IRO Journal on Sustainable Wireless Systems (ISSN: 2582-3167)
www.irojournals.com/irosws/

A Hybrid Wireless Sensor Network Protocol for Time-Sensitive Emergency Operations

Dinesh Kumar Anguraj

Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Koneru Lakshmaiah (KL) University, Vaddeswaram, A.P, India

E-mail: adinesh@kluniversity.in

Abstract

Wireless sensor networks consists of nodes that are connected via wireless links and collaborate to self-organize into a network without utilizing any centralized infrastructure. Sensor networks encompass a wide range of paradigms and from that this research study focuses on the mobile networks, which recently significant potential for public/commercial environments and emergency disaster management services. Despite the hype, the wireless mobile networks are also experiencing the challenges such as communication failure, power consumption and network lifetime challenges. This paper presents a hybrid K-Means and Logistic Regression (LR) based algorithm to build a time sensitive multi hop communication to identify the shortest path to the base station and establish a flawless long distance communication. The proposed model metrics are defined to handle an emergency search and rescue operations in India. The NS2 simulator has been used to simulate the efficiency of the proposed model. The following metrics are utilized to analyse the performance: energy consumption, packet delivery ratio (PDR) and network lifetime.

Keywords: Mobile Adhoc Networks (MANET), emergency operations, Mo-LEACH, time-sensitive model

1. Introduction

Every year, natural and man-made disasters affect the millions of people's lives across the globe. Disasters have major consequences on infrastructure and property, in addition to human losses. Disaster management activities are carried out before, during, and after the event with a goal to avoid human losses and safeguard people and infrastructure by mitigating the economic consequences and restoring normalcy. The severity and

DOI: https://doi.org/10.36548/jsws.2022.1.006
Received: 15.04.2022, received in revised form: 08.05.2022, accepted: 26.05.2022, published: 06.06.2022

complexity of disasters, as well as the criticality and complexity of disaster operations, necessitate effective disaster management techniques. Evolution of WSN and its utilization in emergency management has gained a great deal of interest since they can gather data more precisely with less human interaction [2]. WSN can assist in collecting on-the-ground intelligence and successfully coordinating the rescue effort. Unlike traditional wired technologies, WSNs are robust and remain operational even when infrastructure fails due to disaster [3].

In addition to being resilient, they are also simple to grow and modify as required. Earlier research on WSN in emergency operations management is more focused onto deployment and integration of unmanned systems to augment the monitoring process [4]. To fully realize the WSNs potential, one must also understand major challenge[s] that WSNs confront in disaster management.

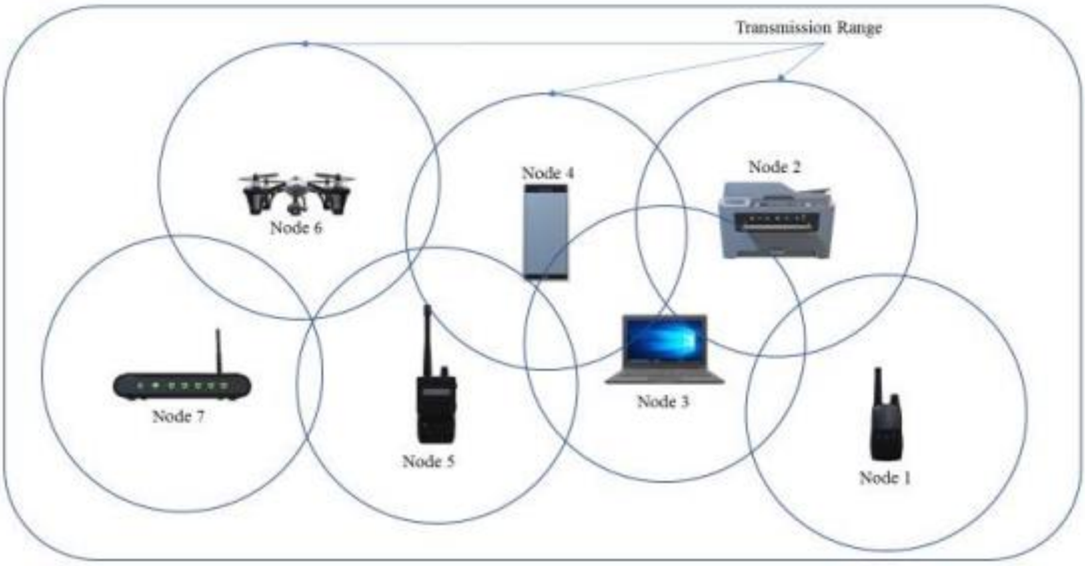

Figure 1. Wireless Sensor Network [1]

