coverage quality, using logical functionalities instead of the physical elements, tractability, and general progress practices in real-time applications [21]. To achieve effective resource management, two factors are involved in the technological modernization and collective advancement of mobile networks [22], [23]. They are establishing virtualized network architecture and developing robust transportation infrastructure. When comparing the proposed 5G mobile networks concerning the traditional supported hardware transportation infrastructure, there needs to be improvisation in virtualization and softwarization of physical resources [24]. There, the high cost involved in resource allocation can be minimized. This can be achieved by partitioning the control, infrastructure, and business process layers, as shown in Figure 2.

In the softwarization of 5G mobile networks, logical components are devoted to dynamic capacity building to meet heterogeneous requirements [25]. Using the same set of processors and servers, the concept of network slicing certificates the conception of slices ardent to logical, autonomous, and apportioned network functionalities. In Figure 3, the pairing of network slicing elements is established [26].

Communication can be intra-layer or through inter-layer slices. In the radio access network, multiple slices can communicate with each other, and in unison, each radio access network slice can be paired with each slice on the core network layer [27]. Such resource management of pairing of network slices can be effective in the performance of mobile networks. The pseudo-code representation of effective resource management using network slicing is shown in Table 2, and the block diagram representation of the proposed system architecture is shown in Figure 4.

