



Faculty of Computer Science and Information Technology

**Improving Channel Assignment for Vehicular Ad-hoc Sensor Network in
Disaster Management System**

Sia Chiu Shoon

**Doctor of Philosophy
2024**

Improving Channel Assignment for Vehicular Ad-hoc Sensor Network in Disaster Management System

Sia Chiu Shoon

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Wireless Networking)

Faculty of Computer Science and Information Technology

UNIVERSITI MALAYSIA SARAWAK

2024

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



.....

Signature

Name: Sia Chiu Shoon

Matric No.: 15010244

Faculty of Computer Science & Information Technology

Universiti Malaysia Sarawak

Date :24/6/2024

ACKNOWLEDGEMENT

All my greatest appreciation and gratitude go to my supervisor, Associate Professor Dr. Mohamad Nazim Bin Jambli, who has been helpful, guided, patient, and assisted throughout my study. His persistent guidance and valuable suggestions have led to the success of this dissertation.

Also, to my family members for their support all the time and to anyone helping me directly and indirectly in making my Ph.D. journey a meaningful and wonderful success.

ABSTRACT

The disaster is categorized as unavoidable and essential planetary action. When these natural phenomena form in extreme format, they could significantly impact daily life, property, the environment generally, and global economics particularly. This aims for design making and actions taken through the collaboration and cooperation of many experts from various disciplines. Although primary and secondary research suggested that there is room for limitations in the existing information and communication technology (ICT) that affects the effectiveness and efficiency of an emergency response task. Due to this, this research focuses on building improved Channel assignments on Vehicular Ad-hoc Sensor Network (VASNET) to investigate the proposed algorithms and methods to improve the reliability of the Disaster Management System (DMS) during emergency operations for natural and man-made disasters. The conventional VASNET in terms of infrastructure that consists of Roadside Sensor Unit (RSU) may partially or entirely destroyed during the post-disaster scenario. As such, performance degradation of VASNET affects the network infrastructure with high packet loss, delay and a massive of energy consumption on Disaster Management System. Therefore, modification of VASNET is a must to improve and solve the current problem of VASNET technology. The proposed algorithms and methods are implemented using an Omnet++ network simulator with network formation, Channel assignment, and Packet Scheduling to reduce node-to-node interference with computational overhead that significantly impacts the performance. Furthermore, large bandwidth is the major problem in current VASNET architecture as the study of network formation and channel assignment to further improved by introducing a backup path in terms of reliability. To assign or allocate the channel in a multi-channel and multi-node environment. We need a medium so-called multi-interface that include switchable and fixed interface on every node UEs (User

Equipment) in the VASNET topology. This is because the channel assigns might under-utilize or fully utilize in multi-node situations. Moreover, a high spectrum and spectrum scarcity could affect the VASNET packet broadcasting performance. Therefore, in this research, we proposed an OFDMA and SC-FDMA implementation in this research study to overcome those problems on the uplink and downlink stage, to ensure Channel Assignment is fully implemented to achieve this research objective and answer the research question as well. This research shows that packet loss has a more significant influence when measured over the proposed methods and algorithms, as well as delay and energy consumption during the evaluation stage. LTE-A Improved Channel (LTE-AIC) was suggested and implemented with proposed algorithms and methods to compare with conventional LTE-A and LTE as a benchmark. According to the simulation result, the packet loss able to reduce on LTE-AIC with an average of 54.82% with respect to normal LTE-A and 64.05% compared to LTE on low data rate (CQI=2). On a high data rate (CQI=7), an average of 10.98% improved for LTE-AIC compared to normal LTE-A and an average of 19.70% with respect to LTE. On the other hand, 36.32% improved on LTE-AIC with an average end-to-end delay compared to normal LTE-A and an average of 49.44% compared to LTE on low data rate. Moreover, an average of 22.91% for LTE-AIC with respect to normal LTE-A and 38.63% compared to LTE for high data rate. In terms of energy consumption, an average of 20.90% improved on LTE-AIC compared to normal LTE-A and 33.36% with respect to LTE on a low data rate. Lastly, an average of 23.69% was reduced on LTE-AIC compared to normal LTE-A, and 44.04% compared to LTE for 1km coverage in this simulation. Consequently, this research study greatly contributes to the proposed methods and algorithms for VASNET in LTE-AIC on improved Channel Assignment for Disaster Management Systems explicitly proposed.

Keywords: VASNET, Channel Assignment, LTE-A, LTE, LTE-AIC

***Kaedah Penyerahan Saluran yang Ditambahbaikan untuk Rangkaian Ad-Hoc
Kenderaan dalam Sistem Pengurusan Bencana***

ABSTRAK

Bencana dikategorikan sebagai tindakan yang tidak dapat dielakkan. Apabila fenomena alam ini terbentuk dalam format yang melampau, ia boleh memberi impak yang besar kepada kehidupan harian, harta benda, alam sekitar dan ekonomi global khususnya. Ini adalah matlamat membuat reka bentuk dan tindakan yang diambil melalui kerjasama pakar dari pelbagai disiplin. Walaupun penyelidikan primer dan sekunder mencadangkan bahawa terdapat ruang untuk batasan dalam teknologi maklumat dan komunikasi (ICT), dari aspek keberkesanan dan kecekapan semasa kecemasan. Disebabkan ini, fokus penyelidikan ini adalah membina Tugas Saluran yang ditambahbaik ke atas VASNET untuk menyiasat sama ada algoritma dan kaedah yang dicadangkan mampu meningkatkan keupayaan Sistem Pengurusan Bencana (DMS). Kelemahan VASNET yang terdiri daripada RSU dimusnahkan sebahagian atau sepenuhnya di pasca bencana. Oleh itu, kemerosotan VASNET menjejaskan rangkaian dengan kehilangan paket yang tinggi, kelewatan, dan menghasilkan sejumlah besar tenaga dalam Sistem Pengurusan Bencana ini. Akibatnya, pengubahsuaian VASNET adalah satu kemestian untuk menyelesaikan masalah teknologi VASNET. Algoritma dan kaedah yang dicadangkan menggunakan simulator Omnet++ dengan pembentukan rangkaian, penugasan Saluran dan Penjadualan Paket untuk mengurangkan gangguan nod-ke-nod yang memberikan impak besar dari segi prestasi. Tambahan pula, lebar jalur yang besar pada peranti-ke-peranti adalah masalah utama dalam pembinaan VASNET. Untuk menetapkan saluran dalam persekitaran berbilang saluran dan nod. Medium yang dipanggil berbilang muka yang termasuk muka boleh tukar dan tetap pada setiap UE nod dalam topologi VASNET. Ini kerana peruntukan saluran mungkin kurang

digunakan sepenuhnya dalam situasi berbilang nod. Selain itu, kekurangan spektrum yang tinggi boleh menjejaskan prestasi VASNET semasa penyiaran paket. Oleh itu, dalam penyelidikan ini, kami mencadangkan pelaksanaan OFDMA dan SC-FDMA, untuk mengatasi masalah tersebut pada peringkat uplink dan downlink, bagi memastikan Channel Assignment dilaksanakan sepenuhnya. Kajian ini menunjukkan bahawa kehilangan paket mempunyai pengaruh yang besar apabila diukur ke atas kaedah dan algoritma yang dicadangkan serta kelewatan dan penggunaan tenaga semasa peringkat penilaian. LTE-AIC dicadangkan dan dilaksanakan dengan algoritma dan kaedah untuk dibandingkan dengan LTE-A dan LTE konvensional sebagai penanda aras. Berdasarkan keputusan simulasi, kehilangan paket dikurangkan ke purata 54.82% LTE-AIC berbanding dengan LTE-A biasa dan 64.05% berbanding LTE pada kadar data rendah (CQI=2). Pada kadar data yang tinggi (CQI=7), purata 10.98% bertambah baik ke atas LTE-AIC berbanding LTE-A biasa dan purata 19.70% berbanding dengan LTE. Sebaliknya, 36.32% bertambah baik pada purata kelewatan hujung ke hujung berbanding LTE-A biasa dan purata 49.44% berbanding LTE pada kadar data rendah. Selain itu, purata 22.91% dari LTE-AIC berbanding LTE-A biasa dan 38.63% berbanding LTE untuk kadar data yang tinggi. Dari segi penggunaan tenaga, purata 20.90% bertambah baik di LTE-AIC berbanding LTE-A biasa dan 33.36% berbanding dengan LTE pada kadar data yang rendah. Akhir sekali, purata 23.69% berkurangan dari LTE-AIC berbanding LTE-A biasa dan 44.04% bertambah baik berbanding LTE, untuk liputan 1km dalam simulasi ini. Akhirnya, kajian penyelidikan ini menyumbang kepada kaedah dan algoritma yang dicadangkan untuk VASNET dari segi keupayaan dalam protokol LTE-A pada Penyerahan Saluran yang dipertingkatkan untuk Sistem Pengurusan Bencana yang dicadangkan secara eksplisit.

Kata kunci: VASNET, Penugasan Saluran, DMS, LTE-A, LTE, LTE-AIC

TABLE OF CONTENTS

	Page
DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
ABSTRAK	v
TABLE OF CONTENTS	vii
LIST OF TABLES	xiv
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xix
CHAPTER 1 INTRODUCTION	1
1.1 Study Background	1
1.2 Problem Statement	5
1.3 Research Question	7
1.4 Research Aims and Objective	8
1.5 Research Methodology	9
1.6 Hypothesis	10
1.7 Main Contributions	11
1.8 Limitation and Significance Study	11
1.8.1 The level of connectivity	11
1.8.2 The problem of deafness	12

1.8.3	The problem of multichannel hidden node	13
1.9	Publication	13
1.10	Thesis Outline	14
1.11	Summary	15
	CHAPTER 2 LITERATURE REVIEW	16
2.1	Introduction	16
2.2	Related Works	17
2.2.1	Time Slot Multichannel	17
2.2.2	Scheduling Channel Prediction	20
2.2.3	Hungarian Algorithm in Channel Allocation Scheme	23
2.2.4	Enhanced MAC Protocol in Channel Assignment	24
2.2.5	Wireless Mesh Networks (WMN) Channel Assignment in Disaster	26
2.2.6	UAV in Channel Allocation for Disaster Scenario	27
2.3	Overview of Channel Assignment and Proposed Method	37
2.4	Overview of Operation modes (Interface)	39
2.5	Introduction of Packet Scheduling	41
2.6	LTE: Architecture	44
2.7	LTE requirement	45
2.8	LTE-A in OFDMA and SC-FDMA	47
2.9	Introduction of OFDMA	49

2.10	OFDMA	50
2.11	Objective of OFDMA	52
2.12	Advantages of OFDMA	52
2.13	Introduction of SC-FDMA	54
2.14	Objective of SC-FDMA	54
2.15	Advantages of SC-FDMA	55
2.16	Research Map	56
2.17	Disaster Simulation Overview	57
2.18	Comparison of Selected Simulator Tools	60
2.19	Definition of Disaster Management System	63
2.19.1	Managing Risk, Emergencies and Disasters	64
2.19.2	Risk	65
2.19.3	Hazard	66
2.19.4	Vulnerability	66
2.19.5	Disaster	67
2.19.6	The Management of Risk	69
2.20	The Management of Emergencies and Disaster:Emergency Management Functions	70
2.20.1	Mitigation	70
2.20.2	Preparedness	71

2.20.3	Response	72
2.20.4	Recovery	72
2.21	The Management of Emergencies and Disaster:Emergency Management Structure	73
2.21.1	The Fire Department	73
2.21.2	Law Enforcement	75
2.21.3	Emergency Department	76
2.21.4	Emergency Medical Service	77
2.22	Summary	78
	CHAPTER 3 RESEARCH METHODOLOGY	79
3.1	Introduction	79
3.2	Summary of Research Flow	79
3.3	Benefits of Multi-Interfaces	80
3.3.1	Interfaces Switching Issues	81
3.3.2	Switching Latency: Interfaces	82
3.4	Formulated Problem	82
3.5	Interfaces Assignment	83
3.5.1	Interfaces Assignment Strategy	83
3.5.2	Protocols between Nodes	84
3.5.3	Packet Insertion into Channel Queues	84

3.5.4	Channel Queues Servicing	85
3.5.5	Proposed Protocol Operation	85
3.5.6	Proposed Packet Operation	87
3.6	Proposed Architecture of Interfaces	88
3.6.1	Architecture of Proposed Interface Structure	90
3.6.2	MIMC Control Sublayer	91
3.6.3	Multi-Interface	92
3.6.4	Channel Assign Method	93
3.7	Reliability (Multicasting)	97
3.8	Why Markov Chains	98
3.8.1	Markov Chains: State and Transition	99
3.8.2	Markov Chains: Proposed Method	101
3.8.3	Markov Chains Modelling: Random Walks	102
3.8.4	Markov Chains in Wireless Networking	104
3.8.5	Absorbing	105
3.8.6	Reflecting	106
3.8.7	Circular	107
3.8.8	Random Walks: Barriers	108
3.9	Markov Decision Process: MDP	108
3.10	Network Establishing: Algorithm	112

3.11	Proposed Sequence Diagram	117
3.11.1	Node Registration	119
3.11.2	Network Discovering Formation and Channel	120
3.11.3	Location Detection	121
3.12	LTE-A Downlink: OFDMA Principles	122
3.13	LTE-A Uplink: SC-FDMA	122
3.14	LTE-A Features: MIMO	124
3.15	Downlink MIMO	125
3.16	Suggested Algorithm: Packet Scheduling	127
3.17	Performance Evaluation: Packet Loss	129
3.18	Contention Window (CW) Mechanism	130
3.19	Delay	131
3.20	Operation of DIFS and SIFS for Packet Transmission	131
3.21	Performance Evaluation: End-to-End Delay	133
3.22	Performance Evaluation: Energy Consumption	137
3.23	Overview of Low Data Rate (CQI=2) and High Data Rate (CQI=7)	139
3.24	Simulation Scenario	140
3.25	Summary	141
CHAPTER 4	RESULTS AND DISCUSSION	143
4.1	Introduction	143

4.2	Simulation setting	143
4.3	Justify: Simulation Time and Coverage	144
4.4	Simulation Result: Packet loss (CQI= 2)	146
4.5	Simulation Result: End-to-End Delay (CQI=2)	148
4.6	Simulation Result: Average Energy Consumption (CQI=2)	150
4.7	Simulation Result: Packet Loss (CQI=7)	152
4.8	Simulation Result: End-to-End Delay (CQI=7)	155
4.9	Simulation Result: Average Energy Consumption (CQI=7)	157
4.10	Correlation Graph of Simulation Result (Packet Scheduling Data: LTE-AIC)	160
4.11	Summary	164
CHAPTER 5 CONCLUSION AND FUTURE WORK		165
5.1	Conclusion	165
5.2	Contributions	166
5.3	Future Work	169
REFERENCES		173

LIST OF TABLES

		Page
Table 2.1	Related works summary (2019-2022)	33
Table 2.2	Comparison of selected simulator tools	60
Table 3.1	Summary of proposed channel assignment packet list	97
Table 3.2	State, Decision and Reward for VASNET on proposed method.	110
Table 4.1	Parameter setting used in the simulation	144
Table 4.2	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=2)	146
Table 4.3	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=2)	146
Table 4.4	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) on average end-to-end delay for (CQI=2)	148
Table 4.5	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) on average end-to-end delay for (CQI=2)	148
Table 4.6	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) average energy consumption for 1km coverage on low data rate (CQI=2)	150
Table 4.7	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) average energy consumption for 1km coverage on low data rate (CQI=2)	151
Table 4.8	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=7)	152
Table 4.9	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=7)	153
Table 4.10	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) on average end-to-end delay for high data rate (CQI=7) with 1km coverage	155
Table 4.11	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) on average end-to-end delay for high data rate (CQI=7) with 1km coverage	155

Table 4.12	LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average energy consumption on 1km coverage for high data rate (CQI=7)	157
Table 4.13	LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average energy consumption on 1km coverage for high data rate (CQI=7)	157

LIST OF FIGURES

	Page
Figure 1.1 Deadliest natural disaster in human history	2
Figure 1.2 Top 11 countries with most disaster 2005-2014 (Pappas, 2018)	3
Figure 1.3 The economic and human impact of disaster in the last ten years (Pappas, 2018)	3
Figure 2.1 LTE system architecture	44
Figure 2.2 Show each of the colours represent the user data to permit users sharing available bandwidth.	48
Figure 2.3 Difference between Distributed and Localized mode	49
Figure 2.4 OFDMA Vs SC-FDMA	49
Figure 2.5 Shows subcarrier mapping mode: Distributed Mode and Localized Mode	56
Figure 2.6 Research map for VASNET in emergency field and UAV in disaster area for channel assignment studies from year 2018-2023	56
Figure 3.1 Summary of research flow on this research study.	80
Figure 3.2 Suggested protocol operation with 2 interfaces and 3 channels	87
Figure 3.3 A simple description of the proposed network Interface	87
Figure 3.4 Suggested fixed interface and switchable interface devices to devices communication	88
Figure 3.5 Proposed generic interface architecture	88
Figure 3.6 The suggested architecture of Interface	90
Figure 3.7 New added field in MIMC proposed packet	92
Figure 3.8 Proposed channel assignment method	96
Figure 3.9 Proposed reliability control of multicast	98
Figure 3.10 State transition for a sample path	101
Figure 3.11 Markov Chain in wireless networking environment	104

Figure 3.12	Absorbing transition probability	106
Figure 3.13	Reflecting transition probability	106
Figure 3.14	Circular Random Walk	107
Figure 3.15	Circular transition probability	108
Figure 3.16	Matrix form of $N \times 1$	111
Figure 3.17	The MDP on Tree diagram of the iteration value	112
Figure 3.18	Proposed network hierachy	116
Figure 3.19	Proposed network hierarchy architecture	116
Figure 3.20	Proposed overall sequence diagram	118
Figure 3.21	Proposed node registration sequence diagram	119
Figure 3.22	Proposed network discovery formation sequence diagram	120
Figure 3.23	Proposed location detection sequence diagram	121
Figure 3.24	OFDM signal processing chain	122
Figure 3.25	SC-FDMA signal processing chain	124
Figure 3.26	General MIMO system	125
Figure 3.27	SU-MIMO and MU-MIMO	126
Figure 3.28	State diagram for proposed packet scheduling	129
Figure 3.29	Various CW ranges for different priority	131
Figure 3.30	Operation of DIFS and SIFS	132
Figure 3.31	Proposed topology (Markov Model)	134
Figure 3.32	UE power consumption model	137
Figure 3.33	Simulation scenario	141
Figure 4.1	Simulation time and coverage justification result	145
Figure 4.2	Simulation result for LTE-AIC, LTE-A and LTE for packet loss 1km (CQI=2)	146
Figure 4.3	Simulation result for end-to-end delay for low data rate (CQI=2)	149

Figure 4.4	Average energy consumption for 1km coverage on low data rate (CQI=2)	151
Figure 4.5	Show the simulation result for average packet loss on high data rate (CQI=7) for 1 km coverage	153
Figure 4.6	Shows average end-to-end delay for high data rate (CQI=7) on 1km coverage	155
Figure 4.7	Shows the simulation result of average energy consumption for high data rate (CQI=7) on 1km coverage	158
Figure 4.8	Energy consumption vs packet loss in CQI= 2	160
Figure 4.9	Energy consumption vs packet loss in CQI= 7	161
Figure 4.10	Delay vs packet loss on CQI= 2	162
Figure 4.11	Delay vs packet loss on CQI= 7	162
Figure 4.12	Energy consumption vs delay on CQI= 2	163
Figure 4.13	Energy consumption vs delay on CQI= 7	163

LIST OF ABBREVIATIONS

3GPP	3 rd Generation Partnership Project
AM	Acknowledge Mode
ANC	Announcement Packet
ANN	Artificial Neural Networks
AODV	Ad-Hoc On-demand Distance Vector Routing
AP	Access Point
APPS	Application
BB	Base Band
BFT	Beam Forming Transmission
BSC	Base Station Controller
BSS	Base Station
BTS	Base Transceiver Controller
BW	Bandwidth
CC	Compensation Counter
CDD	Cooperative Data Dissemination
CDMA	Collision Detection Multiple Access
CELL _D CH	Cell Dedicated Channel
CELL _P CH	Cell Paging Channel
CIF-Q	Channel-Condition Independent Packet Queueing
CoMP	Coordinated Multipoint
CQI	Channel Quality Indication
CR	Cognitive Radio

CRN	Cognitive Radio Networks
CS	Control Server
CSMA	Carrier Sense Multiple Access
CSMA/CD	Collision Sense Multiple Access with Collision Avoidance
CTS	Clear-To-Send
CVN	Cognitive in Vehicle Networks
D2D	Device To Device
DC	Deficit Counter
DCF	Distributed Coordination Function
DE-OLSR	Differential Evolution Optimized Link State Routing
DFT	Discrete Fourier Transform
DINS	Distributed Inter-Node Space
DL	Downlink
DMS	Disaster Management System
DRR	Deficit Round Robin
DSR	Diameter Signalling Router
DSRC	Dedicated Short-Range Communication
DSRP	Dynamic Source Routing Protocol
DSS	Disaster Surveillance Services
E-UTRAN	Evolved UTMS Terrestrial Radio Access Networks
eNodeB	Evolved Node B
ePDG	Evolved Packet Data Gateway
FAMA	Flow Acquisition Multiple Access
FDD	Frequency-Division Duplex
FFT	Fast Fourier Transform

FSF	Frequency Selective Fading
FTP	File Transfer Protocol
GERAN	GSM Edge Radio Access Networks
GPS	Global Positioning System
GUI	Graphical User Interface
HSS	Home Subscriber Service
IaaS	Infrastructure as a Service
ICI	Intercarrier Interface
I-CSDPS	Improved Channel State Dependent Packet Scheduling
ICT	Information Communication Technology
IEEE	Institution of Electrical and Electronic Engineer
IFDMA	Interleaved SC-FDMA
IFFT	Inverse Fast Fourier Transform
IMT-A	International Mobile Telecommunication-Advanced
IoT	Internet of Things
IPv4	Internet Protocol version 4
IPv6	Internet protocol version 6
ISI	Inter-symbol Interference
ISM/UNIF3	Industrial, Scientific, and Medical/ Unlicensed F3 band
ITS	Intelligent Transportation System
ITSS	Intelligent Transportation System and Service
IWFQ	Idealized Wireless Fair Queueing
LoTEM	Location-based Temporal Macro Task
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced

LTE-AIC	Long Term Evolution-Advanced Improved Channel
MAC	Medium Access Control
MACA	Multiple Access with Collision Avoidance
MAI	Multiple Access Interference
MAN	Metropolis Area Networks
MaxCIR	Maximum Carrier-to-Interference Ratio
MBMS	Multimedia Broadcast Multimedia Service
MC-IF	Multi-Channel Interface
MC-MAC	Multi-Channel Medium Access Control
MIMO	Multi-Input Multi-Output
MME	Mobility Management Entity
MU-MIMO	Multi User Multi Input Multi Output
NetIF4	Network Interface
NLOS	Non-Line of Sight
NS-2	Network Simulator-2
NS-3	Network Simulator-3
OBU	On-Board Unit
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing Access
OLSR	Optimized Link State Routing
OSPF	Open Shortest Path First
PaaS	Platform as a Service
PAPR	Peak to Average Power Ratio
PCRF	Policy and Charging Rules Function
PDNGW	Packet Data Network Gateway

PDU	Protocol Data Unit
PF	Proportion Fair
PHY	Physical layer
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
QS	Quantum Size
RAN	Radio Access Networks
RAT	Radio Access Technology
REQ	Request
RLC	Radio Link Control
RR	Round-Robin
RSS	Road Side Sensor
RSU	Road Side Unit
RTS	Request-To-Send
SC-FDMA	Single Carrier Frequency Division Multiplexing Access
SCH	Service Channel
SC-IF	Static Channel Interface
SC-MAC	Static Channel Medium Access Control
SGW	Service Gateway
SHR	Self-Healing Routing
SINR	Signal Interference to Noise Ratio
SINS	Short Inter-Node Space
SMS	Short Messaging Service
SSR	Self-Selective Routing
SS	Speed Strategy

SS	Subscriber Station
SUMIMO	Single User Multi Input Multi Output
SUMO	Simulation of Urban Mobility
Tcl	Tool Command Languages
TCP-IP	Transmission Control Protocol/Internet Protocol
TDD	Time-Division Duplex
TDMA	Time Division Multiple Access
TDMA/CSMA	Time Division Multiple Access/ Carrier Sense Multiple Access
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UM	Un-acknowledge Mode
UMTS	Universal Mobile Telecommunication Service
UMTS/GSM	UMTS/ Global System for Mobile Communication
UTRAN	UMTS Terrestrial Radio Access Networks
VASNET	Vehicular Ad hoc Sensor Network
VoIP	Voice of Internet Protocol
WAVE	Wireless Access Vehicle Environment
WCDMA	Wideband Code Division Multiple Access
WLAN	Wideband Local Area Networks
WMN	Wireless Mesh Networks
WRP	Wireless Routing Protocol
WSA	WAVE Message Announcement

CHAPTER 1

INTRODUCTION

This chapter aims to present the structure and organization of this research. As an initial stage, the research background, problem statement, and research objective will be under discussion in this chapter. Further, it also outlined the research question with research methodology to illustrate the overall image of this research. Finally, it concludes with the chapter-by-chapter outline of the structure of this thesis.

1.1 Study Background

In human civilization from the past until the present era. Natural disasters and catastrophes sacrifice billions of innocent human life around the world. For instance, the Yellow River (Huang He) in China in the year 1887 was the deadliest disaster in human history, around 900,000 people die on this heavy floor. Dykes contain on the river as it flowed among the central of China. It can cause the river to lift in elevation and hit the river with heavy rains swelled in September 1887, the dykes spilled into low-lying land surrounding 5,000 square miles and 12,949 square kilometres. Following the earthquake in Shannxi China that caused 830,000 innocent people died, homes collapsed and fires occurred after an earthquake. Actual reading for magnitude lost in history, but with the latest human technology recorded estimated the magnitude reading is 8. Another deadliest natural disaster was a cyclone that happened at Bhola on 12. Nov.1970. This storm was lifting a 12-foot storm surge over the flat terrain bordering the Bay of Bengal causing widespread flooding. According to the report from the Natural Hurricane Centre and the Pakistan Meteorological Department year 1971. Death estimation of human losses ranges from up to 500,000 people

(Pappas, 2018). The summary of the violent natural disaster presented in Figure 1.1, kill large swaths of the human population until the present day.

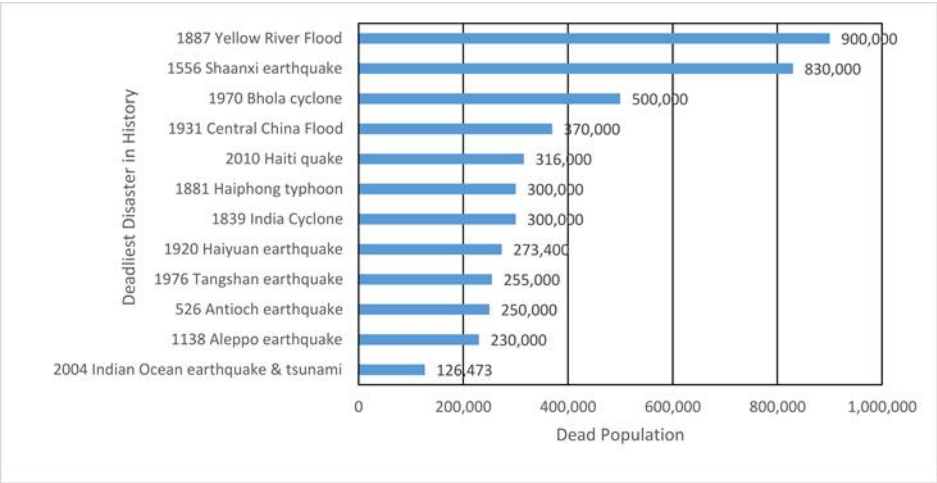


Figure 1.1: Deadliest natural disaster in human history

On the other hand, the rate of disaster increases rapidly every year, which involves the devastation and catastrophe increasing at the same time. Also, every authorize organization has been established to overcome the wreckage of the disaster (Wellington & Ramesh, 2017). China recorded the most disaster cases from 2005 until 2014, based on the data from United Nations Office for Disaster Risk Reduction. The US has incurred the most damage, and while Japan is behind in the number of disasters, its economic loss is almost as significant as China’s. The summary of the top 10 countries hit by disasters between the years 2005 and 2014 that mostly affected human daily life in terms of economics was presented in Figure 1.2.

Economics losses and human impact of the disaster from the year 2005 until 2014, which emphasize the losses of property of around 1.4 trillion in which 1.7 billion people were affected and 0.7 million were killed on disaster occurred. The following shows the Economics and Human impact in the last ten years (2005~2014) in Figure 1.3.

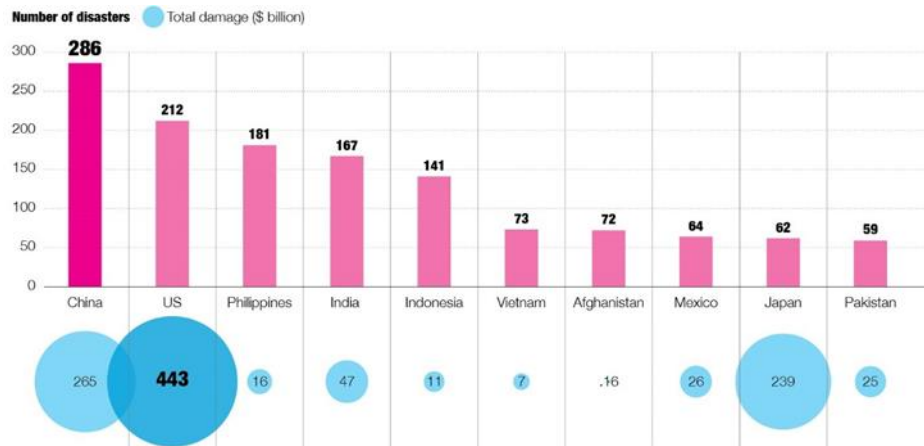


Figure 1.2: Top 11 countries with most disaster 2005-2014 (Pappas, 2018)

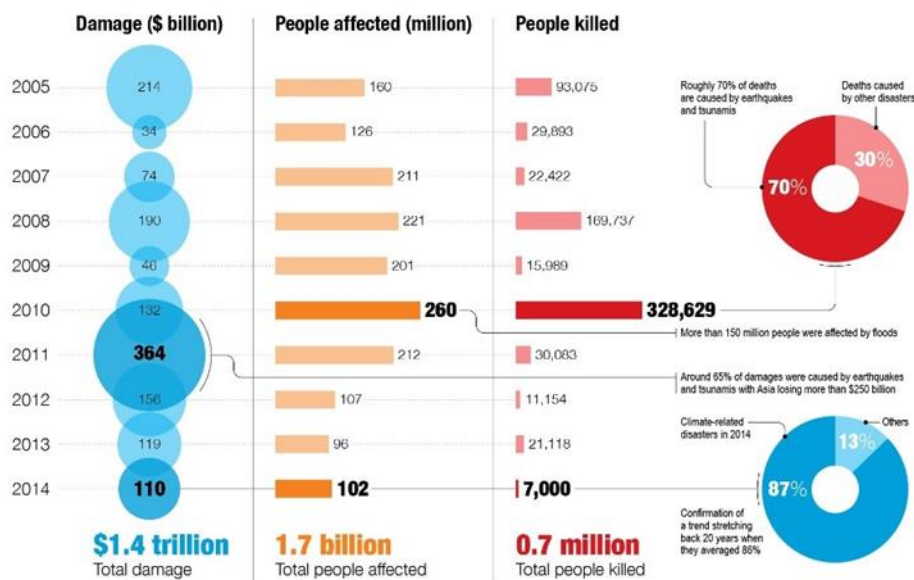


Figure 1.3: The economic and human impact of disaster in the last ten years (Pappas, 2018)

A natural disaster can be defined as the effect of a natural hazard in terms of environment, financial, and human losses. For instance, flood, tornado, volcano eruptions, earthquakes, and landslides (Bankoff & Frerks, 2013). Disaster comprises natural hazards, and human-made disasters happened randomly (Xu et al., 2018). Disasters or catastrophes have significant characteristics of unpredictability and human are not always capable of

avoiding catastrophe to happen. Flexibility and simplicity of the system are, therefore, the primary vital words (Walsh, 1989), to reduce human casualty.

During emergencies on any community, anywhere at any time can negatively impact the community generally and specific public agencies in particular (Valcik & Tracy, 2017). As such, the similar rescue system applies previously are not suitable and effectively implement on various emergency (Asimakopoulou et al., 2011) The rescue system must design in such a way that the flexibility, stability, scalability, and reliability applied to suit various disaster or catastrophes occur. For example, the framework of disaster management for flood situations is prohibited from applying to earthquake situations.

As mentioned above, the rescue team involve various professional from many disciplines with various area of expertise. To bring that expertise from different parties consider the most challenging part in terms of making an appropriate decision during emergency periods. As such, when emergency operations have occurred, "the team members often hardly know each other and frequently have to work co-located.". A team will need to perform "many tasks partly in parallel, partly in series while fighting a disaster". For a successful response operation during a critical situation to unexpected incidents, all members should show knowledge and understanding to access relevant data and expertise as they were able to collaborative assessments to make effective decision-making. Consequently, the latest information regarding the existing situation, decision, and work in the plan should be capable of communicating among relevant and local distributed parties. (Asimakopoulou & Eleana, 2008).

1.2 Problem Statement

A natural disaster, even a human-made disaster, is not a new trend that happened all the time or several decades ago. Billions of innocent people were killed during post-disaster was unexpected and predicted, especially in landslide and tsunami situations. This is because current human technology is unable to verify or even detect the pre-disaster accurately in terms of location or position. Moreover, the evacuation plan, especially during heavy floods during emergencies, was ineffective for large populations of humans. For example, in 2004, a heavy tsunami struck Japan that wiped out almost 230,000 human lives just in a few hours and was declared the deadliest tsunami disaster in human history (Rossi et al., 2018). Trillion of property lost with sacrifices of loved ones may have a big impact on any survivor physically and mentally for the rest of their life. Thus, various research has been conducted by a researcher worldwide to minimize human lives and property loss. Various experts from IT, Engineering, Geology and Medical team up and develop state-of-the-art methodological approaches that cost massive financial support and resources. Which consider unreliable and effectively for any rescue plan created. A systematic rescue plan must be executed to apply to any disaster or catastrophe. For instance, the existing rescue plan for landslides implemented might not be sufficient or effective on volcanoes or floods. Therefore, wireless networking in VASNET has become an essential or main solution to reduce human life by implementing onto strategic rescue plan capable of being used in all types of disasters. For instance, a car trapped on heavy flood and a bus stuck on landslide, in which major communication infrastructure down during post disaster scenario. The smart devices like smart phone, watch and handheld device plays an important role during emergency rescue plan, in terms of communication among rescue team and survivor. Another major advantage of VASNET networking is the transmission medium use of ‘space’ which is the ultimate

choice to overcome wired networks to reduce financial support as the primary purpose for rescue plans in post-disaster scenarios.

From the wireless networking research point of view, the intention to adopt VASNET needs to be examined in a disaster environment. There is a possibility that traditional VASNET is experiencing many problems and limitations to apply to the current disaster management system. According to a study by Tomar (2022) the broadcast mechanism in the mode of simplicity faces heavy broadcast storm networks (Alsarhan et al., 2018), network contention on mobile networks with the problem of a network partition. The authors suggested three methods, namely flooding, counter, and probability, for analysis comparison by implementing a parameter. Nevertheless, this method could have high bandwidth due to massive retransmission probabilities with a huge amount of repetition and delay.

Moreover, frequent topology changes with nodes moving at a high-speed cause broad bandwidth in conventional VASNET infrastructure. A collision might cause unbounded delay, which completely wastes the channel time assigned during a post-disaster scenario (Sharma et al., 2019). Conventional VASNET infrastructure consists of mobile nodes and base stations, with RSU facing high spectrum congestion regard of allocation of spectrum bands, especially in post-disaster situations. Instead of this, the huge amount of devices in traditional wireless networking are unable to handle due to failure of network availability and high outage probability with high losses on packet propagation at network boundary coverage (Wang et al., 2020). Another wireless networking characteristic that can be considered is spectrum scarcity caused by spectrum resources when using DSRC in current research work done by researchers named Liu and Li (2019); the identity of his works in the MAC layer is to prioritize the channel allocation broadcast for safety messages. Related to

current research works, some researchers applied IEEE 802.11p to the MAC layer for communication on vehicular networking. However, due to rapid topology change and high-density node traffic, IEEE 802.11p could not perform as expected on RSU to deliver the message correctly (Gui & Cai, 2021).

Further, the current multi-channel on the MAC layer selects the available channel randomly to broadcast the packet. This channel selection mechanism causes over-utilization and under-utilization of channel resources (Nguyen et al., 2018). Mobile nodes could communicate based on a node-to-node scheme when communication infrastructure broke down during post-disaster. In this scheme, the high probability of channel reuse becomes the main contribution which affects the VASNET networking performance to drop instantaneously. This is due to the channel interference for connecting nodes when channel reuse is present (Dai et al., 2018).

From the above discussion, VASNET unable to implement in a disaster without proper channel assignment to apply, especially on a huge number of nodes. Consequently, there is a need to conduct a research study on channel assignment to cope with those channel problems in VASNET by a proposed algorithm called node establishing and multicasting multi-channel assignment to construct on VASNET for disasters, namely improved channel methods that potentially used on various disaster or catastrophe occurs.

1.3 Research Question

From the previous discussion in the section Problem Statement. There is a finding or positive gap in current research work conducted by professional researchers worldwide. High spectrum congestion or spectrum scarcity occurred during multi-hop or multi-node approach communication during post-disaster scenarios. Similarly, RSU functions to form a

vehicle-to-Infrastructure (V2I) communication that is also unable to be executed as it might fully or partially destroy during a disaster or catastrophe occurs (Ahmed et al., 2013). Modifying the current VASNET is a must to implement varying emergency rescue plans that will become more effective and efficient. Apart from that, various channel assignment research methods were conducted mainly on clustering approaches. Which also rare to conduct large-scale scenarios and centralised approaches to effectively and reliably, mainly to rescue a survivor or victim as many as possible in the shortest time. Hence, to achieve the research objective, a specific research question are presented as follows.

- 1). How to reduce channel repetition, redundancy, and interference in multiple channel mode for VASNET in Disaster Management System?
- 2). What kind of method is to be used to prevent under or over-channel utilization in multi-channel multi-node on VASNET architecture in Disaster Management System?
- 3). How to distribute a spectrum resource in the multi-channel multi-node environment on VASNET architecture in disaster management system?

1.4 Research Aims and Objective

There is room for this research study to use in Search and Rescue operations during post-disaster scenarios. Network formation on multi-channel, multi-cast and channel assignment formation algorithm proposed to achieve the research aim. Communication among rescue teams and survivors is one of the studies to alleviate the disastrous consequences and save more human lives during an emergency. Attempting to develop an effective channel assignment, interface, and protocol operation is the key point that works

in Search and Rescue Operations. In this research, the parameter used to evaluate the proposed algorithms and methods is also understudy to validate the performance in terms of reliability. Following is the objective outlined to achieve this research aims.

- 1). To design an interface architecture with channel assignment and network establishing algorithms in multi-channel to avoid channel repetition, redundancy, and interference on current VASNET infrastructure.
- 2). To utilize the channel assign in VASNET infrastructure by construct a Packet Scheduling and Markov Chains.
- 3). To apply OFDMA in downlink and SC-FDMA in uplink on VASNET infrastructure to reduce spectrum scarcity.

1.5 Research Methodology

This section discussed the research methodology implemented in this research process to gather and assess any related information to develop and evaluate the proposed improved channel assignment method.

A literature review is applied to gather relevant information about current research involving channel assignment or allocation used in the disaster management system. This ability assists the understanding of the complexity of emergency management structure with the particular emergency response due to the phases of any natural disaster or even human-made disaster. Secondly, identify any problem or research gap of current technology used on channel assignment in disaster management systems. Furthermore, the literature review presented relevant information on current ICT technology applied when emergency response is operating in general, with the type of communication protocol implemented during the

post-disaster scenario in particular. Thus, by this literature review, we can notice existing research limitations conducted by other researchers regarding network infrastructure, hardware modelling, and system or algorithm implementation on search and rescue operations.

A more in-depth study of the search and rescue operation framework to further understand disaster management systems through the literature review process. The hypothesis of the research able to be provided and constructed to meet and achieve the research aims and objective. The proposed improved channel method could be constructed or designed for this study to meet the designed hypothesis capable of contributing new development or knowledge of channel assignment on VASNET in disaster management systems used on various catastrophes to reduce human casualties effectively.

The method proposed will undergo testing by using simulation tool to examine the reliability of communication protocol and performance. Data collected undergo analysis to validate that the result meets the research required before generating a technical report to share a new contribution of this research on VASNET for improved channel assignment method. Data gathered after analysis can only meet the research requirement under study for the hypothesis once it fulfils the research required before generating a technical report.

1.6 Hypothesis

This research study focus on designing an interface to optimize the communication by integrate improved channel formation algorithm, network formation with a packet scheduling algorithm of VASNET in the disaster management system among the rescue team and survivors.

1.7 Main Contributions

The main contributions of this research can be summarized as below.

1. Introduced an interface to VASNET on improving channel assignment algorithm in the disaster management system. To develop the method, involve the interface on transmitter switchable fixed receiver that able to leads to the development of node establishing (hierarchical) with network formation algorithm in multichannel multicast approach.
2. To develop packet scheduling algorithm and apply Markov Chain in this research for channel assignment approach in order to overcome the channel reuse and repetition with redundancy in multi-node environment.
3. Implement OFDMA and SC-FDMA on uplink and downlink communication for VASNET in Disaster Management System. Apply LTE-AIC in this research instead of conventional VASNET short range communication protocol like DSRC.

1.8 Limitation and Significance Study

In this section, a few challenges and limitations that related to channel assignment will undergo discussion as below.

1.8.1 The level of connectivity

The assigned channel for each of the nodes that connect with each other and receive the reply message will result in a decreased connectivity degree. The transmitter-receiver switchable approach shows the highest level of connectivity due to broadcasting and reception in any channel compared to the transmitter switchable with a receiver fixed. However, this is only sometimes true, as the reason below.

The transmitter-receiver switchable approach requested current common channel control compared to transmitter switchable with a receiver fixed. Therefore, the probability of the network being linked together depends on the current common channel control probability. Another reason was common channel control inhibition for data communication (Almasaeid & Kamal, 2014). This gives way for the transmitter to be switchable with the receiver fixed to another channel to be used for data communication. Lastly, the effectiveness of connectivity on available channels distributed to a node and its nearby node. It is likely for the available channel at the specific node to be free at its nearby node, which can minimize the likelihood of a node getting disconnected from its nearby node with the requirement of the fixed assigned channel to receive on it.

1.8.2 The problem of deafness

This problem was very obvious to occur on wireless networking equipped with directional antennas (Gossain et al., 2004). The deafness occurred when node 1 wanted to communicate with node 2, and node 2 was currently communicating with node 3. Due to this, node 1 experienced no reply from node 2 (caused by the node 2 antenna being tuned to node 3) and executed systematic backoff processes. This becomes worse if node 2 transmits a message or packet multiple times, in which node 1 will perform several backoff processes meaninglessly. Assume f_1 , f_2 , and f_3 represent the assigned channels to nodes 1, 2 and 3, respectively. When node 1 fails to connect with node 2 on f_2 due to node 2 being tuned to f_3 and node 1 performing an unnecessary backoff process results in a similar deafness problem on directional antenna use. This problem is not valid on transmitter-receiver switchable and transmitter-fixed receiver switchable as the nearby node transmitter can notice the ongoing communication process by overhearing the information broadcasting on common channel control (Almasaeid & Kamal, 2014).

1.8.3 The problem of multichannel hidden node

This problem is popular in wireless networking communication. In conventional single-channel wireless networking, MAC protocol used IEEE 802.11. The RTS/CTS applied among the transmitter and receiver are able to cope with this hidden node problem. However, in transmitter switchable with receiver fixed mode. This hidden might exist in a multichannel environment. Therefore, the RTS/CTS need to be cloned on this multichannel rather than using a single interface among the node that significantly shows the most delay problems (Almasaeid et al., 2015).

1.9 Publication

This thesis included work that has been published in journal and conference as listed as below:

1. Jambli, Mohamad Nazim and Shoon, Sia Chiu and Khan, Adnan Shahid (2016) A survey of VASNET framework to provide infrastructure-less green IoT communications for data dissemination in search and rescue operations. *Journal of Electronic Science and Technology*,14(3). 220-228. ISSN1674862X
2. Shoon, S. C., Jambli, M. N., Suhaili, S. M., & Zakaria, N. H. (2022). Evaluating hybrid framework of VASNET and IoT in disaster management system. *International Journal of Advanced Computer Science and Applications*, 13(9).

