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RESEARCH ARTICLE

Reliable and Efficient Routing Model for Unequal Clustering-Based Wireless Sensor Networks

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Abstract – The lifetime of Wireless Sensor Networks (WSNs) can be extended with the adoption of an effective clustering method. However, the major problem of a multihop-based clustered network is the "hotspot" problem i.e., the Cluster Head (CH) closer to the base station tends to die very fast in comparison with far away nodes due to inter-cluster communication. Furthermore, no prior works have considered reliability and efficient factors together for provisioning modern data-intensive applications under WSN. In addressing research issues, this paper presents a Reliable and Efficient Routing (RER) design under an unequal clustering environment. The RER employs a two-phase model, first an effective CH selection strategy for enhancing efficiency; secondly, Reliable and Efficient Route Selection (RER) model for provisioning application with QoS constraint. Experiment outcomes show that the proposed routing strategy improves network lifetime with reduced communication overhead and communication delay.

Index Terms – Clustering, Energy Efficiency, Reliability, Unequal Clustering, Cluster Head, Assistant Cluster Head.

1. INTRODUCTION

The future generation WSNs are required to be installed into the Internet of Things (IoT) environment for provisioning different applications such as disaster management, environment monitoring, precision agriculture, etc. [1]. WSNs are composed of a large number of tiny and self-organized sensor devices, generally placed in hazardous locations for carrying out different operations, such as sensing, aggregation [2], data collection, and data transmission for realizing intelligent decision making. WSNs provide certain benefits such as low power consumption, high reliabilities, and ease of deployment; thus, are adopted in different domains such as in healthcare, surveillance system, etc. [3]. However, it has certain limitations such as limited bandwidth, storage, processing power, and computation capacity; thus, reducing the lifetime of WSNs [4]. As the sensor devices are battery-powered, preserving the energy becomes of utmost importance, and energy-efficient schemes are most desired. Further, an effective route selection design is needed for providing reliability requirements of modern applications [5, 6].

Clustering techniques such as Low Energy Adaptive Clustering Hierarchy (LEACH) have been emphasized for boosting the lifetime of the network [7, 8]. In LEACH, the WSNs are segmented into smaller clusters and sensor devices with maximum energy levels are chosen as Cluster Heads (CHs) and the rest all will behave as member nodes. Here, the member devices communicate the sensed information with their respective CHs (i.e., intra-cluster communication), then, the CHs perform aggregation of data to eliminate redundant information [9, 10] and transmit through single or multi-hop fashion towards the base station (inter-cluster communication). In multi-hop [11, 12] based clustering model, the CH that is placed far away from the base station consumes less energy in comparison with CH closer to the base station; thus, resulting in a high probability of energy hole problem i.e., the node closer to the base station is expected die faster [13]. In WSNs, generally, the sensor device is placed randomly, and nodes placed closer to the base station consume more energy in comparison with the nodes that are placed far away from the base station. As a result of these, the nodes closer to the base station tends to die faster resulting in an energy-hole problem. In addressing the energy-hole problem, a new method is modeled in [14], an unequal cluster algorithm where each cluster will have a different size; the cluster far away from the base station will have a larger cluster size and cluster closer to the base station will have smaller cluster size, as shown in Figure 1. Adoption of unequal clustering mechanism aids in preserving some energy of relay nodes during intra-cluster communication. Relay nodes are a special type of nodes in sensor networks, whose task is only to transmit data generated by other sensor nodes,

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without sensing the environment. However, no prior works have considered CH selection and routing considering QoS constraint under unequal clustering environment. Further, in the existing model, relay path formation is done randomly, subject to availability without considering QoS constraint; thus, failed to assure reliability requirement for provisioning modern data-intensive workload applications. This motivated the proposed work to design a reliable and efficient routing model considering QoS constraints for WSNs.

The objective of the RER model is to develop an efficient CH selection strategy that improves network coverage and reduce hotspot spot problem considering an unequal clustering environment. To reduce re-clustering overhead assistant cluster head is elected. Further, the objective of the RER model is to find reliable and efficient relay nodes for communicating data toward base stations. In RER a multi-objective metrics is defined that minimize energy, several relay node required, and also minimize packet loss. Finally, the multi-path is obtained for transmitting a packet with and without QoS prerequisite.

The significance of using a reliable and efficient routing model is as follows.

- The RER model provides an improved CH selection model by considering unequal cluster size effectively to mitigate hotspot problems by preventing loss of connectivity problem; thereby improving lifetime performance.
- In RER, the packets are aggregated in CH and relay nodes are used for sending aggregated packets towards the base station.
- The RER reduces re-clustering overhead by the election of an assistant cluster head.
- The RER model can offer high energy efficiency and reliability by employing multi-objective parameters such as energy efficiency, packet failure, and hop size.

The organization of the paper is as follows. In section 2, the Literature survey is explained. In section 3 reliable and efficient routing model for wireless sensor networks is presented. In section 4, the performance achieved using RER concerning the existing routing mechanism is discussed. In the section 5, the paper is concluded with future research directions.

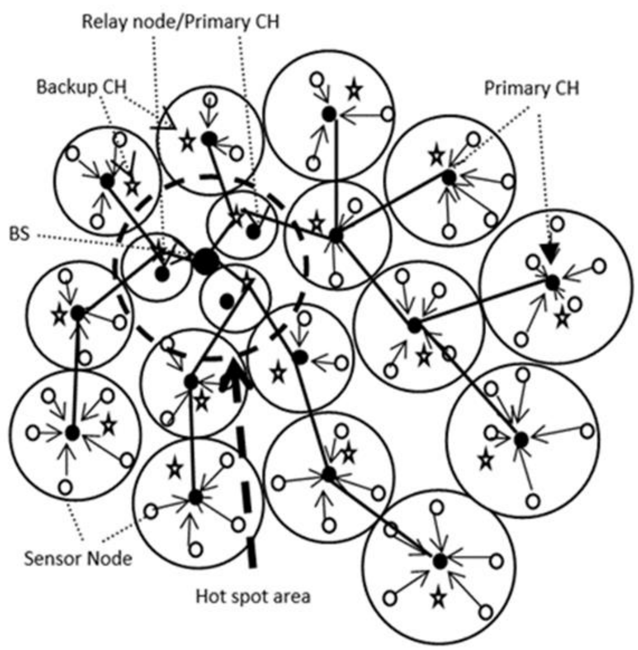

Figure 1 Unequal Clustering-Based Wireless Sensor Networks

2. LITERATURE SURVEY

The survey is done to study various recent routing designs presented for WSNs [15], [16]. The authors presented an ideal clustering model for data transmission emphasizing improving lifetime and energy efficiency of networks considering future generation communication environments such as 5G networks, IoT, and many more. K-mean clustering method is used for creating clusters and a multihop mechanism is used for creating routing paths in [17]. Here cluster-based routing is done till two-third of sensor devices die in the network; after that, packets are routed in a multihop fashion by forming a chain. However, the major limitation of

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work induces higher overhead to CH closer to the base station.

