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Opponent Review of the Dissertation Thesis

PhD Student:	**M.Sc. Ibrahim Ahmed Salman Alameri**
Dissertation Work Topic:	**Modification of the AODV Routing Discovery Mechanism in Wireless Mesh Networks**
Supervisor:	**Prof. Ing. Jitka Komárková, Ph.D.**

Thesis Theme and the Actuality of the Problem

As the candidate explores suitably the networking industry has shown heightened interest in WMNs mainly because of their inherent merits, such as multi-hop routing, self-configuration, and self-healing capabilities. Furthermore, WMNs offer robust reliability and scalability, which make them well-suited for a broad spectrum of applications. These networks also present significant advantages in terms of initial setup costs, ease of maintenance, and operational robustness. Significantly, the mesh architecture can be incrementally expanded, allowing scalable performance to meet evolving needs.
The candidate also discover the challenges of the rapid technological advancements in wireless communications, as the IoT has gained monumental importance, leading to a proliferation of interconnected devices. This has subsequently highlighted the critical role of WMNs in providing robust, inter-device communication and seamless connectivity to broader networks, including cellular networks and the Internet. WMNs, with their self-configuring, infrastructure-independent architecture, and multi-hop wireless communication capabilities, emerge as a compelling solution for many applications.

Research Goals

The goal set by the candidate is to strengthen mesh network performance in the dynamic landscape of variable network conditions and developing application requirements. The objective is to formulate dynamic and adaptive network management frameworks and routing solutions capable of efficiently navigating diverse network conditions while supporting resource-intensive applications.

Thus, this research focuses on enhancing the AODV routing protocol, a powerful utilized algorithm in mesh networks. Although AODV stands out in on-demand route discovery and is proficient in identifying optimal paths between nodes, it shows limitations in adaptability and decision-making in ever-changing mesh network environments.

Thesis Structure and Methodology Implemented

This thesis is structured to explore and develop an integrated methodology for the efficient AODV in the context of Wireless Mesh Network (WMN) comprehensively. The candidate provides an overview of WMNs in Chapter 1, clarifying their inherent characteristics and architectural framework. In the Chapter 2, the candidate presents an overview of the primary goal of the dissertation, which is the introduction of an adaptive routing protocol that combines the AODV routing protocol with fuzzy logic. The Chapter 3 presents a systematic and rigorous analysis of the extensions of the AODV protocol. Utilizing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, the chapter adheres to the highest academic standards to ensure the integrity and scholarly rigor of the review process. The Chapter 4 introduces the idea that unlike traditional methods fuzzy logic can handle uncertain and variable network conditions more effectively. Delving into the theoretical underpinnings of the subject, the chapter provides a comprehensive overview of fuzzy sets and membership functions. The chapter looks also at the improvements made to the broadcast forwarding algorithm thanks to fuzzy logic. It talks about how the algorithm can adjust itself based on the current state of the network, which helps it make better decisions about sending data. In Chapter 5, the candidate provides a comprehensive investigation of the FCEE protocol within the NS-2 simulation framework. A significant part of the chapter is dedicated to the methodology, which includes a thorough description of the simulation environment and the specific modifications made to adapt the NS-2 framework to the FCEE protocol. The chapter then delves into the performance evaluation of the FCEE protocol, comparing it against standard AODV and other variations. Furthermore, the chapter discusses the mobility model used in the simulations, providing a comprehensive description and justification for the assumptions made. The Chapter 6 details the methodology, describing the simulation environment and the modifications made to adapt NS-2 to the FCEE protocol. The chapter proceeds to evaluate the performance of the FCEE protocol against standard AODV and other modern versions of the AODV. It outlines the scenarios used for testing, which include different network densities, traffic patterns, and node velocities. A comprehensive results analysis is detailed in the Chapter 7. The chapter includes a statistical analysis section, underscoring the importance of statistical methods in ensuring the robustness and adaptability of routing protocols in dynamic network environments. The Chapter 7 also provides a comprehensive summary of the thesis undertaken, as well as possible directions for future research.

Thesis Criticism and Results Evaluation

As the candidate affirms, the increasing complexity of contemporary mesh networks, accentuated by the exponential growth of big data and IoT, poses significant challenges. These

encompass the management of capacious data, the optimization of routing protocols, and the assurance of dependable, efficient communication.
Consequently, conventional networking methodologies often fail to address these challenges, especially in resource-intensive and time-sensitive scenarios. Thus, the candidate proposes in this thesis an approach to decrease the level of cruciality in such research area.
Besides, the thesis supports incorporating of the fuzzy logic methodologies into the AODV protocol to improve these drawbacks. Fuzzy logic, a perceptive mathematical framework designed to manage ambiguity and uncertainty, is invaluable in handling imprecise routing metrics. The planned integration aims to develop adaptable routing strategies adapted to diverse network conditions, elevating overall network performance.
Another incentive for this research is the escalating integration of IoT and its complexities. The large influx of IoT devices generates substantial amounts of data, necessitating efficient data management solutions within mesh networks. This research is designed to address the complexities engendered by IoT within the context of mesh networking.
Furthermore, conventional static membership functions in routing protocols often prove insufficient for adapting to dynamic network conditions. This research proposes the implementation of dynamic membership functions based on fuzzy logic, thereby fostering enhanced routing performance and overall network efficiency.
And finally, this thesis is driven by the goal of optimizing the AODV routing protocol's performance within mesh networks through the integration of fuzzy logic and dynamic membership functions. This approach seeks to address the challenges presented by the proliferation of IoT devices and enhance the efficiency and reliability of communication in modern wireless networks.

Further Comments and Questions to Discuss

For the appreciation of the problem researched in this thesis, it would be an advantage to discuss the following issues:

1) What is the further potential against challenges in the focus?
2) What are the other candidate technologies in the area?
3) How the PhD candidate sees further development of WMNs?
4) Routing mechanisms in Wireless Mesh Networks are one of the most energy consuming elements – what would be further alternative solutions/approaches to decrease energy without loss in latency?
5) Did you have an opportunity to test your approach in some working network, in comparison or in addition to the simulations in NS-2?
6) Fuzzy Logic or other AI related methods implementation – advantages/disadvantages?
7) What further simulation environments can be useful for your approach?
8) How would you evaluate implementation your method in the industrial/commercial IoT?
9) What is the level of limitation for max. number of users simultaneously in a network?
10) It would be interesting to see some case studies, for future, within the Internet of Vehicles implementation field.

Summary and Recommendations

The research work performed by Mr. Ibrahim Ahmed Salman Alameri provides an innovative approach for applying informatics principles to wireless communications, mainly designing adaptive routing solutions for WMNs. The candidate effectively demonstrates the FCEE protocol's advantages through rigorous simulations, showing its potential to improve link stability and network performance. Further, the candidate contributes to the field of wireless communications and applied informatics, offering a novel perspective on tackling routing challenges in WMNs and highlighting the importance of data-driven decision-making in modern networking environments. He sets a precedent for future research at the intersection of networking and informatics.

Above and beyond, Mr. **Ibrahim Ahmed Salman Alameri** proved to expose theoretical as well as empirical methods to work independently with. All requirements to the academic work and the PhD standards are met. This in turn authorizes to allow Mr. **Ibrahim Ahmed Salman Alameri** to defense his thesis, and after a successful completion

I recommend

to grant Mr. **M.Sc. Ibrahim Ahmed Salman Alameri** an academic degree

Philosophiae Doctor (PhD)

in the related field.

In Bratislava, 03.01.2024 Prof., Dr. Natalia Kryvinska