The challenges in implementing WSNs for search and rescue operations are:

1.1 Energy Availability

WSNs require considerably more energy to transmit data than wired versions. The amount of data sent increases the energy usage. Furthermore, a large number of nodes complicates energy management by reducing network efficiency [5]. The limitation of accessible energy in sensors, and most of today's research studies aim to highlight the efficient techniques to preserve energy in sensors.

1.2 Network Lifetime

Since the energy consumed for establishing a communication in wireless sensor networks is much higher than that used for computing, it must be handled with utmost consideration to extend network lifetime. Clustering-based routing methods are commonly employed to extend the lifetime of sensor networks [6].

1.3 Network Architecture

It is always crucial to eliminate complexity and achieve a successful data routing towards base station. Scaling basic architecture is quite difficult, while analysing the complicated architecture is computationally high. Furthermore, the standard protocol will not consider node's efficient energy utilization.

1.4 Node Deployment

The deployment must guarantee consistent distribution, coverage of the entire disaster area in order to assure smooth sensor node placement and data retrieval. The manner of deployment is particularly critical since it will have a direct impact on the network deployment duration and endurance of each node [7]. Given these constraints, this research study suggests wireless mobile networks deployment in the emergency operations to collect real-time sensitive data from affected zone to assist the response team in acting more effectively. The proposed research study makes the following contributions:

- Designed infrastructureless wireless networks for emergency search and rescue operations with a minimum infrastructure.
- Proposed a hybrid K-Means and logistic regression based protocol for effective and timely routing with minimal data loss and fast data packets delivery to the sink node/base-station.
- Proposed a novel technique to avoid irrelevant data in the cluster. This mechanism prevent the network traffic and substantially increases the network lifetime.

2. Literature Review

Routing protocols in MANET states different ways to transmit information in the form of data packets from an initiating point to a destination (base station). Two different actions occur in routing protocols before correspondence may occur between nodes. The first is the confirmation of the optimal routing path [8] and the transmission of packets via the system while consuming minimal energy. In addition, for the aforementioned operations to be accomplished, each routing protocol employs a variety of attributes [9] to determine the best path for packets to be transmitted in the system. Efficient execution of a system is possible if significant attention is given to routing computations, topology, and execution constraints. There are two routing protocol types, they are reactive and proactive protocols. The difference is that reactive protocols determine the path when a desired packet should be sent, whereas pro-active routing systems determine the route on a regular schedule.

Reactive routing techniques include dynamic source and on-demand distance vector routing. [10] Proactive routing protocols include optimal link state routing and destination sequenced distance vector. The most challenging fact in the time sensitive applications is that the lifetime of the wireless network should survive the full duration of emergency operations.

Since there is a limited node energy, it restricts the wireless networks' lifespan. Various studies have developed energy-efficient routing strategies. An Energy Efficient Routing for Cluster based WSN. This method of clustering employs Cluster-tree generation [11]. Time-division Multiple Access (TDMA) is used for the cyclic scheduling of data transfer in a Zigbee context [12].

When there are movements in opposing directions in a WSN, the cluster would be only active once over the schedule period, resulting in so-called cyclic behaviour of periodic scheduling. When additional activities are integrated in existing schedule, the sensor node mobility or router mobility is not handled and this results in a scheduling problem.

The energy-efficient adaptive clustering hierarchy [13] uses random turnover of local cluster head to appropriately divide the power distribution demand among network sensor nodes. One hop transmission of information to the base station was a notable shortcoming of this protocol. This lacks the consideration of sensor node's residual energy while carrying out the process of cluster head selection. In [14], authors have suggested a hierarchical decentralized cluster-driven multi-hop routing method in WSNs to make it energy-efficient. The multi-hop routing is used concurrently to decrease the energy consumption related to control packets.