1.10 Thesis Outline

This thesis consists of 5 chapters as discussed as below.

Chapter 1: Introduction

Introduces the background of the disaster history from past until present day, including problem statement, research aims and objectives, outlined the research question, research methodology, hypothesis, main contributions with limitations, and significance of the study.

Chapter 2: Literature Review

The background of this research in the disaster management system introduced a method of technologies implemented in search and rescue operations in various situations. The problem of current research, such as energy consumption, channel assignment method, and communication protocol.

Comparison of a simulation tool to examine the suggested methods and algorithms described in this chapter.

Further, this chapter outlined the type of disaster (natural and human-made) or catastrophe that occurs. Definition of risk, hazard, vulnerability, the disaster with the management of emergencies and disaster functions and structures. The studies and overview on related works were conducted by using a research map to illustrate more clearly and precisely.

Chapter 3: Research Methodology

Focus on the proposed network formation and node registration algorithm. An interface designed link with channel assign, energy consumption study, the communication protocol used on this research and elaborate the reliability with suggested packet scheduling

algorithm as well. Node coordination approach by using Markov Chain and Markov Decision Strategy with parameter use to validate the result for any research finding to achieve research objective also highlighted in detail in this chapter.

Chapter 4: Results and Discussion

Identify the simulation result by using a parameter (Packet loss, Delay, and Energy Consumption) and validate the research with the hypothesis. Define the simulation time and coverage to validate the proposed methods and algorithms and present the simulation result performance and data analysis in graphical form in detail for discussion was under this chapter.

Chapter 5: Conclusion and Future Work

Conclude by summarizing the research study contribution. Indicate and confirm the research study to achieve research aims and objectives. Highlight a future works was under discussion in this chapter.

1.11 Summary

This chapter discussed the background of this research, with the problem statement to be justified, and the aims and objectives of this study including the research methodology used. The research question, hypothesis, main contribution, and limitation with the significance study also being discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The rapid development and comprehensive utilization of wireless communication technologies are able to benefit and transfer daily human lives by providing the most convenience and flexibility in accessing Internet services and various applications. Recently, researchers conceptualized the idea of communicating with vehicles on the rise of Vehicular Ad-Hoc Sensor Networks (VASNETs), in which the main focus of scientists and engineers who yearn to turn cars into smart or intelligent machines that are capable of communicating for safety and comfort purposes. Moreover, VASNET technology, equipped with wireless communication devices, positioning systems, and digital maps directly being chosen for disaster management systems (Artail & Merashad, 2012).

Wireless sensor technology, which is able to sense, process data, and broadcast data in terms of various physical and dynamic environmental changes, is crucial for natural disaster management. Sensor nodes that could detect the humidity and temperature were ultimately helpful for detection.

In this chapter, we addressed the current research works on disaster management systems using the wireless sensor, VASNET, VANET and UAV are classified into the following subchapters. The overview of channel assignment under discussion to identify clearly why this research is conducted by introducing a channel assignment method, interface mode operation, packet scheduling with research gap and introduction of OFDMA and SC-FDMA on objective with advantages of those OFDMA and SC-FDMA that be

elaborated in this chapter. Moreover, the definition of a disaster management system was clearly discussed in this chapter. Lastly, a comparison of various network simulation tools in any aspect to select the most suitable simulation platform for the proposed methods and algorithms also be presented in this chapter.

2.2 Related Works

2.2.1 Time Slot Multichannel

Channel allocation in a fixed-size environment may cause insufficient channel resources for the huge amount of messages in broadcast and a waste of channels in fewer-message broadcasting. The limitation of channel resources leads to improper channel resource distribution. Further, multi-channel for the hidden terminal could have been more efficient in reusing time slots. Therefore, to overcome those problems, the authors (Nguyen et al., 2018) presented a multi-channel MAC protocol under TDMA and CSMA to justify the time slot according to traffic density. The suggested Markov Chain is used to justify the time slots under high saturation traffic. In the author's works (Yu et al., 2018), Markov Chain was implemented on a selected back-off period for contention window under conditions of highly saturated traffic. At the beginning stage, the selected contention window is under its optimal size and occasionally updates the size. This helps in the transmission of new messages as well. In the author's works (Aung et al., 2018), the Markov Chain model was introduced to predict the accident likely in urban areas among the correlation of latent variables with observations. This variable consists of velocity, location, and weather with density. In this paper (Wang et al., 2019), the authors presented a TDMA approach for utilizing research on effect capture and frame length setting by RSU. A discrete-time Markov Chain applied by authors is for analysing the effect capture on channel utilization. In this author's works (Johari & Krishna, 2022), RSU with vehicles regularly transmits a WAVE

Message Announcement (WSA) message on the network. The vehicles accepted the message, able to communicate with a provider through BSS. In a stochastic environment, the existing state of the system can calculate the probability of the incoming or next state based on the Markov model. Therefore, the author presented an approach of the Markov model to verify the probability of any successfully reserved time slot and determine the channel switching if all the channel was fully occupied without any time slot for any available channel reserved. As such, the authors developed an algorithm so-called the time slot allocation function in the Markov model and the reusability of the time slot function. Based on the author's proposed algorithm, the reservation time slot was done by identifying the probability of a successful time slot on any requested channel. Various types of cases could be considered as available time slots requested or no available time slots with the quantity of contenting nodes larger than the sum of available time slots. Inversely, where there is no available time slot at a particular time, a node is under waiting conditions for a specific time slot. As such, the author also introduced an algorithm called selecting victim node function for this purpose.

For the channel switching environment, the algorithm's so-called function of channel switching was discussed in his works (Johari & Krishna, 2022). According to this proposed algorithm, the Markov model is applied to determine the probability of switching from an existing channel to a requested channel. In other words, the switching probability from the existing channel to another depends on the type of message broadcasting. Therefore, the vehicles transmit the message in a requested channel with a reserved time slot. Another author works on a similar time slot (Nguyen et al., 2016) introduced Dedicated Short-Range Communication (DSRC) in multi-channel MAC using TDMA/CSMA in the VANET environment. Each node is equipped with a specific time slot under TDMA reserved time

and broadcasts an Announcement Packet (ANC) on the mentioned time slot. Each time slot for the respective node transmits on the ANC packet contains information about the adjacent node. Once it received the ANC packet from adjacent nodes, it also learned the adjacent nodes. As such, this method can minimize the reservation time frame, in which the node transmits an ANC packet containing a TDMA reservation time frame in this author's works.

Further, the author (Nguyen et al., 2016) proposed a discrete-time Markov chain with transition probability on the TDMA time slot that can reduce the collision probability when a new node is in an increasing trend. In other words, collision among the node for packet transmission in the same time slot will decrease and improve the delay in the time for packet transmission. However, this author's works face a high payload to transmit onto any nearby node when the node density becomes bigger, especially in the metropolis area. Even though the authors proposed a discrete-time Markov chain, some of the authors could clearly discussed channel switching with delay time for any vehicles or nodes in more detail. Apart from this, the energy consumption of packet broadcasting may lead to the proposed Markov Chain works being degraded in terms of throughput and efficiency. This is a positive gap for this research field to consider the study of packet energy consumption in disaster or catastrophe on post scenario by implementing Markov Chain for VASNET in the channel switching field. Inversely, some of the papers need a thorough discussion of the limitations and challenges of the proposed system. The paper (Aung et al., 2018) needs to provide a detailed analysis of the computational complexity and resource requirements, which limits its scalability and practicability to verify its effects on real-world scenarios.

Moreover, the paper (Nguyen et al., 2018) does not critically analyse Markov model assumptions and limitations. For the paper (Yu et al., 2018), a proposed solution is

impractical in a real-world environment. For instance, the MAC protocol requires a control channel for reservation, which may not be feasible in large-scale VASNET. Some schemes require accurate predictions of vehicle density, which is only sometimes possible, mainly during disasters. The paper (Johari & Krishna, 2022) could explore alternative approaches to address the challenges of multi-channel TDMA MAC for Service Channel (SCH) for using cognitive radio and software-defined networks. Overall, there is a room to explore further and analyse the challenges and solutions related to time slot reservation with channel switching in vehicular ad-hoc networks.

2.2.2 Scheduling Channel Prediction

There is a big impact of VASNET characteristics in emergencies that experience high mobility of vehicles, and high delay in data broadcasting due to shorter time connection with frequent communication changes among RSU and vehicles (Liu et al., 2016; Wu et al., 2018). In order to cope with this problem, authors (Zeng et al., 2017) introduced an algorithm called recursive least squares for channel prediction on a large scale with less computerization in real-time situations. In this research study, authors proposed that each vehicle is equipped with a GPS module consisting of velocity and position that can link with RSU for data transmission. This RSU relates to Control Server (CS) by a backbone wired to execute the schedule when vehicles enter the region provided with an RSU. The CS executed scheduling by making channel prediction decisions through Vehicle-to-Infrastructure (V2I) communication. This enables the number of vehicles in a particular region can be identified and calculated through this proposed algorithm. Once the CS completes an algorithm analysis, it will transmit the prediction channel on the transmission phase to the relay node in a specific region. It potentially assigns a predicted channel to all vehicles under that region through Vehicle-to-Vehicle (V2V) communication. Nevertheless, in real situations for large-

scale, the number of vehicles in a specific area or region may increase tremendously and high-speed movement. This might cause some channels to be predicted as unassigned and become redundant channels. Not less, the author was not defined, more specifically, any vehicle entering overlapping regions among two RSU, which will cause channel repetition and interference that degrade the performance of proposed research works. Moreover, by consideration of CS for the proposed strategy, which is impractical for all VASNET deployment. To overcome the limitation of the author's works (Zeng et al., 2017), the authors (Zhang et al., 2020) presented multi-channel data broadcasting scheduling algorithms. This algorithm indicates that message sending in an emergency is sound time-sensitive. It needs to transmit to a particular vehicle before the assigned time provided comes to an end. Therefore, highly requirement for the stability of data broadcasting must be in scheduling mode. As such, this author constructed an interference map based on the traffic situation. This map presented a broadcasting scheme of any vehicle that received the data, and the edges showed interference among the broadcasting scheme. Further, the author also introduced a channel assignment algorithm based on the Signal-to-Noise ratio (SINR) calculated by RSU before allocating the channel. Consequently, if a specific vehicle SINR is larger than the threshold set, it might consider the specific vehicle receives data successfully. There are other author works in this data broadcasting scheduling field on the interference graph. Authors (Liu et al., 2015) presented an algorithm so-called Cooperative Data Dissemination algorithm (CDD) to cope with the problem of scheduling with a greedy algorithm. It suggested an RSU manage the V2V and V2I communication data broadcasting that shows the coordinated data broadcasting scheduling is an NP-hard problem. The data schedule is moved into a bigger set-in interference graph independently. Lastly, RSU transmits to the corresponding vehicle to improve throughput. An author (Azizian et al.,

2016) discussed a clustering broadcasting scheduling scheme. This scheme can allocate the designated time slot in various subsets, improving the throughput by providing free contention transmission for specific vehicles. Another author (Peng et al., 2019) presented data broadcasting scheduling in the multi-channel algorithm. This algorithm constructs a conflict matrix according to the relationship among request vehicles for transmission. It showed that the constructed conflict matrix having semi-definite is positive for a channel assignment to cope with the problem of the scheduling scheme. It organized a conflict graph by asking the model and solving the graph to gather the broadcasting scheme optimally. Nevertheless, the paper (Azizian et al., 2016) assumed that interference from the transmitter could be an additive noise. However, the interference can be more complex in real-time environments and may not be accurately modelled as noise. This paper also assumed that each route is a two-hop at most. It may not be a realistic assumption in overall scenarios, and the proposed solution may not be applicable in more complex network topologies. The author's paper (Zhang et al., 2020) does not consider scalability, complexity, and energy efficiency factors. This paper does not address the potential impact on the proposed algorithm with potential trade-offs among different performance metrics. This paper lacks of discussion for the practical implementation of the proposed algorithms and potential challenges with limitations in real-world scenarios. For instance, the proposed algorithm assumes perfect channel conditions and does not consider the impact of channel fading, shadowing, and other environmental factors on algorithm performance. Overall, those paper primarily focuses on the technical aspect of the problem and does not consider the potential practical implication of the proposed solution. It also does not address the potential limitations or challenges that may arise in implementation in a real-world environment.

2.2.3 Hungarian Algorithm in Channel Allocation Scheme

According to Federal Communications Commission (FCC), the IEEE MAC 802.11p-based contention was not insufficient to apply to Cognitive in-Vehicle Networks (CVN). Due to this reason, many researchers are working related to this field. Such as the authors (Zhang et al., 2014) presented the cooperative spectrum in multiple-channel Cognitive Radio (CR) networks. In this work, the channel characteristics have been reflected. Authors (Luo et al., 2014) proposed channel scheduling, power allocation, and access, especially for trade-offs between power dissipation and capacity in perception situations. For channel allocation by other authors (Almasaeid & Kamal, 2014) suggested a channel allocation in receiver basic. This suggested model was improved compared to the conservative model as an algorithm named heuristic was adapted to cope with a problem by NP-hard integer linear programming. In authors (Li et al., 2017), a Markov strategy was presented to implement on channel resource assignment scheme, with the model reward of roadside analysed. By applying this strategy, a great return to the overall system was varied categories of service are allocated adaptively by several channels assigned. Similar authors (Liu & Li, 2019) employed a Hungarian algorithm in VANET for the channel assignment scheme. In this scheme, the author introduced a new method named matrix rule to work together with the proposed algorithm. This matrix rule subtracted a repetitive row of elements with the most negligible value on each row to gather a new matrix. A similar method applies to columns to obtain the new matrix as well. Next, the minimum value of the row and column in the new matrix was covered by a 0 value to determine that the order of the matrix was equal to the number of lines created. Therefore, this matrix can justify the channel allocation value from the proposed Hungarian algorithm.

Nevertheless, the paper's authors (Zhang et al., 2014) suggested different approaches to overcome the problem. However, it still needs to be determined how scalable these approaches are in large-scale Cognitive Radio Networks (CRN) with a large number of RSUs and channels. Regarding the channel access in the joint relay, the paper (Luo et al., 2014) does not consider the impact of interference from another wireless network on the performance of the proposed schemes. The paper by Almasaeid and Kamal (2014) assumes that channel availability at a RSU may be different in dynamic environments. Secondly, an assumption for a simple path loss model for channel attenuation, which may not accurately reflect the real-world scenario. Using a simple path loss model may limit the applicability of the proposed model in real-world scenarios. Thirdly, the assumption of all cognitive radio has the same transceiver sensitivity, which may be different in practice. In the author's paper (Liu & Li, 2019), the assumption may not always hold in practice, and the paper does not provide a clear strategy for handling situations where the priority of users changes dynamically. Lastly, all the above research work applies DSRC, which is unable to achieve bandwidth requests in-vehicle networks that cause high latency.

2.2.4 Enhanced MAC Protocol in Channel Assignment

In recent years, several research papers published and studied the MAC protocol on channel access divided into various categories, namely Clustering-based, TDMA-based, and multi-channel-based with Ad-Hoc based MAC protocol. For Clustering-based applied on VASNET in multi-channel. Authors (Zhang et al., 2006) developed a MAC-based network in real-time traffic to improve throughput. Unfortunately, the high trade-off value between throughput and latency causes the most significant effect that degrades the performance of this author's works. For instance, it is still being determined how the proposed scheme would perform in highly congested traffic scenarios or in areas with poor network coverage.

Moreover, the authors (Anusuya & Sakthi Priya, 2021) implemented a clustering-based equipped with an On-Board Unit (OBU) as an interface and dual antenna that is able to switch between DSRC and ISM/U-NIF3 bands. In this clustering mechanism, speed and heading became a parameter to enable communication between vehicles within a cluster. Apart from that, a table called channel availability is also presented by authors Anusuya and Sakthi Priya (2021). The corresponding channel is assigned to the channel frequency in DSRC and ISM bands. The channel status indicated "0" for idle and "1" for busy. In addition, the author developed an algorithm called channel allocation for this work. Based on this proposed algorithm, when a free channel is available, the message is mainly transmitted to its destination node. Else, the message is checked in case the channel is fully occupied. However, this might cause high latency and unreliable connection in the condition of the massive number of cluster-based nodes.

Further, the high mobility of the node makes it possible to break a connection using DSRC, making this research work unsuitable for implementation in disaster scenarios. Following the TDMA protocol, authors (Sahoo et al., 2013) introduced virtually implemented segments on the network. A local coordinator node provides a time frame to transmit to all nodes over a network. However, this TDMA protocol is facing a hidden terminal when a selected node as a coordinator with high mobility, causing the main limitation in this author's works. Regarding multi-channel MAC protocol, the authors (Han et al., 2012) presented a safe message broadcasting and low latency with high throughput.

Nevertheless, this work requested QoS on maintenance constantly. Ad-Hoc based MAC protocol was developed to prevent congestion in VANET for channel and effectively reduce collision, encounter hidden and exposed terminal as well. However, this Ad-Hoc

based unable to prioritize the safety message, which leads to high delivery time in end-to-end with degradation of throughput performance. Overall, those paper needs to provide a comprehensive analysis of the limitation and challenges of the proposed approach. For instance, Anusuya and Sakthi Priya's (2021) paper assumes that all participating vehicles are equipped with GPS, which may not be the case in real-world scenarios.

2.2.5 Wireless Mesh Networks (WMN) Channel Assignment in Disaster

Instead of VASNET, other author-related works on channel assignment can consider is a Wireless Mesh Networks (WMN) for disaster or catastrophe environments. The connection between WMN and the access point constantly changes, and the path restoration with channel allocation must be considered for a new channel connection. Furthermore, radio interference needs to take into account for multiple channels assigned to improve the WMN. To solve the problem, the authors (Ikeda & Kinoshita, 2019) suggested channel allocation by considering two types of antennas: omnidirectional and directional. The author implemented WMN to suit for disaster by deactivating a few Access Points (AP) to make the routes unavailable with some AP equipped with directional antennae. The deactivated AP's location consists of an omnidirectional antenna for the restoration route. The authors aim to choose AP with fewer hops from the backbone, in which the channel was not allocated. This method assigned the channel with the condition no interference happens on the network, and the same channel was also assigned to the AP interface to establish a connection among the AP. However, fairness consideration between user and throughput is not an essential factor in network congestion or signal strength. Further, the proposed approach does not communicate equally in certain situations, which might only sometimes be the case in actual practice.

2.2.6 UAV in Channel Allocation for Disaster Scenario

In recent years until nowadays, there has been no VASNET research in disasters involving channel assignments. However, the related channel assignment or allocation has been conducted on Unmanned Aerial Vehicle (UAV). Therefore, there is an open and positive gap to fill in order to design an effective and efficient algorithm and method on VASNET to improve the existing channel assignment on the post-disaster scenes. The author introduced the research of UAVs in this channel assignment on the disaster (Dai et al., 2022), providing that UAVs can communicate and become data storage for survivors in post-disaster situations. This UAV plays an aerial base station in the author's works.

Nevertheless, the communication coverage of UAVs was limited by network resources, and the author developed a channel assignment that considers mutual interference in the progress of improving the network throughput. The author (Dai et al., 2022) also discussed channel allocation according to survivor to select the channel based on the Stackelberg game. Whereby the UAV plays as a game leader and survivors as game followers. As such, the author designed an algorithm for the survivors based on this and let the survivor choose the channel to prevent interference and rewards given by equipped with a high transmission rate.

In contrast, the author needed to elaborate on the UAV position based on the Cartesian coordinate for X and Y axis in the disaster area. The authors only discussed the UAV in terms of speed and position with respect to other UAVs. This is very important to know the network's coverage in terms of position to identify the network coverage size. In addition, on-channel assignments in the authors' work could be more logical to deploy in real-time post-disaster situations. The reason for this is that when there is a considerable

number of survivors in the post scenario, the quantity of UAVs to fulfil the survivors on the ground will make the proposed method or approach less reliable and effective.

A similar work conducted by the author (Wang et al., 2020) introduced a dynamic graph colouring algorithm on channel assignment with reusability characteristics. The authors presented a proposed algorithm for channel selection for decentralized situations. This channel selection used local information for self-organizing decision-making. The proposed algorithm adapted to the network topology to integrate on the colouring graph and learn to improve the speed on network topology by fully utilizing the local information in terms of decision making. An amount of UAV was treated as a flying Base Station (BS) to broadcast the information during an emergency in multicast mode to any survivor during a post-disaster environment. This author also suggested a time slot consisting of UAVs and survivors in his research work. This time slot is divided into a set of survivors and UAVs. The decision for channel selection was determined by the 3-D dimensional of the UAV on the selected channel in each time slot with space complexity that included all UAVs, channels, and time slots. The author also discussed the distance between two devices by using Euclidean distance among their coordinates. This improves the author's works (Dai et al., 2022) that were previously discussed.

Moreover, OFDMA was applied to consider the channel able to be reused under the same spectrum. In other words, multiple UAVs can use the same channel in this research study. However, by reuse of channel selection, especially when there is a massive number of survivors or nodes, co-channel interference may occur and cause the network quality issue by multiple bandwidths. This directly requests more energy consumption and delay on node-

to-node basic might experience high trade-off when delivering the packet, which increases tremendously even though OFDMA was applied to this author's work.

Besides, the author (Wang et al., 2020) used a self-organizing method. The author (Fiedler & Glatz, 2007) implemented the self-organizing channel assignment for the disaster recovery phase by proposing IEEE 802.16 interface. This author proposed IEEE 802.16 due to the wide communication coverage and QoS guaranteed. This interface is used with wireless MAN to connect with UMTS/GSM base station, providing connectivity for another router. The interface can connect a cell and router to the network through Subscriber Station mode (SS). Therefore, this author presented a distributed algorithm that automatically connects routers to form multi-hop in a self-organized method. In these algorithms, the router switched an interface to connect the selected router in wireless links under base station mode. The channel was also located at this base station interface. In addition, the network construction is in increasing mode and includes the link selection and link quality estimation with channel assignment. In his work, the author also developed a strategy called divide and conquer to minimize the topology complexity. The author suggested a SNR to measure overall links chosen in topology constructed and implemented link qualities measurement. Based on link qualities, the author adapted a modified Dijkstra algorithm to increase the probability of joining the chosen router to form the following network. This connection requests a switching on BS interfaces to allocate a channel to the interface. By this, all the connected routers and cells are provided with respective channels through an interface with link quality assured. Nevertheless, this author's works need a more vital point involving the terms of topology, in which this topology is not biased to real-time disaster post scenario, especially in the recovery phase due to the rapid change of cell mobility and router position. Consequently, the research works of this author could be more reliable and convincing as all

the work done is under the author's criteria without a deep study of the disaster management systems.

All the previous works discussed rarely involve a resource allocation aspect as this is the essential disaster management system due to channel assignment. Therefore, the authors (Su et al., 2020) introduced a novelty resource allocation on UAVs during disaster relief networks. In this author's works, the base station provides a communication service on User Equipment (UE) for channel allocation. The author implemented the Stackelberg game similarly to the author's works (Dai et al., 2022) for UAVs to access channel optimization. This will increase the efficiency of resource allocation. The author proposed UAVs to deploy UAVs as network operators' base stations on communication capacities when wired communication breakdowns during a post-disaster situation. This UE is able to access networks through UAV to gather a tremendous amount of service during rescue operations. Through this proposed model, the authors introduced a channel allocation algorithm for UEs. This algorithm will select the strategy randomly by determining each of the initial strategies and available strategies. Based on this strategy, the proposed algorithm calculates the initial utility and other utility of strategies before selecting the maximum utility for UEs. Otherwise, the UE will maintain or retain current strategies and update the selection strategies after performing the proposed algorithms. Each of the UEs is able to reuse the channel assigned to communicate a broadcast message through UAV in a specific area for low latency and improved transmission range in disaster scenarios. Nonetheless, the reusability of the channels in this author's works potentially produced interference with other UEs or node-to-node UEs in the same network coverage region. This will reduce the efficiency of the author's proposed work in terms of throughput. The authors also need to discuss in more detail on his work on UAVs, especially on position and height among the UEs to UAV, and

propose or use what kind of theory and work from another author as well. More is needed to convince the author to work on this research study.

Besides resource allocation, high-speed transmission during emergencies and post-disaster plays an essential role in rescuing as many survivors as possible. Therefore, the authors (Gui & Cai, 2021) introduced a combination of millimetre waves (mmWave) with a sub-6 GHz frequency band to pave the way for building high-speed UAVs in disaster relief networks. Authors suggested Beam Forming Transmission (BFT) mechanism to gather SNR value for communication among UAVs and ground terminals for channel assignment. In this author's works, an interference graph construction algorithm has been developed to catch up links that are not used with similar channels concurrently. It sets a threshold value for the interference graph; if the energy efficiency exceeds the threshold value, a new link will add to the same channel as the original links. The author designed an iterative channel allocation algorithm based on this interference graph to reduce mutual interference to ensure energy efficiency less than the threshold value for better channel quality.

The author also presented a training initiation node to equip mmWave BFT to coordinate the training process. When the network size is large, multiple initiation nodes will perform as a hierarchy to cope with it. As such, UAVs became training initiation nodes, and UAVs handled the channel allocation problem. On the contrary, the author could have elaborated more clearly on the maximum number of channels that can be set if most channels are detected over the threshold value when energy consumption is high due to channel reuse causing interference in certain areas. In addition, UAV implementation might need to be more efficient and sufficient during emergencies because UAVs are now rechargeable.

There might experience a communication breakdown in search and rescue situations when the rechargeable battery life span comes to an end.

To conclude this section, below is the summary table for all the related works done from 2019 until 2022.

Table 2.1: Related works summary (2019-2022)

Author	Year	Problem	Method	Algorithm/ Protocol
Tengyuan Liu and RuiFong Li (Liu & Li, 2019)	2019	DSRC unable to achieve bandwidth requirement in vehicle networks caused high latency.	Perform transformation using Hungarian algorithm to gather vehicle location and channel.	Hungarian Algorithm (Assignment problem)
Kohki Ikeda, Kazuhiko Kinoshita (Ikeda & Kinoshita, 2019)	2019	Low throughput due to interference leads to fairness problem on channel assigned	Selected AP channel changed if interference occur on nearby AP	-
Benhong Zhang, Baomi Yuan, Xiang Bi, ZhenChun Wei, MingYuen Zhang (Zhang et al., 2020)	2020	High mobility of vehicle and high data transmission delay lead to a connection time shortage with frequent communication confusion among RSU and vehicles.	RSU in network model. Respective vehicle consists of cache data with data request. RSU transmit data on nearby vehicles.	Multichannel data transmission cooperative scheduling.
Bowen Wang, Yan Jing Sun, Nan Zhao, Guan Gui (Wang et al., 2020)	2020	Co-channel interference	1. Adapted proposed algorithm with network topology for channel allocation 2. Reuse of channel by OFDMA in proposed algorithms	1. Dynamic Graph Colouring Algorithm 2. OFDMA protocol

Table 2.1 continued

Sachin Sharma, Piyush Agarwal Seskadri Mohan (Sharma et al., 2020)	2020	Security Challenges and Future Aspects of Fifth Generation Vehicular Ad Hoc Networking (5G-VANET) in Connected Vehicles	1. Spectrum band allocation due to high spectrum congestion on traditional networks for vary mobile or devices connected to main stations. 2. Traditional sensor network is unable to support huge amounts of devices traffic and leads to packet scheduling and network availability failure. 3. Devices facing high level outage and interference at network coverage. 4. High propagation losses.	5G-VANET
Zhou Su, MingHui Dai, Qi Chao Xu, Ruidong Li (Zhou et al., 2020)	2020	1. Limited transmission rate on UAV in post-disaster 2. Unreliable connection for UAV in disaster situation	1. Suggested resource allocation with UAV, when UAV as Base station to UE 2. Based on potential game among UAV and UEs to access channel optimally 3. Incentive scheme was followed Stackelberg model for UAV	Channel allocation for UEs

Table 2.1 continued

Dr K.V. Anusuya, M. Sakthi Priya (Anusuya et al., 2021)	2021	Spectrum scarcity caused by limited spectrum resources on DSRC.	Implemented Clustering-based message dissemination mechanism to switch among ISM and DSRC band with U-NII3 that transmit safety message.	Channel Allocation algorithm
JinSong Gui, FuJian Cai (Gui et al., 2021)	2021	1.Mutual interface 2. Conventional sub-6GHz having limited spectrum resource	1.Beamforming Training Mechanism to gather SNR value 2. This SNR value is the connection among UAV with ground 3. Plot on suggested graph of interference algorithm 4. Channel can be define based on graph	1. Interference graph algorithm 2. Channel allocation algorithm
Minghui Dai, Tom H. Luan Zhou Su (Dai et al., 2022)	2022	1. Channel congestion when used some channel resources 2. Low network throughput 3. Huge amount of data stored on wireless devices leads to economic losses	Propose UAV as aerial base station for communication with data delivery scheme and suggested channel allocation service	Channel Allocation algorithm based on Stackelberg game (User to choose the channel and lead by UAV as leader)

Table 2.1 continued

Suchi Johari, M. Bala Krishna (Johari & Krishna, 2022)	2022	Channel selection randomly cause over utilization and under utilization	Time slot with Markovian modelling for channel switching	1. Time slot allocation with Markovian model 2. Reusability of time slot 3. Channel switching (Markovian model) 4. Multi-channel TDMA in collision strategy 5. Time-slot hand-over vehicle allocation
--	------	---	---	--

2.3 Overview of Channel Assignment and Proposed Method

For the past 5 years, channel assignment-related research has been conducted by academic researchers around the world. The research was primarily conducted on emergency instead of disaster environments. This is due to the topology and characteristics of current VASNET networking, which involves RSU and vehicle-to-vehicle communication with short-range communication that has been implemented due to the high mobility of this VASNET networking. Thus, communication between two vehicles may generate a distortion with the condition of the same channel applied during network formation and data transmission. To tackle the distortion generated, the channel can switch or assign different channels to reduce distortion with data transmission improvement. Therefore, the authors (Gui & Cai, 2021) introduced an interference graph by gathering the SNR signal to identify the SNR value to assign a channel with the requirement of exceeding a particular threshold value of SNR for a specific node by implementing a proposed algorithm. Instead of using the SNR parameters, a time for message or data transmission, especially for large-scale environments and clustering situations when a considerable amount of nodes be presented in those scenarios. High delay and packet loss reduce the quality of link connection among node-to-node, causing a low throughput in certain areas during an emergency. This significantly impacts a rescue team's gathering first-hand information to identify a survivor's position or location when a communication link breaks down. As a result, the authors (Johari & Krishna, 2022) suggested a time slot channel switching equipped with Markovian modelling for node-to-node communication. According to this author's work, the time slot channel switching proposed potentially improved the delay and packet loss compared with conventional wireless networking.

Apart from that, based on the publisher of the academic research journals for this VASNET in channel assignment for disaster or catastrophe, it becomes a positive gap in which none of the specialist or networking researchers conducted a study of VASNET in disaster involved of the channel assignment topic. However, Wireless Mesh Networking (WMN) and UAV have been conducted in the disaster-affected channel assignment field. The author (Ikeda & Kinoshita, 2019) presented the Access Point (AP) in WMN to be implemented in a post-disaster scenario by indicating the interference that occurs during the search and rescue plan. Channel allocation to a node or survivor is to avoid the same channel implemented on a specific area for a group of AP communication. This method can cope with the problem of interference during post-disaster using WMN networking by emphasizing AP use.

On the other hand, the author (Dai et al., 2022) applies UAV for channel assignment by a proposed algorithm with the Stackelberg game applied to the node on the ground in his study. Similarly, author in (Su et al., 2020) also implemented a method from the author works on (Dai et al., 2022) among UAVs and nodes so-called UE, in such a way that the UAV acted as a leader and UE as a follower. Thus, channel resources assigned based on UAV in a disaster will be rewarded to UE with a suitable data rate for any message transmission. Nevertheless, due to the limitation of communication protocol. The number of UE becomes a barrier that not all UE can send a message or signal concurrently during the post-disaster scenario. Thus, the author's works (Wang et al., 2020) has been discussed improving the mentioned limitation by suggesting OFDMA transmission protocol with a dynamic colouring algorithm by reusing the channel in their work. The author presented a colouring algorithm to allocate the reuse channel based on the colour assigned for post-disaster. This channel reuse facilitates OFDMA, enabling UAVs to communicate UE as

much as possible. This successfully solved the problem of UAV communication. However, OFDMA characteristic is sending or broadcasting a message on multiple frequencies divided into sub-carrier frequencies to a particular receiver node. Even if this method can reduce the interference on the reuse channel, it will face difficulty when broadcasting a message similarly. Some of the UE may not receive the reply message due to the delay or using the same channel that causes the connection link to be affected by packet congestion simultaneously.

Therefore, SC-FDMA is introduced on uplink communication and OFDMA on downlink communication in this research study. As such, the proposed research study in this thesis can be listed as a suggested network-establishing algorithm with a channel assignment algorithm consisting of the hierarchical method with packet scheduling. The interface on the channel in transmitter switchable fixed receiver mode and lastly, Markov decision strategy or Markov chain as well. The details of this proposed methodology will be elaborate in more detail in the following chapter.

2.4 Overview of Operation modes (Interface)

According to the joint temporal of the spectrum availability, different nodes might consist of different types of available sets of channels. As such, 4 operation modes can be described for the respective node as below.

1. Transmitter-receiver switchable

- A node with a secondary node is able to broadcast and receive on any available channel.

2. Transmitter switchable with receiver fixed

- A node can broadcast on any available channel to be received by other nodes on a fixed channel corresponding to the available channel used for broadcasting.

3. Transmitter fixed with receiver switchable

- A node broadcasts a message on a specific channel to any receiver node channel. Nevertheless, only the transmitter node receives a message with the same fixed channel.

4. Transmitter receiver fixed

- A node is only broadcast and received by other nodes on a specific channel (Almasaeid et al., 2015).

The transmitter-receiver switchable is the most popular in the multimode field for wireless networking. It allows the node to apply on any available channel for broadcasting purposes and/or receive the message for the transmitter. Due to this, the problem of channel assignment under this category will be the channel that assigns to connect to each other. A specific node under this paradigm might apply a different type of channel for broadcasting and receiving once the communication link has been established with the adjacent node. Therefore, the transmitter must acknowledge the receiver to tune a designated channel to enable communication among themselves. Nevertheless, the common channel control cannot be used in this paradigm. Because of this reason, it is necessary to devise a new communication paradigm that proposes an allocation strategy using a transmitter switchable with a receiver fixed in this research study.

2.5 Introduction of Packet Scheduling

Nowadays, various wireless networking is growing instantaneously and rapidly designed with the development of packet scheduling algorithms in wireless systems instead of wired technology, which has become crucial research for the packet transmission field. Until now, various researchers have introduced and suggested a massive amount of wireless packet scheduling algorithms in many published research papers. One of the algorithms suggested by authors named Lu et al. (2004) introduced packet scheduling in wireless networks and managed the error that occurred on location for wireless connection links. This suggested algorithm was the so-called Idealized Wireless Fair Queueing (IWFQ), which is equipped with an error-proof service system as a function of reference for predicting channels to monitor the link status for each of the packet flow and verify the status either 'good' or 'bad.' The main difference between the suggested algorithm compared to conventional WFQ is that when a packet is predicted in a bad link state, it would not transmit, and the packet is picked on the next smallest complete time. The whole process repeats until the scheduler gathers a packet to transmit with a good state on the link. However, this suggested algorithm does not consider a delay on a real-time basis. In fact, there is no difference for various applications in QoS requirements. In addition, the throughput guarantees and delay are tightened to each other. In various situations on a real-time basis, delays caused by bandwidth are mostly attractable approaches (Tsou et al., 2001).

Similarly, another author, Stoica et al. (1998), proposed error-proof fair queueing as a reference point called Channel-Condition Independent Packet Queueing (CIF-Q) (Ng et al., 1998). This proposed algorithm selects a Start-Time Fair Queueing (SFQ) as the basis of CIF-Q. The main difference of this algorithm, compared to IWFQ, is that CIF-Q was able to lead the flow to continuously receive at an average rate ar_i , whereby r_i is considered as

service rate to flow in i and a is a parameter configurable. This algorithm distributed a *lagging* flow proportional to its service rate s instead of IWFQ selecting the smallest service tag. However, this algorithm is also unable to achieve delay requirements from bandwidth as IWFQ.

There is a modified version of Deficit Round Robin (DRR), the so-called Improved Channel State Dependent Packet Scheduling (I-CSDPS), presented by A.T. Campbell et al. (1999). In this scheduler, each packet flow has its queue provided in Round Robin schedule format. It will remain 2 parameters name Quantum Size (QS) with Deficit Counter (DC). The function of QS is to verify how many credits are provided to each packet flow on the respective turn. However, on the other hand, the DC is a sum of credit for packet transmission. In the beginning stage, QS credit size will add to DC. Then, the scheduler's task is to serve the queue to transmit the first N packet in the queue, whereby the N is the maximum integer on where l_i is the i th packet size on the queue. After the transmission of DC, it will be minimized. DC will reset to zero when the condition of the scheduler is served a queue and when there is no packet on any queue. In order to receive compensation for each flow, there will lose the service due to a link problem. Therefore, the I-CSDPS added a counter called Compensation Counter (CC) for each respective flow. This CC will track the amount of service loss for each of the respective flow. When there is a link problem, the scheduler will delay the packet's transmission, leading to the decrease of corresponding DC by QS flow and CC increase by a QS.

Further, to prevent problems by unbounded compensation, the accumulated credit in DC will not exceed the DC maximum (DC_{max}). In this DC_{max} cause the trade-off between

the compensation and delay for each flow lost on their service. However, this delay bound is loose and proportioned to a quantity of all packet flow actively (Tsai et al., 2010).

Besides this, there are two most popular packet scheduling algorithms, especially for wireless networking consisting of the Maximum Carrier-to-Interference Ratio (MaxCIR) (Borst, 2003) and the Proportion Fair (PF) algorithm. This MaxCIR can increase the system's capacity with the most reliable channel connection in terms of quality regarding fairness since the connection for the channels of bad quality will not be served. This PF maximizes fairness by choosing the largest channel quality when the related channel quality is the ratio among the existing connection by data rate and its throughput on average. However, the recently published research paper for the PF algorithm stated that most priority connections equipped the channel with high variance (Kazmi & Wiberg, 2003). In other words, the utilization efficiency of radio resources is scarce under a massive amount of downlink traffic; the scheduling, called opportunistic scheduling, had to be considered in a wireless network. This PF was originally proposed by the author named Kelly in his paper (Kelly et al., 1998) for a max-min scheduler to attract a trade-off between user fairness and throughput average. This PF was introduced after the study of unfairness exhibited when CDMA capacity increased by differentiation among various users. The transmission of various users can verify the channel information by maximizing the resource to allocate the user equipped with the best channel to increase the system capacity of the CDMA application. This resource allocation results in minimizing fairness among various users. The PF algorithm increases the fairness between the user and keeps high throughput concurrently.

Further, this PF algorithm potentially achieves multi-user (Tse, 2001; Viswanath et al., 2002). Whereby the scheduler detects the channel fluctuations and schedules, only the

channel quality exceeds the benchmark provided. In addition, this PF is based on a channel scheduling algorithm on the concept of user diversity. This PF extends and is widely applied in single-carrier environments. It was also implemented on a single antenna for non-real-time traffic, which achieved larger throughput compared to Round-Robin (RR) scheme (Borst, 2003). This PF is able to provide some fairness level as the RR on average (Jalali et al., 2000).

2.6 LTE: Architecture

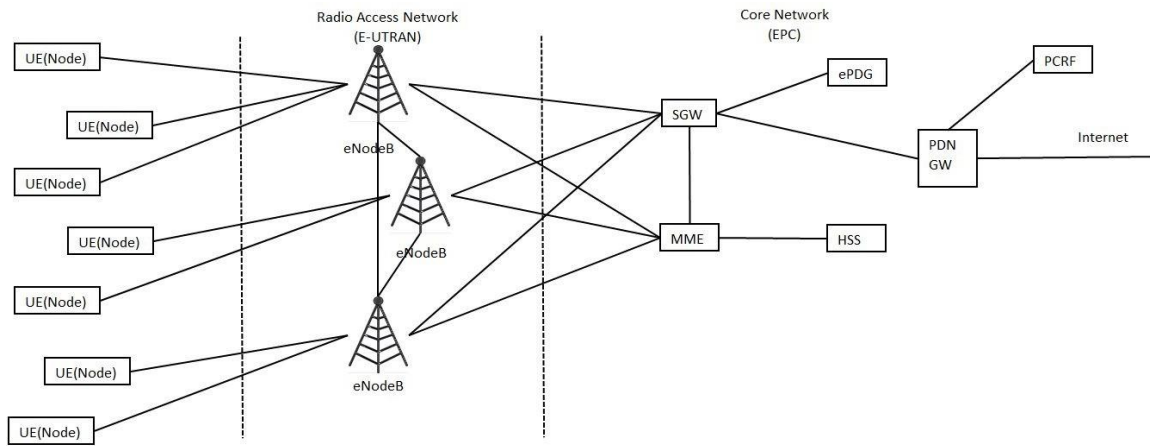


Figure 2.1: LTE system architecture

Figure 2.1 described the LTE network at a high-level description. In the traditional GSM, there consists of BTS with BSC on network UTRAN. It having an eNodeBs with RNC and varies entities inside the core network.

On LTE, it is provided with eNodeBs on the RAN network, which come in various sizes with configurations. These eNodeBs are different from GSM or even UTRAN in that eNodeBs do not have separate controller elements. The primary changes are due to the drive on low response time. One of the QoS parameters is latency. Various interactive applications like interactive games are typically shortened on response time with many elements on signal path and spending much on processing the signal before it can reach a particular destination.

Furthermore, by bringing more intelligence to the eNodeBs, it can handle more requests from the mobile directly from core network without consultation. These may shorten the signal control from latencies (Korhenan, 2014).

Note:

1. SGW: Service Gateway
2. ePDG: evolved Packet Data Gateway
3. PDN GW: Packet Data Network Gateway
4. PCRF: Policy and Charging Rules

Function

5. MME: Mobility Management Entity

HSS: Home Subscriber Server (Korhenan, 2014)

2.7 LTE requirement

For Peak data rate on the downlink, it has a 100Mbps on peak data rate with a 20MHz downlink spectrum allocation (5bps/Hz). Inversely, the peak data rate for uplink is 50Mbps with 20MHz spectrum allocation (2.5bps/Hz). The latency on Control-plane for the transition time for a camped state is less than 100ms for Release 6 in an idle mode to an active state like Release 6 CELL_DCH. In the dormant state, the transition time is less than 50ms for Release 6 CELL_PCH with Release 6 CELL_DCH in the active state. In the capacity of control-plane, they are supported on an active state for a minimum of 200 users per one cell on up to 500MHz for spectrum allocations.

Further, latency on user plane for the unloaded condition for small IP packets is less than 5ms. Moreover, on user throughput, the downlink state for the user throughput average per MHz is 3~4 times for Release 6 HSDPA per MHz in average. Reversely, the uplink enhancement on throughput is 2~3 times for Release 6 in average per MHz. In regards to

spectrum in terms of efficiency. The target for downlink is 3~4 times on a network loaded for Release 6 HSPDA. The target spectrum efficiency for uplink on a loaded network for the Release 6 enhanced link is 2 to 3 times. In mobility terms, the optimization range for low mobile speed is 0 to 15km/h on E-UTRAN. The mobile speed for higher ranges is 15 to 120 km/h, capable of supporting high performance. In a cellular network, the mobility must maintain a speed from 120km/h to 350km/h. As for coverage, throughput, spectrum efficiency, and mobility target must meet the coverage of 5km cells. Also, On 30km, the cells may start experiencing degradation. The cells were not precluded in the range up to 100km.

Furthermore, the MBMS requirement of the terminal can reduce the complexity for unicast operation, coding modulation, UE node, and multiple access approaches must be the same. The MBMS services equipped with the dedicated voice were simultaneously on the user by providing the spectrum management on paired and unpaired. In terms of spectrum efficiency, the E-UTRAN operation in spectrum allocation in uplink with downlink capable of supporting paired and unpaired spectrum in various sizes comprises of 1.25 MHz, 1.6MHz, 2.5MHz, 5MHz, 10MHz, 15MHz and 20MHz. This spectrum flexibility also supports the delivery of content on an aggregation resource for similar and different radio band resources on uplink and downlink in both adjacent and non-adjacent channel arrangements. The exact geographical area with co-location for GERAN/UTRAN adjacent channels can be considered Co-existence. Operation of E-UTRAN and/or GERAN supported by the E-UTRAN terminal can do measurement with handover to both 3GPP GERAN. When handover in real-time, the essential during interruption among E-UTRAN and UTRAN must be less than 300ms. The architecture of E-UTRAN can be considered single and packet-based. E-UTRAN must be able to support real-time and class traffic conversationally. This E-UTRAN architecture potentially minimizes the 'single point of

failure' and supports QoS in end-to-end basic with Backhaul optimization on communication. For radio resource management, it requests end-to-end QoS Enhancement and various radio access technologies to support load sharing with management policy. For transmission terms, it is more efficient on a higher layer. This LTE requirement provided a mandatory, not redundant feature and minimizes the number of options as well.

