A HYBRID ROUTING APPROACH FOR DISASTER MANAGEMENT IN MANET

ABDUL MAJID SOOMRO

A thesis submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy in Information Technology

Faculty of Computer Science and Information Technology
University Tun Hussein Onn Malaysia

JUNE 2022

In the name of Allah, Most Gracious, Most Merciful.

I praise and thank Allah.

Special thanks to my beloved Mother (Hameed bibi)

For dearest, (Brothers and Sisters)

For their love, support, enthusiasm, encouragement, and motivation.

For my supervisor,

Assoc. Prof. Ts. Dr Mohd. Farhan Md Fudzee

For her incredible help, patience, understanding, support, and motivation.

For all postgraduate members, fellow friends and housemates.

This thesis is dedicated to all of you.

ACKNOWLEDGEMENT

In the name of ALLAH, witnessing that there is no God but ALLAH and Hazrat Muhammad (P.B.U.H) is HIS last prophet who made knowledge as the basis for guiding humanity towards the right path. I am not adequately capable of finding textual representation for thanking ALMIGHTY ALLAH, whose benediction bestowed me the talented teachers, provision of profitable opportunities and enablement for undertaking and furnishing this research journey.

Firstly, my deepest gratitude for my worthy and kind-hearted supervisor, Assoc. Prof. Ts. Dr Mohd. Farhan Md Fudzee and Dr Muzamil Hussain for their professional and sincere guidance throughout my research work. They always guided me sincerely and honestly throughout my whole research work. Without their support, my objective was impossible to be accomplished. Their capabilities have made me complete my research work within the prescribed timeframe.

I will never forget the educational facilities and research-oriented environment provided by the Faculty of Computer Science and Information Technology (FSKTM) at University Tun Hussein Onn Malaysia (UTHM). The sincere and continuous efforts of UTHM staff and administration to provide modern and latest facilities to ensure quality education in all fields are remarkable. Their sincere efforts and approaches have made us learn information technology (IT) in a research-oriented dimension.

At last, it is hard to describe that I could not manage enough time to serve my old Parents during this long research journey, but their prayers are always with me unconditionally. Their sincere prayers, advice, support, love, and care helped me a lot in every step of my journey in this world. I dedicate this research to my parents. I am also thankful to my brothers, sisters and family members especially Safdar ali for their full support and cooperation. I am also thankful to UTHM friends for their guidance, support, encouragement, and wonderful time with me during this long stay outside my countryand never let me feel away from my home. Thank you so much.

ABSTRACT

Mobile Ad-Hoc Networks (MANET), known as dynamically reconfigurable networks, have no centralized control. MANET facilitates reliable communication between crew and fighters involved in uncertain situations and between central command crew and fighters. Routing is the search for a suitable route for communication, especially in disaster situations. MANET is the appropriate ad-hoc network to handle disaster situations due to its effectiveness and cost for the areas where fixed infrastructure was unavailable. There are many challenges in MANET related to the routing criteria of routing protocols. MANET suffered from two major issues when applied for data communication. The first drawback is a failure in the dynamic nature of nodes and instability, and the second is rapid change in the topology due to their mobility. The main reason behind the loss is a disaster that disturbs the normal execution of functionality. MANET still has route discovery issues because their communication between nodes is highly concerned. The cause behind this drawback is a route disconnection from source to destination, making the topology of nodes highly dynamic, especially in disaster management. Therefore, in this research, an improved hybrid approach (IHRP) that combines proactive and reactive routing protocols is suggested for these issues through quick network convergence in terms of speed and network density with the help of MANET services. The improved hybrid approach reduces route discovery and link breakage between highly mobilized nodes during disaster management. For this purpose, qualitative research methodology focuses on interpretation situations as well as the dedication to a case-based scenario is used in experiment 1 and experiment 2 that is related to the speed and network density in the research work towards helping the members of the community of practice (CoP) to utilize MANET services. The contrasting results between the IHRP and existing protocols indicate that the IHRP outperforms and increases from 9% to 12%.

ABSTRAK

Rangkaian Ad-Hoc Mudah Alih (MANET), dikenali sebagai rangkaian boleh dikonfigurasikan semula secara dinamik, tidak mempunyai kawalan terpusat. MANET memudahkan komunikasi yang boleh dipercayai antara krew dan pejuang yang terlibat dalam situasi yang tidak menentu dan antara krew arahan pusat dan pejuang. Penghalaan ialah pencarian laluan yang sesuai untuk komunikasi, terutamanya dalam situasi bencana. MANET ialah rangkaian ad-hoc yang sesuai untuk mengendalikan situasi bencana kerana keberkesanan dan kosnya untuk kawasan di mana infrastruktur tetap tidak tersedia. Terdapat banyak cabaran dalam MANET berkaitan dengan kriteria penghalaan protokol penghalaan. MANET mengalami dua isu utama apabila digunakan untuk komunikasi data. Kelemahan pertama ialah kegagalan dalam sifat dinamik nod dan ketidakstabilan, dan yang kedua ialah perubahan pesat dalam topologi disebabkan oleh mobiliti mereka. Sebab utama di sebalik kerugian adalah bencana yang mengganggu pelaksanaan fungsi biasa. MANET masih mempunyai isu penemuan laluan kerana komunikasi mereka antara nod sangat mengambil berat. Punca di sebalik kelemahan ini ialah pemutusan laluan dari sumber ke destinasi, menjadikan topologi nod sangat dinamik, terutamanya dalam pengurusan bencana. Oleh itu, dalam penyelidikan ini, pendekatan hibrid (IHRP) yang dipertingkatkan yang menggabungkan protokol penghalaan proaktif dan reaktif dicadangkan untuk isu-isu ini melalui penumpuan rangkaian pantas dari segi kelajuan dan kepadatan rangkaian dengan bantuan perkhidmatan MANET. Pendekatan hibrid yang dipertingkatkan mengurangkan penemuan laluan dan pemecahan pautan antara nod yang sangat digerakkan semasa pengurusan bencana. Untuk tujuan ini, metodologi penyelidikan kualitatif memfokuskan pada situasi tafsiran serta dedikasi kepada senario berasaskan kes digunakan dalam eksperimen 1 dan eksperimen 2 yang berkaitan dengan kelajuan dan ketumpatan rangkaian dalam kerja penyelidikan ke arah membantu ahli komuniti. amalan (CoP) untuk menggunakan perkhidmatan MANET. Keputusan yang berbeza antara IHRP dan protokol sedia ada menunjukkan bahawa IHRP mengatasi prestasi dan meningkat daripada 9% kepada 12%.

CONTENTS

TITLE		**i**
DECLARATION		**ii**
DEDICATION		**iii**
ACKNOWLEDGEMENT		**iv**
ABSTRACT		**v**
ABSTRAK		**vi**
TABLE OF CONTENTS		**vii**
LIST OF TABLES		**xii**
LIST OF FIGURES		**xiii**
LIST OF ALGORITHMS		**xvi**
LIST OF SYMBOLS AND ABBREVIATIONS		**xvii**
LIST OF PUBLICATION		**xviii**
CHAPTER 1	**INTRODUCTION**	**1**
1.1	Research background	1
1.2	Problem statement	5
1.3	Research objective	6
1.4	Research scope	7
1.5	Research significance	8
1.6	Thesis outline	8
CHAPTER 2	**LITERATURE REVIEW**	**10**
2.1	Introduction	10

