UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CENTRE BASED EVOLVING CLUSTERING FRAMEWORK WITH EXTENDED MOBILITY FEATURES FOR VEHICULAR AD-HOC NETWORKS

MOHAMMED SAAD TALIB

DOCTOR OF PHILOSOPHY

2021

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MOHAMMED SAAD TALIB

A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy

Faculty of Information and Communication Technology

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2021

DECLARATION

I declare that this thesis entitled “Centre Based Evolving Clustering Framework with Extended Mobility Features for Vehicular Ad-Hoc Networks” is the result of my own research except as cited in the references. The thesis has not been accepted or not concurrently submitted in the candidature of any other degree.

Signature : ….....

Name : Mohammed Saad Talib

Date : 22 / 7 / 2021

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : .....

Supervisor Name : TS. Dr. Aslinda Hassan

Date : 22 / 7 / 2021

DEDICATION

I'm dedicating this thesis to my beloved family, especially my parents, wife, and children, who have supported me throughout my life. They are always persistent in providing me the assistance and encouragement to push forward. This thesis is a humble and sincere acknowledgment of their graciousness given to me during my journey. I also would like to show my appreciation and gratitude to my grandparents, brothers, sisters, and uncle. May Allah has mercy on them. Finally, I would like to dedicate this thesis to the person I will never forget, Professor Dr. Burairah Hussin. He was my former main supervisor and the former Dean of Fakulti Teknologi Maklumat dan Komunikasi (FTMK), UTeM. May Allah has mercy on him. His departure has been the biggest challenge for me throughout this journey.

ABSTRACT

Vehicular Ad hoc Network (VANET) clustering is an active research area where a group of connected vehicles forms an ad hoc network. A stable cluster is essential for routing and data dissemination in VANET to avoid various issues such as packet loss, broadcast storm, and increased overhead resulting in an unstable clustering. Therefore, clustering is regarded as an essential part of the hierarchy of intelligent transportation systems. The literature contains numerous approaches for VANETs clustering. The majority of the approaches follow heuristic-based protocol combined with various connected phases and processes, such as cluster formation, cluster head selection, and cluster maintenance. Due to the high mobility of vehicles in VANET, it is more attractive to adapt the evolving data clustering to an evolving VANET clustering framework. The inclusion of extended mobility features has not been observed in most of the clustering approaches. The required extended mobility features are essential to overcome the challenges of vehicle movement. Moreover, relying on the non-valid assumptions such as the nature of the spherical cluster and the pre-knowledge about the number of clusters may not be feasible in many cases. In addition, most of VANETs clustering approaches use simple evaluation methodology where most of the approaches disregard a significant issue in the evaluation methodology. This thesis presents VANETs clustering framework called Centre-based Evolving Clustering with Grid Partitioning (CEC-GP). This framework uses an evolving data clustering algorithm by adopting the concept of grid granularity to capture the features of a cluster more efficiently. CEC-GP includes extended mobility features and provides the capability to avoid spherical assumptions for clusters, which is employed in most of the distance-based clustering. Besides, this framework offers high performance even with the challenging and high mobility scenarios related to the variability of mobility behaviour. The developed CEC-GP also includes an integrated approach that combined all clustering tasks such as cluster formation, cluster head selection, and cluster maintenance. Finally, CEC-GP shows a better stability performance compared with "Centre-based Stable Clustering (CBSC)" and "Evolving Data Clustering Algorithm (EDCA)" based on different performance metrics such as the clustering efficiency, the cluster head, and cluster member duration, the cluster head change rate, and the number of created clusters. The performance evaluation results show CEC-GP is better compared with the other two benchmarks in term of stability and consistency.