2.8 LTE-A in OFDMA and SC-FDMA

OFDMA in LTE-A provided with high resistance to interference, due to modulation it makes it ultimately suitable to carry high transmission data rate and ability to implement on TDD and FDD (Electronics et al.). The availability of OFDMA in multiple channels allows it more efficiently to be used on total available bandwidth as sub-channels which is close spaced (Techtarget, n.d.). OFDMA transmits a considerable amount of multiple carriers provided by a high data rate, each broadcasting a low data rate stream. Further, the proper selection of symbol duration and carrier spacing potentially modulates efficiently and demodulates the specific signal (Jalali et al., 2000).

The LTE-A broadcast in Downlink was implemented using OFDMA. OFDM and OFDMA vary in terms of variation on similar wireless broadcasts, which often need clarification. This OFDMA is in the form of OFDM, which is the underlying technology (Remy & Letamendia, 2014). The significant difference between both is the use of a schedule. In terms of this OFDM, channel bandwidth is located to specific user for any time period. Nevertheless, multiple channel bandwidth of OFDMA showed by multiple users in each time period. As such, an implementation on this OFDMA improved the utilisation of spectrum with interference and narrow-band fading prevention. Figure 2.2 shows the difference between OFDM and OFDMA (Anritsu).

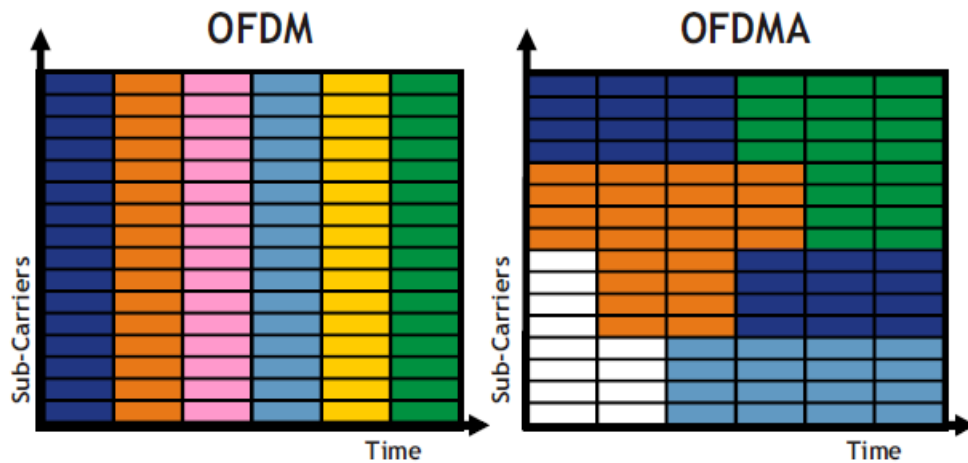


Figure 2.2: Show each of the colours represent the user data to permit users sharing available bandwidth.

On uplink of LTE-A broadcast was equipped by SC-FDMA. It has been chosen due to low PAPR, less complexity and high quality in the frequency domain; bandwidth assigns are more flexible with the information symbol grow on subcarrier available to prevent information modulated loss entirely in the cast of partial information or even move on subcarriers due to the reason of fading (Surgiewicz et al., 2014). SC-FDMA provided significant performance using a mapping mode comprising distributed and localized modes (Surgiewicz et al., 2014). In terms of localized mode, user will apply a series of subcarrier that broadcast information. In the most specific terms, the fraction of bandwidth to be apply on a user. Using this, able to achieve multi-user in frequency channel selection in the case of subcarriers was assigned to each of the respective users with a high channel gain. In distributed situation, the subcarriers are implemented to grow bandwidth entirely. One of the general versions of this distributed mode, named Interleaved SC-FDMA (IFDMA), assigned the terminals with subcarriers and distance equally to one and another, become the disadvantages of this IFDMA to vary users (Surgiewicz et al., 2014). Figure 2.3 show the various scheme of distribution and localized mode.

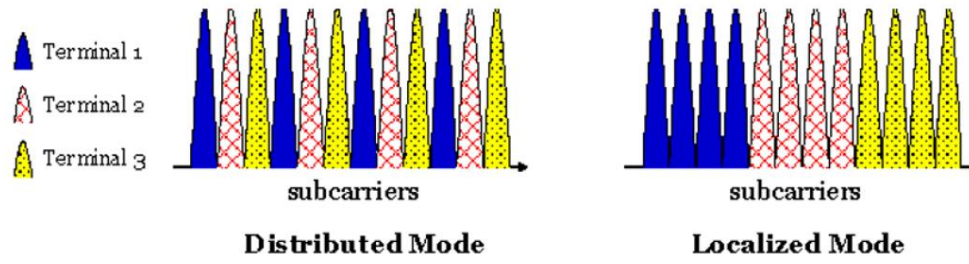


Figure 2.3: Difference between Distributed and Localized mode

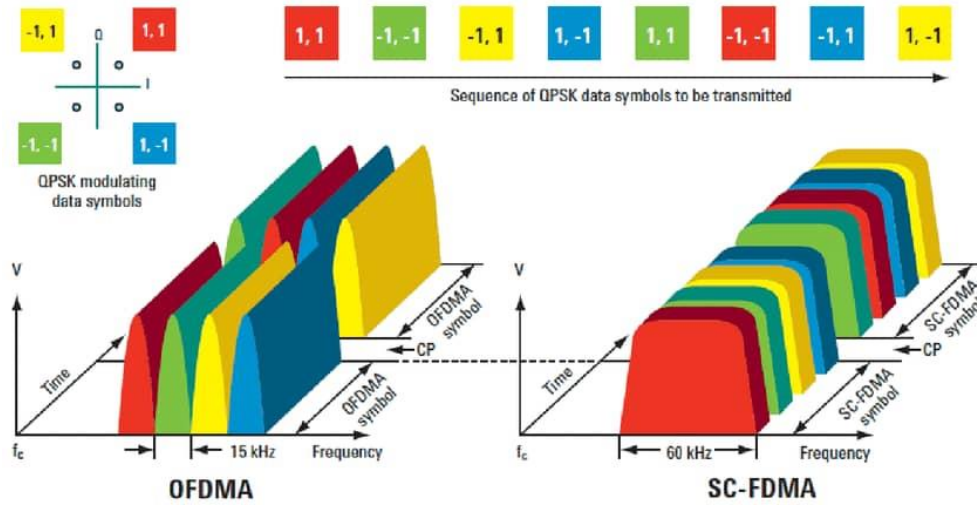


Figure 2.4: OFDMA Vs SC-FDMA

Figure 2.4 shows the difference between OFDMA and SC-FDMA. 4 sub-carrier are implemented on both schemes. In a real-time LTE-A environment, the 12 subcarriers were implemented. According to the Figure 2.4 (left side), the subcarrier is varying on coloured to significantly present on QPSK in long period of time relatively when compared to SC-FDMA. The right-hand side shows a single carrier consisting of multiple sub-carriers. Nevertheless, those sub-carriers are modulated by similar QPSK symbols. Therefore, the same colour is used on it (Hatoum et al., 2014).

2.9 Introduction of OFDMA

The technology of OFDMA was used in LTE, LTE-A, and 4G systems (Faruque & Faruque, 2019). In this OFDMA, many users can simultaneously access communication

resources through channel by medium of air. It can disseminate the data by a subcarrier in series to a specific people or devices. For OFDM, each of the users is equipped with fixed subcarriers to broadcast parallel data simultaneously. As only a single user able to broadcast the data, other users need to wait for their turn for data broadcasting. Therefore, OFDMA can assign multiple users to a particular subcarrier individually, enabling multi subcarriers to transmit simultaneously at one time.

2.10 OFDMA

OFDMA can be described as various subcarriers of different OFDM are able to allocate to vary user. The transformation of OFDM on a multiple access, enabling different users access any resources at the same time. This OFDM could divide the carrier into numerous narrowband into full subcarriers that handle by this OFDM individually. The characteristics of those subcarriers are narrow, causing the channel response on a non-selective frequency receiver, which assumption can be made on a signal called narrowband that similar to a distorted subcarrier for overall frequency field. As such, the bandwidth of channel frequency on flat channel must smaller compared to coherence bandwidth. Therefore, this makes it much easier to design the receiver more efficiently. Nevertheless, in practice mode, this frequency channel remains unusable, with the present requirement of the bandwidth is smaller compared to coherence bandwidth.

Those moved closer to each of the subcarrier and usually, interference cause among the subcarrier as well. The definition of 'O' on OFDM can be elaborated as ***orthogonal*** and method for arranging the work. These subcarrier frequencies are selected because of the orthogonal characteristics concerning each other, and the subcarrier does not interfere with

each other either. It may not be necessary to equip with guard bands among the subcarriers. These orthogonal requests a spacing of subcarrier as below (Access, 2010)

$$\Delta f = \frac{k}{T_u}$$
Equation 2.1

Where,

T_u = duration symbol in seconds

k = positive integer, 1

Notify that the subcarrier orthogonality. The OFDM was extremely efficient on spectral due to subcarrier are tightly packed. Further, these OFDM is sensitive to the frequency in offset. When frequency lost synchronization, the orthogonality of subcarrier will go. Therefore, a receiver suffers severe inter-carrier interference (ICI). The typical radio channel may suffer from the effect of multipath. The receiver gained the same signal in the delayed version, which happened due to a long propagation path that overlapped at the receiver area onto the next symbol in ISI.

The cyclic prefix becomes a guard interval, added among OFDM symbols. It provided a copy of the similar OFDM symbol on each part. It was a push at the beginning of the symbol on the transmitter and removed when it arrived on the receiver. Overall, it is possible to remove the expected ISI period. These guard intervals must not be longer than usual as it is quick long for channel capacity on guard interval, which may come as a waste of it (Korhenan, 2014).

2.11 Objective of OFDMA

The OFDMA provides many users with various bandwidths, enabling the user to communicate concurrently. Basically, OFDMA split the amount of spectrum to assign it on different types of users. It equipped with highly reuse frequency that effectively separate the spectrum into orthogonal. Further, it can minimize frequency fading by fully implement multiple subcarriers in orthogonal mode. Moreover, this OFDMA is referred on radio resources that potentially select which type of frequency sets to assign to a specific user in frequency domain and time domain (Salem et al., 2010) (Kadir et al., 2012). It ensures the whole system by increasing the transmission of data and allocates the orthogonal subcarrier to varies users effectively. For a purpose of better capacity with wider coverage and high data rate on existing cellular network. The cell splitting is requested. This will maximize the quantity of Base Station (BS) for specific areas, and the cost of installation might increase due to the high density of BS. By applying OFDMA, it will eradicate this problem.

2.12 Advantages of OFDMA

The function and characteristics of OFDMA enable various users to share the transmission bandwidth of multiple channels simultaneously. However, compared to traditional OFDM, the overall bandwidth for assigned channel respect to specific user is only one period of time. Thus, implementing OFDMA improves the spectrum's utilisation and avoids interference with narrow-band fading (Karabulut et al., 2020). Below is the advantage of OFDMA over OFDM. Thus, OFDMA implemented on this research study are mainly on multi-channel multi-node environment of the downlink stage.

- **Scalability**

The ability of OFDMA is to model the quantity in DFT with amount of subcarrier located on specific channel.

- **Orthogonality**

All the subcarriers are orthogonal with each other, which it capable of reducing the interference of subcarriers in the amount assigned.

- **MIMO**

Data broadcast in parallel mode onto multiple channels are simultaneously due to the application of MIMO antenna on OFDMA.

- **Frequency Selective Fading Minimization**

The subcarrier broadcast data with part of the sub-bands will cause the performance drop by fading. Instead of whole sub-bands. This potentially minimizes the Frequency Selective Fading (FSF) (Yin & Alamouti, 2006).

- **Spectral Efficiency**

The spectrum comprised of sub-bands which overlap one of another. This will ensure high spectral efficiency.

- **Multiple Carriers and Access**

A subcarrier series was located with each user under OFDMA; as subcarriers are narrowband with orthogonal, the quantity of those subcarriers is better on OFDMA. The amount of user can access multiple of subcarrier through a system.

- **Minimize Channel Interference**

An orthogonal subcarrier is overlap each of another. It does not show any impact on subcarriers among each other.

- **Cost Saving**

Cost saving by employing an OFDMA with the implementation of hardware. This OFDMA was capable of minimizing multi-path distortion (Bhardwaj et al., 2012) and noticed the OFDMA on high diversity (Bulbul et al., 2019).

2.13 Introduction of SC-FDMA

This SC-FDMA uses multiple access methods on modulated subcarrier in broadcasting process and receiving process on frequency domain (Myung, 2007). It considers as a revised version of an OFDMA on uplink level communication for high data rate. The significant characteristic on this SC-FDMA is lower PAPR compared to OFDMA. At the current stage, SC-FDMA used on LTE under 3GPP for multiple access system (Myung et al., 2006).

2.14 Objective of SC-FDMA

On current Internet Mobile with wireless networking are widely used technology that equipped with high data rate and QoS for communication (Bulbul et al., 2019). This SC-FDMA was implemented on uplink level on both LTE and LTE-A under 3GPP in the current application. As such, the frequency carrier selection for every channel becomes intense. To prevent frequency fading, the multicarrier divided the sub-bands into narrow sub-carrier, which have been fully utilized. The OFDMA is equipped with a multicarrier that conveys the data orthogonality (Myung et al., 2006). It divides into low-speed data and broadcast the

data bits in parallel mode that avoid ISI (Myung et al., 2008) . Since there is a limitation on OFDMA in uplink cause high PAPR. The improved version of OFDMA can be based on SC-FDMA applied. Therefore, low PAPR is necessary for uplink communication in wireless systems. To avoid high power consumption, low PAPR becomes a must which SC-FDMA provides.

2.15 Advantages of SC-FDMA

It provided free Multiple Access Interference (MAI) on various users by applying various subcarriers. It maintains orthogonal characteristics along the subcarriers for multi-channel between various users (Yune et al., 2010). The main advantage is low PAPR, suitable for multi-user, and high coverage for uplink communication (Ciochina et al., 2007). For the modulation stage, this SC-FDMA provided the best performance and coding sets (Grammenos & Darwazeh, 2010). It ensures better immunisation against electromagnetic interference, low sensitivity, better power efficiency, and minimised fluctuation.

SC-FDMA is more significant to be affected by the mapping mode divided into distributed and localised. In order to clearly defined both distributed and localised modes. Below is the diagram to differentiate both modes in SC-FDMA.

Figure 2.5. In distributed criteria, the sub-carriers applied to user able to transmit the information provided an inherent frequency diversity on the entire transmission bandwidth. Unfortunately, this assignment to any terminal is an equal distance from each other. As such, this disadvantage is potentially losing user diversity. Each user is equipped with a series of adjacent sub-carrier to broadcast the information on localised criteria. In more specific terms, the fraction of bandwidth was implemented on single user. Thus, it shows an advantage of SC-FDMA in localised criteria to achieve multiple users in any selected frequency channel

in which the assigned sub-carriers to each of the users will have a channel gain in optimum conditions. In conclusion, OFDMA and SC-FDMA in localised criteria are chosen in this research study to achieve our research objective by solving a research question stated previously.

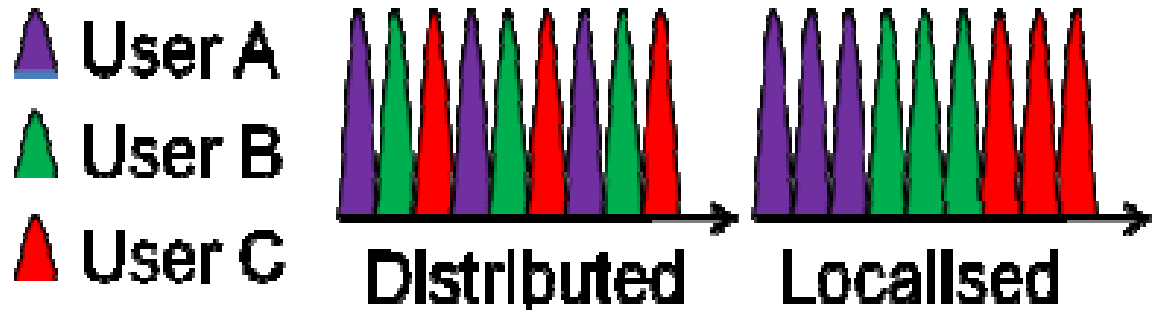


Figure 2.5: Shows subcarrier mapping mode: Distributed Mode and Localized Mode

2.16 Research Map

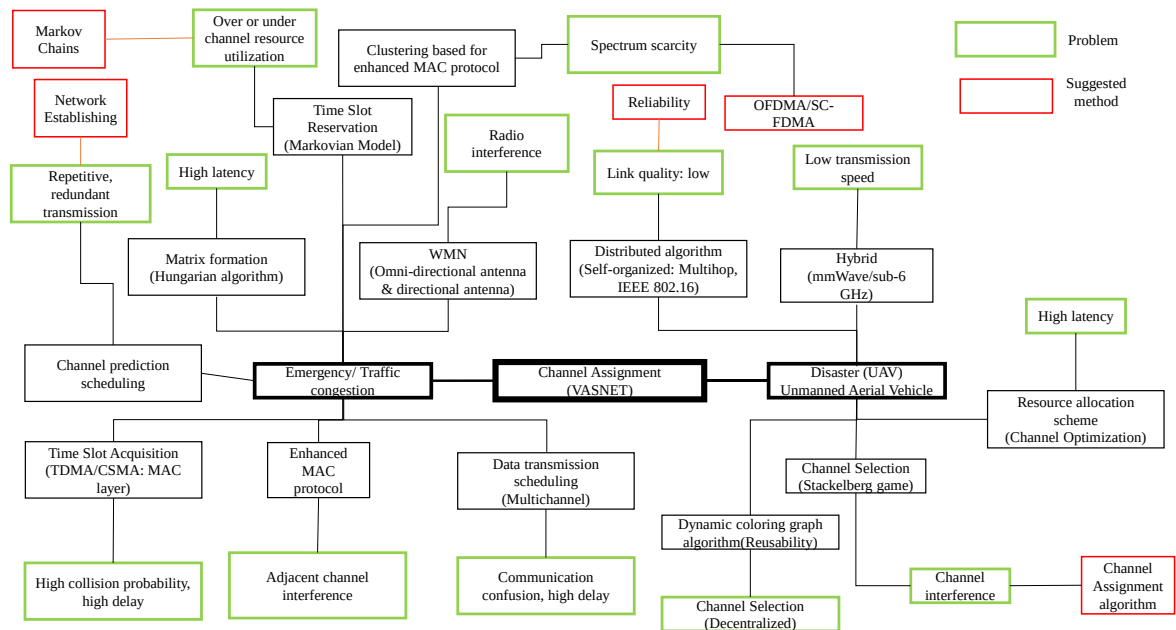


Figure 2.6: Research map for VASNET in emergency field and UAV in disaster area for channel assignment studies from year 2018-2023

Figure 2.6 shows the research map from 2018-2023 based on the literature review study discussed before. According to this research map, VASNET mainly involves the

emergency research fields, likely on the MAC layer, data transmission, and time slots in the MAC layer with matrix formation method on the Channel assignment field of studies. The green column above represents the current research problem facing in channel assignments for VASNET networking. Further, the red column is the proposed study in this research work to cope with the existing problem and improve the channel assignment by modifying the current VASNET infrastructure to be implemented in any Disaster Management System. Apart from that, UAVs have been widely used in the past 5 years ago in disasters management system, mainly on post-disaster scenarios for rescue plans that suggested a method for channel assignment, including the algorithm like dynamic colouring, channel selection in the Stackelberg game, resource allocation, the distributed algorithms in multi-hop and self-organized with the implementation of mmWave and sub-6 GHz. Therefore, there is a big room and gap clearly defining why this research work is to be conducted on VASNET in disaster to contribute to the proposed method and algorithm in this research study.

2.17 Disaster Simulation Overview

To examine the suggested channel method for VASNET in disaster management systems. The survey has been conducted for any disaster rescue plan scenario to run the simulation. According to a survey, the major disasters frequently occurring in Japan are most likely earthquakes and tsunamis (Yamada & Yamasaki, 2021). The earthquake on Nankai Trough clustering with an interval of 100-150 years, as more than 70 years on Showa Tononkai having earthquake with Showa Nankai on year 1944 and 1946 respectively cause likelihood in worse situation (Hyuga-Nada Sea, 2021). Moreover, the Hyuga-Nada earthquake recorded 7.0 magnitude or bigger, which is well known on Miyazaki Prefecture on every decade (Naoui et al., 2020) and can reach 7.6 magnitudes. Therefore, according to

previous research studies (Isagawa & Ohno, 2019; Yamada & Kishimoto, 2015), it can be observed that the tsunami rescue plan involves the evacuation or rescue of the survivors is preferred in inland direction (move to safer place). Up to date, there is no analysis of any earthquakes, and the tsunami rescue plan toward coastline to verify the rescue using simulation (Yamada & Yamasaki, 2021). As such, the proposed method consists of Base Station (BS) as the major communication was designed in the inland direction (mainland) among the rescue members with any survivors in a multi-node environment.

To validate the VASNET on the proposed channel with communication protocol in uplink and downlink. Distance among survivors and emergency rescue member will be determined by implementing the Markov Chains and proposed packet scheduling algorithms. Its analysis can be supported by this simulation from authors named Yamada and Kishimoto (2015) on his paper. The authors identify that the distance of facility and shore, direction, distance with facility capacity are affected by tsunami, especially rescue facility located inland. Another author Ohata et al. (2007), simulated the tsunami rescue plan and confirmed that tsunami rescue infrastructure was very importance and difficult on ground to reach in Urban area. In addition, McCaughey et al. (2017) classified that for those stay close to inland rescue plan are recommended. Indeed, for the year 2011 also presented the most rescue plan is recommended on inland situation instead of rescue infrastructure on the coast (Isagawa & Ohno, 2019).

Besides the simulation situation or location, another factor that needs to be considered is validated network communication. In the situation of a survivor's trap inside the vehicles or any building, it is possible to happen in real-time, especially earthquakes and tsunamis, which move faster and more rapidly changes. The research works conducted by

Mas et al. (2015) point up the simulation by considering the infrastructure with route of pedestrian-car developed according to the rescue plan at Kesennuma City when tsunami with earthquake hit on East Japan (Makinoshima et al., 2016). The population of survivors (nodes) is also under examination to confirm the proposed method's and algorithms' reliability. The population will be based on the least until a maximum of survivors (nodes) to be conducted on large-scale and small-scale in this simulation. This can be supported by previous rescue plan studies showing the most suitable time to start a rescue plan was depend to an attribute population and occurrence time of disaster (Yun & Hamada, 2015). Lastly, the disaster management system on tsunami simulation was conducted instead of validating the objective and research question. It also determines the route communication link between rescue members with victims or survivors, with a population (nodes) of victims/survivors on communication quality to/from rescue members on parameters of packet loss, delay, and energy consumption.

2.18 Comparison of Selected Simulator Tools

Table 2.2: Comparison of selected simulator tools

Evaluation metric	NS-3 (Font et al., 2010; ns (simulator), 2019)	SUMO (Behrisch et al., 2011; Glomosim, 2013)	SENSE (Glomosim, 2013)	Omnet++ (Behrisch et al., 2011; Giovanni Nardini, 2015)
Operating system	Linux, Cygwin (Window)	Linux, Window	Linux Windows	Linux, Window
Open source	✓	✓	✓	✓
Event	Discrete	Traffic	Component	Discrete
Programming language	C++/ Python	C++, Tcl	C++	C++
Routing protocol	IPv4, IPv6, TCP, UDP	OLSR, AODV, IPv4	SSR, SHR, AODV	IPv.4, IPv6, TCP, UDP
Mobility model	Waypoint Markov	Traffic	Random	Static, Angular, Markov
Multipath, Multi-hop	✓	✓	✓	✓
Model development	✗	✓	✗	✓
Scalability	✓	✓	✓	✓
Reusability	✓	✗	✓	✓
Energy/Power consumption	✓	✗	✗	✓
Network layer	MAC	MAC, DSR, ZRP	MAC, IEEE802.11, DSR	MAC, IEEE 802.11
Data Execution	Direct	Data file	Text file	Direct
GUI for simulation	✗	✓	✗	✓
OFDMA and SC-FDMA	✓	✗	✗	✓
Channel mode	✓	✓	✓	✓

Table 2.2 shows the comparison of the selected simulation tool based on its popularity in the research and education field.

According to Table 2.2, NS-3, SUMO, SENSE, and Omnet ++ can be used on both the Linux and Windows environments. To run NS-3 on the Windows version, researchers need to install Cygwin for this purpose, which makes NS-3 minor disadvantages compared with other simulation tools. This simulation tool is Open-Source software making it the most popular among researchers in the field of wireless sensor networking. NS-3 and Omnet++ is a discrete-event widely implemented in wireless sensor infrastructure, rather than SUMO using traffic simulation and SENSE using component-event simulation framework. Most simulation tools were written in C++ programming language, and NS-3 with SUMO can be supported using Python and Tcl language. In terms of routing protocol, NS-3, SUMO, and Omnet++ applying IPv4, IPv6, TCP, and UDP compared with SENSE using SSR, SHR, AODV, and DSR that have individual functions depending on any research done by researchers. For the mobility model, NS-3 uses waypoint, Markov walk, velocity, and position quick similar to Omnet++ using the same mobility model, except Omnet++ uses the module for easy development and setting based on any research purpose done in wireless networking. All selected simulation tools are provided with the service of multipath and multi-hop, which can be used for medium and large-scale network coverage or infrastructure. For model development, it supports only SUMO and Omnet++, which is an advantage over NS-3 and SENSE in developing a flexible model by researchers.

The characteristic of scalability and reusability of selected simulator tools is one of the key points why those simulator tools are the majority used for networking research and are user-friendly compared with other simulator tools. However, for SUMO, it does not

support reusability, which is a major weak point of SUMO compared with others. For large-scale wireless network infrastructure, energy or power consumption becomes the main parameter to judge whether the framework is excellent in performance in terms of stability and reliability. As such, Omnet++ is equipped with this function to make it a significant advantage compared to NS-3, SUMO, and SENSE.

Among the selected simulator tools for the network layer, SUMO consists of DSR, AODV, and IPv4, if compared with NS-3, SENSE, and Omnet++, which use the MAC layer with IEEE 802.11 for SENSE. Besides the network layer, the channel model also is one of the parameters used to examine the selected simulator tools. Except for SENSE, all simulator tools provided with this channel model use the fixed channel when running the simulation. A good and powerful GUI can be a significant reason, as this was accepted by most researchers, which is more user-friendly if the simulator tools can set any parameter request directly. For this, only Omnet++ is equipped with this facility among the other simulator tools. To gather or collect the data after the simulation process in an easier way, saving more time for researchers to analyse the data as quickly as possible. Therefore, the figure shows that NS-3 and Omnet++ are the most helpful simulator tools compared to SUMO and SENSE. The last and the most wanted parameter in choosing the best simulator tool for our research study is the communication protocol on OFDMA and SC-FDMA. NS-3 and Omnet++ in LTE and LTE-A simulation for IoT research work is being provided by this protocol over the other simulator tools. As our conclusion for this comparison, Omnet++ is chosen to validate our proposed methods and algorithms in this study.

Therefore, why Omnet++ is chosen among selected simulator tools, is because Omnet++ provides and equipped with a mobility model on a modular basis that any value

can be set in terms of node position and velocity in static or angular movement, which reflects our Disaster Management System proposed using Random Walk of mobility model. Easy to develop model, also making Omnet++ excellent for any model to be decided in random form or circular form that depends on the study on research work. Lastly, powerful GUI on Omnet++ is the primary key for our study, and it can set a parameter to suit our proposed research method to achieve research objective which is already discussed in the previous chapter.

2.19 Definition of Disaster Management System

The definition of Disaster Management (DM) can be described as "the conceptual practice and a systematic strategy to combat and reduce risks through systematic efforts to analyse and manage the common factors of disasters. For example, reduced vulnerability to hazards, property and people, and life management includes flora and fauna comprising the environment and improving the preparedness level for adverse events" (Usman, 2017). The impact of cataclysm can be prevented by involving preparedness, response, and recovery for minimization.

The most susceptible involve climate change adaption can be referred to as a natural disaster. Most of the country experience the effect of natural disaster, which refer to earthquakes, floods, droughts, and famines that deteriorate the infrastructure entirely in terms of life and property. In contrast, man-disaster-like gas explosions, oil fires, and road accidents have contributed to significant devastation to the hilly and plain areas of the country (Azme et al., 2014). Hence, a valuable and flexible characteristic of any Disaster Management System is a much to build-up in order to face multi-situation during a

catastrophe that aims to lessen human life and minimize the impact on infrastructure and socio-economics globally.

2.19.1 Managing Risk, Emergencies and Disasters

One of the ways for humans, organizations, and whole societies to reduce their vulnerability to hazards that maximize their likelihood of survival. Great efforts have been taken to reduce the occurrence of disasters, and systems with structures have been put in place to respond and recover effectively. In the United States of America, the government has even permitted this emergency management in complete decentralization with the ability to tailor their emergency management to involve specific hazards in the community.

They were using technology and innovation to further advance on contribution to overall human disaster resilience, which may be an increasing trend. Therefore, developing new and improved mitigation techniques permitted us to effectively manage risk by decreasing the chances that hazards result in actual disasters and minimizing the consequences when they do. Warning systems and hazard detection can increase their ability to inform society of coming events, sometimes in advance of hazards like cyclonic storms and blizzards (Coppola & Maloney, 2017). With the emergence of increasingly advanced and coordinated response systems, these many accomplishments are improving the odds for the ever-increasing number of people that live in hazard-prone areas. In the foreseeable future, disaster will continue to strike heavily in more regular times. Governments must contend with limited resources, labour, and equipment, and a degree of risk acceptance. Inevitably levees fail, warnings come too late, building collapse, and infrastructure is knocked out is the fate of the individual must ensure their survival, which lies in their actions.

The following topic discussed more Disaster Management concepts and explained these concepts apply to human, organizational, and community-based disasters. Risk, hazard, vulnerability, and disaster are discussed and elaborated in more detail in the subchapter on emergency management discipline.

2.19.2 Risk

Risk is defined in emergency management as the context that the associated outcome of a possible adverse event will cause something wrong to happen. The risk of a particular form may be considered unavoidable. Risk, therefore, has a significant impact on all people without exception and geographical location, even socioeconomics. Individuals and most societies need continuously make any choices that can be classified into the factor of risk in known and unknown factors with avoidance of complete risk, which is unable to achieve. (Coppola & Maloney, 2017).

The concept of risk can be a drastically different type of group depending upon the context in which it is used. For example, in the business sector, Investment risk is an opportunity for profit-making. A medical patient should know the risk of an experimental treatment for a future opportunity without any illness or otherwise incurable. For the disaster sector, it is always negative. For the most comfortable illustrations of the term, preferred many emergency managers illustrated by using the equation in which risk is equal to likelihood multiplied by the consequence of the event (Ansell & Wharton, 1992).

$$Risk = Likelihood \times Consequence \quad \text{Equation 2.2}$$

From Equation 2.2, the likelihood can be defined as either probability or frequency, which is the analysis to be considered, and the consequence, which is a measurement of hazard, either property or people. It was beneficial as easy to reduce the hazard, either

likelihood or consequence, potentially resulting in both when risk decreases. In other words, the likelihood and consequence of hazard were directly increased when proportionally concerning hazard risk. (Coppola & Maloney, 2017).

2.19.3 Hazard

Hazard is believed to be extracted from the French word called *hazard* (game of dice predating craps) or from the Arabic word *al-zahir* (literally "the die"). According to this definition, hazardous events or physical situations are highly to cause fatalities, infrastructure, environmental damage, business interruption, or any negative consequences.

A unique "hazard portfolio" influences everybody, business, organization, community, or country. Many methods distinguish them as being natural, intentional, or technological. Some hazards may fit appropriately into more than one of these three groups. Factors comprise of location, topography, industrial activities, behaviours, laws, climate, demographics, income, and many others that not only determine what kind of hazards compliance of this portfolio, but the risk presented by each other depends on the size of level and how the significant standard on the risk mentioned (Coppola & Maloney, 2017).

2.19.4 Vulnerability

The word *vulnerability* comes from the Latin "vulnerabilis, "to wound". It is defined as a combination of all aspects, like economic, social, and environmental factors and processes. Vulnerabilities decreased upon the action to lower the propensity. For example, a building withstands the shaking effects caused by an earthquake able to lower the building's vulnerability which lowers the risk. Populations also have a vulnerability, which is increased or lowered based on practices and economic status. As such, the main crucial of this is public

education, which effectively affects the populations and individuals regarding vulnerability (Coppola & Maloney, 2017).

The degree of susceptibility can be specified into object and country generally that can be measured by vulnerability to the hazard of a consequence. Vulnerability is linked to risk by verifying a complete set of variables. The destructive individual event can affect individuals and communities related to a similar force known as a minor issue and a disaster that can consider others. When the destruction of a hurricane, for instance, the house is immediately destroyed, one is not facing any injuries or damage. It can be observed that two earthquakes caused 100 deaths lesser on LA, but 20,000 innocent people were sacrificed was happened at Gujarat, India. (Cairns, 2005).

2.19.5 Disaster

The etymology of the term *disaster* comes from the Italian words *disaster*, "ill-starred event," from *dis-* (expressing negation) + *Astro*'star' (from Latin *Astrum*) (Huq, 2016). A *disaster* can be defined as disruption over a short period relatively, which involves a community and society that cause an impact in terms of humanity, economy, and loss of environment. Consequently, it has an ability that affects the whole society or community, like resources that we need to cope ultimately (Ababa, 2017; Staff, 2017).

When there is a hazard, the consequence is left to be managed by individuals and communities. If individuals and/or the community respond to the event, it can be called a disaster. However, there is not necessary to consider all events as a disaster; those overwhelming response capacities are a disaster. The consequence to be managed by vulnerability and capacity determine whether it is a disaster or an emergency event. The most important is the dissimilarity between an *emergency* with a *disaster*. For example, a

house burning may react to the fire department. The victims may experience a loss in terms of life and property.

Nevertheless, fires are a routine that, in the occurrence category, is easily managed and not considered a disaster. In 1871, the great Chicago fire disaster affected around 2,000 acres which were knockdown in three days. Generally, the degree of destruction over 28 miles of road, 120 miles of sidewalk, 18,000 buildings, and 2,000 lamp posts total more than \$200 million in property loss (Pauly, 1984). People died in a range of 200 and 300 innocent people. Categorized in the class of fires and Chicago fire fall inside the event called a disaster.

Disaster may grow in intensity when overwhelming a larger response unit progressively. Some organizations need help to control the consequence of a particular event. Therefore, they will contact the authority department such as the fire department, police, and medical department. If those agencies are not to be included in the event adequately, they request assistance from mutual aid partners, followed by the state or the provincial government. If assistance from the next higher level was insufficient to manage the disaster became national and requested the national government's intervention. If they cannot manage an event's consequences, those events will become an international-level disaster involving a global agency in terms of response and relief.

The disaster has been identified as a loss in terms of life, injuries sustained, and degradation of the environment. Those consequences manifest two terms: direct or tangible or vice versa. Disaster can onset suddenly or "creeping." The onset of disaster happens without warning, and most damage is sustained within hours or even a day. An example is natural disasters like earthquakes, volcanoes, and floods. The creeping disaster depends on

the response agencies' performance to rescue the victims, which may be time-consuming and take around a week, months, or even a year to discover. For instance, drought, famines, soil salination, epidermis, and erosion (Coppola & Maloney, 2017).

2.19.6 The Management of Risk

Management can be defined as the performance and responsibility of an individual on a personal level. It involves preparing or mitigating those risks on a personal or small scale when consequences fail to take precautions. (Even if *catastrophic* to the individual). Examples of those risks can be classified into the following categories:

1. Health risks
2. Economic or financial risks
3. Social risks
4. Physical or safety-related risks

In terms of collective scale, single events may happen on a large scale in the range of hazards in nations, communities, and societies. Earthquakes, volcanoes, terrorist attacks, and pandemics are a sample taken based on the list of possibilities. Those large-scale hazards commonly show lower absolute (population-wide) consequences than a sum-total consequence from individuals facing the danger. They lack focus on emergency and risk managers of their spectacular nature and the fact that they may be of such enormous magnitude as to overwhelm the organisations or the community's response and recovery capacity.

When we consider large-scale hazards, the vulnerability can be reduced by conducting it at the community, regional and national levels, depending on the nature of the hazard. The government's responsibility is to control and minimize the hazard risk for most

hazards. In actual disasters resulting from those hazards, the government has been authorized to respond and provide recovery assistance accordingly.

2.20 The Management of Emergencies and Disaster: Emergency Management Functions

In this modern society for comprehensive disaster management, which can comprise 4 functional components:

1. Mitigation
2. Preparedness
3. Response
4. Recovery

The 4 components can be elaborated cyclically with the occurrence in the pre-disaster event involving mitigation and preparedness. In post-disaster events, response and recovery will take place on it. In common practice, actions involved in each function interact with each other. They are performed in varying degrees before, during, and after, able to gain knowledge and experience on the previous disaster, which influence the preparedness, mitigation, response, and recovery actions to be taken in the next disaster to apply those functions respectively depicted on the following subchapter.

2.20.1 Mitigation

Reduction and elimination are classified as hazard risks involved in mitigation components (likelihood and consequence). It was defined as a “cornerstone” a hazard that influences society to a lesser degree (Waugh, 2015). When preparedness, response, and recovery react to the hazard or participate in consequences. Mitigation seems to minimize the likelihood or consequences of hazard risk before a disaster happens. Mitigation is not a

simple solution for a hazard risk. In reality, the level of difficulties generally due to the majority of mitigation measurements only within this few decades. The mitigation potentially reduced the risk that has been recognized. In real-time, mitigation tends to be disruptive, costly, socially unpalatable, and time-consuming. Usually, it carries a similar risk, and it does not always work as expected. This mitigation is hard to involve in politics in any situation, and public attention can accommodate significant changes to make mitigation work. However, growth of mitigation practices emerges as a measurement to reduce the incidence of various types of catastrophes. (Coppola & Maloney, 2017).

2.20.2 Preparedness

Preparedness can be defined as victims affected by a disaster or catastrophe, which can help and equipped with tools to increase the likelihood and potentially minimize the losses in terms of finances. We can achieve preparedness by conducting proper training involving agencies response at the government level by organizing a seminar in order to educate the public on the suitable action to be taken as the purpose to minimize the risk and vulnerability. This activity may involve authority agencies like emergency response, citizens, officials, and relative government. Respective role and responsibilities can achieve when disaster strike. The initial activities of the preparedness function are expanded to verify that the response is successful. The objective of preparedness is listed below:

1. What are the things we need to do after disasters
2. How we can do it right
3. Need to do it right with equipped proper tools

A good and effective precaution and better organization in terms of efficiency with action on delivery and recovery can minimize the preparedness. These actions and activities

are comprised according to the recipient. It can be a group under one government's emergency management, administrative, and/or other authorized agencies.

The second group was individual and business. The first preparedness group is typically derived and conducted by designing and applying an Emergency Operation Plan (EOP) with training and exercises for the second group to educate and guide the public on preparedness. (Coppola & Maloney, 2017).

2.20.3 Response

Respond is the action taken to minimize the impact of disasters that are about to happen. Those actions minimize the injuries, life loss, property, and the downturn of socio-economics and the environment. The response directly addresses the activities such as search and rescue with medical treatment and the systems created to support and coordinate the efforts. In addition, these functions facilitate the rapid resumption of critical infrastructure that permits the recovery to occur and minimize injuries and life loss with speed up to the normal function of society. The response starts as it was evident when hazard comes from complicated four functions of emergency management that happen during very high stress and time wavering confidence with direction to a tragedy and destruction. That provision must reflect the survivors that can be a sign in the subcomponent response function (Coppola & Maloney, 2017).

2.20.4 Recovery

Recovery includes what has been lost in terms of repair, reconstruction, and regaining of disaster and reduces hazards in the future of similar catastrophes. It started when the response phase was completed in months or years. When talking about this emergency management system, during the planning phase, long before a disaster happens, action can

begin on early stage that involves four phases planning the disaster in the beginning stage like mitigation with preparedness actions, and recovery actions. These actions link with the most varied of the overall emergency management system: the recovery phase. It can be range from individuals, organizations, and groups involved, which higher than any function. Due to the spectacular natural disaster events and disastrous consequences that affect many people's lives, the recovery possible generates enormous attention and interest in the international community. Recovery from disaster is also the least of studies and organized for all the disaster management systems and the most haphazardly performed (Coppola & Maloney, 2017).

2.21 The Management of Emergencies and Disaster: Emergency Management Structure

In countries like America, emergency management is practised at all levels of government, either locally or regionally, including state, province, or national. Those hazardous events request a response in the form of emergencies that happen on a daily basis, For instance, fires and floods. Those events were controlled under the local level of emergency services, such as the fire department, police, and first-aid services. Those organizations with other participating agencies involved in emergency management activities are elaborated in the following subchapter.

2.21.1 The Fire Department

The fire departments can be called "Fire services" which is the most general local emergency management structure. It developed the agencies to a structural with other forms of fires, and many nations' fire department expanded their ability to address the broader ranges involving natural hazards with rare hazard risks that may happen. The activities in charge of the fire department are:

- Coordination response in disaster
- Emergency management and medical services
- Investigation on fire and arson
- Structural safety inspection
- Fire suppression include structural, brushfire, wildfire, hazardous material fire
- Warning issuance and hazard
- Risk and hazard prevention activities
- Hazardous materials response and clean up
- Issuance and enforcement or permit
- Rescue an urban, swift water, wilderness, cave, airborne, alpine, dive, crack, and crevice
- Training
- Vehicle extraction

The fire department can be arranged at local, regional, or national levels. In most countries, the fire department exists almost exclusively at the municipal and country level. Individual facilities like airports or seaports may also maintain fire departments to reflect the emergency. How the government structured the fire department depends on personnel paid or volunteers and types of government in those areas. The fire department's drive-by both found access and risk to the community. The source of funds and level was different from the community, which exist in sufficient levels to adequate by fire risk with all the fire department requests to meet that involve:

- Personnel
- Training

- Equipment, example:
 - Apparatus
 - Firefighting equipment
 - PPE
 - Rescue equipment
- Communication system, example:
 - Notification systems enable the public during emergencies which notice to the related department about an emergency (e.g. 999 system)
 - Responders able to communicate with others and to a Command Centre respectively through a radio system
 - Enables Responders to communicate to the public by using a broadcast system involve
- Facilities
- Information
- Authority (Coppola & Maloney, 2017)

2.21.2 Law Enforcement

Police are the government responsible for maintaining law and order in the community. The primary responsibility of the police department is crime-fighting; law enforcement officers participate in all emergency management functions. The emergency management of law enforcement responsibility can be included as below:

- Assessment
- Bomb removal and disposal
- Crime fighting

- Crowd control
- Disaster scene security
- Investigation
- Search and Rescue
- Security at critical facilities
- Traffic control
- Warning issuance

Most law enforcement agencies, especially federalised systems, are centralised and controlled at the national government level. For example, the United States of America maintains local and organised forces. Others, like Canadians, serve on national jurisdiction while three provinces and cities maintain their local forces. On Centralised systems, officers are based within their local communities or assigned to other communities their own. Officers are traditionally more secure and most significant than other first-responding teams, including fire and emergency medical departments (Coppola & Maloney, 2017).

2.21.3 Emergency Department

For large-scale events, officers in emergency management will execute four phases, beginning with mitigation, preparedness, response, and recovery planning and coordination. In the 1950s, when the government began to prepare for nuclear war, it appeared in a unique field rather than the new primary during civil defence. Those officers started to pay more attention to disaster risk and hazard-equipped responsibilities in phases like response and recovery coordination. Nowadays, most of the country will maintain emergency management at the national level, addressing the first and second phases of the severe disaster. A country like America enforces their national's emergency management office,

which is equipped with the third and fourth phases locally rather than in their place. Generally, police and fire departments at the local and regional levels can manage emergency management in terms of planning and coordination. Even though many cities and overall U.S. states have generated a dedicated office of emergency management (Coppola & Maloney, 2017).

