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Water rippling shaped clustering strategy for efficient performance of software define wireless sensor networks

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Abstract The routing protocols are the hot areas to manage the network quality-of-service (QoS), viz., energy consumption, lifetime, network design and packet overhead. Network optimization relies on different calibers of decision: to discuss the network parameters meticulously for overall network improvement. Thus several criteria are proposed which fixate on energy conservation, architecture design, etc. to implicitly or explicitly amend the network performance. We propose a novel strategy named as Water-Rippling Shaped Clustering (WARIS) is a hybrid approach applies to cluster the large-scale software define wireless sensor network, which resembles the shape of water rippling. Major achievements are improved cluster design, energy aware cluster head (CH) selection method and reducing re-clustering overhead. The centrally controlled layer design locally restricted clustered design, and then cluster member selection in WARIS gives better performance as compared to the other two state of the art competitors MCDA and EELBCRP. The to-and-fro message communication between the deployed nodes and BS for exchanging parametric values and making decisions makes this cluster design process lengthy. Load management is done during the process cluster size formation which improves the network performance. Performance simulations illustrate that WARIS is a better choice to implement over wireless sensor networks, predicated on energy consumption and set-up completion time.

Keywords Software define network · Wireless sensor network · Energy efficient clustering · Re-clustering · Water rippling shaped clustering · Routing

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1 Introduction

The first wireless network that is the most reflecting first step towards advanced Wireless Sensor Networks is the Sound Surveillance System. This system was launched by the United States Military in the 1950s for the purpose of detecting and tracking the submarines of Soviet Union in Atlantic, and Pacific Oceans Hydro pones and submerged acoustic sensors were the major components of the deployed network [1].

The kindred sensing technology is still in service today. However, nowadays it is obliging more tranquil functions. Its primary functions are monitoring volcanic activities and marine wildlife. Later to cope up with the growing engineering challenges of this network, academia, and industry made the joint efforts. Some initiatives in this regard are UCLA Wireless Integrated Network Sensors in 1993, the University of California at Berkeley Pico Radio program in 1999. Adaptive Multi-Domain Power Vigilant Sensors program at MIT in 2000, NASA Sensor Webs in 2001, ZigBee Coalition in 2002 and Center for Embedded Network Sensing in 2002 are some renowned among the available long list. The contributions mentioned above along with the others have put consequential advances in four key technology areas; CMOS-predicated semiconductor devices, sensors, energy storage with generation technology and networking protocols that help in reducing the overall deployment and functional cost of WSN. The emerging field of Internet of Things (IoT) predicated on the deployment of WSN is the culmination of these efforts [2]. Sensor nodes comprise of sensing, data processing, and communication capabilities. The sensing circuit measures the environmental, physical quantity that circumvents the sensor and transforms it into the electrical signal, process the received signal and turn up with properties of objects located or transpiring of some event somewhere in the vicinity of the sensor.

The sensed and processed data is sent to a command center via radio transmitter either directly or through a gateway (data concentration center). The gateway customarily performs data fusion for filtering out the erroneous data and anomalies for drawing the conclusions from the reported data. The deployed nodes in sensor network field build up either flat architecture or clustered architecture. According to the study of Soroush et al. [3], clustering schemes show paramount advantages over flat strategies. Authors enumerated the following benefits of clustering protocols which initiate them to the most compatible protocols of WSNs attributes:

- Overall transmission power is minimized.
- The imbalanced load over the deployed nodes is virtually balanced with the equal size clusters and centralized management.
- Bandwidth constraint issue is resolved by efficiently reducing the bandwidth demand.
- The overhead for routing and topology maintenance is being reduced due to centralized management.
- Data aggregation can be efficaciously used to eliminate the redundant and highly correlated data.
- Multi-power levels can be habituated to reduce the collision and interference during inter-cluster and intra-cluster communication.
- The manageability and scalability of the network are improved.
- The routing table turns out to be very small due to localizing the route setup within the cluster boundaries.

To better understand clustering-based WSN, its key points are summarized as follows:

Clustering strategy: Partitioning the networks by a grouping of autonomous nodes to designate one node as head and others as members.
Constituents of clustering: The group of nodes named as a cluster. The selected node which collects data from other nodes in clusters is known as a cluster head (CH) and the non-cluster head nodes i.e. member nodes are called as group members.
Cluster head rotation: During network operation, the optimality of CHs turns to non-optimality. So, there is a need to transfer this label to some other most suitable node to keep the network function properly.
Re-clustering: For large scale nets, performing the clustering process is required periodically to maintain the system functional and assure its efficient working state.
Forwarding node (relay) selection: Approaching the data from the remote node in large scale network to the Base Station (BS), the collected data at the CHs should be forwarded to the destination through the transient node(s) that acts as the relay node or forwarding node.