In [18], Ademola et al., presented a hierarchical-based data transmission mechanism for WSNs using a fog computation environment. They used fog computing for optimizing the energies of WSNs for catering requirements of IoT-based applications. To establish an ideal path, an ant colony optimization model is employed. The model suffers from convergence overhead in establishing the ideal route. In [19], Prachi et al. presented a butterfly optimization model for selecting the ideal CH in the cluster of sensor devices. The CH selection is optimized considering multi-objective parameters such as connectivity, neighbor density, distance with the base station, distance among neighbors, and residual energy. Then, the Ant Colony optimization model is used for picking the ideal path considering multi-objective parameters such as connectivity, distance, and residual energy. The major limitation it suffers from a hotspot problem and CH selection induces non-polynomial deterministic problems.

Fang et al., presented the routing model in [20] that is energy efficient and addressed the hotspot problem by adopting an unequal clustering environment. Further, to reduce the energy overhead of CHs, double cluster heads are elected. An effective CH selection considering the event and energy-driven rotation strategy is adopted for balancing the energy of cluster members and CHs. Addressing the hotspot problem is not considered and works only for the smaller network.

In addressing the hotspot problem in [21], Jin Wang et al. presented multiple mobile sink-based data collection mechanisms. Here, every device transmits the information to a mobile sink employing single-hop communication. Authors presented an effective mobile sink moving trajectory employing modified particle swarm and genetic algorithm optimization model together, where Particle Swarm Optimization (PSO) is utilized to place sink with high coverage rate and Genetic Algorithm (GA) are utilized to establish a moving path of different sinks. However, employing such a model is expensive because of buffer concurrency and communication overhead. High uncertainty in establishing node position and energy levels of sensor devices will significantly impact the energy efficiency of WSN [22]; in addressing such issues, recently, several models have emphasized using the type-1 fuzzy rule.

A soft computing technique was used in [23], by employing type-2 fuzzy rules for cluster head selection. The model is further, aimed at balancing the load among CH; however, the model is designed considering homogenous cluster size and factors like packet loss and link quality are not considered during inter-cluster communications. In addressing the hot-spot problem in [24], the authors proposed a type-2 fuzzy rule and emphasized a different routing design for improving lifetime and as well as enhancing security in wireless sensor networks. The type-2 fuzzy rules added interval for building membership function; thus, can handle uncertainty in comparison with the type-1 fuzzy rule [25]. However, CH selection is done through a single-objective strategy; thus, inducing additional energy overhead due to poor balancing of load.

Yang Tao et al in [14], presented unequal clustering methodologies using type-2 TSK fuzzy logic theory (UCT2TSK) with intervals by employing type-2 fuzzy rule Takagi-Sugeno-Kang (TSK) for designing Unequal Clustering (UC) algorithm. The UCT2TSK addresses the hotspot problem, with less computational complexity (such as distance towards base station, node density, and remaining energy), and enhance network lifetime. Here multi-objective parameters such as device density, residual energy, and distance to the sink are considered for optimization using fuzzy rule [26-28]; the outcome is used for optimizing the cluster size and selecting cluster head. However, UCT2TSK doesn't consider QoS prerequisite for the selection of Cluster head or Relay nodes (RNs). The RNs act as a hop node, thus aiding in reducing the distance between the faraway sensor device and the base station/sinks.

In addressing the research challenges the following problem statement the RER model is aimed at addressing. First, efficient CH selection under an unequal clustering environment should be designed. Second, an efficient relay node must be selected that must be energy efficient and at the same time should take less time to transmit. Third, should be reliable for communicating both applications with and without QoS prerequisite. The reliable and efficient routing model is methodology is presented in the next section to overcome the above-mentioned problem stated.

3. PROPOSED METHODOLOGY

The major factor impacting the lifetime performance of sensor nodes is the hotspot problem (i.e., the batteries of sensor nodes near the base station drain out very fast). To address such a problem, recent work hypothesis includes employing unequal clustering for performing routing and employing a soft-computing technique that enhances lifetime performance [29]; however, this induces additional computation overhead for carrying out optimization process, resulting in loss of energy.

Further, in the existing model, relay path formation is done randomly, subject to availability without considering QoS constraint; thus, failed to assure reliability requirement for provisioning modern data-intensive workload applications. This paper uses the hypothesis of the RER model, selects CH with high efficiency using multi-objective parameters under an unequal clustering environment. Relay nodes are chosen with high reliability considering multi-objective parameters; thus, aiding in improving the overall performance of WSNs.

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3.1. Reliable and Efficient Routing Model

This sub-section presents a routing model for WSNs that is highly reliable and efficient. First, the RER describes the system and energy model used in the RER model. Then, discusses the standard CH selection algorithm. Further, an improved CH and Assistant CH [3] selection model considering an unequal clustering environment is presented. Later, discusses data aggregation and relay selection model for performing hop-by-hop transmission. Finally, reliable, and efficient routes are identified for communicating the packets both with and without QoS constraint. The phases involved in RER are shown in Figure 2.