2.21.4 Emergency Medical Service

The short form of Emergency medical services is defined as EMS or in terms of ambulance service. The main task is specialized medical care performed during an emergency when a disaster or catastrophe occurs. Authorized EMS, or what we call Emergency Medical Technicians (EMTs), are being trained professionally to provide essential first-aid assistance. The main task of EMTs is to stabilize the victim's transfer to a hospital equipped with good equipment and better conditions. Even though most police officers with firefighters are trained to serve first aid and medical service to survivors during disasters or emergencies. EMS is usually being trained and equipped to go more than basic or even to execute any invasive procedures or to administer tonnes of drugs which is certified. The training available is different in the EMS system on their level of funding and equipment quality. Most countries offer private agencies and charge the victims for the EMS service. EMS may have collaborated with a hospital or fire department and/or an independent public service. The member of EMS officers is the majority of a group of volunteers (Coppola & Maloney, 2017).

2.22 Summary

This chapter discussed the literature on disaster management systems with an emergency for various wireless networking, including WSN, VASNET, VANET and UAVs. The overview of channel assignment and the method to be used for suggested improved channel assignment has also been discussed in this chapter. Further, the survey of operation mode for interface operation and packet scheduling has also been elaborated in detail to further study the current method for channel assignment with some appropriate way to adapt to the proposed algorithm and method. Moreover, OFDMA and SC-FDMA were introduced, and advantages were discussed as a communication protocol to link all the nodes on the disaster incident scene to be able to generate a communication link with eNodeB (antenna), which function is a multi-antenna used to connect the node in multi-node basic. Furthermore, the definition of a disaster management system was understudied to apply on disaster management system. The simulation tool is successfully discussed in this chapter by comparing the features and advantages to analyse current wireless networking simulation tools. According to the analysis, Omnet++ has been chosen and selected to run the research algorithm and method. These findings provide a sufficient finding and an idea for the research work conducted in this thesis.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter introduced the proposed method for VASNET with improved channel assignment on device-to-device communication in Disaster Management Systems in order to achieve the research objective. The infrastructure of the research method will explain more deeply in this chapter on what kind of method to be use on interface and how it works or function in this research study. Markov Chains series are also proposed in this study with suggested network algorithms to reduce the node-to-node electromagnetic interference. The LTE and LTE-A as a benchmark communication protocol discussed in this chapter that implement a packet scheduling algorithm in LTE-AIC as one of the ways to evaluate the research objective. The reliability characteristic also aims to examine the performance of the suggested method during a disaster or catastrophe in a critical situation. The parameter used to examine the proposed method's performance, like packet loss, delay, and energy consumption, will also be further explained in this chapter. Moreover, OFDMA and SC-FDMA will elaborate in more detail to achieve our research objective and answer the research question in this research study.

3.2 Summary of Research Flow

This research flow involves the modified VASNET with an interface and Improved Channel Assignment and Network Establishing algorithm with Packet Scheduling to link together to this research study and apply to Disaster Management System. All the proposed algorithms and methods were under indication, as presented in the diagram of Figure 3.1 on this research flow as to clearly illustrate the contribution and method applied in this study.

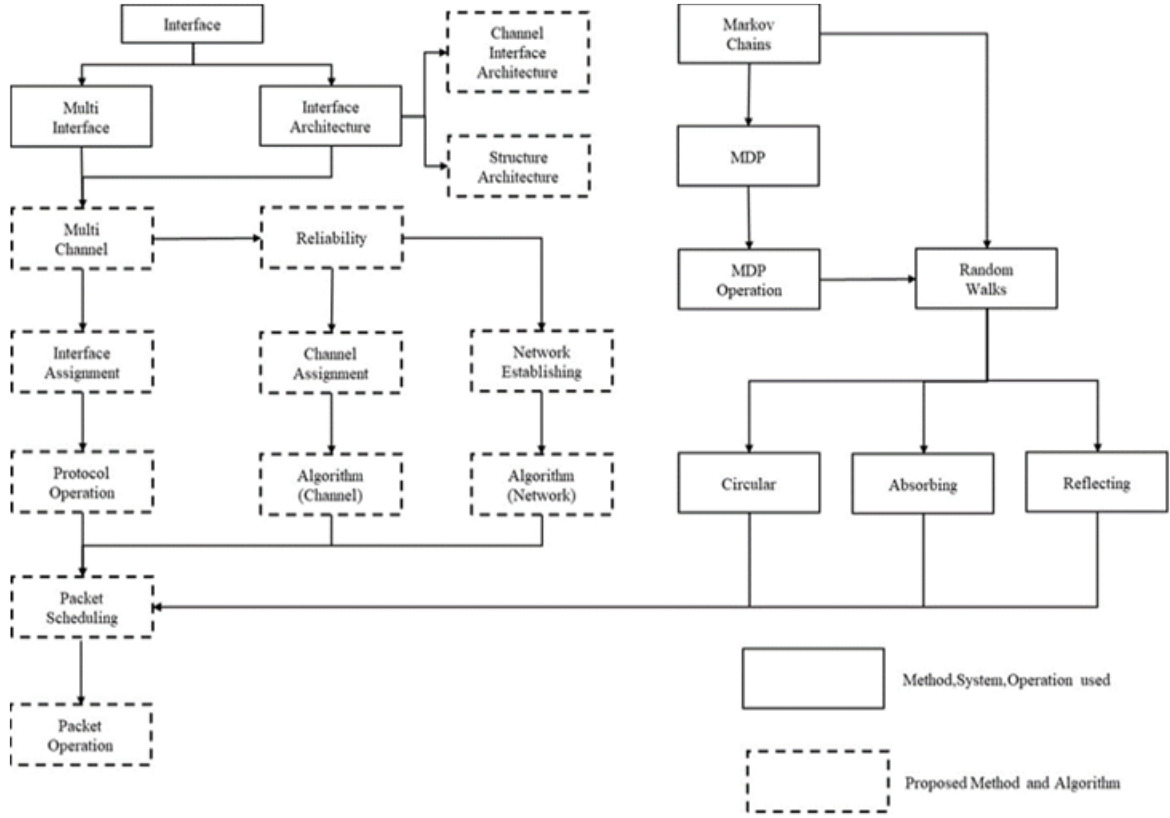


Figure 3.1: Summary of research flow on this research study.

3.3 Benefits of Multi-Interfaces

When a single channel is available in multi-hop networks, then a single interface suffices. Nevertheless, if multiple channels provide more than one interface is very beneficial. Presenting a related work in a single interface approach to exploit multiple channels (Bahl et al., 2004; So & Vaidya, 2004a, 2004b). If single interfaces on vary channel for 2 nodes, then both unable to communicate with each other. The aims is to reduce overheads and synchronization, each of the interfaces should stay on a channel for the massive amount of packet transmitted, typically 100ms (So & Vaidya, 2004) and 10ms (Basha et al., 2008). Therefore, packets traverse in multi-node paths, facing delays at each node unless the next node is on the same channel. If a single channel is available, the end-to-end delay may increase if vary nodes traverse on different channels. Otherwise, a major

node on a similar channel broadcast to consecutive nodes that experience interference, that reduces capacity. As such, TCP throughput is affected significantly. Another advantage of multi-channel is to broadcast and receive a data simultaneously.

Furthermore, wireless interfaces on half-duplex unable to broadcast and receiving a data in parallel mode. Nevertheless, when the presence of multi-interfaces with multi-channels, one of the functions of the interfaces is to receive the data on a particular channel, and the following interfaces can broadcast the data on a different channel concurrently (Kyasanur et al., 2006). In normal conditions, this method can maximize the throughput on a multi-hop route to reach a certain achievable level.

3.3.1 Interfaces Switching Issues

It is a crucial fundamental for an interface to do channel switching to others channel that fully utilizes an available channel in any situation. However, the quantity of the interfaces much less than any available channels. Switching the channels requires a change in the frequency of operation; they might be a delay switching declared as **D** when switching from one channel to another channel on an interface. On present literature estimating the **D** switching among channels on similar level of frequency band within the range of milliseconds and commodity of IEEE 802.11 hardware (Bahl et al., 2004) to a few hundred microseconds. It improved current technology to reduce switching delay until a few tens of microseconds (Bahl et al., 2004). Interface switching protocols should have flexible characteristics that can accommodate a switching delay. It is also possible for interface switching across different levels of the frequency band. For instance, current wireless cards are compatible with and support IEEE 802.11A (operates on the 5GHz band) with IEEE 802.11b (operates on the 2.4GHz band), which are flexible to switch between both bands

(Kyasanur et al., 2006). However, the current market available on hardware shows a significant delay in switching across bands, which expected to improve and minimize a delay on future undertaken.

3.3.2 Switching Latency: Interfaces

Switching Delay means switching the interface from the existing channel to the next channel that is non-negligible of delay. Based on the current literature, switching Delay estimation (switch among channels in similar frequency band) and within a range of milliseconds for commodity IEEE 802.11 (Chandra & Bahl, 2004) (Raniwala & Chiueh, 2005). It could improve the switching latency expected to a range of few tens' microseconds (Bahl et al., 2004). The present protocols should fully utilize interface switching to have characteristics of flexibility that fit in a range of switching delays. The delay parameter evaluates the proposed methods' performance to validate the proposed algorithm reliability.

3.4 Formulated Problem

The main purpose of this study is to suggest a protocols on multi-node network wirelessly for channel assignment used. The situation of nodes inside the network is all on the mobile node. The assumption of this research for traffic patterns include communication among the node pairs. It unless 2 interfaces on it. We describe an objective of a multi-channel, multi-interface solution that has the following characteristics:

1. Fully utilize any available channels in order to improve the networks in terms of capacity. The quantity of an interfaces must less than the quantitys of channels per host. The primary solution is able to fit various interfaces and channels.

2. Ensure the network is linked with a single shared channel and continuously connected to multiple channels.

3.5 Interfaces Assignment

One of the requirements is to achieve an assignment strategy for an interface to assign specific channel to the amount of available interfaces, in which it much less than the amount of available channels. Moreover, fully utilizing available channels may result in switching interfaces, and the protocol must decide the interface to switch from an existing channel to another channel as well. It is to ensure a protocol on node X 's neighbours able to communicate on demand basic. All neighbour's node X must aware of one channel in node X that provided the interface. It is classified in the author paper for interface assignment strategies by Kyasanur et al. (2006).

3.5.1 Interfaces Assignment Strategy

Assume that Y interfaces are provided at each node. It is comprised of 2 subsets.

1. Fixed Interfaces: Interface X out of Y on the specific node is set to some X channels for long intervals. We declared those as a “fixed interfaces” with the channels set as “fixed channels”.
2. Switchable Interfaces: Balanced Interfaces $Y-X$ are assigned dynamic $Y-X$ channel according to data traffic. We called these interfaces “switchable interfaces”, and switchable interfaces could be assigned for “switchable channels”.

The different kinds of nodes can be assigned X -fixed interfaces to various sets of X channels. Each node can have various values of X and Y , potentially changing X with respect to time. The node called K and the packet sent onto node I will deliver a packet to fixed

channel of **I**. Therefore, the following section, will explain a new protocol strategy on link layer to be implemented and full utilizes the protocol on all the channels in more detail.

3.5.2 Protocols between Nodes

To discuss the architecture of layer protocol, we simplify the description for easy understanding; we assume that $\mathbf{Y} = 2$, $\mathbf{X} = 1$ for all nodes, with the requirement of single fixed interface, and single switchable interface, to be extended to any kind of $\mathbf{Y} \geq 2$ with $1 \leq \mathbf{X} < \mathbf{Y}$ for suggested protocol. Each of the nodes at the initial stage was assigned one interface to become a fixed interface and one is a switchable interface. The fixed interface will be assigned as a "fixed channel" for longer intervals.

3.5.3 Packet Insertion into Channel Queues

A packet transmitted in single-channel networks has a high possibility of being received by all adjacent nodes through the transmitter. But, when multiple channels are present, the packet transmitted onto specific channel can only receive by the node that can listen on that specific channel. Most protocols in the higher layer (For instance, routing protocol) may transmit packets received by all nodes in the neighbourhood. The protocol may support neighbourhood broadcasts by separately broadcasting the packet over every channel. A copy of any broadcast packet can be added to a specific channel queue and sent out when the protocol for transmission schedules the channel. Even though a copy of a specific channel sending may increase the broadcast together with the quantity of channels increases, the cost per channel still can maintain the same. For instance, $\mathbf{X}$ channels keep transmitting packet copies of $\mathbf{X}$ channels, which may have 1 packet per channel. Therefore, channel overhead is similar in a single-channel network.

3.5.4 Channel Queues Servicing

The packets queued up during broadcasting from fixed interfaces onto fixed channel. The packets transmission all over the channels by the presence of a switchable interface. When this switchable interface is ready to shift to a new channel, it will always be switched to that specific channel with a previous queued data. This is to ensure fairness over time. The channel on the switchable interface changes with the requirement of a packet queued to another with obeys one of the two conditions listed below.

1. Empty queue on the switchable interface for specific channel.
2. The switchable interface must be present on that channel for the same periods to avoid starvation from other queues.

3.5.5 Proposed Protocol Operation

Multi-Channel Multi-Interface (MCMI) are the most advantages compared with other methods. In this method, neighbour's nodes inhibit sharing the occupied channel, maximising the packet transmission simultaneously; when 2 neighbour's nodes are on the same channel, one can communicate at one time, which is called the maximise channel distribution. Wireless communications contribute significant benefits in multicast of providing open communication media such as "air" to all the nodes permitting a communication range that can tune to the channel. This advantage may disappear when experiencing maximised channel distribution. To solve this problem, the researchers have suggested the top-down approach and multicasting centralisation as the centralised approach increases control message overhead, and top-down enforcement is able to break the balance of other communications (Chen et al., 2013). The bottom-top approach proposed provided a

better network environment by scaling up where different communications co-exist and require fewer overheads control (Zeng et al., 2007).

In this bottom-up approach study, the proposed network model includes various mobile nodes, which are equipped with two wireless interfaces called interface assignment strategies (Kysanur et al., 2006; Zeng et al., 2007) — one of the interfaces used as a function to receive the data called as Fixed Interface. When a node broadcasts the data to others, the Switchable Interface change the channel to fixed condition onto next node before broadcasting. When 2 neighbours' nodes on same fixed channel, data is broadcast to a fixed interface through the transmitter.

Provided node A ready to send packet onto node C through node B. As illustrated in Figure 3.2, Nodes A, B, with C are provided with fixed interfaces assigned as 1, 2, with 3 and interfaces switchable to each node as 3, 1, and 2. At initial stage, node A capable of switching to switchable interfaces from channel 3 to channel 2 before broadcasting a packet to destination node B on a fixed interface known as channel 2. Then Node B able to receive a packet after a fixed channel listens to switchable interface channel 2 from node A.

In the second step, node B can switch to the switchable interface from 1 to 3 to transmit the packet to node C on a fixed interface provided by channel 3. When the switchable interface is set up correctly in the initial stage, there not necessary to switch the interface provided that the subsequent packets on the flow. Therefore, switchable interfaces must tune to other channels for broadcasting a packet on the various channel or terminate after the node (survivors and victims') of the node as mentioned earlier has been rescued by the rescue teams.

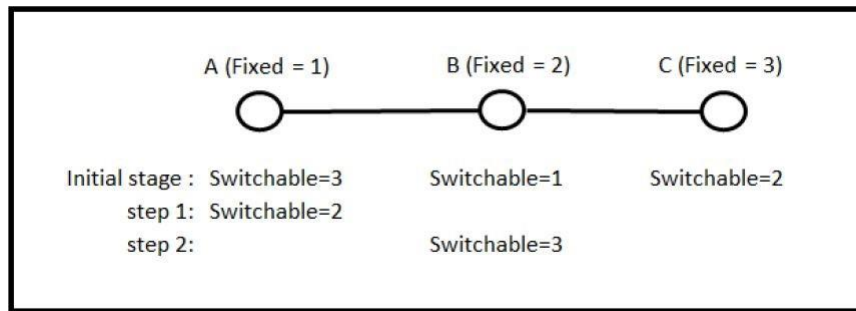


Figure 3.2: Suggested protocol operation with 2 interfaces and 3 channels

3.5.6 Proposed Packet Operation

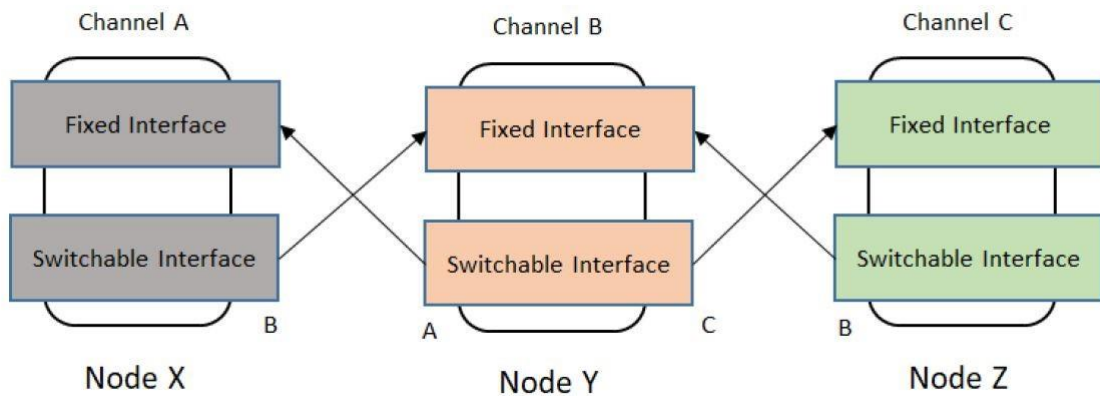


Figure 3.3: A simple description of the proposed network Interface

Figure 3.3 describes the proposed Interface, which is divided into 3 nodes X, Y, and Z with channel fixed on each node A, B, and C. The information periodically broadcasts a “Hello” message to all potential channels when node exchange on their interface occurs. Exchanging a “Hello” message can confirm the link quality for each node with each of the neighbour’s nodes. A particular node could estimate link quality among the node by implementing backwards and forward link delivery probability. Each node will include inside the neighbour’s list for a fixed channel among the neighbour’s node with link quality among them on the message “Hello”. As a result, all the nodes can be equipped with existing information on one-hop and two-hop neighbours, as described in Figure 3.4.

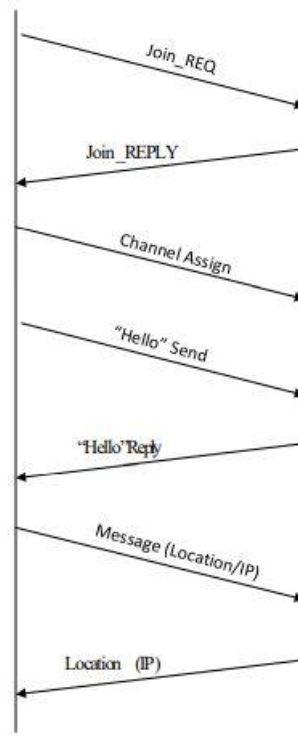


Figure 3.4: Suggested fixed interface and switchable interface devices to devices communication

3.6 Proposed Architecture of Interfaces

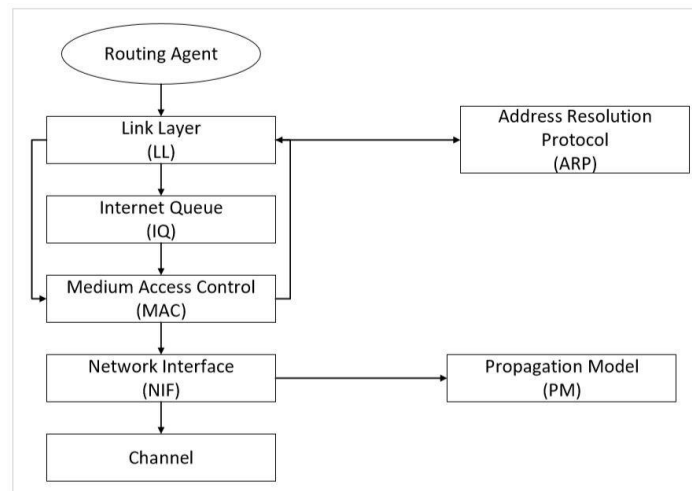


Figure 3.5: Proposed generic interface architecture

Figure 3.5 described the proposed architecture on single mode channel with multi-node environment interface wirelessly implemented in this research study. This architecture

comprises of application, routing agent, Link Layer (LL), Address Resolution Protocol (ARP) module to LL, Internet Queue (IQ), MAC, with a network NetIF and PM.

In this architecture, the function of the Routing Agent is applying a simulation on protocols application with individual algorithms. The LL responsibility is to simulate link protocol data. Various link protocols could be applied in this layer—for instance, the reliable link protocol with reassembly and fragmentation in the packet. The module of ARP can resolve the conversations of all IP-to-MAC addresses. The priority of IQ is to queue to the routing protocol packet on the header in a queue using the inserting method. It can be supported to filter all queue packets and remove them with a specific destination address. MAC layer function is to apply MAC protocols wirelessly. The Net IF hardware interface can access a channel through MAC layer. Usually, the PM incorporated with Friis-attenuation for nearby distance in two ways transmission approximately at certain distances. The channel can be described as a wireless connection physically that links one to other node that sharing all nodes using the multi-node network wirelessly.

3.6.1 Architecture of Proposed Interface Structure

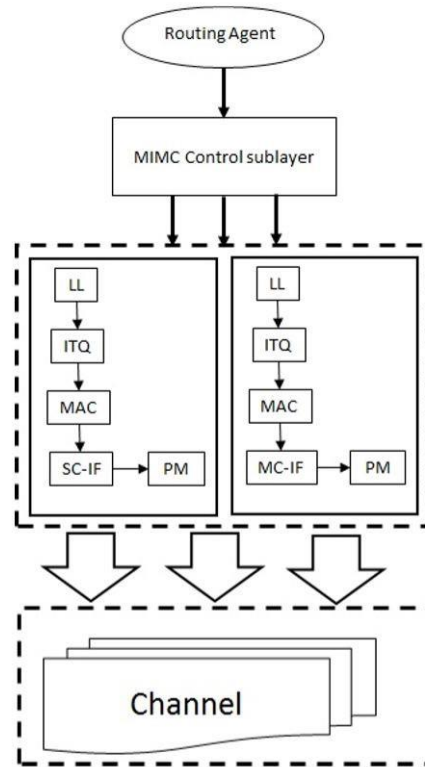


Figure 3.6: The suggested architecture of Interface

Figure 3.6 shows overall suggested architecture to achieve our research objective. It consists of an MIMC, a control sublayer, separate interface (Fixed with Switchable). These control sublayers manage the interfaces with channels that provide the service on the upper layer. Respective IF provides LL, Physical Layer, MAC layer with PM, which is able to support heterogeneous physical interfaces. When implementing suggested algorithms so-called channel assignment, the respective interface will be assigned by a decided channel on MAC layer protocol channel and more channel assign on multi-channel in MAC protocol. Overall, different channel use on the same node on IF. This architecture provides the interface consisting Static Channel-Interface (SC-I) / Multi-Channel-Interface (MC-I) MAC, LL, NetIF, ARP with PM. The IF is able to support 3 types of MAC protocols, which is standard MAC protocol that applies in the single and fixed channel secondly, Channel-

switching on MAC protocol that switch channel to one another using switching method specifically.

In the following section, we elaborate further on this architecture in terms of MIMC control sublayer and multi-interface.

3.6.2 MIMC Control Sublayer

This sublayer is designed among the routing agent with the IF in this proposed architecture Interface. Besides on manage and control, it can support other services, like topology and power controlling on channel assignment. According to routing agent, the sublayer potentially minimizes the complexity of proposed Interface architecture by improving the current upper-layer protocols in terms of compatibility. Therefore, this layer can minimize the upper-layer protocol on complexity according to the MIMC with the amount of modifications on existing upper-layer protocols.

Two significant issues that should be addressed are packet uploading with the delivery of packet downloading. Uploading can be simple when dealing with the packet when the packet receives the IF that is moved to upper layer on this sublayer immediately. Nevertheless, packet downloading is much trickier for delivery on the channel assignment in multi-mode. The reason for this, is due to the selected IF with a packet received on the channel from the upper layer is executed using suggested algorithm (Channel Assignment) to be apply on this upper layer or sub-layer. On the other hand, particular packet gathers an information of the IF with the assigned channel was executed on suggested algorithms. Therefore, information received is delivered on this packet to IF and channel precisely. Consequently, 2 new fields can be gathered for packet frame to specify suggested algorithm

on channel and IF on respective packet. A suggested frame added in packet was presented in Figure 3.7.



Figure 3.7: New added field in MIMC proposed packet

3.6.3 Multi-Interface

The IF is independent of each other (Fixed and Switchable). It contained of ARP, LL, IQ, SC/MC-MAC, PM, with NetIF. The IF structure is designed in such a way that it facilitates the upper-layer protocol operation like MAC protocols. These upper-layer protocols implemented on multiple interfaces with the channel on the MIMC control sublayer, contain of SC/MC-MAC on a MAC protocol, to work in a similar model on various IFs.

SC-IF is the interface with only one NetIFs and one single channel simultaneously. It supports fixed SC-MAC with switch SC-MAC protocols. The MC-IF is an interface contains of multiple NetIF with a corresponding channel. It can connect NetIF on a channel. An MC-MAC protocol can also control the NetIF with channel assigned on respective NetIF based on suggested algorithm. This protocol considers more sophisticated compared to SC-MAC type protocols.

This proposed Interface architecture is modified from Xin's model (Kuang et al., 2015) but much more different in the implementation method used in this Disaster Management System to apply to the existing VASNET structure in this proposed research study. Furthermore, the modified architecture is generic and flexible, with the capability of

both MIMC simulation following the MAC protocol and MIMC network-establishing algorithms with proposed channel assignment algorithms as well.

3.6.4 Channel Assign Method

The amount of the channel for Interface per node must be able to switch Interfaces among the channel. For instance, a single Interface per node on a network with six nodes is fixed on the same channel on each node. It is considered a waste to use available channels. We could not fix the Interface on other channels, as the nodes were provided with two different channels that prohibited communication with respective nodes. Therefore, channel assignment algorithms are served to coordinate among the nodes and are equipped with schedules assignment for switching channels between the Interface to utilize multiple channels fully. The most beneficial of this method is the need for a channel assignment algorithm to specific network demands (Lohia & Ruchita Gupta, 2014).

One of the ways is to use as many as possible for the channel on the quantity of Interfaces per node available. The N amount of interfaces on the node can be fixed to n various channels. It leads to a simplified scenario to control communications on multiple channels simultaneously. However, there is no suitable solution as the various channel was inefficient and unused; in this case, the amount of Interfaces is hugely less when compared to the number of channels. Others were approachable to fix the Interface on the various node to non-disjoint with a set of various channels. Each of the nodes shared a minimum of one various channel with other nodes, as discussed in the previous topic to propose inside this research study. It was able to balance up the load on various channels by fully utilizing all channels effectively. It might simplify protocol on a single assignment channel that improved the network's connectivity (Lohia & Ruchita Gupta, 2014).

This proposed Channel Assignment algorithm can suit the network where the node has a varies quantity of interfaces (fixed and switchable channels) and able to communicate neighbour nodes in specific wireless network coverage.

There is some assumption in the proposed algorithms.

- All the nodes are equipped with more than one Interface.
- In non-overlapping multiple channels, each of the nodes is noticed on which is the control channel.
- Quantity of Interfaces was less than amount of non-overlapping channels on the respective node.
- The amount of non-overlapping channels with carrier frequency on respective channels for every node.
- Equipped with fixed control Interface and data Interface to avoid overlapping on each node.
- The control Interface able to be fixed with a common control channel with the switch to switchable data Interface on data channels.
- The transmitted frames are on control channel (Choi et al., 2010).

Figure 3.8 shows the proposed Channel Assignment method to assign the channel after the Network Establishing stage. Join _ADV broadcast by the source node (Rescue Team) at an initial stage to node A as relaying Node function as Coordinator node (Parent Node), which is responsible for making routing decisions (Abbasi & Shahid Khan, 2018) if a node matches the relay node on the IP address when received a Join_ADV. Node B with Node E will be contributed as Multichannel Coordinator node as intermediate node who relays Multicast Data to the Child node on the multi-hop scenario. Node A (Parent node)

broadcasts Join _REQ to Node B with Node E followed the Markov chains property to child nodes Node C with D (Node B) and Node F with Node G (Node E) for channel assignment on the level child node. When Node C and Node D receive the Join _REQ, it will reply by sending Join_ RPL to Node B, in which store the reply message from Node C with Node D inside the channel list before sending it to the Parent node (Node A) that send the channel list to Source Node. Once receive a reply message from Node A, a Source node will assign the channel based on the channel list received by the sender node (Node A) to assign the channel to Node A and B as channel 1, Node B and C as channel 2 and Node B and D as channel 3 to avoid the Co-Channel Interference during emergency periods. These processes will continue for Node E, Node G, and Node F once we receive the reply message from these nodes through Node A. Therefore, Node A and Node E as Channel 4, Node E and F as Channel 5, and Node E and Node G as Channel 6 as assigned by the Source node inside the channel list. This Channel Assignment to all specific nodes on network coverage can reduce message overhead sent by Source node that locks the specific nodes on specific channel. Below is the Channel Assignment Algorithm for suggested Channel Assignment explained before, with a summary table of all the types of messages and descriptions in the Table 3.1

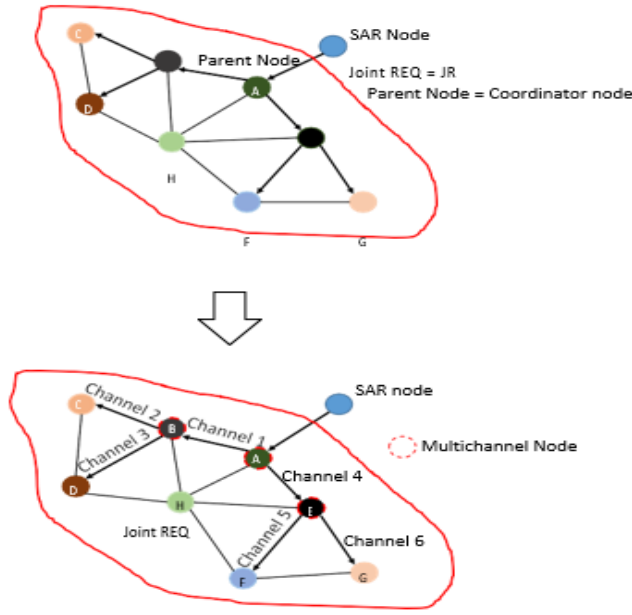


Figure 3.8: Proposed channel assignment method

Algorithm 1 Channel Assignment Formation

Require P: current Parent node, J = Join Child node

Ensure: CH_P = Fixed Channel of Parent

Ensure: CH_J = Fixed Channel of Child Node

Ensure: $C-list_P$ = Child Node list of Parent Node

Ensure: $CH-list_P$ = Channel list of Parent Node

OUTPUT: CH_{ASS} = Fixed Channel to be stored inside channel list information

If ($C-list_P = \emptyset$) **then**

($CH_J = CH_P$)

CH_{ASS} = One of the Channel in $CH-list_P$ consists of CH_J ;

$CH_{ASS} = CH_J$

CH_{ASS} = The dominant Fixed Channel in $C-list_P$.

end if

Table 3.1: Summary of proposed channel assignment packet list

Join_REQ	To address the node (IP Address) to form network	Unicast to each node to join the network (Mesh topology) consist of "Hello" message
Join_REP	To permit the network join to Switchable Interface of Coordinator node	Unicast message send to multichannel Coordinator and Coordinator by replying the packet REQ
Multicast Data	"Positioning" data of each node	Multicast data through multichannel Coordinator to Source node (SAR Node)
Checksum	Validate the Child Node	Resist fake or false data on each Child node to Source Node

3.7 Reliability (Multicasting)

During the construction of network establishment and channel assignment at an initial stage. We can notice that channel assignment has side effects on Link Fluctuation that significantly caused a significant impact on the degradation of the reliability of multicasting (Chen et al., 2013). In Figure 3.9, the wireless connection from Source Node (Node A) to Node 3 is declared as a one-hop route on multicasting at an initial stage. We assume that node 3 is the client for this multicasting session. Node 3 can receive a probing child message from node A for network construction and channel assignment. This node 3 can set node A as a parent node in one hop. Node 3 receives data in multicast mode, neither node 1 nor node A. However, when the link quality between node A with node 3 potentially becomes low for some reason, Node A will not be delivered multicast data to node 3, as in Figure 3.9 (Ding et al., 2007). The link quality becomes weak, which may be due to the various physical characteristics of each channel. For instance, characteristics of the device's battery (Power) and antenna may be equipped with signal power stronger or higher tolerance with respect to

specific interference compared to other available channels (Ding et al., 2007). As a result, 2 neighbouring nodes link in wireless environment could be disconnected and become weak when switching during channel operating. In order to solve this problem, we keep several parent nodes instead of one parent node for a multicast during channel assignment and network construction. Next, the node receives data on the selected parent node on the list in multicast mode, able to show the link quality in an optimum situation among the node.

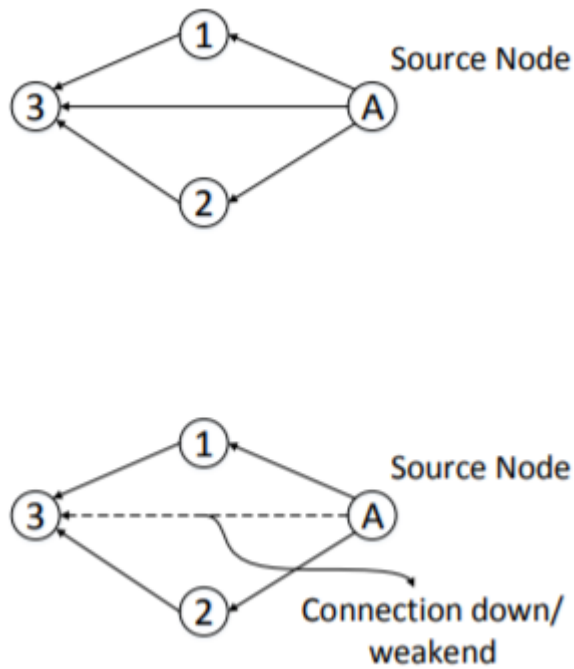


Figure 3.9: Proposed reliability control of multicast

3.8 Why Markov Chains

In this research, VASNET, with an improved channel assignment algorithm able to implement in Disaster Management Systems, needs help in tracking and coordinating rescue time. Notably, massive floods, tsunamis, and volcanoes, whereby the victims or survivors may trap from the current position or location when network and channel assignment has been formed and configured with the specific communication range. For instance, a group

of survivors in floating places (damaged buildings in a tsunami during the post-disaster scenario) may experience the high possibility of moving from an existing location to a new location randomly during rescue time. It may be time-consuming for the response team to track or detect the location of survivors accurately. Moreover, the effectiveness of any Coordination Strategy Plans causes a significant impact on generating the shortest path if the location of survivors moves dynamically instead of stationary.

Consequently, Markov Chains have been introduced in this research to overcome these problems to increase the effectiveness and reliability of this research study. Furthermore, due to the weakness of Global Positioning System (GPS), unable to be used when survivors are trapped inside the tunnel, Markov Chains become a valuable solution to solve this problem as the aims to achieve the research objective in this study. Markov Chains is the stochastic process, whereby the latest state of the survivor's condition depends on the present state or decision (information to the Response Team about the survivor's coordination) of the survivor's location that is able to track the location of survivors easily (Markov Chains, 2019). The details operation and definition of Markov Chains are explained in the following topic.

3.8.1 Markov Chains: State and Transition

This Markov Chains consists of types of dependency, which is the simplest kind of it. On this random situation, existing state with conditional probability of next state are depending on existing state, and independent on the process history. This process considers random, and knows as a process of stochastic in the series of variables. We assuming a series in spaced that equally on time represented as epochs. Those success of epochs in interval of time can be considered a step or a period. At the respective epoch, the observation of the

system will be in a number of finites mutually exclusive states. One of the values is in-state, possibly on a random variable. The random process of Markov property can be described as the knowledge needed in history to be a model of its future behaviours probabilistically.

The N states on the Markov chain can be decided as a series of $1,2,3,4\dots N$. This series can be considered as state infinite number and N can declared as finite integers. All possible series of states can be described as state-space with $E = 1,2,3,4\dots$. This series is called as epochs together with time-series that equal in spaced points. The epoch can be considered as n series of $= 0,1,2,3,4\dots$. The n is denoted as a time end of n , in which the initial periods is $n+1$. The random variable X_n can be declared as chain states in n epoch. Therefore, can be defined as sequence of random variables X_0, X_1 , and X_2 that include in the Markov property. The index of n on epoch for random variable state can be consider. Therefore, the series of states in this Markov Chain can be declared as epochs consecutive.

The n index, generally described as observation time and an epoch, which other parameters like observation order can be observed. For instance, n index indicates customer served in n th trial in the contest, and n th item being inspected. On n epoch in state chain i , the $X_n = i$. As such, in probability, this chain in n epoch at i state represented existing $P(X_n = i)$ epoch. In terms of probability, state j chain on $n+1$ epoch; is the following epoch considered as $P(X_{n+1} = j)$. Therefore, based on probability of conditional, the state j in chain epoch denoted as $n+1$ given i state on n epoch as $P(X_{n+1} = j | X_n = i)$. This can be considered as the probability transaction which called as P_{ij} as indicated in Equation 3.1

$$P_{ij} = P(X_{n+1} = j | X_n = i) \quad \text{Equation 3.1}$$

Thus, the transition probability can be called as probability of conditional with state i in chain for existing epoch and state j as following epoch. P_{ij} considered a one-step transition

for those transition probabilities due to period of time. This Markov Chain property can ensure the transition probabilities on existing state in process called X_n . Therefore, the history in this process can be described by a state of sequence X_0, X_1, X_2, X_{n-1} , occupied before the existing epoch to be ignored. As such, this transition probability is a constant, and epoch n is independent as illustrated in Equation 3.2 (Sheskin, 2016).

$$P_{ij} = P(X_{n+1} = j | X_n = i) = P(X_1 = j | X_0 = i) \quad \text{Equation 3.2}$$

3.8.2 Markov Chains: Proposed Method

The Markov Chains chosen in these proposed mobile nodes is to obey the bottom-up approach. These Markov Chains can work as a modelling of a sequence of dependent events of following event depending only on the existing state on the present node, as illustrated in Figure 3.10 (Sheskin, 2016) by Chapman-Kolmogorov (Equation 3.3) (Chapman–kolmogorov equation.).

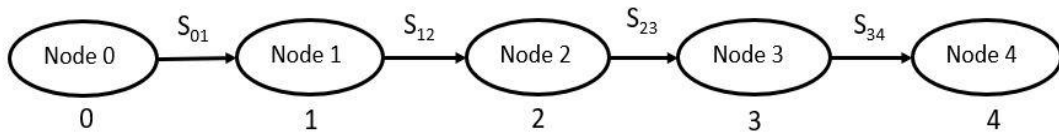


Figure 3.10: State transition for a sample path

$$S(Node0, Node1, Node 2, Node3, Node4)$$

$$S = \{S(Node0)S(Node1|Node = 0)S(Node2|Node = 1)S(Node3|Node = 2)S(Node4|Node = 3)\} = S_{01}S_{12}S_{23}S_{34} \quad \text{Equation 3.3}$$

Where S = state, S (Node 0) = Initial state

3.8.3 Markov Chains Modelling: Random Walks

Random Walks is defined as a modelling situation for an object moving in a step on a random sequence in chosen directions. Suppose that, at a certain time a particle moving between a position in a line. The specific epoch, moving to right side in one position represented by p probability and move to left side represented by $1-p$ probability. This process is continuous and vice versa when reaches one of the end points that called as a barrier. Since the particle movement depends on the existing location and do not consider previous location in any mode. This modelling was so called Markov Chain. It also considered as non-steady movement of individual epoch in random walk (Häggström, 2002). A state presented is an integer in consecutive process that possible for epoch on the line. When the epoch was in n , position, it considered as state i in random walk. Therefore, the state $X_n = i$ is the particle or epoch after move in n step position.

Suppose R_n is the probability that given a position of n and R_0 if starting position is at 0. In case, position of w is the end position, then, $0 < n < w$. We can divide the analysis into two cases based on the direction of the first hop as listed below.

If first hop is to the left, then the position is $n-1$ and eventually falls into probability R_{n-1}

- If first hop is to the right, then the position is $n+1$ and eventually falls into probability R_{n+1} .

As such, By Total Probability Theorem (Random walks -mit opencourseware.)

$$R_n = \frac{1}{2}R_{n-1} + \frac{1}{2}R_{n+1} \quad \text{Equation 3.4}$$

However, R_n is a function of both a preceding term (R_{n-1}) and next term (R_{n+1}). We can rearrange the terms in the recurrence equation as indicated as below in Equation 3.5

$$R_{n+1} = 2R_n - R_{n-1} \quad \text{Equation 3.5}$$

Consider another example in state i whereby $0 < i < 4$, is one position probability moving on the right direction in at Equation 3.6

$$R_{i,i+1} = R(X_{n+1} = i + 1 | X_n = i) = P \quad \text{Equation 3.6}$$

Similarly, the probability to move position to left is as Equation 3.7

$$R_{i,i-1} = R(X_{n-1} = i - 1 | X_n = i) = 1 - P \quad \text{Equation 3.7}$$

The remaining transition probability are 0. Which is Equation 3.8

$$P_{i,j} = 0 \quad \text{Equation 3.8}$$

for $j \neq i-1$ and for $j \neq i+1$

The probability of transition on $i=0$ with $i=4$, which called as a state of that terminal according to the barrier nature are presented on the terminal as those specific states (Sheskin, 2016).

3.8.4 Markov Chains in Wireless Networking

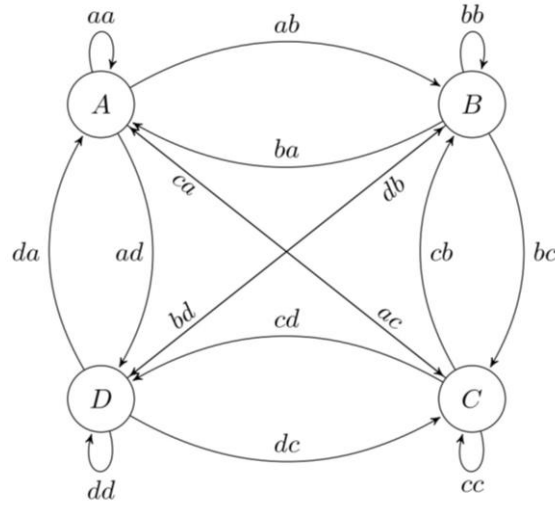


Figure 3.11: Markov Chain in wireless networking environment

$$\begin{bmatrix} A_{aa} & A_{ab} & A_{ac} & A_{ad} \\ B_{ba} & B_{bb} & B_{bc} & B_{bd} \\ C_{ca} & C_{cb} & C_{cc} & C_{cd} \\ D_{da} & D_{db} & D_{dc} & D_{dd} \end{bmatrix} \quad \text{Equation 3.9}$$

Figure 3.11 shows the Markov Chains used on wireless networking for communication systems. The primary function of Markov Chains is used to design a wireless channel model, which can switch among the possible or given channels based on the probability of the transition matrix shown in Equation 3.9. In other words, the Markov Chains property is to satisfy when the current state of any process is good enough to predict the next or future state of the process. This prediction can be as good as possible to predict by examining their history (Sánchez et al., 2012). Based on Figure 3.11, when node A requests to have a communication link to node B. Node A should predict the movement of node B (current state) to predict the next movement of node B after certain periods of time by assigning a specific channel among node A and node B. Therefore, by prediction, the next movement of the following state of node B. Node A capable of communicating and sharing any necessary information, especially during rescue plans. This is very helpful when

applying disaster management systems in which all the survivors (nodes) are moving randomly, and rapid pattern changes cannot be handled by any communication method without this Markov Chains system. Inversely, node B can predict the next state or movement of node A by knowing the current movement or movement history to send any valuable information during emergencies, especially heavy floods or tsunami situations (Sánchez et al., 2012). This enables any channel switching according to this transition property that increases the performance of communication quality by reducing packet loss during broadcasting and improving the wireless communication system. Lastly, the Markov Chains system proposed in this research study will be modified to suit the improved channel algorithm (discussed previously), network-establishing algorithm, and packet scheduling algorithm, which will elaborate in more detail in the next section.

3.8.5 Absorbing

The node will maintain its position in that state when it arrives at an absorbing barrier. Thus, its barrier represented a state that can be considered a state of absorbing. The transition probability in a random walk of fine-state together with 2 absorbing barriers presented state 0 and 4 by absorbing as indicated on Figure 3.12 (Sheskin, 2016).

X_n/X_{n+1}	0	1	2	3	4
0	1	0	0	0	0
1	$1-p$	0	p	0	0
2	0	$1-p$	0	p	0
3	0	0	$1-p$	0	p
4	0	0	0	0	1

Figure 3.12: Absorbing transition probability

3.8.6 Reflecting

The adjacent state can enter the subsequent transition when the node arrives at the reflecting barrier. The transition probability in the random walk on a five-state together with 2 reflecting barriers, presented state 0 with state 4 in Figure 3.13 (Sheskin, 2016).