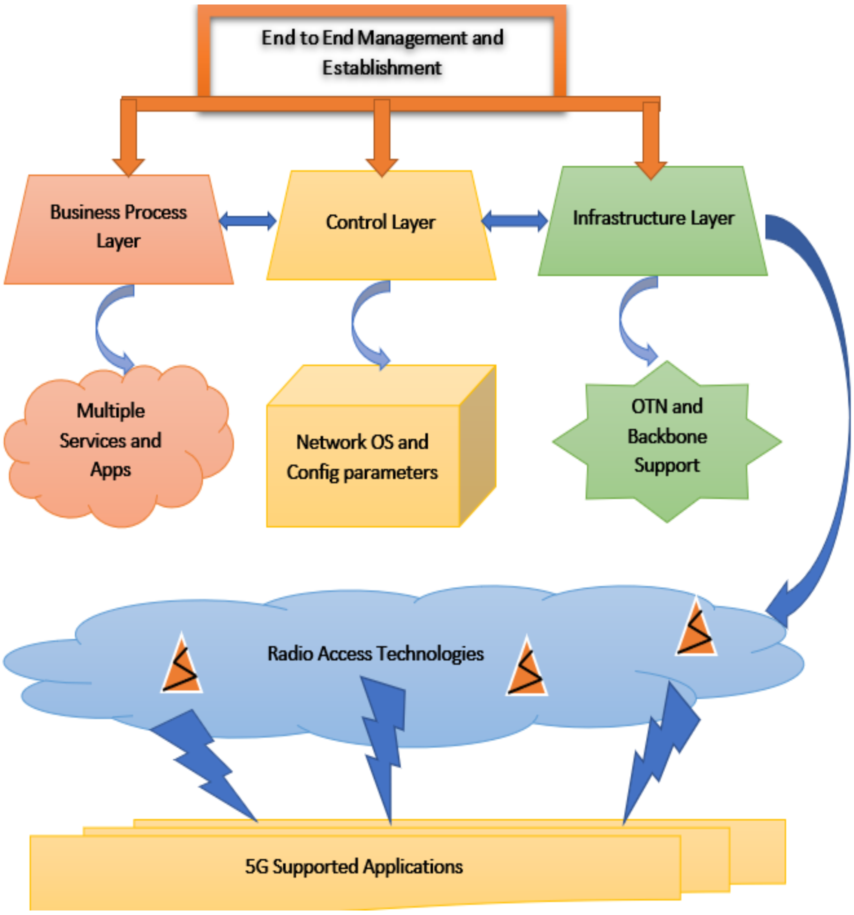


Figure 2. System architecture of 5G mobile networks

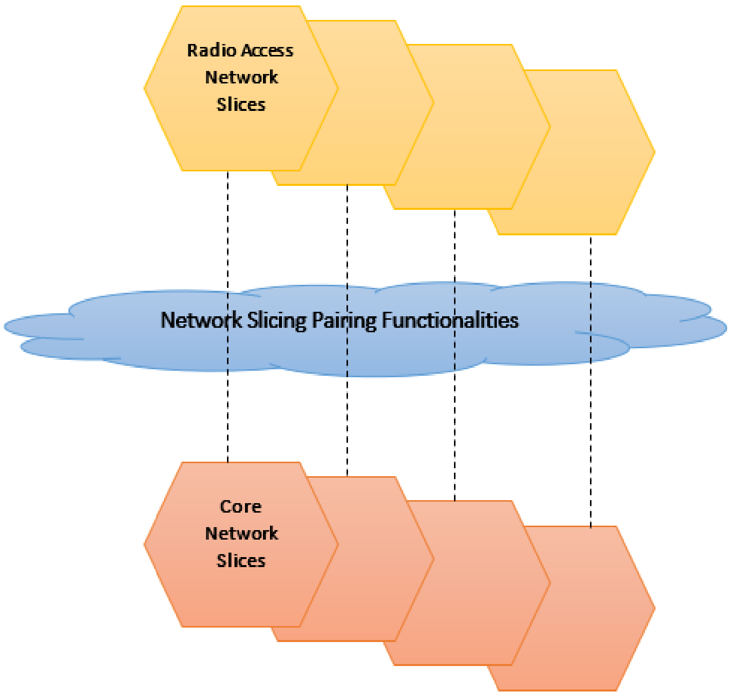


Figure 3. Pairing of network slices

Table 2. Pseudo code for effective resource management

| Sl. No | Pseudocode |
|---|---|
| 1 | Define the network slicing parameters such as bandwidth, latency, and availability.<br>*Bandwidth = B //Total available bandwidth Latency = L //Maximum tolerable end-to-end latency Availability = A //Minimum required availability percentage* |
| 2 | Collect network data, including traffic patterns and resource usage |
| 3 | Determine the network slice requirements based on the data collected.<br>*Network Slice Bandwidth Requirement = B_slice //Bandwidth requirement for a particular network slice Latency Requirement = L_slice //Latency requirement for a special network slice Availability Requirement = A_slice //Availability requirement for a specific network slice* |
| 4 | Slice the network based on the requirements and allocate resources accordingly.<br>*Bandwidth Allocation = (B x B_slice) / (Total Network Slice Bandwidth Requirements) Latency Allocation = min(L, L_slice) Availability Allocation = A_slice* |
| 5 | Monitor network performance and adjust resource allocation as necessary.<br>*Network Performance Metrics: End-to-End Delay = t_receive - t_send //time taken for a packet to reach th the receiver from the sender Throughput = (Number of bits transmitted) / (Total time taken) Resource Utilization = (Total used bandwidth) / (Total available bandwidth)* |
| 6 | Use machine learning algorithms to predict future traffic patterns and adjust resource allocation preemptively.<br>*Machine Learning Algorithm: Traffic Prediction = f(Traffic Data) //Predict future traffic patterns.*<br>*Resource Allocation Adjustment: If Traffic Prediction indicates an increase in traffic, allocate additional resources to the network slices to meet the predicted demand* |

The physical properties of the network elements are converted as logical functionalities using virtualization and softwarization in 5G mobile networks. Then, using intra-layer and inter-layer slicing, the pairing of slices is incorporated for effective resource management. Then, the proposed system architecture is simulated in a laboratory environment to compare performance metrics regarding the end-to-end delay, total throughput, and resource utilization. The simulated metrics are compared with the traditional mobile networks, which are taken as benchmarks.

