



Optimized Cluster Head Selection with Traffic-Aware Reliability Enhanced Routing Protocol for Heterogeneous Wireless Sensor Network (HWSN)

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Abstract – Clustering-based routing protocols are mainly used for extending the node's existence in Heterogeneous Wireless Sensor Networks (HWSNs). Several clustering protocols have been designed for splitting the network into different clusters and choosing the Cluster Heads (CHs) for each cluster effectively. Among those, a Traffic-Aware Reliability-based Enhanced Technique for Ordering of Preference by Similarity-Ideal-Solution (TARE-TOPSIS) protocol can determine the probability of every node is considered as CH by considering traffic load, initial and residual energy of each node in the multi-heterogeneity scenarios. It considers only coverage and energy for determining the amount of cluster and the corresponding probabilities. Nonetheless, noise and data transmission rates have a high effect on information or data packets transmitted between nodes and the Base Station (BS). The noise interference in the communication can let few nodes link to further far-away CHs and exploit the multipath amplification. The multipath diversion consumed additional energy than usual energy. Therefore in this article, an Optimized Clustering TARE-TOPSIS (OC-TARE-TOPSIS) protocol is presented for increasing the energy efficacy and the network lifespan by determining the optimal clusters. Initially, the network model is designed which characterizes the transmission environment noise. After, a multipath energy model incorporating the probability of data delivery is determined. Also, the optimum amount of clusters and optimal probability are derived to decide the amount of CHs in noise-prone multi-heterogeneity transmission scenarios. Energy-efficient data transfer from CHs to BS is achieved by the contribution of fewer nodes in the noisy networks. At last, the simulation results demonstrate the OC-TARE-TOPSIS realizes better efficiency compared to the conventional protocols in the aspect of different evaluation metrics.

Index Terms – HWSN, Clustering, Routing protocols, TARE-TOPSIS, Noise, Energy Conservation.

1. INTRODUCTION

WSNs is the network that connects a set of sensor nodes that interact with each other through a wireless medium for assembling, processing, and transmitting the required data to the nearest BS. These nodes are normally constructed for various purposes such as defense, agricultural monitoring, atmospheric conditions forecasting, healthcare, and home appliances. Typically, it has two categories: homogeneous and heterogeneous WSNs. In the homogeneous WSNs, every node is deployed with an equal functional capable hardware component. But in Heterogeneous WSNs (HWSNs), few high configurations or high capable nodes are deployed among other equal functional nodes for prolonging the lifetime of a network [1]. This type of network is popular in recent years and predominant in many real-time appliances for prolonging network lifetime. In contrast, effective routing is a vital challenge in these networks because of the energy, bandwidth, and storage constraints.

Routing is the development of methods for discovering the way between the source and destination nodes. Most of the routing protocols utilize clustering protocol which is a more energy-efficient method that splits the networks into clusters and selects the nodes with the highest remaining energy for data transfer [2-5]. As a result, the scalability and network lifetime are improved while utilization of energy is reduced. Among most clustering protocols, Low-Efficiency Adaptive Clustering Hierarchical (LEACH) protocol is widely used due to its unproblematic performance. The advanced routing protocols are designed by considering the basic principle of this protocol [6-8]. In this protocol, two main stages called setup and steady phases. Each node in the network checks them in the setup phase to become a CH or not in each round.

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Also, the CH selection is mainly decided by the required amount of CHs and the occasions that the node has become a CH until now. It forwards the data to other nodes while CH chooses the node effectively. As well, CH replacement is done in each cycle for disseminating equal energy between nodes. In the steady phase, each node transmits the sensed data to the CH which compresses the data to directly transmit it to the BS. It needs 1-hop transfer, so it is not suitable for applying large size networks. Additionally, CHs are chosen by considering the probability and so uniform distribution, as well as load-balancing, is not guaranteed. In the past few years, several clustering-based routing protocols are developed for HWSNs for optimizing energy consumption and enhancing network lifespan. Among those, a RE-TOPSIS using fuzzy logic has better performance on CHs election [9]. Here, the LEACH protocol used index value values in RE-TOPSIS rank, and the election of CH in each cycle is avoided. To elect the CHs, many criteria are taken into consideration like residual energy, the distance among nearby nodes, energy efficiency, accessibility of neighbor nodes, distance from CHs to each cluster member as well as distance between sink and CHs. On the other hand, the considered criteria are not suitable for providing efficient routing in multi-heterogeneity WSNs.

To solve this problem, a TARE-TOPSIS protocol has been proposed that considers traffic load, initial and residual energy of each node during the CH election [10]. It can select the CHs in the energy and traffic heterogeneities scenarios. In each cycle, the probability of CH for each node is determined depending on traffic and energy heterogeneity criteria in RE-TOPSIS. In this protocol, the amount of cluster and the corresponding probabilities are determined only based on coverage and energy.

1.1. Motivation

In HWSNs, the data transmission rate among sensor nodes and CH is affected by noise availability in the network. Here, noise is representing as an ineffective transfer of data packets from nodes to CHs or BS. It will assume some nodes link to further far-away CHs and use the multipath amplification which causes high energy utilization. Also, the probability of data delivery is considered for simulating the noise level in WSNs. So, this paper presents an OC-TARE-TOPSIS that determines the optimum amount of clusters to enhance the energy efficiency and the network lifespan.

1.2. Contributions of this Research

The major contributions are the following:

- At first, the network model which characterizes the transmission environment noise is designed.
- Then, a multipath energy model incorporating the probability of data delivery is determined.

- Further, the optimal clusters and optimal probability are derived to decide the amount of CHs in noise-prone multi-heterogeneity transmission scenarios. Because of introducing more noise in the network, only fewer nodes are selected to transfer data to the CHs and BS for energy-efficient transmission.
- It needs few CHs, as well as the position of BS, is not highly affecting the selection of optimal clusters and respected chance of a node to become CH.

