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An energy based cluster head selection unequal clustering algorithm with dual sink (ECH-DUAL) for continuous monitoring applications in wireless sensor networks

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Abstract The essential sections of the hot spot problem are network lifetime improvements and uniform residual energy distribution in wireless sensor networks (WSN). Clustering of sensor nodes is a significant process that improves network lifetime and energy efficiency of WSN. Usage of equal cluster sizes in WSN causes more energy to be consumed by the cluster heads when the data is routed to sink thus resulting in hot spot problems. Hence, recent research papers focus on unequal clustering where cluster size increases as the distance to the sink increases. In this paper, cluster heads are selected by modifying energy efficient unequal clustering mechanism (EEUC). This process is done in two ways. Firstly, in EEUC, final cluster heads are selected based on the residual energy of the randomly selected tentative cluster heads. In our algorithm, tentative cluster head is selected based on energy based timer, residual energy, node IDs and trust value. Final cluster head selection approach selects final CHs based on competition range, node degree and head count. Secondly, in applications like continuous monitoring, usage of static sink causes the clusters near the sink to die out faster, as the cluster heads in these clusters form the fixed path for data routing, hence resulting in hot spot problems. In this work, an energy based cluster head selection unequal clustering algorithm (ECH-DUAL) using dual (static and mobile) sink is proposed. The simulation shows that proposed system (ECH-DUAL) improves network lifetime of continuous monitoring wireless sensor networks significantly over EEUC.

Keywords Cluster head · Dual sink · Energy based timer · Hot spot problem · Mobile sink · Network lifetime · Residual energy · Static sink and unequal clustering

1 Introduction

Use of the wireless sensor network (WSN) has tremendous improvement in the real-time world to a greater extent. The crucial task in WSN is the reduction of power consumption, communication cost and increasing the node lifetime. Concurrently the hike of cost, power consumption and lifetime are vulnerable to an improvement of WSN communication. Many energy saving methods are introduced by various researches, but no articles accomplish the network life time and energy distribution in an efficient manner. The proposed Energy Aware Unequal Clustering routing algorithm with DUAL sink makes the data collection and data forwarding effective. This process increases the network lifetime and balanced energy distribution over the base station or static and mobile sink. When equal size clusters are used, energy consumption will be high. Meanwhile, with respect to the static sink, inter and intra cluster communications create the hot spot problem. More energy is consumed by the cluster near the static sink that involves in intra-cluster communication. Hence intra-cluster communication presides over the hot spot problem, as cluster heads nearer to the static sink are left out with less energy. The hot spot problems are accomplished by using mobile sink.

In continuous monitoring applications, usage of mobile sink may cause delay constraints and time taken for the communication is more. Combination of the static and mobile sink (called DUAL SINK) is introduced to reduce both delay constraint and hot spot problem.

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Nayak et al. proposed the front-leading energy efficient cluster heads (FLEECH) for cluster head (CH) Selection from the multiple clusters [1]. They overcome the difficulties in clustering as well as network communication. These challenges are achieved by organizing sensor nodes in a communication network and routing the sensed data to a remote sink from sensor nodes. The other proposed concept returns the extension of lifetime of network and energy consumption by sensor nodes. It transmits the aggregated data to the sink directly or through neighbor nodes. Rajkumar and Mohammed Uveise proposed method for network lifetime enhancement in WSN [20].

Yuan et al. deal with the unequal clustering algorithm [2] and Zhang et al. also discussed, unequal-clustering routing algorithm for extending sensor node lifetime and energy hole and network partition [3]. This system reduces the heavy relay traffic between the nodes and also reduces the constraints like Increasing network lifetime and minimum energy consumption (MEC) [2]. The heavy relay traffic causes the early loss of a sensor node. To overcome these drawbacks and increase the network lifetime, M-LEACH is proposed by the Yuan et al. (2011). They are prolonging the lifetime over 20 %.

