




Article

Energy Saving Optimization Technique-Based Routing Protocol in Mobile Ad-Hoc Network with IoT Environment

Vinoth Kumar Krishnamoorthy ¹, Ivan Izonin ², Sugumaran Subramanian ³, Shishir Kumar Shandilya ⁴, Sivasankaran Velayutham ^{5,*}, Thillai Rani Munichamy ^{6,*} and Myroslav Havryliuk ²

¹ Department of Electrical and Electronics Engineering, New Horizon College of Engineering, Bengaluru 560103, India

² Department of Artificial Intelligence, Lviv Polytechnic National University, 79013 Lviv, Ukraine

³ Department of Electronics and Communication Engineering, Sreenivasa Institute of Technology and Management Studies, Chittoor 517127, India

⁴ School of Computing Science and Engineering, VIT Bhopal University, Bhopal 466114, India

⁵ School of Electrical and Electronics Engineering, VIT Bhopal University, Bhopal 466114, India

⁶ Department of Electronics and Communication Engineering, Sri Krishna College of Technology, Coimbatore 641042, India

* Correspondence: pvs.sankaran@gmail.com (S.V.); thillairani.m@skct.edu.in (T.R.M.)

Abstract: The Mobile Ad-hoc Network is a self-configuring decentralized network, where the network topology is dynamically modifiable. The IoT (Internet of Things) based Wireless Sensor Network contains more sensors and shares information over the Internet to a cloud server. However, the IoT-based wireless sensor network channel has moderate security is poor compared to MANET and packet loss is increased due to attackers. In IoT, all the sensors forward the detected data frequently to the internet gateway, so the energy saving in the network is low compared to MANET. In this work, the smart environment of IoT, Wireless Sensor Networks (WSN) and MANET make a great heterogeneous network in IT Technology; the combination of this heterogeneous network has new challenging issues. In this heterogeneous network, MANET provides a trusted route between the sensor to gateway nodes into the IoT environment using Energy Saving Optimization Techniques [MANET-ESO in IoT]. It saves energy for each node and reduces the economic level. The results of the ns-3 simulation show that the proposed method provides better results in Alive node counts, residual Energy, throughput, packet delivery ratio and routing overhead.

Keywords: heterogeneous network; IoT; MANET; internet; cloud



Citation: Krishnamoorthy, V.K.; Izonin, I.; Subramanian, S.; Shandilya, S.K.; Velayutham, S.; Munichamy, T.R.; Havryliuk, M. Energy Saving Optimization Technique-Based Routing Protocol in Mobile Ad-Hoc Network with IoT Environment.

Energies **2023**, *16*, 1385. <https://doi.org/10.3390/en16031385>

Academic Editor: Oscar Barambones

Received: 22 December 2022

Revised: 11 January 2023

Accepted: 23 January 2023

Published: 30 January 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

The nodes of the Mobile Ad-hoc Network (MANET) are the group of self-organized mobile nodes that are deployed randomly without predefined models. These mobile nodes follow adhoc modelling for data communication in the absence of a router or any centralized devices. MANETs are widely applied for observing terrestrial abnormalities such as earthquakes, forest disasters and other natural disasters. Generally, MANETs are deployed with a vast amount of adhoc nodes to cover a wide range of geographical areas to detect notable natural objects. In this case, the Internet of Things (IoT) is considered a decentralized MANET environment. IoT base is required to take MANET observations into the internet domain, or any processing node (cloud system) deployed outside the local network domain. In the same manner, WSN is a type of network that contains resource-limited sensor nodes with a homogeneous type of internal components. In this work, WSN has mostly energy-limited sensor nodes than MANET nodes. In addition, sensor nodes deployed under the WSN environment need a gateway node to reach the outer network. The combination of MANET and WSN under an IoT environment creates heterogeneous network characteristics. Under this environment, energy optimization and routing protocol

optimization are challenging tasks. This work takes this challenging research problem to be solved.

The MANET topology changes dynamically between multiple nodes, Jamali et al. [1] and Devi et al. [2]. The routing protocols are providing a route from source to destination. At the same time, various types of routing attacks in the network are reducing the performance of the network and minimizing the rate of transferred packets from sender to receiver, Kumar Debnath et al. [3]. This kind of problem can be solved using the trust route method. Initially, available routes are identified using the route discovery process. Finally, the best and trusted route is selected from the available routes with the support of optimization techniques. WSN nodes are spatially dispersed and linked to the wireless medium, Hu, Z et al. [4]. The sensors collect data from the physical environment and transmit the data to a centralised location, Khokhlovova et al. [5]. The nodes of the IoT environment can collect, control and monitor environmental data such as weather, forecast, object detection, gas leakage, etc. In an IoT environment, the collected information is stored and processed in the cloud system.

The MANET carries more data than the WSN, but the WSN consists of more sensors than the MANET, Ray, S et al. [6] and Jayalakshmi et al. [7]. The number of WSN sensor nodes is static and sensor nodes consume less energy than a MANET node. In contrast, node mobility is higher in MANET than in WSN. The MANET provides better power utilization and increases network lifetime through various energy-saving routing algorithms. The MANET is a special network, it utilizes less amount of energy with good scalability. In a MANET, the energy-saving mode increases the lifetime of each node's energy level and controls energy utilization by the appropriate selection of the energy-saving algorithm.

The MANET connects the nodes to the Internet through the gateway node. The gateway node acts as a connector to connect the MANET node to the Internet. The source MANET node is connected directly to the gateway node, or connected to the gateway node with the support of the adjacent node. The gateway node connects the different networks by MANET routing protocol and DNS server.

In this paper, the destination node gathers all of the sensor nodes' details, like protocol address, position and mobility rate (meters/second) in MANET. Here, IoT communication is established by WSN, MANET and the Internet. Consequently, this kind of network is represented as a heterogeneous network. The source sensor nodes detect the physical information and transfer the data to destinations through a multi-hop fashion. The clustering method is used to form the MANET. The cluster node reduces power wastage while transmitting and receiving the data. Finally, the data is forwarded to the gateway node to reach the internet server point. The gateway node is connected to a cloud network and the cloud system collects the data and stores the details.

The following conditions are considered in the research:

1. Cluster Network: More than one sensor node is connected as a cluster in the MANET. Each cluster is connected through a selected cluster head.
2. Routing Protocol: MANET considers an optimized routing protocol to determine the shortest route between sensors to the gateway node.
3. Internet and IoT: Data collected from various nodes are stored in the internet cloud server.

The IoT is a recent technology widely applied in this electronic world. Generally, the open wireless medium has poor security and utilizes more energy to sense the data and transmit the data to the nearest gateway. The recent works developed for wireless data communication use secure internet protocol functions and transport layer functions. In this network, neighbouring sensor nodes are formed into a small group by one MANET node is called a cluster network. In the cluster, MANET nodes act as cluster heads (CH) to forward the information between sensors. This cluster formation is reducing the bandwidth utilization rate and increasing the sensor node's lifespan. In addition, MANET is creating a trusted route and shortest route between sensors in the Internet Cloud.