1.3. Scope of this Research

The scope of this work is follows:

- It helps to increase the network performance in terms of throughput, Packet Delivery Ratio (PDR), packet delay and packet drop ratio.
- It can reduce the energy consumption of nodes and so increase the network lifetime efficiently.
- It helps to construct the robust network for different real-time applications like healthcare monitoring, industrial monitoring, etc.

1.4. Organization of the Paper

The remaining sections of the article are ordered as follows: The literature papers are reviewed about CH selection and transmission of packets using CHS for HWSNs are presented in Section 2. Section 3 describes the OC-TARE-TOPSIS. Section 4 explains how networks are initiated and measure the simulation outcomes. The conclusion of the work is given in Section 5.

2. LITERATURE SURVEY

Bara'a & Khalil [11] developed a novel evolutionary-based routing protocol for clustered HWSNs. The key objective was to avoid the unwanted activity of evolutionary algorithms while dealing with clustered routing problems in WSN by formulating the novel objective factor which combines clustering characteristics: cohesion and partition error. But, it needs to analyze the effect of varying BS location and weight in the objective factors. Singh et al. [12] proposed a power effective transfer method depending on power and gap-based CH selection. First, the node's residual power was considered for electing CH. After, every node was chosen as CH and communicated with the BS. But, it was not effective for HWSNs.

Soni & Dey [13] proposed an efficient approach in which CH was dynamically chosen from the cluster of CHs within the cluster. In this approach, multiple CHs were chosen within the cluster and after specific rounds, normal nodes may become CHs if the power range was smaller or equivalent to common nodes in the groups. Besides, the mastership of CHs was rotated continuously to make the network without a halt. But,

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it needs to consider many parameters to further improve the network efficiency.

Ke et al. [14] suggested a new energy-aware hierarchical cluster-based routing protocol to reduce the overall energy usage and ensure the fairness of energy use between nodes. The relay node selection problem was formulated as a nonlinear programming problem and the property of convex function was used for finding the optimal solution. However, the data delivery ratio was less.

Ali et al. [15] proposed a novel Reconfigurable CH (RCH) selection protocol. In RCH protocol, the status reconfigurable was referred to as the system resets via choosing fresh CH. Also, the robustness and interval of transmission were maintained through electing the fresh CH in the group to secure the transmission. On the other hand, the processing time was high due to high network overhead.

Wei-Xin et al. [16] proposed Energy and Delay Efficient Routing Protocol (EDERP) for threshold-based CH choice in HWSNs. In EDERP, delay, energy, and velocity-based adaptive threshold scheme was introduced for designing a new CH selection scheme. The nodes were categorized as normal, advanced, and herculean levels. Also, the CH was chosen from these categories in accordance with the Euclidean gap, speed, and power in which the chance was assigned for the remaining power. At last, the cluster was created for transmitting the packets via the selected nodes. But, its efficiency was not highly effective in terms of PDR and throughput.

Priyadarshini & Sivakumar [17] proposed the Minimum Connected Dominating Set Multi-hop Information (MCDS-MI) with Bi-partite Graph (BG) method for electing CHs with reduced computational complexity. In this method, the remaining energy of each node was computed for achieving load-balancing. After that, the nodes having the highest residual power were chosen as the best CH dominator. Then, a highly improved Steiner tree was built for improving the fault tolerance and transfer dependability. But, it does not consider the delay which also affects the node's existence.

Behera et al. [18] developed effective CH election scheme i.e., residual energy-based CH selection that spins the CH location surrounded by the maximum energy nodes. In this scheme, primary power, remaining power, and optimal CHs were considered for selecting the subsequent set of CHs. The remaining power of the non-CH nodes was verified after completing each round and the node with higher energy maintain a larger chance for CH election for the ongoing cycle. But, it needs to analyze more parameters delay, traffic, etc., to precisely know its effectiveness.

Haseeb et al. [19] proposed a Reliable Cluster-based Energy-aware Routing (RCER) method for HWSNs. It has two major steps. Originally, the nodes were grouped into clusters for

providing the system highly power-effective. After, an optimum routing was performed based on RCER to enhance the subsequent hop selection via considering the residual energy, hop count, and weighted Round Trip Time (RTT) factors. Further, the routes were restored depending on computing the measurement of wireless connections and node's condition. But, the PDR and route lifetime were still not highly increased.

Zeng et al. [20] proposed an Energy-Coverage Ratio Clustering Protocol (E-CRCP) depending on minimizing the power use and using the local coverage fraction. Initially, the power model was constructed. Then, the optimum amount of clusters was computed depending on power reduction, and the CH choice was achieved depending on the local coverage improvement. Also, the CH with the least remaining power and the maximum power use was changed in the next iteration of CH selection for increasing the network's lifespan. However, its efficiency was depending on the proper selection of the number of nodes in the network.

Mehta & Saxena [21] presented a multiple fitness-based clustering and Sailfish Optimizer (SFO) guided routing method for increasing the power efficacy in WSNs. The CH was chosen depending on the suitable objective factor. Then, SFO was applied for choosing the optimal route to sink and transmitting the data. But, it was not able to handle the mobility-based densely distributed WSNs.

Yadav et al. [22] designed a Section-Based Hybrid Routing Algorithm (SBHRA) by artificial bee colony for increasing the efficiency of WSNs. This algorithm was used for the network which was split into regions. Also, hybrid routing was used by the network to transmit the data in the heterogeneous scenario. But, the BS was stationary and it needs to consider more factors at every node for improving the network lifetime.

Nivedhitha et al. [23] developed a Dynamic Multi-hop Energy Efficient Routing Protocol (DMEERP) for balancing the route reliability rate and energy usage. Initially, the system framework and fundamental assumptions have been prepared for creating clusters and establishing the multi-hop paths. Then, each data of CH and MNs was stored and maintained by the super CH. The node's activation weighing function were determined for obtaining new CH when the existing breaks. Further, the route reliability rate was determined for routing the data with the minimum loss. But, its performance was not effective in terms of PDR and energy efficiency.