The proposed approach is a hybrid technique to design the clustered network. The available literature shows, Multilayer Cluster Designing Algorithm (MCDA) [4] and Extended Multilayer Cluster Designing Algorithm (E-MCDA) [5] seem to be the most state-of-the-art schemes in clustered networks. However, Due to some homogeneous attributes for the comparative study of our proposed method, we choose MCDA and Energy Efficient Level Based Clustering Routing Protocol (EELBCRP) [6]. EELBCRP is a centralized approach for designing the clustered network. WARIS and EELBCRP are homogeneous regarding Base Station(BS) location, i.e. in the center of deployed nodes. The concept of levels in EELBCRP and layers in WARIS are same. Both protocols use various signal levels to define the layers. In MCDA, the authors utilize the term layer; however, their style of designing is different as compared to that of levels and layers in EELBCRP and WARIS respectively. Additionally, they don't use different signal levels to define the layers. BS invent the first layer that is placed on one side of the deployed nodes, and then every layer initiates the process of developing subsequent layer. Due to those above paramount homogeneous attributes, we prefer MCDA and EELBCRP as the competing schemes to our proposed solution. Our major contributions in this research work are as follows:

The authors introduced a novel clustering method nominated as WARIS with energy efficient CH selection technique for network lifetime improvement through energy-aware network design. Energy-aware and the less often re-clustering conception is floated to enhance the network lifetime. We organize the rest of the paper as follows. Section 2 include a detailed literature survey. The postulations related our proposed solution are provided in section 3. Section 4 presents the energy consumption model at Sensor level and data communication levels and energy utilization during data communication for one round. Section 5 covers the topic of network design proceeded by the proposed solution in detail inside section VI. Construction of layers and cluster designing subsections are the major components of this section. The experimental graphs along with the extensive discussions are expounded in Section VII, which is preceded by conclusion section. References are designated at the terminus.

1.1 Literature review

The unique features of clustering have emerged it in many perpetual types of research on energy efficient architecture and routing in WSN. Early work such as Low Energy Adaptive Clustering Hierarchy (LEACH) [7] and Energy Efficient Clustering Scheme (EECS) [8] target one hop distance transmission between the sink and the designated CHs, and are only appropriate for small-scale networks. Hybrid Energy-Efficient Distributed Clustering (HEED) [9] fixates on diminishing the intra-cluster communication cost by conscientiously selecting the CHs. Power-efficient Gathering in Sensor Information Systems (PEGASIS) [10] is another one. Un-Equal Cluster Based Routing (UCR) addresses the hotspot issue along with decrementing the load balancing.

V-LEACH [11] is one of the latest ramifications of LEACH by Yassein et al., with improved architecture and design approach including the adjustment of vice CH. EELBCRP [6] is another cluster based architecture following centrally initiated multilayer distributed cluster designing strategy. From the cluster predicated architecture with centralized design approach, we have chosen Threshold Based Load Balancing Protocol For Energy Efficient Routing (TLPER) by Butt et al. which takes nodal density and geographical location of nodes to decide centrally about the CHs and distributed a selection of group members [12]. Their proposed design, in addition, has involution of assistant CHs with innovative LBT (Load Balancing Threshold) and RTT (Role Transfer Threshold) techniques. Another idea of introducing the assistant clusters is presented by Dajin Wang for power mitigating [13]. He appoints these assistant clusters as partaker nodes. These particular nodes support the CH in the regular job of data accumulation. As an alternative of having CH to collect data solely from all sensors in the cluster, a certain number of partaker nodes participate in data accumulation.

A Distributed and Adaptive Routing Protocol (DARC) for clustered WSN is proposed by Z. Xu et al. [14]. CH manages the inter-cluster routing with the strategy of adaptive energy threshold, while for the relay selection, a tunable cost function is designed. All fundamental algorithms execute based on distributed information exchanged during the process of dynamic clustering which accomplishes low overhead. A novel idea is proposed for cluster designing in [4] with the denomination, MCDA. It is a hybrid approach regarding communication and architectural design perspectives. MCDA uses multilayered approach comprising of the first flat layer in the footprint of the BS and the subsequently clustered layers. Former layer design is centrally initiated while the alternate case uses distributed property. Reference [5] shows the extension of this work.

SK Gupta et al. designed an incipient method called Energy efficient clustering protocol for minimizing cluster size and inter-cluster communication (EEPC) to discover the group of CHs at the end of steady state phase in each round [15]. The concept of the sub-cluster head is introduced to reduce the communication distance of CHs to the BS. Thus the energy can be preserved more efficiently.

Meenakshi et al. proposed a level-based hierarchical clustered routing algorithm called EELBCRP [6]. The proposed algorithm increases the network lifetime by reducing the energy consumption that results in lessening the number of dead nodes. This notion of dividing the network into levels gave us a clue of the multi-layer design of Wireless Sensor Networks.

The authors presented research on mobile sinks which brings advance challenges when densely deployed in large-scale WSNs [16]. A protocol called Intelligent Agent Based Routing (IAR), was introduced that provides efficient data distribution to mobile sink. It trim down signal overhead and recovers degraded route called triangular routing problem. The results show that the scheme sufficiently strengthens sink mobility with low overhead and the adjustment of triangular routing problem.

In [17], the cooperation of multiple BSs in download and the system's energy efficiency is targeted to propose a formation on dynamic clustering algorithm. The authors derived the formula of spectral efficiency and energy efficiency for the data transmit and authentic transmit cases by the utilization of per antenna equal power constraint and symbol equal power allocation. Similarly, dynamic clustering algorithm based on the channel norms is also presented. The leader BS is elected with the highest element in the current interference matrix. The other BSs with comparatively less interference coefficient as of leader BS are given a chance to join the cluster until the formation of the cluster. The computational complexity of the proposed algorithm is analyzed as well.