2.2 Ad-hoc networks 10

2.3 Characteristics of MANET 18

2.3.1 Benefits of MANET 18

2.4 Application and common challenges of MANET 19

2.5 Overview of routing protocol 22

2.5.1 Proactive routing protocol (PRP) 23

2.5.1.1 Destination sequence distance vector routing protocol (DSDV) 23

2.5.1.2 Link state routing protocol 24

2.5.2 Reactive routing protocol 26

2.5.2.1 Ad-hoc on-demand distance vector routing protocol (AODV) 26

2.5.2.2 Route discovery of AODV protocol 29

2.5.2.3 AOMDV 31

2.5.2.4 OLSR routing protocol 32

2.5.2.5 Dynamic source routing protocol 34

2.5.2.6 Temporally ordered routing algorithm 35

2.5.3 Hybrid routing protocol (HRP) 36

2.5.3.1 Zone routing protocol (ZRP) 38

2.5.3.2 Zone-based hierarchical link state 38

2.6 Comparative study of routing protocol 39

2.7 Overview of software availability 40

2.8 Existing work on wireless MANET 41

2.9 Research gap derivation 52

2.10 Development environment 54

2.10.1 Experiment carried out in NS-2 54

2.11 Chapter summary 55

CHAPTER 3 RESEARCH METHODOLOGY 56

3.1 Introduction 56

3.2 Research activities 56

3.3 Research process 59

3.3.1 PHASE I : Data gathering and analysis 61

3.3.1.1 Literature review and scenarios 61

3.3.1.2 MANET 61

3.3.1.3 Study of MANET performance metrics 62

3.3.2 PHASE II: Identification criteria 62

3.3.2.1 Improved (IHRP) 63

3.4 PHASE III: Network approach training procedure 66

3.4.1 Experimental setup 67

3.4.2 Routing protocol selection 67

3.4.3 Tools selection 67

3.4.4 Training of the network 68

3.4.5 Experiment1: Impact of speed on nodes 69

3.4.6 Experiment 2: Impact network density on nodes 70

3.5 Comparative approaches 70

3.5.1 Zone routing protocol (ZRP) 70

3.5.2 Advance on demand distance vector (AODV) 71

3.5.3 Optimized link state routing protocol (OLSR) 72

3.5.4 Zone-based hierarchical link state (ZHLS) 73

3.6 PHASE IV: Results analysis 73

3.6.1 Performance metrics for comparison 74

3.6.1.1 Average end to end delay 74

3.6.1.2 Network load 75

3.6.1.3 Throughput 75

3.6.1.4 Average packet delivery ratio 75

3.7 Comparison analysis 75

3.8 Chapter summary 76

CHAPTER 4 THE IMPROVED HYBRID APPROACH 77

4.1 Introduction 77

4.2 Implementation of hybrid approach 78

4.2.1 Hybrid criteria 78

4.2.2 Selected protocols to be hybrid 78

4.3 Improved hybrid routing approach 79

4.4 Chapter summary 86

CHAPTER 5 RESULTS AND DISCUSSION 87

5.1 Introduction 87

5.2 Simulation results and discussion of experiment 1 88

5.2.1 Number of link breaks vs. max speed 88

5.2.2 Packet delivery fraction vs. max speed 89

5.2.3 Network routing load vs. max speed 92

5.2.4 End-to-end delay vs. max speed 93

5.2.5 Throughput vs. max speed 95

5.2.6 Received packets vs. max speed 96

5.2.7 Routing packets vs max speed 97

5.3 Simulation results and discussion of experiment 2 98

5.3.1 Packet delivery fraction vs. max speed 99

5.3.2 Network routing load vs. max speed 99

5.3.3 Throughput vs. number of nodes 100

5.3.4 End-to-end delay vs number of nodes 101

5.3.5 Receive packets vs. number of nodes 102

5.3.6 Routing packets vs. number of nodes 102

5.4 Chapter Summary 105

CHAPTER 6 CONCLUSION AND FUTURE WORK 107

6.1 Introduction 107

6.2 Achievement of objectives 109

6.2.1 First objective 109

6.2.2 Second objective 110

6.2.3 Third objective 111

6.3 Research contribution 112

6.4 Future work 115

6.5 Concluding remarks 116

REFERENCES 117

APPENDIX 135

VITA 137

LIST OF TABLES

1.1	Network Damages Caused by recent Disaster	4
2.1	Proactive Routing Protocol Comparison	25
2.2	MPR and Selectors for OLSR	34
2.3	Reactive Routing Protocol	36
2.4	Comparison between different types of routing protocol	39
2.5	List of network simulated software	40
2.6	Comparative comparison of related work	50
3.1	Tabular explanation of Figure 3.3	65
3.2	Parameters setting of the improved approach used in normal to disaster management	67
4.1	Route discovery distance value	83
5.1	Methodology of experiment 1 and experiment 2	88
5.2	Comparison of AODV, OLSR, ZRP, ZHLS with IHRP in terms of packet delivery ratio (PDR) and throughput	104
5.3	Comparison of AODV, OLSR, ZRP, ZHLS with IHRP in terms of end-to-end delay and routing load	105

LIST OF FIGURES

1.1	Types of network disaster	3
2.1	Infrastructure network	11
2.2	MANET network	12
2.3	Classification of WSN	13
2.4	MANET node transition	15
2.5	Application area of MANET	20
2.6	Overview of MANET routing protocol	23
2.7	DSDV routing protocol	24
2.8	OLSR routing protocols	25
2.9	Route request	27
2.10	Route reply	27
2.11	Route request to determine route	28
2.12	Working of AODV routing protocol	30
2.13	Re-routing for route discovery	30
2.14	Node disjoint	32
2.15	Link disjoint	32
2.16	Example of OLSR routing protocol	34
2.17	Route discovery	35
2.18	Route request	35
2.19	Tora routing protocol	36
2.20	Hybrid Routing	37
2.21	ZRP routing protocol	38
2.22	NS-2 architecture	54

2.23	NS-2 working environment	55
3.1	Flow chart of processes	58
3.2	Research Process	60
3.3	Connection finish time (CFT) for all routes	65
3.4	ZRP routing protocol	71
3.5	a) Propagation of ROUTE REQUEST RREQ	72
	b) Path of RREP to the source	72
4.1	Flowchart of the improved approach	81
4.2	MPR selection during route discovery	82
4.3	OLSR found the route for communication	83
4.4	Route Request Process of AODV and AOMDV	83
4.5	Route link breakage recovery process	84
4.6	IHRP implementation flowchart	85
5.1	Comparison of link breakage and maximum speed	89
5.2	Comparison of sending of packets and nod-id	90
5.3	Comparison between receiving of packet and node id	91
5.4	Comparison between packet delivery fraction and max Speed	91
5.5	Comparison of routing packets and node id	92
5.6	Comparison of network load and max speed	93
5.7	Comparison of packet send time and packet id	94
5.8	Comparison of packet receive time and packet id	94
5.9	Comparison of end-to-end delay and max speed	95
5.10	Comparison of receive bits and node id	96
5.11	Comparison of throughput with max speed	96
5.12	Comparison of received packets and max speed	97
5.13	Comparison of routing packets and max speed	98
5.14	Packet delivery fraction and max. speed	99
5.15	Network routing load vs number of nodes	100
5.16	Throughput vs number of nodes	101
5.17	End-to-end delay vs number of nodes	102

5.18 Receive packets vs number of nodes 102

5.19 Routing packets vs number of nodes 103

LIST OF ALGORITHMS

3.3.2.1 For route discovery in improved hybrid approach 63

LIST OF SYMBOLS AND ABBREVIATIONS

WSN	-	Wireless Sensor Network
MANET	-	Mobile Ad Hoc Network
PDR	-	Packet Delivery Ratio
AODV	-	Ad Hoc on Demand Vector
AOMDV	-	Ad Hoc On-Demand Multiple Path Distance Vector Dynamic Source Routing
DSR	-	Temporary Ordering Routing Algorithms
TORA	-	Associativity Based Routing
ABR	-	Destination Sequenced Distance Vector
DSDV	-	Link State Routing
LSR	-	Optimized Link State Routing
OLSR	-	Zone Routing Protocol
ZRP	-	Multi-Point Relay
MPR	-	Literature Review
LR	-	Vehicle Ad Hoc Network
VANET	-	Wireless Telecommunications Symposium
WTS	-	Local Area Network
LAN	-	Wide Area Network
WAN	-	Elliptic Curve Cryptographic
ECC	-	Route Request Packet
RREQ	-	Route Error Packets
RERR	-	Transmission Control Protocol
TCP	-	File Transfer Protocol
FTP	-	User Datagram Protocol Hypertext Transfer Protocol
UDP	-	Object-Oriented Tool Command Language
HTTP	-	Route Reply
OTCL	-	Zone-Based Hierarchical Link State
RREP	-	Improved Hybrid Routing Protocol
ZHLS	-	
IHRP	-	

LIST OF PUBLICATIONS

Journals:

i. **Soomro A.M,** Fudzee M.F.B.M, Hussain D.H. Saim M.H (2022). "A Hybrid Routing Approach Comparison with AODV Protocol regarding speed for Disaster Management in MANET," Journal of Computer Science., 18(3), 204-213 (**Scopus indexed).**

ii. **Debnath, S. K.,** Omar, R.., Abdul Latip, N. B.., Bagchi, S.., Sabudin, E. N.., Mumin, A. R. O.., **Soomro, A. M**..,, Nafea, M.., Muhammad, B. B.., & Naha, R. K.(2020).Computationally efficient path planning algorithm forautonomous vehicle. Jurnal Teknologi, 83(1), 133-143, **(Scopus indexed)**.

iii. **Abdul Majid Soomro**, Mohd Farhan Md. Fudzee, Hafiz Muhamad Saim, and Gohar Zaman,. "Route Discovery using Hybrid Approach for Disaster Management in MANET Journal of Communications, 17(7), 566-573, **(Scopus indexed)**.

iv. **Soomro A.M**, Fudzee M.F.B.M, Hussain D.M., Saim M.H. (2022). "Comparative review and analysis of routing protocols in MANET," Journal of Communications, accepted to be published tentatively vol. 17, no. 9, **(Scopus indexed).**

CHAPTER 1

INTRODUCTION

1.1 Research background

Mobile Ad-Hoc Network (MANET) is self-organized without a wireless network(Naik *et al*., 2019). In MANET, each node communicates arbitrarily without anydirection (Nayar, 2018). The dynamic nature of nodes is more adaptable for militaryand natural disaster applications (Rishiwal *et al*., 2016) due to unpredictable, rapidchanges in the topology of nodes. MANET is a wireless sensor network (WSN). Thisnetwork is known as a self-configured and self-governing network. All the activities, such as topology, discovery, and link breakage of the route, for packet delivery aregoverned by nodes themselves. This renders the routing function inconvenient inmobile nodes, especially in disaster scenarios. In MANET, nodes act as routers movingrandomly and chaotically managing themselves due to uncertain changes in topology.Here, mobile nodes directly communicate with other nodes within the radio range andthe remote nodes through the intermediate nodes. Therefore, this network can workanywhere without any supplementary infrastructure, due to which it is known as anad-hoc network.