Rodríguez [24] developed a new energy-efficient clustering routing protocol for WSNs depending on Yellow Saddle Goatfish Algorithm (YSGA). In this protocol, the number of optimal CHs was chosen by the YSGA when the sensor nodes were allocated to their closest CH. But, it needs to consider the uniform cluster sizes for achieving load balancing. Zhao et

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al. [25] suggested a routing protocol for HWSNs depending on the modified grey wolf optimizer. Initially, the suitable primary clusters were chosen by defining various fitness functions for heterogeneous energy nodes. Then, the node's fitness values were computed and considered as primary weights in the grey wolf optimizer. Also, the weights were dynamically modified based on the distance between the wolves and their prey as well as coefficient vectors for choosing the optimal CHs. But, it does not reduce the additional energy consumed by the sensor nodes for transmitting their location information to the BS.

Hassan et al. [26] developed a framework that splits the CH traffic into small ranges in an adapted way and assigns these ranges to the entire nodes in the group. First, the CH was selected depending on the minimum gap to the Member Nodes (MNs) and the BS. Then, by using the wireless energy exchange, every MN can forward a certain power to the CH for determining the fraction of load rather than the entire load using quantum particle swarm optimization and player concept. But, the game theory has high complexity and time consumption.

3. PROPOSED MODELLING

This section explains the OC-TARE-TOPSIS protocol in detail. In OC-TARE-TOPSIS, various considerations and systems are considered. Different systems include the noise model, network model, clustering, and CH election model.

3.1. Noise Model

Noise is an undesirable occurrence that influences the data transmission among nodes and BS. It is described using the chance of acceptance (\mathcal{P}_r). If $\mathcal{P}_r = 1$, then the network is noise-free; otherwise, the network is noise-prone with a specified range. The impact of noise on the source is computed by random integer U ($0 \leq U < 1$). When $U < \mathcal{P}_r$, the data is effectively accepted by the destination i.e., either CH or BS. Or else, ineffective data transfer exists and power is depleted. Typically, noise might influence the TARE-TOPSIS protocol in the below styles:

- Normally, nodes interact with the closest CH as its MNs for conserving the power. Noise might alter it and consider few nodes interact to remote CH and so utilize the multipath amplification and additional power.
- Generally, cluster MNs transmit data to the corresponding CHs. Noise might affect it and not used few MNs to interact with the CH and so its data packet's powers are wasted.
- Typically, CH transmits its integrated data to the primary BS. Noise might deny a few CHs from interacting with the BS and thus energies are wasted.

3.2. Network Model

The presumptions considered in HWSNs configuration:

- Every sensor nodes in networks are heterogeneous; they comprise different hardware configurations and are allocated with different initial energy levels.
- Nodes are uniformly scattered in the geometrically derived network and every node in a network has a sensor to sense the data in the surroundings in a sphere of radius r .
- BS is situated outer surface of the HWSN.
- Whether nearest or not, every node should link to CH (if noise occurs).
- The noise range symbolized by the chance of acceptance \mathcal{P}_r is constant throughout the given interval.

Figure 1 depicts the system architecture of proposed OC-TARE-TOPSIS protocol for HWSNs.

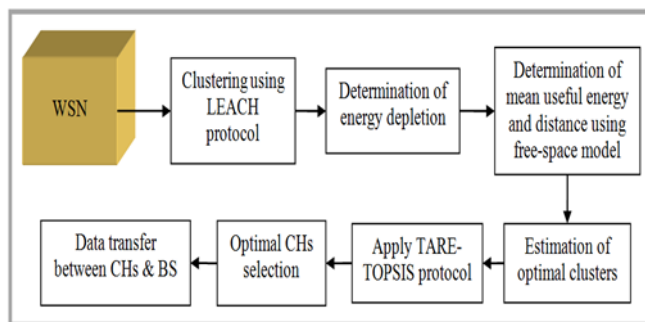


Figure 1 System Architecture of OC-TARE-TOPSIS Protocol for HWSNs

3.3. Clustering using LEACH Protocol

Initially, the nodes are clustered into different groups using LEACH protocol which consists of setup and steady-state steps. Among each sensor node, the predetermined possible CHs are selected in the setup step. The selected CHs transmit their positions and meta-data as advertisements to the BS within their communication region during the steady-state step. Due to the fixed CHs, the network efficiency may reduce in the aspect of throughput, packet dropping, etc. As a result, the OC-TARE-TOPSIS is designed to increase network efficiency by choosing the optimal number of CHs during clustering.

3.4. Optimized Clustering TARE-TOPSIS Protocol for CH Election

The power consumed by the HWSNs in a single round of the TARE-TOPSIS and adding \mathcal{P}_r to point how better the transmission media utilize energy as useful or waste. The energy utilized for transmitting packets from MNs to CHs and

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CHS to BS is categorized as useful whereas energy consumed by nodes for dropping packets while sending to CHs or dropping packets while sending to BS is categorized as waste. The mean useful energy during a single TARE-TOPSIS round ($E_{srnd-useful}$) is calculated by:

$$E_{srnd-useful} = \mathcal{P}_r * k * E_k \tag{1}$$

In Equation (1), k denotes an average amount of clusters in the HWSN and E_k denotes the power utilized by the cluster. If $\frac{N}{k}$ denotes the average quantity of nodes per clusters, then each cluster energy is computed as follows:

$$E_k = E_{CH} + \gamma \mathcal{P}_r \left(\frac{N}{k} - 1 \right) E_{MN_{fs}} + (1 - \gamma) \mathcal{P}_r \left(\frac{N}{k} - 1 \right) E_{MN_{mp}}$$

$$E_k \approx E_{CH} + \gamma \mathcal{P}_r \frac{N}{k} E_{MN_{fs}} + (1 - \gamma) \mathcal{P}_r \frac{N}{k} E_{MN_{mp}} \tag{2}$$

