I. J. Mathematical Sciences and Computing, **2022, 3, 37-48**
Published Online August 2022 in MECS (http://www.mecs-press.org/)
DOI: 10.5815/ijmsc.2022.03.04

Energy Efficient Multipath Routing in Zone-based Mobile Ad-hoc Networks: Mathematical Formulation

Vinay Sahu
Assistant Professor, LNCT, Bhopal
Email: sahu.vinay@gmail.com

Rani Sahu
Assistant Professor, UIT RGPV, Bhopal
Email: rani.princy28@gmail.com

Received: 22 April 2022; Revised: 27 May 2022; Accepted: 25 June 2022; Published: 08 August 2022

Abstract: A wireless mobile ad hoc network (MANET) is a dynamic network that can be built without the need for any central governance system and pre-existing infrastructure, in which each node can act as a router. During the transmission of information in any network, energy consumption is an important factor for the efficiency and lifetime of the network. A reduction in energy consumption is achieved by detecting the energy consumption at the node at each stage of transmission.

The main objective of this paper is to formulate mathematical models of energy consumption. A mathematical model of the energy consumption of a network is to be built on the basis of available nodes and links to formulate mathematical models related to energy. When constructing this mathematical model for the challenge related to mobility and low connectivity due to limited battery power in the network, the failure of the links present in the network and the estimated energy consumption are taken into account. Due to the greater mobility of this type of network, nodes rapidly change their positions, causing nodes to drain the battery very quickly, thus reducing network performance. So we need a mathematical model which helps in developing a mathematical model after developing a conceptual model. Which helps in predicting the quantitative behavior of a system. Weaknesses and strengths of a model can be identified from the quantitative results of a mathematical model.

Index Terms: Mobile Ad Hoc Network; Dynamic Mobility; Energy Efficiency; Zone based technology; Wireless Routing Protocol.

1. Introduction

A wireless-type infrastructure-less network that transmits packets between nodes without the aid of an access point is known as a mobile ad hoc network (MANET)[1]. Thus, where it is not possible to sell a wired network, such a network can be developed by deploying it in difficult and hostile conditions. Similarly, in situations where battery replacement is not possible in the node, it is also helpful to deploy in adverse conditions.

Routing protocols[2] play an important role in forwarding packets in any network. In addition to this, energy consumption can be reduced by reducing traffic overhead of mobile nodes, number of failed nodes and data redundancy. This type of network can be deployed to establish networks in different locations. In extensive applications such as command control centers, information between soldiers, vehicles, and weapon systems can be used in military battlegrounds. Business applications with the help of ad hoc network architecture are being used on a large scale to increase effectiveness and efficiency in corporate companies.

This type of network faces many challenges such as reducing energy consumption, managing persistent link failures between nodes due to dynamic behavior[3]. Seeing these challenges, various scientists and researchers have drawn attention to research related to these selections[4]. Due to this research work various technologies and equipment have been developed to face the challenges like residual energy consumption and transmission energy consumption. Multipath routing protocols have progressed to a very high level in the field of routing protocols.

Energy proficient Routing is a compelling method for diminishing the Energy utilization during the transmission in Mobile Ad hoc Network (MANET)[5]. All in all, connect disappointment in the system prompts fruitless transmission and makes retransmission of Packet from one node another. This adds up to the wastage of Energy of the nodes in the path. Hence, Energy effective Routing in impromptu systems is neither finished nor proficient without the consideration of connection appraisal before the transmission. Transmission on solid connected way upgrades the unwavering quality and nature of the ser-bad habit. It is alluring for a steering convention to adapt up to undesired-capable circumstance like connection disappointment and connection breakdown circumstance. This paper gauges Energy prerequisite for the effective transmission of parcel in the system. It thinks about conceivable utilization of Energy of each of the three sorts of node in the system.

With the help of this paper, the proper organization of AOMDV based multipath protocols with zone-based technology represents significant performance, inefficiently using resources and improving the life of nodes. The nodes are organized into groups of equal size by incorporating a large energy-efficient region-based network segmentation scheme. A comparison with previous analysis has shown that this research is more energy-efficient than previous single-path and multipath routing[6]. To complete the above mentioned paper, this dissertation has been divided into The introduction in section 1 deals with the introductory part of the above work. Section 2 Literature Review, Literature Review on Routing Problems, Energy Conservation, and Battery Life and Its Applications and Work in the Area Section 3 Identify the key parameters of the functionality, deal with detailed functional functions and mobile ad-hoc networks and brief description. Section 4 Results and discussion, simulation and description of network parameters in brief and analysis Simulated results with screenshots of the prepared interface. Section 5 concludes the overall work done in this research. Future work, highlights the scope of future work in the present subject.

2. Literature Survey

An Energy-Efficient multipath routing protocol has been proposed. Which is known as Ad-hoc On-Demand Multipath Routing with Lifetime Maximization (AOMR-LM)[7]. Through this protocol, the residual energy of the nodes is balanced by conserving the consumed energy, thus helping to extend the network lifetime. To achieve this goal, the node energy level has been calculated based on residual energy. In this work, only node energy levels based on residual energy are used. It does not include other parameters such as distance or node position that can be used to reduce the amount of energy consumed.

The Energy Aware. A Multi-path AODV protocol (EAMAODV) based on AODV has been developed to select energy efficient routes[8]. It has used nodes energy by upgrading the route maintenance process of AODV. Calculates the drop rate obtained with the help of total hop routes. The route is fixed using the drop threshold. It has also used residual energy and node energy of intermediate nodes simultaneously with drop rate. This protocol can be improved by developing a better drop rate and drop rate threshold based on network characteristics.

This protocol[9] has been developed to optimize energy consumption in ad hoc. Ad Hoc on Demand Multipath Distance vector protocol with fitness function (FF-AOMDV) has been developed by applying the fitness function technique. An attempt has been made to reduce energy consumption by using the fitness function. The technology used in this protocol can be modified using a zone-based network.