Generally, clusters are created in MANET to easily organise the topology. In this manner, recent techniques use various energy-efficient clustering approaches for improving

the performance of routing protocol. On the scope, clustering algorithms such as Low Energy Adaptive Clustered Hierarchy (LEACH) is a well-known algorithm for choosing the cluster heads based on optimal energy constraints. LEACH is a cluster formation protocol in a tree-based (hierarchical) network environment. Notably, the clusters of mobile nodes or sensor nodes are formed under the base station (centralized control centre). Clusters of nodes under each base station provide hierarchical network architecture. The IoT environment of cluster nodes can communicate with other cluster nodes through a centralized base station (control unit). In this case, cluster heads (nodes with the highest residual energy) can reach the base station for communicating the data [8].

In the same manner, real-time challenges and flat architectures in making MANET clusters are significantly noted by various research works. Unlike hierarchical IoT structures, flat network clusters can be formed for the distributed scenario. Particularly, flat networks deploy multiple gateway nodes for collecting the field node's data through cluster heads. The chosen gateway nodes are deployed in each cluster. In this method, cluster heads and other cluster nodes that are nearer to gateway nodes of neighbour clusters can communicate with each other. This kind of mechanism reduces energy overhead happens in each cluster head. Thus, the effective formation of clusters creates a crucial impact on energy-efficient data communication in IoT environments (hierarchical and flat networks) [9].

In this article, the MANET-ESO performance in the IoT environment is experimented with using the modules such as clustering principles, MANET-based on-demand routing process, IoT data collection process and trusted route establishment policies.

The simulation environment is created by MANET mobile nodes and Wireless sensor nodes with Internet (cloud network). The Sensor nodes are divided into small clusters and grouped by Mobile Ad-hoc nodes. Upon the validation of energy levels, nodes are assigned as CH to control sensor nodes. The routes are discovered from the sensor source to the gateway node with the help of the MANET cluster and on-demand routing protocol. The best route is evaluated by the total energy of the route, time is taken from source to destination and minimum hop count. In this method, IoT communication is stabilized over a long period of time using node energy level. In this case, the trust validation algorithm improves the packet delivery ratio, throughput, and reduces the routing overhead of the selected route among clusters.

The rest of this paper follows as: Section 2 expresses the literature review of problem formulation. Section 3 offers suggestions for network topology measurement tools. Section 4 describes the suggested approach for heterogeneity network utilising MANET-ESO in IoT Algorithm. The simulation and algorithm results are discussed with various parameters in Section 5. Section 6 is concluding the article with future work.

2. Literature Survey

To enhance the performance of MANET and IoT environments, the authors suggest a new routing protocol. The existing techniques are compared in this section. The Dynamic Critical Node Identification (DCNI) method was suggested by the authors Jayalakshmi et al. [7] and Hou, Y.T. et al. [10], who also identified the MANET-IoT network critical nodes. In this section, the currently used methods are contrasted. The DCNI approach controls the dynamically changing topology to identify fusion nodes in one topology. The outcome of DCNI supports the identification of the crucial nodes and results with enhanced quality and time complexity. However, only simple DOS attacks were used to evaluate the DCNI technique, Alam et al. [11]. The author Niu Z et al. [12] and Narayandas et al. [13] discusses the operation of MANET systems in IoT. This is a basic MANET with an IoT technique that already exists. This technology uses programmers to run the MANET, where some systems have more end devices.

The Dynamic Range Clustering (DRC) method with a learning-based routing scheme implements the load balancing strategies that are optimising the performance of MANETs, Aroulanandam V et al. [14] (LR). The management of network data and energy is improved by this strategy. The cluster has increased network stability with distinctive neighbours for

learning-based routing and enabled non-congested data transformation at various network traffic rates. Because of the dynamic topology, the LR method's delay time is getting longer.

A new multi-objective scheme in a heterogeneous network is introduced as a multi-characteristics model by Amiri et al. [15]. This scheme achieves better throughput, energy usage, packet delivery ratio, fewer dead nodes throughout more rounds, and increased network lifetime. Using various network metrics, the cluster creates the network path and transfers the data from the source node to the neighbour node. However, large routing networks have little fault tolerance and significant delay times in this case.

To avoid the pitfall of becoming stuck in local optima, the author devised the Energy Efficient Cluster Head Selection Using Improved Sparrow Search Algorithm (EECHS-ISSA-DE), Kathirolu et al. [16] method. Based on residual energy, this algorithm chooses CH. Although the CH is not distributed evenly, stability is good. This algorithm's results for handling vast amounts of data take less time, and the crossover and CH selection procedures are enhanced. Nonetheless, the breadth and connectivity of this approach are crucial. In WSN, the Butterfly and Ant approach is suggested by Maheswari et al. [17]. In WSN, route generation and the best CH selection are challenging tasks. The path is chosen based on the nodes' energy, their distance from one another and the base station and the node's degree. This methodology's simulation results are taken into account for the local base station and global network.

To choose the best energy-saving nodes, the author Rajpoot et al. [18] proposed a modified Bellman-Ford algorithm. This algorithm was tested in both static and dynamic networks. This scheme found that the static network provided accuracy between 34 and 48 percent and the dynamic network provided energy savings between 35 and 42 percent. However, we found that the amount of energy saved depends on the network's size. In addition, routing protocols play a major role in energy-saving plans. In comparison, Adhoc On-Demand Routing Protocol (AODV) and Energy Quantized (EQ-AODV) routing protocols, the Energy Efficient AODV (EE-AODV) in Mobile Ad-hoc network has increased the energy level of the nodes. Since the ties in this protocol are less stable, the scientists intend to use a genetic algorithm to strengthen the links in their subsequent work.

Li Y et al. [19] proposed a novel EED algorithmic approach. The authors used two parameters such as hop count and residual node energy to estimate an optimal load distribution-based routing mechanism. This work expected the outcomes like optimal energy usage, maximum packet delivery ratio and maximum network lifetime. However, this method implemented a load-balancing routing mechanism to the MANET without considering IoT.

In the description of Er-rouidi M et al. [20], MANET and IoT networks with energy optimization rules are suggested to increase network efficiency. Additionally, the improved cluster method for a heterogeneous network uses the sensor node energy level to determine the route. Due to insufficient load balancing, the tiny size of a node in the network consumes more battery power than the huge size of the network.

Similarly, Vu Q.K. et al. [21] found energy efficiency and safe weight of the cluster approach when MANET and WSN are combined. In this work, all routes' costs are represented by the cluster-weighted values from the sources to the receiver. In MANET, the dynamic genetic algorithm is utilised to determine the dynamic topology based on the many node characteristics of power, position, availability, and latency, Bruzgiene R et al. [22] Chatterjee B et al. [23]. This approach is one of the path-finding optimization techniques. However, in a large-scale network, the network's accuracy is lower. The aforementioned existing algorithm has improved network performance using a variety of techniques such as residual energy calculation and clustering procedures. It has also optimized packet loss, hop count, distance, increased throughput, and packet delivery ratio. It has also formed a heterogeneous network with low cost and high performance. However, in this approach, every author focuses on a distinct characteristic and omitting any one of the crucial ones has decreased the service's quality.

The existing works are formed by heterogeneous networks with different algorithms, like cluster creation and genetic algorithms, to improve the performance of the network. However, the existing work has not fulfilled the expectations. Some clustering algorithms do not distribute clusters evenly, consequently, CH energy is drained soon. The genetic algorithm saves the network energy but has less fault tolerance and a high time delay.