In Equation (2), E_{CH} is energy utilized by the CH, $E_{MN_{fs}}$ and $E_{MN_{mp}}$ are the energy utilized by the MNs of a specified cluster while utilizing the free-space (fs) or multipath (mp) amplification models, accordingly. Also, γ is the part of MNs that transmit b -bit data packets by fs system whereas $(1 - \gamma)$ is the part of non-MNs that transmit b -bit data packets using mp system. The value of E_{CH} is given by:

$$E_{CH} = E_D(b) + E_{toDA} + E_S(b, d)$$

$$E_{CH} = \mathcal{P}_r \frac{N}{k} b E_{ele} + \mathcal{P}_r \frac{N}{k} b E_{DA} + b \epsilon_{mp} d_{BS}^4 \tag{3}$$

In Equation (3), $E_D(b)$ is the energy utilized in the destination node to receive b -bit data packets, E_{toDA} represents energy depleted by the destination to aggregate b -bit data packets per signal, $E_S(b, d)$ represents energy utilized by the source node to process and send out b -bit data packets over distance d (distance between source and destination), E_{ele} represents energy utilized by radio in joules/bit for activating the source/destination, E_{DA} is the energy utilized by the destination to aggregate one bit per signal, ϵ_{mp} is the transmission amplification for multipath fading propagation model and d_{BS} is the gap between CHs & the BS. Here, $E_S(b, d)$ is computed as:

$$E_S(b, d) = E_{S-ele}(b) + E_{S-amp}(b, d) \tag{4}$$

$$E_{S-ele}(b) = b * E_{ele} \tag{5}$$

$$E_{S-amp}(b, d) = \begin{cases} b \epsilon_{fs} d^2, & \text{if } d < d_0 \\ b \epsilon_{mp} d^4, & \text{if } d \geq d_0 \end{cases} \tag{6}$$

Where, $E_{S-ele}(b)$ and $E_{S-amp}(b, d)$ are energy utilized by the source electronics and amplifier to process and send out b -bit data packets over d , ϵ_{fs} is the transfer amplification for fs model, $d_0 = \sqrt{\epsilon_{fs} / \epsilon_{mp}}$ is the gap threshold to change from fs to mp systems. Also,

$$E_D(b) = E_{D-ele}(b) = b * E_{ele} \tag{7}$$

$$E_{toDA} = s * b * E_{DA} \tag{8}$$

As well, $E_{MN_{fs}}$ and $E_{MN_{mp}}$ are computed as:

$$E_{MN_{fs}} = E_S(b, d) = E_{S-ele}(b) + E_{S-amp}(b, d)$$

$$= b E_{ele} + b \epsilon_{fs} d_{CH_{fs}}^2 \tag{9}$$

$$E_{MN_{mp}} = E_S(b, d) = E_{S-ele}(b) + E_{S-amp}(b, d)$$

$$= b E_{ele} + b \epsilon_{mp} d_{CH_{mp}}^4 \tag{10}$$

In Equations (9) & (10), $d_{CH_{fs}}$ and $d_{CH_{mp}}$ are the distances between MNs and their related CH using the free-space and multipath models, accordingly. This is calculated due to channel noise influences of nodes while interacting to the CH that is not near to it ($d > d_0$). According to Equation (6), substituting Eqns. (3, 9, and 10) in Equation (2) to obtain:

$$E_k = \mathcal{P}_r \frac{N}{k} b E_{ele} + \mathcal{P}_r \frac{N}{k} b E_{DA} + b \epsilon_{mp} d_{BS}^4 + \gamma \mathcal{P}_r \frac{N}{k} (b E_{ele} + b \epsilon_{fs} d_{CH_{fs}}^2) + (1 - \gamma) \mathcal{P}_r \frac{N}{k} (b E_{ele} + b \epsilon_{mp} d_{CH_{mp}}^4)$$

$$E_k = \mathcal{P}_r \frac{N}{k} b E_{ele} + \mathcal{P}_r \frac{N}{k} b E_{DA} + b \epsilon_{mp} d_{BS}^4 + \gamma \mathcal{P}_r \frac{N}{k} b E_{ele} + \gamma \mathcal{P}_r \frac{N}{k} b \epsilon_{fs} d_{CH_{fs}}^2 + (1 - \gamma) \mathcal{P}_r \frac{N}{k} b E_{ele} + (1 - \gamma) \mathcal{P}_r \frac{N}{k} b \epsilon_{mp} d_{CH_{mp}}^4 \tag{11}$$

Thus, the overall useful energy consumption for the period of a single TARE-TOPSIS round is specified by substituting Equation (11) in Equation (1) to acquire:

$$E_{srnd-useful} = \mathcal{P}_r^2 N b \left(2 E_{ele} + E_{DA} + \frac{k}{\mathcal{P}_r N} \epsilon_{mp} d_{BS}^4 + \gamma \epsilon_{fs} d_{CH_{fs}}^2 + (1 - \gamma) \epsilon_{mp} d_{CH_{mp}}^4 \right) \tag{12}$$

The mean distances $\mathbb{E}[d_{CH_{fs}}]$, $\mathbb{E}[d_{CH_{mp}}]$, and $\mathbb{E}[d_{BS}]$ should be determined for finding the optimum amount of clustering to reduce the network energy consumption. The most essential distance is $\mathbb{E}[d_{CH_{fs}}]$ because it has a huge impact in determining the optimum number of clusters in a TARE-TOPSIS scenario. Also, $\mathbb{E}[d_{CH_{mp}}]$ and $\mathbb{E}[d_{BS}]$ are mean distances calculated outside of any clusters. This value cannot be used for finding an optimal number of clusters since it may cover many clusters.