In this paper[10], a Power-Aware Multiple Path Multicast Adhoc On Demand Distance Vector (PAMPMAODV) for MANET is developed. Its main purpose was to use batteries in the future. Parameters such as hop count, end-to-end delay, and residual battery capacity have been used for route selection. Battery energy is used. Battery energy can be processed using PAMPMAODV.

In this paper[11], the author has summarized the findings by presenting the objectives of the research paper related to the cluster formation algorithm in a tabular form. Many researchers used the cluster formation algorithm to divide the network into a cluster. The network is divided into clusters in such a way that the control message can be reduced. Parameters such as CH selection criteria, clustering type, neighbor method, clustering parameters, partition type, number of clusters, energy consideration and re-clustering have been discussed by the reviewers. Simulation related data such as simulation parameters, mobility model and simulation matrix are also presented. Cluster formation algorithms should be designed based on the most important parameters. These parameters are, the remaining energy, degree, relative mobility (direction, speed), communication weight, confidence, reputation, and neighboring quality. The selection of the cluster scheme and the CH selection process should be done very carefully to make quality clusters. Any multi-purpose optimization technique (such as evolutionary algorithms, herd intelligence, neural networks, fuzzy logic, game theory, etc.) can be used to create a clusterMany researchers are working on various new energy-conscious algorithms using the concept of clustering. In this paper[12], the author an attempt has been made to analyze the various issues and challenges of the algorithm using clustering. Many network clustering algorithms have been proposed, keeping in mind the mobility of the nodes and power of the battery in MANET, Who have made various contributions to the growing life of the network. This algorithm is still swinging between different issues and challenges. There is still a need to be felt in this area that using a cluster should be developed a strong energy-aware algorithm which should be taken care of the criteria not considered by the research. Many network clustering algorithms have been proposed, keeping in mind the mobility of the nodes and power of the battery in MANET, Who have made various contributions to the growing life of the network. This algorithm is still swinging between different issues and challenges. There is still a need to be felt in this area that using a cluster should be developed a strong energy-aware algorithm which should be taken care of the criteria not considered by the research.

In this paper[13], AOMR-LM protocol works based on residual energy of nodes and balanced the consumed energy to increase the lifetime of network. Its multipath routing protocol based on AOMDV, with new path classification mechanism according to energy level of node forming these paths which can be high, low and average. The idea is to build paths in the terms of energy; this can balance the consumption energy of every nodes and avoid link failures due to node energy depletion. Increase the lifetime of network, Consume less energy and average end to end delay.

The main objective of this section of research is to address the problem arising from the review of the above literature.

- In MANET, concerns such as energy consumption, network life, overhead, floods and collisions in communication are among the most discussed concerns. These concerns should be removed.
- The sustainability of the zone in the MANET is a serious concern. Due to the rapid failure of the Zone, in the overall network of mobile ad-hoc networks, there is high energy consumption for low stability and recalculation of the zone.
- The selection of a leader node in zone-based techniques is one of the most important tasks. A leader node is the main node of a specific zone. Leader nodes play a special role in zone-based technology, which should be chosen very carefully. In the research work related to the previously done leader node selection method, the leader nodes are searched only by considering the hop count. Depending on the hop count, we cannot show the correct distance between the two nodes. Therefore, for the discovery of such networks, there should be an efficient energy-based routing protocol, which should take care of the energy level in each node.
- Zone-based technology has many problems, such as blockage of network communication from "death" of nodes due to lack of energy. The limited battery capacity of the leader node in the base technology affects the network's existence.
- Due to high mobility in MANETs, the nodes present in the network dynamically change their position. In this changing environment, there is a need to exchange explicit messages between the nodes. Thus, the exchange of information consumes a considerable amount of energy and bandwidth. Preventing this energy consumption has also become the concern of research for zone-based technology.

Considering the above problem related to the literature review, the following objectives have been included in this research.

- Realizing the existing energy conserving protocol for MANET.
- Identify the critical parameters of energy conservative protocol.
- Design a new energy conservation strategy /protocol based on the Zone-based approach.
- Implement newly design energy conservative protocol.
- Compare the result of the new design protocol with existing standards protocol.

Based on the above objectives, the Zone-based protocol is designed. Zone-based technology is used to improve network efficiency, energy consumption, expansion capacity, ease of navigation, and stability.

3. Zone-Based Technology

Zone-based technology is generally divided into two phases, zone formation, and zone maintenance. The process of building a zone structure for a MANET is released from the zone formation. How to update the zone structure during the underlying network topology change, its information and maintenance are described by the Zone Maintenance[14].

- **In the Zone Formation phase**, initially, each node is given a random ID value. It transmits its ID value to its neighbors and creates its neighborhood table. Each node ID in the network converts the weight to its neighbors. The tables created by receiving information from neighboring nodes include factors like communication range, battery power, node connectivity, and node distance. Where the number of nodes coming from the node connectivity to the transmission range is detected, which are able to communicate directly with the node. The information related to energy can be suppressed with the power of the battery. On the basis of node distance, its communication range is detected. The calculation of the weight of yourself and neighbor node is done with information received from the transmission node, reception power, and the remaining energy in each node. Each node conveys its received information to its neighbors. The Leader node is selected based on high transmission power, high reception power, and high remaining energy. After selecting the leader, it analyzes the transmission power and reception power. Power analysis is done on the basis of RSS[15].
- **In the Zone Maintenance phase,** after the formation of the zone, the leader nodes periodically send the residual energy level (battery power) of every node with the help of the HELLO message[16]. It is updated in

the routing table. As soon as a new node is added to the zone or the leader node fails, it is necessary to pick the fresh head node. Here, the energy of the node starts decreasing with time, every 10 seconds we have achieved a threshold value by selecting it on the basis of the remaining energy level. When the value of the leader node is less than the threshold value, then the leader node selects the new leader node again from the routing table with the process described previously. By using this zone-based technology developed.

The decomposition of networks into contiguous zones is called a zone-based network. The ZBLE protocol (Zone-Based Leader Election Energy Constrained AOMDV Routing Protocol) relies on a zone-based network. One node from each zone is chosen as the leader. Leader nodes are represented using criteria such as high battery power and power analysis. Connectivity through reliable intermediate nodes is established with the help of the leader node.