The different routing protocols used for clustering and cluster head selection are tabulated below:

Table 1. Different Routing Protocols and Cluster Head Selection

Algorithm	**Inter cluster routing**	**CH selection parameters**
Destination-Sequenced Distance Vector (DSDV) [10]	Multihop	1. CH selection will be based on the neighboring node distance.
Hierarchical Cluster-Based Routing [13]	Multihop	CHs would be chosen along the tree's borders using effective local knowledge. By considering 1. Each node's residual energy and distance to base station. 2. Each node determines whether or not to become a CH on its own.
EEMST Algorithm [15]	Multihop	1. Remaining node energy 2. Total node distances with the neighboring nodes. 3. Total possible node distances in the formed cluster 4. Node distance
LEACH Algorithm [16]	One-hop	Random CH selection without considering the residual energy.
Naïve Bayes Algorithm [17]	Single-hop	1. Remaining node energy 2. Local distance between member node to CH

2.1 Mobility based cluster head selection

Mobility oriented architecture and cluster head formation is focused towards the remaining energy and mobility parameters. Clusters are formed based on two different parameters, they are, connectivity time and established link stability by assessing the network congestion. It is a modification of the cluster centred routing algorithm. The proposed technique enables distributed data processing, which results in the selection of two different cluster heads within a particular region with identical/similar parameters [19].

Multilayer clustering allows for a high number of nodes to be distributed in the same region of interest [ROI]. It is similar to the earlier technique of employing gateways across clusters. Researchers have effectively handled the hotspot challenge in WSN clustering.

3. Proposed Hybrid Routing Protocol

3.1 Set-up Phase

3.1.1 K-Means Clustering

K-Means is primarily dependent on the Euclidian distance, and further the cluster selection is determined by node residual energies [12]. So, in this case, the central node receives information on node position, ID and residual energy of the entire active nodes and saves it in a table in the centralized node. By gathering this information from each and every node, the k-means clustering will be executed.

Algorithm 1:

Step 1: Cluster the random nodes by initially placing K no. of centroids at random places within the search and rescue region.

Step 2: From the K no. of centroids, calculate the Euclidean distance between each node towards the initialized centroids. Form K initial clusters based on the calculated Euclidean distance.

Step 3: Assume there are nodes, each of which belongs to different distance N_d. The difficulty of determining the k centroids is the same as that of determining the minimal variance grouping of these nodes into k clusters, it is calculated by

$$\left(\frac{1}{d}\right) \times \sum \left(min_{i,j}\, d^2\,(X_i, Y_j)\right)\ i, j = 0 \rightarrow n$$

$d(X_i, Y_j)$ denotes Euclidean distance between X_i and Y_j.

Step 4: Again calculate the position of centroids available at every K cluster and assess the variation in its position when compared to its initialized position.

Step 5: If any positional variation is detected in the centroid, repeat the process step 2, else clusters can be finally obtained.

Here, every node contributes to making decision. Every node here receives the clustering information from other available nodes. With this, the algorithm clusters all nodes to determine the cluster head.

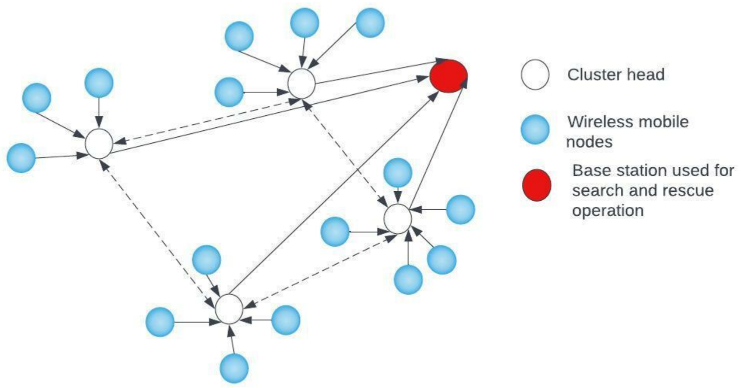

Figure 2. Proposed Hybrid Algorithm

3.1.2 Cluster Head Declaration

After the clustering the centred node and cluster head selection, the centred node communicates the knowledge gained about the cluster I which it retains. As a result, each and every node will be aware about its cluster information. This ends the clustering mechanism.