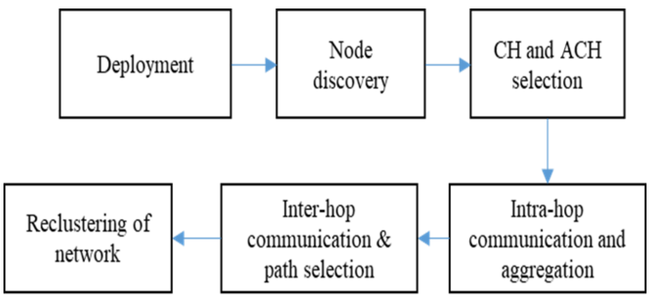

Figure 2 Block Diagram of Different Phases of Reliable and Efficient Routing Model for WSNs

3.2. System Model

This subsection presents a cluster-based routing model with unequal cluster size for providing reliable and efficient communication among sensor devices. In an unequal clustering environment, the cluster size is smaller near the base station and the cluster gets bigger as it moves away from the base station. A sample representation of unequal clustering is shown in Figure 1. The RER model working process is given in Algorithm 1. Here, the sensor device is placed randomly across the sensing location. Each sensor device sends its present energy level and location information to the corresponding gateway/base station. The node with the highest reliability factor is selected as CH and the node with the second-best reliability is elected as assistant cluster head (ACH). Note that, ACH will not take part in sensing and transmission operations. Then, the other device (i.e., member device) connects to the respective CH. Here, the member node collects sensory information and sends it to the respective CH and CH transmits the sensory information to other CH or Relay Nodes (RN) towards the base station. Once the CH reaches the lower energy threshold level, it becomes a member node and ACH becomes CH. In this way, it aids in reducing re-clustering overhead.

Step1. Start

// Stage 1- Deployment

Step 2. Initialize system parameter for deploying network

- Initialize system parameters such as initial energy, sensor nodes size, sensing and communication range
- Place sensor nodes randomly across the area of $A \times A$

//Stage 2- Node discovery

Step 3. Compute parameter for node discovery

- Every sensor node transmit their energy level and distance concerning the base station
- Compute the distance between the adjacent sensor node and communicate to the base station

//Stage 3- CH selection

Step 4. Select CH using modified equation

- The base station selects CH using Equation (8).
- The node with $\max T(d)$ is selected as CH.
- Then the other device within the CH coverage area is added to it as member nodes.

//Stage 4- Intra-hop communication and aggregation

Step 5. CH gathers and aggregate data from its member

- Every member communicates the sensed data to its CH.
- CH performs aggregation of data.

//Stage 5- Inter-hop communication & path selection

Step 6. Using best path CH transmit to the base station

- CH finds a reliable and efficient path with a fewer number of hops, minimal energy consumption, and less packet loss using Equation (12).

//Stage 6-Re-clustering phase

Step 7. Re-clustering of the network.

- Once the CH reaches the lower energy threshold level, it becomes a member node and ACH becomes CH
- Once ACH reaches the lower energy threshold value, go to step 3 and a new CH and ACH are selected.

Step 8. Stop

Algorithm 1 The Reliable and Efficient Routing Model

3.3. Energy Model

This work considers cluster-based communication under an unequal clustering environment. The clustered-based

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communication is composed of two phases as inter and intracluster communication. Thus, the energy required for communication among different sensor devices varies under both inter and inter-cluster communication. Alongside, the sensor device changes its operating mode from sensing $K_{\mathbb{E}}$, central processing unit (CPU) $L_{\mathbb{E}}$, and radio transmission mode $D_{\mathbb{E}}$, where each mode will have a different energy consumption model [9]. This work uses the energy dissipation model presented in [30]. The total energy consumption $C_{\mathbb{E}}$ is measured by adding all energy modes put forth together using the following equation

$$C_{\mathbb{E}} = K_{\mathbb{E}} + L_{\mathbb{E}} + D_{\mathbb{E}} \quad (1)$$

The adoption of cluster-based communication aid in preserving batteries of senor devices by changing its states from active to sleep and vice versa [17]; thus energy consumption will vary according to its operating states as defined below

$$K_{\mathbb{E}} = K_{0\to 1} + K_{1\to 0} + K_{1\to 1} \quad (2)$$

where $K_{0\to 1}$ defines the energy required for changing states from $sleep$ to $active$, $K_{1\to 0}$ defines the energy required for changing states from $active$ to $sleep$ and $K_{1\to 1}$ defines the energy required for carrying out sensing operation.

In a similar manner to Equation (2) the processing unit $L_{\mathbb{E}}$ energy consumption for changing state [11] is measured using the following equation

$$L_{\mathbb{E}} = L_0 + L_1 \quad (3)$$

where L_0 defines the energy induced in each operating state, and L_1 defines the energy required for changing from one state to another state. In general, adopting a cluster-based communication model, the CPU has three states such as sleep, idle, and active states. Therefore the CPU energy consumption is measured using the following equation

$$L_{\mathbb{E}} = \sum_{a=1}^{b} D_{0(a)}\, T_{0(a)} + \sum_{u=1}^{v} S_{1(u)}\, R_{1(u)} \quad (4)$$

where $D_{0(a)}$ defines the energy required to be in the state a, $T_{0(a)}$ defines session instance of CPU in the state a, where $a = 1,2, \dots b$ defines the present state, $S_{1(u)}$ defines counter for establishing the frequency of new state u, where $u = 1,2, \dots, v$, v defines total size state fluctuation, $R_{1(u)}$defines the energy required for performing state transition.

The energy consumption of radio unit $D_{\mathbb{E}}$ is measured using the following equation

$$D_{\mathbb{E}} = D_{\frac{\mathcal{T}}{\mathcal{R}}}(q, M) = \begin{cases} qK_{\varepsilon} + q\alpha f(M)^2 & M < M_0 \\ qK_{\varepsilon} + q\alpha x(M)^4 & M > M_0 \end{cases} \quad (5)$$

where M defines distance and q defines packet size in bits, the $M_0 = \sqrt{\frac{q\alpha f}{q\alpha x}}$ defines the distance parameter, $D_{\mathcal{T}}$ defines energy required for transmitting q nits of packet considering certain distance M, $D_{\mathcal{R}}$ defines energy required for transmitting q nits of packet considering certain distance M, αx defines multipath amplification energy and αf defines free space propagation parameter. The aforementioned energy model provides a more idealistic model for unequal and heterogeneous clustered-based WSNs.