Routing is a mechanism of path selection and sending data. This approach is used to interchange information between nodes about their topology, link breakage, and routing algorithm for the path of the network. After discovering the route between sources towards the destination, the next level is preserving the route with a data packet towards the destination. In terms of link breakage, maintenance is a reliable and efficient route for exchanging information, as nodes move freely without any fixed position in MANET. Therefore, if any link breaks down due to any situation during communication, the source node again starts the route discovery procedure to find new

paths towards the destination.

A disaster is a sudden event that can transform the functionality of the whole environment. Early warning is more beneficial in disaster management. Early warning is more useful than late in disaster management and damage treatment. Apart from natural disasters, some others include industrial chemical disasters. Communication through information technology has gradually improved disaster management. Huge disaster-relevant data is being generated. Through simulation exploring critical infrastructures, executable plans are being flourished by the government and other organizations. The wireless sensor systems provide related information. The different communication channels like social media have been flooded with disaster information. Routing has major rolling disaster management. Current routing protocols are diversified and provide weak integration capabilities in disaster management. The scenario is due to their weakness of some routing protocols choosing the path from the source towards the destination. However, the reliability of the path during data transfer might not always be efficient or consume more time during route discovery link breakage, especially in disaster management. This is the situation when the functionality of the whole environment is disturbed.

During the disaster management, mobility and topology issues of nodes lead to a problem of route discovery of efficient path. Figure 1.1 describes various network disasters. This problem transfers available information more effectively through a robust routing approach, leading to an improved routing approach. This approach supports route discovery and link breakage mainly for normal to disaster management. Performance metrics for this research are packet delivery ratio, end-to-end delay, routing load or overhead, and throughput. The occurrence of disaster left a highly violent situation in the country. Complete prevention of any disaster is beyond the potential of individual capabilities. However, the participation of technology and communication-based systems through routing protocols is a panacea for disaster management.

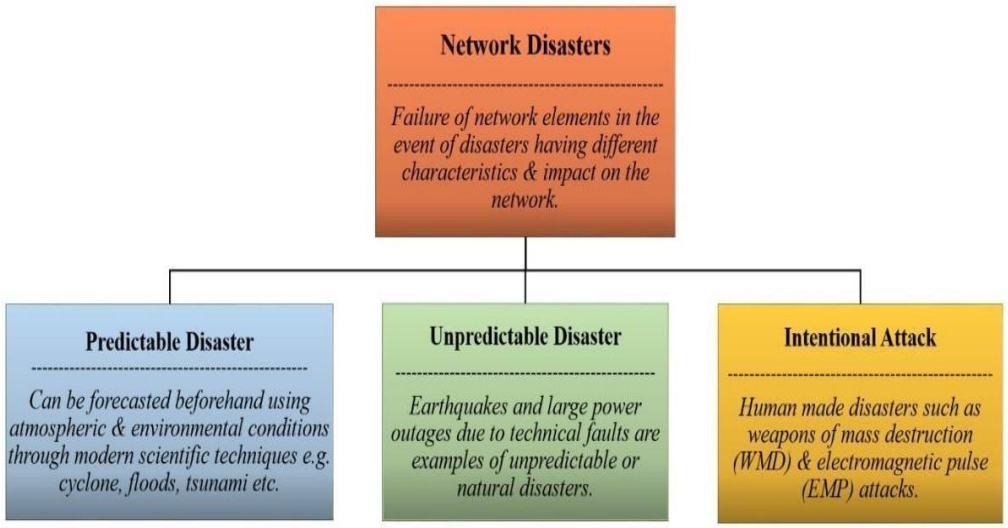

Figure 1.1: Types of network disaster (Alazzam *et al*., 2020)

Although, MANET is one of the most effective parts of networking and has been applied for solving various kinds of disaster issues. Many previous researchers have solved MANET's routing discovery and link breakage issues. However, there are still some gaps associated with standard MANET, and there is much work needed to improve the existing MANET in terms of route discovery and link breakage.

This research aims to set the routing protocols of the existing MANET structure to improve route discovery and link breakage. Proactive routing protocols are table-driven routing protocols that continuously maintain information through the network. In contrast, reactive routing protocols are link-state that keep information on demand. Disaster management reduces in performance metrics like packet delivery ratio, end-to-end delay, throughput, and routing load or overhead from normal to disaster management (Narayana *et al*., 2018). Secondly, the improved hybrid approach performed well in the simulation environment in terms of network convergence to improve the route discovery procedure and link breakage. Finally, this research reduces route discovery and link breakage issues between highly mobilized nodes during disaster management (Trivedi *et al*., 2020). The first part elucidates the thesis'smobile ad-hoc network (MANET) and disaster. Routing protocols provide a way of communication in MANET.

routing protocols are categorized as proactive, reactive, and hybrid approaches that combine both proactive and reactive approaches (Waseem *et al.*, 2020) are illustrated in the section of the literature review Section 2.5. MANET has a major role in circumstances where the setting up of infrastructure is quite difficult. Typical main challenges of disaster managements are as follows (Sahoo *et al*., 2018; Satijadi *et al.*, 2018):

i. Link breakage and route discovery of the route
ii. Defense of soldiers
iii. Health care, heat, wind, rain, artificial situations
iv. Accidents (Haglan *et al*., 2021).

This study establishes an improvement in route discovery and link breakage procedure without communication breakage using either unicast or multipath. Table 1.1 presents the network damages caused by the recent disaster (Wareen *et al.*, 2020).

Table 1.1: Network damages caused by recent disaster

Year	**Nature of Disaster**	**Damage & Network Availability**	**Reference**
2017	ico Earthquake ofmagnitude 7.1	355 people were killed, 6100 wereinjured, and nearly 444,000 buildings, including telecom infrastructure, were destroyed.	https://www.usaid.gov/sites/default/files/documents/1866/mexico_eq_fs05_09- 29-2017.pdf
2015	Earthquake-affected the Rural Information and Communication Technology (ICT) Infrastructure and Services in Nepal	Collapsing of the houses, schools,ICT access centers, BTS,transmission towers, fiber backhaul, microwave links were damaged.	http://seismonepal .gov.np/ (B. R.Dawadi and Shakya *et al.*,2016)
2011	The Great East Japan Earthquake and Tsunami's main shocks and aftershocks	The primary shock affected 1,500 telecom buildings, and 700telecom buildings had poweroutages, disrupting connectivity between some segments of thetraffic flow.	(Adachi *et al*., 2011)

The magnitude-9 earthquake and resulting tsunami in March 2011 off the coast of Japan that savaged the Fukushima nuclear power plant also damaged about half of

the existing transpacific communication (Zarei *et al.*, 2015). Fortunately, the other half of the communication was undamaged, so network operators could reroute traffic to minimize complete outages. A more recent incident of an earthquake of magnitude 7.1 struck central Mexico on 19 September 2017, caused 355 fatalities, 6100 injuries, and collapsed nearly 44000 buildings, including telecom infrastructure. Some network interruptions appear to be intentional attacks, the motivations of which are hard to observe (Zhao *et al.,* 2019). A later occurrence, including three men associated with scuba diving to cut off the undersea communication at the bank of Egypt, happened in March 2013. Many specialists feel that deliberate damage to communications is unrealistic or impossible; however, ad-hoc wireless networks have the potential for serious interruptions, causing network providers to search for efficient paths to connect the continents. (Zhong *et al.,* 2018).

1.2 Problem statement

The main concept of mobile ad-hoc networks (MANET) has been widely implemented in recent years. It provides efficient communication and packet delivery services in all telecom areas or special situations. These genres include accident, flood,earthquake, heat, windstorm, fire, and man-created situations. MANET Due to the self-organized nature of nodes, MANET is categorized into two routing areas: route discovery and link breakage of the network (Rathi & Thaneeghaivel, 2021). Routing protocols are rules that describe how data is transmitted throughout the network. The working criterion of routing protocol for route discovery and link breakage regarding packet delivery is highly dynamic in MANET. Because mobility plays a prime role in MANET, the topology of nodes becomes highly dynamic (Yang *et al.*, 2017). This situation leads to the disconnection of routes from source to destination. Several approaches have been proposed, and techniques have been developed to handle the disaster. However, all of these techniques suffer from different types of drawbacks like link breakage, route discovery, bandwidth, lateness, and scalability. Therefore, much work needs to be done in this situation in terms of route discovery and link breakage to develop an improved approach, especially for solving disaster management in MANET (Zafar *et al.,* 2017).

The network performance is degraded by the frequent breakage of links during disaster management, which creates a breakage of communication between established

paths from source to destination. The routing protocol performs route discovery, which consumes many network resources and severely affects network performance (Khan *et al*., 2020). The routing protocol performs route discovery, which consumes many network resources and severely impacts on network performance. Proactive and reactive protocols and a hybrid approach that combines proactive and reactive routing protocols (wang *et al.,* 2018) are already in place. The process of rebroadcasting is, also known as flooding, represent the flow of traffic, andit is the primary cause of increased route request known as route request RREQ message retransmission in the network; as a result, due to their pre-set path, it causes high network congestion in terms of link breakage and major network performance loss (Yegireddi *et al.,* 2016).