In this proposed work, the energy utilisation of network nodes is improved using clustering, S. Sugumaran et al. [24] and a trust route selection method. The nodes in the network are divided into small segments using cluster techniques. The cluster nodes are formed by mobile ad-hoc nodes and sensors. The sensors are linked to neighbouring mobile ad-hoc nodes. The node with more sensors is elected as CH. Otherwise, the mobile ad-hoc node is acting as an adjacent node between the sensor (source) and destination. The CH is re-elected by the residual energy of the node. The route discovery process Kanthe A.M et al. [25] is selecting the different routes from source to destination. However, the best and trusted route is evaluated by the total energy utilisation of the nodes, and the distance between the source and destination, S. Sugumaran et al. [26]. This type of route selection provides a better result in terms of saving the total energy of the route, Lorincz et al. [27] under both malicious (DoS) and non-malicious conditions.

3. The Measurement Tools of Network Topology

The clustering techniques manage the large size of the network effect and control traffic and improve the energy level of each node. Faulty nodes can be easily identified in a cluster and automatically replaced by a suitable algorithm. In the cluster network, Venkatasubramanian et al. [28], the graphical method $G(N, E)$ is represented. Here, N is the number of nodes in the cluster, and E is the total energy utilized to transmit the packet from node i to j and $i, j \in N$. CH energy is evaluated by the residual energy of the node E_{Ri} . The residual energy E_{Ri} is calculated from the total energy of the node to the utilized energy of the node and distance d_{ij} is equal to the velocity of sending the packet to the time required to send all the packets from i to j . The Energy required to transmit one packet E_p and a Total number of packets P_n .

$$E_{CH} = \frac{E_{Ri}}{\sum_{j=1}^n ((d_{ij} + (E_p \times P_n)))} \quad (1)$$

The data packet travels from one sensor node to another sensor node and is significantly observed in the network. Particularly, the data throughput of the network is evaluated from the amount of data transferred between the source and destination within a second.

The time, S. Sugumaran et al. [29] is considered depending on the state of the node. At some point, the node acts as inactive, sleeping and idle. The total time is regarded as,

$$T_{Total} = T_{Active} + T_{Sleep} + T_{idle} \quad (2)$$

In active mode, nodes start to transfer and receive the packet with less delay. But few nodes enter sleep mode because of a less level of energy and other nodes act in idle mode. It takes a bit more time to complete the packet transmission and receive, S. Sugumaran et al. [29]. The active time is evaluated by the total bandwidth of the sender-to-receiver channel and the total number of nodes within a network

$$T_{Active} = \frac{\sum_1^n BW_{ij}}{N_{ij}} \quad (3)$$

Distance is very important in the routing algorithm; the shorter distance brings the data to the destination in less time. In this work, the distance is calculated as the sum of the distance between the adjacent node from i to j , and the total transfer and receive time of the packet. The bandwidth, $S M, B$ et al. [30] is the capability of the route to take the data

$$D_{ij} = \sum_{i=1}^j d_{ij} \text{per Seconds} \left(T_{\text{Total}} (\text{Sec}) \times \frac{1 \text{ min}}{60 \text{ Seconds}} \right) \quad (4)$$

The total residual energy, $S M, B$ et al. [30] of the network is taken into account by the energy of the cluster network and the remaining energy of the MANET route.

$$E_{T=\sum_{r=1}^n (E_{CH} + E_{MANET})} \quad (5)$$

where r is the route between the sender and destination, and E_{CH} is CH residual energy. The MANET discovered the route's residual energy determined by the sum of the energy level between the adjacent links. The energy level of each link is calculated from the residual energy of the packet sent and received. The hop count of the source sensor node to the destination node is evaluated on all the discovered routes in MANET. The hop count is evaluated between the adjacent sequential nodes from the sensor to the destination. Sequential count details are collected from the route discovery process. Different types of routing algorithms provide more than one number of routes to reach the gateway node discovered by any one of the routing algorithms. However, the trusted route (R_t) offers long life, less time delay, reduced packet loss and improved performance of the system, Poluboyina et al. [31]. In this work, MANET optimized energy-saving route algorithm for IoT is evaluated using residual energy level of the node and distance D_{ij} , hop count.

4. Proposed Work of MANET-ESO in IoT

The MANET is using the proposed MANET-ESO in an IoT environment, and it increases the rate of trust and successive communication between sensor nodes. The IoT is consisting of WSN techniques with internet service. The mutual internet world of the electronics domain is growing with intelligent network applications. The IoT sensors are successively gathering physical incidents to digital data in different time intervals. Nevertheless, IoT data transmission delay and power utilization are increased due to the uncertainty of sensor nodes. However, the proposed model increases throughput and minimizes energy factors. This MANET Algorithm has improved network performance through trust and the best route optimization method. In Figure 1, different sensor nodes are connected to the adjacent mobile nodes. Additionally, mobile nodes are forming the cluster using a high density of sensors in that network.

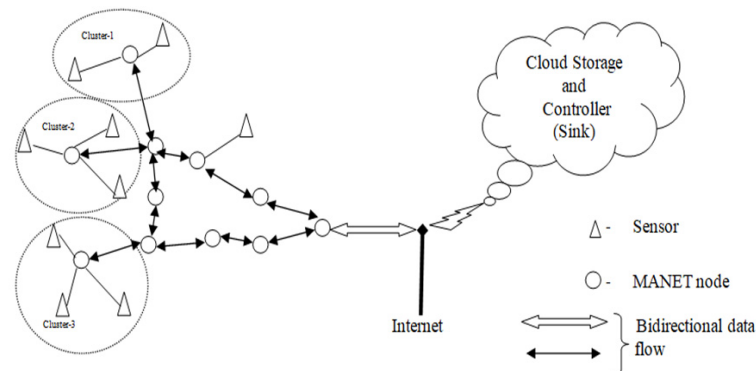


Figure 1. Heterogeneous Network Constructed by Sensor, MANET and Cloud storage through the Internet.

The CH controls, monitors and collects data from sensors. The CH is dynamically changing in the network in terms of the distance from the sensor to the mobile node and the energy level of the mobile node. In the MANET, the information is linked to the gateway node through the CH node, adjacent nodes and gateway nodes using the internet cloud network. The route created in MANET optimizes the energy and enables trusted route paths. Table 1 shows the abbreviations used in the manuscript.

Table 1. Abbreviations and Details.

Abbreviations	Details
MANET-ESO	Mobile Adhoc Network-Energy Saving Optimization
IoT	Internet of Things
WSN	Wireless Sensor Network
IP	Internet Protocol
DNS	Domain Name services
DoS	Denial of Service Attack
CH	Cluster Head
E_{Ri}	Residual Energy of the node
E_p	Energy required to transmit one packet
P_n	Total number of packets
T_{Total}	Total Time
T_{Active}	Active node Time
T_{Sleep}	Sleepy node Time
T_{Idle}	Idle node Time
D_{ij}	Distance between adjacent node i to j
E_{CH}	CH residual energy
E_{MANET}	MANET discovered route residual energy
R_t	Trusted Route

In this case, available routes and the best routes are created sequentially using the proposed model. In addition, the MANET transmits and stores data or receives commands using the Internet service. Consequently, a heterogeneous network is created to transfer or receive the data through the internet between MANET and the cloud systems (via gateways). The gateway nodes have created the link between the MANET and the cloud routing algorithm.

In this case, the overall performance of the network is higher than a simple IoT network with optimal performance metrics (throughput, energy, delay, packet delivery ratio and routing overhead) while using MANET-ESO (Algorithm 1).