3.1.3 Energy Consumption Model

The communication protocol was developed with the intent of improving network energy efficiency. An effective energy consumption model is studied, in which energy dissipation is proportional to the sent packets. The wireless transmitter and receiver utilize 40nJ/bit energy. We assume that the amplifier's transmitter requires 120P J/bit/m2 to achieve the desired Signal to Noise Ratio (SNR).

$$E_T(a,b) = E_{T_E}(a) + E_T(a,b) \qquad \text{\_\_\_\_\_\_\_\_ (1)}$$

$$E_T(a,b) = E_M \times a + \epsilon_a \times a \times b^2 \qquad \text{\_\_\_\_\_\_\_\_ (2)}$$

$$E_R(a) = E_{R_E}(a) \qquad \text{\_\_\_\_\_\_\_\_ (3)}$$

$$E_R(a) = E_M(a) \qquad \text{\_\_\_\_\_\_\_\_ (4)}$$

Where,

E_{T_E} = Energy consumed to transmit

E_{R_E} = Energy consumed to receive

E_M = Minimum energy required to transmit and receive

a = no. of data packets

b = distance (meters)

E_T = Total energy consumed in the transmitter side

E_R = Total energy consumed in the receiver side

Equations (2 & 4) calculates the total energy consumed by Tx and Rx for transferring data packets to a distance of b meters. As a result, we can calculate the overall energy consumed by proposed WSN model. This energy model is used in proposed K-Means clustering mechanism.

3.2 Routing Phase

Following the selection of K-centroids, a regression analysis is done to determine the nearest neighbour of CH to route the data packets. The initial node detects the nearest neighbour in the other K-clusters. The source node broadcasts beacon messages to all sensor nodes in order to calculate distance. The sensor nodes' distances are determined using the moment of arrival (MoA) approach. The difference between the beacon message emitted from the initial node and reply info returned to source node is referred as moment of arrival.

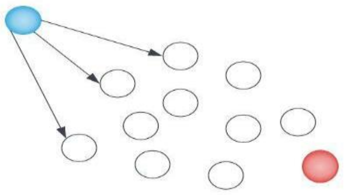

Figure 3. Baecon Messages Transfer

Figure 5 depicts the distribution of Beacon messages to locate the nearest neighbour. In Figure 5, the blue node represents the source node, while the red node represents the sink node. The beacon message is distributed to all sensor nodes by the source node [18]. The following formula is used to compute the distance of source node and other sensor nodes:

$$D = T_{BM} - T_{RM}$$

Wherein

T_{BM} indicates transmission time required for beacon messages

T_{RM} indicates about the time required to deliver the reply acknowledgement messages.

All distance data is acquired, and a regression analysis is performed to determine the next neighbouring node.

Logistic regression is a model that has been used to determine the connection of the dependent variable to one or more independent and dynamic variables. Independent factors in this case are the sensor node distances, and the dependent variable in this study are the regression results (i.e. neighbour node/distant node).

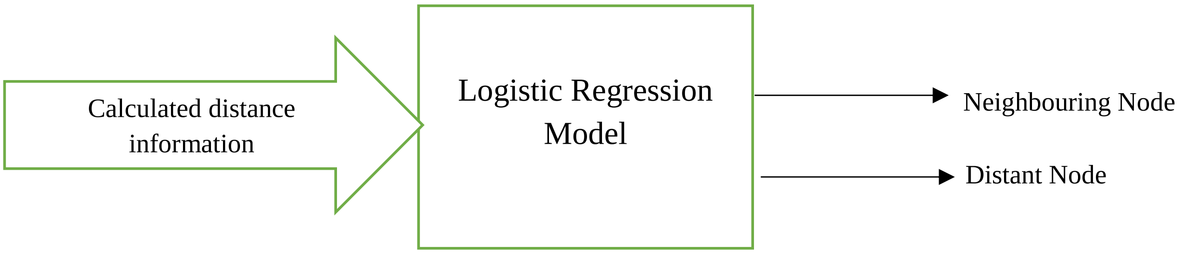

Figure 4. Proposed logistic Regression Analysis

Figure 4 depicts a logistic regression analysis between independent and dependent variables. The regression analysis is carried by employing the below-mentioned mathematical equation,