On the other hand, existing hybrid protocols concentrate less on such problems, where new routes have a high latency rate (Sahu *et al*., 2021). Existing hybrid protocols like ZRP, ZHLS, on the other hand, still requires a high Quality of Service to properly support networking applications for route discovery and link breakage, particularly in disaster management (Wadhwani *et al.,* 2020). Discovering a route in the existing hybrid approach create issues of lateness, overlapping, high traffic, and disconnection between sources to destination nodes serves as motivation for an improved hybrid technique for route discovery and link breakage in disaster management. An improved hybrid approach selects an improved route that reduces the number of route re-discovery and link breakage procedures and ultimately improves network performance (Veeraiah *et al.,* 2021).

1.3 Research objectives

This research focuses on discovering efficient routes and minimum link breakage in MANET from the source towards destination during normal to disaster managements regarding variation in speed and direction. This research also seeks to find network routing criteria to improve route discovery and link breakage.

In order to resolve issues associated with MANET, the following objectives have been set to achieve performance from the improved work:

i. To analyze the criteria used in designing routing protocol for a mobile ad-hoc network to reduce route link breakage during disaster managements.
ii. To improve a hybrid approach concerning criteria in (i), integrate the link breakage, and improved route discovery mechanisms based on reactive and

proactive routing protocols.

iii. To evaluate and compare the performance of the improved approach regarding performance metrics. These metrics include packet delivery ratio, end-to-end delay, throughput, routing, or load or overhead through simulation.

1.4 Research scope

The prime objective of the research was to analyze, improve, implement, and evaluate the improved approach in MANET for route discovery and link breakage, from normal to disaster management. Data sets taken for this purpose are from real-time scenarios like a flood, earthquake, fire, and accident examined under the normal and the disaster conditions. To evaluate the improved approach through discrete network simulator NS-2 (Roshan et al., 2019), specialized for network problems, were tested on datasets. NS-2 is a discrete event simulator for researchers around the networks, and these network conditions are altered according to the scenarios. These datasets are taken from reality-based scenarios regarding normal to disaster performance metrics (Sharmin *et al.*, 2019). The routing protocols, including ad-hoc on-demand distance vector (AODV), ad-hoc on-demand multipath distance vector (AOMDV), and optical link-state routing (OLSR), were adopted to be hybrid due to their different routing strategies (Vigneshwaran *et al.*, 2015). The AODV unicast routing protocol opted for the successor to Dynamic Source Routing protocol DSR. AOMDV was taken as the successor of AODV. Multiple paths and OLSR were chosen as the successors of link-state routing for Multipoint Relay (MPRs) nodes (Verma *et al.*, 2015). There are some desirable features or factors of this thesis that need to be addressed with the support of the network simulator environment. Those features or simulated factors could be the heavy load noise, accident and high temperature, flood, earthquake, and accident and fire in the MANET (Shirke *et al.*, 2016). These aid concrete performances than the normal disaster through increment in speed as performance measurement. Another limitation is that these under investigation protocols are quite a minimum outdated.

REFERENCES

Adhvaryu, K. U., & Kamboj, P. (2017). Performance comparison between multicast routing protocols in MANET. *In Electrical, Computer and Electronics (UPCON), 2017 4th IEEE Uttar Pradesh Section International Conference on* (pp. 16-20). IEEE.

Agarwal, N., & Manglani, N. (2015). A New Approach for Energy Efficient Routing in MANETs Using Multi Objective Genetic Algorithm. *International Journal of Science, Engineering and Technology Research (IJSETR)*, 4(6), 1780-1784.

Aggarwal, R. (2018). A Survey to Improve the Network Security with Less Mobility and Key Management in MANET.

Andugula, P., Durbha, S. S. (2015). Post-Disaster image comparison using domain adaptation. *In 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)* (pp. 4848-4851). IEEE.

Anand, A., Aggarwal. H, and Rani. R. (2016). Partially Distributed Dynamic Model for Secure and Reliable Routing in Mobile Ad hoc Networks", *IEEE Explore Journal Of Communications And Networks,* Vol. 18, No. 6, December 2016.

Archana, P. Mandhare, Sujata V. (2016) E-TWRP: Establishing Trust Worthy Reliable Path in Mobile Ad-hoc Network", IEEE, 2016.

Adachi, T., Ishiyama, Y., Asakura, Y., and Nakamura, K. (2011). The restoration of telecom power damages by the Great East Japan Earthquake," in IEEE 33rd International Telecommunications Energy Conference (INTELEC), 2011, pp. 1-5.

Al-Shora, M. A., Nouh, S. A., and Khalifa, A. R. (2018). ''Reliable dynamic source routing (RDSR) protocol with link failure prediction for mobile ad hoc networks (MANET),'' J. Netw. Commun. Emerg. Technol., vol. 8, no. 3, pp. 13–20. [Online]. Available: https//www.jncet.org

Agrawal, P., and Sarkeja, A. (2017). ''A survey on optimum neighbour discovery techniques in mobile ad-hoc networks,'' Int. J. Comput. Appl., vol. 162, no. 12,

pp. 1–4

Anjum, S. S., Noor, R. M., & Anisi, M. H. (2015). Survey on MANET based communication scenarios for search and rescue operations. *In 2015 5th International Conference on IT Convergence and Security (ICITCS)* (pp. 1-5). IEEE.

Abdali, A., and Muniyandi, R. C. (2017). "Optimized Model for Energy Aware Location Aided Routing Protocol in MANET," *International Journal of Applied Engineering Research*, vol. 12, no. 14, pp. 4631-4637.

Alazzam, M. B., & Alassery, F. (2021). The Dynamic Movement of Disaster Management Systems Based on Vehicle Networks and Applied on the Healthcare System. *Applied Bionics and Biomechanics*, *2021*

Alameri, I. A., & Komarkova, J. (2020, June). A Multi-Parameter Comparative Study of MANET Routing Protocols. In 2020 15th Iberian Conference on Information Systems and Technologies (CISTI) (pp. 1-6). IEEE.

Bai, Y., Mai, Y., & Wang, N. (2017). Performance comparison and evaluation of the proactive and reactive routing protocols for MANETs. *In Wireless Telecommunications Symposium (WTS)*, 2017.

Barve, A., Kini, A., Ekbote, O., and Abraham, J. (2016). ''Optimization of DSR routing protocol in MANET using passive clustering,'' *in Proc. 2nd Int. Conf. Commun. Control Intell. Syst. (CCIS)*, pp. 23–27.

Bheemalingaiah, M., Naidu, M. M., Rao, D. S., & Moorthy, P. S. (2017). Survey of Routing Protocols, Simulation Tools and Mobility Models in Mobile Ad Hoc Networks. *International Journal of Innovations & Advancement in Computer Science (IJIACS)* ISSN, 2347-8616.

Chau, A., Dawson, J. F., Mitchell, P. D., & Loh, T. H. (2018). Medium Access Control Protocol for Wireless Sensor Networks in Harsh Environments with Directional Antennas. *In Loughborough Antennas Propagation Conference (LAPC 2018).*

Chen, J., & Wang, Z. (2019). Topology control in hybrid VLC/RF vehicular ad-hoc network. IEEE Transactions on Wireless Communications, 19(3), 1965-1976.

Chourasi, R., Boghe, R. K., (2017). Novel IDS Security against Attacker Routing Misbehaviour of Packet Dropping in MANET", IEEE.

Chawda, K., & Gorana, D. (2015). A survey of energy efficient routing protocol in MANET. *In Electronics and Communication Systems (ICECS), 2015 2nd International Conference on (pp. 953-957)*. IEEE.

Chhabra, S., & Arora, V. (2017). A Review On General Self-Organized Tree-Based

Energy-Balance Routing Protocol For Wireless Sensor Network. *International Journal Of Computers & Technology*, 16(2), 7591-7595.

Correia, A., Moura, R., and Fonseca, M. (2020). "Assessing the location of search and rescue stations on the Portuguese coast," *In Developments and Advances in Defense and Security,* Springer, Singapore, pp. 321-331.

Conti, M., and Giordano, S. (2014). Mobile ad hoc networking: Milestones, challenges, and new research directions,'' IEEE Commun. Mag., vol. 52, no. 1, pp. 85–96.

Clausen, T., Cordero, A. T., Yi, J., and Igarashi, Y. (2018). 'Use'em or lose'em: On unidirectional links in reactive routing protocols, Ad Hoc Netw., vol. 73, pp. 51–64.

Clausen, T., Dearlove, C., Jacquet, P., and Herberg, U. (2014). ''The optimized link state routing protocol version 2,'' *IETF-ImprovedStand, New York, NY, USA, Tech. Rep.* RFC 7181, vol. 7681.

Clausen, T., Yi, J., and Herberg, U. (2017). ''Lightweight on-demand ad hoc distance-vector routing-next generation (LOADng): Protocol, extension, and applicability,'' *Computer Network*, vol. 126, pp. 125–140.

Daas, A., Mofleh, K., Jabr, E., & Hamad, S. (2015, February). Comparison between AODV and DSDV routing protocols in mobile Ad-hoc Network (MANET). *In Information Technology: Towards New Smart World (NSITNSW), 2015 5th National Symposium on (pp. 1-5).* IEEE.

Dubey, M., & Yadav, M. Y. (2015). Comparative Comparison of Cryptographic Algorithms.

Dafalla, M. E. M., Mokhtar, R. A., Saeed, R. A., Alhumyani, H., Abdel-Khalek, S., & Khayyat, M. (2021). An optimized link state routing protocol for real-time application over Vehicular Ad-hoc Network. Alexandria Engineering Journal.

