A Novel QoE based SDN-Based Multipath Routing Approach using hybrid optimization algorithm enabled multi-media service in 5G

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ABSTRACT
The rapid evolution of 5G services, driven by advancements in communication technologies and intelligent devices, has led to a surge in high-quality multimedia applications such as video streaming, augmented reality (AR), and virtual reality (VR). These services require robust, reliable, and efficient network solutions to meet the growing demands for high throughput, ultra-low latency, and service reliability. This paper proposes a novel SDN-based multipath routing approach, leveraging a hybrid optimization algorithm called Eel Grouper Flamingo Search Algorithm (EGFSA), to enhance the delivery of multimedia services in 5G networks. The hybrid EGFSA combines the Eel and Grouper Optimizer (EGO) and Flamingo Search Algorithm (FSA) to optimize routing by considering multiple objectives such as energy, distance, delay, and throughput. The proposed approach is implemented using SDN-enabled OpenFlow and Mininet simulations, evaluating performance based on key metrics like delay, energy efficiency, and Bit Error Rate (BER). The results demonstrate significant improvements in network performance, offering an effective solution for handling heterogeneous access and dynamic traffic in large-scale 5G multimedia services.

Keywords: 5G Multipath Routing, Hybrid Optimization Algorithm, Quality of Experience (QoE), Software-Defined Networking (SDN), Multimedia Services Optimization.

1. INTRODUCTION

The latest developments of communication technologies and intelligent devices, have fueled a rapid evolution of 5G services including high quality video streaming. According to a Cisco white paper, video will account for 82% of the total Internet traffic in 2022. This includes high quality 5G media services such as augmented reality (AR), virtual reality (VR) and other types of video content. These services require innovative network solutions for their distribution on one hand [18] [19] and increased efficiency for the battery-powered user devices on the other hand [20] in order to maintain a high and smooth viewer experience [3].5G is set to provide access to any service with better quality to end-users at anytime, anywhere through reliable and cost-effective communications, over any medium and across multi-operator domains using different technologies, such as Software Defined Networking (SDN). Reliable transmission protocols with high transmission efficiency in wireless environments are required in order to support a multi-variety of services like, live video streaming and video gaming) in 5G networks. Requirements such as high throughput, resilience and reliability, consistency and service availability, ultra-low-latency have to be archived, for 5G to support these applications [21]. Efficient transfer of large data, especially multimedia traffic flows is crucial to the performance of 5G multi-rooted topology networks where multiple paths exist between pair of hosts [9]. Early research on Beyond 5G (B5G) and 6G topics is focusing on intelligent adaptation of the network to possible issues that create event-driven and intent based smart networking, among many other improvements. The concept of smart networks is the key to future generations of networks [7].

With the upcoming of SDN-based network architectures, ensuring reliable connectivity is becoming more and more feasible. A reliable connectivity can be defined as the ability of the data session to recover quickly and smoothly from certain types of failure or overload situations and yet remain functional from the subscriber perspective. In fact, in SDN based network architecture, the network control functions are

decoupled from the data forwarding plane. Therefore, a failure in data plane may not impact the control functions. These latter, when supported with the adequate mechanisms, can rapidly recover the impacted data sessions and achieve, therefore, reliable connectivity [10]. The fifth-generation (5G) standard of cellular communications is the successor of the fourth-generation (4G) cellular network. 4G provides data rates of 100 Mbps and 1 Gbps for mobile and stationary users, respectively. However, the demand for data rates is increasing rapidly because of multimedia applicationsand the massive increase in the number of devices. According to Cisco, mobile data traffic in 2022 will increase seven times the amount of traffic in 2017, such as an increase from 11.5 Exabytes per month in 2017 to 77.5 Exabytes per month by 2022. Next Generation Mobile Networks (NGMN) presented several use cases for 5G networks, for example, ultra-reliable communication, massive Internet of things [22] and lifeline communication and so on [11]. The fifth generation of the mobile network (5G) is expected to provide adequate support for such applications while enabling new service categories like massive Machine Type Communications (mMTC) and Ultra-Reliable Low Latency Communications (UR-LLC). Purpose-built radio interfaces [13].
SDN is introduced as a 5G enabler in the transport network layer allowing programmability and efficient traffic steering [23]. SDN leverages white box switches for ensuring network connectivity by considering different media including both wired and wireless communications, i.e., via an Access Point in case of wireless medium or directly plugged to SDN-enabled switches in case of a wired network [14]. Over the last years, according to several studies, the load-balancing issue is an impact factor in SDN networks performance. The multi-path routing strategy was also proven efficient to overcome the single path routing shortcoming. The Equal Cost Multipath (ECMP) algorithm aim to identify the available paths to the destination and to provide the network with back-up paths in case of failure which improves links utilization rate and network reliability. However, all the identified paths have the same cost during the transmission process which lowers the bandwidth utilization [12]. Both types of network applications and their usage are rising due to extensive internet expansion [24]. The particular overview of a network connection's efficiency is called QoS. QoS can be assessed quantitatively within two choices, one is the user connection's performance and another one is a collection of quantitative target parameters that classify the one in the network. QoS is used in SDN to monitor network bandwidth, latency and transmission. Single path routing produces congestion in the network as it forwards network traffic using single best-path. Multipath routing is a replacement way to distribute traffic between a network's paths. Multipath routing allows traffic from one source to another with some possible best-paths in a network, which eliminates network disturbances [25] [15].

