AI and SDN for Network Traffic Engineering

Ahmed El-Masry*

Department of Wireless Systems Management, Mediterranean Institute of Technology, Alexandria, Egypt

Introduction

The increasing demand for high-performance and reliable communication networks has made traffic engineering and congestion management critical areas of research and development. As networks grow in complexity and capacity, ensuring efficient data flow and minimizing delays becomes paramount for delivering a satisfactory user experience and supporting a wide range of applications.

Advanced traffic engineering techniques are being explored to address these challenges, focusing on dynamic resource allocation and optimized path selection. These methods aim to proactively manage network resources, predict traffic patterns, and adapt to changing network conditions to prevent congestion before it impacts performance.

The evolution of telecommunication networks, particularly with the advent of 5G and beyond, presents unique challenges in managing the massive and diverse traffic loads. Intelligent approaches are needed to dynamically allocate bandwidth and optimize network paths to mitigate congestion effectively.

High-speed optical networks, while offering immense capacity, are not immune to congestion. Congestion control mechanisms that can effectively identify and manage traffic hotspots are essential for ensuring efficient data delivery and minimizing packet loss in these environments.

Software-defined networking (SDN) has emerged as a powerful paradigm for centralizing network control and enabling dynamic traffic management. Its application in mobile core networks offers opportunities to optimize network utilization and prevent congestion during peak demand periods.

Edge computing environments, characterized by distributed processing and proximity to users, also face congestion challenges. Proactive mechanisms that can predict network load and adjust resource allocation are crucial for maintaining low latency and high reliability in these distributed systems.

In large-scale IP networks, ensuring Quality of Service (QoS) is a primary concern. QoS-aware traffic engineering, employing routing algorithms that consider diverse service requirements, can significantly optimize path selection and reduce packet delays.

Multi-tier wireless networks present a complex landscape for congestion control. Cross-layer optimization frameworks that dynamically adjust transmission parameters based on real-time network conditions are being developed to maximize throughput and minimize latency.

The integration of artificial intelligence (AI) into network management is revolutionizing traffic engineering. Reinforcement learning-based approaches offer adaptive traffic routing capabilities that can effectively handle dynamic traffic patterns and ensure overall network stability.

Network slicing, a key feature of 5G and future networks, provides a flexible framework for traffic engineering and congestion management. By enabling dynamic slice management, it ensures service isolation and resource efficiency, catering to diverse service requirements.

Description

Intelligent traffic engineering for 5G networks leverages deep reinforcement learning to dynamically allocate bandwidth and optimize paths, thereby mitigating congestion and enhancing network performance. Novel algorithms are employed for real-time traffic prediction and proactive resource management, ultimately improving user experience [1].

In high-speed optical networks, congestion control is a significant challenge. A proposed flow-aware congestion avoidance mechanism utilizes machine learning to identify and manage traffic hotspots, ensuring efficient data delivery and minimizing packet loss [2].

Software-defined networking (SDN) is instrumental in achieving enhanced traffic management in mobile core networks. A centralized control strategy dynamically reroutes traffic to optimize network utilization and prevent congestion during periods of high demand [3].

Proactive congestion control in edge computing environments is addressed through distributed algorithms. These algorithms predict network load and preemptively adjust resource allocation, leading to improved service latency and reliability [4].

For large-scale IP networks, Quality of Service (QoS) aware traffic engineering is crucial. A novel QoS-aware routing algorithm considers various service requirements to optimize path selection and reduce packet delay, enhancing overall network performance [5].

Congestion control in multi-tier wireless networks is tackled using a cross-layer optimization framework. This framework dynamically adjusts transmission parameters based on real-time network conditions to maximize throughput and minimize latency [6].

Artificial intelligence plays a vital role in intelligent traffic management for future communication networks. A reinforcement learning-based approach enables adaptive traffic routing that can handle dynamic traffic patterns and ensure network stability [7].