To compute $\mathbb{E}[d_{CH_{fs}}]$, spherical network geometry is considered. In this topology, the volume of the 3D spherical HWSN area and the mean cluster area are defined as:

$$V_{sph} = \frac{4}{3} \pi r_{sph}^3 \tag{13}$$

$$V_k = \frac{4 \pi r_k^3}{3k} \tag{14}$$

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The optimal amount of clusters and the optimum chance to achieve that are determined as:

$$r_k = \frac{r_{sph}}{\sqrt[3]{k}} \tag{15}$$

And also,

$$f(r, \theta, \Phi) = \frac{1}{V_k} = \frac{3k}{4\pi r_k^3} \tag{16}$$

Considering that the CH is situated at the cluster’s centroid, then the *fs* possible distances between nodes and CH is calculated as:

$$\mathbb{E} [d_{CH_{fs}}^2] = \int_0^\pi \int_0^{2\pi} \int_0^{\frac{r_{sph}}{\sqrt[3]{k}}} r^4 \frac{3k}{4\pi r_k^3} \sin(\Phi) dr d\theta d\Phi$$

$$\mathbb{E} [d_{CH_{fs}}^2] = \frac{3r_{sph}^2}{5r_k^{2/3}} \tag{17}$$

Substituting Equation (17) in Equation (12), and taking the first derivative of $E_{srnd-useful}$ for k , the optimum amount of clusters is determined as:

$$\frac{\partial E_{srnd-useful}}{\partial k} = 0 \tag{18}$$

$$k_{optimal} = \left(\frac{2}{5} \gamma \mathcal{P}_r N \frac{\epsilon_{fs} r_{sph}^2}{\epsilon_{mp} d_{BS}^4} \right)^{3/5} \tag{19}$$

The optimal probability for choosing the estimated clusters is determined by:

$$\mathcal{P}_{optimal} = \frac{k_{optimal}}{\gamma \mathcal{P}_r N} = \left(\frac{1}{\gamma \mathcal{P}_r N} \right)^{2/5} \left(\frac{2 \epsilon_{fs} r_{sph}^2}{5 \epsilon_{mp} d_{BS}^4} \right)^{3/5} \tag{20}$$

If the $\mathcal{P}_{optimal}$ is the maximum, then the estimated amount of clusters are chosen and their corresponding CHs are decided by the TARE-TOPSIS protocol. Figure 2 depicts the overall flow diagram of the OC-TARE-TOPSIS protocol. Table 1 lists all the symbols defined in this article.

Symbols	Description
\mathcal{P}_r	Probability of reception
$E_{srnd-useful}$	Mean useful energy during single TARE-TOPSIS round
k	The average number of cluster
E_k	The energy utilized by the cluster
N	Amount of nodes in the HWSN
E_{CH}	The energy utilized by the CH
$E_{MN_{fs}}$	The energy utilized by the MN of a specified cluster while utilizing <i>fs</i> amplification model

$E_{MN_{mp}}$	The energy utilized by the MN of a specified cluster while utilizing <i>mp</i> amplification model
γ	Part of MNs that transmit <i>b</i> -bit data packets using <i>fs</i> model
$1 - \gamma$	Part of non-MNs that transmit <i>b</i> -bit data packets using <i>mp</i> model
$E_D(b)$	The energy utilized in the destination node to receive <i>b</i> -bit data packets
E_{toDA}	The energy depleted by the destination to aggregate <i>b</i> -bit data packets per signal
d	Gap between source & the destination
$E_S(b, d)$	The energy utilized by the source node to process and send out <i>b</i> -bit data packets
d_{BS}	Gap between CHs & the BS
E_{ele}	The energy utilized by radio in joules/bit for activating the source or destination
E_{DA}	The energy utilized by the destination to aggregate one bit per signal
$E_{S-ete}(b)$	The energy utilized by the source electronics to process and <i>b</i> -bit data packets
$E_{S-amp}(b, d)$	The energy utilized by the source amplifier to send out <i>b</i> -bit data packets over distance <i>d</i>
ϵ_{mp}	Transfer amplification for <i>mp</i> model
ϵ_{fs}	Transfer amplification for <i>fs</i> model
d_0	Gap threshold to change from <i>fs</i> to <i>mp</i> models
$d_{CH_{fs}}$	Distances between MNs and their related CH using <i>fs</i> model
$d_{CH_{mp}}$	Distances between MNs and their related CH using <i>mp</i> model
$\mathbb{E} [d_{CH_{fs}}]$	Mean distances between MNs and their related CH using <i>fs</i> model
$\mathbb{E} [d_{CH_{mp}}]$	Mean distances between MNs and their related CH using <i>mp</i> model
$\mathbb{E} [d_{BS}]$	Mean distance from CHs to the BS
V_{sph}	The volume of 3D spherical network area
r_{sph}	The radius of 3D spherical network area
V_k	The volume of mean cluster area

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r_k	The radius of mean cluster area
$k_{optimal}$	The optimum amount of clusters
$\mathcal{P}_{optimal}$	The optimum chance to choose the estimated optimum amount of clusters

Table 1 Summary of Notations

Input: Number of nodes

Output: Optimum amount of clusters & optimum chance to attain that

1. Construct an HWSN with n number of nodes;
2. Apply LEACH protocol for clustering;
3. *for(each cluster)*
4. Compute the energy for each CH and cluster members using (2) & (3);
5. Calculate the energy used in the source and destination nodes to transmit b -bit data packets using (4)-(8);
6. Calculate the energy consumed in free-space & multipath amplification model using (9)-(10);
7. Determine the mean useful energy for single TARE-TOPSIS protocol round using (12);
8. Compute the mean cluster area using (13)-(14);
9. Calculate the expected distance among nodes with CH in free-space model using (17);
10. Find the optimal number of clusters using (18)-(19);
11. Determine the optimal probability to select the estimated amount of clusters using (20);
12. *if(probability is high)*
13. Choose the optimal amount of clusters;
14. Perform TARE-TOPSIS protocol;
15. Decide the optimal number of CHs;
16. *else*
17. Repeat the process;
18. *end if*
19. *end for*

Algorithm 1 Algorithm for OC-TARE-TOPSIS

The algorithm 1 describes the process of the OC-TARE-TOPSIS protocol. *Step 1* indicates the creation of HWSN using n nodes. Then, *Step 2* applies the LEACH protocol for grouping the nodes into the different clusters. For each cluster, their optimal CHs are chosen based on different processes defined in *Step 3-Step 19*. Thus, it provides the

optimal number of CHs for data transfer in HWSNs and enhances network efficiency significantly.