KERANGKA PENGKLUSTERAN TERKEMBANG SECARA BERPUSAT DENGAN CIRI-CIRI MOBILITI DIPERLUAS UNTUK RANGKAIAN AD-HOC KENDERAAN

ABSTRAK

Pengklusteran rangkaian ad-hoc kenderaan (VANET) adalah bidang penyelidikan yang aktif di mana sekumpulan kenderaan dihubungkan untuk membentuk satu rangkaian ad-hoc. Kluster yang stabil adalah penting untuk penghalaan dan penyebaran data dalam VANET bagi mengelakkan pelbagai isu seperti kehilangan paket, ribut siaran, dan peningkatan overhed yang boleh menyebabkan kluster menjadi tidak stabil. Oleh itu, pengklusteran dianggap sebagai satu bahagian yang penting dalam hierarki sistem pengangkutan pintar. Literatur mengandungi pelbagai pendekatan untuk pengklusteran dalam VANET. Sebilangan besar pendekatan tersebut mengikuti protokol berdasarkan heuristik yang digabungkan dengan pelbagai fasa dan proses yang terhubung seperti pembentukan kluster, pemilihan kepala kluster dan penyenggaraan kluster. Disebabkan mobiliti kenderaan yang tinggi dalam VANET, adalah lebih menarik untuk menyesuaikan pengklusteran data yang terkembang kepada kerangka pengklusteran VANET yang terkembang. Walau bagaimanapun, tiada ciri-ciri mobiliti terluas dikaji dalam kebanya kan pendekatan pengklusteran. Ciri-ciri mobiliti diperluas yang diperlukan sangat penting untuk mengatasi cabaran pengerakan kenderaan. Tambahan pula, kebergantungan kepada andaian yang tidak sah seperti kluster yang bersifat sfera dan pengetahuan awal mengenai bilangan kluster mungkin tidak sesuai untuk kebanyakan kes. Selain itu, kebanyakan pendekatan pengklusteran dalam VANET menggunakan metodologi penilaian yang mudah di mana kebanyakan pendekatan tersebut tidak mengambil kira isu penting dalam metodologi penilaian. Tesis ini membentangkan kerangka pengklusteran dalam VANET bernama Pengklusteran Terkembang secara Berpusat dengan Pemetaan Grid "(CEC-GP)". Kerangka ini menggunakan algoritma pengklusteran data terkembang dengan mengadaptasi konsep butiran grid bagi mengkaji ciri-ciri kluster dengan lebih berkesan. CEC-GP merangkumi ciri-ciri mobiliti yang diperluas dan memberikan kemampuan untuk menghindari andaian sfera bagi satu kluster, yang mana andaian ini digunakan dalam kebanyakan pengklusteran berasaskan jarak. Selain itu, kerangka ini menawarkan prestasi yang baik walaupun dalam senario mobiliti yang mencabar dan dinamik yang berkaitan dengan kebolehubahan tingkah laku pemandu. CEC-GP yang dibangunkan juga merangkumi pendekatan bersepadu yang menggabungkan semua tugas pengklusteran seperti pembentukan kluster, pemilihan kepala kluster, penye nggaraan cluster. Akhirnya, CEC-GP menunjukkan prestasi kestabilan yang lebih baik berbanding dengan "Centre-based Stable Clustering (CBSC)" dan "Evolving Data Clustering Algorithm (EDCA)" berdasarkan metrik prestasi yang berbeza seperti kecekapan pengklusteran, jangka masa kepala kluster dan anggota kluster, kadar perubahan kepala kluster dan bilangan kluster yang terbentuk. Keputusan penilaian prestasi menunjukkan CEC-GP adalah lebih baik dibandingkan dengan dua penanda aras yang lain dari segi kestabilan dan konsistensi.

ACKNOWLEDGEMENTS

بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيمِ

اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ * خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ * اقْرَأْ وَرَبُّكَ الْأَكْرَمُ * الَّذِي عَلَّمَ بِالْقَلَمِ * عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ

صدق الله العلي العظيم

سورة العلق (1-5)

First and foremost, praise is to Allah for giving me this opportunity, the strength, and the patience to complete my thesis finally, after all the challenges and difficulties.

My utmost appreciation goes to my main supervisor, Ts. Dr. Aslinda Hassan, FTMK - Universiti Teknikal Malaysia Melaka (UTeM) for all her support, advice and inspiration. Her constant patience for guiding and providing priceless insights will forever be remembered. Also, to my co-supervisor, Assoc. Prof. Dr. Zuraida Abal Abas from Universiti Teknikal Malaysia Melaka (UTeM) who constantly supported my journey. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform and all the facilities and supporting to complete this study.

I do not forget my first main supervisor, Prof. Dr. Burairah Bin Hussin (رحمه الله), for his high motivation and most significant contribution in this study from 2017 until 2018. He left an immense sadness in my heart, and I always remember him in my Doa' and asking Allah to forgive him, Ameen.

Finally, thank you to all the individual(s) who had provided me the assistance, support, and inspiration to embark on my study.