$$P(N) = \frac{1}{1 + e^{-(\beta_i + \beta_{i+1} + \delta)}}$$

Where,

β = Regression coefficient

δ = Exploratory analysis

The values of i starts from 0 and iterates consecutively

Proposed Hybrid Model

1: begin

2: if node=CH

3: while centroid exists

4: if Node contains data then

5: Transmit Data to CH

6: else if

7: Send nil message to CH

8: end if

9: end if

10: For all high energy sensor nodes

11: Source node identifies NN

12: Compute the distance d

13: Perform regression analysis P ቩSNኻ

14: Identify the NN 15. Construct route from source to base station

15: Transmits data packets to base station through NN

16: End for

---

4. Simulation

The NS2 simulator is used to simulate the proposed methodology as well as existing techniques such as DEARER and BeeSwarm. 500 sensor nodes are distributed in a square area of A 1500m × 1500m for simulation purposes. The Random Navigational Mobility Model is used to assess the mobility of a node.

Energy efficient sensor nodes will be selected from the distributed sensor nodes and clustered as K-Clusters for routing data packets ranging 10-100. The simulator time has been set at 250 seconds. To route data packets, the DSR protocol is used.

Table 2. Simulation Description

Parameters	Values
Simulator	NS2
Network area	1500m×1500m
N umber of sensor nodes	50,100,150, 250
Protocol	DSR
Simulation time	250 sec
Mobility	RNM
Data packets	10, 20,30, 40, 50
Number of runs	20

The simulation results and discussion of several characteristics such as energy consumed, network lifetime, and transmission reliability and the proposed method's values are compared with the existing methods such as BeeSwarm and DEARER.

4.1 Energy Consumption

In WSN, energy consumption generally defined as the total amount of energy used by sensor nodes to sense different environmental conditions. The formula for measuring energy consumption is as follows:

$$E = N \times E_N$$

Where, E denotes the energy consumed, N denotes the total no. of nodes and E_N denoted the energy consumed by a single sensor node.

Table 3. No. of Sensor Nodes vs. Energy Consumption

No. of Sensor Nodes	Proposed Hybrid Method (Joules)	Existing DEARER Approach(Joules)	Existing BeeSwarm Approach(Joules)
50	30	35	42
100	36	44	53
150	38	48	53
200	42	50	58
250	44	53	61

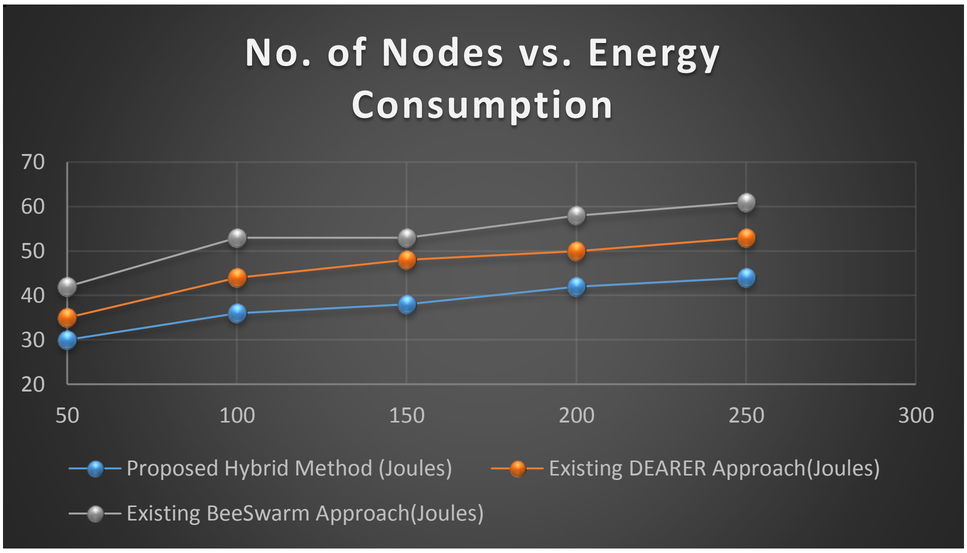

Figure 5. No. of Sensor Nodes vs. Energy Consumption

From Table 3 and Fig 5, it is observed that the proposed model has consumed an average energy of 40 Joules, whereas the existing techniques have consumed in the range of 50 Joules. Hence, it is evident that the proposed model has consumed less energy.

