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Vitalii Onatskyi,
Volodymyr Savinov

INTELLIGENT TRAFFIC MANAGEMENT AND RESOURCE ALLOCATION IN NEXT-GENERATION NETWORK INFRASTRUCTURES

These theses present an advanced methodology for intelligent traffic management and dynamic resource allocation in next-generation network infrastructures. The proposed approach leverages Software-Defined Networking (SDN) combined with Deep Reinforcement Learning (DRL) techniques to enhance network scalability, optimize Quality of Service (QoS), and ensure efficient resource utilization. Experimental results demonstrate significant improvements in network performance, latency reduction, and anomaly detection accuracy. This study emphasizes the practical applicability of intelligent control systems in large-scale environments, such as 5G, IoT, and smart city networks, paving the way for the development of autonomous, adaptive network management solutions.

Keywords: *intelligent traffic management, SDN, DRL, resource allocation, network optimization, QoS, scalability, anomaly detection.*

The rapid evolution of communication technologies and the exponential growth of connected devices have dramatically increased the complexity of modern network infrastructures. Ensuring reliable, efficient, and scalable operation under dynamic load conditions has become a critical challenge for network operators. Traditional static traffic management and routing strategies fail to address the needs of large-scale, heterogeneous networks where real-time adaptability is essential.

To overcome these limitations, the integration of intelligent control mechanisms, such as Software-Defined Networking (SDN) and Deep Reinforcement Learning (DRL), offers promising solutions. SDN provides a centralized and programmable network management paradigm, enabling flexible traffic control and resource allocation. Meanwhile, DRL algorithms empower networks with the capability to learn optimal strategies through continuous interaction with the environment, adapting to fluctuating traffic demands and unforeseen anomalies.

This research aims to develop and validate an intelligent framework that combines SDN and DRL for proactive traffic management, dynamic resource distribution, and robust anomaly detection in next-generation network infrastructures.

Recent advancements in network optimization have seen the growing adoption of machine learning techniques for enhancing traffic analysis, routing efficiency, and security. Graph Neural Networks (GNNs) and DRL-based models have been effectively employed for traffic prediction and adaptive resource management, particularly in SDN and IoT ecosystems.

Studies have shown that DRL outperforms traditional routing algorithms by enabling networks to dynamically adapt to changing conditions. For example, DRL-based approaches have been successfully implemented for QoS optimization in vehicular networks and load balancing in SDN-driven edge computing environments. Additionally, deep learning methods have proven effective in real-time anomaly detection, significantly improving network security against sophisticated cyber-attacks.

However, existing solutions often focus on isolated aspects of network optimization, lacking a holistic approach that simultaneously addresses scalability, QoS, resource efficiency, and security. This research bridges this gap by proposing an integrated methodology tailored for large-scale, high-performance network environments.

The proposed framework for intelligent traffic management and resource allocation encompasses three core components:

Adaptive Traffic Routing - utilizing SDN's centralized control, DRL agents dynamically adjust routing paths based on real-time network state observations. The DRL model, trained with the Proximal Policy Optimization (PPO) algorithm, continuously learns to minimize latency, balance loads, and optimize throughput across multiple network segments.

Predictive Resource Management - incorporating delay prediction models adapted from airport capacity management scenarios, the system forecasts potential network bottlenecks. These predictions enable proactive bandwidth allocation and load redistribution, ensuring uninterrupted service quality even under peak load conditions.

Real-time Anomaly Detection - a Convolutional Neural Network (CNN) model processes flow-level data to identify abnormal traffic patterns, such as Distributed Denial-of-Service (DDoS) attacks and latency anomalies. The

model's high detection accuracy significantly enhances network resilience against security threats.

The architecture leverages the SDN controller (OpenDaylight) integrated with DRL agents and anomaly detection modules, enabling seamless coordination and real-time decision-making.