3.4. Standard Cluster Head Selection Model

In standard clustering protocol, each sensor node acts as a CH for a fixed interval of time in an unbiased and random manner. Each round is composed of two-phase such as the setup phase and the steady phase. In the setup phase, the cluster formation is done where every node sends an energy parameter to the base station, the base station selects the node with the highest threshold parameter $T(d)$ as CH. For balancing energy every round new CH are elected. In the steady phase, each node carries out sensing and transmits to the CH and then CH will transmit the packet towards the base station through different intermediate CHs. The CH election using standard clustering model is defined in below equation

$$T(d) = \begin{cases} \dfrac{r}{1 - r \times [\varphi mod(1/r)]}, & if\ d\epsilon S; \\ 0, & Otherwise. \end{cases} \quad (6)$$

where r defines the average ratio among CH concerning total sensor nodes, φ defines present round number which varies between $0 \leq \varphi < \infty$, and S set of nodes that have not yet been CH considering session $1/r$ rounds. Using Equation (6) different CHs are elected for a certain period in their respective round. The node that has been as CHs in the previous round will not take part CH selection process in the next round; in this way overhead of CH can be reduced. However, the standard selection suffers from a hotspot problem. In addressing the hotspot problem in the next sub-section a new CH selection model is presented.

3.5. Cluster Head Selection and Assistant Cluster Head Selection Model

The sensor nodes will have identical communication range S and are placed randomly across WSNs with density δ. This work adopts an unequal clustering algorithm as in [20]; thus, every cluster will have a different cluster size. As a result, in this work, the parameter r is optimized considering normalized overlapping region concerning certain sensor device d in standard CH selection model as in Equation (7) which is defined below

$$r(d) = \propto \times\, \omega(d), \quad (7)$$

where $\propto$ represents the average size of cluster and ω describes

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sensor device normalized overlapping region. The modified threshold model $T(d)$ for selection of CH for respective node d is obtained using the following equation

$$T(d) = \begin{cases} \dfrac{r(d)}{1 - r(d) \times [\varphi mod(1/r(d))]}, & if\ d \in \bar{S}; \\ 0 & Otherwise. \end{cases} \quad (8)$$

where $\bar{S}$ defines member node which has not been CH yet for respective session period, d represents the CH for round $1/r(d)$; thus, different devices will have a different probability of being CH. The node with the second-best threshold parameter is elected as Assistant CH (ACH) [20].

3.6. Data Aggregation Model

Here, the probability of packet failure in the network is computed. In this work, a Rayleigh fading [11] channel is considered. The probability of packet failure rate relies on the neighboring density of CHs. Here using signal-to-noise-ratio considering distance s among CHs is used for measuring average bit error rate $L_\prime^b$of respective channel. Therefore, the probability of packet failure considering B bit packet length can be established using the following equation

$$L_\prime^p = 1 - (1 - L_\prime^b)^B. \quad (9)$$

Therefore, the aggregated data by cluster head considering packet failure is measured by assuming th at both sensor node sends $\mathscr{b}_o$ bits towards respective CH; thus, the total data $\mathcal{B}_\hbar$ bits aggregated by respective CH is measured using the following equation

$$\mathcal{B}_\hbar = \sum_{j=1}^{\hbar} \mathscr{b}_o - L_\prime^p \quad (10)$$

where $\hbar$ defines the member size of respective CHs. An important thing to be noted here is that the adoption of unequal clustering results in having a different size for different CHs.

3.7. Relay Node Selection Model

The Base station selects a set of relay nodes (RN) utilizing multi-objective parameters such as coverage time, association time, traffic load, and connectivity. Every CH searches for RN (i.e., μ) in one hop distance and extends routing path $U_{\gamma\mu}^q$ using (11).

$$U_{\gamma\mu}^q = H_\gamma + \left(\frac{F_O^{\mathbb{M}} - F_\mu^c}{F_O^{\mathbb{M}}} * \frac{W_O^{\mathbb{M}} - W_\mu^c}{V_O^{\mathbb{M}} + W_\mu^c} * \frac{S_O^{\mathbb{M}} - S_\mu^c}{S_O^{\mathbb{M}} + S_\mu^c} \right) \quad (11)$$

where H_γ represent hop count of γ concerning base station for reliable routing path formation (RRPF), $F_O^{\mathbb{M}}$ represents sensor node residual energy, F_μ^c defines present energy of μ, $W_O^{\mathbb{M}}$ defines maximal mobility nature of sensor node, W_μ^c represents present mobility nature of μ, $S_O^{\mathbb{M}}$ represents maximum coverage range of sensor node, and S_μ^c defines the present coverage range of μ.

3.8. Reliable and Efficient Route Selection Model

The objectives of the reliable and efficient route selection (RERS) model are used to improve energy efficiency and at the same time meet the reliability requirement of real-time application. Here, we adopt a multi-objective parameter such as residual energy, hop count, and packet failure probabilities for building RERS path P_M as in equation (12).

$$P_M = \mathcal{E} + H_\gamma + \overline{H}_\gamma + P_l \quad (12)$$

where $\mathcal{E}$ represents the residual energy of the sensor device, H_γ defines the anticipated size of the intermediate/relay device, $\overline{H}_\gamma$ defines the inverse of the anticipated size of the intermediate device and P_l defines the packet failure probability parameter. Here, we adopt a multipath-based transmission model for balancing load, reducing latency, and improving energy efficiency for transmitting packets with and without QoS constraints. Using threshold parameter, we will obtain multipath G using the following equation

$$G = U + N \quad (13)$$

The RER model uses U for transmitting packets without QoS constraint which is obtained using equation

$$U = \frac{L}{L + J} G \quad (14)$$

where L defines packets without QoS constraint and J defines packet with QoS constraint and uses N paths for transmitting packets with QoS constraint which is obtained using the following equation

$$N = \frac{J}{J + L} G \quad (15)$$

These G paths can be used for transmitting packets, where U is used for transmitting packets without QoS constraint and N paths are used for sending packets with QoS constraint.

The routing objective metrics: In section 3.4 this work presented an effective CH and ACH selection methodology that improves coverage and address hotspot problem, respectively; and thereby improving network lifetime. After electing CH and ACH the data is aggregated to reduce the size of data for transmitting in inter-hop communication as shown in section 3.6; thereby improving the energy efficiency of the network. Using section 3.7 set of relay nodes is elected for inter-hop communication and using section 3.8 a multi-objective parameter is modeled that reduces the number of hops involved with minimal energy consumption and packet loss. Finally, multipath is obtained toward the base station to improve QoS i.e., netter data delivery, throughput, etc.

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The adoption of effective CH selection considering unequal clustering, packet failure optimization, multi-objective relay nodes selection, and multipath-based transmission helps the RER model to improve lifetime efficiency with minimal communication overhead in comparison with existing routing models which is experimentally proved through a simulation study.