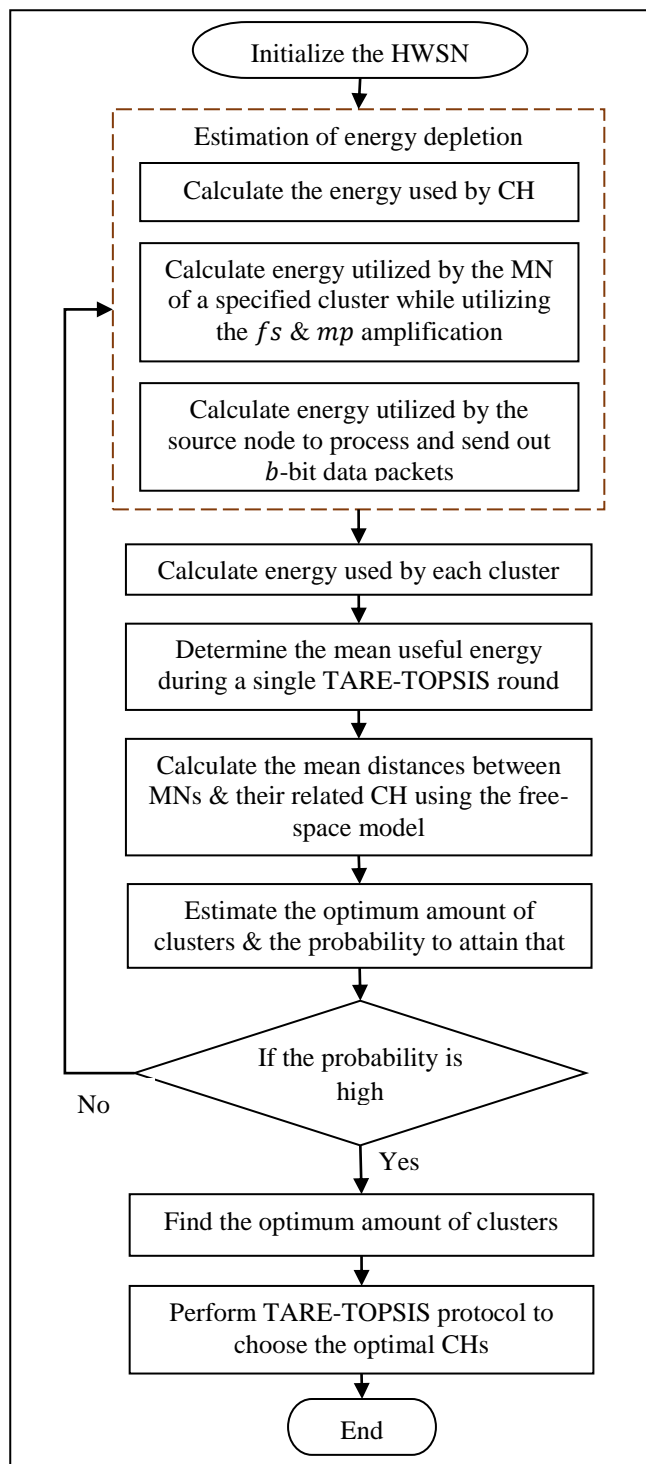


Figure 2 Overall Flow Diagram of OC-TARE-TOPSIS Protocol for HWSNs

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4. SIMULATION RESULTS

The parameter for simulating the network and the evaluation parameters are explained in this section. The simulation is conducted using Network Simulator (NS2.35) and the proposed OC-TARE-TOPSIS is compared with the existing protocols: LEACH, RE-TOPSIS, and TARE-TOPSIS in terms of network lifespan, mean energy consumption, throughput, PDR, packet delay, and packet drop ratio. The parameter list used for simulation is listed out in Table 2.

Parameters	Value
Area of the network in Simulation	1050×1050m ²
Min to Maximum nodes in the network	110-150
The location of the Sink node	(50,50)
Start-up allocated energy of nodes	0.5J
The range of transmission allocated to nodes	20m
Packet size	500bytes
Size of control or hello packet	25bytes
Energy consumption for the Aggregation process	50pJ/bit
Energy required for each packet Transmission	100nJ/bit
Energy required for each packet Reception	50nJ/bit
Sender's amplifier power	100pJ/bit/m ²
Simulation time	300sec
Pause time	10sec

Table 2 Simulation Parameters

4.1. Network Lifespan

It measures the interval between the transmission starting time and the time at which the final node vanishes.

Figure 3 illustrates the No. of alive nodes after transmissions in the network to measure network lifespan. It indicates that OC-TARE-TOPSIS always has a higher No. of alive nodes than all other existing protocols with different rounds of transmission. For example, 86 alive nodes are available for OC-TARE-TOPSIS at the end of 1000 rounds whereas LEACH, RE-TOPSIS, and TARE-TOPSIS are having 50, 60, and 80 alive nodes, respectively. This is because of splitting the network into the most appropriate amount of groups efficiently depending on the power and traffic load of each node. Hence, it verifies that OC-TARE-TOPSIS prolongs the node's existence compared to the other protocols.

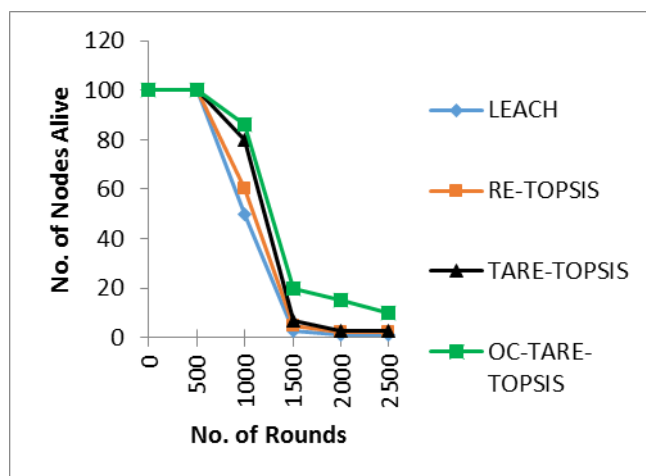


Figure 3 Network Lifespan vs. No. of Rounds

4.2. Mean Energy Consumption

It is the mean energy consumed by all nodes in the network during the various numbers of transmissions.