Zone Based Technology in Ad Hoc networks has many advantages compared to the traditional networks. They are as follows:

- It allows the better performance of throughput, scalability and power consumption.
- It helps to improve routing at the network layer by reducing the size of the routing tables.
- It decreases transmission overhead by updating the routing tables after topological changes occur.
- It saves energy and communication bandwidth in Mobile Ad-hoc networks.

4. Categorization According to Modeling Approach

In this area, we present a diagram of the various classes of Energy framework models. The classification is made by the demonstrating approach as opposed to the framework limit. Figure 4 outlines the division into three classes: computational, numerical, and physical models. The division among computational and numerical models is clarified by Fisher and Hen zinger: computational models are a succession of directions that can be executed by a PC, yet scientific models are a progression of conditions that indicate connections between various significant factors and boundaries. The improvement of numerical models went before the utilization of PCs. Be that as it may, approximations to scientific models are generally evolved utilizing numerical strategies, which would then be able to be understood (or recreated) utilizing a PC[17].

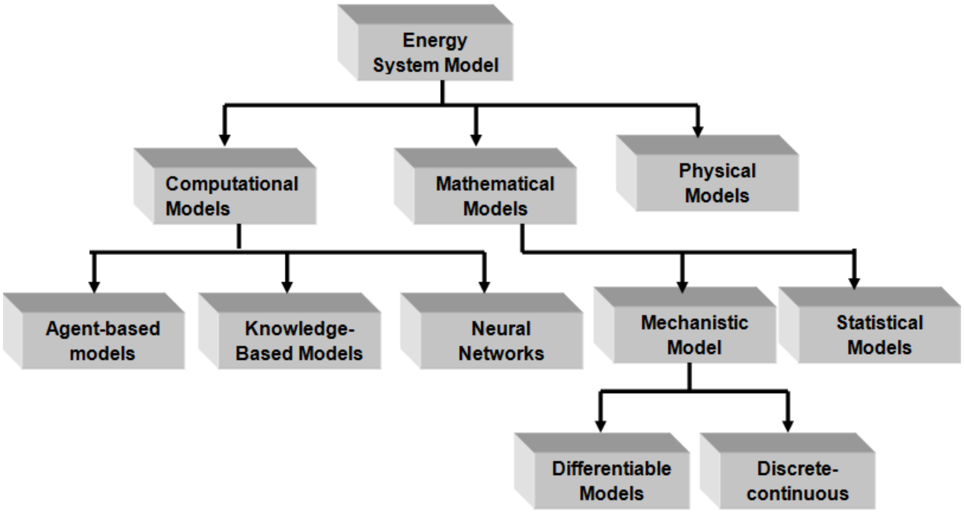

Fig.1. Classification of energy system models according to modeling approach

5. Zone Based Model

A zone-based architecture has been used to create mobile ad-hoc networks. The energy of the nodes in the network is used to determine whether any of them are capable of sending data. The initial battery power is used to mark each node. Over time, the energy label's strength diminishes. The energy threshold value is used to identify the energy of a specific node. The threshold value is used to assess the ability of nodes to transfer data. Only at a point greater than or equal to the power threshold can the node communicate. The process is continued by picking the most energetic nodes as the leader nodes. Using power analysis for transmission and reception energy, the cost of transmission energy is calculated to RSS (received signal strength). The route is accepted and processed based on the RSS (received signal) cost of transmission energy. The mobility model is used to start the source and destination search. This protocol may also retrieve the number of devices in each zone, the selection of leader nodes, and knowledge of nearby nodes by utilizing the random mobility model to obtain the start and finish positions of all nodes, as well as the number of devices in the range of their zones. Can assist in data transmission. The representation of the power signal is used to examine the leader node, transmission energy, and reception energy[18]. The most dependable path has been chosen. The leader node, transmission energy and reception energy are analyzed through the representation of the power signal. The most reliable path has been selected through the RSS value.

6. Mathematical Formulation of Zone based Model

Lemma's system parameters such as packet loss, node mobility, and protocol overhead are included for analysis to verify the zone based algorithm by preparing a set of Lemma[19].

6.1 Lemma-1

The term dynamics has been used to refer to the average speed of a node. The lemma has ensured that routing overheads increase with mobility. Equations (1) and (2) can be used to express this very simply.

$$ZM_1 > ZM_2,\ \phi_{PZ}(ZM_1) > \phi_{PZ}(ZM_2) \quad (1)$$

$$ZM_1 > ZM_2,\ \phi_{RZ}(ZM_1) > \phi_{Rz}(ZM_2) \quad (2)$$

Routing overhead with the help of protocols is very important for managing the information of nodes in any network. The number of routing packets can be used for the transmission of a single data packet. With no mobility in the wired network, route discovery and routing overhead are done only once. In contrast, the presence of dynamic topology in ad hoc networks often requires route detection. By changing the topology of the network more frequently, mobility succeeds in generating the multiplier effect. Due to this high mobility, route maintenance also has to be taken care of In which the need for more route search makes the possibility of high routing overhead.

Assume that all nodes present in the network have the probability zp_r of trying to retrieve the RREQ packet at its destination. The zm hops to reach the destination and the average destination is ZN_{avg}. Thus the routing overhead is zp_r x ZN_{avg} for the first hop. This is illustrated with the help of equation (3) by re-representing the entire route overhead present in the network from the source to the destination.

$$ZR_e = 1 + zp_r.ZN_{avg}.ZN_f + zp_r^2.ZN_{avg}ZN_f^2 + \cdots + zp_r^m.ZN_{avg}.ZN_f^{m-1} \quad (3)$$

The route request packet RREQ is received using ZN_f to represent the number of all neighbors of any node in the network. The same RREQ packet is rebroadcast with the probability zp_r again in the next hop. The sum of finite geometric progression is shown in equation (3). Simultaneously, ZRe reduces to equation (4).

$$ZR_e = 1 + zp_r.ZN_{avg}\sum_{i=0}^{m-1}\left(zp_r.ZN_f\right)^i \quad (4)$$

Reactive routing protocol e.g. AODV where intermediate nodes always have rebroadcast. In this case $zp_r = 1$ is set and we get

$$ZR_e = \begin{cases} 1 + zp_r.ZN_{avg}\left(\frac{1-\left(zp_r.ZN_f\right)^m}{1-zp_r.ZN_f}\right) for\ \ any\ zp_r\ and\ ZN_f \\ 1 + zm.zp_r.ZN_{avg} if\ zp_r ZN_f = 1 \end{cases} \quad (5)$$

The frequency of route discovery increases as the mobility of nodes increases.