X_n/X_{n+1}	0	1	2	3	4
0	0	1	0	0	0
1	$1-p$	0	p	0	0
2	0	$1-p$	0	p	0
3	0	0	$1-p$	0	p
4	0	0	0	1	0

Figure 3.13: Reflecting transition probability

3.8.7 Circular

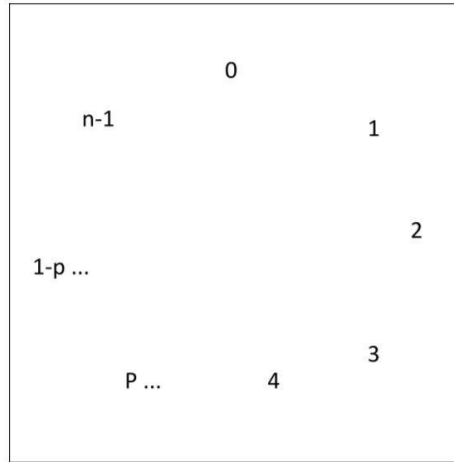


Figure 3.14: Circular Random Walk

Figure 3.14 presented a particle moving in circular motion with state $E = 0, 1, 2, 3, 4$. The particle moves in the clockwise direction respect to adjacent particle considered as p , and anticlockwise direction can be declared as $1-p$. The 0 and 4 particles are on circular motion with adjacent of another particle as well. Thus, a circular motion on a random walk does not have a barrier. The probability of transition for random walk-in circular was shows in Figure 3.15 (Sheskin, 2016).

$$P = [p_{ij}] =$$

X_n/X_{n+1}	0	1	2	3	4
0	0	p	0	0	$1-p$
1	$1-p$	0	p	0	0
2	0	$1-p$	0	p	0
3	0	0	$1-p$	0	p
4	p	0	0	$1-p$	0

Figure 3.15: Circular transition probability

3.8.8 Random Walks: Barriers

Random Walks have different types of barriers. The most common types of barriers used in this research are Absorbing, Reflecting, and Random Circular Walk proposed in this research for node (survivors or victims) movement during the post-disaster-scenario emergency rescue time.

3.9 Markov Decision Process: MDP

The MDP is a decision sequential process that can produce Markov Chains in sequence and rewards (Sheskin, 2016). The MDP was able to generate a sequence of states as the associated rewards from one state to another state, which both is transition probabilities and the decision made in series. An MDP model aims to verify the optimal policy, either the expected reward, maximising the gain per period or the expected total being maximised when discounted reward is received in every state (Sheskin, 2016).

Based on Markov Chains policy. It can be a node connected with the neighbour node to form a channel using proposed Channel Assignment algorithms. This is to follow the

bottom-up approach as elaborated in previous topic. The Rescue Team consists of Coordination Strategy Action Plan will be the mother node on this MDP series. Each decision in every state on this MDP can be linked probabilities with a reward (Sheskin, 2016). As such, Rescue Team denotes as a state X_{n-1} as the mother node on this MDP series toward the beginning stage of this research study. This series of chains has four states which correspond the four-level consisting of child nodes (survivors or victims in incident area).

The Table 3.2 identifies the 4 states, decision alternatives with the rewards associated. It presents a mother node indicated as Command Control Center on state 1 offered three kinds of decisions listed in Table 3.2. Mother node making a decision (which in this is 3 states of decision) provided a reward by sending any necessary valuable data in terms of multimedia format such as video recording, message and incident location tracking to Command-and-Control Centre. Thus, it flows to state X_n after the rewarding process to the incident area. On this state X_n , it making 2 decisions as depicted on the Table 3.2 and waits for instruction from Command Control Centre to take any necessary action after the reply from primary Command Control Centre as a reward. This process is continuous until four levels as the Command Control Centre given a precise and accurate data to get the most appropriate action in shortest time or path to the Response Team to save or rescue the survivors on this channel as soon as possible.

Table 3.2: State, Decision and Reward for VASNET on proposed method.

Node	State	Decision	Action	Rewards
Mother node	1	1	Sending "Hello" message	Waiting next action
		2	Coordination of survivors/victims	Waiting next action
		3	Available/nearby Response Team.	Data/Information send back to Command Control Center
Child node (level 2)	2	1	Coordinate the survivors/victims location.	Waiting instruction from Response Team.
		2	Number of injury person and condition	Sending data among Response Team and Command Control Center.
Child node (level 3)	3	1	Coordinate the survivors/victims location.	Waiting instruction from Response Team.
		2	Number of injury person and condition	Sending data among Response Team and Command Control Center.
Child node (level 4)	4	1	Coordinate the survivors/victims location.	Waiting instruction from Response Team.
		2	Number of injury person and condition	Rescue by Response Team

For any N-state process, n can be identified as a policy in the following $N \times 1$ column vector matrix form in Figure 3.16.

$$X_n = \begin{bmatrix} X_1(n) \\ X_2(n) \\ X_3(n) \\ \vdots \\ X_n(n) \end{bmatrix} = [X_1(n)X_2(n)X_3(n)...X_n(n)]$$

Figure 3.16: Matrix form of N x 1

This is called a decision vector. Vector $X(n)$ identifies every state at epoch n . Moreover, $X_n = K$ indicate in s state on n epoch, it making K decision. Each decision in the state where the reward associated with a probability distribution on transition is out of the state. K is to designate the decision on a state. Thus, P_y^k presented the transition probability determined the decision K in state s on epoch n from S state to Y state (Sheskin, 2016) which is this Equation 3.10

$$P_{sy}^k = P(X_{n+1} = Y | X_n = S \cap X_s(n) = K) \quad \text{Equation 3.10}$$

The iteration value implemented on MDP, defines $X_i(n)$ when $X_i(n)$ is the total reward earned expectantly if the system on i state ended on period n with the optimal policy until the planning horizon ended. The informal derivation is extended for the iteration value when the iteration value is algebraic from the equation on an MDP presented in the following Equation 3.11

$$X_i(n) = \max[q_i^k + \sum_{j=1}^N P_{ij}^k v_j(n+1)] \quad \text{Equation 3.11}$$

for $n = 0, 1, \dots, T-1$ and $i = 1, 2, \dots, N$

Figure 3.17 represents the iteration value equation in the tree diagram for an algebraic form for MDP in the existing state, together with two decisions on Equation 3.12

$$X_i(n) = \max[q_i^k + P_{ij}^k v_j(n+1) + P_{ih}^k v_h(n+1)], [q_i^b + P_{ij}^b v_j(n+1) + P_{ih}^b v_h(n+1)] \quad \text{Equation 3.12}$$

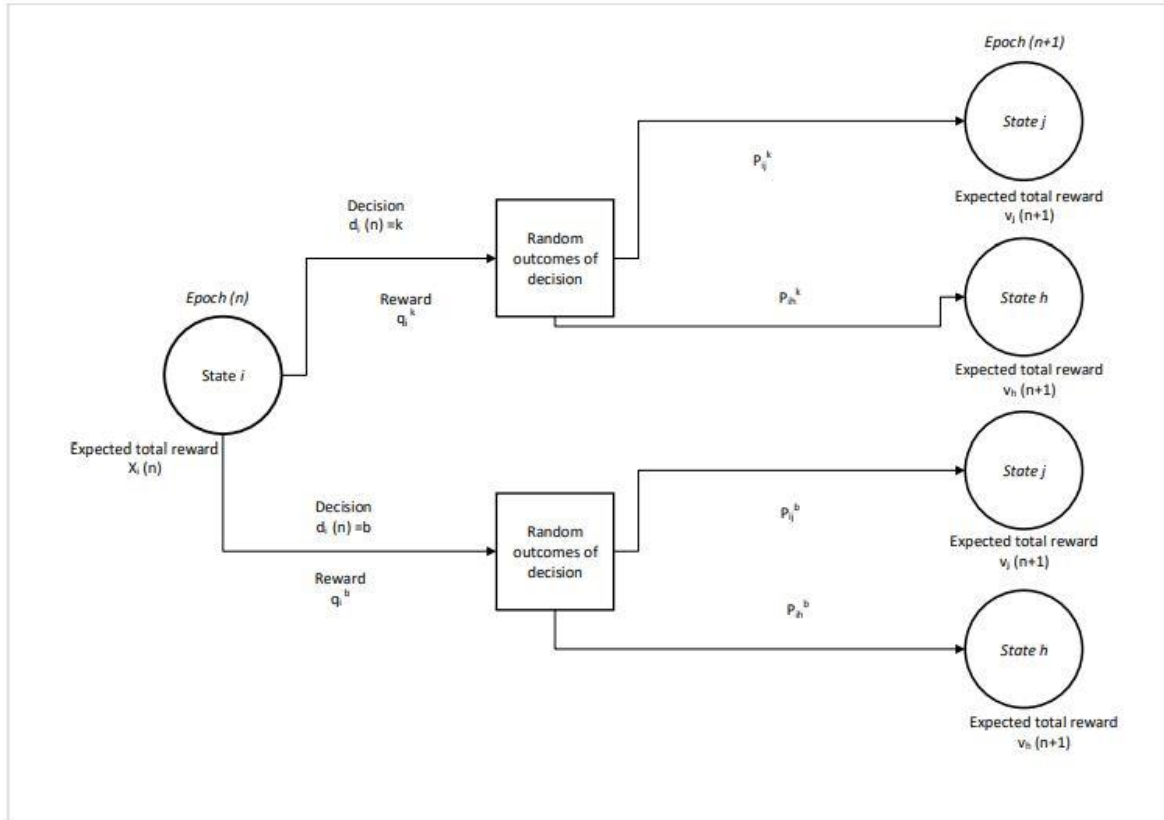


Figure 3.17: The MDP on Tree diagram of the iteration value

3.10 Network Establishing: Algorithm

The network efficiency can be improved by applying Multi-Interface Multi-Channel (MIMC), which implements multiple channels wirelessly via multiple interfaces. This MIMC technic reduced the same channel interference and prevented throughput degradation overheads of packet loss and delay, minimizing the actual goodput to any wireless network drastically. Even though the number of hops increases (Kyasanur et al., 2006; Kyasanur &

Vaidya, 2005; Sheskin, 2016; Raniwala & Chiueh, 2005; Raniwala, 2004). Furthermore, the permission of multiple transmissions simultaneously with a neighbourhood. Therefore, the interference of the co-channel can be alleviated. As a result, the higher throughput possibly be achieved as expected (Hai-tao & Yue, 2011), and confliction of the packet may be decreased to the lowest level (He & Xu, 2010). Moreover, the adjacent hops interference in a multiple node network can decrease further on available bandwidth.

The number of users in multi-channel can eliminate those problems. The extended bandwidth was available within interference removing communication in simultaneous mode between adjacent hops over a non-overlapping channel. When we were unable to equip the nodes on interfaces for the non-overlapping channel, as the result of power consumption, the algorithms of channel assignment should be revised to switch the interfaces from one channel to another channel in the cost of switching delay (Lohia & Ruchita Gupta, 2014). The strategy maintains the connectivity on the network and, at the same time, switches the channel quickly. Apart from this, nodes noticed a lot of neighbour's fixed interfaces on the same level of the channel, able to switch the "fixed" interfaces to the indicated channel in order to minimize the collision. There is a difference in comparison to switchable interfaces from switching and switching off must be very careful on fixed interfaces during channel changes and advertise to all nearby nodes. All the neighbour's nodes that wish to communicate must switch the switchable channel to the selected channel if the switchable channel is not available on those channels (He & Xu, 2010). When nodes offer the same channel to each other, data transmission performance may decrease drastically when distance or range for each node within or outside the network coverage. Consequently, to cope with this problem, each node assigns a particular channel appropriate to each parent node to emphasize the interoperability to generate a link communication between child

nodes and parent nodes. The Markov Chains and Markov Decision Process (MDP) be proposed for such a network by dividing a node into a level consisting of the Source node (Rescue Team), parent node, sub-parent node, and child nodes as illustrated in Figure 3.18 and Figure 3.19.

According to Markov Chains property, a Source node disseminates multiple times an advertisement message to every node in the disaster area at an initial stage. This message is relayed due to some designated intermediate node chosen between the existing senders in one-hop neighbours (Ding et al., 2007). Generating an advertisement message in the multicast tree is disseminated in the model of the node to node. Thus, a node attempting to join the group upon receiving the advertisement message replies to a join message onto the parent node that can send itself an advertisement message. When a parent node receives the join message from the child node. It considered the sender node to become its child node and reply messages to a particular node. The network establishing formation proceeds as the advertisement message keeps disseminating by the parent node through the sub-parent node (previously child node) to any nodes nearby to the sub-parent node. When a node replies to a join message to more than 1 sender node, the sender node compares the child node list on sender nodes to permit the sender node with most child nodes as parent nodes for the nodes sent the join message by reply the message to the join message sent node to form a network topology. Following show the algorithm 2 of network formation.

Algorithm 2 *Network Formation*

Require: D: Packet inside network

Require: R: Multicast tree

Ensure: Partition nodes into different levels;

for $\forall \text{node } n \in V(D)$ **do**

$S = [v]$ *true* if and only if v is a multi-node receiver or the source node.

end for

for $I = \text{level} - 1, I \geq 1, I - 1$ **do**

$N_i = \text{node } V_i | V_i \text{ as level} - I;$

$N_j = \text{node } V_j | V_j \text{ as level} - 1 \text{ and } S[V_j] = \text{True};$

while $S_j = \emptyset$ **do**

Find V_{j1}, V_{j2} with the minimum number of parents;

Along the parents of V_{j1}, V_{j2} find node N_p with the
Maximum number of child node.

$S[N_p] = \text{true};$

$S_j = S_j - [N_p];$

$S_j = S_j - [\text{the child node of } N_p];$

end while

end for

for $\forall \text{ node } n \in V(D)$ **do**

$V(R) = V(R) \cup S\{v\}$ if and only if $S[v] = \text{true};$

$\text{Edge } f = (V, V' \text{ subparent});$

$f(R) = f(R) \cup \{f\};$

end for

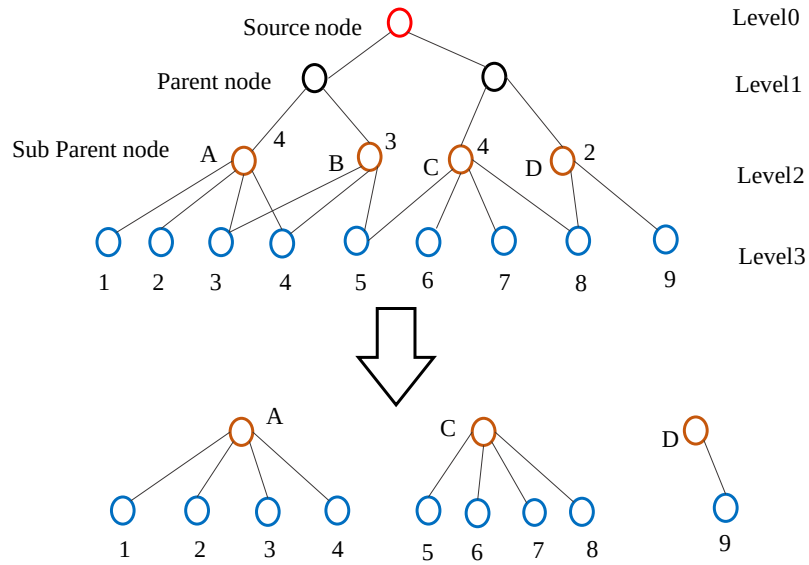


Figure 3.18: Proposed network hierarchy

It forms network hierarchy (Figure 3.18) to construct a network coverage. Figure 3.19 is the diagram illustrated based on the proposed network establishing formation as above.

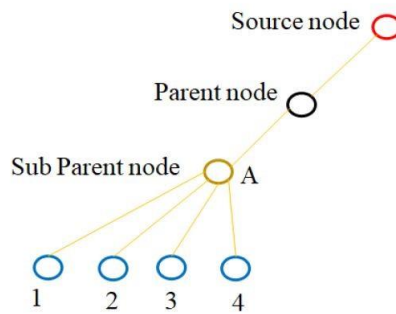


Figure 3.19: Proposed network hierarchy architecture

3.11 Proposed Sequence Diagram

Figure 3.20 depicted the proposed sequence diagram. This sequence diagram provided all the necessary parts designed for this research study. It consists of Rescue Team from various expertise, background, and professional group of people and is well-trained to handle any emergency in a post-disaster scenario. Node A and Node B consider victims or survivors during an emergency period, ready with any wireless devices like smartphones, tablets, smartwatches, and various handheld devices that provide an LTE and LTE-A with LTE-AIC as a communication protocol in this research study which also consists of Interface as to link VASNET structure to proposed methods. In this sequence diagram, a gateway with a database (Cloud computing technology) is under the category of IoT level in a Disaster Management System that ready to store and retrieve any data from the database of victims or survivors in a particular area (urban or City) with any coordination mechanism to find appropriate solution or methods in shortest time or path. The following topic elaborates further on each function divided into the respective section.

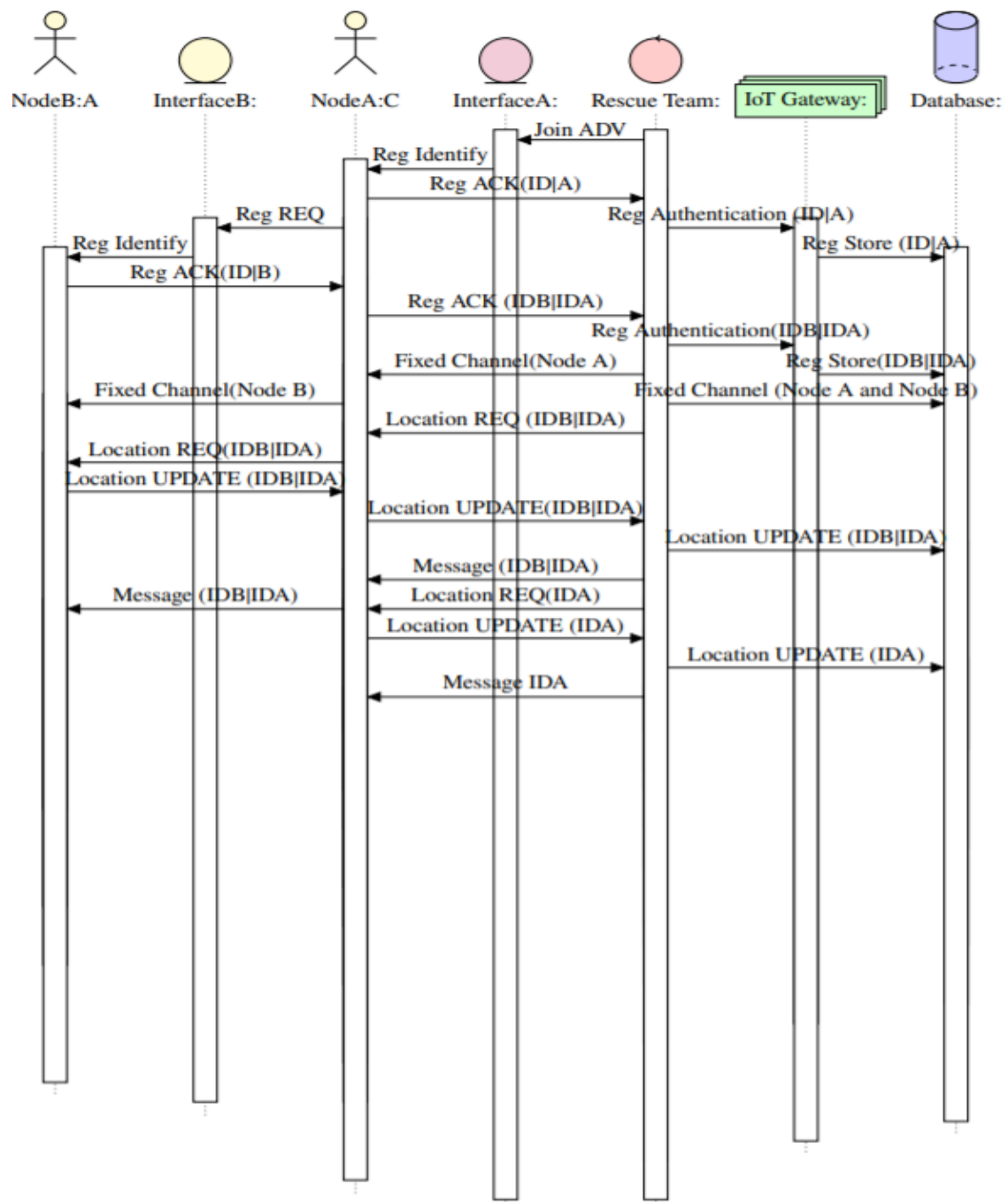


Figure 3.20: Proposed overall sequence diagram

3.11.1 Node Registration

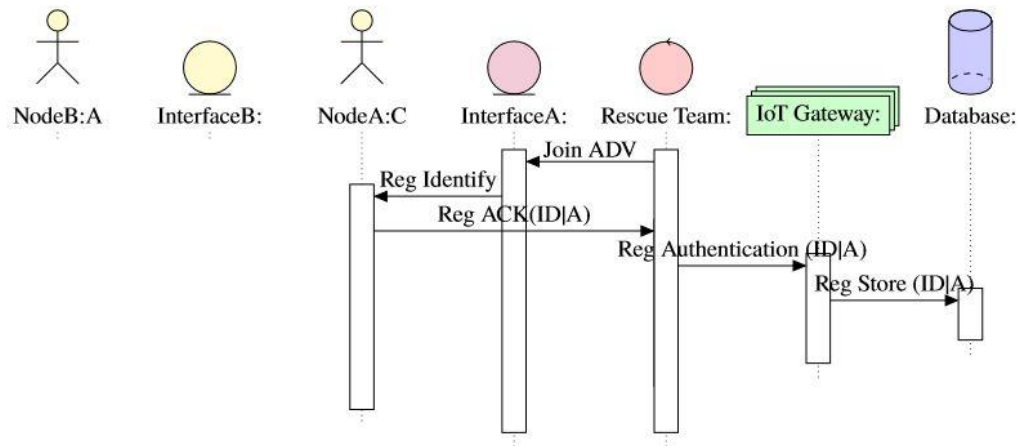


Figure 3.21: Proposed node registration sequence diagram

The Source Node (Rescue Team) disseminates the Advertisement message and Reply by Node A through Interface A and replies the join message to the Source Node with the IP address of Node A. This IP address of Node A as Parent Node is stored inside the database through the IoT Gateway by Source Node. Figure 3.21 depicts the operation of this Node Registration as above.

3.11.2 Network Discovering Formation and Channel

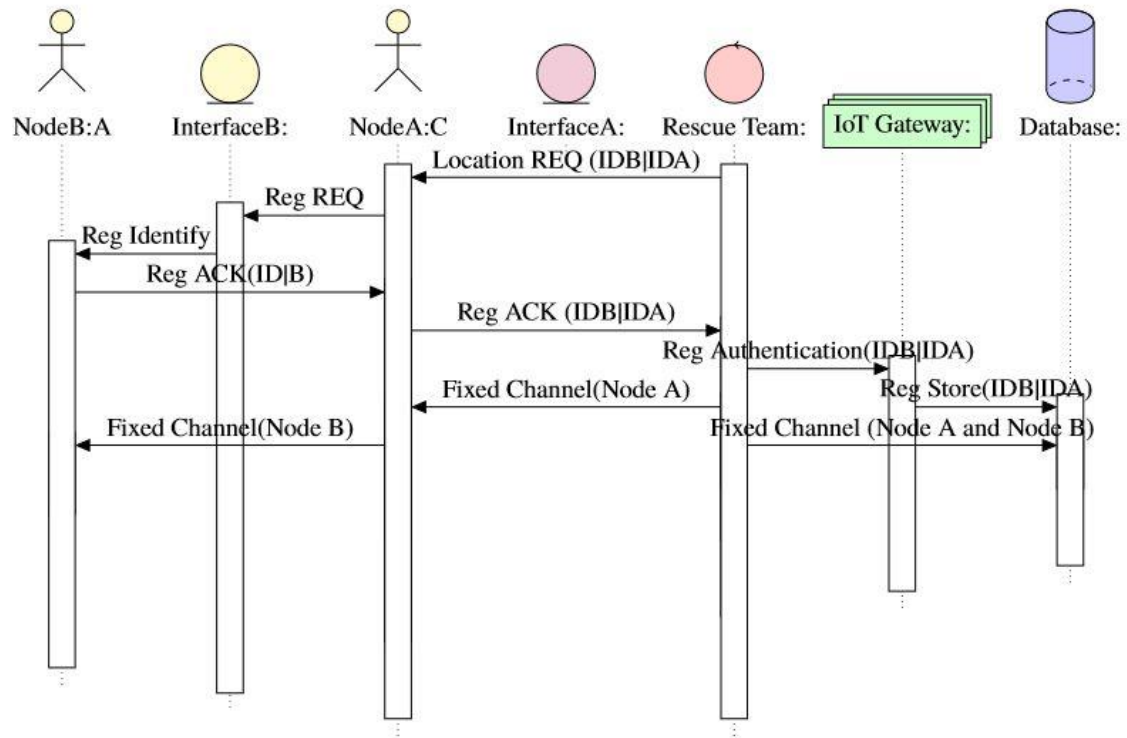


Figure 3.22: Proposed network discovery formation sequence diagram

In this stage, as a Parent node, Node A sends or broadcasts a Join_REQ to the next node level (Node B) to form a network coverage. Reply from the node (Node B) stored inside the central database by Source Node through Parent node (Node A) on the IP address obeying the Markov's Chains property. All operation was illustrated in Figure 3.22 sequential diagram as mentioned before.

3.11.3 Location Detection

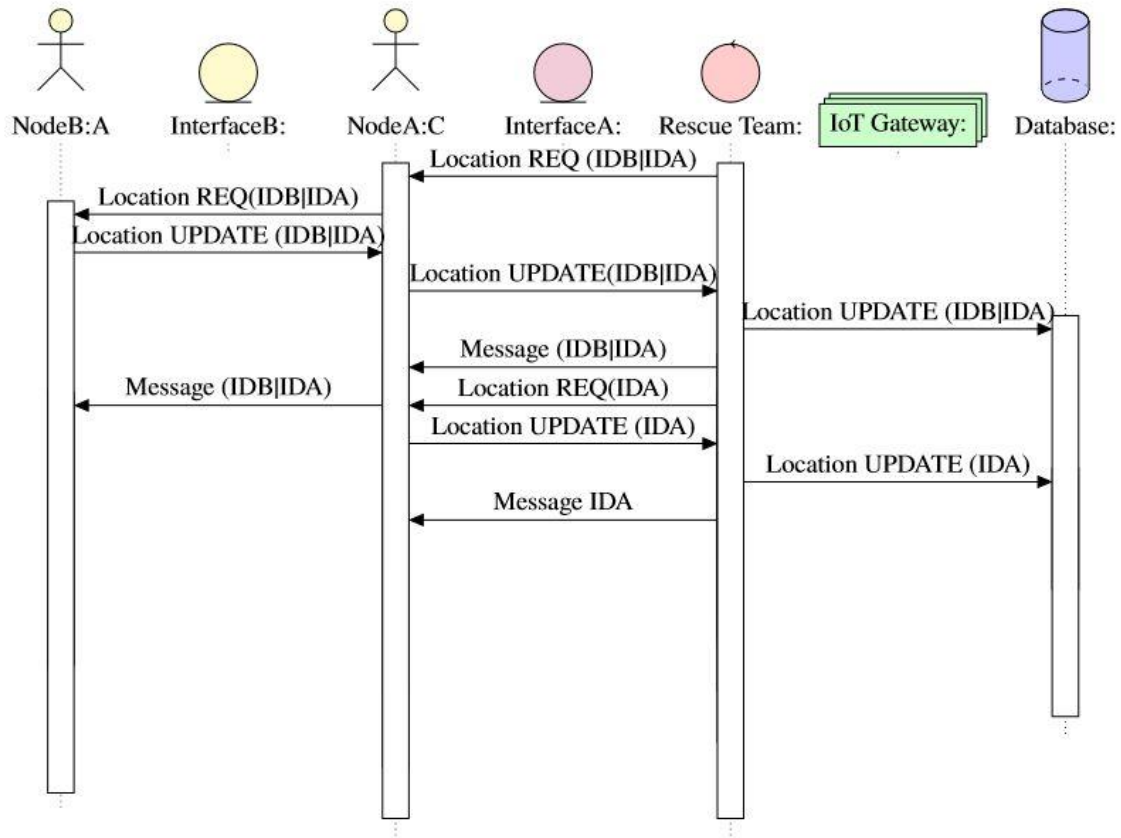


Figure 3.23: Proposed location detection sequence diagram

Upon the formation of network discovery and channel, the Source node sends a location REQ message to a fixed channel on the specific node (Node B) through the Parent node (Node A) to get the actual location of survivors. Message Reply by the survivor's will contains the location of the nodes by the fixed channel that ability to reach to Source Node for any immediate action by the Rescue Team. All the transaction messages on the fixed channel are stored on the central database through IoT Service Provider under the LTE and LTE-A with LTE-AIC communication protocol for future reference and data analysis. Figure 3.23 above explains the operation of this sequential diagram.

3.12 LTE-A Downlink: OFDMA Principles

The OFDMA implemented in LTE and LTE-A, which consist of similar principles on each other. Nevertheless, the LTE-A gives more advantages and improve the capabilities of the system with other enhancement technical. This OFDMA applied on vary LTE when regards to uplink and downlink.

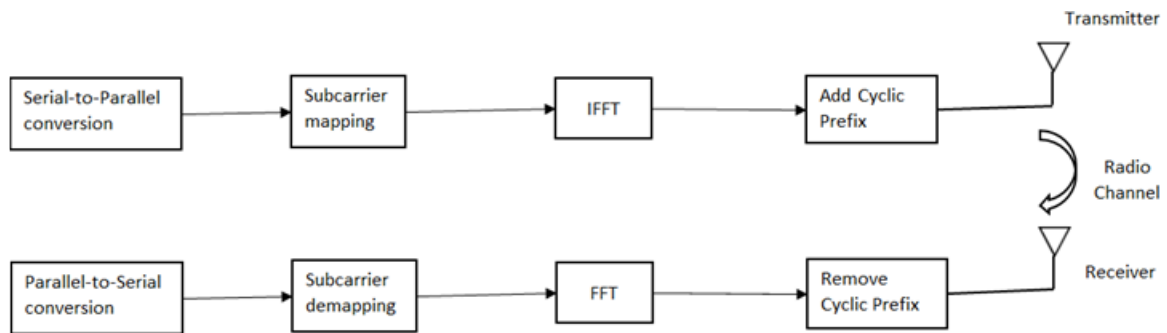


Figure 3.24: OFDM signal processing chain

Figure 3.24 depicts a simplified OFDM signal processing chain. As this OFDM equipped with varies narrowband on data broadcasting scheme, each of the subcarrier consist of individual stream in parallel mode. However, the Inverse Fast Fourier Transform (IFFT) transforming the subcarrier that being modulated from frequency to time-domain (Oran Bringham, 1988) The inverse-FFT with Fast Fourier Transform are dominated in engineering field. The signal from FFT can convert the time domain to frequency domain, and IFFT does other way. Therefore, the functionality of IFFT was transmitter and FFT as a receiver (Korhenan, 2014).

3.13 LTE-A Uplink: SC-FDMA

One major problem of OFDM is extremely high value of PAPR implemented on downlink LTE. All the subcarrier applied on power in high level concurrently, and because of this, the combination of all carrier potentially has an extremely high-power level problem. This problem can handle on the base station transmitter, but on UE, it may face a high PAPR

in which power amplifier performance could be more efficient and may cause a short battery life. Consequently, other techniques named as a SC-FDMA was introduced for the LTE uplink.

SC-FDMA can be elaborated as a combination of low level PAPR onto carrier system shows significant result over OFDM system.

Figure 3.25 presents SC-FDMA processing chain in high level of block diagram which similar with OFDM, that exclude the broadcasting chain at initial stage. The signal implemented FFT in order to transform, the time signal to frequency signal. This directly cause the information spreading on all the subcarrier beside downlink of OFDM, where the bits separated to subcarrier and deliver in parallel mode. Consequently, the PAPR become much smaller. That subcarrier was set to zero and not implemented on uplink broadcasting scheme. The IFFT function was transfer those signals to time domain and added cyclic prefixes in similar way as OFDM. Further, both SC-FDMA and OFDM used 15KHz of carrier spacing.

The receiver of SC-FDMA diagram can be considered as a mirror of transmitter diagram. SC-FDMA has some advantageous features, as listed below (Korhenan, 2014).

1. Spread the data bits on wider channels, offers a level of diversity frequency.
2. Unsensitivity of SC-FDMA compared to OFDM in terms of frequency offset.
3. Less complexity transmitters.

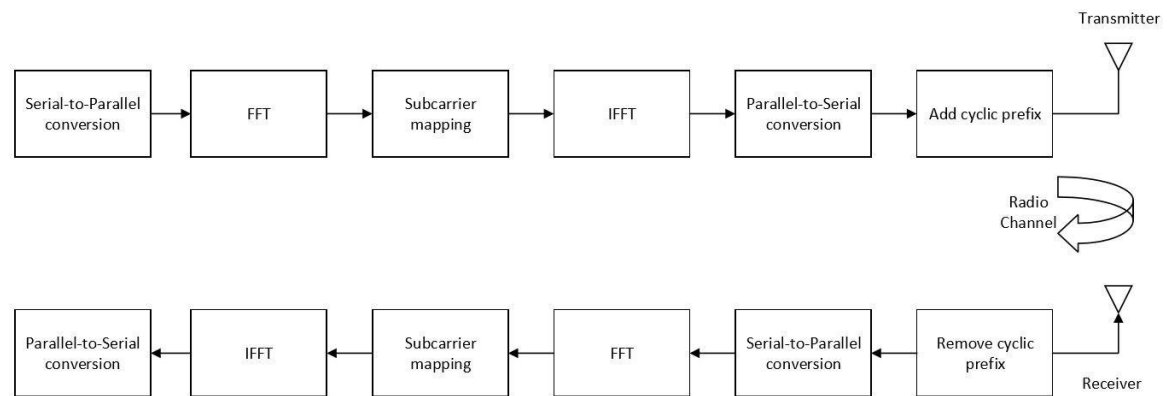


Figure 3.25: SC-FDMA signal processing chain

3.14 LTE-A Features: MIMO

MIMO is defined as Multi-Input Multi-Output, which form by a multi-antenna technology, which form by a multi-antenna named spatial multiplexing. This MIMO was not included in 3GPP and implemented onto UTRAN for Release 7 and LTE on initial Release 8. Nevertheless, this MIMO is enhanced level of LTE-A. MIMO consider as a system that exploits diversity in spatial.

On this multiplexing of spatial, each of the antenna deliver data streams independently. We introduce the MIMO to handle the radio interface channel resources to solve this. The existing channel transmission needs to share allocation between the user by partitioning and utilise the time and frequency. But, new series of spatial presented on this MIMO. It can separate more transmissions at the receiver when they send using similar frequency, code, and time, that shows vary spatial signatures. This able to be done using vary antenna equipped with transmitting and receiving, that is sufficiently far enough for both antenna on radio link and environment full of scatter. When the condition of antenna is optimal, there can form parallel transmission channels severally that employ similar frequency, code space, and time to increase the capacity. This system consists of m and n received by antenna able to achieve $C = \min(m, n)$ subchannel independently. To achieve

optimum condition in MIMO, request high SNR in multi-path as shows in Figure 3.26 (Korhenan, 2014).

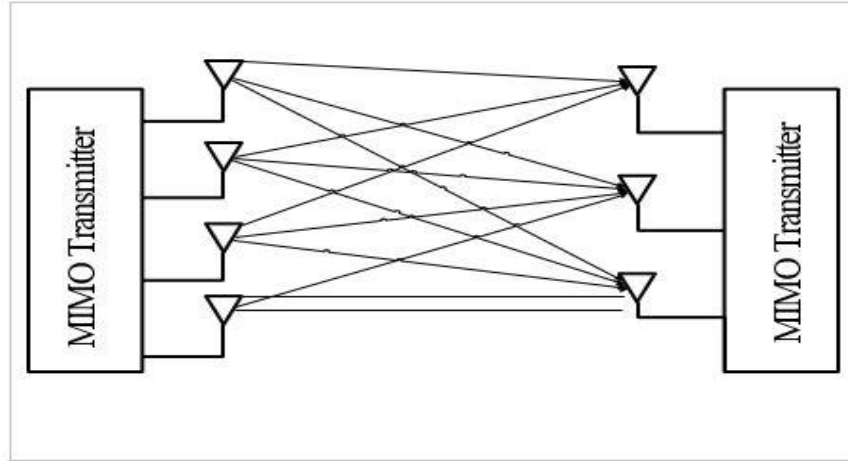


Figure 3.26: General MIMO system

Nevertheless, the amount of independent sub-channel with transmitting and receiving antenna keep in increase trend will reduce the performance of this MIMO system. This channel must be un-coupled and un-correlated that contribute more work when lot of antenna pack into tiny devices. The larger the distance among the antenna, the transmission will undergo fading separately. On recent year, MIMO antenna was developed into vary types of antennas which equipped individual performance (Korhenan, 2014). However, MIMO antenna equipped with minimum of half of wavelength on UE design. The major challenge of MIMO is lower frequencies handsets. Nevertheless, there is an advantages or minimum factor for those large display and bigger tablet provided when MIMO antenna attach on it.

3.15 Downlink MIMO

The LTE Release 8 and 9 can support 4x4 on downlink with 2x2 on uplink. However, LTE-A can be upgraded until 8x8 on downlink and 4x4 on uplink. This 8x8 equipped in both

eNodeBs with UEs on 8 antennas are complicated and costly on operation networks. This 8x8 types MIMO able to deploy around 20MHz and data rate on 600Mbps theoretically. Further, the LTE-A implemented carrier aggregation with 5 types of carriers. Assuming, 8x8 with 5x20MHz carrier aggregation and maximum theoretical rate up to 3Gbps.

The MIMO on 3GPP consist of 2 ways which is SU-MIMO and MU-MIMO. Therefore, in this research study the proposed method is shown in Figure 3.27.

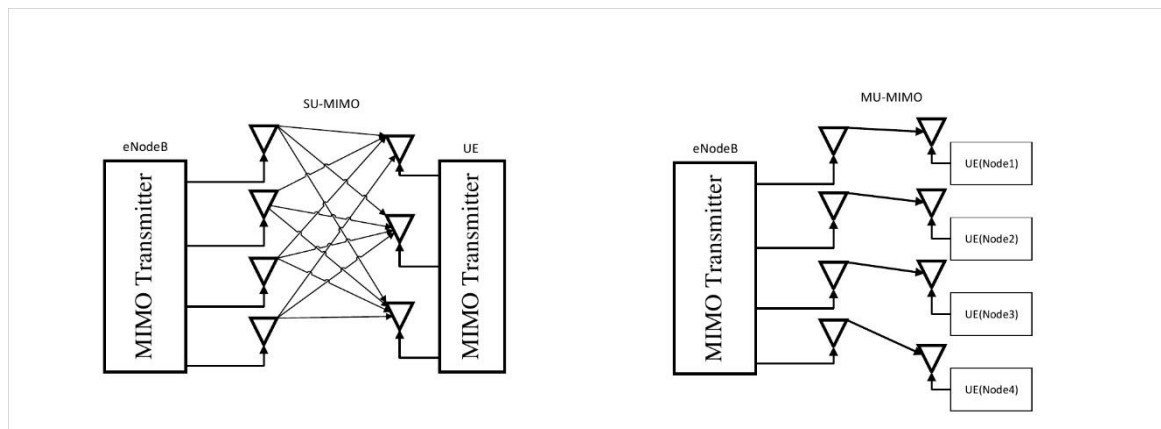


Figure 3.27: SU-MIMO and MU-MIMO

On SU-MIMO, the MIMO layer is provided to all UE. On the other hands, MU-MIMO are different on vary UEs. Those cells dynamically switching among the mode. In UE-MIMO type of cell, the UE will not have to worry among other type of UEs, as it spatially multiplexed to apply on similar frequency or time resources. Furthermore, the SU-MIMO provided high peak data rate for only one user, but in real-time environment, full 8x8 type SU-MIMO was not be used for some periods of time. It requests various layers not to spatial correlated with both eNodeBs and UE that equipped with 8Tx/Rx antennas.

Furthermore, general application does not request or continuously provide the high data rate. As such, applying 8x8 types of antennas on SU-MIMO will likely to have better solution system wisely. But, MU-MIMO considers a much better solution in this matter

overall. The MU-MIMO can deploy single type of antenna on UE. Which MU-MIMO is available on LTE-A for all UE. Further, individual UEs are different in MIMO layers that are separately spatial. Therefore, the MU-MIMO are better compared to SU-MIMO in terms of high throughput per cell or sector (Korhenan, 2014).

3.16 Suggested Algorithm: Packet Scheduling

After the formation of the network establishing with the proposed channel assignment algorithm. Based on the suggested hierarchical flow and Markov Chains decision strategies, the packet is ready to be broadcast from the parent node to the child node. As an initial stage, the connection of node-to-node plays a crucial role in order for the packet to broadcast in post-disaster with the requirement of link quality among the survivor or victim in any emergency situation. Therefore, the packet scheduling algorithm must define the link quality connection using the network-establishing algorithm previously. When the link connection is defined, the packet or message is ready to be transmitted to a designated node in a particular time slot. In some situations, the time slot is over for a particular packet in a specific channel (high-traffic environment). This packet will have a backoff process waiting for another time slot for packet to transmit to the designated node. It is also applicable for any link quality below a certain level, most likely during rescue time when many nodes (survivors) in a specific area cause the packet on node-to-node communication to experience a backoff process. This directly cause high power consumption, electromagnetic interference, high noise level signal, and low throughput with any other factor cause packet loss during the broadcasting process. Meanwhile, when heavy traffic comes into a certain area, especially during a tsunami or heavy flood, the connection of parent node with the child node might not be able to connect due to rapid change and fast movement in a random situation (Gao et al., 2020) even Markov Chains has been established on this propose

Algorithm 3 Packet Scheduling

When 1= Good, $\emptyset$ = NG, N= Node & l = Link

Define $l_{(quality)}$ condition > 1 , shortest time = t_s

If $l_{N(quality)} \rightarrow l_{N+1} = \emptyset$

Then queue $t_{s(N)}$

Else packet $\rightarrow N_{N+1}$

If $l_{N(quality)} = \emptyset$, When $\emptyset > 3$ times

Then $l_N \rightarrow l_{t+i} + N_{N+i}$

Else packet $P \rightarrow N_N$

End If

End If

methods. As such, the suggested packet scheduling is important in improving those situations by establishing a new link with network and channel assignment algorithm with Markov Chains to any adjacent node based on the previously discussed Markov Chains decision strategy. When the link connection is successful, the packet will broadcast to a designated node in its time slot to avoid any node (survivors) missing during any rescue plan. Otherwise, the packet will return to the original node (Parent node), waiting for its time slot to be transmitted to the designated node. This algorithm minimizes any node, especially the hidden nodes (survivors), during critical times (especially on network coverage boundary) to rescue as many survivors or victims as possible to reduce casualties in post-disaster scenarios. This process is continuous in any rescue plan in which the rescue team can communicate with the survivor in a bi-directional communication link. Above is the proposed packet scheduling algorithm and state diagram in Figure 3.28 to clearly illustrate the whole process. The communication protocol use is LTE-A that namely LTE-AIC for this research study.