The Position based Beaconless Routing algorithms (PBR) for WSN is discovered to find the path between the source and destination nodes by reducing the non-essential transmission [18]. PBR contains two algorithms as well i.e. for packet forwarding and next forwarding node selection. The selection parameters are the angle based neighbor selection and the distance at each forwarding step. They carried out a mathematical analysis of an average number of successful hops, expected distance between sender and next forwarder and also the distribution of sensors in the forwarding area. An efficient survey presented by Rawat on recent developments and potential synergies [19]. Results are convincing. The work in [20] is additionally a consequential effort.

Keeping in view all these efforts, we raise the conclusion that none of the algorithms discussed in this section except in

[4, 15, 19] are precisely concentrating on the feature of cluster design. However, among the three parameters, performance efficiency of the WSN on energy and time in cluster designing is not dedicatedly addressed. In our underlying research work, we propose a clustering protocol, Water Rippling Shaped Clustering (WARIS), to partition the large scale network into water ripple-shaped clusters. Based on the proposed strategy, energy conserving components like network clustering, CH selection, and re-clustering are built up. It considers the efficiency with respect to time during the network setup phase. These contributions preserve plenty of message broadcasting, minimizing the cost of cluster designing, cluster head selection, and re-clustering. Jang et al. suggested similar work [21]. Similarly, Pandya and Mehta did it too [22]. They make the network into concentric rings. These schemes follow the LEACH like methods to compose the clusters that are in contrast to our method where each ring or layer is divided into near equal size clusters.

2 System model

2.1 Assumptions

In this section, we are providing the assumptions made during the design and simulation model of our network. Few postulations are taken from [23] as Guidelines that are:

Assumption 1 (Network Nodes' Deployment and Reliability): The deployed network nodes are uniformly and independently distributed in the sensor field. The sink node is located in the center of the network. The nodes are reliable, secure and will not be malfunctioning, hacked or die suddenly. The deployed nodes are considered dead when their energy approaches a defined threshold.

Assumption 2 (Homogenous Nodes): All the sensor nodes have the same configuration, sensing, communication range and have the same energy level. Moreover, they have the same transmission power and transmission rate.

Assumption 3 (Communication Radius Model): The communication range of a sensor node A has the radius R of the location at c.It can be defined as $CR(c, R) = \{A, q \in S{:}|\, D(A-q) \leq R_A\}$ Where CR represents communication radius, S accounts for the set of deployed nodes and $D(A-q)D(A-q)$ is the distance between nodes A and q in the deployment area.

Assumption 4 (Reliable Communication Link): We have assumed Additive White Gaussian Noise channel and have adjusted Signal to Noise Ratio in such a way that as soon as signal reaches the destination node to a suitable energy, the overall detection probability is acceptable.

Assumption 5 (Vicinity Knowledge): Each deployed sensor node is aware of its polar (X, Y) coordinates to the sink node. This knowledge can be from some localization algorithm or via attached GPS device.

2.2 Energy consumption model

In this section, we model energy consumption at various aspects. It comprises of energy consumption at sensor node level, data communication level and also energy consumption for one round. Total data communication energy consists of energy consumption for intra-cluster communication, inter-cluster communication, and data processing. Hence this Section has further three subsections, i.e. *Calculating* (E_{Intra}), *Calculating* (E_{Inter}) and Calculating.

2.2.1 Energy consumption at sensor level

Let E is the total energy dissipated to transmit a single packet of $l-bit$ from a transmitter to its receiver at a distance d over a single link. The baseline levels of energy consumption at the transmitter radio are e_t and at the receiver is e_r. The transmission energy consumption is dependent on the distance threshold, d_{Th} and the distance d of the link between the two nodes i.e. either $\in_{fs}d^2$ or $\in_{mp}d^4$ which can be proved as:

$$E = \left\{ \begin{array}{ll} 1\left(e_t + e_r + \in_{fs} d^2\right) & if\ \ d < d_{Th} \\ 1\left(e_t + e_r + \in_{mp} d^4\right) & if\ \ d \geq d_{Th} \end{array} \right\} \quad (1)$$

If the distance d is less than the distance threshold d_{Th} i.e. $d \leq d_{Th}$. $\in_{fs}$ is used to reflect "free-space" conditions, while the longer links that are potentially affected by multipath fading are represented as $\in_{mp}$.