Algorithm 1: Algorithm for MANET-ESO in IoT

Initialized: Simulation area considered with n —number of sensor nodes

CH—Cluster Head

m —number of mobile nodes

GW—Gate Way nodes

E_{CH} —residual energy of CH

r = number of discovered routes

E_T = Total residual energy of the node

E_{th} = Energy Threshold Level

E_{min} = Route total Energy threshold level

D_{ij} = distance between sensor nodes

H_p = destination sequential count

If m is connected with more than one number of n , //cluster head selection

Then, $m = CH$

else,

m - act as an adjacent node in the network

Algorithm 1: Cont.

```

End if
If m is connected to Internet service, // gateway node identification
    Then, m = GW
else,
    m-act as an adjacent node in the network
End if
if  $E_{CH} \geq E_{th}$ , // CH is reelected by Energy level of the node
    Then, retained as a CH
else,
    CH is re-elected
End if
ri=1 // discovered routes are being checked one by one
While  $r_i \leq r$ 
    Energy =  $E_T$ 
    Distance =  $D_{ij}$ 
    Hop Count = HP
    If  $E_T \leq E_{min}$  then
        If  $D_{ij} \leq \text{Threshold-D}$ , then
            If  $H_p < \text{Threshold-H}$ , Then
                 $r_i = \text{Trusted}$  // All the conditions are satisfied then act as a
                // trusted route
            else
                 $r_i = r_i++$ 
        End if
    End if
    Repeat the Trust condition
End while;

```

5. Simulation and Result of MANET-ESO in IoT Techniques

The simulation of MANET-ESO using IoT Techniques has been simulated by ns-3 on Ubuntu 20 platform.

The experimental configuration considers a MANET, cloud and wireless sensor network with the internet. Since the network has three separate network protocols and it is heterogeneous, the simulation area is estimated to be $1500 \times 1500 \text{ m}^2$. All mobile nodes in the network are considered with the same memory size and random mobility model. A clustered network is made up of multiple sensors connected to CH. Therefore, CH in the MANET node is connected with more sensor nodes. All simulator parameters taken into consideration are shown in Table 2.

This situation is accomplished with internet Gateway nodes. The Gateway node is considered the right side centre of the network area, sensor nodes are considered the left side of the network area and MANET nodes are placed between the sensor to Gateway node in different positions. Every node in the network is dynamically adjusted to a different angle and orientation. In a simulation environment, the traffic generation models, mobility models, topology management models and traffic scheduling models give a realistic network platform. As illustrated in Table 2, a Poisson traffic model is configured under random packet generation mode. The packets generated in the traffic models are measured from 500 bits to 1500 bits in size based on the type of nodes in the IoT environment (mobile adhoc or sensor nodes). Generally, sensor nodes generate minimal-size packets compared to mobile adhoc nodes. Similarly, the mobility model has been configured with random waypoint procedures that allow mobile adhoc nodes to move independently at variable velocities (meters/seconds). In addition, the channel allocation models used in the 802.11 environments are working based on frequency-time allotment principles. The universal frequency band for IoT is configured in an ns-3 simulation environment as illustrated in Table 2. The topology followed in this IoT environment is a hybrid model that is configured with a star topology and mesh topology. Star topology is configured in the ns-3 framework to manage higher-level internet cloud points with other geographical nodes. At the lower level, mobile adhoc nodes and sensor nodes are adopted with mesh topology

as they are communicating directly for signal propagation. This simulation considers this dual-topology model as optimal for constructing the entire IoT infrastructure. Anyhow, the sensor nodes are mobile nodes are using random packet distribution schemes based on their initial energy and residual energy rates.

Table 2. Simulation Parameters.

Parameters	Value
Field Area	1500 × 1500 m ²
Number of sensors nodes	50
Number of Mobile nodes	100
Percentage of cluster head	10%
Radio Propagation model	Free space
Mini. And Max Position of 5G BS	[0, 200]
Antenna Model	Omni directional Antenna
Initial Energy of the sensor node	0.5 Jules
Packet Size	500–1500 bits
MAC	802.11
Packet Scheduling Model	
Mobility model	Random way
Traffic generation Model	Random Poisson Traffic Model
Initial Energy of the mobile adhoc node	1.25 Joules
Wireless Channel Allocation Models	Frequency and Time Division Model
Node's mobility	10, 15, 20, 25 and 30 m/s (Variable)
IoT Frequency Band	2.4–5 GHz
Proposed Method	MANET-ESO
Adhoc Routing Protocol	AODV
Simulation Tool	Network Simulator (NS-3)

The implementation part of the ns-3 simulation testbed contains the modules of the proposed protocol, existing techniques (EECHS-ISSA DE and Butterfly and Ant) and network characteristics. In the simulated network environment (Table 2), procedure 2 has been implemented among the nodes in the IoT platform. In a similar manner, EECHS-ISSA DE and Butterfly and Ant are implemented separately for evaluating the test cases. The protocols and traffic models used in the experiment are implemented as random Poisson event procedures, Adhoc On-Demand Routing Protocol (AODV), distributed LEACH protocol and energy models. On the basis of this experimental test bed, the performance metrics such as the number of active nodes, throughput rate, residual energy, packet delivery rate and average routing delay are calculated. The mentioned metrics are calculated for iteratively varying network parameters such as the number of nodes, test rounds and suspicious nodes. The prescribed ns-3 simulation model has been implemented using C++ modules (Initial network deployment). In addition, python codes are used for importing the library functions of routing protocols and traffic models.

5.1. Results and Analysis in Terms of Node Alive Node vs. Number of Rounds

When using IoT approaches, the node alive time of MANET-ESO is compared with existing algorithms such as EECHS-ISSA DE [16] and Butterfly and Ant [17] method. Figure 2 illustrates the testing of the proposed methodology and the existing algorithm using 50 sensor nodes, 100 MANET nodes and one Gateway node in the ns-3 simulator. This shows the performance of the number alive node is better than the existing algorithm in a different number of rounds. The WSN constructed with MANET nodes using 10% of clusters was tested for 1800 rounds without dead nodes and produced better results. However, compared to other existing algorithms, the MANET-ESO protocol achieved high alive nodes up to 4500 rounds.

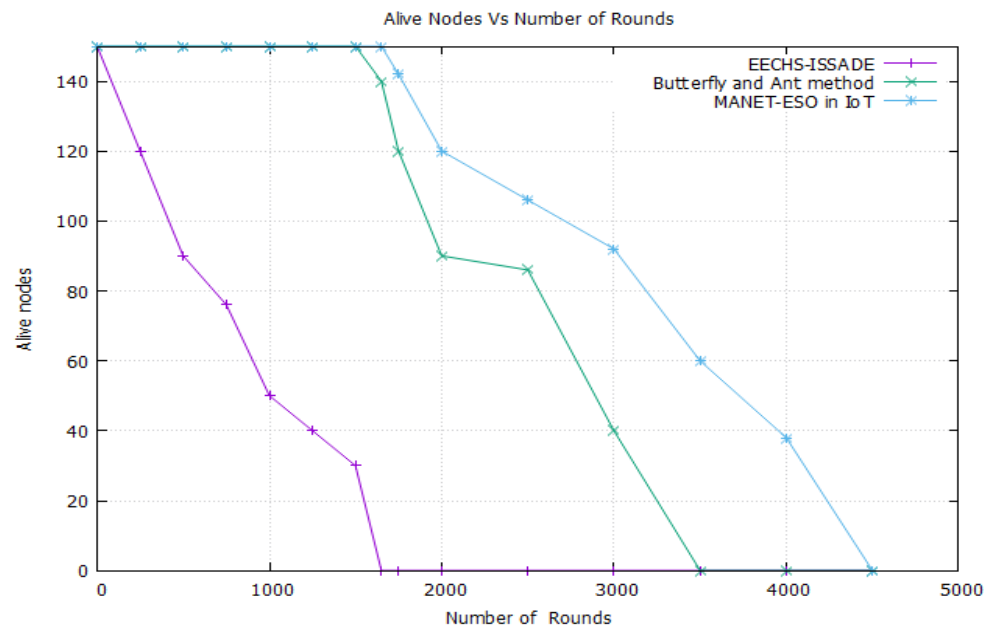


Figure 2. Live nodes vs. number of rounds.