4. RESULT AND DISCUSSION

Here, the experiment is conducted for validating the outcome achieved using RER, LEACH, and UCT2TSK [14]. The SENSORIA [31] simulator is used for evaluating different routing models. All the models considered for evaluation are implemented using C# programing language. The parameters used for studying the performance of the different model is described in Table 1. The metrics considered for validating the routing model are lifetime, communication delay, and control channel communication overhead.

Simulation Parameter	Value
Network area	100m× 100m
Base station	1
Base station position	Placed outside sensing region (i.e., at the edge of the network)
Number of sensor devices	500 to 3000
Transmission range	10 meters
Sensing range	5 meters
Sensor type considered	Temperature
Initial energy	$0.1 - 0.2$ j
Radio unit energy consumption	50 nj/bit
Amplification energy (Emp)	100 pJ/bit/m^2
Idle energy consumption (Eelec)	50 nj/bit
Control packets size	512 bits
Data packets size	5000 bits
Transmission speed	256 bits/s
Bandwidth	5000 bits/s
Sensing time	0.1s

Table 1 Simulation Parameter Used for Evaluation

4.1. Lifetime Performance

In this section lifetime performance of using RER, LEACH, and UCT2TSK routing models considering varied sensor devices is studied. In Figure 3, the sensor devices are varied from 500 to 3000 and the lifetime outcome achieved using RER, LEACH and UCT2TSK routing models is graphically shown. Figure 3 interprets that RER model improves lifetime performance by 53.44%, 58.002%, 61.55%, 63.68%, 64.3%, 66.15%, and 61.18% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 3 interprets that RER model improves lifetime performance by 70.49%, 75.82%, 84.96%, 89.58%, 89.75%, and 90.79% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model improves lifetime performance by 83.56% and 61.18% on average when compared with LEACH and UCT2TSK routing models, respectively. The significant result shows that RER is scalable considering smaller and larger density WSN environments due to the adoption of improved CH and ACH selection under unequal clustering environments.

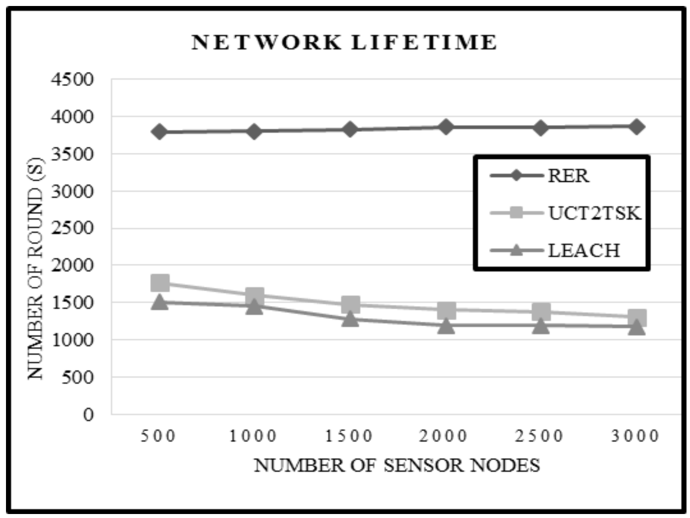

Figure 3 Network Lifetime under Varied Density

4.2. Communication Delay

In this section, the time required for communicating the packets from sensor devices to cluster head, thereby to BS is discussed and the performance of the RER model is compared with LEACH and UCT2TSK routing model. The routing model is considered with varied sensor devices from 500 to 3000. Figure 4 shows the comparative graph and interprets the RER model reduces communication delay by 54.03%, 48.63%, 46.24%, 53.88%, 57.63%, 55.48%, and 52.65% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 4 interprets that the RER model reduces communication delay by 57.11%, 54.91%, 54.99%, 61.27%, 61.42%, and 59.50% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model reduces communication delay by 58.2% and 52.65% on average when compared with LEACH and UCT2TSK routing models, respectively. The

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significant reduction of delay is due to the adoption of multipath-based route selection for transmitting packets according to the QoS prerequisite. The result achieved by RER is due to adoption overall result showing the RER can satisfy the QoS requirement of modern applications.