4.2 Network Lifetime

The ratio of a number of higher energy cluster nodes selected from the total deployed sensor nodes for effective routing is termed as network lifespan. The network lifespan is calculated in the following manner:

$$N = \frac{Total\ no.of\ selected\ higher\ energy\ nodes}{n} \times 100$$

Table 4. No. of Sensor Nodes vs. Network Lifetime

No. of Sensor Nodes	Proposed Hybrid Method (%)	Existing DEARER Approach (%)	Existing BeeSwarm Approach (%)
50	88	76	68
100	96	88	74
150	94	86	77
200	97	89	78
250	96	86	79

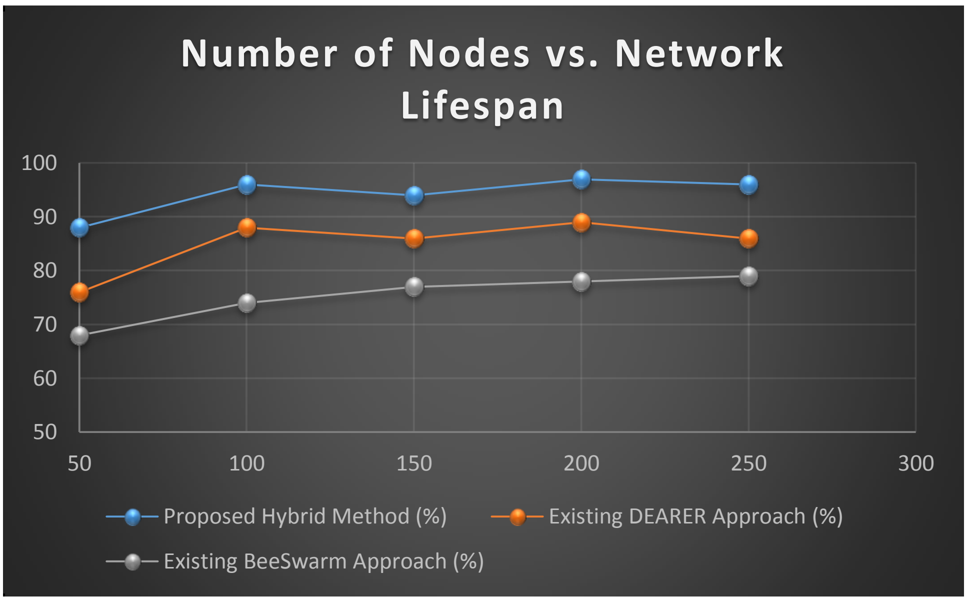

Figure 6. No. of Sensor Nodes vs. Network Lifetime

From Table 4 and Fig 6, it is observed that the proposed model has utilized more amount of higher energy nodes, whereas the existing techniques have used a comparatively less count. Hence, it is evident that the proposed model has achieved an enhanced network lifespan.

4.3 Network Reliability

Here, reliability is measured based on the packet delivery ratio, which is defined as the ratio of the number of data packets delivered at the base station to the total number of data packets sent from the source node. It is calculated as follows

$$Reliability = \frac{No. of\ Data\ Packets\ Received}{No. of\ Data\ Packets\ Sent} \times 100$$

Table 5. No. of Sensor Nodes vs. Reliability

No. of Data Packets	Proposed Hybrid Method (%)	Existing DEARER Approach (%)	Existing BeeSwarm Approach (%)
10	75	65	55
20	85	75	65
30	91	85	70
40	92	88	79
50	94	89	80