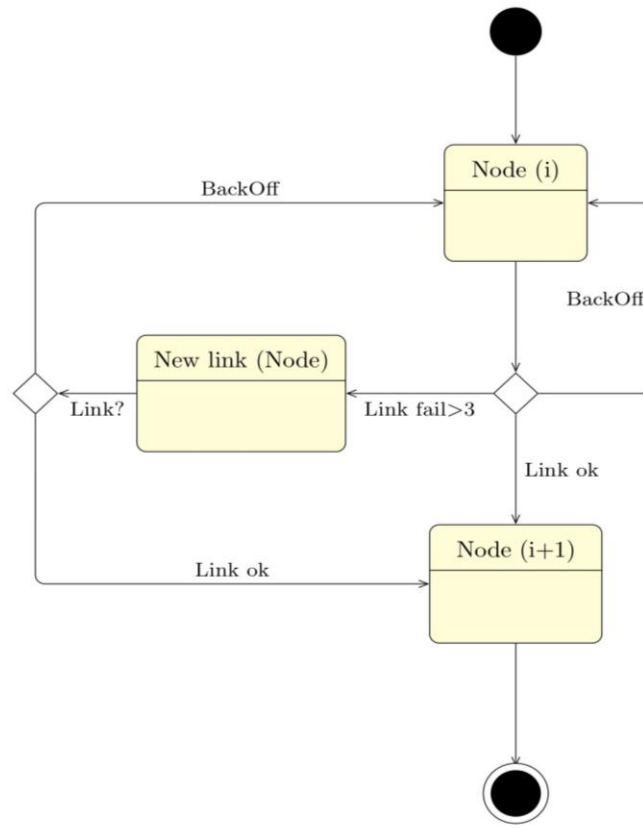


Figure 3.28: State diagram for proposed packet scheduling

3.17 Performance Evaluation: Packet Loss

In this experiment, we examined the packet loss in terms of average values as node density (Vehicle density) is set from 20 to 100 nodes in random mode. The average packet loss of an intended area is adopted to measure the percentage of the packet received by the node (Vehicles or Survivors). The percentage value of average packet loss is intractable for the following reasons. Once the channel conditions and vehicle mobility are integrated into the joint distribution of inter-vehicle distance. The other part is that the packet received is affected by the number of relay nodes and relay location. A packet loss leads to the loss of the data gathered from multiple nodes (Sun et al., 2018)

Calculation:

$$\sum_{i \neq 0}^n (Packet\ loss) = \sum_{i=1}^n (Packet\ sent) - \sum_{i \neq 0}^n (Packet\ received) \quad \text{Equation 3.13}$$

$$Average\ Packet\ Loss\ (\%) = \frac{\sum_{i \neq 1}^n (Packet\ loss)}{\sum_{i=1}^n (packet\ sent)} \times 100\% \quad \text{Equation 3.14}$$

3.18 Contention Window (CW) Mechanism

The authors named Chrysostomou, Djouvas, and Lambrinos (2012) defined the word Contention Window as an interval for a random number drawn to apply a random backoff mechanism. This CW increased exponentially after the collision. Thus, it reduced the collision probability among the same stations. Further, an initial backoff stage in the linear increasing method will have a similar CW size. This linear increase of CW enables the reduction of delay for difference packet broadcast from various cycles of backoff in order to minimize collision in subsequent cycles. This CW mechanism is divided into two levels of priorities. Based on Figure 3.29, the left-hand side represents high priority, and the right-hand side is equipped with a low priority cover of the CW range. The high priority provided with smaller backoff interval compared to low priority on high backoff interval. Thus, the delay of high priority smaller than low priority with regards to retransmission and equipped with reliability characteristics to reduce delay as much as possible. In the proposed method, the low priority will always select a high backoff value compared to the high-priority slot. In terms of fairness, a low priority initially selects a backoff value from 1CW to 2CW. However, after 1CW backoff slots countdown. It takes the backoff value from 0 to CW/2, a high-priority slot. Therefore, it effectively equals high priority when backoff countdown to the range of high priority slots. As such, it is able to maintain the equilibrium between low and high-priority traffic.

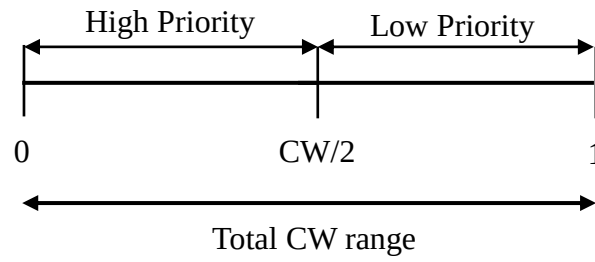


Figure 3.29: Various CW ranges for different priority

3.19 Delay

Through RTS/CTS mechanism, it can prevent packet collision due to hidden node problems. If ACK cannot receive, the packet transmission will not proceed (Shahen Shah et al., 2019).

No other senders detect idle channels for Double Inter Frame Space (DIFS) at the end of ACK sent (Bianchi, 2000). Even though the ACK is broadcasting in various ways, there is no collision happening among the packet between the receiver and other senders. There is a possibility for a collision between the packet while broadcasting it between the sender and receiver. The Markov Chain model is designed in such a way to validate the characteristic of packet broadcasting (Nguyen et al., 2018). Further, Marko Chains models assumed that all collision probability of any packet broadcasting colliding with each other's is considered constant and independent in the backoff stage (Bianchi, 1998; Shin, 2012).

3.20 Operation of DIFS and SIFS for Packet Transmission

In this section, packet transmission will undergo a scheme or mechanism called three-way handshaking involving Request-to-Send (RTS), Clear-to-Send (CTS) and Acknowledgement (ACK). Based on this mechanism, the transmitter or Mother node sends out the RTS to a specific destination node in order to establish a network connection through the proposed network and channel assignment algorithm. When the specific destination node

receives the RTS, it delivers CTS to the transmitter node that, permits a packet broadcast to the specific destination node. While the packet is successfully received, this specific destination node will broadcast or transmit the ACK packet to the transmitter node, indicating that the network connection is guaranteed for a fixed packet size (Chen & Agrawal, 2004). Figure 3.30 illustrate how the packet works involving DIFS and SIFS.

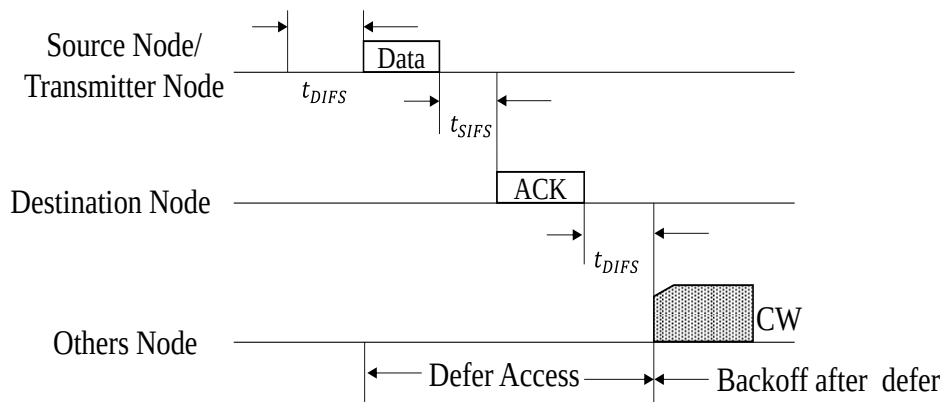


Figure 3.30: Operation of DIFS and SIFS

Figure 3.30 depicted the operation of packet works. Before the packet is broadcast. A Source node or transmitter node will sense the transmission medium and ensure the medium is under idle state for a specific and short duration time of DIFS before broadcasting. If the medium is sensed under a busy state, then the Source node becomes idle and waits under the DIFS period to select a backoff time to determine the time needed that allows the packet to be ready to transmit. During the idle state for the sensed medium, it will transmit the packet to the destination node by decreasing or shortening the backoff time until it reaches the zero state after the DIFS duration. The destination node will receive the packet and broadcast the ACK packet after sending it on the SIFS time frame. This ensures that a particular channel's connection is guaranteed between the Source node and the Destination node. The idle state after the DIFS time frame is considered to be CW. This CW is initially

assigned at minimum CW size to shorten the delay by broadcasting the packet when the medium is under an idle state.

In case the packet experiences collision along the medium or lost connection. This CW size will double the maximum value each time for any affected Source node delivers the packet. It will remain at the maximum size even if there is more and more packet collision to happen (Specifications, 2022). Therefore, to reduce or minimize the packet collision and delay under this mechanism, especially during a large number of nodes (Child Nodes) for any disaster rescue plan. The packet scheduling algorithm (as discussed in the previous section) is introduced and proposed to improve the proposed channel assignment, and delay performance compared to the conventional method and maintain the CW size to avoid packet collision and delay (Chen & Agrawal, 2004). Further, the backoff function in this research is workable to reduce hidden terminals as all the nodes can hear each other by adapting the proposed channel assignment and network establishing algorithm with the most importantly of Markov Chain decision strategies applied to it, especially during emergency rescue plan for post-disaster scenario.

3.21 Performance Evaluation: End-to-End Delay

One of the parameters used to examine the proposed algorithm performance is the End-To-end Delay parameter that effectively evaluates the designed methods and algorithms. The End-To-End Delay can be defined as the delay encountered by a packet which is measured from the time the packet is generated to the time the Source node receives a REP packet indicating successful reception of the packet by the destination node (Kumar et al., 2010). In this implementation stage, we used a modified Delay Cost Estimation (Chen & Sheu, 2001) with the Markov model (Random Walk model) (Sheskin, 2016) as the

parameter to validate the performance and reliability of the proposed methods and algorithms.

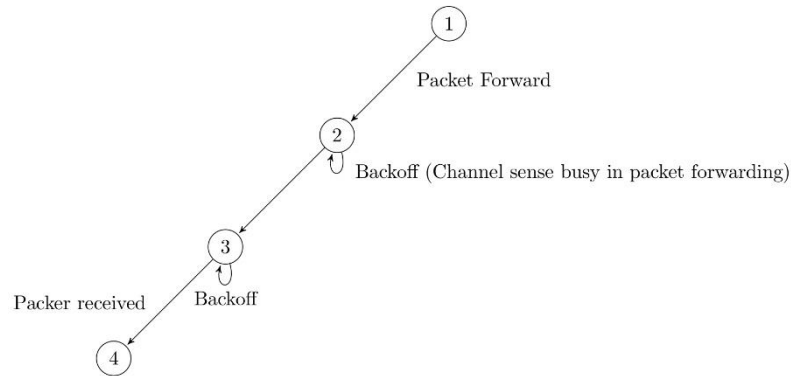


Figure 3.31: Proposed topology (Markov Model)

It can be seen from Figure 3.31 that packet generated by Source node (Node 1) was forwarded to the relay node before arrived at the Destination node (Node 4) and received the REP packet sent by the Destination node. Recall the Distributed Coordination Function (DCF) (Sheskin, 2016) used as the MAC protocol to avoid the collision. It uses RTS and CTS to control packet overcome the well-known channel problem and to provide virtual carrier sense for battery power saving (Kumar et al., 2010). As such, each of data packets transmission should first issue RTS and CTS followed by a REQ. In DCF, we need two essential DINS and SINS during Backoff period for data packet transmission. The SINS used to guarantee the data packets to have a higher priority to transmit packets when it over the waiting time during relay node switch on the switchable channel to an appropriate channel for the data transmission. Apart from this, each time a node wants to transmit data packet must sense channel idle and set to the appropriate channel before data transmission. Therefore, the SINS was shorter than DINS.

We let $P_{idle}^i(t)$ as a probability of packet i successes in sensing channel idle for time interval t . Therefore, the probabilities of the state transition from packet forwarding to states *Backoff* are P_{idle}^i (DINS) and $1 - P_{idle}^i$ (DINS) respectively. In the *Backoff* states, i has the probability $1 - P_{idle}^i$ (DINS) to sense channel busy after finishing its waiting time. In this situation, it will delay $RTS + SINS + CTS + Packet_len + SINS + REQ$ before its next state. (Notation $RTS/CTS/REQ$ and $packet_len$ for the required time to transmit on $RTS/CTS/REQ$ control packet and a data packet). Once i detects or sense an appropriate channel of the switchable channel for the relay node, it enters the transfer state to transmit the packet. In this state, i first issue RTS control packet and waits for CTS packet to make sure the path is clear. If no CTS is detected within a slot time i will return *Backoff* state immediately. This is to avoid any packet collision during packet transmission from current state to next state of the relay node. For packet transmit successfully, it needs $RTS + SINS + CTS + SINS$ time period to make sure the reservation is successful. Now, we can calculate the probability P_{idle}^i and average *Backoff* time $\bar{x}$. Assume that, the packet arrival rate of a relay node obeys the Poisson distribution and the average arrival rate of the station is α . Let $P_n(t)$ as the probability of n packet arrive a node during time interval t .

$$P_n(t) = \frac{(\alpha t)^n}{(n!)} \times e^{-\alpha t} \quad \text{Equation 3.15}$$

Hence, when no packet arrives at a node during the interval time t is

$$P_0(t) = e^{-\alpha t} \quad \text{Equation 3.16}$$

Therefore, the probability P_{idle}^i can be derived as follows:

$$P_{idle}^i = e^{-\bar{x}t} \quad \text{Equation 3.17}$$

Now, we can estimate the expected End-To-End Delay in Ready state ($R(i)$) and *Backoff* status ($B(i)$). Thus,

$$\begin{aligned} \sum_{i=1}^n (R(i)) &= \sum_{i=1}^n [P_{idle}^i (node) \times (RTS + 2(SINS) + CTS)] \\ &+ [(1 - P_{idle}^i) \times (RTS + 2(SINS) + B(i))] \end{aligned} \quad \text{Equation 3.18}$$

And,

$$\begin{aligned} \sum_{i=1}^N B(i) &= \sum_{i=1}^n [P_{idle}^i (DINS) \times (DINS + \bar{x})] + [1 \\ &- P_{idle}^i (DINS) \times \bar{\gamma}] \end{aligned} \quad \text{Equation 3.19}$$

Where,

$$\bar{\gamma} = RTS + (2 \times SINS) + CTS + packet_{len} + REQ$$

Finally, total End-To-End Delay will consist of three sections as follow:

- Time packet to transmit once successfully
- Total time a packet spends in Backoff state
- Total transmission time used to retransmission of the packet.

$$\sum_{i=delay}^i = \sum_{i=1}^i R(i) + [\sum_{i=1}^i B(i) \times \frac{packet \ len}{T_R}] \quad \text{Equation 3.20}$$

When,

$$T_R = \text{Transmission rate of each node in unit } \frac{bits}{seconds}$$

Packet_len = Packet length

3.22 Performance Evaluation: Energy Consumption

Designing a smart devices chipset or operating a mobile network to balance and reduce the energy consumption of the nodes as well as prolong the network lifetime (Sun et al., 2018). We need to determine how certain parameters can affect a specific smart devices power consumption and figure out how to adjust the parameters to improve battery life. The key parameters are Uplink (UL) and Downlink (DL), data rate (R), transmit (Tx) and receiver (Rx), power level (S), Base Band (BB), cell Bandwidth (BW) and Rx and Tx radio frequency (RF) components (Jensen et al., 2012). The model of power consumption of the node is modified and depicted in Figure 3.32 (Lauridsen, 2014) and defined as follows:

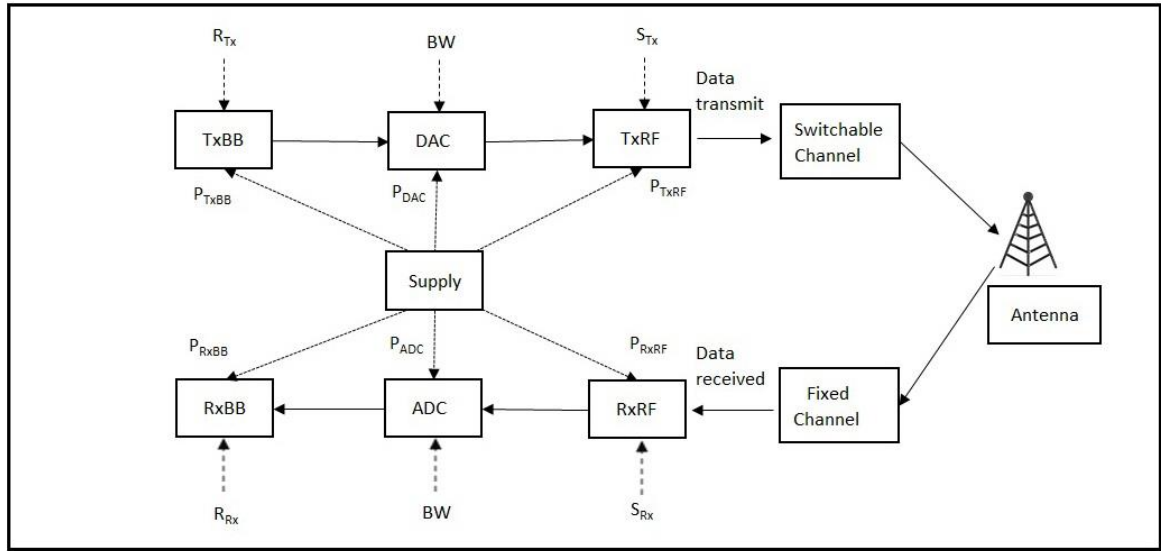


Figure 3.32: UE power consumption model

$$\sum_{i=1}^n P_T = m_{idle(i \rightarrow n)} P_{idle(i \rightarrow n)} + \overline{m_{idle(i \rightarrow n)}} \{ P_{con} + m_{Tx} \cdot m_{Rx} \cdot P_{Tx+Rx} \quad \text{Equation 3.21}$$

$$+ m_{Rx} [P_{Rx} + P_{RxRF}(S_{Rx}) + P_{RxBB}(R_{Rx})$$

$$+ m_{2cw} \cdot P_{2cw}] \cdot m_{Tx} [P_{Tx} + P_{TxRF} + P_{TxBB} R_{Tx}] \} w$$

Where $\mathbf{P}$ is the power consumption. The $\mathbf{P}$ defines the total power consumption, idle consumption, and connected mode, R_{xRF} and T_{xRF} is the consumption of the RF part in the R_x and T_x chains respectively. R_{xBB} and T_{xBB} is the consumption of the BB parts and 2CW is related to increased consumption when using two code words (CW) in DL. The parameters P_{RX} , P_{TX} and P_{RX+TX} is included to model the base power the R_x and T_x chains consume when active. The logical variable m is the mode, which can be idle, receive, transmitting and indicate the use of 2CW. The R_x and T_x power levels are defined as S and R is the R_x and T_x data rate respectively (Traditionaloven, 2018).

Each of the nodes was set to the power equal to 50mW as obey to the LTE and LTE-A characteristics with low power consumption. To get the result of the energy consumption of each node, we converting each packet (bytes) divided by the power setting of each node to the main base station. Whereby, the power is equal to Joule per second (Traditionaloven, 2018).

$$\sum_{i=1}^n P_T = \frac{\sum_{i=1}^n \text{Joule}}{\text{Seconds}} \quad \text{Equation 3.22}$$

$$\sum_{i=1}^n \text{Joule} = \sum_{i=1}^n P_T \times \text{Seconds}(s) \quad \text{Equation 3.23}$$

To get the energy consumption of the average packet sent from each of node. We use the below equation as stated on Elminaam et al. (2009).

$$\sum_{i=1}^n \text{Energy Consumption (Average)} = \frac{\sum_{i=1}^n \text{Joule}}{\text{Byte}}$$

$$= \frac{\sum_{i=1}^n (P_t \times \text{Second}(s))}{\text{Byte}}$$

As for the comparison to this result, we were using the LTE energy consumption to compare with LTE-A energy consumption and LTE-AIC energy consumption.

3.23 Overview of Low Data Rate (CQI=2) and High Data Rate (CQI=7)

To validate the proposed methods and algorithms in terms of parameter packet loss, end-to-end delay with energy consumption. This simulation was run into two categories as indicated in Table 4.1 (Chapter 4) divided into Channel Quality Indicator (CQI) 2 and 7. The function of CQI was to provide accurate channel quality by performance degradation characteristics (Othman et al., 2015). Furthermore, CQI is equipped with features like reduced latency, coverage, and spectral efficiency (Abdulhasan et al., 2013). The high data rate (CQI=7) provides a data rate of value = 1.4766 (bps/Hz) and the low data rate (CQI= 2) with data rate = 0.2344 (bps/Hz) (Kuo & Chou, 2015). Consequently, CQI =2 is a low data rate and CQI =7 consider a high data rate with a low coverage area compared to CQI =2. Both CQI was used to validate the performance depending on parameter metrics like packet loss, end-to-end delay, and energy consumption. LTE and LTE-A protocol was set as the benchmark for this simulation to compare with LTE-AIC equip with packet scheduling algorithm that were elaborated in this chapter 3. All node settings provided are 20, 40, 60, 80, and 100 nodes running with high mobility (50 m/s) that suit real-time conditions during an emergency-like scenario as discussed in this Chapter 3 as well. All simulation results are presented in tabular form and graphical form to give a clear image of the evaluation of proposed methods and algorithms in terms of performance. All data table collected also

shows the associated margin error for these data, which will be always less than 10% for a confidence level of 95 (Mata-Díaz et al., 2014).

3.24 Simulation Scenario

To determine the proposed method and simulation overview studies. A multi-cell (Nodes) has been developed with a coverage radius of 500m and 1km. The simulation will be conducted using Omnet ++ network simulator as explained on our studies in the Literature Review chapter. Previously, simulation overview stated that the simulation of tsunamis is conducted on the mainland instead of the seaside or seashore. As such, this simulation will follow the simulation overview studies conducted on the mainland. Figure 3.33 illustrates the diagram used in this simulation, which consists of one BS or eNodeB and a variable quantity of nodes (UEs) within range of 20~100 nodes. Mobility of UE/node is on a random point modelling equipped with a speed of 50m/s respectively for each UE. To guarantee each of the UE under coverage for network and channel utilization. Each UE will be equipped with transmitter power equal to 20mW and receiver sensitivity of -85dBm with node power equal to 50mW for all the UEs/nodes applied. The path loss be set to follow the ITU-R standard for any bandwidth conducted in this simulation. All packet used for transmission is set constantly with 100 bytes on each UE transaction to examine the proposed method and algorithms. OFDMA will be adapted on the downlink, and SC-FDMA will be implemented on the uplink on this simulation, as depicted in Figure 3.33. The low data rate used for broadcasting on each transaction can also be justified as CQI= 2, and the high data rate is CQI= 7 to evaluate the proposed method and algorithms. The BS or eNodeB will be set to 100mW to confirm the suggested method performance. All result reading on this simulation will be on average to verify the proposed method with algorithms performance through end-to-end connection of UE/node.

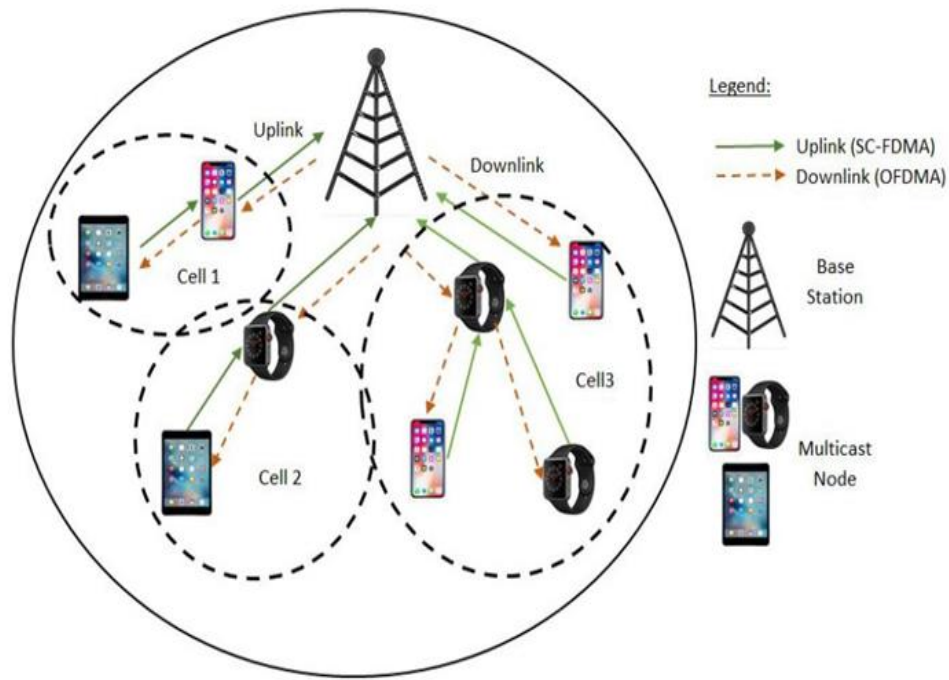


Figure 3.33: Simulation scenario

3.25 Summary

This chapter discussed the research methods and algorithms to achieve the research objective. It elaborated on the benefit of interface and operation for suggested Channel Assignment algorithm with reliability feature in order to improve the channel assign on VASNET for Disaster Management System. Markov Chain on Random Walks with Markov Decision Process (MDP) was introduced as a gateway for channel distribution and network establishing for generating communication on multi-node or multi-hop on VASNET in an emergency. The Sequence diagram explains the network formation and channel distribution more clearly.

Moreover, the explanation of why OFDMA and SC-FDMA were proposed in this chapter has been discussed clearly. This chapter has also suggested a packet scheduling algorithm to answer the research question with a state diagram explained in more detail by

using LTE-AIC (Suggested) in this research study with conventional LTE-A and LTE (Benchmark). Further, this chapter highlighted the parameters used, like packet loss, delay, and energy consumption, to examine the performance of proposed methods and algorithms in the VASNET environment. In addition, summary of research flow indicates clearly on contribution in this research study as well. Lastly, in order to simulate the proposed VASNET on algorithms and methods. The overview of the simulation scenario also has been discussed in this chapter, and by referring to this, the simulation scenario has been generated in order to simulate the improved channel assignment and other methods on VASNET are close to the real-time Disaster Management System, especially during emergency rescue plan for a post-disaster scenario. The simulation result of the proposed methods and algorithms will be discussed in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presented the simulation result and discussion about the performance of suggested methods and algorithms. Setting on simulation to run the research proposed methods and algorithms, on how the simulation is running based on the previous chapter (Research Methodology) that presented. A parameter such as packet loss and end-to-end delay with energy consumption is implemented to examine and validate the suggested methods and algorithms. The simulation result is discussed in this chapter. LTE and LTE-A communication protocols are used as a benchmark for this simulation together with packet scheduling algorithm LTE-AIC to validate the proposed channel assignment algorithm. The following discuss all the content highlighted in this introduction in more details analysis.

4.2 Simulation setting

These proposed methods and algorithms were implemented on Omnet Simulator with version 5.62 running on a PC using Intel® Core™ i5-7200 CPU @ 2.5Hz, memory 4.00 GB, and Windows 11 Pro Edition. Table 4.1 shows all the parameters and settings to run the proposed methods and algorithms to get the result based on the parameter discussed in the Research Methodology chapter.

Table 4.1: Parameter setting used in the simulation

No	Parameter	Value
1	Tx Power	100mW
2	Node Power	50mW
3	Pathloss	ITU-R
4	Cable Loss	2dB
5	Node	50
6	Noise figure	7dB
7	Packet size	100 Byte
8	CQI (bit rate)	2, 7 Mbps
9	Transmitter power	2mW
10	Receiver Sensitivity	-85dBm
11	Coverage	600 m
12	Simulation Time	6,000~12,000 (Sec)
13	Mobility Speed	50 (mps)

4.3 Justify: Simulation Time and Coverage

To justify the proposed algorithms and methods more effectively. This proposed algorithm undergoes several simulation time and coverage tests to ensure proposed algorithms (Channel Assignment, Network Establishing, and Packet Scheduling), reliability features, and Markov Decision process with Markov Chain implemented in this testing using LTE-AIC protocol. In other words, the shortest time to do a simulation could cause some features and algorithms not to be fully applied in the VASNET environment, likely a few seconds or minutes to apply for 100 nodes. It may affect the performance of the proposed methods, which are unable to contribute the requested result to answer the research question. Conversely, long simulation time makes it time-consuming for all algorithms, features, and systems to run more than desired time, which consider as a waste to validate the proposed methods. Consequently, to justify the suitable simulation time and coverage, this simulation will run on time intervals of 6,000 seconds, 7,200 seconds, and 7,800 seconds until 12,000

seconds, with 20~100 nodes and a high data rate of CQI= 7. To simulate the proposed algorithms and methods in VASNET on high mobility, which is close to the real-time emergency rescue plan during post-disaster scenarios. All setting follows Table 4.1 for this verification purpose. Data was collected based on 1km and 500m coverage for all simulation times. The result is presented in Figure 4.1.

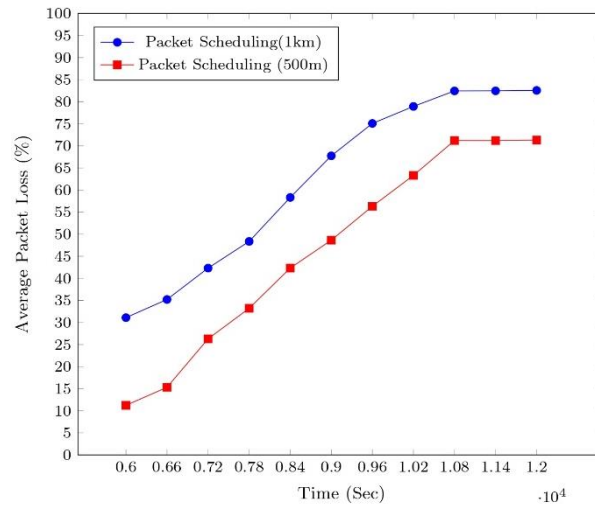


Figure 4.1: Simulation time and coverage justification result

Figure 4.1 above shows the result to validate the simulation time and coverage for proposed methods and algorithms. As shown in Figure 4.1, 10,800 seconds upward, the average packet loss percentage for 1km coverage was at the maximum point of around 82% among all the simulation time applied compared to 500m coverage. Meaning to say, at this level of time, all the algorithms, features, and the proposed system has fully implemented to examine the proposed method's performance. As a result, 10,800 seconds will be used to evaluate the proposed methods based on the parameter setting in Table 4.1 and coverage of 1km to be implemented to validate the proposed methods and algorithms. The following section is the simulation result with a discussion to achieve the research objective and research question.

4.4 Simulation Result: Packet loss (CQI= 2)

Table 4.2: LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=2)

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	7.69	23.56	7.26	22.55
40	15.18	34.36	14.95	34.26
60	23.20	43.22	23.07	42.92
80	23.20	48.33	23.07	48.16
100	23.20	55.27	23.07	54.85

Table 4.3: LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=2)

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	7.69	30.65	7.26	29.22
40	15.18	39.53	14.95	39.45
60	23.20	52.61	23.07	52.32
80	23.20	63.25	23.07	63.13
100	23.20	71.25	23.07	69.95

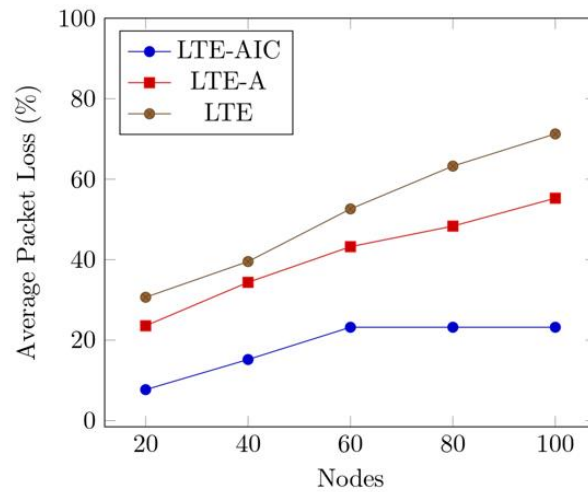


Figure 4.2: Simulation result for LTE-AIC, LTE-A and LTE for packet loss 1km (CQI=2)

Table 4.2, and Table 4.3 shows the simulation result for packet loss on LTE-AIC and LTE-A with LTE for low data rate setting (CQI=2).

Figure 4.2 shows the simulation result of average packet loss in percentage for 20 nodes until 100 nodes for 1km coverage.

As shown in Figure 4.2, LTE-AIC shows improvement compared to LTE-A without the Packet Scheduling algorithm and LTE. Overall, 54.82% reduced average packet loss with respect to normal LTE-A and 64.05% improved compared to normal LTE protocol. This is more significant on 100 nodes, in which the difference is 48.05% of the average packet loss value with respect to LTE, followed by LTE-AIC with Packet Scheduling compared with LTE-A around 32.07% reduced in average value.

Packet loss keeps increasing due to the number of nodes or UEs in coverage of 1km, experiencing high collision probability, especially on 60 nodes or UEs onward. Rapid topology change and high mobility of UEs, which are the main characteristics of VASNET, contribute to high average packet loss and are more evident on LTE with LTE-A. Moreover, the movement of UEs that are close to the boundary of coverage able to communicate is one of the reasons why the LTE-AIC implement the Markov Chain to establish a connection among the UEs or nodes, to control the channel is thoroughly utilized by applied improved Channel Assignment together with Network Establishing algorithms. This is clearly defined (based on simulation results) that LTE-AIC with Packet Scheduling, Reliability features, Network Establishing, and Channel Assignment algorithms with Markov Chains is able to minimize channel repetition, redundancy, and channel underutilization problems compared with normal LTE and LTE-A implementation. Besides the above, the low electromagnetic spectrum scarcity is an improved average of packet loss value. This proposed algorithm is also one of the contributions with OFDMA and SC-FDMA applied on uplink and downlink communication involving a multichannel antenna equipped on every UE or node. This is

more obvious when the node starts from 60 UEs and reaches 100 UEs having constant average packet loss value with respect to LTE and LTE-A without applying the Packet Scheduling algorithm, which is in linear increasing trend direction on the quantity of UEs increase simultaneously.

4.5 Simulation Result: End-to-End Delay (CQI=2)

Table 4.4: LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) on average end-to-end delay for (CQI=2)

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	4.26	17.25	0.32	0.43
40	12.15	25.50	0.35	0.65
60	29.65	36.22	0.54	0.95
80	29.65	43.25	0.54	1.36
100	29.65	43.25	0.54	1.36

Table 4.5: LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) on average end-to-end delay for (CQI=2)

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	4.26	21.25	0.32	2.26
40	12.15	36.52	0.35	2.36
60	29.65	42.37	0.54	2.13
80	29.65	49.65	0.54	2.85
100	29.65	58.61	0.54	3.62

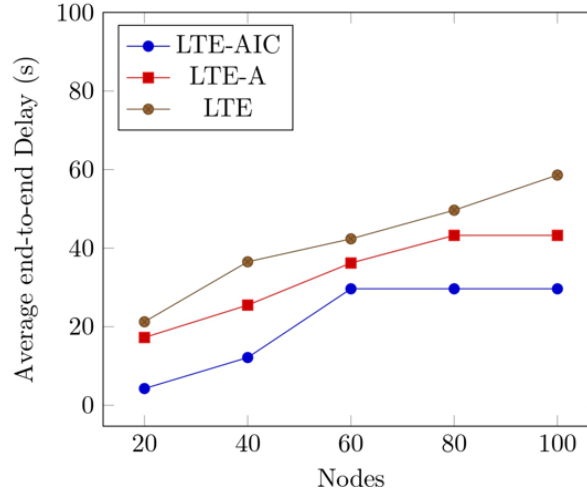


Figure 4.3: Simulation result for end-to-end delay for low data rate (CQI=2)

Table 4.4 and Table 4.5 shows the tabular form for simulation result on average end-to-end delay for low data rate (CQI=2) and coverage of 1km.

Figure 4.3 shows the average end-to-end delay simulation result for low data rate (CQI=2) for coverage of 1km between 20 nodes and 100 nodes.

As presented on Figure 4.3, LTE-AIC improved the channel assignment proposed compared to LTE-A without Packet Scheduling on node 60 upward. The difference at node 60, around 18.11%, was reduced in delay simulation, and node 80 and node 100, around 31.0% reduced. On the other hand, LTE-AIC proposed respect to LTE without Packet Scheduling also shows improvement in this simulation result. The difference for node 60 was around 30.0% reduced, node 80 around 40.3% reduced, and node 100 around 49.41% reduced. Consequently, 36.32% of proposed methods improved compared to normal LTE-A and 49.43% compared to normal LTE in the overall trend in this simulation result.

This is clearly defined that the proposed Channel Assignment and Network Establishing with Packet Scheduling algorithms together with Markov Chain decision

strategies potentially reduced the broadcast storm problem when many packet broadcasting under multichannel and multi-interface proposed. This can be observed in this low data rate of packet transmission in this delay parameter simulation on 60 nodes and above becomes stable with no further delay of proposed methods and algorithms in the VASNET environment. Moreover, CW setting and DIFS and SIFS discussed in Research Methodology Chapter also significantly contribute to this delay simulation on low data rate. The low value of CW enables the packet to be considered a high-priority packet and yet reduces the backoff time to broadcast the packet on the assigned channel. With this, it will shorten the delay at a particular relay node regardless of how many relays node transmit the packet to the destination node. Improvement in fairness in terms of packet transmission is also one of the contributions of these proposed methods. All the relay nodes can function by applying the improved Channel Assignment algorithm plus the reliability features with Markov Chain; even the link connection is broken. It can search for an optional link or alternative link to transmit the packet to a specific destination node compared to LTE and LTE-A without Packet Scheduling that experiencing high delay time that affect the performance of VASNET during emergency rescue plans.

4.6 Simulation Result: Average Energy Consumption (CQI=2)

Table 4.6: LTE-AIC compared with LTE-A and Confidence Level (C.L) (95%) average energy consumption for 1km coverage on low data rate (CQI=2)

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	5.63	5.95	2.1	3.8
40	12.33	15.33	3.2	2.1
60	23.22	27.35	1.2	5.7
80	26.32	34.52	4.1	5.1
100	29.33	39.25	3.9	4.2

Table 4.7: LTE-AIC compared with LTE and Confidence Level (C.L) (95%) average energy consumption for 1km coverage on low data rate (CQI=2)

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	5.63	6.22	2.1	4.1
40	12.33	21.24	3.2	3.8
60	23.22	33.31	1.2	2.8
80	26.32	39.22	4.1	2.4
100	29.33	45.32	3.9	3.1

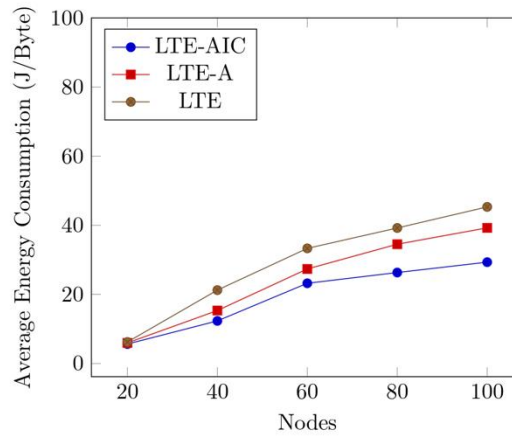


Figure 4.4: Average energy consumption for 1km coverage on low data rate (CQI=2)

Table 4.6 and Table 4.7 shows the tabular form for simulation result on average energy consumption for low data rate (CQI=2) and coverage of 1km.

Figure 4.4 shows the simulation result for average energy consumption of LTE, LTE-A without Packet Scheduling and LTE-AIC on low data rate (CQI=2) for 1km coverage.

According to Figure 4.4, it presented that the performance of suggested LTE-AIC was better than LTE and LTE-A without proposed algorithms and methods. The difference becomes more visual, starting from node or UE 60 upward. At 60 UE, the LTE-AIC with proposed methods and algorithms potentially reduced the energy consumption by an average of 30.30%, and compared with LTE-A without the proposed algorithms is around an average of 15.13%. Further, at the 100 UEs level, the improved gap becomes more significant by showing LTE-AIC an average of 35.29% with respect to LTE and LTE-A without proposed

methods and algorithms is around an average of 25.30% reduced in energy consumption. Overall, the proposed methods LTE-AIC are able to show better results compared to normal LTE-A, around an average of 20.90% and 33.36% compared to normal LTE.

This is because packet transmission or broadcasting in end-to-end nodes and frequent channel switching keep changing by directly increasing the number of UEs or nodes in this simulation, causing dissipation of energy consumption. Retransmission of packet, especially the node, becomes hidden or lost, enabling high energy consumption during dense network traffic when many packets are transmitted in multi-channel mode or environment. This is more obvious when using LTE with a low data rate when channel usage becomes limited or over-utilized, highly contributing to energy dissipation when broadcasting the packet to many relay nodes during the high density of nodes in a particular or specific area. High mobility (50 m/s) potentially causes the channel to switch to a particular channel when the packet transmission path is lost and searching for an alternative path due to the rapid change of node topology. This is also one of the reasons why LTE and LTE-A, without proposed methods and algorithms, contribute to high energy consumption in this simulation. This is improved by suggested LTE-AIC with proposed methods and algorithms with low data rate, as shown in Figure 4.4, that can achieve our research objective.

4.7 Simulation Result: Packet Loss (CQI=7)

Table 4.8: LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=7)

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	21.32	28.32	25.14	12.58
40	35.20	39.22	13.96	26.47
60	54.30	60.22	32.18	33.54
80	77.52	85.21	26.68	22.91
100	82.45	91.25	29.45	26.48

Table 4.9: LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average packet loss evaluation (CQI=7)

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	21.32	36.22	25.14	16.58
40	35.20	48.30	13.96	21.37
60	54.30	68.20	32.18	29.58
80	77.52	89.21	26.68	24.21
100	82.45	95.32	29.45	28.54

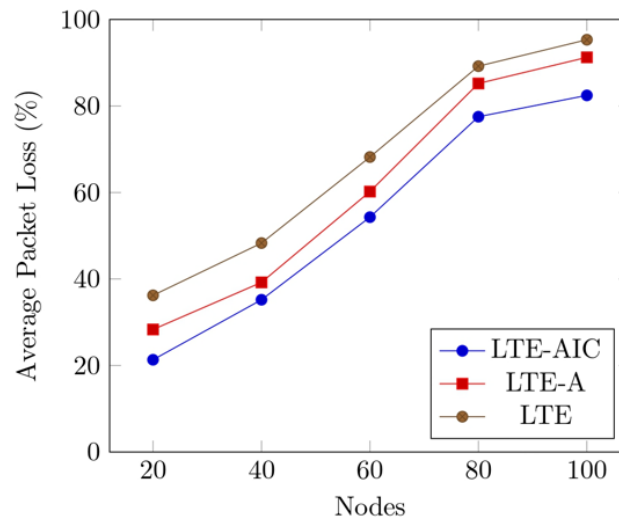


Figure 4.5: Show the simulation result for average packet loss on high data rate (CQI=7) for 1 km coverage

Table 4.8 and Table 4.9 presented the simulation result for packet loss on LTE-AIC and LTE-A with LTE for high data rate setting (CQI=7).

Figure 4.5 shared the simulation result of average packet loss in percentage for 20 nodes until 100 nodes for high data rate (CQI=7) on 1km coverage.

Based on Figure 4.5, LTE-AIC with the suggested Packet Scheduling algorithm, improved the packet loss percentage compared to normal LTE-A and LTE. This is obvious when reaching node 80 and onward. The improved percentage of LTE-AIC is around 9.02% reduced in packet loss compared to conventional LTE-A. Besides this, around 13.10%

reduced compared to LTE with LTE-AIC on Packet Scheduling as well. Overall, this is significant to prove that the suggested LTE-AIC is able to improve the channel assigned on both low and high data rate with proposed algorithms on Channel Assignment and Network Establishing.

The proposed methods and algorithms show improvement in this simulation result because the channel assigned was fully utilized by all the respective Source nodes or Mother nodes. Even though this simulation set all the nodes in high mobility and random movement. The channel was fully assigned and statically over time so that the network establishment could be executed to communicate with all related UEs or relay nodes in specific regions. Further, the high frequency of channel switching in multi-channel and multi-node environments potentially causes a high probability of packet loss sequentially when the number of nodes increases. Thus, this directly makes the whole network experience high electromagnetic interference, and the communication of nodes in end-to-end situations becomes unstable. Implementing the OFDMA and SC-FDMA in both uplink and downlink communication can solve this problem with Markov Chains decision strategies to ensure all the nodes can be detected by knowing the current state. The Packet Scheduling algorithm further improves this situation by connecting related UEs in desired and alternative modes when specific nodes or UEs lose contact due to fast topology change of UEs movement. This guarantees that the packet is broadcast and received by the destination node or UEs regardless of time transmission. In conclusion, this data rate dramatically contributes to this packet loss simulation on OFDMA and SC-FDMA are the most suitable to be used in this data rate transmission. As such, it fulfils the high data rate requirement to be applied in emergency rescue plans during post-disaster scenarios.

4.8 Simulation Result: End-to-End Delay (CQI=7)

Table 4.10: LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) on average end-to-end delay for high data rate (CQI=7) with 1km coverage

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	13.27	27.30	0.25	0.97
40	25.22	42.10	2.14	3.61
60	47.21	59.22	3.98	2.86
80	62.32	75.31	4.80	2.19
100	81.26	93.50	5.19	3.87

Table 4.11: LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) on average end-to-end delay for high data rate (CQI=7) with 1km coverage

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	13.27	33.21	0.25	1.6
40	25.22	59.52	2.14	2.8
60	47.21	73.16	3.98	3.9
80	62.32	92.51	4.80	3.5
100	81.26	115.21	5.19	4.1

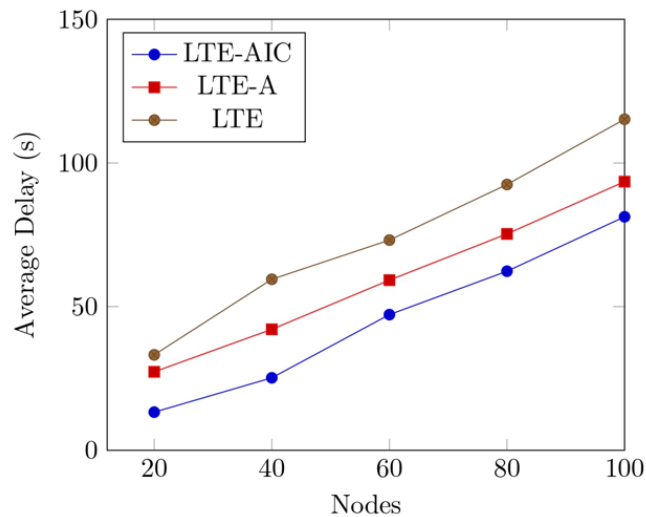


Figure 4.6: Shows average end-to-end delay for high data rate (CQI=7) on 1km coverage

Table 4.10 and Table 4.11 shows the simulation result in average end-to-end delay for 1km coverage on high data rate (CQI=7).