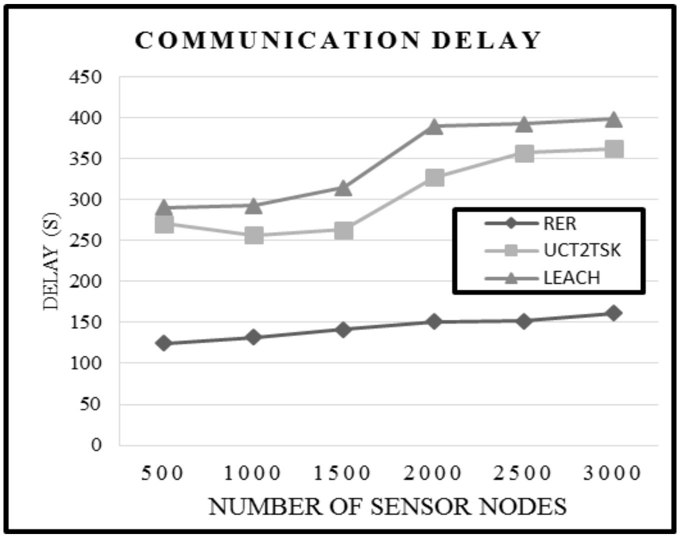

Figure 4 Communication Delay Performance Delay under Varied Density

4.3. Control Channel Communication Overhead

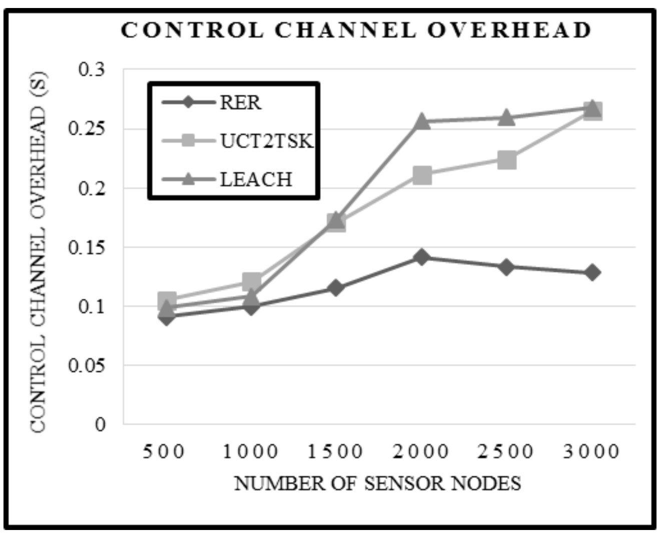

Figure 5 Control Channel Overhead under Varied Density

In this section CCH overhead performance of using RER, LEACH, and UCT2TSK routing models considering varied sensor devices is studied. In Figure 5 the sensor devices are varied from 500 to 3000 and CCH overhead achieved using RER, LEACH, and UCT2TSK routing models is graphically shown. The Figure 5 interprets that RER model reduces CCH overhead by 22.51%, 25.73%, 38.28%, 42.56%, 40.58%, 47.8%, and 36.24% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 5 interpret that the RER model reduces CCH overhead by 17.78%, 17.38%, 39.23%, 52.64%, 48.71%, and 48.29% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model reduces CCH overhead by 37.34% and 36.23% on average when compared with LEACH and UCT2TSK routing models, respectively. The result shows up to node size of 1000 all routing model attain similar result; however, as nodes size is increased beyond 1000 it can bees both LEACH and UCT2TSK routing models induces significantly higher CCH overhead. On the other side, the RER model induces slight overhead because of minimizing re-clustering overhead through a selection of ACH in the RER model.

4.4. Throughput

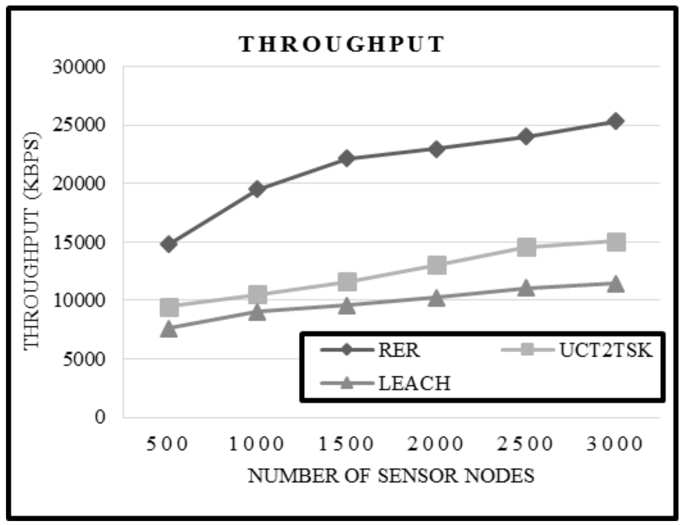

Figure 6 Throughput under Varied Density

In this section throughput performance of using RER, LEACH, and UCT2TSK routing models considering varied sensor devices is studied. In Figure 6 the sensor devices are varied from 500 to 3000 and throughput achieved using RER, LEACH, and UCT2TSK routing models is graphically shown. The Figure 6 interprets that RER model improves throughput by 35.91%, 46.24%, 47.56%, 43.25%, 39.27%, and 40.41% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 6 interpret that RER model improves throughput by 48.52%, 53.76%, 56.75%, 55.28%, 53.95%, and 54.69% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model improves throughput by 53.82% and 42.11% on average when compared with LEACH and UCT2TSK routing models, respectively. The significant result achieved is due to the adoption of improved cluster head selection that focuses

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on improving coverage thereby increasing the lifetime of the network and generation of a higher number of packets in comparison with LEACH and UCT2TSK routing models.

4.5. Packet Delivery Ratio

In this section packet delivery ratio performance of using RER, LEACH, and UCT2TSK routing models considering varied sensor devices is studied. In Figure 7 the sensor devices are varied from 500 to 3000 and the packet delivery ratio achieved using RER, LEACH and UCT2TSK routing models is graphically shown. Figure 7 interprets that the RER model improves the packet delivery ratio by 8.44%, 10.41%, 10.67%, 12.13%, 10.7%, and 15.32% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 7 interpret that RER model improves packet delivery ratio by 14.2%, 15.94%, 17.1%, 23.33%, 23.26%, and 28.046% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model improves the packet delivery ratio by 20.31% and 11.27% on average when compared with LEACH and UCT2TSK routing models, respectively. The significant result achieved using the RER model is due to the adoption of improved cluster head selection that focuses on improving coverage and adoption of multi-objective multipath routing design.

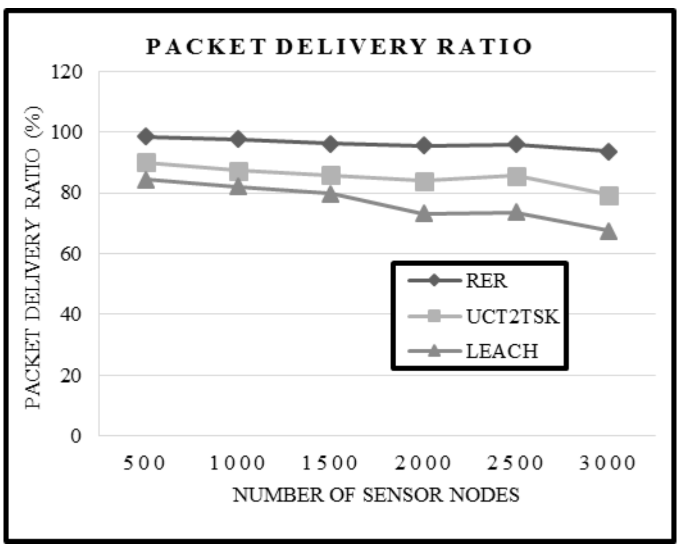

Figure 7 Packet Delivery Ratio under Varied Density

4.6. Packet Drop Ratio

In this section packet drop ratio performance of using RER, LEACH, and UCT2TSK routing models considering varied sensor devices is studied. In Figure 8 the sensor devices are varied from 500 to 3000 and the packet drop ratio achieved using RER, LEACH and UCT2TSK routing models is graphically shown. The Figure 8 interprets that RER model improves packet drop ratio by 35.91%, 46.24%, 47.56%, 43.25%, 39.27%, and 40.41% in comparison with UCT2TSK when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. Similarly, Figure 8 interpret that RER model improves packet drop ratio by 48.52%, 53.76%, 56.75%, 55.28%, 53.95%, and 54.69% in comparison with LEACH when device size is set to 500, 1000, 1500, 2000, 2500, and 3000, respectively. The RER model improves packet drop ratio by 53.82% and 42.11% on an average when compared with LEACH and UCT2TSK routing models, respectively. The significant result achieved is due to the adoption of multi-objective multipath routing metrics that incorporate packet loss parameters where paths are selected with minimum packet loss.