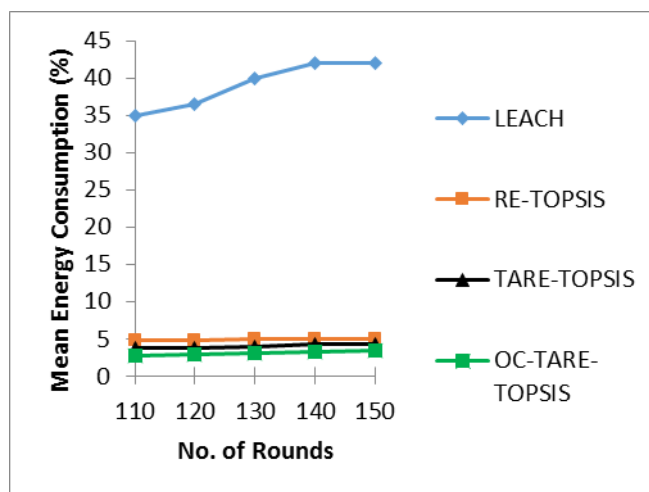


Figure 4 Mean Energy Consumption vs. No. of Rounds

The mean energy consumption for various numbers of transmissions is represented in Figure 4. The percentage of energy consumed for transmission from overall energy is measured for OC-TARE-TOPSIS, TARE-TOPSIS, RE-TOPSIS, and LEACH protocols. OC-TARE-TOPSIS consumed 92%, 41.67%, and 24.32% energies which are less than the LEACH, RE-TOPSIS, and TARE-TOPSIS protocols, respectively. Similarly, the OC-TARE-TOPSIS consumes less energy than existing protocols for any number of rounds. Because of considering the traffic and energy of each node including clusters during transmission, OC-TARE-TOPSIS can reduce the considerable amount of energy utilization.

Compared to the LEACH, the RE-TOPSIS chooses the CH using the rank index value under energy heterogeneity

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scenario so that it reduces the energy consumption and increases the network lifetime in the HWSNs. Compared to the RE-TOPSIS, the TARE-TOPSIS chooses the CH under both traffic and energy heterogeneities for reducing the energy use and increasing the network lifetime. Compared to the TARE-TOPSIS, the OC-TARE-TOPSIS can decide the most optimal CH in spherical network geometry. This routing protocol rounds spheric geometry consume less energy by using the free-space model compared to the other network configurations. This results in higher network lifetime.

4.3. Throughput

It is the total amount of bits transferred to the BS within the given time from all nodes for a specified number of transmission (rounds).

$$Throughput = \frac{Total\ number\ of\ bits\ transferred\ to\ the\ BS}{Time} \quad (22)$$

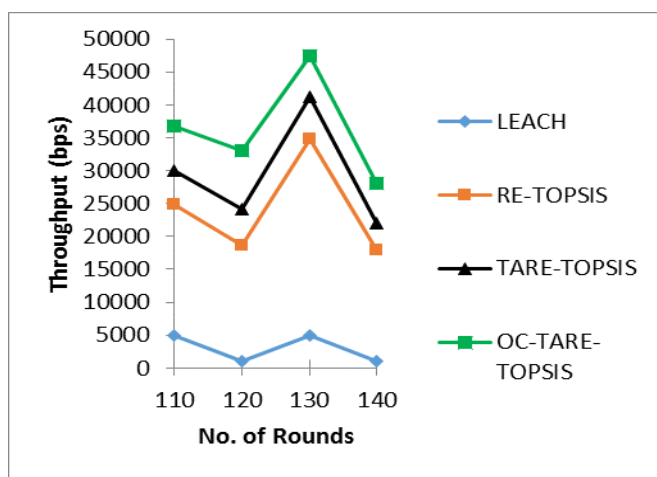


Figure 5 Throughputs vs. No. of Rounds

Figure 5 displays the throughput as bits/sec (bps) for the different number of rounds in OC-TARE-TOPSIS, TARE-TOPSIS, RE-TOPSIS, and LEACH protocols. It indicates that the throughput of OC-TARE-TOPSIS for 130 rounds is 47500bps whereas TARE-TOPSIS, RE-TOPSIS, and LEACH have the throughput ranges of 41200bps, 34900bps, and 4900bps, accordingly. So, it validates that OC-TARE-TOPSIS has always greater throughput compared to the other protocols for any number of rounds, resulting in higher overall network performance.

4.4. Packet Delivery Ratio (PDR)

It measures the fraction of the total packets accepted to the total packets transferred through the communication channel by all nodes in a network.

$$PDR = \frac{Total\ number\ of\ packets\ accepted}{Total\ number\ of\ packets\ transferred} \quad (23)$$

The PDR (in %) is compared in Figure 6 for OC-TARE-TOPSIS, TARE-TOPSIS, RE-TOPSIS, and LEACH using a varied quantity of nodes. It indicates that the PDR value of OC-TARE-TOPSIS is 65.3% which is greater compared to LEACH, RE-TOPSIS, and TARE-TOPSIS whose PDR ranges are 23.5%, 43.4%, and 58.6%, accordingly. So, it is confirmed that OC-TARE-TOPSIS always outperforms any number of nodes or rounds compared to the other protocols.