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ACD	-	Average cluster duration
ACHD	-	Average cluster-head duration
ACHCR	-	Average cluster-head change ratio
AC size	-	Average cluster size
ACMD	-	Average cluster-member duration
ACVL	-	Average coverage zone vehicles list
AGG	-	Aggressiveness of mobility behaviour
ALM	-	Aggregate Local Mobility
AMACAD	-	Adaptable Mobility-Aware Clustering Algorithm based on Destination
A no. of c	-	Average number of clusters
ASVL	-	Average stable vehicles list
AU	-	Application Unit
BS	-	Base station
CBSC	-	Centre-based stable clustering
CEC-GP	-	Centre-based evolving clustering with grid partitioning
CH	-	Cluster Head
CHCR	-	Cluster-head change ratio
CM	-	Cluster Member
C_{th}	-	Counter threshould
DBC	-	Density-Based Clustering
DLC	-	Discretionary Lane Change
DMAC	-	Distributed Mobility-Adaptive Clustering
DMBC	-	Distributed model-based clustering
DMCNF	-	Distributed Multi-hop Clustering using Neighborhood Follow
DSRC	-	Dedicated short-range communications
EDCA	-	Evolving data clustering algorithm

EIV	-	Expected incoming vehicles
eNodeB	-	Evolved Node Base station
FLBA	-	Fuzzy-Logic-Based Algorithm
GDMAC	-	Generalised Distributed Mobility Aware Clustering
GOA	-	Grasshoppers Optimization-based clustering Algorithm
GPS	-	Global Positioning System
HT	-	High Traffic
IDM	-	Intelligent Driving Model
IT	-	Information Technology
ITS	-	Intelligent Transportation System
LBC	-	Lane-Based Clustering
LID	-	Lowest-ID clustering
LT	-	Low Traffic
LTE	-	Long-Term Evolution
MANET	-	Mobile Ad-Hoc Network
Max	-	Maximum value
MCTC	-	Mean Connection Time Clustering
MDMAC	-	Modified Distributed Mobility Aware Clustering
MG	-	Manhattan Grid model
Min	-	Minimum value
MLC	-	Mandatory Lane Change
MOBIC	-	MOBIlity metrics Clustering
NMCS	-	Neighbour Mobility-based Clustering Scheme
Ns-2	-	Network simulator 2
Ns-3	-	Network simulator 3
NT	-	Normal Traffic
OBU	-	On Board Unit
OMNET++	-	Optical Micro Networks Plus
PC	-	Passive Clustering
PDR	-	Packet delivery ratio
PLR	-	Packet loss rate
PPC	-	Position-based Prioritised Clustering
Q1	-	First quartile of Box-Plot

Q2	-	Second quartile of Box-Plot
Q3	-	Third quartile of Box-Plot
RD	-	Random Direction Model
RMAC	-	Robust Mobility Adaptive Clustering
RSU	-	Road Side Unit
RW	-	Random Walk Model
SBCA	-	Stability-Based Clustering Algorithm
SUMO	-	Simulation of Urban MObility
TBC	-	Threshold-Based Clustering
TCRP	-	Triple Cluster-based Routing Protocol
TR	-	Transmission Range
TI	-	Time interval
UFC	-	Unified framework of clustering
UOFC	-	User-Oriented Fuzzy-logic-based Clustering
V	-	Velocity
V2H	-	Vehicle-to-Human
V2I	-	Vehicle-to-Infrastructure
V2R	-	Vehicle-to- Road Side Unit
V2S	-	Vehicle-to-Sensor
V2V	-	Vehicle-to-Vehicle
VANET	-	Vehicular Ad-Hoc Network
VMaSC	-	Vehicular Multi-hop algorithm for Stable Clustering
VPC	-	Vehicular Passive Clustering
VWCA	-	vehicle clustering based on the weighted clustering algorithm
V_{th}	-	Velocity threshould
WSN	-	Wireless sensor network

LIST OF PUBLICATIONS

This study grants an account of the study undertaken by the authors. Some articles have been presented as follows:

1. Talib, M. S., Hassan, A. and Abas, Z. A., 2020. A Center-based Stable Evolving Clustering Algorithm with Grid Partitioning and Extended Mobility Features for VANETs. *IEEE Access*, Vol. 8(sep), pp. 169908–169921. doi:10.1109/access.2020.3020510. (Published) ISI Q1 Impact Factor 3.745.

2. Talib, M. S., Hassan, A. and Abas, Z. A., 2020. Analysis of mobility model effect on stable and coverage list in VANETs clustering. *International Journal of Advanced Science and Technology*, Vol. 29(8), pp. 1764–1775. (Published) Scopus.

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