



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



DOCTOR OF PHILOSOPHY

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Faculty of Information and Communication Technology

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

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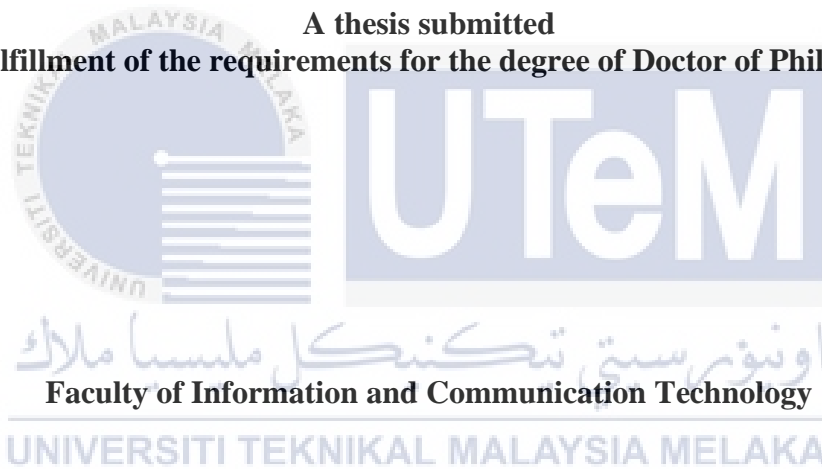
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**CENTRE BASED EVOLVING CLUSTERING FRAMEWORK WITH EXTENDED
MOBILITY FEATURES FOR VEHICULAR AD-HOC NETWORKS**

MOHAMMED SAAD TALIB

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

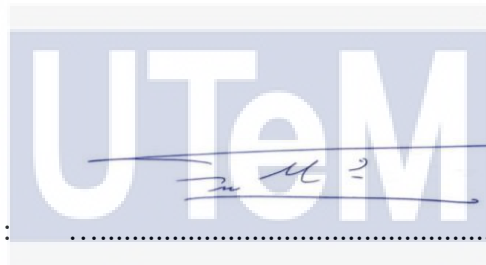


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2021

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.



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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.

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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 overhead 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 berkembang kepada kerangka pengklusteran VANET yang berkembang. Walau bagaimanapun, tiada ciri-ciri mobiliti terluas dikaji dalam kebanyakan pendekatan pengklusteran. Ciri-ciri mobiliti diperluas yang diperlukan sangat penting untuk mengatasi cabaran pergerakan 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 Berkembang secara Berpusat dengan Pemetaan Grid "(CEC-GP)". Kerangka ini menggunakan algoritma pengklusteran data berkembang 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, penyenggaraan 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.

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صدق الله العلي العظيم
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TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATIONS	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF APPENDICES	xiv
LIST OF ABBREVIATIONS	xv
LIST OF PUBLICATIONS	xviii
CHAPTER	1
1 INTRODUCTION	1
1.1 Background	1
1.2 Motivation	2
1.1.1 Statistics of cost	2
1.1.2 The importance of VANETs	3
1.1.3 The importance of VANETs clustering	4
1.3 Problem statement	4
1.4 Research questions	6
1.5 Research objectives	7
1.6 Research scope	7
1.7 Research Contributions	8
1.8 The link between research structures	9
1.9 Thesis organization	10
2 LITERATURE REVIEW	14
2.1 Introduction	14
2.2 Intelligent transportation system	15
2.3 Mobile Ad hoc networks	16
2.4 Vehicular ad hoc networks	18
1.1.4 Vehicular networks architecture	18
1.1.5 Vehicular communication	19
2.4.1.1 Vehicle to vehicle communication	19
2.4.1.2 Vehicle to infrastructure communication	20
2.4.1.3 Hybrid architecture	20
2.4.2 Vehicular ad hoc network characteristics	21
1.1.6 Vehicular ad hoc network applications	22
1.1.7 Vehicular ad hoc network challenges	23
1.1.8 Data dissemination in VANETs	24
2.5 Mobility models	24
2.6 Clustering	32

