CPSC 644 - Computer Networks

Research Proposal

AI-Driven Network Management and Self-Healing Networks

Submitted by

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1 Description

For my research paper I have chosen the topic *AI-Driven Network Management and Self-Healing Networks*.

Defining this research topic requires defining two closely related principles and also identifying their differences. First, AI-Driven Network Management (AINM), often referred to as AI Networking (AIN), is a generic term that describes the integration of Artificial Intelligence (AI) and Machine Learning (ML) into the area of computer networks with the goal of improving efficiency and effectiveness. This includes areas such as dynamic resource allocation, fault detection and analysis, and security enhancement [14]. Second, Self-Healing Networks (SHN) represent networks that can autonomously detect, diagnose, and resolve network failures in real time without the need for human intervention. This is often achieved by using AI or Machine Learning (ML) in a closed-loop system to continuously monitor performance and quickly detect disruptions or irregularities and responding by dynamically rerouting traffic, adjusting configurations, or isolating problematic components [15].

Although these concepts are closely related, they differ in their objective. AIN tries to integrate *intelligence* into the network to make it more efficient and secure, whereas SHN focus on building self-sustaining and more resilient networks. Consequently, SHN could be seen as a subset of the broader area of AIN.

2 Motivation

Modern computer networks are constantly growing and becoming more complex, exceeding the capabilities of human oversight by far. Therefore, rule-based and manual methods for network monitoring are insufficient for the scale, complexity, and sophistication of today's networks, that connect thousands of devices simultaneously [17]. According to a report from Dynatrace, a company that develops AI solutions for observability, the average multicloud environment spans 12 different services and platforms [16]. Furthermore, their report finds that more than 80% of technology leaders say that the effort their teams spent on maintaining monitoring tools and preparing data for analysis steals time form innovation.

These circumstances highlight the need for AIN and SHN to analyze large amounts of data in real-time to identify and address potential network issues before they grow into larger problems [18]. Integrating these mechanisms reduces costs by optimizing network resources, decreasing operational downtime, and automating routine tasks to free up IT staff for higher-level network management jobs [17].

However, integrating AI into network management poses significant challenges. These include data privacy concerns, high investment costs for infrastructure, and a shortage of skilled personnel. Furthermore, handing over the control of critical enterprise infrastructure to an autonomous system, introduces serious risks. An AI may not always choose the optimal decision in edge-case scenarios that were not present during

training which could potential lead to cascading network failures [18].

3 Proposed Paper Outline

Abstract

The abstract provides a succinct summary of the transition from manual network administration to autonomous AIN and SHN frameworks. It highlights the shift towards ML-based solutions employing Graph Neural Networks (GNN), Transformers, and Reinforcement Learning (RL). Furthermore it summarizes predictive networking and incident management. It concludes by previewing future research directions.

Introduction

The introduction defines AI-Driven Networking [14] and SHN [15] in more detail for a general audience. It provides motivation by explaining how automation can lower operational costs, minimize downtime, and strengthen network security. The section highlights the need for proactive fault mitigation in modern complex networks. Finally, it outlines the structure of the research paper.

Literature Survey

The literature survey reviews the transition from manual oversight to an AI-Driven networking paradigm. It examines Zero Touch architectures for network automation [2] and foundational ML frameworks for the improvement of networks [3], [12]. Lastly, emerging SHN within the cellular domain are reviewed [7].

Real-World Usage

This section evaluates practical implementations ranging from Reinforcement Learning (RL) for congestion control [1], [9] to Graph Neural Networks for network optimization [10]. Furthermore, fault detection using transformer models [11] and unsupervised anomaly detection methods [4] are reviewed. Additionally, a closed-loop system without human intervention is reviewed [6].

Emerging Trends

This section investigates future trends in AIN such as resource management in 6G networks [5] and the integration of large language models (LLM) for incident management [8]. Finally, Network Digital Twins (NDT) frameworks for proactive simulation of networks are investigated [13].

Conclusion

The conclusion summarizes the findings from the foregoing literature survey and case studies to provide a holistic perspective on AIN and SHN. It evaluates performance benefits and associated risks of autonomous methods. Finally, the section outlines remaining research gaps and a strategic outlook for the future is given.

4 Bibliography

This section lists the initial core bibliography that will form the foundation of my research paper. This list will be further extended during the writing phase of my research paper.

[1] P. Gawłowicz and A. Zubow, "Ns-3 meets openai gym: The playground for machine learning in networking research," in *Proceedings of the 22nd International ACM Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems*, ser. MSWIM '19, Miami Beach, FL, USA: Association for Computing Machinery, 2019, pp. 113–120. DOI: 10.1145/3345768.3355908. [Online]. Available: https://doi.org/10.1145/3345768.3355908.

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[11] P. Dubey, P. Dubey, and P. N. Bokoro, "Transformer-driven fault detection in self-healing networks: A novel attention-based framework for adaptive network recovery," *Machine Learning and Knowledge Extraction*, vol. 7, no. 3, 2025. DOI: 10.3390/make7030067. [Online]. Available: https://www.mdpi.com/2504-4990/7/3/67.

[12] S. Ayoubi et al., "Machine learning for cognitive network management," *IEEE Communications Magazine*, vol. 56, no. 1, pp. 158–165, 2018. DOI: 10.1109/MCOM.2018.1700560.

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Mark Breakdown

Your proposal should be a detailed outline of the research paper you will produce. The proposal should include for the selected research topic the sections: description, motivation, outline, and bibliography. The main body (not including the bibliography, cover page) must not exceed two pages in length (single spaced, single column, 12pt font)

- **Topic Choice (2.5 marks):** Evaluation based on relevance, innovation, and level of difficulty.
- **Description (5 marks):** A clear definition of what the research topic is.
- **Motivation (2.5 marks):** An explanation of why the research topic is interesting or significant.
- **Outline (15 marks):** A clear, focused outline stating precisely what the proposed research will cover.
  - Must include appropriate citations.
  - Each section/subsection requires a short summary (3–4 sentences) describing the focus of the final research paper in that section.
- **Bibliography (15 marks):** A well-researched list of sources.
  - Minimum of 8 sources total (at least 3 recent reviewed sources per team member).
  - At least 75% must be reputable sources (e.g., peer-reviewed journals, conferences, established community sources).
  - Textbook usage is permitted.
  - Any reputable bibliography style is acceptable (IEEE or ACM recommended) if used consistently.
  - *Note:* Ensure the paper format remains single column.

Topic Description

AI-Driven Network Management and Self-Healing Networks

Explores the integration of machine learning for automated fault detection, prediction, and real-time optimization in large-scale networks.

Motivation: Reduces downtime and operational costs in complex, dynamic environments.