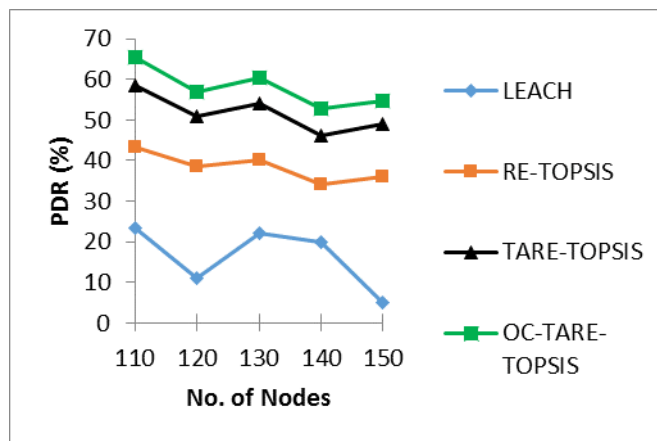


Figure 6 PDR vs. No. of Nodes

4.5. Packet delay

It measures the difference between the time of a packet being received at the destination and the time a packet is transmitted at the source node.

$$Packet\ delay = packet\ received\ time - packet\ transmitted\ time \quad (24)$$

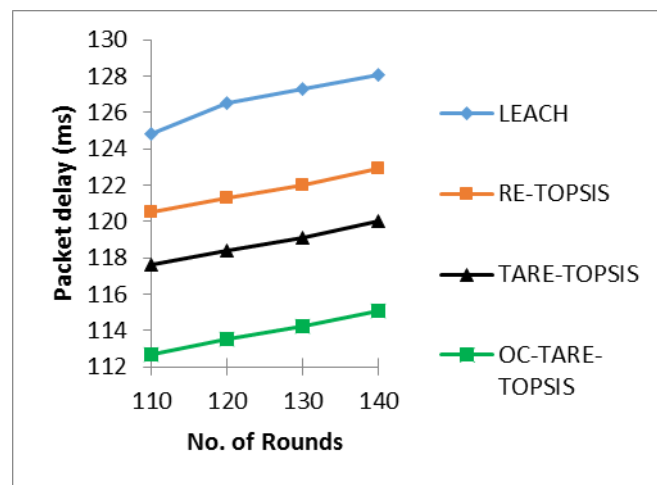


Figure 7 Packet Delay vs. No. of Rounds

Figure 7 illustrates the packet delay as milliseconds (ms) for different rounds in OC-TARE-TOPSIS, TARE-TOPSIS, RE-TOPSIS, and LEACH. It observes that the packet delay of OC-TARE-TOPSIS for 130 rounds is 114.2ms whereas



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TARE-TOPSIS, RE-TOPSIS, and LEACH have the packet delay of 119.1ms, 122ms, and 127.3ms, accordingly. So, it is confirmed that OC-TARE-TOPSIS has less packet delay compared to the other protocols for any rounds, resulting in higher throughput and PDR.

4.6. Packet Drop Ratio

It measures the fraction of the total packets dropped to the total packets transmitted in the network.

$$\text{Packet drop ratio} = \frac{\text{Total number of packets dropped}}{\text{Total number of packets transferred}} \quad (25)$$

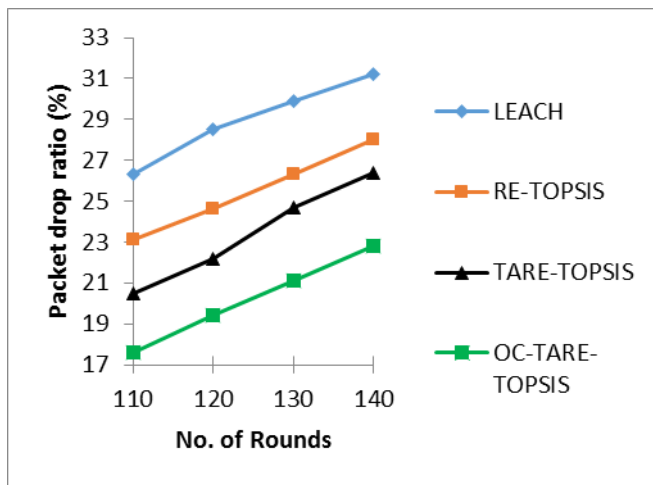


Figure 8 Packet Drop Ratio vs. No. of Rounds

Figure 8 displays the packet drop ratio as % under the different number of rounds in OC-TARE-TOPSIS, TARE-TOPSIS, RE-TOPSIS, and LEACH. It examines that the packet drop ratio of OC-TARE-TOPSIS for 130 rounds is 21.1% whereas TARE-TOPSIS, RE-TOPSIS, and LEACH have the packet drop ratio of 24.7%, 26.3%, and 29.9%, respectively. Therefore, it is obvious that the OC-TARE-TOPSIS has less packet drop ratio than the other protocols.

Compared to the LEACH, the RE-TOPSIS takes reliability index to choose the CH which results in better throughput, PDR and packet delay. Compared to the RE-TOPSIS, the TARE-TOPSIS can consider both traffic and energy levels including reliability index for choosing the CH which improves the network performance. Compared to the TARE-TOPSIS, OC-TARE-TOPSIS determines the probabilities of nodes becoming a CH which helps to decide the most suitable CH among all available CHs. This may reduce the packet drop ratio, and delay, resulting in higher throughput and PDR.

5. CONCLUSION

The OC-TARE-TOPSIS protocol improves the power efficacy and the node's existence by determining the optimal amount of clusters. At first, the network model is designed which describes the transmission environment noise. Then, a

multipath energy model with the probability of data delivery is computed. Besides, the optimum amount of clusters and optimum probability are determined for electing the amount of CHs in the noise-prone multi-heterogeneity communication settings. Because of the availability of more noise when the network is initiated, only the minimum number of nodes allowed to take part in the energy-efficient data delivery to the header node of the cluster and BS. Finally, the simulation outcomes confirmed that the OC-TARE-TOPSIS has a higher node's lifetime, throughput, PDR, and less mean energy consumption than the TARE-TOPSIS protocol. But, the mobility of nodes may impact the network efficiency and constrain the discovery of adjacent nodes during routing. So, the future extension of this work will focus on analyzing the impact of node's mobility on network efficiency and adapt effective method to find the adjacent nodes during data transfer.

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