Overhead is expressed in the search for a single route with the help of equation (5). This proves that overhead routing increases with the mobility of nodes.

6.2 Lemma-2

Packet loss percentage also increases with node mobility. Equations (6) and (7) have been used to express this.

$$ZM_1 > ZM_2,\ ZPL_p(ZM_1) > ZPL_p(ZM_2) \quad (6)$$

$$ZM_1 > ZM_2,\ ZPL_R(ZM_1) > ZPL_R(ZM_2) \quad (7)$$

Proof

As indicated in Lemma 1, it can be said that the increase in the mobility of a node is due to the increase in route discovery process resulting from the failure of continuous link failure. Thereby improving the possibility of packet loss with link failure. As a conclusion it has been concluded that as the mobility increases the packet loss percentage also increases.

ZM_1 And ZM_2 have been used to denote varying values of mobility. The packet loss function is represented by mobility with derivatives ZPL_p (ZM)> = 0 and ZPL'_r (M)> = 0.

6.3 Lemma-3

It can be easily demonstrated by equation (8), that the energy consumption in the active and reactive protocols increases with node mobility.

$$ZM_1 > ZM_2 \; then \; ZE(ZM_1) > ZE(ZM_2) \tag{8}$$

Proof:

The amount of energy consumed by the protocol is represented using equation (9). Various paid costs such as route discovery(ZRD) and route maintenance(ZRM) performance are illustrated by the cost paid in the sum of energy consumption.

$$ZE^p = ZE_{RD} + ZE_{RM} \tag{9}$$

ZE p has been used to represent the energy consumed. The various notations used for energy consumed are designed to route maintenance to ERD and ERM. RREQ packets in route search and the energy cost in RREP packets are expressed from equation (10).

$$\begin{cases} \sum_{R_i=1}^{Rmax}\left(ZE_{R_i}\right)ZR_i \; if \; no \; RPEP \; received \\ ZErrep + \sum_{j=1}^{j=n_{rrep}}(RREP)_j \; if \;\; Rrrep = 1 \\ \sum_{R_i=1}^{R_{rrep}}\left(ZE_{R_i}\right)ZR_i + \sum_{j=1}^{j=n_{rrep}}(RREP)_j \; otherwise \end{cases} \tag{10}$$

ZR_{zrerep} and zrrep are taken to be the same in the RM process by expressing the energy consumption from equation (11).

$$ZE_{RM} = ZE_{mon} + ZE_{LLR} + \sum_{k=0}^{k=j}(ZRREP)_k \tag{11}$$

Consumption link monitoring energy is denoted by ZE^p. The calculation of the total energy consumed from equations (10) and (11) can be obtained as a sum. Increasing the mobility of nodes leads to routing overhead with associated energy consumption.

7 Results and Discussion

The zone-based multipath routing protocol ZBLE is demonstrated experimentally in this section. This protocol is designed with the enhancement of the famous routing protocol AOMDV. Various enhancements such as throughput, network lifetime, routing overheads, and energy consumption are incorporated to refer to this enhancement with well-known existing protocols. In addition, various lemons have been formally demonstrated to prove this. For simulation is demonstrated using NS2.35. A random dynamics scenario is selected for this simulation. All the parameters used in this simulation are represented with the help of Table 1. A rectangular area 1507 m x 732 m has been used to randomly distribute nodes in the simulation area.

Table 1.Simulation Parameters

Parameters	Value
Simulator	NS2.35
Simulator Area	1507 m x732 m
Number of nodes	50,75 and 100 nodes
Node Speed	3, 5, 7 and 9 Meter/second
Queue size	50 packets
Studies Routing Protocols	AODV, AOMDV& ZBLE
Data Payload	1000, 1100, 1200 & 1300 bytes/packet
Initial energy	50 joule
Idle Power	0.100
Sense Power	0.0175
Energy Consumption of transmitting data	0.35 J/bit
Energy Consumption of receiving data	0.35 J/bit
Traffic Type	CBR
Simulator Time	100, 200, 400 and 600
Channel Type	Wireless channel
MAC type	802.11
Mobility	Random Way point
Antenna Scenario	Omni

This section shows the results of Simulation. After implementing protocols in NS2.35 simulator some screenshot of network topology is shown in Figure 2.