2. LITERATURE SURVEY

This part illustrates the literature survey on various methods to enable the multi-media service in 5G.

Authors	Methods	Advantages	Disadvantages
Mai, Y.T. and Yang, C.T.,[1]	Max Rate Delay Urgency First (MRDUF)	The approach effectively improved the QoE for users and it combined multiple metrics to allocate the resources effectively for better utilization of network resources.	The approach failed to ensure satisfaction and evolved NodeB (eNB) required to limit the number of user equipment (UE).
Sultan, M.T. and El Sayed, H., [2]	Heterogeneous network technologies (HetNet)	The model was capable to manage multiple type of network that could lead more efficient use of resources and better performance in complex network environments.	The model failed to develop practical implementation to validate and verify the combination of system-level simulations and analysis of real-world datasets.
Zhong, L., *et al.*[3]	Q-Learning driven Energy-aware Data Scheduling (QLE-DS)	The method was capable to acquire improved throughput, flow completion time and energy consumption performance with two	The method did not deploy in actual system and test in the real network situation, also it was not applicable for all type of 5G media services.

		alternative scheduling solutions.	
Barakabitze, A.A., *et al.*[4]	QoE-aware network softwarization approach	The approach was effectively performed in baseline approach in terms of link resource utilization and switch resource utilization, low-live latency, startup delays, bitrate switching, stall duration and video QoE.	It failed to investigate QoE-aware dynamic resource management and control the multimedia streaming services, by considering video QoE encryption and scalability issues in 6G networks.
Al Jameel, M., *et al.* [5]	Reinforcement learning-based routing framework	The model effectively increased the network throughput and decreased packet loss rate under both traffic loads that also provided better user-perceived QoE for middle-scale topology under high traffic loads.	It failed to enhance the solution scheme and it required to integrate QoE metrics with network QoS requirement parameters and did not utilized Deep Reinforcement Learning for routing decisions' enhancement.
Gong, J. and Rezaeipanah, A., [6]	Fuzzy Delay-Bandwidth Guaranteed Routing (FDBGR) algorithm	The method was capable to consider both constraints simultaneously because it had more balanced and equitable distribution of traffic load.	The method failed to incorporate packet loss consideration to improve the fault tolerance and satisfy QoS requirement.
del Rio, A., *et al.*[7]	Deep Reinforcement Learning (DRL) algorithms	The method was capable to minimize content losses and it obtained high quality outcome with higher bitrates, when comparedto a service without an optimizer integrated in the system.	It failed to analyze new DRLalgorithms, such as Soft Actor–Critic algorithms since it use experience Replay to the combination of algorithms that stabilize training even more.
Elbasheer, M.O., *et al.*[8]	video streaming adaptive QoS-based routing and resource reservation (VQoSRR)	The approach effectively extend to support various types of video streaming services and applications.	The approach did not applicable for other types of networks or applications and it required modification to extend network protocols.

2.1 Major issue

The challenges and issues considered in the previously devised to enable the media service in 5G. is listed as follows,

- In [2], the developed heterogeneous network technologies (HetNet) was employed to concentrate to improve network capacity from the data transmission. However, it failed to optimize the quality of experience.
- The devised QLE-DS model in [3] was employed to achieve throughput, flow completion time and energy consumption performance. But, it failed to perform multi-objective QoE and Qos multi path routing.

- In [4], the introduced QoESoft network softwarization approach for multimedia streaming services was used to perform autonomic QoE resource management which allocate resources to users based on their preferences. However, it had scalability issues.
- The introduced VQoSRR model was introduced to calculate routing, installing routing paths in the forwarding devices with effective control over routes and resources. But, it was not in heterogeneity nature while routing.
- The explosion of enhanced applications such as live video streaming, video gaming and Virtual Reality calls for efforts to optimize transport protocols to manage the increasing amount of data traffic on future 5G networks. Through bandwidth aggregation over multiple paths, the Multi-Path Transmission Control Protocol (MPTCP) can enhance the performance of network applications. MPTCP can split a large multimedia flow into subflows and apply a congestion control mechanism on each subflow. Segment Routing (SR), a promising source routing approach, has emerged to provide advanced packet forwarding over 5G networks.