2.6.1	Clustering applications	33
2.6.2	Clustering procedure	37
2.6.3	Cluster formation	38
2.6.3.1	Cluster head selection	45
2.6.3.2	Cluster maintenance	48
2.6.4	Clustering topology	50
2.6.5	Clustering approaches	52
2.6.6	Research gaps and limitations in the VANETs clustering approaches	73
2.7	Summary	75
3	RESEARCH METHODOLOGY	76
3.1	Introduction	76
3.2	General methodology	76
3.3	Highway model	79
3.4	Evolving VANETs clustering framework	80
3.4.1	Traffic generator	81
3.4.2	Features extraction	86
3.4.3	Clustering algorithm	86
3.4.3.1	Assign	87
3.4.3.2	Cluster head selection	89
3.4.3.3	Maintenance	90
3.5	Evaluation scenarios	92
3.6	Sensitivity analysis	95
3.6.1	Velocity threshold	98
3.6.2	Counter threshold	99
3.6.3	Aggressiveness parameter	100
3.6.4	Grid granularity	102
3.6.5	Merging distance	103
3.6.6	Clustering threshold	103
3.7	Performance metrics	103
3.7.1	Clustering efficiency	104
3.7.2	Average cluster head duration	104
3.7.3	Average cluster member duration	105
3.7.4	Average cluster head change rate	105
3.7.5	Number of clusters	106
3.8	Results validation	106
3.9	Evaluation technique	106
3.10	Simulation parameters	112
3.11	Summary	113
4	RESULT AND DISCUSSION	114
4.1	Introduction	114
4.2	Sensitivity analysis	115
4.3	Results and analysis	119
4.3.1	Low aggressiveness	120
4.3.1.1	Efficiency	120

4.3.1.2	Average cluster head duration	126
4.3.1.3	Average cluster member duration	132
4.3.1.4	Average cluster head change rate	137
4.3.1.5	Number of clusters	142
4.3.2	Medium aggressiveness	149
4.3.2.1	Efficiency	150
4.3.2.2	Average cluster head duration	152
4.3.2.3	Average cluster member duration	154
4.3.2.4	Average cluster head change rate	156
4.3.2.5	Number of clusters	158
4.3.3	High aggressiveness	161
4.3.3.1	Efficiency	162
4.3.3.2	Average cluster head duration	163
4.3.3.3	Average cluster member duration	165
4.3.3.4	Average cluster head change rate	167
4.3.3.5	Number of clusters	168
4.4	Results validation	172
4.5	Effect of mobility aggressiveness analysis	175
4.6	Evaluation technique	177
4.7	Summary	182
5	CONCLUSION AND RECOMMENDATION	183
5.1	Research summary	183
5.2	Research achievements	185
5.3	Conclusions	186
5.4	Limitations of the research	188
5.5	Future works	189
5.6	Summary	190
	REFERENCES	191
	APPENDICES	211

LIST OF TABLES

TABLE	TITLE	PAGE
1.1	Link between research questions, objectives, and contributions	9
2.1	Differences between VANETs and MANETs (Sood and Kanwar, 2014)	17
2.2	The advantages and challenges of DSRC and LTE (Iftikhar et al., 2018)	21
2.3	Summarizes and analysis the mobility models	30
2.4	General-purpose of clustering approaches (Cooper et al., 2017)	34
2.5	Safety application of clustering approaches (Cooper et al., 2017)	35
2.6	Routing application of clustering approaches (Cooper et al., 2017)	35
2.7	Security application of clustering approaches (Cooper et al., 2017)	36
2.8	Channel access of clustering approaches (Cooper et al., 2017)	36
2.9	Combination with Infrastructure of clustering approaches (Cooper et al., 2017)	37
2.10	Analysis of clustering approaches	61
2.11	The critical review of clustering approaches	66
2.12	Types of network simulations (Gayathri and Vadivel, 2017)	73
3.1	Levels of traffic for evaluation scenarios	94
3.2	Result scenarios based on number of vehicles, number of lanes, and aggressiveness factor (AGG)	95
3.3	Sensitivity analysis of velocity threshold in level one	98
3.4	Sensitivity analysis of velocity threshold in level two	98
3.5	Sensitivity analysis of velocity threshold in level three	99