In the EECHS-ISSA DE method, all the nodes are connected via the clustering technique, and the cluster head selection process requires more energy to discover the route. Hence live nodes are limited after 1800 rounds.

In the Butterfly and Ant method, the link to the BS station is discovered by two different algorithms. Firstly, it forms clusters and discovered routes. Both are utilizing less energy compared with EECHS-ISSA DE methods. However, the performance is not better than the proposed work. In the proposed work, the energy utilization of the network is reduced by the clustering algorithm. The cluster head is controlling all nodes in the cluster. So apart from cluster head remaining node energy utilization is less and increasing the alive in the network. Figure 2 shows the proposed algorithm performance, as the alive node is an average of 67.7% higher than EECHS-ISSA DE and an average of 10.7% higher than the Butterfly and Ant Method.

5.2. Results and Analysis in Terms of Residual Energy vs. Number of Rounds

This section discusses the residual energy of the node after 'n' rounds. The results are contrasted with the existing methodology. Figure 3 shows the results of residual energy vs. the number of rounds; the results of the proposed methods are compared to those of the EECHS-ISSA DE and Butterfly and Ant method. Both the cluster energy method and MANET trusted route algorithm compute and identify the best route to improve the residual energy of the route. The overall energy utilization is based on the number of adjacent nodes in the route. The performance of MANET-ESO in IoT is compared to other existing work and observed that EECHS-ISSA DE and Butterfly-Ant methods are wasting the energy level. The EECHS-ISSA DE reduces the energy level over the course of 1000 rounds. The energy balancing approach is being used in Butterfly and Ant method, which has maintained an energy level for up to 8200 rounds. Finally, when compared with the proposed method, the trusted route energy optimization method is choosing the best route based on the total energy utilization of the node, minimum distance and minimum hop count. So, the selected route is using less energy to complete the task and improved the performance of the network compared to other methods. The residual energy of nodes is increased by an average of 75% in this proposed algorithm compared to EECHS-ISSA DE and a 7.1% increase compared to Butterfly and Ant method.

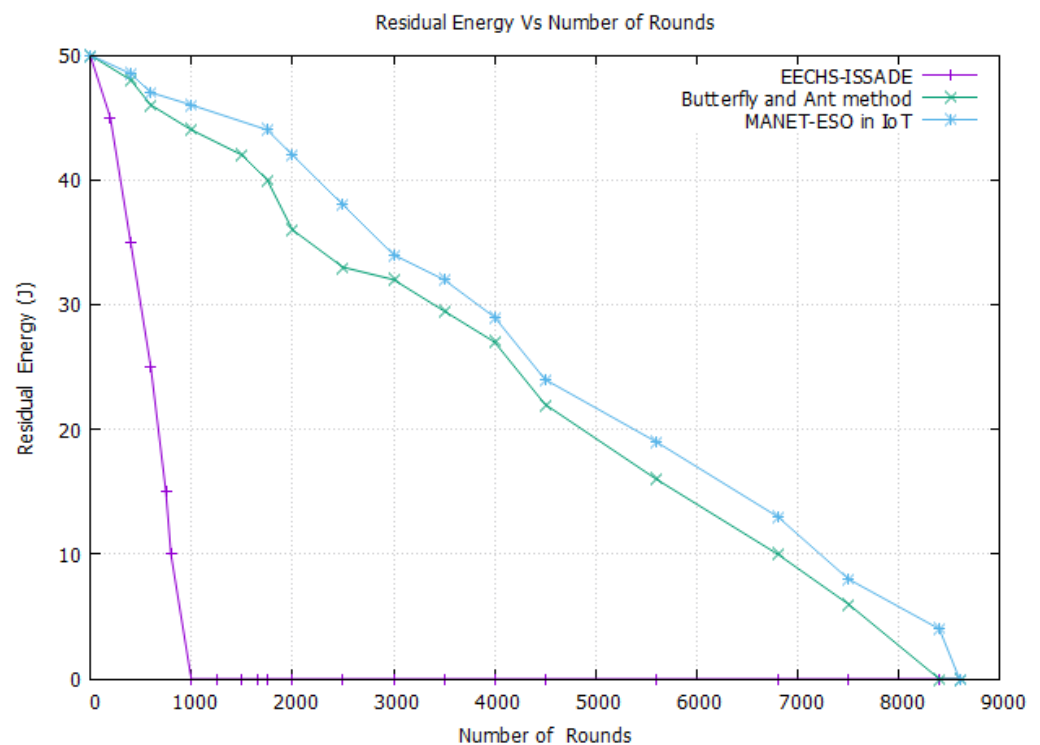


Figure 3. Residual Energy vs. number of rounds.

5.3. Results and Analysis in Terms of Throughput vs. Number of Rounds

The throughput is calculated by the total time taken to transport all packets from the source to the destination. This algorithm identifies the shortest distance by total time duration to transfer packets and less hop count of the discovered routes. It is carrying more packets within a minimum time. So, it increases the throughput of the network compared to other existing work. In EECHS-ISSA DE and Butterfly and Ant methods, throughputs are reduced due to node energy loss. As a result, nodes become dead and the throughput of the network is minimized. However, compared with existing works, the proposed method has outperformed up to 6800 rounds in the network. The Proposed algorithm has a throughput average of 75% higher than EECHS-ISSA DE and an average of 12.2% higher than the Butterfly and Ant Method (Figure 4).

5.4. Performance Evaluation of Packet Delivery Ratio (PDR) and Routing Overhead

This session compares the proposed work performance to EECHS-ISSA DE and Butterfly and Ant algorithms in terms of packet delivery ratio and routing overhead. Figure 5 illustrates the evaluation of the packet delivery ratio with respect to 50, 100, and 150 nodes. Comparing this proposed method to existing ones, the packet delivery ratio is high. The clustering method and trust routing algorithm in the network reduced the packet transmission delay and transferred the packet to a short distance. As a result, all packets reach the destination node with minimum loss than other existing methods. Under 50 and 100 nodes scenarios, the packet delivery ratio of the proposed method is increased by approximately 8% compared to EECHS-ISSA DE and approximately 4% increase compared to the butterfly ant method. The PDR is increased by 8% to 9% for 50 nodes when compared to EECHS-ISSA DE and Butterfly and Ant Method. Figure 6 shows the routing overhead of the proposed work in comparison to the existing algorithms.