2.2.2 Energy consumption at data communication level

The major events related to energy consumption that comes under the head of data communication are Intra-cluster communication (E_{Intra}), Inter-cluster communication (E_{Inter}), and the data processing (E_{Proc}). By considering the energy consumption in one round, the total communication energy consumption is

$$E_{Comm} = E_{Intra} + E_{Inter} + E_{Proc} \quad (2)$$

i) Calculating (E_{Intra})

Each layer L_i comprises of n_i clusters that generate n_i $n_i$summary packets in total. These generated packets are forwarded to the next layer i.e. L_{i-1} layer. Moreover, apart from its packets, layer L_i relays receive packets coming from the outer layer, L_{i+1} and transmits to the inner layer, L_{i-1}. Hence $n_T(i)$, the total number of packets that are forwarded by the L_i layer is estimated by

$$n_T(i) = \sum n_j, for i \leq j \leq K \quad (3)$$

ii) Calculating (E_{Inter})

During one round, a packet encapsulates the observed information in each sensor. The packet is then transmitted to the corresponding CH. After collecting all the encapsulated packets from the member sensor nodes at the CH, accumulated packets are then combined into a single summary packet reflecting the summarizing observation of the particular area. At the sensor node level, there are $aW\sigma$ nodes in a particular level, L_i. Here $aW\sigma - n_i$, represents the accumulated observation packets received at n_i CHs on the level L_i.

iii) Calculating (E_{Proc})

Despite packets exchange, data processing is the least energy consumption event, however yet important. There is also utilization of energy in data processing for summarizing packets at each involved CH. If E_{bit} is the energy consumption for one bit of data, then the processing energy E_{Proc} at i^{th} CH is$E_{Proc}(i) = laW\sigma E_{bit}$.

Considering the energy consumption model for the sensor, calculations for E_{Inter}, E_{Intra} and E_{Proc} can be updated as follow.

Case 1) Considering the case of $E_{inter}(i)$ at L_i, If the transmission energy cost is $E_{Tx}(i)$ during one round, then the approximation of energy consumption in the transmission of a packet with average length, l is $E_{Tx}(i) \approx n_T(i)(e_t + \in_{mp}D^4)l$. The CH nodes in i^{th} layer L_i also have the use of sensor energy in receiving the incoming packets from the outer layers. It results in $E_{Rcv}(i) \approx e_r(n_T) - n_i)l$. Hence, we approximate the cost for the total inter-cluster communication of layer L_i during the round is:

$$E_{inter}(i) \approx l\Big(e_r + e_t + \left(\in_{mp}D^4\right)n_T(i) - le_r n_i.$$

Case 2) in the case of $E_{Intra}(i)$ at L_i, considering the energy consumption in transmission and reception events, we come up with the following formulation if the distance between the node j into its affiliated CH isd_j.

$$E_{Intra}(i) = l\left(\sum_{j \leq aW\sigma - n_i}\left(e_t + \epsilon_{fs}d_j^2\right)\right) + l(Wa\sigma - n_i)e_r \quad (4)$$

2.2.3 Energy consumption in data communications for one round

Here are the final approximations of energy consumption during intra-cluster $E_{Intra}(i)$, Inter-cluster, $E_{inter}(i)$ and data processing, $E_{Proc}(i)$events:

$$E_{Intra}(i) \approx l\left(\sum_{j \leq aW\sigma - n_i}\left(e_t + \epsilon_{fs}d_j^2\right)\right) + l(Wav\sigma - n_i)e_r \quad (5)$$

$$E_{inter}(i) \approx l\Big(e_r + e_t + \left(\epsilon_{mp}D^4\right)n_T(i) - le_r n_i \quad (6)$$

$$E_{Proc}(i) \approx laW\sigma E_{bit} \quad (7)$$

The extraction of three expressions is briefly explained in the above subsection. The derived approximation for the consumption of energy in the communication of data, $E_{Comm}(i)$ during a single round of data collection in the layer, L_i is given below.

$$\boldsymbol{E_{Comm}(i)} = l\left(\sum_{j \leq aW\sigma - n_i}\left(e_t + \epsilon_{fs}d_j^2\right)\right) + l(Wa\sigma - n_i)e_r \quad (8)$$

$$+ laW\sigma E_{bit} + l\Big(e_r + e_t + \left(\epsilon_{mp}D^4\right)n_T(i) - le_r n_i$$

2.3 Network model

The BS node is located at the center of deployed network whereas the positioned nodes are in the region of BS. The network is fashioned into concentric layers that shape like the rings. As a broader vision, the network field is modeled into Water-Ripple Shaped Clusters as shown in Fig. 1. All the planned layers are of equal size i.e. r except to that of the first layer which has its size $>r$ i.e.,.. These layers took the shape of clusters and subdivided into clusters. This idea is like the track and sectors on the hard disk to store the data. Though the nodes deployment takes place in randomly distributed order, still, we plan to make the size of clusters almost equal. It helps in load balancing quality of the proposed method. As the size of each outer layer is L_{i+1} greater than that of every inner layer L_{i-1}, so the number of clusters and their size is an important factor to consider. The aim is to design near-equal size clusters, for that the i^{th} layer ought to be separated into $(2i - 1) \times n$ clusters. We set the value of n as 4 in our case which is a natural number. This approach makes the clusters as square shaped rather than making them too flat or slight and keep the position of CHs nearly at the Pivotal area, their expected distance minimum to their members.