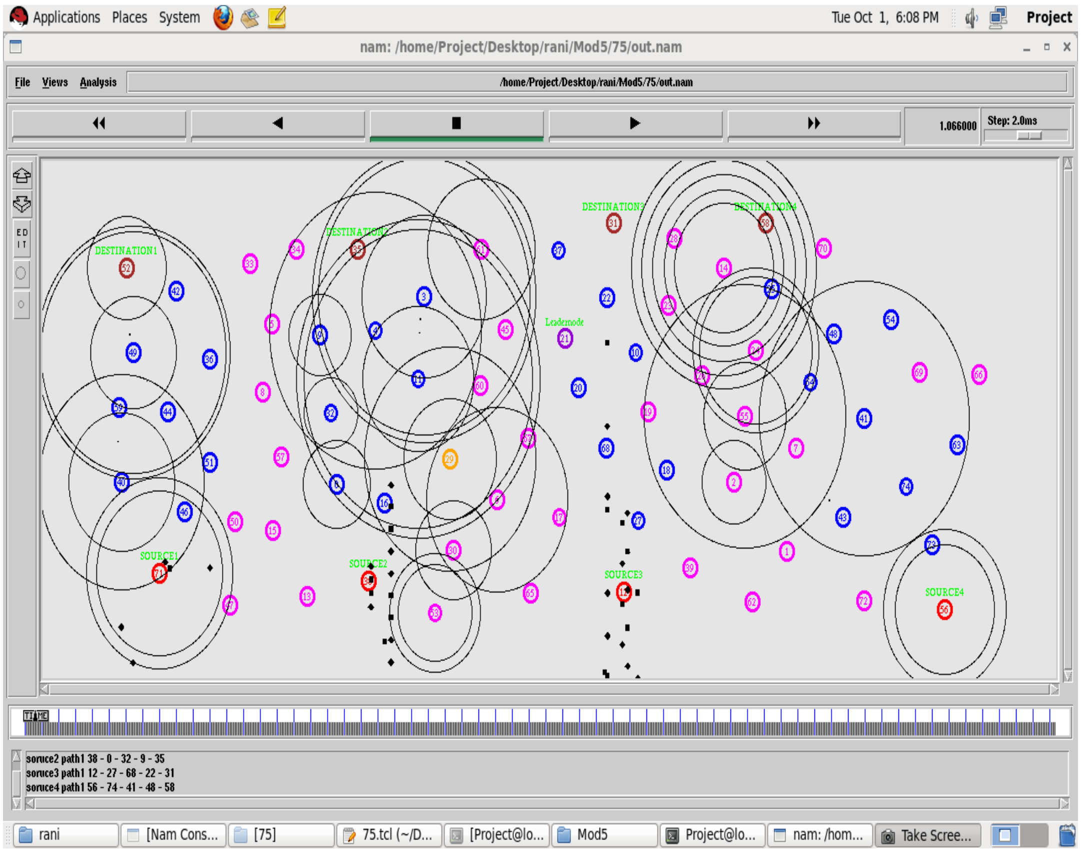

Fig. 2. Network Simulator Windows

7.1 Throughput

Table 2 shows the throughput data, whereas Table 3 shows a comparison of the ZBLE protocol with the AODV and AOMDV protocols. Figure 3 depicts the simulation outcome as a graph. The simulation results demonstrate the impact of varied node speeds on Throughput numbers. The node's throughput is assessed at three different speeds: 3, 5, 7, and 9 metres per second.

Table 2. Throughput of AODV, AOMDV and ZBLE with different speeds of node

PROTOCOLS	**SPEED OF NODES VS THROUGHPUT**			
	3	**5**	**7**	**9**
AODV	8752.32	4313.88	6911.60	7643.07
AOMDV	10110.70	11860.34	5622.18	4940.08
ZBLE	14831.45	12009.58	9218.64	9597.85

Table 3. Throughput comparison of ZBLE with AODV and AOMDV

SPEED OF NODES in second	**3**	**5**	**7**	**9**	**Average/overall**
ZBLE compared to AODV	40.98%	64.07%	25.02%	20.36%	39.50%
ZBLE compared to AOMDV	31.82%	1.24%	39.01%	48.52%	28.74%

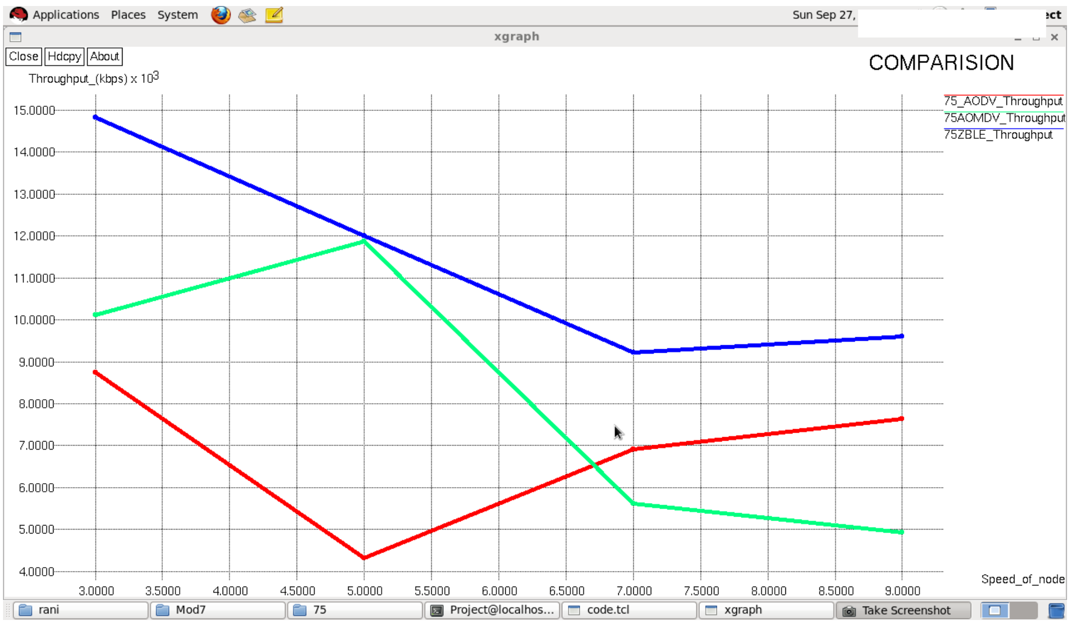

Fig. 3. Throughput comparison based on Scenario 3

7.2 Energy Consumption

The data related to Energy Consumption are shown in Table 4 and in Table 5 a comparison of the ZBLE protocol is related to the AODV and AOMDV protocols. In this simulation, the graph related to scenario 1 is shown in Figure 4. Simulation results show the effect based on different speeds with the variation of energy consumption. Speed of nodes is varied as 3, 5, 7, 9 meters per second.

Random movement takes nodes in different directions for different runs. In these protocols, as the node speed increases, different flows occur. As the mobile node accelerates, the flow of the three protocols is affected. The energy consumption performance is evaluated through the speed of different nodes. Energy in relation to the speed of different nodes in the table Consumption performance is shown. For ZBLE, the source node consumes less energy through the route with the highest level of energy and less energy with the least distance.