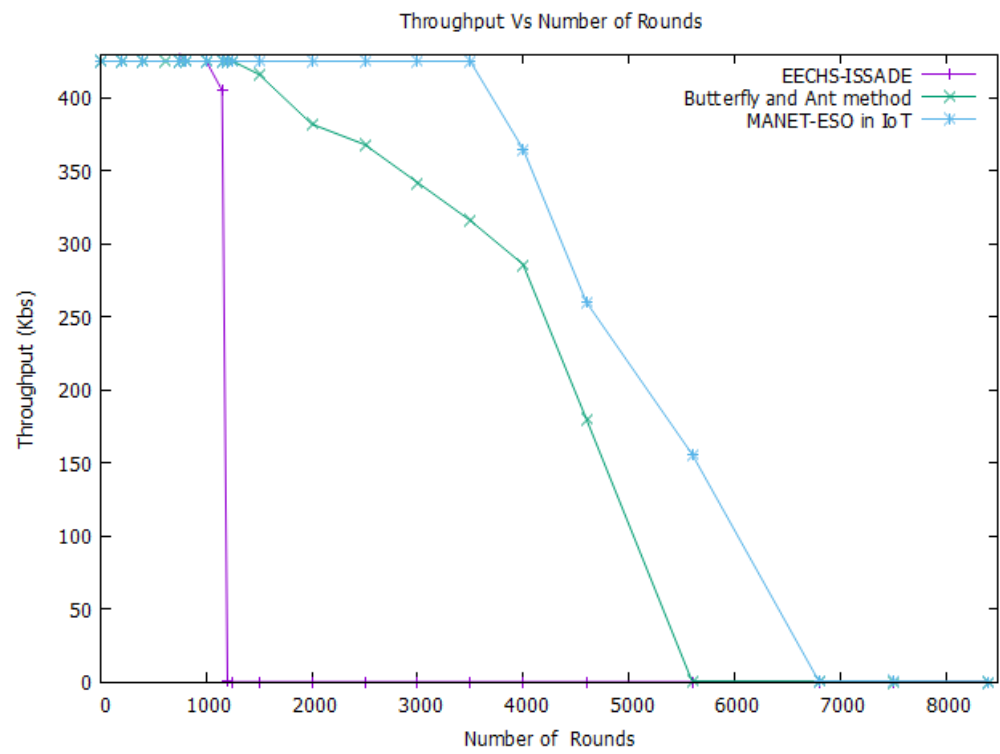


Figure 4. Throughput vs. number of rounds.

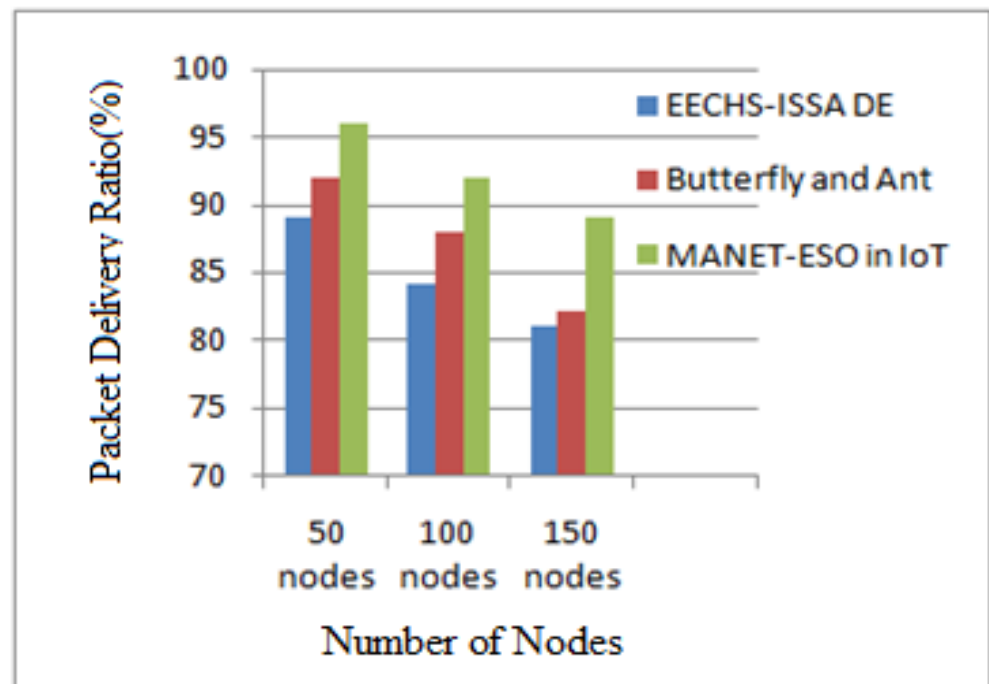


Figure 5. Packet Delivery Ratio vs. Number of Nodes.

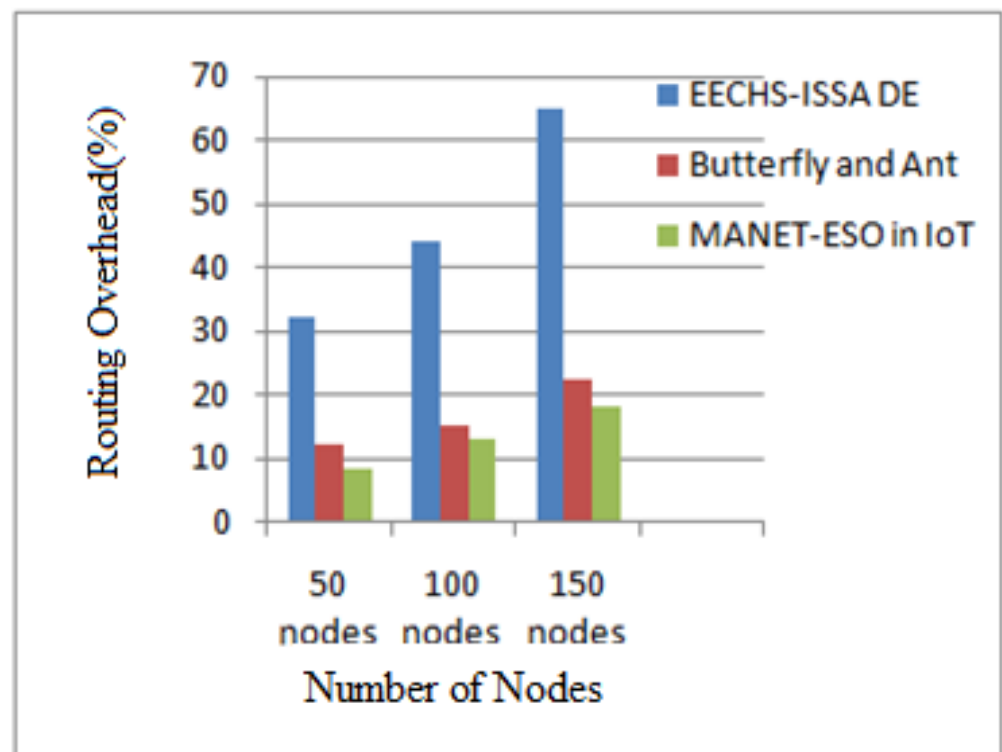


Figure 6. Routing Overhead vs. Number of Nodes.

The trusted routing method increases the route's life span and decreases routing overhead compared to other existing algorithms. In the simulation scenarios compared with 50, 100 and 150 nodes, the output result is 71% better compared to EECHS-ISSA DE and 20% better compared to the Butterfly and Ant method.