Dawadi, B. R and Shakya, S. (2016) "ICT Implementation and Infrastructure Deployment Approach for Rural Nepal," *in Recent Advances in Information and Communication Technology*: Springer, 2016, pp. 319-331.

Dhende, S. L., & Shirbahadurkar, S. D. (2021, February). Performance Evaluation of Routing Protocols in Mobile Ad-Hoc Networks. In Proceeding of First Doctoral Symposium on Natural Computing Research: DSNCR 2020 (Vol. 169, p. 367). Springer Nature.

Diab, R. A., Bastaki, N., & Abdrabou, A. (2020). A survey on routing protocols for delay and energy-constrained cognitive radio networks. IEEE Access, 8, 198779-198800.

Dugaev, D., Zinov, S., Siemens, E., and Shuvalov, V. (2015). ‘‘A survey and performance evaluation of ad-hoc multi-hop routing protocols for static outdoor networks,’’ *in Proc. Int. Siberian Conf. Control Commun. (SIBCON)*, pp. 1–11.

Er, J. K., & Er, G. S. (2017). Review study on MANET Routing Protocols: Challenges and Applications. International Journal of Advanced Research in Computer Science, 8(4).

Fang, X., & Wu, Y. (2017). Investigation into the elliptic curve cryptography. In Information Management (ICIM), 2017 *3rd International Conference on (pp.412-415). IEEE*

Ganguly, S., Basu, S., Roy, S., & Mitra, S. (2015). A location-based mobility prediction scheme for post disaster communication network using DTN. *In 2015 Applications and Innovations in Mobile Computing (AIMoC)* (pp. 25-28). IEEE. Gopalan, S. H., & Krishnan, R. R (2016). Trust Based Fuzzy Aided ACO for Optimal Routing with Security in MANET", *Asian Journal of Research in Social Sciences and Humanities* Vol. 6, Special Issue Sept 2016, pp. 529-544.

Garcia, S. A., Castaneda-Camacho, J., Guerrero-Castellanos, J. F., & Mino-Aguilar, G. (2018). Evaluation of AODV and DSDV routing protocols for a FANET: Further results towards robotic vehicle networks. *In 2018 IEEE 9th Latin American Symposium on Circuits & Systems (LASCAS*) (pp. 1-4). IEEE.

Goswami, M. M. (2017). AODV based adaptive distributed hybrid multipath routing for mobile AdHoc network. *In Inventive Communication and Computational Technologies (ICICCT)*, 2017 International Conference on (pp. 410-414). IEEE

Grover, J., & Mehta, A. (2019, February). On Demand Multipath Routing Protocol for Emergency Ad Hoc Networks. In 2019 Second International Conference on Advanced Computational and Communication Paradigms (ICACCP) (pp. 1-5). IEEE.

Gupta, K., & Chakraborty, C. (2017). Efficient routing algorithm for disaster recovery over wireless MANET networks based communication system. *In 2017 3rd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT*) (pp. 171-175). IEEE.

Gulati, M. K., and Kumar, K. (2014). Performance comparison of mobile Ad Hoc

network routing protocols," International Journal of Computer Networks & Communications, vol. 6, no. 2, pp. 127-142.

Gupta, K., & Chakraborty, C. (2017). Efficient routing algorithm for disaster recovery over wireless MANET networks based communication system. *In 2017 3rd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT)* (pp. 171-175). IEEE.

García-Campos, J. M., Gutiérrez, D., Sánchez-García, J., & Marn, S. T. (2018). A Simulation methodology for Conducting Unbiased and Reliable Evaluation of MANET Communication Protocols in Disaster Scenarios. In Smart Technologies For Emergency Response and Disaster Management (pp. 106-143). IGI Global.

Hara, T. (2017). Data management issues in mobile ad hoc networks. Proceedings of the Japan Academy, Series B, 93(5), 270-296.

Hartinah, S., Prakoso, H., & Anwar, K. (2018, September). Routing of mobile cognitive radio base station for disaster recovery networks. *In 2018 International Conference on Electrical Engineering and Informatics (ICELTICs)* (pp. 1-6). IEEE.

Hassan. M. H and Muniyandi, R. C. (2017). An improved hybrid technique for energy and delay routing in mobile ad-hoc networks," International Journal of Applied Engineering Research, vol. 12, no. 1, pp. 134-139.

Hassan, M. H *et al*.,(2018) "A hybrid algorithm for improving the quality of service in MANET," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 8, no. 4, pp. 1218-1225.

Hassan, M. H. (2019). "Integrating African Buffalo Optimization Algorithm in AODV Routing Protocol for improving the QoS of MANET," Journal of Southwest Jiaotong University, vol. 54, no. 3, pp. 1-12.

Hassan, M. H., Mostafa, S. A., Mahdin, H., Mustapha, A., Ramli, A. A., Hassan, M. H., & Jubair,M. A. (2021). Mobile ad-hoc network routing protocols of time-critical events for search and rescue missions. *Bulletin of Electrical Engineering and Informatics*, *10*(1), 192-199. Huang, H., Yin, H., Luo, Y., Zhang, X., Min, G., & Fan, Q. (2016). Three-dimensionalgeographic routing in wireless mobile ad hoc and sensor networks. IEEE Network, 30(2), 82-90.

Han, B., Ding, L., Ji, Y., Wang, X., & Wang, B. (2020, December). A TORA-based Wireless Protocol for MANET with Low Routing Overhead at Link Layer. In 2020 IEEE 17th International Conference on Mobile Ad Hoc and Sensor Systems

(MASS) (pp. 283-291). IEEE.

Hasan, M. Z., Al-Rizzo, H., & Al-Turjman, F. (2017). A survey on multipath routing protocols for QoS assurances in real-time wireless multimedia sensor networks. IEEE Communications Surveys & Tutorials, 19(3), 1424-1456.

Hu, Z., Wang, Y., and Han, S. (2018). "A maritime spectrum sensing scheme based on Ad Hoc network and non-uniform quantization," *37th Chinese Control Conference (CCC),* pp. 4223–4227.

Hines, P. D., Blumsack, S., & Schläpfer, M. (2017). Centralized versus decentralized infrastructure networks. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* Vol. 6, Special Issue 1, March 2017.

Haglan, H. M., Mostafa, S. A., Safar, N. Z. M., Mustapha, A., Saringatb, M. Z., Alhakami, H., & Alhakami, W. (2021). Analyzing the impact of the number of nodes on the performance of the routing protocols in manet environment. *Bulletin of Electrical Engineering and Informatics*, *10*(1), 434-440

Jadhav, S. S., Kulkarni, A. V., & Menon, R. (2014). Mobile Ad-Hoc Network (MANET) for disaster management. *In 2014 Eleventh International Conference on Wireless and Optical Communications Networks (WOCN)* (pp. 1-5). IEEE.

Jahir, Y., Atiquzzaman, M., Refai, H., Paranjothi, A., & LoPresti, P. G. (2019). Routing protocols and architecture for disaster area network: A survey. Ad Hoc Networks, 82, 1-14.

Jameel, F., Hamid, Z., Jabeen, F., Zeadally, S., & Javed, M. A. (2018). A Survey of Device-to-Device Communications: *Research Issues and Challenges. IEEE Communications Surveys & Tutorials.*

Jain, G., Rajawat, G. S., "Secure AODV Routing protocol based on Homographic Digital signature, IEEE , 2016.

Jubair, M. A., *et al.,* "Bat Optimized Link State Routing Protocol for Energy-Aware Mobile Ad-Hoc Networks,"Symmetry, vol. 11, no. 11, pp. 1-22, 2019.

Jubair, M., and Muniyandi, R. (2016). "NS2 Simulator to Evaluate the Effective of Nodes Number and Simulation Time on the Reactive Routing Protocols in MANET," *International Journal of Applied Engineering Research,* vol. 11, no. 23, pp. 11394-11399, 2016.

Jubair, M. A., Salama, A., Mustapha, A., & Gunasekaran, S. S. (2018). "Performance Evaluation of Ad-Hoc On-Demand Distance Vector and Optimized Link State

Routing Protocols in Mobile Ad- Hoc Networks," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 8, no. 4, pp. 1277-1283.

Jyothi V., Suhas K. R., Mohankumar N. M., Devaraju J. T. (2015) "Performance Study of Proactive, Reactive and Hybrid Routing Protocols for MANET in Multiple CBR Scenario," *International Journal of Computer Science and Technology*, vol. 6, no. 1, pp. 57-61.

Jaiswal, A. K., and Tiwari, S. (2015). ''A survey on optimal route selec- tion approaches using different protocol in MANET,'' vol. 1, no. 4, pp. 434–441.

Jha, R. K., and Kharga, P. (2015) ''A comparative performance analysis of routing protocols in MANET using NS3 simulator,'' vol. 7, no. 4, pp. 62–68, 2015. Jahir, Y.,

Guaya-Delgado, L., Pallarès-Segarra, E., Mezher, A. M., and Forné, J (2019) ''A novel dynamic reputation-based source routing protocol for mobile ad hoc networks,'' *EURASIP J. Wireless Commun. Netw*., vol. 2019, no. 1, p. 77.

Kapoor, S., & Saini, P. (2015). A hybrid routing algorithm against routing attacks in Mobile Adhoc Networks (MANETs). *In Computing, Communication & Automation (ICCCA), 2015 International Conference on (pp. 380-383). IEEE*.