Table 4. Energy Consumption of AODV, AOMDV and ZBLE with different Number of Nodes

PROTOCOLS	SPEED OF NODES VS ENERGY CONSUMPTION			
	3	5	7	9
AODV	195.862	180.739	195.817	180.504
AOMDV	196.17	196.69	195.989	180.779
ZBLE	173.465	173.441	173.418	173.369

Table 5. Energy Consumption comparison of ZBLE with AODV and AOMDV

SPEED OF NODES in second	3	5	7	9	Average/overall
ZBLE compared to AODV	11.43%	4.03%	11.43%	3.95%	7.86%
ZBLE compared to AOMDV	11.57%	11.82%	11.51%	4.09%	9.86%

It is clear from this figure and the table that the ZBLE routing protocol has seen a higher drop in energy consumption than both AOMDV and AODV in terms of energy consumption. ZBLE provides an average improvement of 7.86% over AODV and 9.86% better over AOMDV.

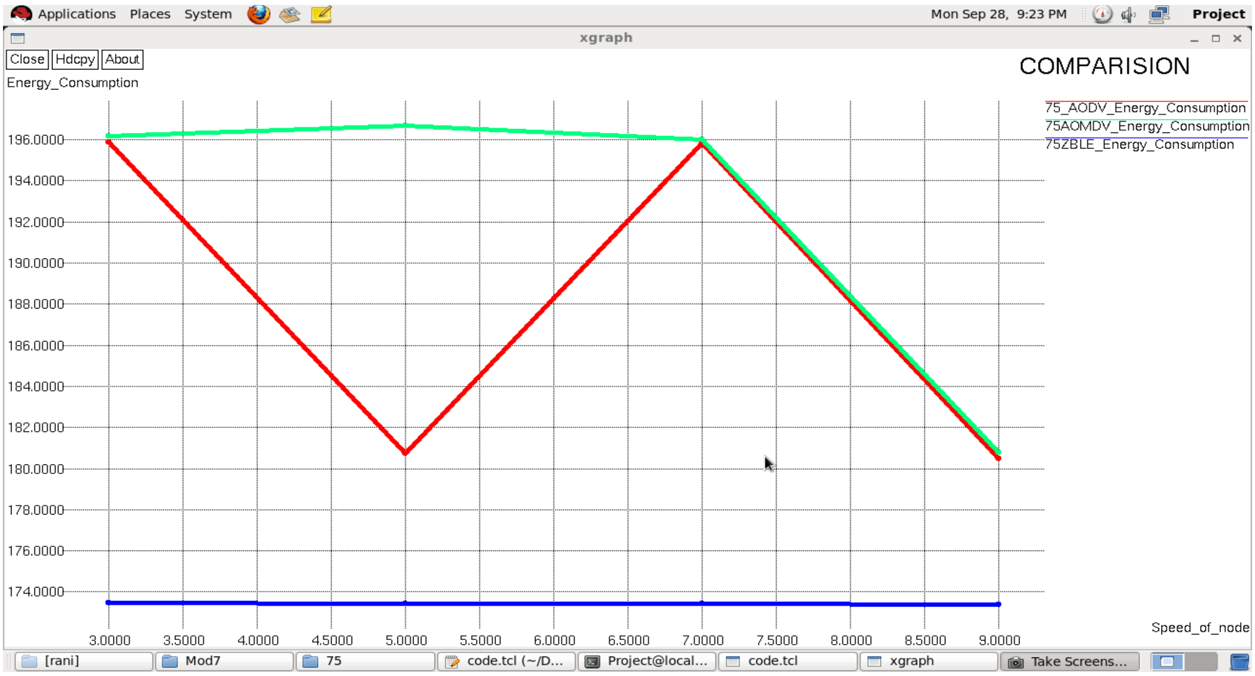

Fig. 4. Energy Consumption comparison based on Scenario 3

7.3 Network Lifetime

Network lifetime shows simulations based on different speeds of a node such as 3, 5, 7, 9 meters per second. The data related to this are shown in Table 6 and the data related to the comparison of both the AODV and AOMDV protocols to the ZBLE protocol is shown in Table 7. In this simulation AODV, AOMDV and ZBLE are shown in Figure 5 for Network Lifetime.

Table 6. Network lifetime of AODV, AOMDV and ZBLE with different Number of Nodes

PROTOCOLS	SPEED OF NODES VS NETWORK LIFETIME			
	3	5	7	9
AODV	4.13794	19.2605	4.18309	19.496
AOMDV	3.83044	3.30996	4.01126	19.2215
ZBLE	26.5354	26.5594	26.5817	26.6313

Table 7. Network lifetime comparison of ZBLE with AODV and AOMDV

SPEED OF NODES in second	3	5	7	9	Average/overall
ZBLE compared to AODV	84.40%	27.48%	84.26%	26.79%	55.71%
ZBLE compared to AOMDV	85.56%	87.53%	84.90%	27.82%	71.42%

The ZBLE routing protocol has better performance than both AOMDV and AODV in terms of Network Lifetime. The average improvement in ZBLE at AODV is 55.71% and at AOMDV is 71.42%.