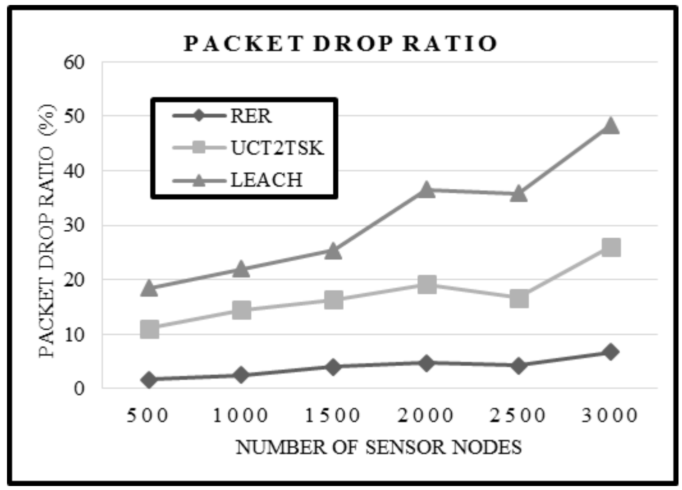

Figure 8 Packet Drop Ratio under Varied Density

4.7. Discussion

The recently modeled routing models namely UCT2TSK routing models achieve very good performance in comparison with baseline LEACH by addressing the hotspot problem. However, there is a major limitation of UCT2TSK such as poor network coverage and application QoS not being considered; thus, leading to a higher packet drop, degraded throughput, and lesser lifetime. On the other side, the RER model improves lifetime due to adoption of improved CH and ACH selection under unequal clustering environment, reduces communication overhead because of minimizing reclustering overhead through a selection of ACH in RER model, lesser delay due to adoption of multipath-based route selection for transmitting packet according to QoS prerequisite, better throughput due to adoption improved cluster head selection that focuses on improving coverage thereby increasing the lifetime of network and generation of a higher number of packet, better delivery ratio due to adoption improved cluster head selection that focus on improving coverage and adoption of multi-objective multipath routing design and lesser packet drop due to adoption multi-objective multipath routing

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metrics that incorporates packet loss parameter where paths are selected with minimum packet loss. Improving the model performance in different phases such as CH and ACH selection, relay selection, route selection, and path selection the RER model achieves significant improvement in comparison with baseline LEACH and existing UCT2TSK routing model.

5. CONCLUSIONS

Minimizing the energy consumption of sensor nodes and addressing the hotspot problem in WSN is most desired. Several methods have been introduced recently to lower energy utilization. Future applications of big data and IoT that use sensor nodes require reduced access to real-time data. The present methods are not appropriate for such applications and significantly fewer studies have been emphasized on unequal clustering networks. This paper presented the RER model that minimizes energy consumption, delay, and packet loss. Tests are performed to estimate the performance of RER and other existing routing protocols such as LEACH and UCT2TSK protocols. The proposed RER method reduces control channel overhead and communication delay and enhances WSNs lifetime over LEACH and UCT2TSK routing models. From the result attained we can say the RER model is scalable regardless of smaller or larger network density adopting an unequal clustering atmosphere.

REFERENCES

[1] Fatma Karray, Mohamed W. Jmal, Alberto Garcia-Ortiz, Mohamed Abid, Abdul fattah M. Obeid," A comprehensive survey on wireless sensor node hardware platforms", Computer Networks, doi: 10.1016/j.comnet.2018.05.010, 2018.

[2] KhadirKumar N and Dr. Bharathi A, "Real time energy efficient data aggregation and scheduling scheme for WSN using ATL", Computer Communications, Volume 151, 2020, Pages 202-207, ISSN 0140-3664, https://doi.org/10.1016/j.comcom.2019.12.027.

[3] H. Yetgin, K. T. K. Cheung, M. El-Hajjar and L. H. Hanzo, "A Survey of Network Lifetime Maximization Techniques in Wireless Sensor Networks," in IEEE Communications Surveys & Tutorials, vol. 19, no. 2, pp. 828-854, Secondquarter 2017, doi: 10.1109/COMST.2017.2650979.

[4] Mohamed Amine Kafi, Jalel Ben Othman, and Nadjib Badache, "A survey on reliability protocols in wireless sensor networks", ACM Comput. Survey. 50, 2, Article 31, 47 pages, 2017.

[5] Reem E. Mohemed, Ahmed I. Saleh , Maher Abdelrazzak and AhmedS. Samra, " Energy-efficient routing protocols for solving energy hole problem in wireless sensor networks", Computer Networks 114, 51–66, 2017.

[6] Nabil Sabor, Shigenobu Sasaki, Mohammed Abo-Zahhad and Sabah M. Ahmed, "A Comprehensive Survey on Hierarchical-Based Routing Protocols for Mobile Wireless Sensor Networks: Review, Taxonomy, and Future Directions", Hindawi, Wireless Communications and Mobile Computing, Volume 2017, Article ID 2818542, 23 pages.

[7] H. El Alami and A. Najid, "ECH: An Enhanced Clustering Hierarchy Approach to Maximize Lifetime of Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 107142-107153, 2019, doi: 10.1109/ACCESS.2019.2933052.

[8] F. A. Khan, M. Khan, M. Asif, A. Khalid and I. U. Haq, "Hybrid and Multi-Hop Advanced Zonal-Stable Election Protocol for Wireless Sensor Networks," in IEEE Access, vol. 7, pp. 25334-25346, 2019, doi: 10.1109/ACCESS.2019.2899752.

[9] Q. Wang, D. Lin, P. Yang and Z. Zhang, "An Energy-Efficient Compressive Sensing-Based Clustering Routing Protocol for WSNs," in IEEE Sensors Journal, vol. 19, no. 10, pp. 3950-3960, 15 May15, 2019, doi: 10.1109/JSEN.2019.2893912.

[10] T. Salam, W. U. Rehman and X. Tao, "Data Aggregation in Massive Machine Type Communication: Challenges and Solutions," in IEEE Access, vol. 7, pp. 41921-41946, 2019, doi: 10.1109/ACCESS.2019.2906880.