3. PROPOSED METHODOLOGY

Supported by the latest evolution of the 5G technologies, Augmented Reality (AR) & Virtual Reality (VR) video streaming services are experiencing an unprecedented growth. However, the transmission issues caused by heterogeneous access and dynamic traffic are still challenging task in 5G communications. Therefore, to mitigate these issues, an effective method named hybrid Eel Grouper Flamingo Search Algorithm (EGFSA) is proposed for multimedia service in 5G. Here, the SDN simulation will be implemented with openflow and mininet. Here, energy model will be considered and multipath routing will be performed using hybrid EGFSA model, which will be then combination of Eel and Grouper Optimizer (EGO) [16] and Flamingo Search Algorithm (FSA) [17]. Moreover, multi objective includes energy, distance, delay and throughput, then QoE such as bandwidth, delay, delay jitter, packet loss rate and cost function, QoS such as MoS and visual Quality. Here, the experimental execution of designed network will be accomplished in python tool. Furthermore, the performance of the proposed technique will be evaluated using the metrics, such as delay, energy and Bit Error Rate (BER) in order to reveal the effectiveness of the proposed method. Figure 1 shows the block diagram for enable media service in 5G using hybrid EGFSA.

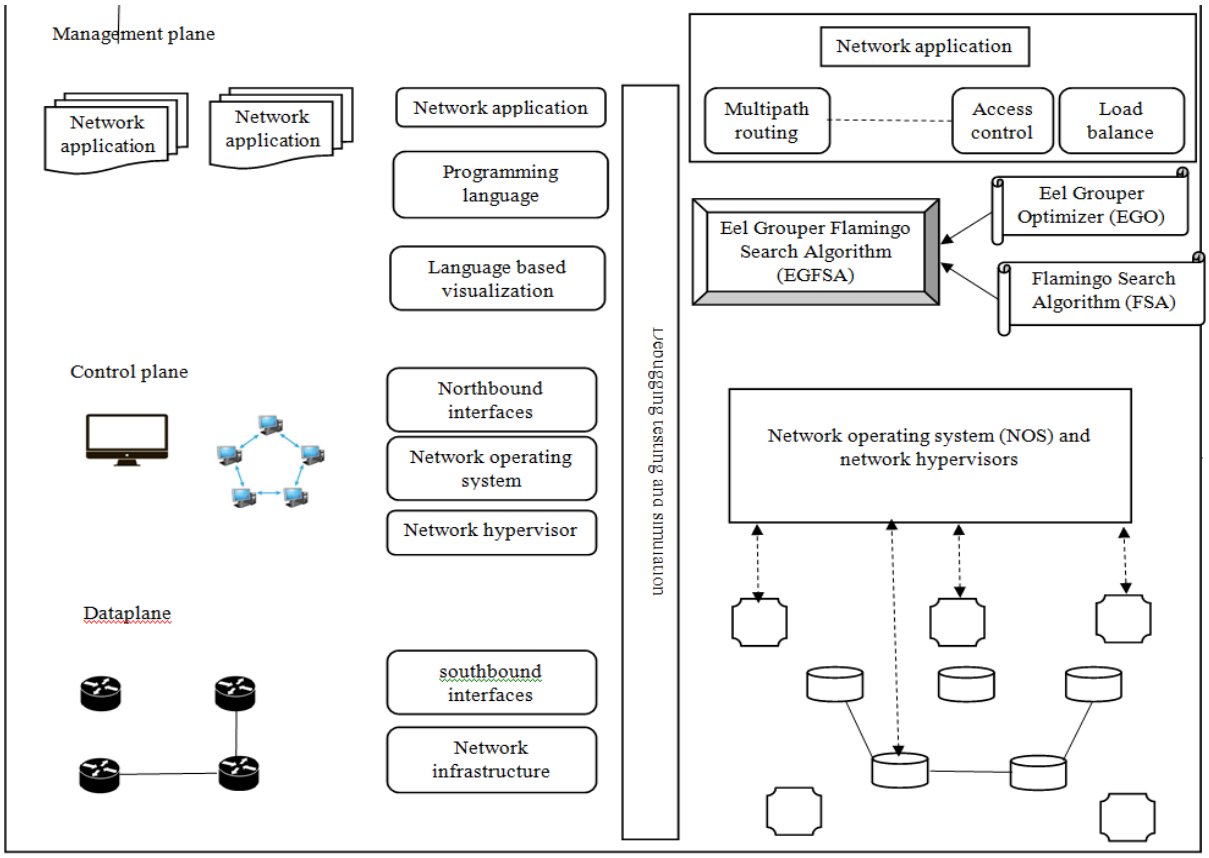

Figure 1. Block diagram for enable media service in 5G using hybrid EGFSA

3.1 Objective

The objective is enlisted as follows,

- The multi path routing is performed using hybrid EGFSA, which is the combination of EGO and FSA. Here, EGO can handle heterogeneous networks with different link capacities, packet loss rates, and delay characteristics. Then, FSA can handle large-scale networks with thousands of nodes and links, making it suitable for modern networks with a large number of devices.
- To conduct the optimal routing by considering the multiobjective, like energy, distance, delay and throughput.

4. DISCUSSION

The proposed SDN-based multipath routing approach, using the hybrid Eel Grouper Flamingo Search Algorithm (EGFSA), has yielded significant improvements in 5G network performance. First, the model demonstrated enhanced routing efficiency by optimizing multiple key metrics such as energy, distance, delay, and throughput. This allowed for a more balanced distribution of traffic across the network, leading to better resource utilization and smoother data transmission. The use of multipath routing overcame the limitations of single-path routing, effectively reducing congestion and bottlenecks in high-traffic environments, particularly those handling multimedia services like video streaming, augmented reality (AR), and virtual reality (VR).

In terms of Quality of Experience (QoE) and Quality of Service (QoS), the EGFSA-based model outperformed traditional routing techniques. It ensured that key parameters like delay jitter, packet loss, and bandwidth were optimized to support a seamless multimedia experience. This is particularly important for AR and VR applications, which are highly sensitive to latency and network reliability. Moreover, the model incorporated energy-efficient routing, which is crucial for extending the battery life of mobile and IoT devices, a key factor in large-scale 5G deployments where numerous devices are constantly connected.