3.6	Sensitivity analysis of counter threshold in level one	99
3.7	Sensitivity analysis of counter threshold in level two	100
3.8	Sensitivity analysis of counter threshold in level three	100
3.9	Sensitivity analysis of AGG in level one	101
3.10	Sensitivity analysis of AGG in level two	101
3.11	Sensitivity analysis of AGG in level three	102
3.12	Expected states at time t and $t+ \Delta t$ with all their transitions possibilities	111
3.13	The simulation parameters of the performed experiments	112
4.1	Efficiency validation using T-test	172
4.2	Cluster head duration validation using T-test	173
4.3	Cluster member duration validation using T-test	174
4.4	Cluster head change rate validation using T-test	174
4.5	Number of clusters validation using T-test	175
4.6	Number of vehicles in each cluster at each time interval in low traffic level	179
4.7	Number of vehicles in each cluster at each time interval in normal traffic level	180
4.8	Number of vehicles in each cluster at each time interval in high traffic level	181

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Thesis organization	12
2.1	Hierarchy of wireless ad hoc networks (Hoa and Cavalli, 2014)	17
2.2	Vehicular ad hoc network architecture (Liang et al., 2017)	19
2.3	Vehicular ad hoc network applications (Amjad et al., 2016)	23
2.4	Taxonomy of mobility models (Harri et al., 2009)	26
2.5	Taxonomy of clustering in vehicular ad hoc networks	33
2.6	Classification of CH selection Parameters (Cooper et al., 2017)	46
2.7	Taxonomy of clustering maintenance in VANETs	48
2.8	Cluster maintenance Processes	49
2.9	Classification of clustering approaches based on topology (Cooper et al., 2017)	51
3.1	General methodology for accomplishing the objectives of the thesis	78
3.2	Clustering in vehicular ad hoc network	80
3.3	Evolving VANETs clustering framework (CEC-GP)	81
3.4	Flowchart of the lane change process	85
3.5	Evaluation methodology of the CEC-GP	93
3.6	Box-Plot representations for AGG and velocity threshold parameters	97
3.7	Sensitivity analysis for the parameters of the traffic generation and the clustering algorithm	97
3.8	Grid granularity on the highway	102

3.9	Performance metrics of clustering stability	104
3.10	Vehicles leaving and joining representation	107
3.11	Vehicles leaving and joining process from/to a cluster	108
3.12	State diagram for vehicles leaving and joining process	111
4.1	Number of vehicles concerning the velocity threshold	116
4.2	Number of vehicles concerning counter threshold	117
4.3	Number of vehicles concerning AGG parameter	119
4.4	Efficiency with low AGG and four lanes	121
4.5	Efficiency as time series for four lanes and low AGG	122
4.6	Efficiency for low AGG and six lanes	123
4.7	Efficiency as time series for six lanes and low AGG	124
4.8	Efficiency with low AGG and eight lanes	125
4.9	Efficiency as time series for eight lanes and low AGG in	126
4.10	Average cluster head duration with low AGG and four lanes	127
4.11	Cluster head duration as time series for four lanes and low AGG	128
4.12	Average cluster head duration with low AGG and six lanes	129
4.13	Cluster head duration as time series for six lanes and low AGG	130
4.14	Average cluster head duration with low AGG and eight lanes	130
4.15	Cluster head duration as time series for eight lanes and low AGG	131
4.16	Average cluster member duration with low AGG and four lanes	132
4.17	Cluster member duration as time series for four lanes and low AGG	133
4.18	Average cluster member duration with low AGG and six lanes	134
4.19	Cluster member duration as time series for six lanes and low AGG	135
4.20	Average cluster member duration with low AGG and eight lanes	135
4.21	Cluster member duration as time series for eight lanes and low AGG	136