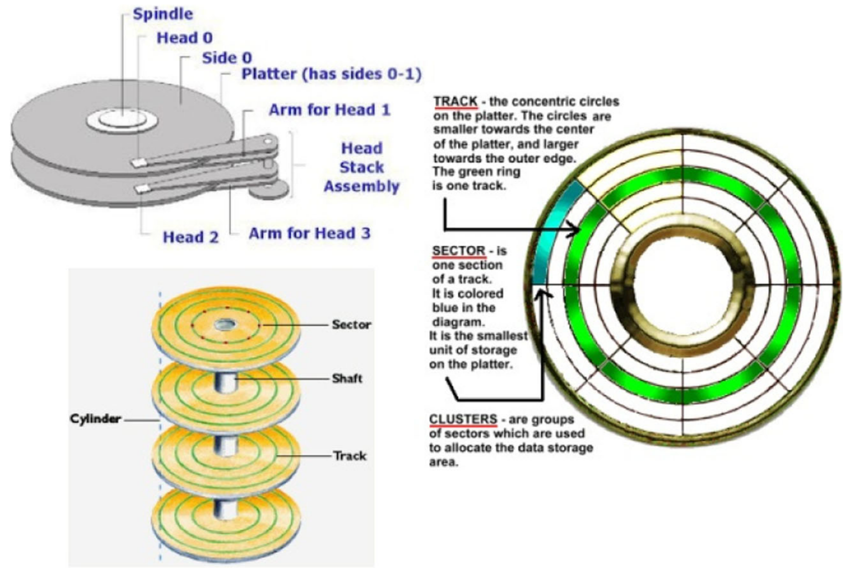


Fig. 1 Typical disk partitioning method

3 Proposed scheme WARIS

Just like disk partitioning method, where initially the tracks are designed and then the sectors are set. The proposed plan is reflecting relatively the same style of clustering the network. Ultimately, this forms the shape like water rippling effect. That's the reason why we denominate it as Water-Rippling Shaped Clustering (WARIS). The scheme works for shaping a large-scale network into water rippling shaped clusters. While developing, the scheme builds the energy preserving components like network clustering, CH selection, and re-clustering. These contributions preserve plenty of message broadcasting; minimize the cost of cluster design, CH selection, and re-clustering. A sequential working mechanism of proposed scheme is divided into two phases (Fig. 2).

3.1 Phase 1

3.1.1 Construction of layers

Layers are concentric at the traffic junction of the BS and are ring-shaped. The BS initiate preparation of this design. It broadcasts the signal with varying levels. All recipient nodes of one signal level become the part of the same layer. As an example, the first broadcast message for layer designing is of $'j'$ signal level. Its recipient nodes become the part of the layer $'i'$. The second broadcast message is of $'j+i'$ signal level, and its receiver nodes become the part of the layer $'i+1'$. Similarly, 'n^{th} broadcast message is of $'j+n'$ signal level, and its beneficiary nodes become the part of the layer $'i+n'$. This idea of power tuning is taken from [24] and is the base for designing the layers of the message broadcast by BS. Since BS is equipped with a continuous source of energy, so it can transmit with maximum power to cover up the whole deployed network.

3.1.2 Cluster size and width

Furthermore, here the precise definition of the value for cluster size is important as it impacts the network performance for the motive that the nodes at layer i always communicate with the layer $i-1$. It ensures that any node within the cluster can relay the packet to the inner layer, L_{i-1} and it ultimately reaches the BS. To make this happen productively, we need to calculate the maximum distance i.e. $(X-Y)$ between the two adjacent clusters i.e. last cluster of the layer i and the first cluster of the

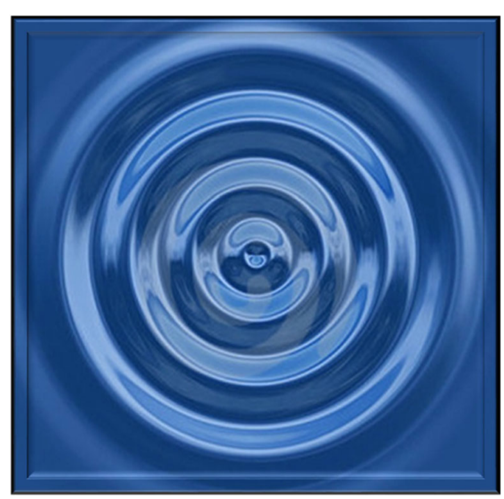


Fig. 2 Water ripple effect

layer $i+1$. The derived coordinates (X, Y) can be calculated as $X\left(r \times (i-1), \frac{-\pi}{(4i-2)}\right)$ and $Y\left(r \times (i-1), \frac{\pi}{(4i-2)}\right)$.

As we know that from the following equation, the distance between X and Y can be calculated as:

$$d_{x-y} = \sqrt{[r(i-1)]^2 + [r(i+1)]^2 - 2r^2(i-1)(i+1)\cos\left(\frac{i\pi}{(i^2-1)}\right)} \quad i \neq 1 \qquad (9)$$

We can get the outcome as the maximum value when $i=3$, d_{X_Y} i.e. $d_{X\_Y} = r \times 3.7318$. Along with the distance, the width of the layer should be manageable enough to make the communication between two adjacent possible clusters. Hence, the transmission radius R must be equal to the distance between X and Y i.e. d_{X_Y}. So, the transmission radius R is getting as $r = \frac{d_{X-Y}|_{i=3}}{3.7318} = \frac{R}{3.7318}$ and the layer width is equal to R.