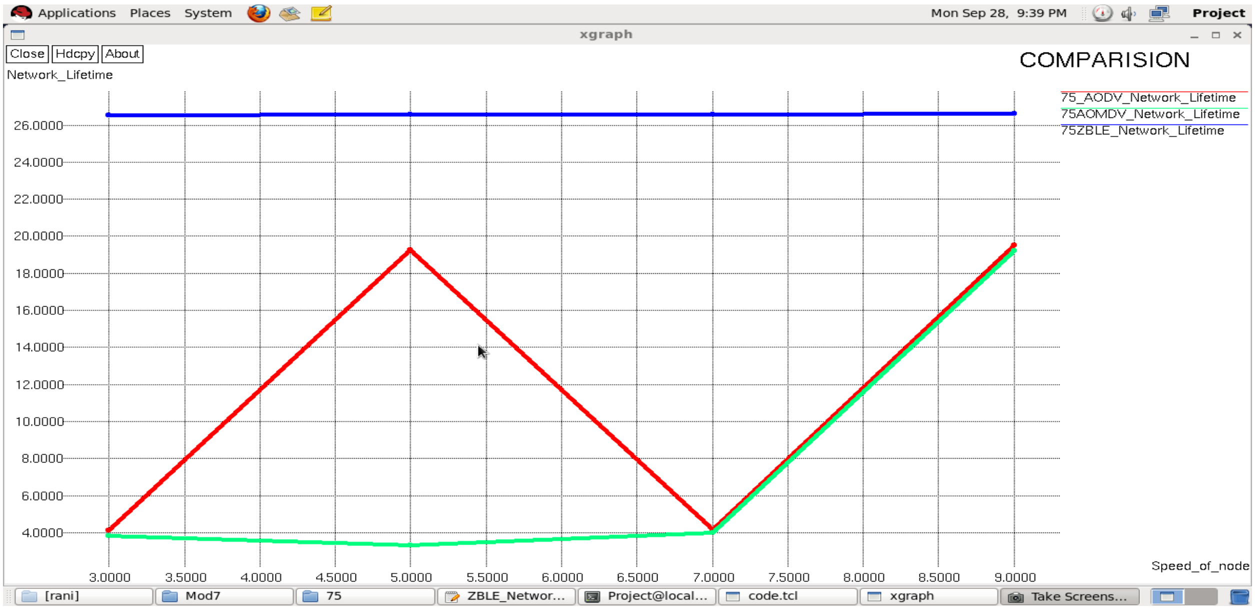

Fig. 5. Network Lifetime comparison based on Scenario 3

7.4 Routing Overhead

Table 8 shows the information on Routing Overhead. Table 9 shows a comparison of the ZBLE protocol with the AODV and AOMDV protocols. Figure 6 depicts the simulation result of routing overhead as a graph. The simulation results indicate the impact of varying node speeds on routing overhead levels. The routing overhead is calculated using node speeds of 3, 5, 7, and 9 metres per second.

Table 8. Routing Overhead of AODV, AOMDV and ZBLE with different Number of Nodes

PROTOCOLS	SPEED OF NODES VS ROUTING OVERHEAD			
	3	5	7	9
AODV	117346.000	83997.000	141451.000	125109.000
AOMDV	46965.000	45868.000	48592.000	32447.000
ZBLE	39014.000	16690.000	14987.000	12511.000

Table 9. Routing Overhead comparison of ZBLE with AODV and AOMDV

SPEED OF NODES in second	3	5	7	9	Average/overall
ZBLE compared to AODV	66.75%	80.13%	89.40%	89.99%	82.21%
ZBLE compared to AOMDV	16.92%	63.61%	69.15%	61.44%	52.14%

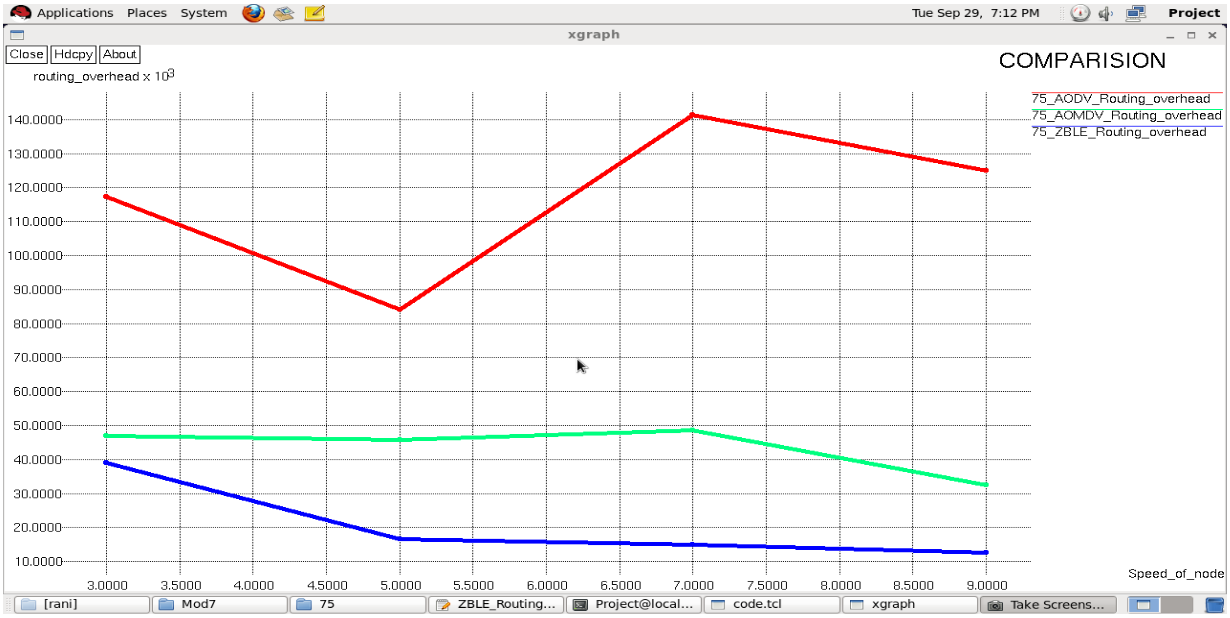

Fig. 6. Routing Overhead comparison based on Scenario 3

In terms of routing overhead, the ZBLE routing protocol outperforms both AOMDV and AODV. In ZBLE, the routing overhead reduction is 82.21 percent at AODV and 52.14 percent at AOMDV.

8 Conclusion & Future Prospects

The ZBLE protocol, which is an enhancement on the AOMDV and AODV protocols, is an energy efficient zone principally based multipath routing protocol using zone approach. In this study, the current ZBLE beats current algorithms in terms of throughput, routing overhead, network longevity, and energy consumption, particularly AOMDV and AODV. This is due to the fact that the ZBLE protocol requires nodes to send packets to destinations in their immediate vicinity. In comparison to the AOMDV and AODV protocols, the experimental results reveal that ZBLE minimizes routing overhead, network lifetime development, throughput, and energy consumption.