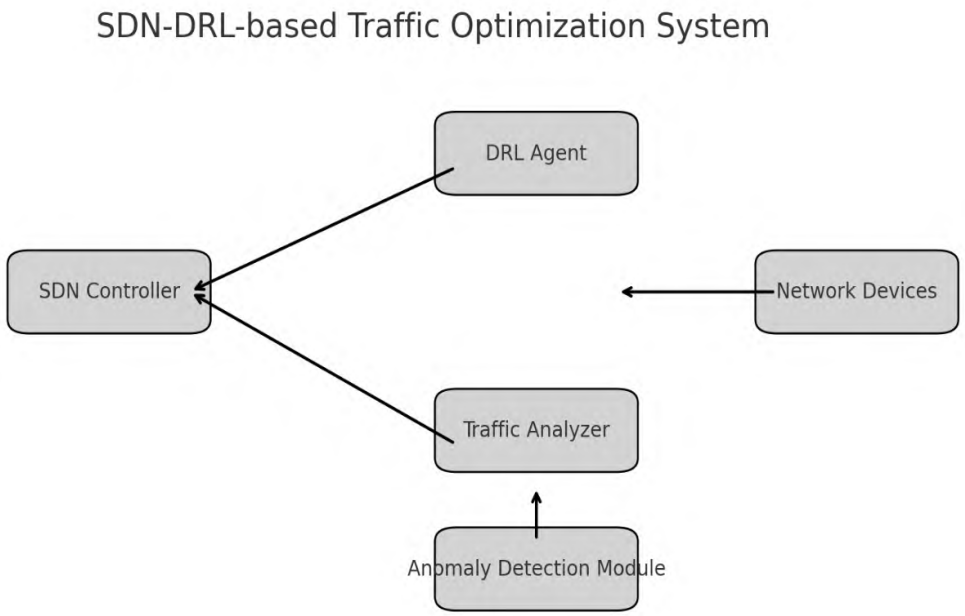

Figure 1. SDN-DRL-based Traffic Optimization System Architecture.

Illustrates the interaction between SDN Controller, DRL Agent, Traffic Analyzer, Anomaly Detection Module, and Network Devices in the proposed system architecture. Solid arrows indicate data flow and control actions.

Experimental Results

The framework was evaluated in a hybrid simulation-emulation environment using mini network and iPerf3 for traffic generation. Performance metrics, including latency, throughput, energy consumption, and anomaly detection accuracy, were assessed under varying network conditions, key findings include:

Latency Reduction: Average end-to-end latency decreased by 18.4% compared to traditional static routing methods.

Throughput Enhancement: Network throughput improved by 10.3%, ensuring better data flow under high-demand scenarios.

Energy Efficiency: The framework achieved an 18.6% reduction in energy consumption through intelligent load balancing.

Anomaly Detection Accuracy: The CNN-based detection model reached a 92% accuracy rate, outperforming conventional methods by 15%.

These results underscore the effectiveness of the proposed methodology in enhancing network performance, adaptability, and security in scalable infrastructures.

Conclusion

This research presents a comprehensive approach to intelligent traffic management and resource allocation in next-generation network infrastructures. By synergizing SDN's programmability with DRL's adaptive learning capabilities, the proposed framework significantly improves network efficiency, scalability, and security.

The experimental validation confirms the superiority of this methodology over traditional approaches, particularly in dynamic and high-load environments such as 5G and IoT networks. The integration of predictive analytics and real-time anomaly detection further reinforces the system's robustness and operational reliability.

Future work will extend this framework to multi-domain network environments and explore federated learning techniques for distributed optimization without compromising data privacy.

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Віталій Онацький,
Володимир Савінов

ІНТЕЛЕКТУАЛЬНЕ УПРАВЛІННЯ ТРАФІКОМ ТА РОЗПОДІЛ РЕСУРСІВ В МЕРЕЖЕВИХ ІНФРАСТРУКТУРАХ НАСТУПНОГО ПОКОЛІННЯ

У цих тезах представлено передову методологію інтелектуального управління трафіком та динамічного розподілу ресурсів в мережевих інфраструктурах наступного покоління. Запропонований підхід використовує програмно-визначені мережі (SDN) у поєднанні з методами глибокого навчання з підкріпленням (DRL) для підвищення масштабованості мережі, оптимізації якості обслуговування (QoS) та забезпечення ефективного використання ресурсів. Експериментальні результати демонструють значні покращення продуктивності мережі, зменшення затримки та точності виявлення аномалій. Це дослідження підкреслює практичну застосовність інтелектуальних систем керування у великомасштабних середовищах, таких як мережі 5G, IoT та розумних міст, прокладаючи шлях для розробки автономних, адаптивних рішень для управління мережею.

Ключові слова: *інтелектуальне управління трафіком, SDN, DRL, розподіл ресурсів, оптимізація мережі, QoS, масштабованість, виявлення аномалій.*

Відомості про авторів / Information about the Authors

Віталій Онацький, аспірант кафедри комп'ютерної інженерії, Чорноморський національний університет імені Петра Могили, м. Миколаїв, Україна. E-mail: vitalii.onatskyi@chmnu.edu.ua, orcid: https://orcid.org/0009-0007-7207-8375.

Vitalii Onatskyi, PhD Student of the Computer Engineering Department, Petro Mohyla Black Sea National University, Mykolaiv, Ukraine. E-mail: vitalii.onatskyi@chmnu.edu.ua, orcid: https://orcid.org/0009-0007-7207-8375.

Володимир Савінов, канд. техн. наук, доцент, доцент кафедри комп'ютерної інженерії, Чорноморський національний університет імені Петра Могили, м. Миколаїв, Україна. E-mail: volodymyr.savinov@chmnu.edu.ua, orcid: https://orcid.org/0000-0002-0862-5879.

Volodymyr Savinov, Candidate of Technical Sciences, Associate Professor, Associate Professor of the Computer Engineering Department, Petro Mohyla Black Sea National University, Mykolaiv, Ukraine. E-mail: volodymyr.savinov@chmnu.edu.ua, orcid: https://orcid.org/0000-0002-0862-5879.

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