Wan et al. (2012) proposed an EEUC algorithm to deal hot spot and unbalanced energy consumption problem. The more energy consumption and less network lifetime are the major drawbacks of WSN. In the proposed EEUC system, to send the data to base station, the CH near to the sink act as relay and it dissipates more energy than other cluster that is away from the base station. In EEUC, the clusters near to the sink are designed small so that during intra-cluster routing it dissipates less energy and save energy to relay the data to the base station that is received from other cluster heads. Their implementation shows that energy utilization and lifetime of WSN increases effectively.

Thakkar et al. discussed about cluster head selection process in WSN [4]. Energy consumption, communication cost, delay and computational constraint nodes are the critical task in WSN. To overcome these drawbacks, the Energy-Delay Index for Trade-off (EDIT) is introduced. This consumes less communication cost and by considering energy and/or delay requirements, cluster heads and “next hop” is selected. Finally, the computational aspects and complexity were reduced by using the selected cluster head.

Instead of fixed sink nodes Wang et al. use the mobile sink node as it can alleviate energy holes, hot spot problem and delay. And also, they overcome the two challenges against energy efficiency and network lifetime of collecting data packets using mobile sink. They introduced Energy-efficient Competitive Clustering Algorithm [5] for Wireless Sensor Networks to improve the sensor networks performance using a controlled mobile sink. This sink controls the competition range and residual energy.

The above-related work of unequal cluster head selection methods and usage of static and mobile sink in a network mostly highlight hot spot problem and delay constraint. These methods reduce WSN performance in terms of energy utilization, network lifetime, network delay, network density, cluster communication cost and so on. Our proposed technique ECH-Dual overcomes above challenges such as hot spot problem and delay constraints for continuous monitoring applications and increase network lifetime and less energy consumption by the sensor nodes.

2 Preliminaries

2.1 System model

This paper proposes a new routing protocol namely Unequal Clustering Algorithm using Dual Sink. The following section will describe the network model and energy model that Unequal Clustering Algorithm using Dual Sink protocol has used.

A. Network model

Network model consist of sensor nodes that are distributed in a uniform manner in a network. This sensor groups are clustered with respect to the cluster head (CH). The base station (BS) is located at each sensor region. Cluster head and the base station remain unchanged during the entire process. But in other case the Sensor nodes are homogeneous and each node is assigned by a unique ID which changes the properties based on the transmission range. These network models have the following properties in WSN:

1. The sensor nodes are always static and it never changes its location. These nodes are used to accumulate surrounding data and forward this data to the base station by wireless communication.
2. The unique identifier (ID) is assigned to every sensor node to merge the excess data. But these sensor nodes cause failure when its energy is empty.
3. Perhaps the nodes are having the ability to adjust its power level dynamically when the transmitting power level decreases.
4. Every sensor nodes calculates their position based on the received signal strength instead of GPS equipment based position finding in the sensor region.

B. Energy consumption model

In LEACH protocol a sensor node is elected as a cluster head for the current rotation round only if the random number chosen by the sensor node is less than the threshold in the following Eq. 1:

$$\mathrm{T\,(i)} = \begin{cases} \dfrac{\mathrm{PCH}}{1-\mathrm{PCH}\times\left(\mathrm{Round\ mod\ }\frac{1}{\mathrm{P}}\right)} & \text{if } i \in Z \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

Where PCH is the desired percentage of CH nodes in the wireless sensor network, Round is the current round number, and Z is the set of nodes that have not been cluster heads in last $\frac{1}{\mathrm{PCH}}$ rounds. In WSN [6,7], the radio energy dissipation model is used to transmit 'm' bit message over a distance 'd' in transmission is

$$ET_x\,(m,d) = \begin{cases} m * E_{elec} + m * \varphi_{fs} * d^2, d < T_i \\ m * E_{elec} + m * \varphi_{mp} * d^4, d \geq T_i \end{cases} \tag{2}$$