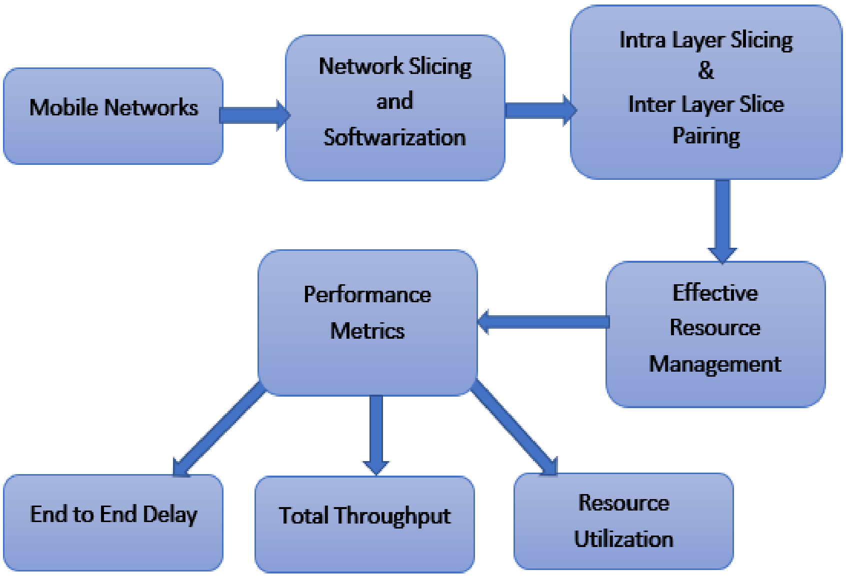


Figure 4. Block diagram representation of proposed system

## 3. SIMULATION ANALYSIS

The viability and the effectiveness of the proposed resource management architecture using network slicing and softwarization are evaluated in the network simulator-3 simulation platform. The simulations are accomplished at a system-level model to establish proof of concept [28], [29]. The benchmark values for the end-to-end delay, total throughput, and resource utilization percentage are taken from traditional 4G mobile networks without network slicing and softwarization. The network's traffic network is taken as a reference for the simulation, and the corresponding performance metrics are measured. The simulation environment is shown in Table 3.

Table 3. Simulation results

| Network simulator | NS-3 (version 3.32) |
|---|---|
| Simulation duration | 100 seconds |
| Traffic model | Poisson |
| Network topology | This realistic 5G network topology has three base stations, ten user equipment, and one core network element. |
| Mobility model | Random Waypoint |
| Network slicing Configuration | Proposed network sliced softwarization of 5G mobile networks (NSS-5G) algorithm and compared it with a traditional Benchmark |

The definitions of network delay, throughput, and resource utilization are below. The delay metric measures the end-to-end delay experienced by network traffic. It quantifies the time it takes for a packet to travel from the sender to the receiver. Lower delay indicates faster communication and better user experience. The total Throughput metric measures the data transmitted over the network during the simulation. It represents the network to handle data traffic. Higher throughput indicates better network performance and higher data transmission rates. Resource Utilization metric evaluates the efficiency of resource allocation in the network and measures the percentage of available resources (e.g., bandwidth) utilized by the network slices. Higher resource utilization indicates more efficient resource allocation and better network efficiency. The analysis shows that NSS-5G networks have minimum end-to-end delay compared to conventional 4G networks, as shown in Figure 5.

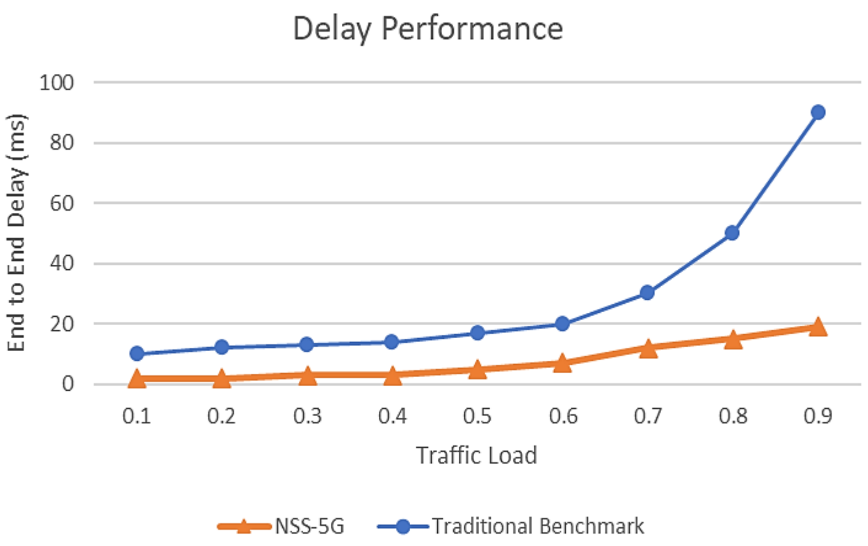


Figure 5. Delay performance analysis

The following implications are from the simulation analysis for effective resource management of 5G mobile networks using network slicing and softwarization. The delay performance analysis for the NSS-5G is compared with the traditional 4G mobile networks, a benchmark. As shown in Figure 6, the total throughput performance analysis for the NSS-5G is compared with the traditional 4G mobile networks. The study revealed that NSS-5G networks have higher throughput efficiency than conventional 4G networks.

The following implications are from the simulation analysis for effective resource management of 5G mobile networks using network slicing and softwarization. The delay performance analysis for the NSS-5G is compared with the traditional 4G mobile networks, a benchmark. As shown in Figure 6, The total throughput performance analysis for the Netwonet worked and NSS-5G is compared with the traditional 4G mobile networks. The study revealed that NSS-5G networks have higher throughput efficiency than conventional 4G networks. The resource utilization performance of the NSS-5G is compared with the benchmark mobile networks, as shown in Figure 7. The analysis shows that the resource utilization performance is better for the proposed system, like NSS-5G, than traditional benchmarks. From the simulation results, the NSS-5G mechanism reached 80 resource utilization compared to the traditional benchmark mechanism.