In this Figure 7, the packet delivery ratio of the MANET-ESO in the IoT algorithm is compared with the EECHS-ISSA DE, Butterfly and Ant algorithms with respect to the percentage of malicious nodes. The number of malicious nodes in the network increased by 10 and we observed that PDR improved.

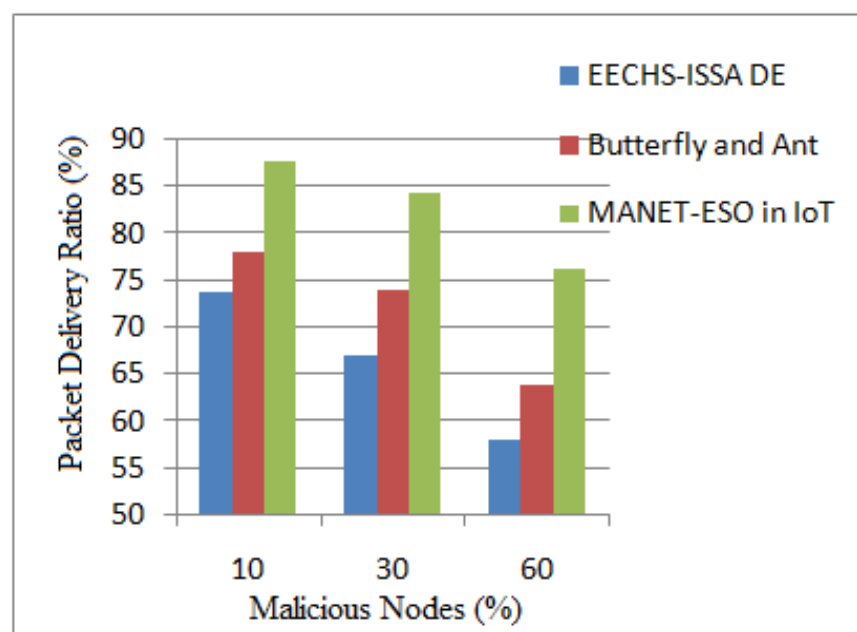


Figure 7. Packet Delivery Ratio vs. Malicious Nodes (%).

Again, the number of malicious nodes is increased to 30% and 60% respectively. Now the proposed algorithm's PDR ratio is reduced due to frequent route failures occurring from the source to the destination.

However, compared with the existing methods, the result of PDR is increased by 24% compared to EECHS-ISSA DE, and increased by 14% compared to the Butterfly and Ant method. Figure 8 shows the performance of the proposed algorithm for routing overhead as the number of malicious nodes increase in the network. The routing overhead is increased due to frequent route failure in the network. Because of the increased malicious activity, the best route selection process requires more time to complete all packet transmission.

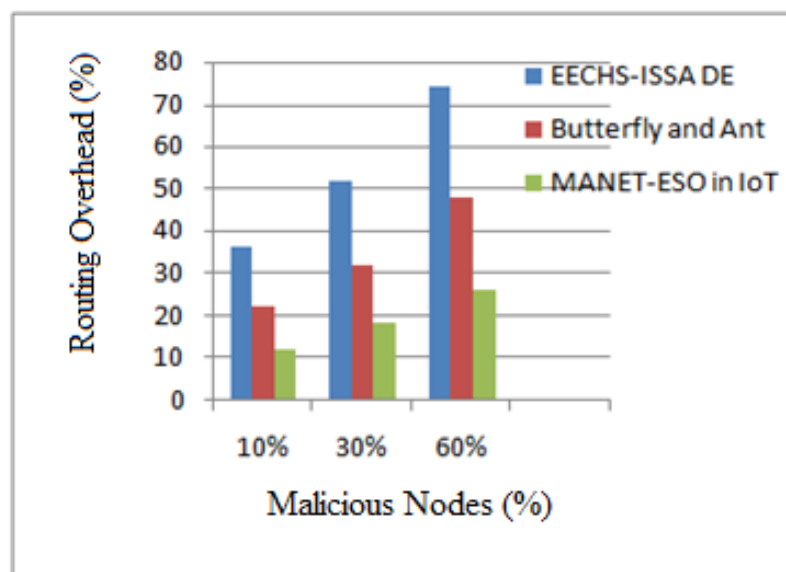


Figure 8. Routing Overhead vs. Malicious Nodes (%).

6. Conclusions

In the IoT, the proposed MANET-ESO algorithm has improved capabilities and reduces the energy utilization of nodes compared to the EECHS-ISSA DE algorithm, Butterfly and Ant method. The simulation environment is created by a heterogeneous network, such as a combination of a WSN, MANET and the internet cloud network. The sensor nodes are connected to MANET using a clustering algorithm. The CH is connected to a variety of sensors and its stability is excellent. The clustering algorithm improved the residual energy of the nodes in the network compared to the existing algorithms. Hence, the number of live nodes is more after the completion of more rounds in the network compared to the existing algorithm. The trusted route algorithm chooses the best route from discovered routes based on the total energy of the node, the distance of the route and the number of hop counts of the route. Under both malicious and benign conditions, the proposed algorithm produced a better packet delivery ratio, optimal throughput and minimal routing overhead. Thus the overall results are better than the existing methods. In the Future, various phishing and spoofing attacks will be used to test the network security. In this way, the level of security will be improved using one of the heuristic methods.

Author Contributions: Conceptualization, V.K.K., I.I. and M.H.; methodology, V.K.K., S.S. and S.V.; software, V.K.K.; validation, I.I. and S.K.S.; formal analysis, S.K.S.; investigation, V.K.K., S.S. and S.V.; resources, I.I.; data curation, T.R.M.; writing—original draft preparation, V.K.K., S.S. and S.V.; writing—review and editing, V.K.K., I.I. and S.K.S.; visualization, T.R.M.; supervision, I.I. and M.H.; project administration, S.K.S.; funding acquisition, I.I. All authors have read and agreed to the published version of the manuscript.