Kapur, R. K., & Khatri, S. K. (2015, September). Secure data transfer in MANET using symmetric and asymmetric cryptography. In 2015 4th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO)(Trends and Future Directions) (pp. 1-5). IEEE.

Kachooei, M. A., Hendessi, F., Ghahfarokhi, B. S., & Nozari, M. (2022). An OLSR-based Geocast Routing Protocol for Vehicular Ad Hoc Networks. Peer-to-Peer Networking and Applications, 15(1), 246-266.

Keerthi, D. S., Chaithanyaranga, H. V., & Shreedevi, P. (2016, December). Study and performance evaluation of mobility models in MANET and WSN. *In Electrical, Electronics, Communication, Computer and Optimization Techniques (ICEECCOT),* 016 International Conference on (pp. 297-301). IEEE.

Kushwaha, K. J., Sharma, H. R., & Ambhaikar, A. (2016). A Novel Selective Encryption Method for Securing Text over Mobile Ad hoc Network, ELSEVIER. Komolkiti, P., Boonkird, T., and Aswakul, C. (2016). "Performance measurement ofmaritime Ad Hoc network testbed in realistic offshore scenario," *International Conference on Electronics, Information, and*

Communications (ICEIC), pp. 1–4.

Kushwaha. A., Sharma. H. R., Ambhaikar. A. (2016). A Novel Selective Encryption Method for Securing Text over Mobile Ad hoc Network, ELSEVIER.

Khalaf, B. A., Mostafa, S. A., Mustapha, A., Mohammed, M. A. and Abduallah, W. M. (2019). Comprehensive Review of Artificial Intelligence and Statistical Approaches in Distributed Denial of Service Attack and Defense Methods," *in IEEE Access*, vol. 7, pp. 51691-51713.

Khalaf, *et al.*, (2019). A Simulation Study of Syn Flood Attack in Cloud Computing Environment," REVISTA AUS, vol. 26, no. 1, pp. 1-19, 2019.

Khalaf, A., Mostafa, S. A., Mustapha, A., and Abdullah, N. (2018). "An Adaptive Model for Detection and Prevention of DDoS and Flash Crowd Flooding Attacks," 2018 International Symposium on Agent, Multi-Agent Systems and Robotics (ISAMSR), Putrajaya, 2018, pp. 1-6.

Kasana, R., Kumar, S., Kaiwartya, O., Yan, W., Cao, Y., & Abdullah, A. H. (2017). Location error resilient geographical routing for vehicular ad-hoc networks. *IET Intelligent Transport Systems*, 11(8), 450-458.

Kuo, W. K., and Chu, S. H. (2016). ''Energy efficiency optimization for mobile ad hoc networks,'' *IEEE Access*, vol. 4, pp. 928–940.

Khudayer, B. H., Anbar, M., Hanshi, S. M., & Wan, T. C. (2020). Efficient route discovery and link failure detection mechanisms for source routing protocol in mobile ad-hoc networks. IEEE Access, 8, 24019-24032.

Kaur, K., and Singh, S.P. (2016). ''Multicasting technique to enhance the performance of DSR routing protocol using various performance metrics under different traffic conditions in mobile ad hoc networks,'' *Int. J. Future Gener. Commun. Netw.*, vol. 9, no. 4, pp. 103–144.

Khan, M. F., & Yau, K. L. A. (2020, August). Route Selection in 5G-based Flying Ad-hoc Networks using Reinforcement Learning. In *2020 10th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)* (pp. 23-28).

Kandace, S. (2020). Routing Efficiency of Infrastructure less Networks: A ComparativeAnalysis. *IEEE Open Journal of the Communications Society*, *1*, 1171-1184

Kumar, N. C., Basit, A., Singh, P., & Venkaiah, V. C. (2017, November). Proactive secret sharing for long lived MANETs using Elliptic Curve Cryptography. In

2017 International Conference on Inventive Computing and Informatics (ICICI) (pp. 312-316). IEEE.

Liu, K., & Cheng, Y. (2018). Enabling data sharing and multimedia applications over a multi-hop ad hoc network formed by un-rooted smartphones. *In IEEE INFOCOM 2018-IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)* (pp. 1-2). IEEE.

Leenas, T., & Shriparen, S. (2021, August). Comparison of Proactive, Reactive, and Hybrid Routing Protocols in Mobile Ad Hoc Networks. In 2021 10th International Conference on Information and Automation for Sustainability (ICIAfS) (pp. 36-41). IEEE.

Lit, A., Rusli, M. S., & Marsono, M. N. (2019). "Comparative performance evaluation of routing algorithm and topology size for wireless network-on-chip," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 8, no. 4,pp. 1239-1250.. Malwe, S. R., & Biswas, G. P. (2015). Location aware sector-based routing in wireless ad hoc networks. *In Green Computing and Internet of Things (ICGCIoT),International Conference on (pp. 154-159). IEEE.*

Mahiddin, N. A., Sarkar, N. I., & Cusack, B. (2017). An internet access solution: MANET routing and a gateway selection approach for disaster scenarios. The Review of Socionetwork Strategies, 11(1), 47-64.

Mehra, A. (2018). To Enhance The Security And Improve The Performance Of Aodv Protocol In Manet Using Delay Per Hop Technique. *Global Journal of Computers & Technology*, 6(2), 354-365.

Mohsin, R., and Woods, J. (2014). "Performance evaluation of MANET routing protocols in a maritime environment," *6th Computer Science and Electronic Engineering Conference (CEEC)*, pp. 1–5.

Mohsin, R. J., Woods, J., and Shawkat, M. Q. (2015). "Density and mobility impact on MANET routing protocols in a maritime environment," *Scienceand nformation Conference (SAI)*, pp. 1046–1051.

Mahe. A swary, Baskar. S. (2016). Letter To Shape Encryption For Securing MANET Routing Protocols", IEEE International Conference on Computational Intelligence and Computing Research, 2016.Acknowledgement Intrusion Detection System in MANETs Using Hybrid Cryptographic Technique, IEEE, 2015.

Min, H. Y., and Zaw, W. (2014) Performance Evaluation of Energy Efficient Cluster-

based Routing Protocol in Wireless Sensor Networks," *International Journal of Computer Science Engineering IJCSE,* vol. 3, no. 2, pp. 71-76.

Mostafa, S. A., Tang, A. Y. C., Hassan, M. H., Jubair, M. A., and Khaleefah, S. H. (2018). "A Multi-Agent Ad Hoc On-Demand Distance Vector for Improving the Quality of Service in MANETs," *2018 International Symposium on Agent, Multi-Agent Systems and Robotics (ISAMSR),* Putrajaya, pp. 1-7

Mohapatra, S., and Kanungo, P. (2014). "Performance analysis of AODV, DSR, OLSR and DSDV routing protocols using NS2 Simulator," Procedia Engineering,vol. 30, pp. 69-76.

Mostafa, S. A et al. (2020). "Social networking mobile apps framework for organizing and facilitating charitable and voluntary activities in Malaysia," *Bulletin of Electrical Engineering and Informatics (BEEI),* vol. 9, no. 2, pp. 827-833.

Madasamy, B., & Balasubramanian, P. (2017). Geographical angular zone-based optimal resource allocation and efficient routing protocols for vehicular ad hoc networks. *IET Intelligent Transport Systems*, 12(3), 242-250.

Malwe, S. R., Taneja, N., and Biswas, G. P. (2017). ''Enhancement of DSR and AODV protocols using link availability prediction,'' *Wireless Pers*. Com-mun., vol. 97, no. 3, pp. 4451–4466.

Mai, Y., Bai, Y., and Wang, N., ''Performance comparison and evaluation of the routing protocols for MANETs using NS3,'' *J. Electr. Eng.*, vol. 5, pp. 187–195. Mallapur, S. V., Patil, S. R., and Agarkhed, J. V. (2016). ''A stable backbone-based on demand multipath routing protocol for wireless mobile Ad Hoc networks,''*Int. J. Comput. Netw. Inf. Secur.*, vol. 3, pp. 41–51.

Moudgil, S., & Rana, S. (2016). Secure & Robust Scheme to Isolate DDoS Attacks Over MANET", *IJCSI International Journal of Computer Science Issues*, Volume 13, Issue 3, May 2016.

Mostafaei, Y., & Pashazadeh, S. (2016). An improved OLSR routing protocol for reducing packet loss ratio in ad-hoc networks. *In 2016 Eighth International Conference on Information and Knowledge Technology (IKT)* (pp. 12-17). IEEE Naik , K. K., Balaswamy, C., & Reddy, P. R. (2019). Performance Comparison ofOLSR Protocol for MANETs under Realistic Mobility Model. *In 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)* (pp. 1-5). IEEE.

Nawir, M., Amir, A., Yaakob, N., & Lynn, O. B. (2019). "Effective and efficient

network anomaly detection system using machine learning algorithm," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 8, no. 1, pp. 46-51

Nayyar, A. (2018). Flying Adhoc Network (FANETs): Simulation Based Performance Comparison of Routing Protocols: AODV, DSDV, DSR, OLSR, AOMDV and HWMP. *In 2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)* (pp. 1-9). IEEE.

Narayana, M. V., & Atmakuri, A. (2018). A-ZHLS: adaptive ZHLS routing protocol for heterogeneous mobile adhoc networks. International Journal of Engineering & Technology, 7(3), 1626-1630.