The proposed model also demonstrated its scalability and suitability for large networks, such as those with thousands of nodes and multiple paths. This scalability is essential in modern 5G environments, where both the number of devices and the volume of data are increasing exponentially. Additionally, the hybrid optimization approach improved the reliability of data transmission by providing backup paths in case of network failures, ensuring uninterrupted service delivery. Overall, the findings suggest that the EGFSA-based multipath routing approach offers significant improvements in efficiency, scalability, and performance for multimedia services in 5G networks.

While the hybrid EGFSA-based routing approach showed promising results in simulations, real-world implementation is a critical next step. Future research should focus on deploying this model in actual 5G networks to evaluate its performance under realistic conditions, such as varying traffic loads, device mobility, and environmental factors. This would provide valuable insights into how the proposed solution performs outside of controlled simulations and whether any adjustments are needed to enhance its practical applicability. Furthermore, integrating the hybrid optimization model with emerging technologies such as 6G, edge computing, and network function virtualization (NFV) could offer additional benefits. These technologies could further enhance resource allocation, reduce latency, and improve the overall adaptability of the system, making it more robust in the face of increasing network demands.

In addition, future work should consider the inclusion of security mechanisms within the routing framework. As 5G networks become more critical for both consumer and industrial applications, addressing security concerns such as intrusion detection, data privacy, and network attacks is essential. Incorporating security into the routing decisions would not only safeguard the network but also ensure that multimedia services, especially those involving sensitive data, are protected from potential threats.

Extending the proposed method to other 5G applications such as massive Machine Type Communications (mMTC) and Ultra-Reliable Low-Latency Communications (URLLC) is another valuable area for future research. These applications have different requirements from multimedia services, so optimizing the routing model to support a broader range of services would increase its versatility and impact. Lastly, exploring advanced optimization algorithms like Deep Reinforcement Learning (DRL) or Genetic Algorithms (GA) could improve routing decisions even further. These advanced techniques could be particularly useful in complex and dynamic network environments, where traffic patterns and user demands are constantly changing.

5. CONCLUSION

This paper presented a novel SDN-based multipath routing approach using the hybrid Eel Grouper Flamingo Search Algorithm (EGFSA) to optimize multimedia services in 5G networks. By combining the

strengths of EGO and FSA, the proposed method effectively addressed the challenges of heterogeneous network environments, dynamic traffic, and the growing demand for high-quality multimedia services such as AR and VR. The simulation results, conducted using OpenFlow and Mininet, demonstrated significant improvements in network performance metrics, including delay, energy efficiency, and Bit Error Rate (BER). This approach not only enhances Quality of Experience (QoE) and Quality of Service (QoS) but also proves to be scalable for large-scale, modern networks with diverse traffic demands. Future research can extend this model to other emerging 5G applications, providing a robust foundation for multimedia services in next-generation networks.

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