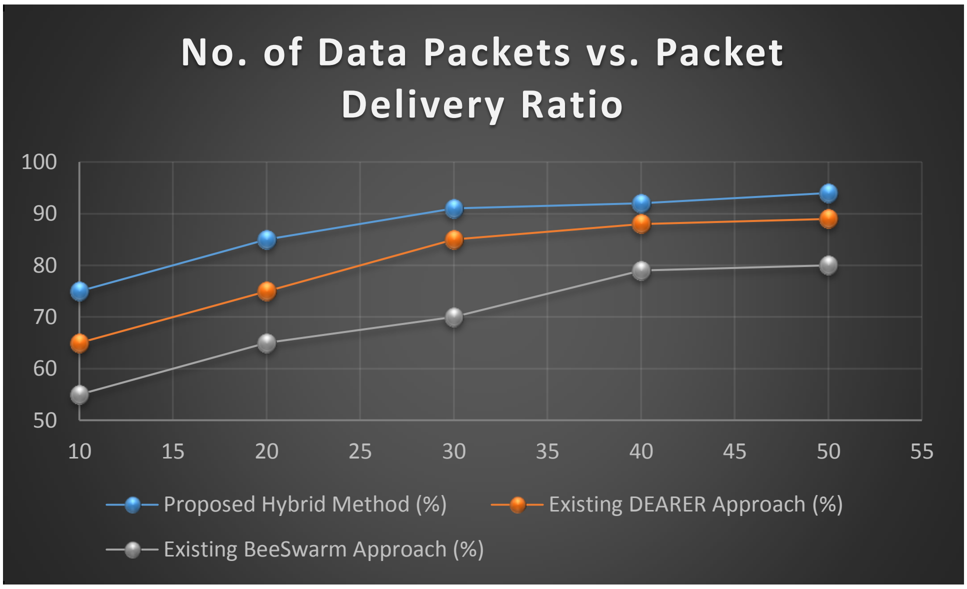

Figure 7. No. of Sensor Nodes vs. Reliability

From Table 5 and Fig 7, it is observed that the proposed model has achieved a high packet delivery ratio approximately 90%, whereas the existing techniques have achieved in the range of 70-80%. Hence, it is evident that the proposed model has consumed less energy.

From the aforementioned results, it is clearly evident that the proposed hybrid method using K-Means and LR has outperformed the existing routing technologies in terms of network reliability by extending the network lifetime and reducing the energy consumption.

5. Conclusion

The proposed research study has suggested a methodology to improve the search and rescue operations with the successful deployment of wireless sensor networks. To reduce network energy consumption, the proposed Wireless Sensor Network employs a K-Means clustering protocol and Logistic regression based model to allow multi-hop routing by successfully carrying out a unique cluster head election process. The infrastructureless placement of wireless sensor nodes assist in attracting and finding survivors, emergency priority and broadcast relevant emergency data to the base station to assist in the emergency rescue and search operations. The proposed model outperforms the other relevant communication models in terms of energy consumption, reliability and network lifetime. The model was evaluated in NS2 simulator yielding reduced energy consumption and reliability average of 40 Joules and 91% respectively. This increased packet delivery ratio and reduced energy consumption allows for the interaction with the survivors, making the relief effort more efficient and successful.

References

[1] Hassan, Marwan Hamid, Salama A. Mostafa, Hairulnizam Mahdin, Aida Mustapha, Azizul Azhar Ramli, Mustafa Hamid Hassan, and Mohammed Ahmed Jubair. "Mobile ad-hoc network routing protocols of time-critical events for search and rescue missions." Bulletin of Electrical Engineering and Informatics 10, no. 1 (2021): 192-199.

[2] Benkhelifa, Imane, Nadia Nouali-Taboudjemat, and Samira Moussaoui. "Disaster management projects using wireless sensor networks: An overview." In 2014 28th International Conference on Advanced Information Networking and Applications Workshops, pp. 605-610. IEEE, 2014.

[3] Nandan, Aridaman Singh, Samayveer Singh, Aruna Malik, and Rajeev Kumar. "A Green Data Collection & Transmission Method for IoT-Based WSN in Disaster Management." IEEE Sensors Journal 21, no. 22 (2021): 25912-25921.

[4] Vanderhorst, Hamlet Reynoso, Subashini Suresh, Suresh Renukappa, and David Heesom. "Strategic framework of Unmanned Aerial Systems integration in the disaster management public organisations of the Dominican Republic." International Journal of Disaster Risk Reduction 56 (2021): 102088.

[5] Ismail, Mohd Ismifaizul Mohd, Rudzidatul Akmam Dziyauddin, Robiah Ahmad, Norulhusna Ahmad, Noor Azurati Ahmad, and Afifah Maheran Abdul Hamid. "A Review of Energy Harvesting in Localisation for Wireless Sensor Node Tracking." IEEE Access (2021).

[6] Sumathi, Jayalekshmi, and R. Leela Velusamy. "A review on distributed cluster based routing approaches in mobile wireless sensor networks." Journal of Ambient Intelligence and Humanized Computing 12, no. 1 (2021): 835-849.