Nabou, A., Laanaoui, M. D., & Ouzzif, M. (2018, October). Evaluation of MANET routing protocols under black hole attack using AODV and OLSR in NS3. In 2018 6th International Conference on Wireless Networks and Mobile Communications (WINCOM) (pp. 1-6). IEEE.

Nabou, A., Laanaoui, M. D., Ouzzif, M., & El Houssaini, M. A. (2021). New method to detect the congestion for green networking in MANET. In Emerging trends in ICT for sustainable development (pp. 161-169). Springer, Cham.

Oukili, S., & Bri, S. (2017). High speed efficient advanced encryption standard implementation. *In Networks, Computers and Communications (ISNCC), International Symposium on (pp. 1-4). IEEE.*

Patil, M. T., Jos, .B. (2016). Improved Nachammai. M, Dr. N. Radha," Securing Data Transmission in MANET using an improved Cooperative Bait Detection approach", *2016 IEEE International Conference on Advances in Computer Applications (ICACA).*

Page, C. E. (2017) "Maximizing maritime safety and environmental protection with AIS: (Automatic identification system)," OCEANS 2017 - Anchorage, pp. 1–4, December 2017.

Paul, S. (2016) Introduction to MANET and Clustering in MANET. New York, NY, USA: Anchor Academic.

Piltyay, S., Bulashenko, A., & Demchenko, I. (2020, October). Wireless sensor network connectivity in heterogeneous 5G mobile systems. In 2020 IEEE International Conference on Problems of Infocommunications. Science and Technology (PIC S&T) (pp. 625-630). IEEE.

Pondwal, V., and Saini, H. (2016). ''A comprehensive survey on routing schemes for high speed networks,'' IUP J. Telecommun., vol. 8, no. 4, p. 7.

Paranavithana, P., & Jayakody, A. (2017). Compromising AODV for better performance: Improve energy efficiency in AODV. *In 2017 6th National Conference on Technology and Management (NCTM)* (pp. 201-204). IEEE

Pathan, A. S. K. (Ed.). (2016). Security of self-organizing networks: MANET, WSN, WMN, VANET. CRC press.

Perumal, N., Prabhu, M., & Selvi, C. S. (2021). Improved Priority Aware Mechanism for Enhancing QoS in MANET. Wireless Personal Communications, 1-16.

Priyanka Patil, Nilesh Marathe, Vimla Jethani," Improved ALERT Protocol in MANET with Strategies to Prevent DOS & MITM Attacks", *International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT) International Institute of Information Technology,* Pune IEEE, 2016.

Priyambodo, T. K., Wijayanto, D., & Gitakarma, M. S. (2021). Performance Optimization of MANET Networks through Routing Protocol Analysis. *Computers*, *10*(1), 2.

Rahmadhani, M. A., Yovita, L. V., & Mayasari, R. (2018, July). Energy Consumption and Packet Loss Comparison of LEACH Routing Protocol on WSN Over DTN. *In 2018 4th International Conference on Wireless and Telematics (ICWT)* (pp. 1-5). IEEE.

Rai, S., Boghey, R., & Yadav, P. R. (2017, November). Cluster based energy efficient authentication scheme for secure IDS over MANET. *In 2017 7th International Conference on Communication Systems and Network Technologies (CSNT)(pp. 200-205). IEEE.*

Rathi, V., & Thaneeghaivel, R. (2021). CARPM: Comparative Analysis of Routing Protocols in MANET. In Data Science and Security (pp. 107-113). Springer, Singapore.)

Rajesh, M., & Gnanasekar, J. M. (2017). Congestion Control Scheme for Heterogeneous Wireless Ad Hoc Networks Using Self-Adjust Hybrid Model. *International Journal of Pure and Applied Mathematics,* 116, 537-547.

Rajesh, M., & Gnanasekar, J. M. (2017). Path Observation Based Physical Routing Protocol for Wireless Ad Hoc Networks. Wireless Personal Communications, 97(1), 1267-1289.

Raghunandan, G. H., Chaithanya, G. H., & Hajare, R. (2017, February). Independent robust mesh for mobile adhoc networks. In 2017 4th International Conference on Electronics and Communication Systems (ICECS) (pp. 125-128). IEEE.

Rao, S. V. R. K. *et al.,* "Wireless sensor Network based Industrial Automation using Internet of Things (IoT)," International Journal of Advanced Trends inComputer Science and Engineering, vol. 7, no. 6, pp. 82-86, 2018B.

Remya S, Lakshmi K S, "SHARP: Secured Hierarchical Anonymous Routing Protocol for MANETs", International Conference on Computer Communication and Informatics (ICCCI -2015), Jan. 08 – 10, IEEE, 2015.

Rangaraj, J., & Anitha, M. (2017). Performance comparison of proactive and reactive protocol under different mobility models for MANET. *In I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC), 2017 International Conference* on (pp. 637-643). IEEE.

Rajkumar, B., Narsimha, D. G "Trust Based Certificate Revocation for Secure Routing in MANET", *2nd International Conference on Intelligent Computing, Communication & Convergence*, Elsevier, *2016.

Rasika R. M., & Sudhir T. B. (2016). Detection of Misbehaving Node using Secure Acknowledgement in MANET", *IEEE Explore, International Conference on Computing, Analytics and Security Trends (CAST) College of Engineering Pune, India*. Dec 19-21.

Rishiwal, V., Agarwal, S. K., & Yadav, M. (2016). Performance of AODV protocol for H-MANETs. *In 2016 International Conference on Advances in Computing, Communication, & Automation (ICACCA)(Spring)* (pp. 1-4). IEEE.

Roshan, R., Mishra, S., & Meher, C. P. (2019, March). A Comparison between the AODV and DSDV Routing Protocols for Mobile Ad-Hoc Network Using NS2. In *2019 6th International Conference on Computing for Sustainable Global Development (INDIACom)* (pp. 286-289). IEEE

Sahoo, A., Shreya, A., Dash, C. S., Priyadarshini, I., Sobhanayak, S., Panda, S. S., ... & Golchha, P. (2018). Performance Evaluation of AODV, DSDV and DSR Routing Protocol For Wireless Adhoc Network. *In 2018 InternationalConference on Advances in Computing, Communication Control and Networking(ICACCCN)* (pp. 348-351). IEEE.

Sani, A. M. I. P. H., Newaz, S. S., Wani, S. M. A., Wan, A. T., & Jahan, S. (2017, September). Tcp performance evaluation under manet routing protocols in disaster recovery scenario. *In 2017 4th International Conference on Advances in Electrical Engineering (ICAEE)* (pp. 389-394). IEEE.

Saritha, V., Krishna, P. V., Alagiri, I., Viswanatham, V. M., & Obaidat, M. S. (2018,

May). Efficient Multipath Routing Protocol with Quality of Service for Mobile Ad Hoc Networks. *In 2018 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE.

Salem, E. M. A. (2014). Comparative study and performance analysis of Routing protocols for MANET. *IOSR Journal of Computer Engineering (IOSR-JCE)* vol. 16, issue 6, pp 25-32.

Suvarna et al "Acknowledgement security for MANET using EAACK", IEEE, 2015. Dr.B.Rosiline Jeetha, K.Sivakamipriya, "Secure Routing and Detection of Hybrid Attacks in MANET",*International Journal of Innovative Research in Computer and Communication Engineering*, Vol. 5, Issue 2, February 2017.

Sharma, A., Bhuriya. D., Singh. U. (2015). Secure Data Transmission on MANET by Hybrid Cryptography Technique, IEEE , 2015.

Setijadi, E., Purnama, I. K. E., & Pumomo, M. H. (2018, September). Performance Comparative of AODV, AOMDV and DSDV Routing Protocols in MANET Using NS2. *In 2018 International Seminar on Application for Technology of Information and Communication* (pp. 286-289). IEEE.

Sharma, A. K., & Trivedi, M. C. (2016). Performance comparison of AODV, ZRP and AODVDR routing protocols in MANET. *In Computational Intelligence & Communication Technology (CICT), 2016 Second International Conference on (pp. 231-236). IEEE.*

Sharmila, S., & Shanthi, T. (2016). A survey on wireless ad hoc network: Issues and implementation. *In Emerging Trends in Engineering, Technology and Science (ICETETS), International Conference on* (pp. 1-6). IEEE.

Shreyas S., & Dhamdhere, V. (2015). Hybrid Cryptography for Malicious Behavior Detection and Prevention System for MANETs, IEEE, 2015.

Sultana, J., & Ahmed, T. (2017). Securing AOMDV protocol in mobile adhoc network with elliptic curve cryptography. *In Electrical, Computer and Communication Engineering (ECCE),* International Conference on (pp. 539-543). IEEE.

Suneja, P., Kumar, A., & Soni, A. (2015). System scenario based investigation of AODV and AOMDV Routing Protocol in MANET. *In 2015 International Conference on Soft Computing Techniques and Implementations (ICSCTI)* (pp. 45-48). IEEE.

Shakir, A. (2019). "Novel Method of Improving Quality of Service for Voice over Internet Protocol Traffic in Mobile Ad Hoc Networks," *International Journal of*

Communication Networks and Information Security, vol. 11, no. 3, pp. 331-341, Dec 2019.

Sharmin, A., Anwar, F., & Motakabber, S. M. A. (2019). "A novel bio-inspired routing algorithm based on ACO for WSNs," *Bulletin of Electrical Engineering and Informatics (BEEI*), vol. 8, no. 2, pp. 718-726.

