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Editorial

Cognitive Software Defined Networking and Network Function Virtualization and Applications

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Abstract: The emergence of Software-Defined Networking (SDN) and Network Function Virtualization (NFV) has revolutionized the Internet. Using SDN, network devices can be controlled from a centralized, programmable control plane that is decoupled from their data plane, whereas with NFV, network functions (such as network address translation, firewall, and intrusion detection) can be virtualized instead of being implemented on proprietary hardware. In addition, Artificial Intelligence (AI) and Machine Learning (ML) techniques will be key to automating network operations and enhancing customer service. Many of the challenges behind SDN and NFV are currently being investigated in several projects all over the world using AI and ML techniques, such as AI- and software-based networking, autonomic networking, and policy-based network management. Contributions to this Special Issue come from the above areas of research. Following a rigorous review process, four excellent articles were accepted that address and go beyond many of the challenges mentioned above.

Keywords: SDN; NFV; AI; machine learning; cloud computing

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1. Introduction

Future networks face numerous challenges due to the growing traffic demand for emerging internet applications and the diversification of Quality of Service (QoS) requirements. Towards meeting the growing traffic demand and ensuring a dynamic QoS of applications, it is expected that future networks will be built on virtualized infrastructures. Network functions, such as network address translation, firewalls, and intrusion detection, will be implemented on cloud infrastructures in virtual machines and containers. Currently, technologies such as Software-Defined Networking (SDN) and Network Function Virtualization (NFV) are capable of making networks flexible, programmable, and vendor-agnostic, as well as cost-effective.

Currently, several management and orchestration platforms [1,2] have been built using SDN and NFV for automating the provisioning, configuration, and monitoring of networks in real-time using Network Functions as a service on a virtualized infrastructure. SDN and NFV bring tremendous possibilities for increasing the management flexibility and efficiency of telecom services. The use of Artificial Intelligence (AI), Machine Learning (ML), and optimization techniques in SDN and NFV for effective decision-making is prevalent, as these technologies aid in gathering a large amount of data from networks and offer many possibilities for placing and deploying network functions in networks. This Special Issue reports the use of AI, ML, and optimization techniques to solve various problems in SDN/NFV, including the following:

1. Solving the Virtual Network Function embedding problem under failure conditions using Deep Reinforcement Learning (DRL) techniques.
2. Solving the scheduling problem of media function virtualization by using greedy algorithms, such as Breadth-First Search and Depth-First Search, and Integer Linear Programming (ILP).

3. Solving the problem of performance degradation in satellite systems with the use of Q-Learning in SDN and NFV.
4. Solving the resource allocation problem in NFV using AI techniques, such as the Long Short-Term Memory (LSTM) algorithm.

This editorial presents a summary of the above-reported problems and solutions from the papers in this Special Issue.

2. Summary

2.1. Paper 1: Scheduling for Media Function Virtualization [3]

This article discusses the problem of scheduling virtualized media functions (VMFs) in a media function virtualization (MFV) environment. MFV proposes the use of COTS hardware to run media processing for VMFs that can be connected in the form of VMF-FGs. The authors first formulate an instance of the VMF-FG scheduling problem as an Integer Linear Programming (ILP) model and prove its NP-completeness. They then propose a greedy algorithm based on Breadth-First Search (BFS) and Depth-First Search (DFS) graph traversals to solve the problem. The evaluation of the proposed algorithm shows that the end-to-end delay increases with the cycle time, and the end-to-end delay can be improved with VMF-FG decomposition, particularly for high-quality media formats. The results also show that the proposed algorithm performs well in resource utilisation, with the average number of cores used per node decreasing with higher quality media formats and increasing with VMF-FG decomposition.

This paper provides a comprehensive analysis of the scheduling problem in a media function virtualisation environment and presents a scalable solution.

Future work will focus on implementing a media service in an MFV environment with VMF-FG scheduling.

2.2. Paper 2: Virtual Network Function Embedding under Nodal Outage Using Deep Q-Learning [4]

Here, the authors propose a solution to the Virtual Network Function (VNF) embedding problem under nodal outages using Deep Reinforcement Learning (DRL). The VNF embedding problem involves finding an optimal placement of Virtual Network Functions (VNFs) in a substrate network, subject to various constraints such as resource availability, link delay, and nodal outages.

The paper proposes a solution for the Virtual Network Function Resource Allocation (NFV-RA) problem using Deep Q-Learning (DQL) models. The DQL models are tested under various network conditions, such as network density, nodal and core capacity, nodal outages, and Virtual Network Function (VNF) complexity. A heuristic model is introduced to improve performance. The results show that the computation time increases with the increase in network density, nodal capacity, or VNF complexity, leading to faster resource depletion. The model also shows that even with a 50% nodal outage, an SAR (Service Acceptance Ratio) of 70–90% can be achieved, although at the cost of high computation time.

In conclusion, the authors demonstrate that DRL is a promising solution to the VNF embedding problem under nodal outages. In future work, the authors plan to study the performance of the DRL model using a different DRL algorithm.

2.3. Paper 3: Smart Site Diversity for a High-Throughput Satellite System with Software-Defined Networking and a Virtual Network Function [5]

This article proposes a solution for the problem of performance degradation in a high-throughput satellite system due to adverse atmospheric conditions. The proposed solution is a Software-Defined Networking (SDN) and Virtual Network Function (VNF) approach that dynamically switches transmissions among the feeder links of the system to alleviate degradation.

The article provides a literature review of previous studies on the use of SDN and VNF in communication systems, highlighting the potential benefits of these technologies for enhancing the reliability and resilience of communication systems.

The authors explore algorithms based on reinforcement learning to reduce packet loss and average latency. Q-Learning performed the best among all the algorithms in all three scenarios given by the author. It produced the lowest average delay and request-loss ratio, especially in the dynamic environment (Scenario-2 and Scenario-3). In contrast, SLA and HSLA take a certain amount of time to adjust their policies and find the best link. Additionally, RR performed the worst among all the algorithms as it did not consider the network conditions and provided no feedback to the learning agent.

Overall, the article presents a novel approach for improving the reliability and resilience of HTS communications and provides insights into the potential benefits of using SDN and VNF in satellite communication systems.

2.4. Paper 4: Proposal and Investigation of an Artificial Intelligence (AI)-Based Cloud Resource Allocation Algorithm in Network Function Virtualization Architectures [6]

This article proposes and evaluates the use of AI-based cloud resource allocation algorithms in NFV architectures. Among the main contributions of the article are (1) the investigation of a prediction-based algorithm for resource allocation in NFV, (2) the investigation of LSTM with asymmetric loss functions for under- and over-provision scenarios in networks, and (3) a comparison with existing work in terms of performance. Results show a 40% cost advantage over prediction techniques that minimize the symmetric cost functions of the prediction error.

Conflicts of Interest: The authors declare no conflict of interest.

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