

UNIVERSITI TEKNOLOGI MARA

**RSU RESOURCE CAPACITY
HANDLING MECHANISM FOR V2R
COMMUNICATION IN VANET
URBAN HIGHWAY MOBILITY**

NURSHAIRILY IDURA RAMLI

Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Computer Science)

Faculty of Computer and Mathematical Sciences

June 2025

ABSTRACT

Vehicular ad hoc networks (VANETs) are crucial technologies for wireless sharing of information and promoting innovative applications for road safety, traffic management, and entertainment. However, the proliferation of these applications comes with a massive amount of data that can overwhelm the capacity of resources, exacerbate congestion, and cause delays, particularly in densely populated areas like urban highways. Various methods and techniques are used to address overloading issues in vehicular networks, including cooperative and non-cooperative approaches. Cooperative methods involve adding nodes as temporary roadside units (RSU) and edge servers, but they face challenges in sharing processing power with other vehicles. Non-cooperative methods include caching, data scheduling, and edge node overload control mechanisms. Edge computing, which provides low-latency services and additional computational power, can help address this issue by equipping VANET with Vehicular Edge Computing (VEC) servers with greater computation, storage, and networking capabilities. However, VEC deployment in urban areas and extreme traffic congestion presents challenges, as overwhelming data limits computational, storage, and memory capacities. The RSU Resource Capacity Handling (RRCH) mechanism is proposed as an integrated solution combining these three mechanisms and is tested and evaluated in a simulated urban highway's standing vehicular traffic congestion scenario. The study evaluates the performance of RRCH in comparison to other approaches namely DQN-ATMOO, DIVINE, BAFOS, AVCIL, and MobTORU in a stationary traffic gridlock scenario, revealing comparative analysis of potential resource capacity depletion, longer delays, decreased throughput, and poorer PDR. Nonetheless, RRCH mechanism reservation of 25% of resource capacity for computation efficiency, resulting in a reduction of delay of up to 36% lower, and higher of 15% in throughput and packet delivery ratio, with an additional 11 to 16% increase in fair service provisioning. The study highlights the importance of efficient storage management in optimizing the operational efficiency with significant improvements in performance compared to other relevant approaches.

ACKNOWLEDGEMENT

With a sense of appreciation and modesty, I offer my utmost reverence and greetings to the Prophet Muhammad PBUH, his wife, his family, associates, and all those who persist in adhering to his teachings until the end of time. I must first acknowledge the immense wisdom of Allah, who is both exceedingly gracious and compassionate. It is due to His fortitude, direction, and enablement that I have successfully overcome the obstacles and accomplished this demanding endeavor. Acknowledging my role as a humble servant, I am deeply humbled by this experience; hence, I commence this portion of recognition by uttering the phrase "Alhamdulillah," which signifies admiration and thankfulness towards the one and only Supreme Being, Allah, for the numerous gifts that have been showered upon me.

I convey my heartfelt gratitude to my esteemed supervisors, Dr. Mohamed Izani Mohd Rawi and Dr. Hakilo Sabit, for their steady support and insightful criticism that have been immensely valuable during this academic journey. I would also like to express my sincere appreciation to my mentor, Dr. Mohd Faisal Ibrahim, for his un- wavering leadership and intellectual mentorship, which served as a constant source of motivation for me to complete this thesis. In addition, I would like to express my gratitude to the Committee of Examiners, Prof. Zuriati Ahmad Zulkarnain, and Associate Professor Mohamad Yusof Darus for their valuable feedback and suggestions to improve this thesis.

The voyage would not have been possible without the support of the Faculty of Computer and Mathematical Sciences at Universiti Teknologi MARA, Shah Alam, hence I convey my appreciation to the students, staff, and colleagues who played a pivotal part in supporting and enriching my academic journey, especially to Puan Suzetty Ezzra Mohd Sanusi, the senior clerk of the FSKM postgraduate office, for her meticulous care, which greatly aided in maintaining my composure and concentration during my academic pursuits. I also would like to gratefully acknowledge the support from the Ministry of Higher Education, Malaysia in providing the Fundamental Research Grant Scheme (FRGS) (Project Number: FRGS/1/2018/ICT03/UITM/02/3) research grant for supporting this study.

I wish to express my profound appreciation to my husband, Adi Azlan, for his constant support, affection, and devotion. I am also grateful to my four pillars of strength, Adi Naufal, Adilia Aishah, Adi Ashraf, and Adi Iskandar, who have consistently provided me with steadfast motivation and joy. Thank you for enduring my idiosyncrasies and accommodating my eccentricities, especially during moments when I let this thesis overwhelm me. I also dedicate this thesis to the cherished memories of my beloved father, Ramli, and my deep gratitude to my mother, for her continuous doa, unrelenting patience and resilience that had inspired me, as well as to my supportive siblings and extended relatives. I dedicate my triumph to all of you, and for that, I express my gratitude by saying Alhamdulillah and thank you.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR’S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xix
CHAPTER 1: INTRODUCTION	1
1.1. Research Background	1
1.2. Problem Statement	4
1.2.1. Issues in Non-Overlapping RSU Transmission Range	4
1.2.2. RSU’s Processing and Capacity Limitations	6
1.2.3. Provisioning Issues in Overwhelming Tasks Requests	8
1.3. Research Objectives	10
1.4. Research Questions	11
1.4.1. Research Question 1 (RQ1)	12
1.4.2. Research Question 2 (RQ2)	12
1.4.3. Research Question 3 (RQ3)	12
1.4.4. Research Question 4 (RQ4)	12
1.5. Contributions	12
1.5.1. Theoretical Contributions	13
1.5.1.1 <i>Segmentation-Based Vehicle Location Detection (SVLD)</i>	13
1.5.1.2 <i>VEC Capacity Reservation Control (VCRC)</i>	13
1.5.1.3 <i>VEC Provisioning Control (VPC)</i>	14
1.5.2. Empirical Contributions	14

CHAPTER 1

INTRODUCTION

1.1 Research Background

With the immense advancement in wireless technology, along with the emergence of autonomous vehicles and smart cities, Vehicular Ad hoc Networks (VANETs) are intensively researched and vastly evolving. It is widely recognized as the next-generation vehicular network which raises the expectation to deliver a broad range of applications and services with optimal network performance and efficiency (Ahangar et al., 2021). Nevertheless, despite the benefits of these technological advancements in enabling various automotive functions and meeting diverse service demands with expected efficiency and productivity, they also present new challenges due to factors such as communication restrictions, limitations in resource capacity, and issues related to road layout. Failure to address these circumstances would result in detrimental effects on the overall performance of VANET operation.

The communication modes in VANET, as implemented in technical design, are susceptible to numerous vulnerabilities. Vehicles as nodes that are naturally dynamic in their mobility are defined by their ability to communicate with other nodes or infrastructure via short-ranged wireless-based communication. This technical requirement itself presents various challenges due to dynamic topology, fast inter-changeable mobility, velocity and density, limitations of capacity, as well as intricate road layout. These factors collectively contribute to the prevalent issues in VANET, particularly in the realm of data communication (Ahangar et al., 2021; Guerna et al., 2022; Mahi et al., 2022).

The efficacy of Vehicle-to-Roadside Unit (V2R) communication is heavily dependent on the establishment of a connection with the roadside infrastructure or Roadside Unit (RSU) for network access and utilization of other resources. However, this reliance might result in difficulties when RSUs are not available or not deployed in specific areas, resulting in limited coverage and connectivity issues. The communication of V2R is restricted by communication range with the RSU, that