3.2 Phase 2

3.2.1 Cluster design

The message is initiated from the base station containing the values of r, the position of the sink and r' the size of the pivotal area. Since the BS is powered by the permanent source of energy, so its transmission covers the whole deployed nodes. The recipient nodes of this cluster designing initiation message calculate their affiliation to the definite cluster. The base is the proximity to this affiliation to CH.

a) Pivotal area of cluster \ re-clustering

We devise a strategy for prolonging the network lifetime by carefully managing the re-clustering process. When the optimality of a current CH turns to non-optimality, a need arises to transfer the role of heading the cluster to some other most suitable node based on some defined parameters. This re-clustering process is one of the most energy consumption events of the cluster based network. To handle this event carefully and to make it happen less frequently to improve the lifetime, a pivotal area is defined. Only the nodes in that defined area are eligible to become the CH. If none of the nodes in it is capable of being designated as the CH, the re-clustering process is triggered, and the new pivotal area is defined as well. Since the pivotal area is in the center and the defined (X, Y) are there too as calculated in the previous section. So, the node right at the (X, Y) coordinate sends a *piv_Area* message. Recipient nodes are then considered to be the part of the pivotal area, and the nodes belonging to it are the first candidates to become the CH. Exploiting the idea, selection of an optimal CH is facilitated that is discussed in the subsequent subsection.

b) Selection of cluster head

In literature, two major techniques of CH selection are available i.e. i) In a centralized fashion, ii) In a distributed fashion. In the first case, the deployed nodes communicate the required decision parameter values like energy level, node degree, geographical location, and output of some decision metrics. Its calculation depends upon the underlying centralized cluster designing CCD algorithm to the BS either through direct or multi-hop using transient nodes considering the network scale [6, 8]. These criteria provide the base how CH are elected, and in some algorithms, affiliated cluster members are chosen too. BS selects the most suitable nodes as CHs based on received information, and the decision is exchanged with the selected CHs. In later case i.e. distributed approach, the decision of CHs is made locally in a different manner as available in the literature. The most modern style is exchanging the value of the decision metric such as energy level, node degree, geographical location, and output of some decision parameters calculation depending upon the underlying distributed cluster designing DCD algorithm among neighboring nodes. The node which has the optimal value among its neighbors is elected as CH. Another style is random selection based on a logical comparison of generated random value between [0, 1] with some calculated probability [9–11]. Our set up approach is DCD; however, we appear with the strong decrease during the message exchange. An energy threshold and a random backoff time are set. If the energy of existing CH approaches to the defined threshold, it initiates the designation rotation message. To inquire for the node present in the central area should have the highest energy level among its neighbors and that the available energy is more than the predefined threshold. The node which fulfills this criterion and its retreat time intervene announce its availability as being the CH by broadcasting a message to its neighbors. All recipient nodes that are even legitimate candidates for becoming the CHs suppress their turn and cancel their back off time. The strategy is simple. However, it has a high impact on message broadcasting for the selection of CH.

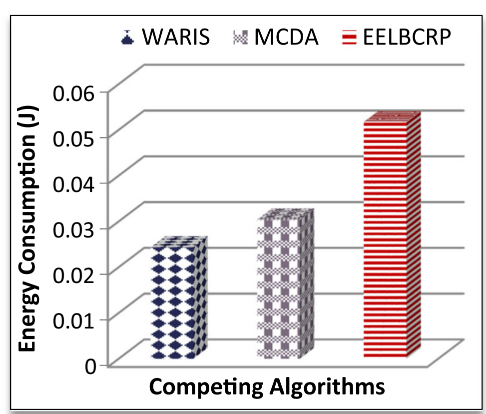


Fig. 3 Average energy consumption per node during cluster design

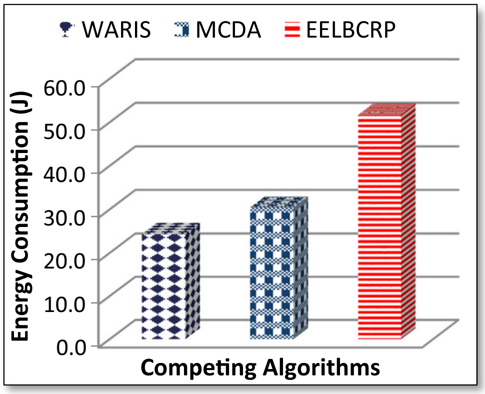


Fig. 4 Total energy consumption in designing of clusters

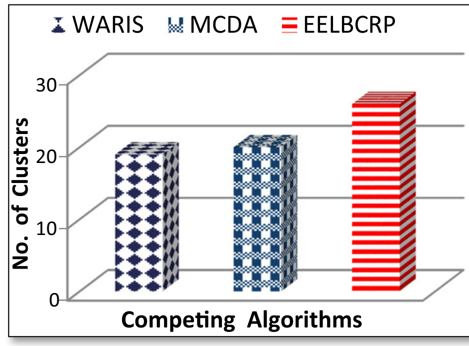


Fig. 6 Number of clusters

4 Simulation and results discussion

This section includes a comprehensive discussion on the comparative analysis of proposed solution, WARIS with the state-of-the-art related algorithms i.e. MCDA and EELBCRP. Parameters like Average energy consumption per node, total energy consumption of the network, the number of packets broadcasted during cluster design, the number of clusters and the number of member nodes per cluster are considered for evaluating the performance in the comparison of algorithms mentioned above. Representation is same as the average value illustrates in Figs. 3, 4, 5, 6, 7, 8, 9 and 10. The repeated experimentation work considering simulation parameters, performed in MAT Lab are given in Table 1.