4.22	Average cluster head change rate with low AGG and four lanes	137
4.23	Cluster head change rate as time series for four lanes and low AGG in	138
4.24	Average cluster head change rate with low AGG and six lanes	139
4.25	Cluster head change rate as time series for six lanes and low AGG	140
4.26	Average cluster head change rate with low AGG and eight lanes	140
4.27	ACHCR as time series for high traffic with eight lanes and low AGG	141
4.28	Average number of clusters with low AGG and four lanes	142
4.29	Standard deviation for the number of clusters in low AGG and four lanes	143
4.30	Number of clusters and standard deviation as the time series for four lanes and low AGG	144
4.31	Average number of clusters with low AGG and six lanes	144
4.32	Standard deviation for the number of clusters in low AGG and six lanes	145
4.33	Number of clusters and standard deviation as the time series for six lanes and low AGG	146
4.34	Average number of clusters with low AGG and eight lanes	147
4.35	Standard deviation for the number of clusters in low AGG and eight lanes	147
4.36	Number of clusters and standard deviation as the time series for eight lanes and low AGG	149
4.37	Efficiency with medium AGG and four lanes	150
4.38	Efficiency with medium AGG and six lanes	151
4.39	Efficiency for medium AGG and eight lanes	151
4.40	Average cluster head duration with medium AGG and four lanes	152
4.41	Average cluster head duration with medium AGG and six lanes	153
4.42	Average cluster head duration with medium AGG and eight lanes	153
4.43	Average cluster member duration with medium AGG and four lanes	154

4.44	Average cluster member duration with medium AGG and six lanes	155
4.45	Average cluster member duration with medium AGG and eight lanes	156
4.46	Average cluster head change rate with medium AGG and four lanes	156
4.47	Average cluster head change rate with medium AGG and six lanes	157
4.48	Average cluster head change rate with medium AGG and eight lanes	157
4.49	Average number of clusters with medium AGG and four lanes	158
4.50	Standard deviation for the number of clusters in medium AGG and four lanes	159
4.51	Average number of clusters with medium AGG and six lanes	159
4.52	Standard deviation for the number of clusters in medium AGG and six lanes	160
4.53	Average number of clusters with medium AGG and eight lanes	160
4.54	Standard deviation for the number of clusters in medium AGG and eight lanes	161
4.55	Efficiency with high AGG and four Lanes	162
4.56	Efficiency with high AGG and six Lanes	162
4.57	Efficiency with high AGG and eight Lanes	163
4.58	Average cluster head duration with high AGG and four lanes	164
4.59	Average cluster head duration with high AGG and six lanes	164
4.60	Average cluster head duration with high AGG and eight lanes	165
4.61	Average cluster member duration with high AGG and four lanes	165
4.62	Average cluster member duration with high AGG and six lanes	166
4.63	Average cluster member duration with high AGG and eight lanes	166
4.64	Average cluster head change rate with high AGG and four lanes	167
4.65	Average cluster head change rate with high AGG and six lanes	168
4.66	Average cluster head change rate with high AGG and eight lanes	168
4.67	Average number of clusters with high AGG and four lanes	169
4.68	Standard deviation for the number of clusters in high AGG and four lanes	169

4.69	Average number of clusters with high AGG and six lanes	170
4.70	Standard deviation for the number of clusters in high AGG and six lanes	170
4.71	Average number of clusters with high AGG and eight lanes	171
4.72	Standard deviation for the number of clusters in high AGG and eight lanes	171
4.73	Mobility behaviour and its effect on various clustering performance metrics	176
4.74	The average number of clusters in CEC-GP	178
4.75	Number of vehicles in each cluster at each time interval for the low traffic level	179
4.76	Number of vehicles in each cluster at each time interval for normal traffic level	180
4.77	Number of vehicles in each cluster at each time interval for high traffic level	181



LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Time Series for Medium and High Aggressiveness	211
B	Evaluation Technique Results for the Different Traffic Density	244



LIST OF ABBREVIATIONS

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 threshold
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 threshold
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.
3. Talib, M. S., Hassan, A. and Abas, Z. A., 2019. Clustering in VANETs perspective: Concepts, topology and applications. *International Journal of Advanced Science and Technology*, Vol. 28(8), pp. 471–484. (Published) Scopus.
4. Talib, M. S., Hassan, A. and Abas, Z. A., 2019. Clustering Based Affinity Propagation in VANETs: Taxonomy and Opportunity of Research', *International Journal of Recent Technology and Engineering*, Vol. 7(6S5), pp. 672–679. (Published) Scopus.
5. Talib, M. S., Hassan, A. and Hussin, B., 2018. A Novel Stable Clustering Approach based on Gaussian Distribution and Relative Velocity in VANETs. *International*