[7] Bezerra, Pamela, Po-Yu Chen, Julie A. McCann, and Weiren Yu. "Adaptive monitor placement for near real-time node failure localisation in wireless sensor networks." ACM Transactions on Sensor Networks (TOSN) 18, no. 1 (2021): 1-41.

[8] Quy, Vu Khanh, Vi Hoai Nam, Dao Manh Linh, Nguyen Tien Ban, and Nguyen Dinh Han. "A survey of QoS-aware routing protocols for the MANET-WSN convergence scenarios in IoT networks." Wireless Personal Communications 120, no. 1 (2021): 49-62.

[9] Jia, Lanfang. "Distributed energy balance routing algorithm for wireless sensor network based on multi-attribute decision-making." Sustainable Energy Technologies and Assessments 45 (2021): 101192.

[10] He, Guoyou. "Destination-sequenced distance vector (DSDV) protocol." Networking Laboratory, Helsinki University of Technology 135 (2002): 1-9.

[11] Stuetzle, Werner. "Estimating the cluster tree of a density by analyzing the minimal spanning tree of a sample." Journal of classification 20, no. 1 (2003): 25-47.

[12] Ahmad, Aasem, and Zdenek Hanzalek. "An energy-efficient distributed TDMA scheduling algorithm for ZigBee-like cluster-tree WSNs." ACM Transactions on Sensor Networks (TOSN) 16, no. 1 (2019): 1-41.

[13] Adu-Manu, Kofi Sarpong, Nadir Adam, Cristiano Tapparello, Hoda Ayatollahi, and Wendi Heinzelman. "Energy-harvesting wireless sensor networks (EH-WSNs) A review." ACM Transactions on Sensor Networks (TOSN) 14, no. 2 (2018): 1-50.

[14] M. Sabet and H. R. Naji, “A decentralized energy efficient hierarchical cluster-based routing algorithm for wireless sensor networks,” AEU - International Journal of Electronics and Communications, vol. 69, pp. 790– 799, 2015. DOI: 10.1016/j.aeue.2015.01.002

[15] Doryanizadeh, Vida, Amin Keshavarzi, Tajedin Derikvand, and Mahdi Bohlouli. "Energy Efficient Cluster Head Selection in Internet of Things Using Minimum Spanning Tree (EEMST)." Applied Artificial Intelligence (2021): 1-26.

[16] Bhola, Jyoti, Surender Soni, and Gagandeep Kaur Cheema. "Genetic algorithm based optimized leach protocol for energy efficient wireless sensor networks." Journal of Ambient Intelligence and Humanized Computing 11, no. 3 (2020): 1281-1288.

[17] Chu, Shu-Chuan, Thi-Kien Dao, and Jeng-Shyang Pan. "Identifying correctness data scheme for aggregating data in cluster heads of wireless sensor network based on naive Bayes classification." EURASIP Journal on Wireless Communications and Networking 2020, no. 1 (2020): 1-15.

[18] Adewale, Oyinkanola Lateef O., Sawal Hamid Bin Md Alli, Ramizi Mohamed, Aremu Olaosebikan Akanni, Shah Murtaza Rashid Al Masud, Abu Bakar Asmidar, Salman Yussof et al. "Deep Neural Classification and Logit Regression Based Energy Efficient Routing in Wireless Sensor Network." Journal of Theoretical and Applied Information Technology 97, no. 07 (2019).

[19] Hassan, Marwan Hamid, Salama A. Mostafa, Hairulnizam Mahdin, Aida Mustapha, Azizul Azhar Ramli, Mustafa Hamid Hassan, and Mohammed Ahmed Jubair. "Mobile ad-hoc network routing protocols of time-critical events for search and rescue missions." Bulletin of Electrical Engineering and Informatics 10, no. 1 (2021): 192-199.

Author’s biography

Dinesh Kumar Anguraj is currently working as Associate Professor in the Department of Computer Science and Engineering at Koneru Lakshmaiah Education Foundation, Andhra Pradesh, India. He received his Doctor of Philosophy in Information and Communication Engineering from Anna University, Tamil Nadu in 2018 and received his Master of Engineering in Computer Science and Engineering from Karpagam University, Tamil Nadu in 2013. His research interest includes Wireless Sensor Network, Body Area Network and Network Security. He is served as a reviewer for various International Journals.