Simulation parameters that are taken during the setting up cost on energy consumption of clusters from the deployed network nodes consume much energy as compared to the other phases. The main activities of the network in operational form are parametric value collection, competition among candidate nodes to become final CH and invitation to the neighboring nodes to become a member of clusters. Transceiver and processor mainly decide the cluster formation cost regarding energy consumption. Considering the hierarchy of performance from worst to the best, EELBCRP consumes overall highest energy as well as at per node level. The main reason is the centralized approach in its cluster design since all the network nodes communicate their required decision parametric values to the BS. In the case of a large network, more involvement of transient nodes in approaching the said values to the BS and vice versa, as we take network area of 1000 m × 1000 m with 1000 deployed nodes. More transient nodes between source and BS result in the extra broadcast. Hence more energy is consumed. WARIS and MCDA, both have almost same energy per node (Fig. 3)and total energy consumption (Fig. 4).

A bit high level of energy consumption in case of MCDA is due to random picking of nodes for the initiation of cluster design process in the current layer. As sometimes, the nodes are picked from the top right most, the energy consumption is high as compared to picking nodes in the center. In the former case, there is more involvement of nodes as candidate CH. However, in the later case, the nodes with lower node density are automatically dropped and less involvement of non-capable nodes to take part in the competition of becoming the CH.

Evaluating WARIS for energy consumption is the least due to defining of layers from the center and set up the clusters in a local way which decreases the message broadcast and reduces

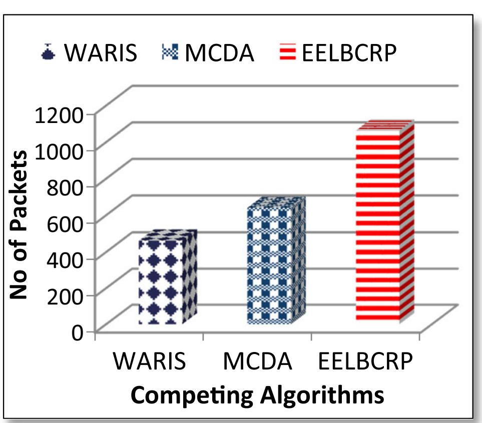
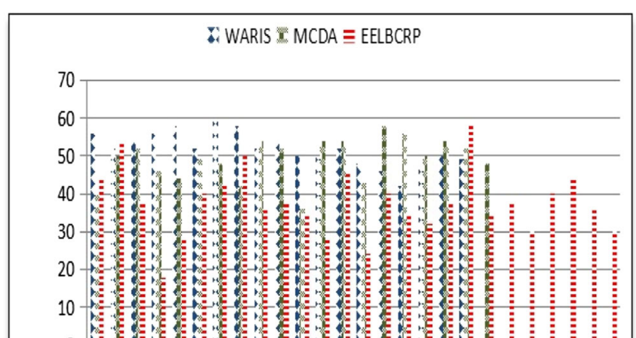


Fig. 5 Number of packets broadcasted during cluster design



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
WARIS	56	52	54	56	58	52	60	58	52	54	50	50	52	48	46	42	48	50	49	0	0	0	0	0	0	0
MCDA	40	50	52	46	44	50	48	42	54	52	36	54	54	43	58	56	50	54	52	48	0	0	0	0	0	0
EELBCRP	44	54	38	18	28	40	42	50	36	38	34	28	46	24	40	34	32	38	58	34	38	30	40	44	36	30

Fig. 7 Number of cluster members

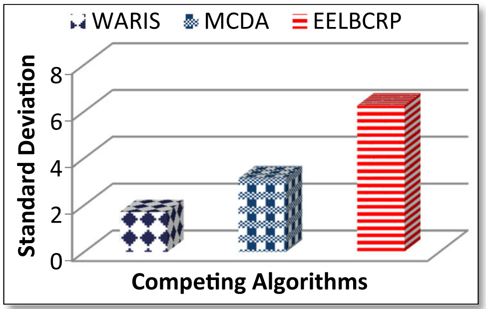


Fig. 8 Standard deviation of number of cluster members

the involvement of nodes to participate in the competition of becoming CH.

Fig. 5, supports the results from message broadcasting point of view. Among all the activities of the transceiver, broadcasting is the most energy consuming activity. Considering the effect of number and size of clusters on the network lifetime, we can have the conclusion from [4], where it is mentioned that more clusters increase the load on hotspot area and very fewer clusters increase the burden on CH. Hence, there must be a way which focuses on the reasonable number of clusters in the network. Going further into this statement, more clusters in a network almost means less number of member nodes in one cluster and vice versa. Moreover, consistency in dividing the number of nodes into clusters should almost be kept same i.e. the Standard Deviation value should be minimized. Fig. 6 shows that EELBCRP has the highest number of clusters compared to other two.