The zone-based technology approach implemented to avoid energy consumption is probably followed by the suggestions below. They can be done as future work for the Attainment of better test results. This research work mainly focuses to design an optimal route finding strategy to enhance the lifetime of the network. Currently, WN has deployed zone-based technology to the IPv4 network. In the future, we can compare the performance of the network by extending the research work by applying it to the IPv6 network[20]. Zone sizes can be considered, especially in large networks. Its results can be attainment when applied to large-scale networks. In the future, we look forward to testing it on large-scale networks in real-time scenarios. The impact of ZBLE implementation has not been shown on jitter. In the simulation of future work, it is necessary to take care of this parameter. One can also compare performance by applying algorithms other than AOMDV for the optimal path of the network.

References

[1] D. Kaur and N. Kumar, "Comparative analysis of AODV, OLSR, TORA, DSR and DSDV routing protocols in mobile ad-hoc networks," *International Journal of Computer network and information security*, vol. 5, no. 3, p. 39, 2013.

[2] R. Fotohi, S. Jamali, and F. Sarkohaki, "Performance evaluation of aodv, lhc-aodv, olsr, ul-olsr, dsdv routing protocols," *International Journal of Information Technology and Computer Science (IJITCS)*, vol. 5, p. 21, 2013.

[3] D. K. Sharma, A. N. Patra, and C. Kumar, "An update based energy-efficient reactive routing protocol for mobile Ad Hoc networks," *International Journal of Computer Network and Information Security*, vol. 5, no. 11, p. 17, 2013.

[4] M. C. Aye and A. M. Aung, "A Modified Energy Constrained Protocol based on AOMDV for Mobile Ad-Hoc Networks," *International Journal of Scientific Engineering and Technology Research*, vol. 3, no. 35, pp. 7013-7018, 2014.

[5] K. Khan and W. Goodridge, "Energy aware Ad-Hoc on demand multipath distance vector routing," *International Journal of Intelligent Systems and Applications*, vol. 7, no. 7, pp. 50-56, 2015.

[6] K. Rajasekaran and K. Balasubramanian, "Energy conscious based multipath routing algorithm in WSN," *International Journal of Computer Network and Information Security*, vol. 8, no. 1, p. 27, 2016.

[7] O. Smail, B. Cousin, R. Mekki, and Z. Mekkakia, "A multipath energy-conserving routing protocol for wireless ad hoc networks lifetime improvement," *EURASIP Journal on Wireless Communications and Networking*, vol. 2014, no. 1, p. 139, 2014.

[8] N. M. Lutimath, L. Suresh, and C. Naikodi, "Energy Aware Multipath AODV Routing Protocol for Mobile Ad hoc Network," *International Journal of Engineering Research ISSN*, pp. 2319-6890, 2016.

[9] A. Taha, R. Alsaqour, M. Uddin, M. Abdelhaq, and T. Saba, "Energy efficient multipath routing protocol for mobile ad-hoc network using the fitness function," *IEEE access,* vol. 5, pp. 10369-10381, 2017.
[10] S. Vijayaragavan, K. Duraiswamy, B. Kalavathi, and S. Madhavi, "Power-aware multiple path multicast adhoc on demand distance vector routing protocol," *IJCA special issue on Mobile Adhoc Networks MANETs,* 2010.
[11] F. Abbas and P. Fan, "Clustering-based reliable low-latency routing scheme using ACO method for vehicular networks," *Vehicular Communications,* vol. 12, pp. 66-74, 2018.
[12] P. Patil and M. Rizvi, "Issues and Challenges in Energy Aware algorithms using clusters in MANET," *International Journal,* vol. 2, no. 2, 2013.
[13] M. Ahmad, A. Hameed, A. A. Ikram, and I. Wahid, "State-of-the-art clustering schemes in mobile ad hoc networks: objectives, challenges, and future directions," *IEEE Access,* vol. 7, pp. 17067-17081, 2019.
[14] R. Sahu, S. Sharma, and M. Rizvi, "ZBLE: zone based leader election energy constrained AOMDV routing protocol," *International Journal of Computer Networks and Applications,* vol. 6, no. 3, pp. 39-46, 2019.
[15] N. Patwari and A. O. Hero III, "Using proximity and quantized RSS for sensor localization in wireless networks," in *Proceedings of the 2nd ACM international conference on Wireless sensor networks and applications*, 2003, pp. 20-29.
[16] I. D. Chakeres and E. M. Belding-Royer, "The utility of hello messages for determining link connectivity," in *The 5th International Symposium on Wireless Personal Multimedia Communications*, 2002, vol. 2, pp. 504-508: IEEE.
[17] J. Fisher and T. A. Henzinger, "Executable cell biology," *Nature biotechnology,* vol. 25, no. 11, pp. 1239-1249, 2007.
[18] R. Sahu, S. Sharma, and M. Rizvi, "ZBLE: Zone Based Leader Selection Protocol," 2019.
[19] N. Sharma, F. Nocera, and P. Gardoni, "Classification and mathematical modeling of infrastructure interdependencies," *Sustainable and Resilient Infrastructure,* vol. 6, no. 1-2, pp. 4-25, 2021.
[20] V. Jain, D. Tiwari, S. Singh, and S. Sharma, "Impact of IPv4, IPv6 and Dual Stack Interface over Wireless Networks," *International Journal of Computer Network & Information Security,* vol. 10, no. 4, 2018.

Authors' Profiles

Mr. Vinay Sahu received BE. Degree (Hons) from BU, Bhopal in 2009. He is working in LNCT, Bhopal. Her research interests include Routing Protocol, Mobile Ad-Hoc Network.

Dr. Rani Sahu is an Assistant Professor of Computer Engineering & Applications in UIT, RGPV, Bhopal, and Madhya Pradesh, India. She obtained his PhD degree from MANIT Bhopal. His research interest is in the field of Network, Image processing, Data security, Data mining, E-learning, Cloud computing, Neural, Machine learning, intelligent tutoring system and more. She is having strong International connections and contribution in research events. He has published approximately (10) International Journals & conferences papers.

How to cite this paper: Vinay Sahu, Rani Sahu, "Energy Efficient Multipath Routing in Zone-based Mobile Ad-hoc Networks: Mathematical Formulation", International Journal of Mathematical Sciences and Computing(IJMSC), Vol.8, No.3, pp. 37-48, 2022. DOI:10.5815/ijmsc.2022.03.04