Funding: The National Research Foundation of Ukraine funded this research under project number 2021.01/0103.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jamali, S.; Rezaei, L.; Gudakahriz, S.J. An Energy-Efficient Routing Protocol for MANETs: A Particle Swarm Optimization Approach. *J. Appl. Res. Technol.* **2013**, *11*, 803–812. [[CrossRef](#)]
2. Devi, M.; Gill, N.S. Mobile ad hoc networks and routing protocols in IoT enabled. *J. Eng. Appl. Sci.* **2019**, *14*, 802–811.
3. Kumar Debnath, S.; Saha, M.; Islam, M.; Sarker, P.K.; Pramanik, I. Evaluation of Multicast and Unicast Routing Protocols Performance for Group Communication with QoS Constraints in 802.11 Mobile Ad-Hoc Networks. *IJCNIS* **2021**, *13*, 1–15. [[CrossRef](#)]
4. Hu, Z.; Odarchenko, R.; Gnatyuk, S.; Zaliskyi, M.; Chaplits, A.; Bondar, S.; Borovik, V. Statistical Techniques for Detecting Cyberattacks on Computer Networks Based on an Analysis of Abnormal Traffic Behavior. *IJCNIS* **2021**, *12*, 1–13. [[CrossRef](#)]
5. Khokhlov, Y.; Hu, Z.; Sydorenko, V.; Oprisky, I. Method for Optimization of Information Security Systems Behavior under Conditions of Influences. *IJISA* **2017**, *9*, 46–58. [[CrossRef](#)]
6. Ray, S.; Mishra, K.N.; Dutta, S. Sensitive Data Identification and Security Assurance in Cloud and IoT Based Networks. *IJCNIS* **2022**, *14*, 11–27. [[CrossRef](#)]
7. Jayalakshmi, D.S.; Hemanand, D.; Kumar, G.M.; Rani, M.M. An Efficient Route Failure Detection Mechanism with Energy Efficient Routing (EER) Protocol in MANET. *IJCNIS* **2021**, *13*, 16–28. [[CrossRef](#)]
8. Jesudurai, S.A.; Senthilkumar, A. An improved energy efficient cluster head selection protocol using the double cluster heads and data fusion methods for IoT applications. *Cogn. Syst. Res.* **2019**, *57*, 101–106. [[CrossRef](#)]
9. Rahman, T.; Ullah, I.; Rehman, A.U.; Naqvi, R.A. Notice of violation of IEEE publication principles: Clustering schemes in MANETs: Performance evaluation, open challenges, and proposed solutions. *IEEE Access* **2020**, *8*, 25135–25158.
10. Hou, Y.T.; Shi, Y.; Sherali, H.D. Rate Allocation and Network Lifetime Problems for Wireless Sensor Networks. *IEEE/ACM Trans. Netw.* **2008**, *16*, 321–334. [[CrossRef](#)]
11. Alam, T.; Rababah, B. Convergence of MANET in Communication among Smart Devices in IoT. *IJWMT* **2019**, *9*, 1–10. [[CrossRef](#)]
12. Niu, Z.; Li, Q.; Ma, C.; Li, H.; Shan, H.; Yang, F. Identification of Critical Nodes for Enhanced Network Defense in MANET-IoT Networks. *IEEE Access* **2020**, *8*, 183571–183582. [[CrossRef](#)]
13. Narayandas, V.; Archana, M.; Raman, D. The Role of MANET in Collaborating IoT End Devices: A New Era of Smart Communication. *Int. J. Interact. Mob. Technol.* **2021**, *15*, 80–92. [[CrossRef](#)]
14. Aroulanandam, V.; Latchoumi, T.; Balamurugan, K.; Yookesh, T. Improving the Energy Efficiency in Mobile Ad-Hoc Network Using Learning-Based Routing. *RIA* **2020**, *34*, 337–343. [[CrossRef](#)]
15. Amiri, I.S.; Prakash, J.; Balasaraswathi, M.; Sivasankaran, V.; Sundararajan, T.V.P.; Hindia, M.N.; Tilwari, V.; Dimyati, K.; Henry, O. DABPR: A Large-Scale Internet of Things-Based Data Aggregation Back Pressure Routing for Disaster Management. *Wirel. Netw.* **2020**, *26*, 2353–2374. [[CrossRef](#)]
16. Kathioli, P.; Selvadurai, K. Energy Efficient Cluster Head Selection Using Improved Sparrow Search Algorithm in Wireless Sensor Networks. *J. King Saud Univ.-Comput. Inf. Sci.* **2021**, *34*, 8564–8575. [[CrossRef](#)]
17. Maheshwari, P.; Sharma, A.K.; Verma, K. Energy Efficient Cluster Based Routing Protocol for WSN Using Butterfly Optimization Algorithm and Ant Colony Optimization. *Ad Hoc Netw.* **2021**, *110*, 102317. [[CrossRef](#)]
18. Rajpoot, P.; Dwivedi, P. Multiple Parameter Based Energy Balanced and Optimized Clustering for WSN to Enhance the Lifetime Using MADM Approaches. *Wirel. Pers. Commun.* **2019**, *106*, 829–877. [[CrossRef](#)]
19. Li, Y.; Xiong, W.; Sullivan, N.; Chen, G.; Hadynski, G.; Banner, C.; Xu, Y.; Tian, X.; Shen, D. Energy Efficient Routing Algorithm for Wireless MANET. In Proceedings of the 2019 IEEE Aerospace Conference, Big Sky, MT, USA, 2–9 March 2019; pp. 1–9.
20. Er-rouidi, M.; Moudni, H.; Mouncif, H.; Merbouha, A. A Balanced Energy Consumption in Mobile Ad Hoc Network. *Procedia Comput. Sci.* **2019**, *151*, 1182–1187. [[CrossRef](#)]
21. Vu, Q.K.; Le, N.A. An Energy-Efficient Routing Protocol for MANET in Internet of Things Environment. *Int. J. Onl. Eng.* **2021**, *17*, 88–99. [[CrossRef](#)]
22. Bruzgiene, R.; Narbutaite, L.; Adomkus, T. MANET Network in Internet of Things System. In *Ad Hoc Networks*; Ortiz, J.H., de la Cruz, A.P., Eds.; InTech: London, UK, 2017; ISBN 978-953-51-3109-0.
23. Chatterjee, B.; Saha, H.N. Parameter Training in MANET Using Artificial Neural Network. *IJCNIS* **2019**, *11*, 1–8. [[CrossRef](#)]
24. Sugumaran, S.; Venkatesan, P. Attacks Reduction in MANET with Cluster Supported Trusted Routing Protocol. *J. Adv. Res. Dyn. Control. Syst.* **2017**, *6*, 2023–2032.
25. Kanthe, A.M.; Simunic, D.; Prasad, R. Comparison of AODV and DSR on-demand routing protocols in mobile ad hoc networks. In Proceedings of the 2012 1st International Conference on Emerging Technology Trends in Electronics, Communication & Networking, Surat, India, 19–21 December 2012; pp. 1–5.
26. Sugumaran, S.; Venkatesan, P. Optimized Trust Path for control the Packet dropping and collusion attack using Ant Colony in MANET. *Int. J. Eng. Adv. Technol.* **2019**, *8*, 4833–4841. [[CrossRef](#)]

27. Lorincz, J.; Ukc, N.; Begusic, D. Throughput comparison of AODV-UU and DSR-UU protocol implementations in multi-hop static environments. In Proceedings of the 2007 9th International Conference on Telecommunications, Zagreb, Croatia, 13–15 June 2007; pp. 195–202.
28. Venkatasubramanian, S.; Suhasini, A.; Vennila, C. Cluster Head Selection and Optimal Multipath Detection Using Coral Reef Optimization in MANET Environment. *IJCNIS* **2022**, *14*, 88–99. [[CrossRef](#)]
29. Sugumaran, S.; Venkatesan, P.; Chitra, M.G.; Sivasakthiselvan, S.; Jayarajan, P. Best Optimized Route in MANET using Token Economy Management System. In Proceedings of the 2022 IEEE 4th International Conference on Advances in Electronics, Computers and Communications (ICAIECC), Bengaluru, India, 10–11 January 2022. [[CrossRef](#)]
30. Benakappa, S.M.; Kiran, M. Energy Aware Stable Multipath Disjoint Routing Based on Accumulated Trust Value in MANETs. *IJCNIS* **2022**, *14*, 14–26. [[CrossRef](#)]
31. Poluboyina, L.; Reddy, V.S.; Prasad, A.M. Evaluation of QoS Support of AODV and Its Multicast Extension for Multimedia over MANETs. *IJCNIS* **2020**, *12*, 13–19. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.