MCDA and WARIS have an almost similar number of clusters. The difference comes from the outlook of the number of member nodes in each cluster that reflects the stability of cluster designing strategy as shown in Fig. 7.

In MCDA, Max. Neighbor Count and Packet Sequence No. play a core role in making clusters and later in the selection of cluster members. It results in cluster balancing. Hence, centrally controlled layer design locally restricted clustered design and then cluster member selection in WARIS give better performance as compared to other two competitors.

The depicted proof of this unsubstantiated claim is very clear from standard deviation (calculated using 'n' method with the

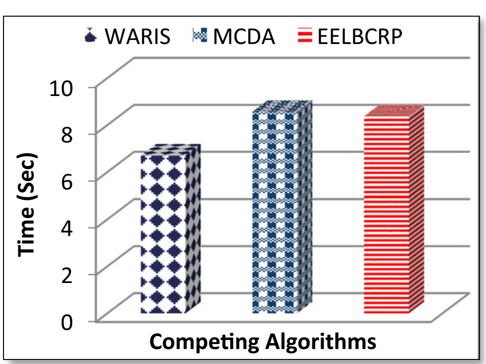


Fig. 9 Time spent in cluster design process

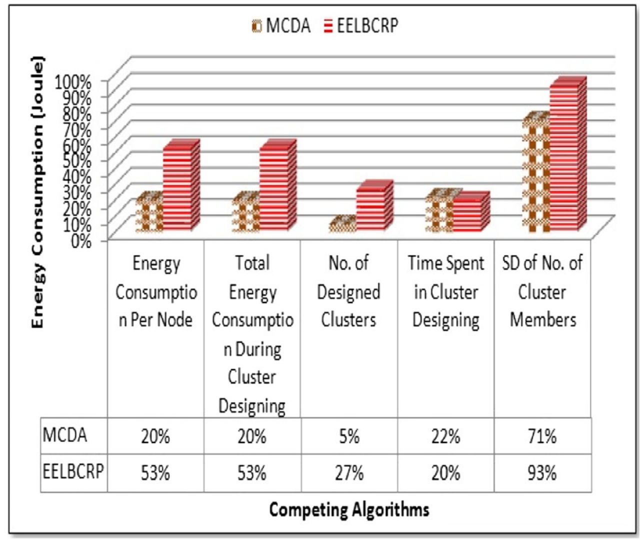


Fig. 10 Performance efficiency of proposed scheme over MCDA and EELBCRP

formula, $\sqrt{\sum\frac{(x-\bar{x})^2}{n}}$) of some cluster members in clusters that can be seen in Fig. 8. Another important parameter of evaluating the proficiency of cluster design algorithms is the time spent during cluster designing. In EELBCRP, the higher time expended in the under-discussed process is due to its centrally controlled style of cluster design. The to and fro message communication between deployed nodes and BS for exchanging parametric values and making decisions make this cluster design process lengthy.

Fig. 9 shows the time spent during cluster design process and comparison with the competitors.

However, in MCDA this is not the case because the cluster designing process is well managed, yet, the time lingers on due to its step by step fashion of cluster design.

Cluster design process of every subsequent layer is initiated, once this process in the very previous layer is completed. The cluster design strategy in WARIS is free from both of these stipulations. Hence, better time completion of cluster design process.

Table 1 Simulation parameters

Parameters	Description
Routing protocols	WARIS(Proposed Solution),MCDA, EELBCRP
Simulation area	1000 m × 1000 m
Data rate	4 Packets/Sec
TCP/IP layer	Network layer
Node to node distance	Random
Node type	Homogenous
No. of nodes	1000
Propagation model	Two ray ground
Initial energy of node	3 J

Fig. 10, concludes the overall comparative results of WARIS, MCDA, and EELBCRP. This figure shows the performance efficiency $\left(\rho = 1-\left(\frac{Proposed\_Scheme}{Competitive\_Scheme}\right)\right)$ of proposed scheme (WARIS) over the competitive schemes i.e. MCDA and EELBCRP. It is very clearly intuited from the Figure that the proposed method outperforms as compared to the competitive plans on energy consumption per node, total energy consumption during cluster design, the number of designed clusters and the time spent in cluster design process.

5 Conclusion

A novel idea for the efficient performance of wireless sensor network with the denomination, WARIS is presented. Its concreteness is evaluated on various parameters in reiterated simulations. As shown and tabulated the corresponding values in Fig. 10, *energy consumption per node* as a performance evaluation parameter, WARIS has 20% better performance compared to MCDA and 53% better performance from that of EELBCRP. We get identically equivalent results predicted total energy consumption during cluster design. In the case of the number of designed clusters, the better values of WARIS compared to MCDA and EELBCRP are 5% and 27% respectively. Considering the result of time spent in cluster design, 22% and 20% are the values with which WARIS performs better. The distribution of load management in the form of cluster size is performed where the performance of proposed mechanism is far better with the value of 71% and 93% as compared to MCDA and EELBCRP respectively. Hence, it is clearly elucidated from the results and the discussion that WARIS is a better choice to implement over wireless sensor networks for efficient performance on energy consumption and set-up completion time.

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