Figure 4.6 shared the graphical result for average end-to-end delay for high data rate (CQI=7) in 1km coverage from 20 nodes until 100 nodes.

As presented on Figure 4.6, LTE-AIC with Packet Scheduling algorithm improved the proposed methods on channel assignment with an average end-to-end delay result of around 22.90% with respect to LTE-A on the standard communication protocol. 38.63% reduced compared to LTE, showing more significant results in this simulation. This is obvious starting from node 40 that the delay value in unit second increases linearly until the maximum of node 100. Similarly, LTE-A and LTE also have similar increase trends in this simulation. The LTE-AIC equipped with the Packet Scheduling algorithm improved by around 13.0% compared with LTE-A without the Packet Scheduling algorithm and 29.46% with respect to LTE. Overall, using this delay parameter, the performance of proposed methods and algorithms successfully shows better improvement in this research study than conventional LTE and LTE-A protocol on VASNET in Disaster Management Systems.

The reason for this can be due to the frequent topology change with high speed on UEs or nodes with a high percentage of channel switching. This is clearer when the number of nodes or UEs increases sequentially. By this, high hidden UEs or nodes or even deafness UEs occurred drastically, directly affecting high delay in this delay simulation, the so-called packet delay in terms of propagation. Further, under multi-channel connection in multi-interface environment, the Backoff process with DIFS and SIFS also experiences a high frequency of changing percentage under this high data rate, which is directly proportional to an increase of UEs or node amount. This situation also increased the delay in LTE-A and LTE in this simulation. Besides this, packet collision may happen during broadcasting under multi-channel when many packets are transmitted under a specific time frame over the

specific channel assigned. All the problems, as stated above, can be reduced by applying proposed methods and algorithms with Markov Chains introduced in this research; knowing the current state UEs or node's movement state can guarantee the channel assigned to transmit the packet through the relay node or UEs during post disaster. Lastly, through this simulation, the proposed algorithms and methods potentially fulfil the research objective by implementing improved Channel Assignment under VASNET on Disaster Management System.

4.9 Simulation Result: Average Energy Consumption (CQI=7)

Table 4.12: LTE-AIC compared with LTE-A and Confidence Level (C.L.) (95%) for average energy consumption on 1km coverage for high data rate (CQI=7)

Node	LTE-AIC	LTE-A	C.L. (LTE-AIC) 95%	C.L. (LTE-A) 95%
20	24.20	25.33	1.3	1.8
40	28.32	32.32	1.5	3.5
60	45.31	63.10	2.6	3.1
80	45.31	63.10	2.6	3.1
100	45.31	63.10	2.6	3.1

Table 4.13: LTE-AIC compared with LTE and Confidence Level (C.L.) (95%) for average energy consumption on 1km coverage for high data rate (CQI=7)

Node	LTE-AIC	LTE	C.L. (LTE-AIC) 95%	C.L. (LTE) 95%
20	24.20	29.33	1.3	2.5
40	28.32	38.09	1.5	3.7
60	45.31	86.24	2.6	3.1
80	45.31	89.61	2.6	4.7
100	45.31	93.51	2.6	3.6

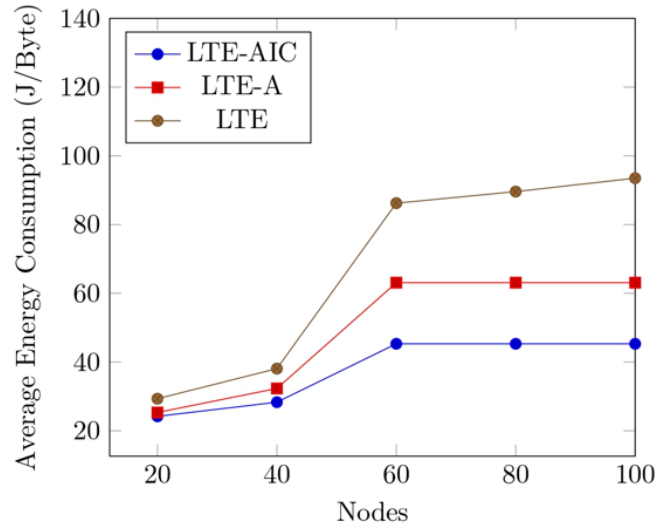


Figure 4.7: Shows the simulation result of average energy consumption for high data rate (CQI=7) on 1km coverage

Table 4.12 and Table 4.13 showed the tabular form of simulation result on average energy consumption for high data rate (CQI=7) with coverage of 1km.

Figure 4.7 presented the simulation result in graphical form for average energy consumption on LTE, LTE-A without Packet Scheduling and LTE-AIC with Packet Scheduling on high data rate (CQI=7) on 1km coverage.

Based on Figure 4.7, it can be seen that the LTE-AIC proposed with the Packet Scheduling algorithm shows better results compared to LTE-A and LTE in this simulation. The average energy consumption is minimised by around 23.68% with respect to normal LTE-A and reduced by an average of 44.04% compared to normal LTE. This is more obvious when the average energy consumption value becomes stable from node 60 onward. The improvement of the proposed LTE-AIC with Packet Scheduling algorithm compared to LTE-A normal is around 28.19% reduced in energy and around 47.45% improved with respect to normal LTE. Overall, it clearly defined that the proposed LTE-AIC with Packet

Scheduling algorithm for Channel Assignment in this simulation showed better results than normal LTE-A and LTE.

When the number of UEs or nodes increases sequentially. It will directly increase the interference among the adjacent UEs or nodes when only a specific channel is implemented. With this, it may affect the whole system performance to degrade from time to time and spectrum scarcity to occur in this simulation. Regarding the utilisation of the spectrum, it significantly improved by maximising the spectrum and reducing interference from the Mother node in the proposed network hierarchy. It also has the potential for UEs or relay nodes to access unoccupied Mother nodes or Child nodes for spectrum holes at the right time and location. This spectrum hole is an electromagnetic spectrum under-utilisation. The high interference is measured by signal power on the receiver side of the fixed interface. The signal received may cause direct interference during packet transmission in multi-interface, multi-channel, and multi-node concurrently. Therefore, packet broadcasting needs more power or energy, especially in this simulation using a high data rate (CQI=7) to transmit the packet to a specific destination UE or node. The energy dissipation worsens if the path to broadcast the packet through multiple UEs and nodes increases. This problem can be improved by the proposed Channel Assignment algorithm presented in the above graphical form of simulation result data. When the channel assigned was fully utilised, it could permit and guarantee the packet broadcast to multiple UEs or relay nodes with the proposed Packet Scheduling algorithm, potentially reducing the energy consumption of the packet transmission.

Further, by applying Markov Chain Decision Strategies, it is beneficial to ensure the connection of UEs or node on it is under optimum conditions and improve the connection

fluctuation in terms of reliability. Even though the node is experiencing frequent topology changes or random movement in high-speed conditions. Lastly, this shows that the proposed methods and algorithms can improve and achieve this research objective.

4.10 Correlation Graph of Simulation Result (Packet Scheduling Data: LTE-AIC)

In this subsection, we discussed the simulation result of the effect of packet loss, delay, and energy consumption in average form on CQI= 2 (Low data rate) with CQI= 7 (High data rate). The correlation among the parameter was illustrated in the 3D-graph for the simulation results on LTE-AIC with all the suggested methods and algorithms. It was obeyed to the simulation time and all the settings done during the simulation. According to the 3D-graph, it was found that there is a direct relationship between that parameter and the properties of node mobility. Below are all the correlations among those parameters in a 3D-graph.

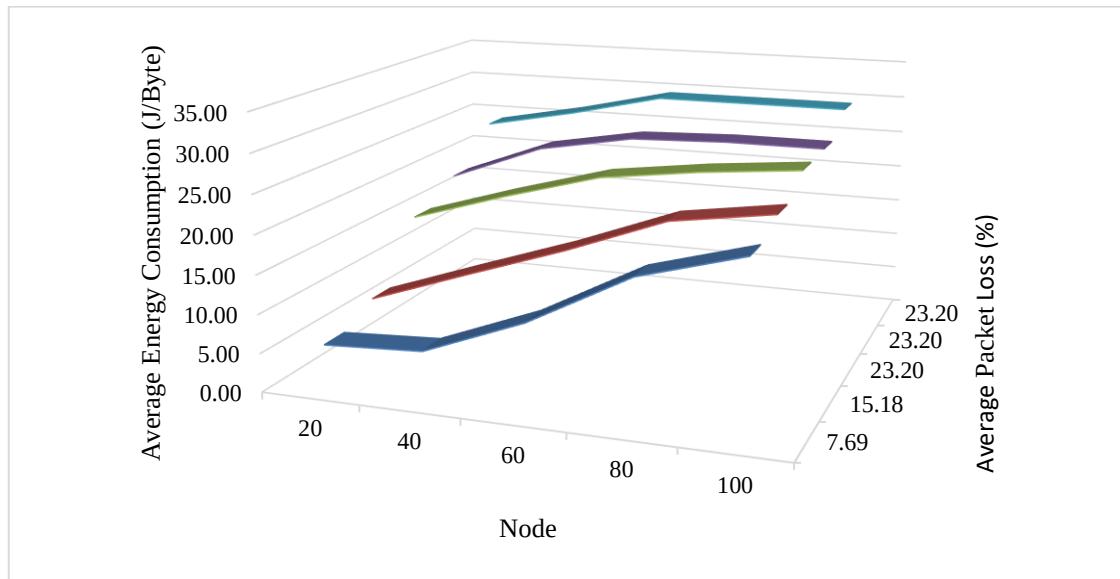


Figure 4.8: Energy consumption vs packet loss in CQI= 2

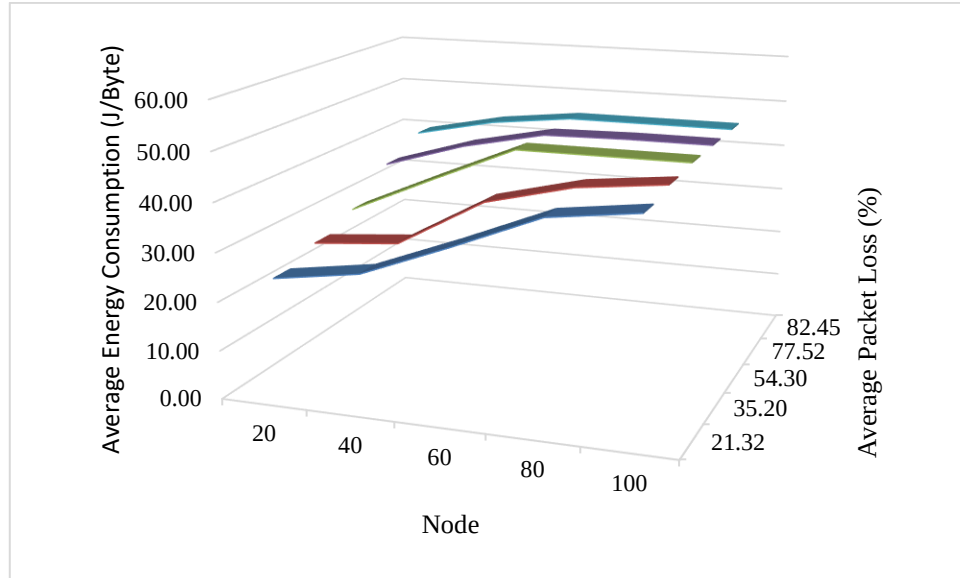


Figure 4.9: Energy consumption vs packet loss in CQI= 7

Based on Figure 4.8 and Figure 4.9, it presented that an average energy consumption increased drastically, directly proportional to the packet loss parameter. It is more obvious that the high data rate (Figure 4.9) causes high energy consumption compared to the low data rate (Figure 4.8) starting from node 60 onward.

The increased energy consumption may be due to the high mobility node in 1km coverage with frequent channel switching. There is a high probability that, in multi-channel and multi-node environments, each of the UEs or nodes in this simulation may cause packet loss to occur. It loses the path either forward or reply packet to the Mother node. It is more significant when the amount of node increase, making the network environment more saturated. Therefore, when the path or distance of the forward and reply packets are far away when respect to the Mother node, that enables more energy to broadcast, in which high packet loss happens directly when the requirement of high saturation of network with high node density concurrently.

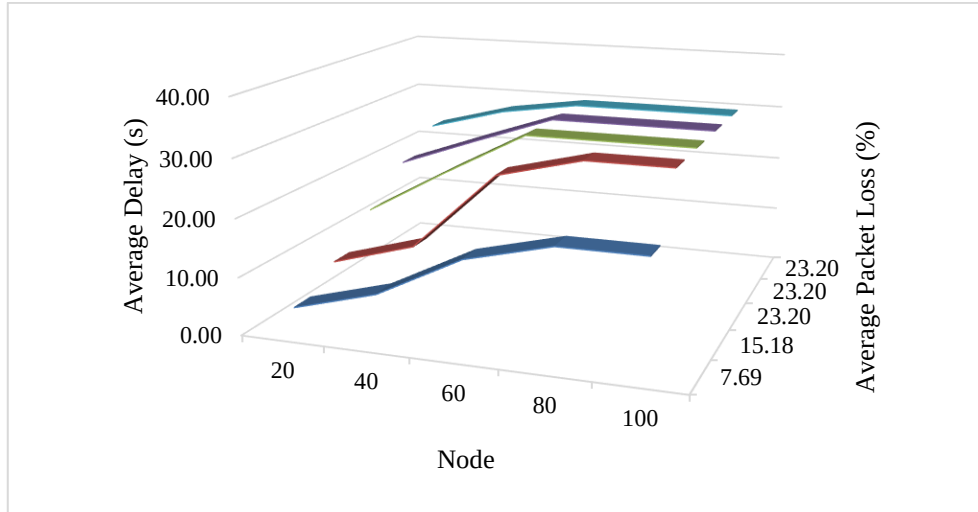


Figure 4.10: Delay vs packet loss on CQI= 2

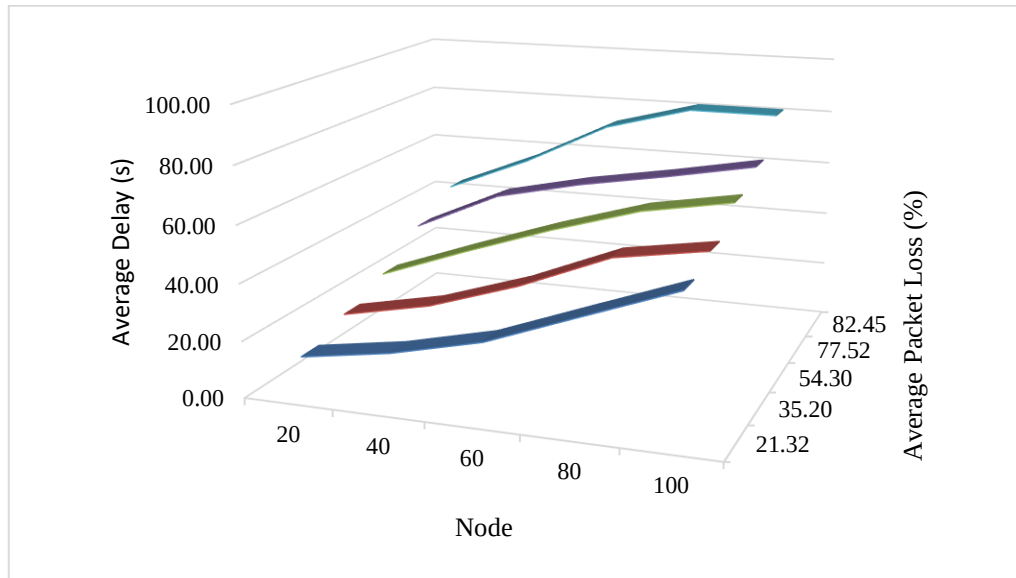


Figure 4.11: Delay vs packet loss on CQI= 7

According to Figure 4.10 and Figure 4.11. Its shows that the high data rate (CQI= 7) contribute more delay and packet loss compared to low data rate (CQI= 2) from node 40 onward.

The reason for delay and packet loss directly increased is due to the fact of data rate characteristics and communication protocol features with high node mobility. This cause amount of packet loss that increased the delay time especially on high data rate of CQI= 7.

Another consideration that can be contribute to this, is the amount of node causing various pattern changed probability in this 1km coverage simulation making the tremendously increase of delay time with packet loss rate.

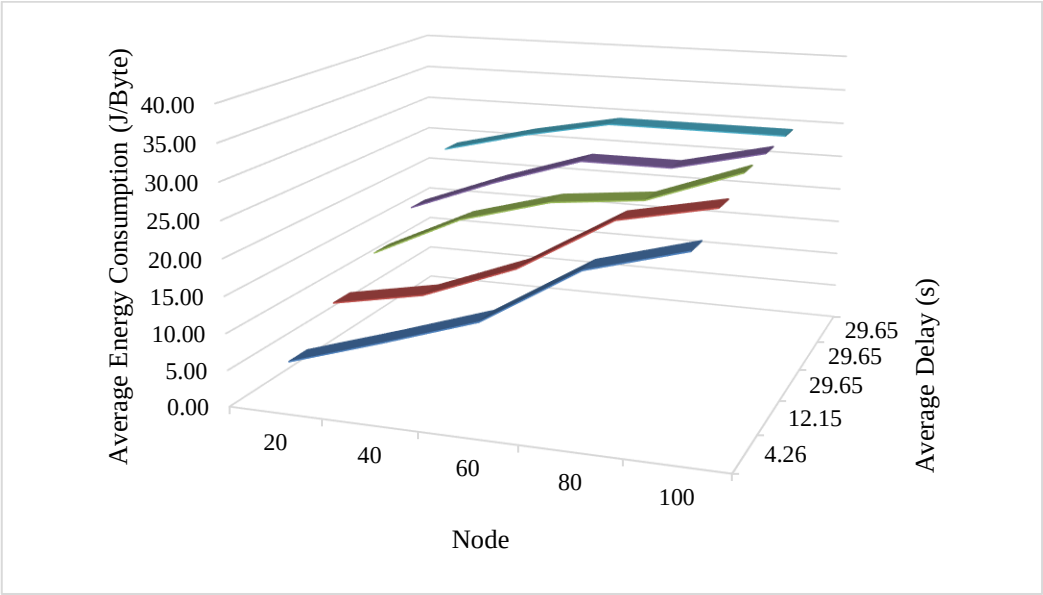


Figure 4.12: Energy consumption vs delay on CQI= 2

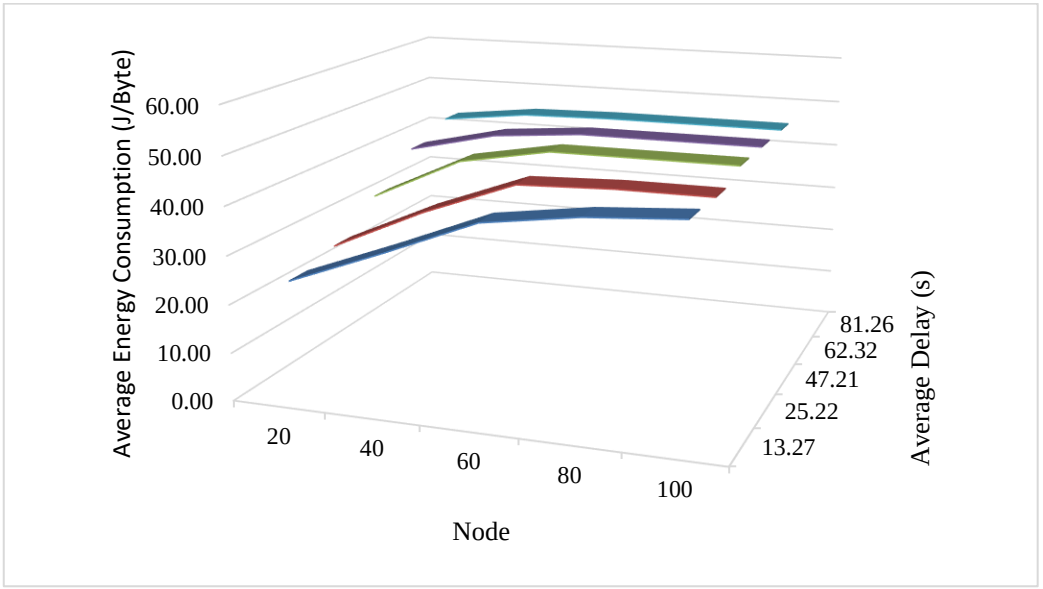


Figure 4.13: Energy consumption vs delay on CQI= 7

As presented on Figure 4.12 and Figure 4.13. The high energy consumption directly causes the delay time to increase, starting from node 60 onward. It was more significant in

Figure 4.13 (CQI= 7), which contributes more energy consumption with delay time compared to Figure 4.12 (CQI= 2).

This is because the node-to-node transmission keeps changing or switching the channel in high speeds node mobility and contributes more energy to the packet, either broadcasting or reply packet. The number of nodes increased, with the path for transmission increasing. Potentially cause a high delay that needs more energy to broadcast or reply. Another requirement is when Child nodes, or Child UEs, were “disappear” or out of coverage. The packet is requested to retransmit in the specific time frame, which also contributes to this as it needs more energy to broadcast or reply packet, causing a high delay time. It became worse when the frequency of retransmission increased drastically.

4.11 Summary

In this chapter, the Omnet++ network simulator has been selected to examine the proposed methods and algorithms based on the characteristics like OFDMA and SC-FDMA with a model to develop the function. Simulation time has also been justified through this chapter to evaluate the proposed methods and algorithms more accurately. The packet loss and end-to-end delay with the energy consumption parameter presented can be used to validate the proposed methods and algorithms in terms of performance. Based on the data gathered, the LTE-AIC equipped with proposed methods and algorithms with packet scheduling shows better results than LTE-A and LTE without Channel assignment and other algorithms and methods. Consequently, this chapter presented the simulation result of suggested methods and algorithms based on the parameter provided, and it meets the target of this research objective.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

In this research work, an improved channel formation and network establishment algorithm has been introduced and developed in order to optimize the communication among the response team and survivor. Demonstration of the suggested interface in terms of architecture, structure and function also been elaborated in more details format. Further, Packet Scheduling algorithm deployed on LTE-AIC and operation with methods on this research study to cope the research problem has been highlighted in Chapter 3 (Research Methodology) as well. Markov Chain and Markov Decision Strategy with implementation of SC-FDMA in uplink and OFDMA in downlink has been discussed in this study to overcome the problem of connection characteristics, especially in huge amount of node with random motion of node in multi-channel multi-interface approach.

It was found that LTE-AIC improved packet loss around 54.80% in average compared to LTE-A and LTE-AIC reduced 64.50% compared to LTE on low data rate. For high data rate, around 10.98% in average for LTE-AIC compared to conventional LTE-A and 19.70% average with respect to LTE. In terms of delay parameter for low data rate, LTE-AIC shows significant result of 36.32% average reduced compared to LTE-A and 49.44% with respect to LTE on end-to-end delay for low data rate. Furthermore, 22.91% improved on LTE-AIC compared to LTE-A and 38.63% when compared to LTE for high data rate as well. For another energy consumption parameter, LTE-AIC showed 20.90% with respect to LTE-A and 33.36% compared to LTE. For high data rate, 23.63% improved on LTE-AIC compared to LTE-A and 44.04% with respect to LTE. Lastly, this research work greatly

contributes the suggested LTE-AIC for VASNET implement on Disaster Management System.

5.2 Contributions

Objective 1). To design an interface architecture with channel assignment and network establishing algorithms in multi-channel to avoid channel repetition, redundancy, and interference on current VASNET infrastructure.

In order to minimize channel utilization problems such as repetition and redundancy with interference in multiple-channel on VASNET infrastructure. Multi-interface has been introduced in this research study. Based on the overview of the interface function. The most suitable interface to be applied in this study was a switchable transmitter with a fixed receiver. This enables the channel assigned to be fully utilized on VASNET infrastructure, especially the number of nodes in increasing trend. However, due to a switchable transmitter in the interface. It is possible to reuse or repeat the channel that causes high interference, although the interface application in this study was equipped in every node or UEs, showing a high probability of this problem. Therefore, Network establishing and improved channel assignment has been introduced and is the main contribution to this research study. The simulation result on the packet loss parameter showed that the suggested Channel Assignment with the Network Establishing algorithm in VASNET infrastructure was better and improved compared to conventional LTE (benchmark) protocol and LTE-A (benchmark). The reason is that when a channel is reused or repeated, it might deliver multiple packet broadcasting in a specific time frame. This can cause high packet collision and loss with unreachable packets to specific destination nodes or UEs in a multi-node environment. Improved Channel Assignment after Network Establishing ensures the packet

deliver to specific destination nodes or UEs under a minimum occurrence rate of interference among the relay nodes or Child nodes on a multi-Channel, multi-Interface with the multi-node environment that applies to the Disaster Management System. Consequently, as a conclusion for this. The improved Channel Assignment greatly contributed to this study to solve the channel repetition with redundancy and directly reduced node-to-node interference on end-to-end connections. This enables and guarantees the communication link among the survivor or victim in an emergency rescue plan to save as many victims as possible on the Disaster Management System using VASNET infrastructure

Objective 2). To construct packet scheduling and Markov Chains in the VASNET infrastructure in order to utilize the channel assign.

Markov Chains and Markov Chains Decision Strategies were suggested to reduce channel utilization in terms of over or under-channel usage. Further, the Packet Scheduling algorithm is also presented to support Markov Chains to minimize this problem. The method of Markov Chains is to identify the next state of nodes or UEs in random movement and rapid change of nodes or UEs topology. This is more helpful in multi-channel and multi-interface when Markov Chains are applied. The method like absorbing, reflecting, and circular movement elaborated in Chapter 3 enables the specific channel assigned to guarantee in-link connection based on the current state to identify the location of the next state of specific destination nodes or UEs in a certain region during a post-disaster scenario. These advantages of the Markov Chain can minimize the Backoff process that links connection promises to broadcast the packet to arrive at destination nodes or UEs in a certain time frame with the Packet Scheduling algorithm on the proposed LTE-AIC protocol and reliability feature, making it more solid to ensure the channel was not over-use or under-use

in VASNET environment. Even though the node movement setting or speed was high enough to suit the real-time disaster situation. This is a very convincing simulation result based on the delay parameter that presented the proposed Packet Scheduling with suggested LTE-AIC combined with reliability features, and Markov Chains Decision Strategies were improved compared to conventional or normal LTE-A (benchmark) and LTE (benchmark) protocol. This is because when the channel is overutilized. Packet under other channels may not be able to broadcast in specific time sequence and this will increase the frequent change of the Backoff process, and CW value will increase instantaneously, degrading the VASNET performance in Disaster Management System. Lastly, the proposed reliability feature and Packet Scheduling algorithm with LTE-AIC protocol contribute to solving this channel utilization with the help of Markov Chains.

Objective 3). To establish OFDMA in downlink and SC-FDMA in uplink on VASNET infrastructure to reduce spectrum scarcity.

To ensure the spectrum resource are promising in a multi-channel multi-node environment. The improved Channel Assignment algorithm contributes to it. This is done by ensuring the channel utilisation can fulfil the number of nodes or UEs, as elaborated clearly in Chapter 3 on Research Methodology. By introducing OFDMA and SC-FDMA in this research study. The uplink and downlink communication are ensured and guaranteed on spectrum resources in the Channel Assignment algorithm. This is because the spectrum may need more resources, especially when the Mother node or emergency rescue team receive many packets from different channel during communication on the uplink stage. This incident was obvious when channel assignment was repeated or reused at a specific time which caused the electromagnetic spectrum to become lessened.

On the other hand, when the Mother node or rescue team member broadcasts the packet to various nodes on multiple channels simultaneously. It may cause a huge amount of spectrum that affects the performance of VASNET in the conventional way. Due to this, OFDMA and SC-FDMA were introduced in this study to ensure the spectrum resource is promising with a Packet Scheduling algorithm that can broadcast the packet in multi-channel to multi-interface in a multi-node environment during a downlink situation. Same for the uplink stage to receive the packet in various channels by providing enough resources of the spectrum to be received by the Mother node or rescue member node at one-time frame. This is proved by the simulation result for the energy consumption parameter that less energy consumption on the proposed algorithm with applying OFDMA and SC-FDMA compared to conventional LTE-A (benchmark) and LTE (benchmark). Therefore, this contribution defines that the frequency and wavelength of OFDMA and SC-FDMA can minimise the spectrum over-utilisation or resource scarcity to solve the current spectrum problem in wireless networking involving multi-node situations. It directly shows improvement on VASNET to apply this OFDMA and SC-FDMA in Disaster Management System in terms of proposed system performance and reliability.

5.3 Future Work

According to the simulation result, the proposed methods and algorithms can be implemented in other disaster scenarios like earthquakes, landslides, and volcanoes instead of tsunamis. This is to test the performance of suggested methods with algorithms on VASNET to be applied to various types of Disaster Management Systems or emergency rescue plans in terms of the reliability and stability of proposed methods and algorithms. Moreover, it could expand the testing coverage to large-scale disaster areas during post-disaster scenarios since the simulation of this study involves small-scale coverage of 1km

on low and high data rates. The testing on large-scale scenarios may involve millions of UEs, nodes, or survivors (in real cases) that current Markov Chains might not be able to handle or insufficient to be applied to that situation. As such, modification work of Markov Chains operation and algorithms can be considered in this research study.

In addition, the proposed Channel Assignment also can be further expanded by the study of channel assignment to be included on high bandwidth, interference by adjacent nodes, and varying channels with an electromagnetic spectrum on a large-scale situation. Another study that can be considered is database storage in various Disaster Management Systems. This is because, based on the study of disasters, there is no research or study involving the database related to the emergency rescue plan. The study of the database is probably improving the performance of VASNET in the Channel Assignment field of study by knowing the identity of victims through the VASNET network involving the Cloud Computing technology in the shortest time as fast as possible.

Besides the study of large-scale and the database. The transmission protocol, also a topic that has a big impact on any research study, involves networking, especially in a wireless environment in terms of transmission distance. The IEEE 802.11 b/g and 5G transmission protocol can be listed in this field of research study instead of using LTE-A and LTE. This is because a long transmission protocol might guarantee that the connection among the UEs or nodes can sustain, especially on large-scale coverage. This directly improves the performance by lessening the packet loss and delay while transmitting the packet or signal from far away. Not less than that, the energy dissipation might be minimised by using IEEE 802.11 b/g and 5G that enable the study of Channel Assignment. It able to show improvement on current research study. Due to the long distance in the large-scale

environment. Another study of multiple stations or Base Stations can be categorised in this study. This multiple Base Station study not only refers to the transmission distance or communication coverage but also includes the study in terms of geographical field in various situations and interference among the main station or Base Station to advance the proposed methods more effectively and efficiently.

Therefore, by involving the database study with multiple main stations and communication protocols, the packet size is a future work as existing studies used the small packet size in few bytes to validate these suggested methods and algorithms. These packet sizes can be facilities for any multimedia format, likely audio, and video format, for large-scale scenarios applied to VASNET topology. This suggested format of packet size enables any rescue team member to gather more precise or clear information or data during an emergency in a post-disaster scenario by making a more accurate decision.

The multimedia packet size can be tested in existing proposed methods and algorithms by modifying multi-interface among the UEs or nodes of survivors. In terms of reliability and stability, the proposed methods and algorithms can be validated by using throughput parameters to minimise the complexity and high computational cost of the proposed structure to reduce the degradation when the proposed methods and algorithms operate over a long period of time in a large-scale environment. This can be done by studying CW in future works that indirectly improve the delay and packet loss. The less value of CW, the better the system in terms of less Backoff process occurring inside the VASNET on signal or packet broadcasting in multi-node and multi-channel situations. Lastly, this can be improved by considering the DIFS and SIFS time slot operation, especially on saturated networks involving millions of UEs and nodes to broadcast the signal or packet. This is

because the study on CW and fixed the value of CW as minimum CW in the saturated network might potentially minimise any hidden node or deafness node in the specific region. This also directly reduces energy consumption generated in high data rate on node-to-node basis that improves the performance of VASNET in Disaster Management System with proposed Channel Assignment.

REFERENCES

- Ababa, A. (2017). Disasters & emergencies: Definitions. Emergency Humanitarian Action via International World Health Organization.
- Abbasi, I., & Shahid Khan, A. (2018). A review of vehicle to vehicle communication protocols for VANETs in the urban environment. *Future Internet*, 10, 14.
- Abdulhasan, M. Q., Salman, M. I., Ng, C. K., Noordin, N. K., Hashim, S. J., & Hashim, F. B. (2013). A threshold feedback compression scheme of channel quality indicator (CQI) in LTE systems. 181–186.
- Access, E. U. (2010). physical channels and modulation (3GPP TS 36.211 version 9.1. (Release 9),”. *ETSI TS*, 136, V9.
- Agarwal, M., Leekha, M., Sawhney, R., Ratn Shah, R., Kumar Yadav, R., & Kumar Vishwakarma, D. (2020). Memis: Multimodal emergency management information system. 479–494.
- Aguirre, B. E., & Dynes, R. R. (1979). Organizational adaptation to crises: Mechanisms of coordination and structural change. *Disasters*, 3, 71–74.
- Ahmed, M., Sattari, M. R., Nasir, M. K., Ghahremani, S., Khorsandroo, S., Ali, S. A., & Noor, R. M. (2013). Vehicle adhoc sensor network framework to provide green communication for urban operation rescue. *Lecture Notes on Information Theory*, 1.
- Ahmed, S., Rehman, M. U., Ishtiaq, A., Khan, S., Ali, A., & Begum, S. (2018). VANSec: Attack-resistant VANET security algorithm in terms of trust computation error and normalized routing overhead. *Journal of Sensors*, 1-17. doi:10.1155/2018/6576841

- Al-Absi, M. A., Al-Absi, A. A., Sain, M., & Lee, H. (2021). Moving ad hoc networks—A comparative study. *Sustainability*, 13, 6187.
- Alazawi, Z., Abdljabar, M. B., Altowaijri, S., Vegni, A. M., & Mehmood, R. (2012). ICDMS: an intelligent cloud based disaster management system for vehicular networks. *International Workshop on Communication Technologies for Vehicles*, (pp. 40–56).
- Alazawi, Z., Alani, O., Abdljabar, M. B., & Mehmood, R. (2014). Transportation evacuation strategies based on VANET disaster management system. *Procedia Economics and Finance*, 18, 352–360.
- Alazawi, Z., Altowaijri, S., Mehmood, R., & Abdljabar, M. B. (2011). Intelligent disaster management system based on cloud-enabled vehicular networks. *2011 11th International Conference on ITS Telecommunications*, (pp. 361–368).
- Alba, E., Luna, S., & Toutouh, J. (2008). Accuracy and efficiency in simulating VANETs. *International Conference on Modelling, Computation and Optimization in Information Systems and Management Sciences*, (pp. 568–578).
- Ali, K., Nguyen, H. X., Vien, Q.-T., & Shah, P. (2015). Disaster management communication networks: Challenges and architecture design. *2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)*, (pp. 537–542).
- Almasaeid, H. M., & Kamal, A. E. (2014). Receiver-based channel allocation in cognitive radio wireless mesh networks. *IEEE/ACM Transactions on Networking*, 23, 1286–1299.

- Alotaibi, M. F., & Ibrahim, D. M. (2018). Coordination Emergency Response Framework (CERF): A Proposed Model. *International Journal of Computer Science and Information Security (IJCSIS)*, 16, 11.
- Alsarhan, A., Al-Dubai, A. Y., Min, G., Zomaya, A. Y., & Bsoul, M. (2018). A new spectrum management scheme for road safety in smart cities. *IEEE Transactions on Intelligent Transportation Systems*, 11, 3496-3506.
- Anritsu. (n.d.). LTE Resource Guide. Retrieved from <https://www.cs.columbia.edu/hgs/teaching/ais/hw/anritsu.pdf>
- Ansell, J., & Wharton, F. (1992). *Risk: Analysis, assessment and management*. John Wiley & Sons Incorporated.
- Ansell, J., & Wharton, F. (1992). *Risk: Analysis, Assessment and Management*. John Wiley & Sons Incorporated.
- Anusuya, K. V., & Sakthi Priya, M. (2021). An enhanced MAC protocol to prioritize channel assignment for safety message broadcast in VANET. *International Journal of Nonlinear Analysis and Applications*, 12, 1845–1854.
- Arslan, M., Roxin, A.-M., Cruz, C., & Gin hac, D. (2017). A review on applications of big data for disaster management. *2017 13th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS)*, (pp. 370–375).
- Artail, H., & Mer shad, K. (2012). A framework for secure and efficient data acquisition in vehicular ad hoc networks. *IEEE Transactions on Vehicular Technology*, 62, 536–551.
- Asadi, A., Wang, Q., & Mancuso, V. (2014). A survey on device-to-device communication in cellular networks. *IEEE Communications Surveys & Tutorials*, 16, 1801–1819.

- Asghar, S., Alahakoon, D., & Churilov, L. (2006). A comprehensive conceptual model for disaster management. *Journal of Humanitarian Assistance*, 1360, 1–15.
- Asimakopoulou, & Eleana. (2008). *A grid-aware emergency response model for natural disasters*. Ph.D. dissertation, © E. Asimakopoulou.
- Asimakopoulou, E. B. (2011). A Collective Intelligence Resource Management Dynamic Approach for Disaster Management: A density survey of disasters occurrence. *2011 Third International Conference on Intelligent Networking and Collaborative Systems.*, (pp. 735–740). doi:<https://doi.org/10.1109/incos.2011.15>
- Aung, N., Zhang, W., Dhelim, S., & Ai, Y. (2018). Accident prediction system based on hidden Markov model for vehicular ad-hoc network in urban environments. *Information*, 9, 311.
- Azizian, M., Cherkaoui, S., & Hafid, A. S. (2016). A distributed cluster based transmission scheduling in VANET. *2016 IEEE International Conference on Communications (ICC)*, (pp. 1–6).
- Bahl, P., Chandra, R., & Dunagan, J. (2004). SSCH: slotted seeded channel hopping for capacity improvement in IEEE 802.11 ad-hoc wireless networks. *Proceedings of the 10th Annual International Conference on Mobile Computing and Networking*, (pp. 216–230).
- Bande, S., & Shete, V. V. (2017). Smart flood disaster prediction system using IoT & neural networks. *2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon)*, (pp. 189–194).
- Bankoff, G., & Frerks, G. (2013). *Mapping Vulnerability:" Disasters, Development and People"*. Routledge.

- Basha, E. A., Ravela, S., & Rus, D. (2008). Model-based monitoring for early warning flood detection. *Proceedings of the 6th ACM Conference on Embedded Network Sensor Systems*, (pp. 295–308).
- Bhabani, B., & Mahapatro, J. (2021). A delay-efficient channel allocation scheme for disseminating alert messages using WBAN and VANET. *ICC 2021-IEEE International Conference on Communications*, (pp. 1–6).
- Bhardwaj, M., Gangwar, A., & Soni, D. (2012). A review on OFDM: concept, scope & its applications. *IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE)*, 1, 07–11.
- Bhondve, T. B., Satyanarayan, R., & Mukhedkar, M. (2014). Mobile rescue Robot for Human body detection in rescue operation of disaster. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 3, 9876–9882.
- Bianchi, G. (1998). IEEE 802.11-saturation throughput analysis. *IEEE Communications Letters*, 2, 318–320.
- Bianchi, G. (2000). Performance analysis of the IEEE 802.11 distributed coordination function. *IEEE Journal on Selected Areas in Communications*, 18, 535–547.
- Borst, S. (2003). User-level performance of channel-aware scheduling algorithms in wireless data networks. *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No. 03CH37428)*, 1, pp. 321–331.

- Buck, D. A., Trainor, J. E., & Aguirre, B. E. (2006). A critical evaluation of the incident command system and NIMS. *Journal of Homeland Security and Emergency Management*, 3, 3.
- Bulbul, A. A.-M., Imam, F., Mitu, M., Akter, S., Das, S. R., & others. (2019). Comparative Analysis between OFDMA and SC-FDMA: Model, Features and Applications. *International Journal of Electrical Engineering and Applied Sciences (IJEES)*, 2, 75–82.
- Cairns, & A. (2005). Disaster lessons: what you don't know can kill you. *Disaster lessons: what you don't know can kill you*. Retrieved from <http://bit.ly/2iqsrHZ>
- Castillo, C. (2016). *Big crisis data: social media in disasters and time-critical situations*. Cambridge University Press.
- Celik, S., & Corbacioglu, S. (2010). Role of information in collective action in dynamic disaster environments. *Disasters*, 34, 137–154.
- Cervone, G., Sava, E., Huang, Q., Schnebele, E., Harrison, J., & Waters, N. (2016). Using Twitter for tasking remote-sensing data collection and damage assessment: 2013 Boulder flood case study. *International Journal of Remote Sensing*, 37, 100–124.
- Chandra, R., & Bahl, P. (2004). MultiNet: Connecting to multiple IEEE 802.11 networks using a single wireless card. *IEEE INFOCOM 2004*, 2, pp. 882–893.
- Chapman–kolmogorov equation. (n.d.). *Chapman–kolmogorov equation*. Retrieved from https://en.wikipedia.org/wiki/Chapman-Kolmogorov_equation
- Chen, G., Branch, J., Pflug, M., Zhu, L., & Szymanski, B. (2005). SENSE: a wireless sensor network simulator. In *Advances in Pervasive Computing and Networking* (pp. 249–267). Springer.

- Chen, J., & Sheu, S.-T. (2001). A novel delay-oriented shortest path routing protocol for mobile ad hoc networks. *ICC 2001. IEEE International Conference on Communications. Conference Record (Cat. No. 01CH37240)*, 6, pp. 1930–1934.
- Chen, J.-J., Cheng, H.-H., Liang, J.-M., & Tseng, Y.-C. (2013). An energy-efficient sleep scheduling with QoS consideration in 3GPP LTE-advanced networks for internet of things. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*, 3, 13–22.
- Chen, R., Sharman, R., Chakravarti, N., Rao, H. R., & Upadhyaya, S. J. (2008). Emergency response information system interoperability: development of chemical incident response data model. *Journal of the Association for Information Systems*
- Chen, Y., & Agrawal, D. P. (2004). Effect of Contention Window on the performance of IEEE 802.11 WLANs. *Proceedings, 3rd Annual Mediterranean Ad Hoc Networking Workshop June*, (pp. 27–30).
- Choi, M. G., Park, J. S., & Kim, H. J. (2010). Multi-interface multi-channel hybrid channel assignment with ieee 802.11 in using a reactive routing protocol in manet. *2010 International Conference on Information Science and Applications*, (pp. 1–5).
- Choi, S., & Bae, B. (2015). The real-time monitoring system of social big data for disaster management. In *Computer Science and Its Applications* (pp. 809–815). Springer.
- Choksi, M., Gamit, H., & Zaveri, M. A. (2018). Data Sensing and Resource Scheduling in Clustered Environment for Post Disaster Management Using Internet of Things. *2018 3rd International Conference for Convergence in Technology (I2CT)*, (pp. 1–5).