[11] D Salangai Nayagi, Sivasankari G G, Vinayakumar Ravi, Venugopal K R and Sankar Sennan, " REERS: Reliable and Energy Efficient Route Selection Algorithm for Heterogeneous Internet of Things Applications", International Journal of Communication Systems, pp 34, 2021 DOI: 10.1002/dac.4900.

[12] Orlando Philco Asqui, Luis Armando Marrone and Emily Estupiñan Chaw, "Multihop Deterministic Energy Efficient Routing Protocol for Wireless Sensor Networks MDR", Int. J. Communications, Network and System Sciences, 14, 31-45, https://www.scirp.org/journal/ijcns, 2021.

[13] Abdulla, Ahmed & Nishiyama, Hiroki & Kato, Nei. (2012). Extending the lifetime of wireless sensor networks: A hybrid routing algorithm. Computer Communications. 35. 1056–1063. 10.1016/j.comcom.2011.10.001.

[14] Y. Tao, J. Zhang and L. Yang, "An Unequal Clustering Algorithm for Wireless Sensor Networks Based on Interval Type-2 TSK Fuzzy Logic Theory," in IEEE Access, vol. 8, pp. 197173-197183, doi: 10.1109/ACCESS.2020.3034607, 2020.

[15] Muhammad K. Khan,2 Muhammad Shiraz, Qaisar Shaheen , Shariq Aziz Butt, Rizwan Akhtar, Muazzam A. Khan and Wang Changda, "Hierarchical Routing Protocols for Wireless Sensor Networks: Functional and Performance Analysis", Hindawi, Journal of Sensors, Volume 2021, Article ID 7459368, 18 pages, 2021.

[16] Zagrouba, Rachid, and Amine Kardi. "Comparative Study of Energy Efficient Routing Techniques in Wireless Sensor Networks" Information 12, no. 1: 42. https://doi.org/10.3390/info12010042, 2021.

[17] Han, S., Liu, Xm., Huang, Hy. et al. Research on energy-efficient routing algorithm based on SWIPT in multi-hop clustered WSN for 5G system. J Wireless Com Network 2021, 49 (2021). https://doi.org/10.1186/s13638-021-01931-5.

[18] Abidoye, A.P., Kabaso, B. Energy-efficient hierarchical routing in wireless sensor networks based on fog computing. J Wireless Com Network 2021, 8 (2021). https://doi.org/10.1186/s13638-020-01835-w.

[19] Prachi Maheshwari Dr. Ajay K. Sharma and Karan Verma, "Energy Efficient Cluster based Routing Protocol for WSN using Butterfly Optimization Algorithm and Ant Colony Optimization", Ad Hoc Networks, doi: https://doi.org/10.1016/j.adhoc.2020.102317, 2020.

[20] Fang Zhu and Junfang Wei, "An energy-efficient unequal clustering routing protocol for wireless sensor networks", International Journal of Distributed Sensor Networks, Vol. 15(9), 2019.

[21] Jin Wang, Yu Gao, Chang Zhou, R. Simon Sherratt and Lei Wang, "Optimal Coverage Multi-Path Scheduling Scheme with Multiple Mobile Sinks for WSNs", Computers, Materials & Continua CMC, vol.62, no.2, pp.695-711, 2020.

[22] Asra Kousar, Nitin Mittal and Prabhjot Singh, "An Improved Hierarchical Clustering Approach for Mobile Sensor Networks Using Type-2 Fuzzy Logic", Advances and Applications in Mathematical Sciences, Volume 18, Issue 8, June Pages 587-604, 2019.

[23] Amarthaluri Thirupathaiah, Dr. S.V.N. Srinivasu and Isunuri Bala Venkateswarlu, "Energy Efficient Clustering in Multi-hop Wireless Sensor Networks using Minimum Distance and Maximum Energy Group Search", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 9 pp. 7178-7183, 2018.

[24] Antonio-Jesus Yuste-Delgado , Juan-Carlos Cuevas-Martinez and Alicia Triviño-Cabrera, "A Distributed Clustering Algorithm Guided

RESEARCH ARTICLE

by the Base Station to Extend the Lifetime of Wireless Sensor Networks”, Sensors, 20, 2312; doi:10.3390/s20082312, 2020.

[25] Amir Masoud Rahmani , Saqib Ali, Mohammad Sadegh Yousefpoor, Efat Yousefpoor, Rizwan Ali Naqvi , Kamran Siddique and Mehdi Hosseinzadeh, “An Area Coverage Scheme Based on Fuzzy Logic and Shuffled Frog-Leaping Algorithm (SFLA) in Heterogeneous Wireless Sensor Networks”, Mathematics 2021, 9, 2251. https://doi.org/10.3390/math9182251.

[26] Kulkarni, Pramodkumar H. and P. Malathi. “PFuzzyACO: Fuzzy-based Optimization Approach for Energy-aware Cluster Head Selection in WSN.” Journal of Internet Technology 20: 1787-1800, 2019.

[27] Shafik, Wasswa & Matinkhah, s. Mojtaba. A Portable Fuzzy Sink Scheme for Wireless Sensor Network Life Expectancy Enhancement. 10.20944/preprints202007.0659.v1, 2020.

[28] Muhammad Amjad, Muhammad Khalil Afzal, Tariq Umer and Byung-Seo Kim, “QoS-Aware and Heterogeneously Clustered Routing Protocol for Wireless Sensor Networks”, IEEE Access, pp. 1-1, DOI 10.1109/ACCESS.2017.2712662, 2017.

[29] Sai Krishna Mothku and Rashmi Ranjan Rout, “Adaptive Fuzzy-Based Energy and Delay-Aware Routing Protocol for a Heterogeneous Sensor Network”, Hindawi, Journal of Computer Networks and Communications, Volume 2019, Article ID 3237623, 11 pages, 2019.

[30] Lin Li, Donghui Li, "An Energy-Balanced Routing Protocol for a Wireless Sensor Network", Journal of Sensors, vol. 2018, Article ID 8505616, 12 pages, 2018. https://doi.org/10.1155/2018/8505616

[31] J. N. Al-Karaki and G. A. Al-Mashaqbeh, "SENSORIA: A New Simulation Platform for Wireless Sensor Networks," 2007 International Conference on Sensor Technologies and Applications (SENSORCOMM 2007), 2007, pp. 424-429, doi: 10.1109/SENSORCOMM.2007.4394958.

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