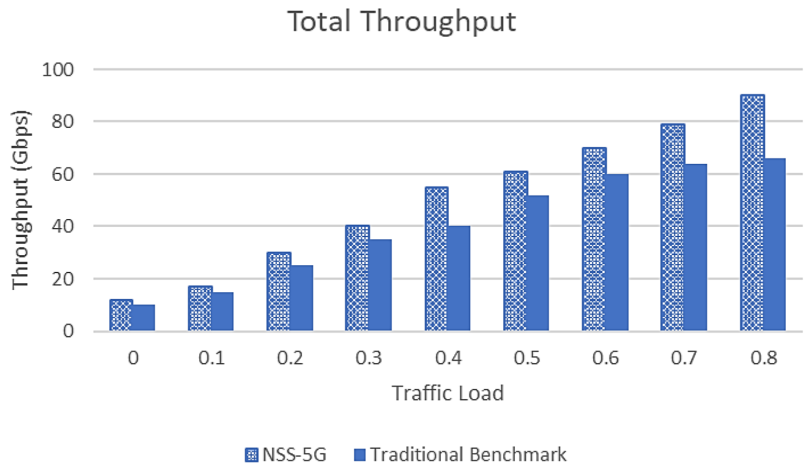


Figure 6. Delay performance analysis

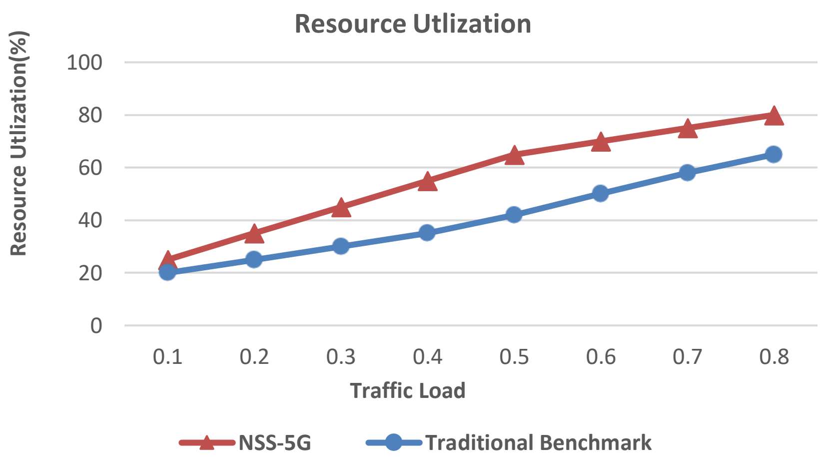


Figure 7. Resource utilization performance

## 4. CONCLUSION

The current work proposes an innovative model network using network slicing and softwarization of 5G Mobile networks. The system architecture, including intra-layer and inter-layer communication between the radio access and core network layers, leads to effective resource utilization in the proposed NSS-5G. Furthermore, the proposed architecture uses logical establishment to empower suppleness and multiple resource management features. Based on the slice requirements and individual pairing of network slices and the notarization of the network elements to handle data traffic communication, the proposed system proves to have better performance in terms of end-to-end delay, total throughput, and resource utilization. With the increasing demand for heterogeneous applications involving multiple technologies, effective management of resources in 5G mobile networks leads to dynamic application features in the business environment. This simulation analysis and results afford groundwork for future research on network slicing and softwarization of next-generation mobile networks. The heterogeneous model involving multiple access technologies can be explored with diversified network resource administration architecture as a next step.

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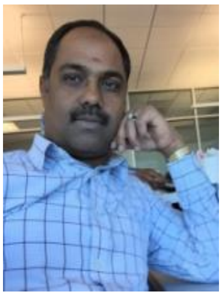
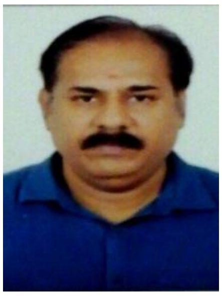


**Mageshkumar Naarayanasamy Varadarajan** is an industry leader and distinguished engineer with over 22 years of experience, captivated the audience with his insights into software development, testing, and DevOps. Well versed with multiple languages, solving critical issues, and leading teams, he spearheaded architectural changes for large scale projects, modernized legacy systems to enhance efficiency and performance, and defined cloud-agnostic solutions, all while receiving recognition for innovative solutions and various successful project implementations. Mageshkumar demonstrates outstanding knowledge in a variety of expertises including cloud and data security, and new technologies like AI and machine learning. He can be contacted at email: magesh27@gmail.com.



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