- Chrysostomou, C., Djouvas, C., & Lambrinos, L. (2012). Dynamically adjusting the min-max contention window for providing quality of service in vehicular networks. *2012 The 11th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net)*, (pp. 16–23).
- Chung, S.-e., Yoo, J., & Kim, C.-k. (2009). A cognitive MAC for VANET based on the WAVE systems. *2009 11th International Conference on Advanced Communication Technology, 1*, pp. 41–46.
- Ciochina, C., Mottier, D., & Sari, H. (2007). An analysis of OFDMA, precoded OFDMA and SC-FDMA for the uplink in cellular systems. *Multi-Carrier Spread Spectrum 2007: Proceedings from the 6th International Workshop on Multi-Carrier Spread Spectrum, May 2007, Herrsching, Germany*, (pp. 25–36).
- Clausen, Thomas, Jacquet, & Philip. (2003). Optimized link state routing protocol (OLSR).
- Coppola, D. P., & Maloney, E. K. (2017). *Communicating Emergency Preparedness: Practical Strategies for the Public and Private Sectors*. Routledge.
- Dahlman, E., Parkvall, S., & Skold, J. (2013). *4G: LTE/LTE-advanced for mobile broadband*. Academic press.
- Dai, M., Luan, T. H., Su, Z., Zhang, N., Xu, Q., & Li, R. (2022). Joint channel allocation and data delivery for uav-assisted cooperative transportation communications in post-disaster networks. *IEEE Transactions on Intelligent Transportation Systems*, 23, 16676–16689.
- Dai, P., Liu, K., Feng, L., Zhang, H., Lee, V. C., Son, S. H., & Wu, X. (2018). Temporal information services in large-scale vehicular networks through evolutionary multi-

- objective optimization. *IEEE Transactions on Intelligent Transportation Systems*, 20, 218–231.
- Das, S. R., Belding-Royer, E. M., & Perkins, C. E. (2003). Ad hoc on-demand distance vector (AODV) routing.
- Day, J. M., Melnyk, S. A., Larson, P. D., Davis, E. W., & Whybark, D. C. (2012). Humanitarian and disaster relief supply chains: a matter of life and death. *Journal of Supply Chain Management*, 48, 21–36.
- Den Hengst, M., & Sol, H. G. (2001). The impact of information and communication technology on interorganizational coordination. *Proceedings of the 34th Annual Hawaii International Conference on System Sciences*, (pp. 10–pp).
- Dijkstra, E. W. (1959). A note on two problems in connexion with graphs. *Numerische Mathematik*, 1, 269–271.
- Dimou, K. W., & Timner, Y. (2009). Handover within 3GPP LTE: Design principles and performance. *2009 IEEE 70th Vehicular Technology Conference Fall*, (pp. 1–5).
- Din, I., & Saqib, N. A. (2008). Passive packet loss detection and its effect on web traffic characteristics. *2008 International Conference on Computer and Electrical Engineering*, (pp. 729–733).
- Draves, R., Padhye, J., & Zill, B. (2004). Routing in multi-radio, multi-hop wireless mesh networks. *Proceedings of the 10th Annual International Conference on Mobile Computing and Networking*, (pp. 114–128).
- Dubey, S., Dahiya, M., & Jain, S. (2018). Application of Distributed Data Center in Logistics as Cloud Collaboration for handling Disaster Relief. *2018 3rd International*

- Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)*, (pp. 1–11).
- Egenhofer, M. J., & Franzosa, R. D. (1991). Point-set topological spatial relations. *International Journal of Geographical Information System*, 5, 161–174.
- Ejaz, W., Azam, M. A., Saadat, S., Iqbal, F., & Hanan, A. (2019). Unmanned aerial vehicles enabled IoT platform for disaster management. *Energies*, 12, 2706.
- Elhag, E., & Othman, M. (2007). Adaptive Contention Window Scheme for WLANs. *Int. Arab J. Inf. Technol.*, 4, 313–321.
- Elminaam, D. S., Kader, H. M., & Hadhoud, M. M. (2009). Energy efficiency of encryption schemes for wireless devices. 1, p. 302. IACSIT Press.
- Fan, C. a. (2018). Establishing a framework for disaster management system-of-systems. *2018 Annual IEEE International Systems Conference (SysCon)*, (pp. 1-7). doi:10.1109/SYSCON.2018.8369545
- Fan, X., Yang, B., Yamamoto, R., & Tanaka, Y. (2015). Road side unit assisted stochastic multi-hop broadcast scheme for instant emergency message propagation. *2015 17th International Conference on Advanced Communication Technology (ICACT)*, (pp. 450-457). doi:10.1109/ICACT.2015.7224909
- Faruque, S., & Faruque, S. (2019). Orthogonal Frequency Division Multiple Access (OFDMA). *Radio Frequency Multiple Access Techniques Made Easy*, 63–77. doi:10.1007/978-3-319-91651-4_6
- Fiedler, U., & Glatz, E. (2007). Self-organized topology construction and channel allocation for multi-IEEE 802.16-2004 radio routers in disaster recovery. *Proc. 1st Workshop on WiMAX, Wireless, and Mobility (WEIRD07), Coimbra, Portugal*.

- Font, J. L., Iñigo, P., Domínguez, M., Sevillano, J. L., & Amaya, C. (2010). Architecture, Design and Source Code Comparison of Ns-2 and Ns-3 Network Simulators. *Proceedings of the 2010 Spring Simulation Multiconference* (pp. 109:1–109:8). San Diego, CA, USA: Society for Computer Simulation International. doi:10.1145/1878537.1878651
- Fujiwara, T., Makie, H., & Watanabe, T. (2004). A framework for data collection system with sensor networks in disaster circumstances. *International Workshop on Wireless Ad-Hoc Networks, 2004.*, (pp. 94–98).
- Gadam, M. A., Ahmed, M. A., Ng, C. K., Nordin, N. K., Sali, A., & Hashim, F. (2016). Review of adaptive cell selection techniques in LTE-advanced heterogeneous networks. *Journal of Computer Networks and Communications*, 2016, 1-12. doi:10.1155/2016/7394136
- Gaillard, J.-C., & Mercer, J. (2013). From knowledge to action: Bridging gaps in disaster risk reduction. *Progress in Human Geography*, 37, 93–114.
- Galbraith, J. R. (1974). Organization design: An information processing view. *Interfaces*, 4, 28–36.
- Gamitl, H., Kumar, J. S., & Zaveri, M. A. (2018, April). Resource Monitoring and Scheduling for Post Disaster Management Using Internet of Things. *2018 3rd International Conference for Convergence in Technology (I2CT)*, (pp. 1-5). doi:10.1109/I2CT.2018.8529785
- Gandotra, P. (2016). Device-to-Device Communication in Cellular Networks: A Survey. *Journal of Network and Computer Applications*, 71. doi:10.1016/j.jnca.2016.06.004

- Gao, H., Liu, C., Li, Y., & Yang, X. (2020). V2VR: reliable hybrid-network-oriented V2V data transmission and routing considering RSUs and connectivity probability. *IEEE Transactions on Intelligent Transportation Systems*, 22, 3533–3546.
- Garton, L., Haythornthwaite, C., & Wellman, B. (1997). Studying online social networks. *Journal of Computer-Mediated Communication*, 3, JCMC313.
- Giovanni Nardini, A. V. (2015). Simulte. *Simulte*. Retrieved from <http://simulte.com/>
- Glomosim simulator. (2019). *Glomosim simulator*. Retrieved from <http://networksimulationtools.com/glomosim-simulator-projects/>
- Glomosim. (2013). *Glomosim*. Retrieved from <https://en.wikipedia.org/wiki/GloMoSim>
- Gomez, J., Campbell, A. T., & Morikawa, H. (1999). The Havana framework for supporting application and channel dependent QoS in wireless networks. *Proceedings. Seventh International Conference on Network Protocols*, (pp. 235–244).
- Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. *MIS quarterly*, 213–236.
- Gossain, H., Cordeiro, C., Cavalcanti, D., & Agrawal, D. P. (2004). The deafness problems and solutions in wireless ad hoc networks using directional antennas. *IEEE Global Telecommunications Conference Workshops, 2004. GlobeCom Workshops 2004*.
- Gossain, H., Cordeiro, C., Cavalcanti, D., & Agrawal, D. P. (2004). The deafness problems and solutions in wireless ad hoc networks using directional antennas. *IEEE Global Telecommunications Conference Workshops, 2004. GlobeCom Workshops 2004.*, (pp. 108–113).

- Grammenos, R. C., & Darwazeh, I. (2010). SC-FDMA and OFDMA: The two competing technologies for LTE.
- Gui, J., & Cai, F. (2021). Efficient Radio Channel Allocation in Integrated mmWave/Sub-6 GHz UAV-Assisted Disaster Relief Networks. *Mobile Information Systems*, 2021, 1–18.
- Häggström, O. (2002). *Finite Markov chains and algorithmic applications* (Vol. 52). Cambridge University Press.
- Hai-tao, W., & Yue, Z. (2011). Channel Assignment and Routing Scheduling in Wireless Mesh Networks. *2011 Fourth International Conference on Intelligent Computation Technology and Automation*, 2, pp. 1074-1077. doi:10.1109/ICICTA.2011.554
- Han, C., Dianati, M., Tafazolli, R., Liu, X., & Shen, X. (2012). A novel distributed asynchronous multichannel MAC scheme for large-scale vehicular ad hoc networks. *IEEE Transactions on Vehicular Technology*, 61, 3125–3138.
- Hartenstein, H., & Laberteaux, K. (2009). *VANET: Vehicular Applications and Inter-Networking Technologies*. doi:10.1002/9780470740637
- Hashimoto, M. (2022). Is the long-term probability of the occurrence of large earthquakes along the Nankai trough inflated?—Scientific review. *Seismological Society of America*, 93, 2311–2319.
- Hatoum, R., Hatoum, A., Ghaith, A., & Pujolle, G. (2014). Qos-based joint resource allocation with link adaptation for SC-FDMA uplink in heterogeneous networks. *Proceedings of the 12th ACM International Symposium on Mobility Management and Wireless Access*, (pp. 59–66).

- He, P., & Xu, Z. (2010). Channel assignment and routing in multi-channel, multi-interface wireless mesh networks. *2010 2nd International Conference on Computer Engineering and Technology*, 3, pp. V3-69-V3-74. doi:10.1109/ICCET.2010.5485774
- Hoang, A. T., & Liang, Y.-C. (2008). Downlink channel assignment and power control for cognitive radio networks. *IEEE Transactions on Wireless Communications*, 7, 3106–3117.
- Hoffer Gittel, J. (2002). Coordinating Mechanisms in Care Provider Groups: Relational Coordination As a Mediator and Input Uncertainty As a Moderator of Performance Effects. *Manage. Sci.*, 48, 1408–1426. doi:10.1287/mnsc.48.11.1408.268
- Hosseinabadi, G. (2007). *Downlink channel assignment and power control for cognitive radio networks using game theory*. Tech. rep., Citeseer.
- Hunger, J. D., & Wheelen, T. L. (2003). *Essentials of strategic management* (Vol. 9). Prentice Hall NJ.
- Huq, S. M. (2016). Community based disaster management strategy in Bangladesh: Present status, future prospects and challenges. *European Journal of Research in Social Sciences Vol, 4*.
- Hussain, S. A., Iqbal, M., Saeed, A., Raza, I., Raza, H., Ali, A., & A., B. (2017). An efficient channel access scheme for vehicular ad hoc networks. *Mobile Information Systems*, 2017.
- Hwang, C. J., Kush, A., & Kumar, A. (2018). Multihop ad hoc networks for disaster response scenarios. *2018 International Conference on Computational Science and Computational Intelligence (CSCI)*, (pp. 810–814).

- Ibrahim, B. F., Toycan, M., & Mawlood, H. A. (2020). A comprehensive survey on VANET broadcast protocols. *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*, (pp. 298–302).
- Ikeda, K., & Kinoshita, K. (2019). A Channel Assignment Method for Wireless Mesh Networks in Disaster Situation. *2019 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW)*, (pp. 1–2).
- Information technology message queuing telemetry transport (mqtt) V.3.1.1. (2016). *Information technology message queuing telemetry transport (mqtt) V.3.1.1*. Geneva Switzerland.
- Insarag guidelines and methodology manual. (n.d.). *Insarag guidelines and methodology manual*. Retrieved from <https://www.insarag.org/methodology/guidelines>
- Isagawa, T., & Ohno, R. (2019). Glomosim simulator. *Japan Architectural Review*, 1, 486–503. Retrieved from [http://networksimulationtools .com/glomosim-simulator-projects/](http://networksimulationtools.com/glomosim-simulator-projects/)
- Jambli, M. N. (2014). *Reducing energy consumption in mobile ad-hoc sensor networks*. Ph.D. dissertation, Newcastle University.
- Jambli, M. N., Khan, A. S., & Shoon, S. C. (2016). A Survey of VASNET Framework to Provide Infrastructure-Less Green IoTs Communications for Data Dissemination in Search and Rescue Operations. *Journal of Electronic Science and Technology*, 14, 220–228.
- Jensen, A. R., Lauridsen, M., Mogensen, P., Sørensen, T. B., & Jensen, P. (2012). LTE UE power consumption model: For system level energy and performance optimization. *2012 IEEE Vehicular Technology Conference (VTC Fall)*, (pp. 1–5).

- Johari, S., & Krishna, M. B. (2022). Time-Slot Reservation and Channel Switching Using Markovian Model for Multichannel TDMA MAC in VANETs. *IEEE Access*, 10, 81250–81268.
- Kadir, M. I., Sugiura, S., Zhang, J., Chen, S., & Hanzo, L. (2012). OFDMA/SC-FDMA aided space–time shift keying for dispersive multiuser scenarios. *IEEE Transactions on Vehicular Technology*, 62, 408–414.
- Karabulut, M. A., Shah, A. S., & Ilhan, H. (2020). OEC-MAC: A novel OFDMA based efficient cooperative MAC protocol for VANETS. *IEEE Access*, 8, 94665–94677.
- Kargbo, A. H., Eveleigh, T. J., & Tanju, B. (2018). Electric grid disaster response management—A systems of systems engineering approach. *2018 Annual IEEE International Systems Conference (SysCon)*, (pp. 1–7).
- Karimi, O. B., Liu, J., & Li, Z. (2010). Multicast in multi-channel wireless mesh networks. *International Conference on Research in Networking*, (pp. 148–159).
- Kazmi, M., & Wiberg, N. (2003). Scheduling algorithms for HS-DSCH in a WCDMA mixed traffic scenario. *14th IEEE Proceedings on Personal, Indoor and Mobile Radio Communications, 2003. PIMRC 2003.*, 2, pp. 1485–1489.
- Kelly, F. P., Maulloo, A. K., & Tan, D. K. (1998). Rate control for communication networks: shadow prices, proportional fairness and stability. *Journal of the Operational Research Society*, 49, 237–252.
- Khaliq, K. A., Chughtai, O., Shahwani, A., Qayyum, A., & Pannek, J. (2019). An emergency response system: construction, validation, and experiments for disaster management in a vehicular environment. *Sensors*, 19, 1150.

- Khan, F. (2009). *LTE for 4G mobile broadband: Air interface technologies and performance*. Cambridge university press.
- Kim, H. (2014). Learning from UK disaster exercises: policy implications for effective emergency preparedness. *Disasters*, 38, 846–857.
- Kim, H., & Han, Y. (2005). A proportional fair scheduling for multicarrier transmission systems. *IEEE Communications Letters*, 9, 210–212.
- Kishorbhai, V. Y., & Vasantbhai, N. N. (2017). AON: a survey on emergency communication systems during a catastrophic disaster. *Procedia Computer Science*, 115, 838–845.
- Korhenan. (2014). *Introduction to 4G Mobile Communications*. Norwood, MA, USA: Artech House, Inc.
- Kosaka, Y., Nomura, N., Oto, A., & Miyajima, M. (2017). Analysis on Tsunami Evacuation by using Multi Agent System Case Study of Wajima District in Wajima City. *Journal of Japan Society of Civil Engineers, Ser. A*, 1.
- Kumar, R., Misra, M., & Sarje, A. K. (2010). A simplified analytical model for end-to-end delay analysis in MANET. *IJCA Special Issue on “Mobile Ad-hoc Networks” MANETs*, 195–199.
- Kuo, Y.-W., & Chou, L.-D. (2015). Power saving scheduling scheme for Internet of Things over LTE/LTE-advanced networks. *Mobile Information Systems*, 2015.
- Kwok, Y.-K., & Ahmad, I. (1998). Benchmarking the task graph scheduling algorithms. *Proceedings of the First Merged International Parallel Processing Symposium and Symposium on Parallel and Distributed Processing*, (pp. 531–537).

- Kyasanur, P., & Vaidya, N. H. (2005). Capacity of multi-channel wireless networks: impact of number of channels and interfaces. *Proceedings of the 11th Annual International Conference on Mobile Computing and Networking*, (pp. 43–57).
- Kyasanur, P., & Vaidya, N. H. (2005). Routing and interface assignment in multi-channel multi-interface wireless networks. *IEEE Wireless Communications and Networking Conference, 2005, 4*, pp. 2051–2056.
- Kyasanur, Pradeep, Vaidya, & Nitin, H. (2006). Routing and link-layer protocols for multi-channel multi-interface ad hoc wireless networks. *ACM SIGMOBILE Mobile Computing and Communications Review*, 10, 31–43.
- Lauridsen, M. (2014). Power-Consumption Measurements for LTE User Equipment: Agilent Application Note.
- Liang, J.-M., Chen, J.-J., Cheng, H.-H., & Tseng, Y.-C. (2013). An energy-efficient sleep scheduling with QoS consideration in 3GPP LTE-advanced networks for internet of things. *IEEE Journal on Emerging and Selected Topics in Circuits and Systems*, 3, 13–22.
- Liou, Y.-A., Kar, S. K., & Chang, L. (2010). Use of high-resolution FORMOSAT-2 satellite images for post-earthquake disaster assessment: a study following the 12 May 2008 Wenchuan Earthquake. *International Journal of Remote Sensing*, 31, 3355–3368.
- Liu, K., Ng, J. K., Lee, V. C., Son, S. H., & Stojmenovic, I. (2015). Cooperative data scheduling in hybrid vehicular ad hoc networks: VANET as a software defined network. *IEEE/ACM Transactions on Networking*, 24, 1759–1773.
- Liu, T., & Li, R. (2019). VANET Channel Allocation Scheme Based on Hungarian Algorithm. *2019 IEEE International Conferences on Ubiquitous Computing &*

Communications (IUCC) and Data Science and Computational Intelligence (DSCI) and Smart Computing, Networking and Services (SmartCNS), (pp. 717–722).

Liu, X., Li, Y., Kuang, H., & Li, F. (2015). A generic model of multi-interface and multi-channel for multi-hop wireless networks. *2015 4th International Conference on Computer Science and Network Technology (ICCSNT)*, 1, pp. 1083–1089.

Liu, Y., Shi, K., Xu, G., Lin, S., & Li, S. (2018). Analysis of Packet Loss Characteristics in VANETs. *2018 8th International Conference on Electronics Information and Emergency Communication (ICEIEC)*, (pp. 219–222).

Lizy, J. J., & Varghese, M. (2014). A High Secure And Efficient Data Acquisition Mechanism In Vehicular Ad Hoc Networks (Vanets). *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, 9, 93–98.

Lohia, P., & Ruchita Gupta, R. N. (2014). Multi-Channel Multi-Interface Wireless Network Architecture. *International Journal for Scientific Research and Development* .

Lu, G., Krishnamachari, B., & Raghavendra, C. S. (2004). Performance evaluation of the IEEE 802.15. 4 MAC for low-rate low-power wireless networks. *IEEE International Conference on Performance, Computing, and Communications, 2004*, (pp. 701–706).

Lu, S., Bharghavan, V., & Srikant, R. (1999). Fair scheduling in wireless packet networks. *IEEE/ACM Transactions on Networking*, 7, 473–489.

Luo, C., Min, G., Yu, F. R., Zhang, Y., Yang, L. T., & Leung, V. C. (2014). Joint relay scheduling, channel access, and power allocation for green cognitive radio communications. *IEEE Journal on Selected Areas in Communications*, 33, 922–932.

- Ma, X., Yang, F., Liu, S., Song, J., & Han, Z. (2018). Sparse channel estimation for MIMO-OFDM systems in high-mobility situations. *IEEE Transactions on Vehicular Technology*, 67, 6113–6124.
- Malone, T. W., Crowston, K., Lee, J., Pentland, B., & Dellarocas, C. (1999). Tools for inventing organizations: Toward a handbook of organizational processes. *Management Science*, 45, 425–443.
- Mammu, A. S., Hernandez-Jayo, U., & Sainz, N. (2015). Direction aware cluster-based multi channel MAC protocol for vehicular ad hoc networks. *2015 IEEE 11th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, (pp. 549–556).
- Markov chains. (2019, May). *Markov chains*. Retrieved from https://en.wikipedia.org/wiki/Markov_chain
- Martinez, F. J., Toh, C. K., Cano, J.-C., Calafate, C. T., & Manzoni, P. (2011). A survey and comparative study of simulators for vehicular ad hoc networks (VANETs). *Wireless Communications and Mobile Computing*, 11, 813–828.
- Mata-Díaz, J., Alins, J., Muñoz, J. L., & Esparza, O. (2014). A simple closed-form approximation for the packet loss rate of a TCP connection over wireless links. *IEEE Communications Letters*, 18, 1595–1598.
- Maxim 2.4ghz 802.11b zero-if transceivers. (n.d.). *Maxim 2.4ghz 802.11b zero-if transceivers*. Retrieved from <http://pdfserv.maximic.com/en/ds/MAX2820-MAX2821.pdf>
- McCaughey, J. W., Mundir, I., Daly, P., Mahdi, S., & Patt, A. (2017). Trust and distrust of tsunami vertical evacuation buildings: Extending protection motivation theory to

- examine choices under social influence. *International Journal of Disaster Risk Reduction*, 24, 462–473.
- Meissner, A., Luckenbach, T., Risse, T., Kirste, T., & Kirchner, H. (2002). Design challenges for an integrated disaster management communication and information system. *The First IEEE Workshop on Disaster Recovery Networks (DIREN 2002)*, 24, pp. 1–7.
- Mershad, K., & Artail, H. (2012). A framework for secure and efficient data acquisition in vehicular ad hoc networks. *IEEE Transactions on Vehicular Technology*, 62, 536–551.
- Mesbahi, N., & Dahmouni, H. (2016). Delay and jitter analysis in LTE networks. *2016 International Conference on Wireless Networks and Mobile Communications (WINCOM)*, (pp. 122–126).
- Mishra, M., & Sahoo, A. (2006). A contention window based differentiation mechanism for providing QoS in wireless LANs. *9th International Conference on Information Technology (ICIT'06)*, (pp. 72–76).
- Motta, M., Abelheira, M., Gomes, O., Fonseca, W., & Besen, D. (2014). Heavy Rains at Rio de Janeiro: Risk Monitoring. *Procedia Economics and Finance*, 18, 157–164.
- Muhammad, K., Ahmad, J., & Baik, S. W. (2018). Early fire detection using convolutional neural networks during surveillance for effective disaster management. *Neurocomputing*, 288, 30–42.
- Myung, H. G. (2007). Introduction to single carrier FDMA. *2007 15th European Signal Processing Conference*, (pp. 2144–2148).

- Myung, H. G., Lim, J., & Goodman, D. J. (2006). Single carrier FDMA for uplink wireless transmission. *IEEE Vehicular Technology Magazine*, 1, 30–38.
- Myung, H. G., Oh, K., Lim, J., & Goodman, D. J. (2008). Channel-dependent scheduling of an uplink SC-FDMA system with imperfect channel information. *2008 IEEE Wireless Communications and Networking Conference*, (pp. 1860–1864).
- Naoi, M., Sato, K., Tanaka, Y., Matsuura, H., & Nagamatsu, S. (2020). Natural hazard information and migration across cities: evidence from the anticipated Nankai Trough earthquake. *Population and Environment*, 41, 452–479.
- Natkaniec, M., & Pach, A. R. (2000). An analysis of modified backoff mechanism in IEEE 802.11 networks. *Proceedings of the Polish–German Teletraffic Symposium (PGTS 2000)*, (pp. 89–96).
- Neves, P. A., Veiga, I. D., & Rodrigues, J. J. (2008). G-JSIM—a GUI tool for Wireless Sensor Networks simulations under J-SIM. *2008 IEEE International Symposium on Consumer Electronics*, (pp. 1–4).
- Ng, T. E., Stoica, I., & Zhang, H. (1998). Packet fair queueing algorithms for wireless networks with location-dependent errors. *Proceedings. IEEE INFOCOM'98, the Conference on Computer Communications. Seventeenth Annual Joint Conference of the IEEE Computer and Communications Societies. Gateway to the 21st Century (Cat. No. 98, 3, pp. 1103–1111.*
- Nguyen, V., Anh Khoa, T., Zin Oo, T., H. Tran, N., Seon Hong, C., & Huh, E.-N. (2018). Time slot utilization for efficient multi-channel MAC protocol in VANETs. *Sensors*, 18.

- Nguyen, V., Kim, O. T., Pham, C., Oo, T. Z., Tran, N. H., Hong, C. S., & Huh, E.-N. (2018). A survey on adaptive multi-channel MAC protocols in VANETs using Markov models. *IEEE Access*, 6, 16493–16514.
- Nguyen, V., Oo, T. Z., Chuan, P., & Hong, C. S. (2016). An efficient time slot acquisition on the hybrid TDMA/CSMA multichannel MAC in VANETs. *IEEE Communications Letters*, 20, 970–973.
- Nourjou, R., Szekely, P., Hatayama, M., Ghafory-Ashtiany, M., & Smith, S. F. (2014). Data model of the strategic action planning and scheduling problem in a disaster response team. *Journal of Disaster Research*, 9, 381–399.
- Nwana, H. S., Lee, L. C., & Jennings, N. R. (1996). Coordination in software agent systems. *British Telecom Technical Journal*, 14, 79–88.
- Ogie, R. I., Rho, J. C., & Clarke, R. J. (2018). Artificial intelligence in disaster risk communication: A systematic literature review. *2018 5th International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*, (pp. 1–8).
- Ohata, T. (2007). Spatial Evaluation of Tsunami Refuge Facilities in the Central Kushiro City: Simulation of Evacuation Behavior from Tsunami Utilizing Multi Agent System. *Journal of Architecture and Planning*, 612, 87–91.
- Oran Brigham, E. (1988). The fast Fourier transform and its applications. UK: Prentice Hall.
- Othman, A., Ameen, S. Y., & Al-Rizzo, H. (2015). A new channel quality indicator mapping scheme for high mobility applications in LTE systems. *Journal of Modeling and Simulation of Antennas and Propagation*, 1, 38–43.

- Pappas, S. (2018). Top 11 deadliest natural disasters in history. *Top 11 deadliest natural disasters in history*. Retrieved from <https://www.livescience.com/33316-top-10-deadliest-natural-disasters.html>
- Paquet, S., Bernier, N., & Chaib-draa, B. (2004). Comparison of different coordination strategies for the robocuprescue simulation. *International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems*, (pp. 987–996).
- Pasi, A. A., & Bhawe, U. (2015). Flood detection system using wireless sensor network. *International Journal of Advanced Research in Computer Science and Software Engineering*.
- Pauly, J. J. (1984). The great Chicago fire as a national event. *American Quarterly*, 36, 668–683.
- Peng, X., Deng, Q., Tian, S., Liu, H., Xie, W., & Li, R. (2019). Data dissemination scheduling algorithm for V2R/V2V in multi-channel VANET. *J. Commun*, 40, 92–101.
- Piro, G., Grieco, L. A., Boggia, G., Fortuna, R., & Camarda, P. (2011). Two-level downlink scheduling for real-time multimedia services in LTE networks. *IEEE Transactions on Multimedia*, 13, 1052–1065.
- Premkumar, R. (2014). Wireless networks for disaster relief. *Department of Computer Science and Engineering, Washington University in St. Louis*, 3.
- Price, K., Storn, R. M., & Lampinen, J. A. (2006). *Differential evolution: a practical approach to global optimization*. Springer Science & Business Media.

- Rahim, A., Khan, Z., Muhaya, F. T., Sher, M., Kim, T.-H., & others. (2010). Sensor based framework for secure multimedia communication in VANET. *Sensors*, 10, 10146–10154.
- Random walks -mit opencourseware. (n.d.). *Random walks -mit opencourseware*. Retrieved from https://ocw.mit.edu/courses/electrical...and.../6.../MIT6_042JF10_chap20.pdf
- Raniwala, A., & Chiueh, T.-c. (2005). Architecture and algorithms for an IEEE 802.11-based multi-channel wireless mesh network. *Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies.*, 3, pp. 2223–2234.
- Raniwala, A., Gopalan, K., & Chiueh, T.-c. (2004). Centralized channel assignment and routing algorithms for multi-channel wireless mesh networks. *ACM SIGMOBILE Mobile Computing and Communications Review*, 8, 50–65.
- Ranjan, G., & Kumar, A. (2005). A natural disasters management system based on location aware distributed sensor networks. *IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005.*, (pp. 3–pp).
- Ranjitha B, N., Kumar, A., & Harish T, A. (2015, May). Efficient Approach for Disaster Management in Wireless Sensor Networks. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*.
- Rathore, M. M., Ahmad, A., Paul, A., Wan, J., & Zhang, D. (2016). Real-time medical emergency response system: exploiting IoT and big data for public health. *Journal of Medical Systems*, 40, 283.

- Reina, D. G., Toral, S. L., Barrero, F., Bessis, N., & Asimakopoulou, E. (2011). Evaluation of ad hoc networks in disaster scenarios. *2011 third International Conference on Intelligent Networking and Collaborative Systems*, (pp. 759–764).
- Remy, J.-G., & Letamendia, C. (2014). *LTE standards*. John Wiley & Sons.
- RF-wireless world. (2017). *RF-wireless world*. Retrieved from <http://www.rfwirelessworld.com/Terminology/Advantages-and-Disadvantages-of-LTE.html>
- Rietjens, S. J., Voordijk, H., & De Boer, S. J. (2007). Co-ordinating humanitarian operations in peace support missions. *Disaster Prevention and Management: An International Journal*, 16, 56–69.
- Rossi, C., Acerbo, F. S., Ylinen, K., Juga, I., Nurmi, P., & Bosca, A. (2018). Early detection and information extraction for weather-induced floods using social media streams. *International Journal of Disaster Risk Reduction*, 30, 145–157.
- Ruchita Gupta, R. N., & Lohia, P. (2014). Multi-Channel Multi-Interface Wireless Network Architecture. *International Journal for Scientific Research and Development*.
- Safa, H., & Tohme, K. (2012). LTE uplink scheduling algorithms: Performance and challenges. *2012 19th International Conference on Telecommunications (ICT)*, (pp. 1–6).
- Saha, S., & Matsumoto, M. (2007). A wireless sensor network protocol for disaster management. *2007 Information, Decision and Control*, (pp. 209–213).
- Salem, M., Adinoyi, A., Yanikomeroglu, H., & Falconer, D. (2010). Opportunities and challenges in OFDMA-based cellular relay networks: A radio resource management perspective. *IEEE Transactions on Vehicular Technology*, 59, 2496–2510.

- Sánchez-Salas, D. A., Cuevas-Ruíz, J. L., & González-Mendoza, M. (2012). Wireless channel model with Markov chains using MATLAB. *Edited by Vasilios N. Katsikis*, 235.
- Sangappa and S. Gupta and C. Keshavamurthy. (2017, February). Cross layer architecture based mobile WSN routing protocol for inter-vehicular communication. *2017 3rd International Conference on Computational Intelligence Communication Technology (CICT)*, (pp. 1-7). doi:10.1109/CICT.2017.7977307
- Sanjay, J., & McLean, C. (2003). A framework for modeling and simulation for emergency response. *Simulation Conference*, 1, pp. 1068–1076.
- Saoud, N. B.-B., Mena, T. B., Dugdale, J., Pavard, B., & Ahmed, M. B. (2006). Assessing large scale emergency rescue plans: an agent based approach. *The International Journal of Intelligent Control and Systems*, 11, 260–271.
- Schilling, M. A. (2000). Toward a general modular systems theory and its application to interfirm product modularity. *Academy of Management Review*, 25, 312–334.
- Seal, V., Raha, A., Maity, S., Mitra, S. K., Mukherjee, A., & Naskar, M. K. (2012). A simple flood forecasting scheme using wireless sensor networks. *arXiv preprint arXiv:1203.2511*.
- Segev, A., Patankar, A., & Zhao, J. L. (2003). e-Business process interleaving: Managerial and technological implications. *Information Systems and E-business Management*, 1, 331–352.
- Sha, X., Sun, J., Wu, T., & Liu, L. (2012). Adaptive resource allocation based packet scheduling for lte uplink. *2012 IEEE 11th International Conference on Signal Processing*, 2, pp. 1473–1476.

- Shahen Shah, A. F., Ilhan, H., & Tureli, U. (2019). CB-MAC: a novel cluster-based MAC protocol for VANETs. *IET Intelligent Transport Systems*, 13, 587–595.
- Sharma, B., Sharma, M. S., & Tomar, R. S. (2019). A survey: Issues and challenges of vehicular ad hoc networks (VANETs). *Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM)*, Amity University Rajasthan, Jaipur-India.
- Sharma, S., Agarwal, P., & Mohan, S. (2020). Security challenges and future aspects of fifth generation vehicular adhoc networking (5G-VANET) in connected vehicles. *2020 3rd International Conference on Intelligent Sustainable Systems (ICISS)*, (pp. 1376–1380).
- Shen, S., & Shaw, M. (2004). Managing coordination in emergency response systems with information technologies. *AMCIS 2004 Proceedings*, 252.
- Sheskin, T. J. (2016). *Markov Chains and Decision Processes for Engineers and Managers*. CRC Press.
- Sheu, S.-T., & Chen, J. (2001). A novel delay-oriented shortest path routing protocol for mobile ad hoc networks. *ICC 2001. IEEE International Conference on Communications. Conference Record (Cat. No. 01CH37240)*, 6, pp. 1930–1934.
- Shin, S. Y. (2012). Unsaturated Throughput Analysis of IEEE 802.11 DCF under Imperfect Channel Sensing. *KSII Transactions on Internet & Information Systems*, 6.
- Sirhan, N. N., & Martinez-Ramon, M. (2022). LTE Cellular Networks Packet Scheduling Algorithms in Downlink and Uplink Transmission, A Survey. *arXiv preprint arXiv:2204.11369*.

- So, J., & Vaidya, N. H. (2004). A routing protocol for utilizing multiple channels in multi-hop wireless networks with a single transceiver. *University of Illinois at Urbana-Champaign*.
- So, J., & Vaidya, N. H. (2004). Multi-channel mac for ad hoc networks: handling multi-channel hidden terminals using a single transceiver. *Proceedings of the 5th ACM International Symposium on Mobile Ad hoc Networking and Computing*, (pp. 222–233).
- Specifications, P. L. (2022). P802. 11bb™/D4. 1 10 Draft Standard for Information technology communications and information exchange between 12 systems Local and metropolitan area networks requirements .
- Su, Z., Dai, M., Xu, Q., & Li, R. (2020). A Novel Resource Allocation Scheme With Unmanned Aerial Vehicles in Disaster Relief Networks. *2020 IEEE/CIC International Conference on Communications in China (ICCC)*, (pp. 102–106).
- Suman, A., & Kumar, C. (2019). Implementation of MAC protocol with enhanced security features in VANET. *International Journal of Vehicle Information and Communication Systems*, 1, 78-90.
- Sun, Z., Tao, R., Xiong, N., & Pan, X. (2018). CS-PLM: Compressive sensing data gathering algorithm based on packet loss matching in sensor networks. *Wireless Communications and Mobile Computing*, 2018.
- Surgiewicz, R., Strom, N., Ahmed, A., & Ai, Y. (2014). LTE uplink transmission scheme.
- Sutanta, H., Bishop, I. D., & Rajabifard, A. R. (2010). Integrating spatial planning and disaster risk reduction at the local level in the context of spatially enabled government.

- Szymanski, B. K., & Chen, G. G. (2007). Sensor network component based simulator, *Handbook of Dynamic System Modeling* (Paul Fishwick, ed.), CRC. *Sensor network component based simulator, Handbook of Dynamic System Modeling* (Paul Fishwick, ed.), CRC. Taylor and Francis Publishing.
- Taghipour, A., & Frayret, J.-M. (2012). Mutual adjustment search with incentive for supply chain planning coordination. *International Journal of Computer Integrated Manufacturing*, 25, 946–962.
- Tan, L., & Wang, N. (2010). Future internet: The internet of things. *2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE)*, 5, pp. V5–376.
- Techtarget. (n.d.). Retrieved from Orthogonal Frequency-Division Multiplexing (OFDM): <https://www.techtarget.com/searchnetworking/definition/orthogonal-frequency-division-multiplexing>
- Tehrani, M. N., Uysal, M., & Yanikomeroglu, H. (2014). Device-to-device communication in 5G cellular networks: Challenges, solutions, and future directions. *IEEE Communications Magazine*, 52, 86–92.
- Thompson, J. D. (2017). *Organizations in action: Social science bases of administrative theory*. Routledge.
- Tomar, R., Sastry, H. G., Prateek, M., & others. (2022). Establishing parameters for comparative analysis of V2V communication in VANET. *Journal of Scientific & Industrial Research*, 79, 26–29.
- Toral, S. L., Barrero, F., Cortés, F., Reina, D. G., Marsal, E., Hinojo, J. M., & Soto, M. (2010). A wireless in-door system for assisting victims and rescue equipments in a

- disaster management. *2010 International Conference on Intelligent Networking and Collaborative Systems*, (pp. 502–506).
- Toutouh, J., & Alba, E. (2011). An efficient routing protocol for green communications in vehicular ad-hoc networks. *Proceedings of the 13th Annual Conference Companion on Genetic and Evolutionary Computation*, (pp. 719–726).
- Toutouh, J., García-Nieto, J., & Alba, E. (2010). Optimal configuration of OLSR routing protocol for VANETs by means of Differential Evolution. *3rd International Conference on Metaheuristics and Nature Inspired Computing, META*, (pp. 1–2).
- Traditionaloven. (2018). *traditionaloven*. Retrieved from <https://www.traditionaloven.com/tutorials/power/convert-watts-w-to-joule-j-per-s.html>
- Tsai, T.-Y., Chung, Y.-L., & Tsai, Z. (2010). Introduction to packet scheduling algorithms for communication networks. *Communications and Networking*, 264–287.
- Tse, D. (2001). Multiuser diversity in wireless networks. *Wireless Communications Seminar, Stanford University*.
- Tsou, F.-M., Chiou, H.-B., & Zsehong, T. S. (2001). WDFQ: An efficient traffic scheduler with fair bandwidth-sharing for wireless multimedia services. *IEICE Transactions on Communications*, 84, 823–835.
- Tubaishat, M., & Madria, S. (2003). Sensor networks: an overview. *IEEE Potentials*, 22, 20–23.
- Tuna, G., Gungor, V. C., & Gulez, K. (2014). An autonomous wireless sensor network deployment system using mobile robots for human existence detection in case of disasters. *Ad Hoc Networks*, 13, 54–68.

- Usman, A. (2017). Integrated disaster risk management in Indian environment: Prediction, prevention and preparedness. *2017 IEEE Global Humanitarian Technology Conference (GHTC)*, (pp. 1–6).
- Valcik, N. A., & Tracy, P. E. (2017). *Case studies in disaster response and emergency management*. Routledge.
- Vallejo, D., Castro-Schez, J. J., Glez-Morcillo, C., & Albusac, J. (2020). Multi-agent architecture for information retrieval and intelligent monitoring by UAVs in known environments affected by catastrophes. *Engineering Applications of Artificial Intelligence*, 87, 103243.
- Van de Walle, B., & Dugdale, J. (2012). Information management and humanitarian relief coordination: findings from the Haiti earthquake response. *International Journal of Business Continuity and Risk Management*, 3, 278–305.
- Van Eenennaam, M., van de Venis, A., & Karagiannis, G. (2012). Impact of IEEE 1609.4 channel switching on the IEEE 802.11 p beaconing performance. *In 2012 IFIP Wireless Days, IEEE*, 1-8.
- Vershinin, Y. A., & Zhan, Y. (2020). Vehicle to vehicle communication: dedicated short range communication and safety awareness. *2020 Systems of Signals Generating and Processing in the Field of on Board Communications*, (pp. 1–6).
- Wafi, Z. K., Malek, M. F., Alnajjar, S. H., & Ahmad, R. B. (2015). Early warning system for Disaster management in rural area. *2015 International Symposium on Technology Management and Emerging Technologies (ISTMET)*, (pp. 369–372).
- Walsh, M. (1989). *Disasters: Current Planning and Recent Experience*. E. Arnold.

- Wang, B., Sun, Y., Zhao, N., & Gui, G. (2020). Learn to coloring: Fast response to perturbation in UAV-assisted disaster relief networks. *IEEE Transactions on Vehicular Technology*, 69, 3505–3509.
- Wang, Y., Shi, J., Chen, L., Lu, B., & Yang, Q. (2019). A novel capture-aware TDMA-based MAC protocol for safety messages broadcast in vehicular ad hoc networks. *IEEE Access*, 7, 116542–116554.
- Waugh, W. L. (2015). *Living with Hazards, Dealing with Disasters: An Introduction to Emergency Management: An Introduction to Emergency Management*. Routledge.
- Wellington, J. J., & Ramesh, P. (2017). Role of Internet of Things in disaster management. *2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, (pp. 1–4).
- Wisner, B. B., & Davis, I. (2010). *At risk natural hazards, people's vulnerability and disasters*. Routledge.
- Wu, L., Xia, Y., Wang, Z., & Wang, H. (2018). Be stable and fair: Robust data scheduling for vehicular networks. *IEEE Access*, 6, 32839–32849.
- Xia, Q., & Hamdi, M. (2006). Contention window adjustment for IEEE 802.11 WLANs: a control-theoretic approach. *2006 IEEE International Conference on Communications*, 9, pp. 3923–3928.
- Xu, X., Zhang, L., Sotiriadis, S., Asimakopoulou, E., Li, M., & Bessis, N. (2018). CLOTHO: A large-scale Internet of Things-based crowd evacuation planning system for disaster management. *IEEE Internet of Things Journal*, 5, 3559–3568.
- Yamada, H., Furuto, T., Urayama, T., Suetomi, I., & Kakumoto, S. (2004). Earthquake disaster prevention information system based on risk adaptive regional management

- information system concept. *13th World Conference on Earthquake Engineering, Vancouver, BC, Canada*, (pp. 1–6).
- Yamada, T., & Kishimoto, T. (2015). Choice behavior model of refuge building selection during a tsunami coastal areas. *J. Archit. Plan*, 80, 125–133.
- Yamada, T., & Yamasaki, N. (2021). Simulation of tsunami evacuation behavior considering inland direction. *International Journal of Disaster Risk Reduction*, 65, 102566.
- Yang, C., & Huang, Q. (2013). *Spatial Cloud Computing: a Practical Approach*. CRC Press.
- Yanhui, L., Chunming, W., Changchuan, Y., & Guangxin, Y. (2006). Downlink scheduling and radio resource allocation in adaptive OFDMA wireless communication systems for user-individual QoS. *Transactions on Engineering, Computing and Technology-World Enformatika Society*, 426–440.
- Yin, H., & Alamouti, S. (2006). OFDMA: A broadband wireless access technology. *2006 IEEE Sarnoff Symposium*, (pp. 1–4).
- Yu, F., & Jain, R. (2011). A survey of wireless sensor network simulation tools. *Washington University in St. Louis, Department of Science and Engineering*.
- Yu, X., Xiao, H., Wang, S., & Li, Y. (2018). An adaptive back-off scheme based on improved Markov model for vehicular ad hoc networks. *IEEE Access*, 6, 67373–67384.
- Yun, N. Y., & Hamada, M. (2015). Evacuation behavior and fatality rate during the 2011 Tohoku-Oki earthquake and tsunami. *Earthquake Spectra*, 31, 1237–1265.

- Yune, T.-W., Choi, C.-H., Im, G.-H., Lim, J.-B., Kim, E.-S., Cheong, Y.-C., & Kim, K.-H. (2010). SC-FDMA with iterative multiuser detection: improvements on power/spectral efficiency. *IEEE Communications Magazine*, 48, 164–171.
- Zeng, F., Zhang, R., Cheng, X., & Yang, L. (2017). Channel prediction based scheduling for data dissemination in VANETs. *IEEE Communications Letters*, 21, 1409–1412.
- Zeng, G., Wang, B., Ding, Y., Xiao, L., & Mutka, M. (2007). Multicast algorithms for multi-channel wireless mesh networks. *2007 IEEE International Conference on Network Protocols*, (pp. 1–10).
- Zhang, B., Yuan, B., Bi, X., Wei, Z., & Zhang, M. (2020). An Adaptive Multi-Channel Cooperative Data Transmission Scheduling in VANETs. *Sensors*, 19, 5612.
- Zhang, B., Yuan, B., Bi, X., Wei, Z., & Zhang, M. (2020). An Adaptive Multi-Channel Cooperative Data Transmission Scheduling in VANETs. *Sensors*, 20, 5612.
- Zhang, J., Zhang, M., Ren, F., & Liu, J. (2016). A decentralised multi-agent system for emergency resource allocation in metropolitan regions. *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems*, (pp. 1482–1484).
- Zhang, N., Liang, H., Cheng, N., Tang, Y., Mark, J. W., & Shen, X. S. (2014). Dynamic spectrum access in multi-channel cognitive radio networks. *IEEE Journal on Selected Areas in Communications*, 32, 2053–2064.
- Zhang, X., Su, H., & Chen, H.-H. (2006). Cluster-based multi-channel communications protocols in vehicle ad hoc networks. *IEEE Wireless Communications*, 13, 44–51.
- Zigurs, I., & Buckland, B. K. (1998). A theory of task/technology fit and group support systems effectiveness. *MIS quarterly*, 22.

Zou, Q., Li, G., & Yu, W. (2017). An integrated disaster rapid cloud service platform using remote sensing data. *2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, (pp. 5221–5224).