Sahel S. S. D., and Boudour, M. (2019). "Wavelet energy moment and neural networks based particle swarm optimisation for transmission line protection," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 8, no. 1, pp. 10-20.

Sharma, P., Jain, P., and Singh, L. (2016). ''Effect of varying source node, relay node and mobility in MANET,'' Int. J. Adv. Res. Ideas Innov. Technol., vol. 2, no. 6, pp. 1–7.

Sharma, M., Singh, M., Walia, K., & Kaur, K. (2019, October). Comprehensive Study of Routing Protocols in Adhoc Network: MANET. In 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON) (pp. 0792-0798). IEEE.

Shirke, S., Shah, V., Ruikar, T., and Abraham, J. (2016) Cluster based hierarchical addressing for dynamic source routing, in Proc. *Int. Conf. Smart Trends Inf. Technol. Comput*. Commun., pp. 264–275.

Suneja, P., Kumar, A., & Soni, A. (2015, October). System scenario-based investigation of AODV and AOMDV Routing Protocol in MANET. *In 2015 International Conference on Soft Computing Techniques and Implementations (ICSCTI)* (pp. 45-48). IEEE.

Suresh, N., & Thirumaran, J. (2018). Balanced and Energy Efficient Multipath Routing With Robust Transmission in Mobile ADHOC Network. *International Journal of Applied Engineering Researc*h, 13(1), 641-646.

Sarkar, N., & Mahiddin, N. A. (2019). An Efficient Gateway Routing Scheme for Disaster Recovery Scenario. *In the 33rd International Conference on Information Networking.*

Sahu, P. K., Acharya, B. M., & Panda, N. (2021). QoSAwareUnicastingHybrid Routing Protocol for MANETs. In *Intelligent and Cloud Computing* (pp. 631-640). Springer, Singapore.)

Subbiah, B., Obaidat, M. S., Sriram, S., Manoharn, R., & Chandrasekaran, S. K. (2020). Selection of intermediate routes for secure data communication systems using graph theory application and grey wolf optimisation algorithm in MANETs.

IET Networks.

Thakker, V. M., Reddy, G. M., Kumar, K. V., & Moses, D. (2018). Choosing optimal routing protocol by comparing different multipath routing protocols in mobile Adhoc networks. *In 2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 1284-1290). IEEE.

Thiagarajan, R., & Moorthi, M. (2017). Efficient routing protocols for mobile ad hoc network. In Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), *2017 Third International Conference on(pp. 427-431)*. IEEE

Thomsen, H., De Carvalho, E., & Popovski, P. (2015). Using wireless network coding to replace a wired with wireless backhaul. *IEEE Wireless Communications Letters*, 4(2), 141-144.

Trivedi, V., Nayak, P., Padhan, D. G., & Mohan, N. (2021, August). Performance Enhancement of AODV Routing Protocol for MANET Using Genetic Algorithm. In 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC) (pp. 975-981). IEEE.

Tundjungsari, V., & Sabiq, A. (2017). Android-based application using mobile adhoc network for search and rescue operation during disaster. *In 2017 International Conference on Electrical Engineering and Computer Science (ICECOS)* (pp. 16-21). IEEE.

Tchinda, A. P., Frick, G., Trick, U., Lehmann, A., TchindA. P., & Ghita, B. (2017). Performance comparison of WMN routing protocols for disaster networks. *In 2017 IEEE Symposium on Communications and Vehicular Technology (SCVT)* (pp. 1-6). IEEE.

Taha, A., Alsaqour, R., Uddin, M., Abdelhaq, M., & Saba, T. (2017). Energy efficient multipath routing protocol for mobile ad-hoc network using the fitness function. *IEEE access*, 5, 10369-10381.

Tariq, R., Ahmed, S., Sani, R. S., Najam, Z., & Shafique, S. (2019). Securing ad hoc on-demand distance vector routing protocol against the black hole DoS attack in MANETs. PeerJ PrePrints, 7, e27905v1.

Tavakkoli-Moghaddam, R., Rahimi-Vahed, A., & Mirzaei, A. H. (2019). A hybrid multi-objective immune algorithm for a flow shop scheduling problem with bi-objectives: weighted mean completion time and weighted mean tardiness. Information Sciences, 177(22), 5072-5090.

Verma, H., and Chauhan, N. (2015). MANET based emergency communicationsystem for natural disasters, *International Conference on Computing, Communication & Automation*, Noida, pp. 480-485, 2015.

Vijayalaxmi, P., Ravindra, E., Kohir, V. V., and VMytri, V. D. (2014). ‘‘Mobility prediction algorithm to improve the routing performance in MANET,’’ *Int.J. Comput. Sci. Netw. Secur.*, vol. 14, no. 9, p. 39.

Verma,U. K., Kumar, S., Sinha, D. (2016). A Secure and Efficient Certificate based Authentication Protocol for Manet, IEEE.

Veeraiah, N., Khalaf, O. I., Prasad, C. V. P. R., Alotaibi, Y., Alsufyani, A., Alghamdi, S. A., & Alsufyani, N. (2021). Trust aware secure energy efficient hybrid protocol for manet. IEEE Access, 9, 120996-121005.

Vigneshwaran, M. M., Chandrasekar, M. P., Kalaivani, M. S., & Maheshwaramuniraj, M. V. (2015). A Survey Of Energy Efficient Routing Protocols In Manet.

Wang, H. M., Zhang, Y., Ng, D. W. K., & Lee, M. H. (2018). Secure routing with power optimization for ad-hoc networks. *IEEE Transactions on Communications*, 66(10), 4666-4679.

Wadhawan, N., & Dave, M. (2017). Improved 2Tier cooperative caching scheme for internet based vehicular adhoc networks (IVANETs). *In Computing, Communication and Automation (ICCCA), 2017 International Conference* on(pp. 653-657). IEEE.

Wang, X., Cheng, H., & Yao, Y. (2016). Addressing-based routing optimization for 6LoWPAN WSN in vehicular scenario. IEEE Sens. J, 16, 3939-3947. Wang, C., Zhang, Y., Wang, X., & Zhang, Z. (2018). Hybrid multihop partition-based clustering routing protocol for WSNs. *IEEE Sensors Letters*, 2(1), 1-4.

Warren, J. I. (2020). Proactive and Reactive Strategies to Prepare the Nursing Workforce. Journal for Nurses in Professional Development, 36(4), 250-252.

Waseem, R. M., Khan, F. Z., Ahmad, M., Naseem, A., Jhanjhi, N. Z., & Ghosh, U. (2021). Performance Evaluation of AOMDV on Realistic and Efficient VANet Simulations. *Wireless Personal Communications*, 1-20.

Wadhwani, G. K., Khatri, S. K., & Mutto, S. K. (2020). Trust framework for attack resilience in MANET using AODV. Journal of Discrete Mathematical Sciences and Cryptography, 23(1), 209-220.

Yegireddi, R., & Kumar, R. K. (2016). A survey on conventional encryption algorithms of Cryptography. *In ICT in Business Industry & Government*

(ICTBIG), International Conference on (pp. 1-4). IEEE.

Yao, J., Feng, S., Zhou, X., & Liu, Y. (2016). Secure routing in multihop wireless ad-hoc networks with decode-and-forward relaying. *IEEE Transactions on Communications*, 64(2), 753-764.

Yang, Y., Hao, S. Y., and Cai, B. H. (2017). ‘‘Comparison and evaluation of routing protocols based on a collaborative simulation using SUMO and NS3 with TraCI,’’ in Proc. Int. Conf. Inf. Syst. Artif. Intell. (ISAI), Jun. 2016, pp. 253–257.work," *4th International Conference on Information, Cybernetics and Computational Social Systems (ICCSS)*, pp. 48–52.

YAHAYA, A., KAWU, A., TABRA, M., & AHMED, M. PERFORMANCE EVALUATION OF ROUTING PROTOCOLS IN MANETS.

Trivedi, V., Nayak, P., Padhan, D. G., & Mohan, N. (2021, August). Performance Enhancement of AODV Routing Protocol for MANET Using Genetic Algorithm. In 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC) (pp. 975-981). IEEE.

Zafar, S., Soni, M. K., Beg, M. M. S. (2015). An Optimized Genetic Stowed Biometric Approach to Potent QOS in MANET", *International Conference on Soft Computing and Software Engineering, Elsevier*, 2015.

Zafar, S. (2017) "Biometric Signature Based ApproachEnhancing Security of Networks Through a Novel", International Journal of Wireless Communications and Mobile Computing 2017; 5(1): 1-5 ISSN: 2330-1007 (Print); ISSN: 2330-1015 (Online).

Zafar, S., Tariq, H., Manzoor, K. (2016). "Throughput and delay analysis of AODV, DSDV and DSR routing protocols in mobile ad hoc networks," *International Journal of Computer Networks and Applications IJCNA*, vol. 3, no. 2, pp. 25- 31.
Zarei, V., Behjat, V., Baziar, R., & Azimizadeh, M. R. (2015). Pre-disaster basemaintains of distribution transformers for improving crisis management. *In 2015 20th Conference on Electrical Power Distribution Networks Conference (EPDC)* (pp. 179-183). IEEE.

Zhao, J., Yang, T., and Feng, H. (2019). "Study on wide-band communication at sea under E-navigation frame.