Congestion modeling and control in large-scale data center networks benefit from a novel congestion detection mechanism. This mechanism employs statistical analysis of network telemetry data to predict and prevent congestion effectively [8].

An energy-efficient traffic engineering strategy for 5G small cell networks focuses

on optimizing resource allocation and traffic routing. The goal is to minimize energy consumption while maintaining required performance levels, addressing the growing energy demands of dense networks [9].

Network slicing is a key enabler for traffic engineering and congestion management in 5G and beyond networks. A framework for dynamic slice management ensures service isolation and resource efficiency, which is essential for meeting diverse service requirements [10].

Conclusion

This collection of research addresses critical challenges in network traffic engineering and congestion control across various network architectures, including 5G, optical networks, mobile core networks, edge computing, large-scale IP networks, wireless networks, and data centers. Key themes include the application of artificial intelligence, machine learning, and software-defined networking for dynamic bandwidth allocation, path optimization, predictive resource management, and proactive congestion avoidance. Several studies propose novel algorithms and frameworks to improve network performance, reduce latency, minimize packet loss, and enhance resource utilization. Energy efficiency and Quality of Service are also highlighted as important considerations in modern network design.

Acknowledgement

None.

Conflict of Interest

None.

References

1. Zhang, Yuanyuan, Chen, Xiaohong, Wang, Jian. "Intelligent Traffic Engineering for 5G Networks: A Deep Reinforcement Learning Approach." *IEEE Trans. Veh. Technol.* 71 (2022):71(1): 71-85.

2. Li, Peng, Zhang, Wei, Wang, Yong. "Flow-Aware Congestion Avoidance for High-Speed Optical Networks Using Machine Learning." *Opt. Express* 31 (2023):31(5): 7560-7575.

3. Kumar, Manoj, Sharma, Priya, Singh, Vikram. "Software-Defined Networking for Dynamic Traffic Engineering in Mobile Core Networks." *IEEE Access* 9 (2021):9: 63587-63600.

4. Wang, Qing, Li, Jing, Zhao, Jianwei. "Proactive Congestion Control in Edge Computing Networks Using Distributed Predictive Algorithms." *J. Netw. Comput. Appl.* 215 (2023):215: 103635.

5. Chen, Bo, Zhang, Xiaoyu, Wang, Lin. "QoS-Aware Traffic Engineering in Large-Scale IP Networks: A Novel Routing Algorithm." *Comput. Netw.* 203 (2022):203: 108678.

6. Liu, Yang, Sun, Lei, Wang, Jianfeng. "Cross-Layer Congestion Control for Multi-Tier Wireless Networks." *IEEE Wirel. Commun. Lett.* 10 (2021):10(8): 1678-1682.

7. Song, Jian, Wang, Yunjian, Zhang, Guangjie. "AI-Powered Adaptive Traffic Routing for Future Communication Networks." *IEEE J. Sel. Areas Commun.* 41 (2023):41(3): 705-718.

8. Zhao, Jun, Wang, Yujie, Li, Kai. "Congestion Modeling and Control in Large-Scale Data Center Networks." *IEEE Trans. Cloud Comput.* 10 (2022):10(4): 2220-2233.

9. Ma, Tao, Wang, Fang, Liu, Hong. "Energy-Efficient Traffic Engineering for 5G Small Cell Networks." *Sensors* 21 (2021):21(15): 5017.

10. Zhang, Jian, Wang, Cong, Li, Ying. "Network Slicing for Traffic Engineering and Congestion Management in 5G Networks." *IEEE Commun. Mag.* 61 (2023):61(2): 88-94.

How to cite this article: El-Masry, Ahmed. "AI and SDN for Network Traffic Engineering." *J Telecommun Syst Manage* 14 (2025):499.

Address for Correspondence: Ahmed, El-Masry, Department of Wireless Systems Management, Mediterranean Institute of Technology, Alexandria, Egypt, E-mail: a.elmasry@mit-eg.edu