E_{elec} is electronic energy and the ratio of φ_{fs} and φ_{mp} are constants that denote the amplifier energy to maintain the acceptable signal to noise ratio. The same procedures are implemented in the receiver and the energy spent for the radio is

$$E_{Rx}\,(m) = m * E_{elec} \tag{3}$$

Compared with the communication energy [5], the energy consumed on computing and storage process is much lower. So for simplicity we only consider the energy consumption on communication. To combine the number's' such messages, the energy consumes

$$E_{Dx} = s * k * E_{merge} \tag{4}$$

In Eqs. 2 and 3, E_{elec} represents the energy consumption of transmit or receive 1 bit message. In Eq. 4, E_{merge} represents the energy consumption of merge 1 bit message. And T_i shows the threshold value, when the distance is less than T_i, the free space channel model(d^2 power loss) is used; when the distance is more than T_i, the multi-path fading channel model(d^4 power loss) is used.

3 Proposed system

In continuous monitoring applications, the usage of static sink causes the clusters near the sink to die out faster, as the cluster heads in these clusters form the fixed path for data routing, hence resulting in hot spot problems. To overcome the above challenges in cluster head selection [4], our proposed (ECH-DUAL) focus on cluster head selection and routes the data from the cluster head to static or mobile sink.

Figure 1 represents cluster formation of network model of the proposed system. This system consists of many clusters with the cluster head (CH), which is formed in each round with signal strength and radio range. The static and mobile sinks are located at networks center path and its function is to gather the data from the cluster head. In the network center, the static sink is fixed and mobile sink moves in a straight line on the network region. The nodes are clustered in each round and the data are collected by static and mobile sink. If the static sink is nearer to the CH, the collected data will be transferred to the static nodes. Meanwhile, if the mobile sink is nearer to the CH, the collected data will be transferred to the mobile sink. The same technique is applied to all clusters for effective communication. This will reduce the communication cost and increase the network lifetime.

3.1 Cluster head selection

In this work, cluster head selection is based on two processes such as TCH selection and FCH selection. Cluster Head is selected using tentative cluster head selection process based on energy based timer (EBT) and trust value (TV). The timer is assigned to the node to choose the TCH, and trust values are computed based on node's overall trust value. Node that possesses highest trust value and Energy is chosen as TCH. In addition to this, final cluster head selection is based on competition range, node degree and head count is proposed.

3.1.1 Tentative CH selection

3.1.1.1 *TCH selection based on energy based timer (EBT)* The TCH selection overcomes the drawback of LEACH and EEUC by using energy based timer (EBT). The sensor nodes are assigned to timer based on each node's energy. The waiting time assigned to the nodes is based on energy. The waiting time is assigned by using two criteria, such as (i) The nodes with higher energy will be assigned lesser waiting time, (ii) nodes with lower energy will be assigned higher waiting time. The node whose timer value expires first would be selected as the Tentative Cluster Head (TCH). This process promotes high energy nodes as the next tentative cluster head. Otherwise the same node of highest transmission energy acts as cluster head. This energy based timer has the following model description. Suppose for a node i, there are k neighbor nodes and each node can calculate the average energy value of their neighboring nodes: $S_i = \{i_{1,}i_{2,}i_{3,} \ldots i_n \ldots .i_{k,}\}$ and i_n denotes the nth neighbor node. The following equation gives the average energy of node i:

$$Average\ Energy\,(i) = \begin{cases} \frac{1}{k}\sum\limits_{n=1}^{k} Energy\,(i_n) & k > 0 \\ 0 & k = 0 \end{cases} \tag{5}$$

TCH is selected from the sensor nodes using the energy based timer. For any sensor node ID S_i, energy based waiting time value can be obtained from the equation:

$$Wait\ Time\,(s_i) = \frac{Avg\ Energy\ of\ s_i\ Neighbor\ node}{Energy\ of\ S_i} \tag{6}$$

From the above equation, the waiting time decreases as the energy of the node increases. The node with higher energy

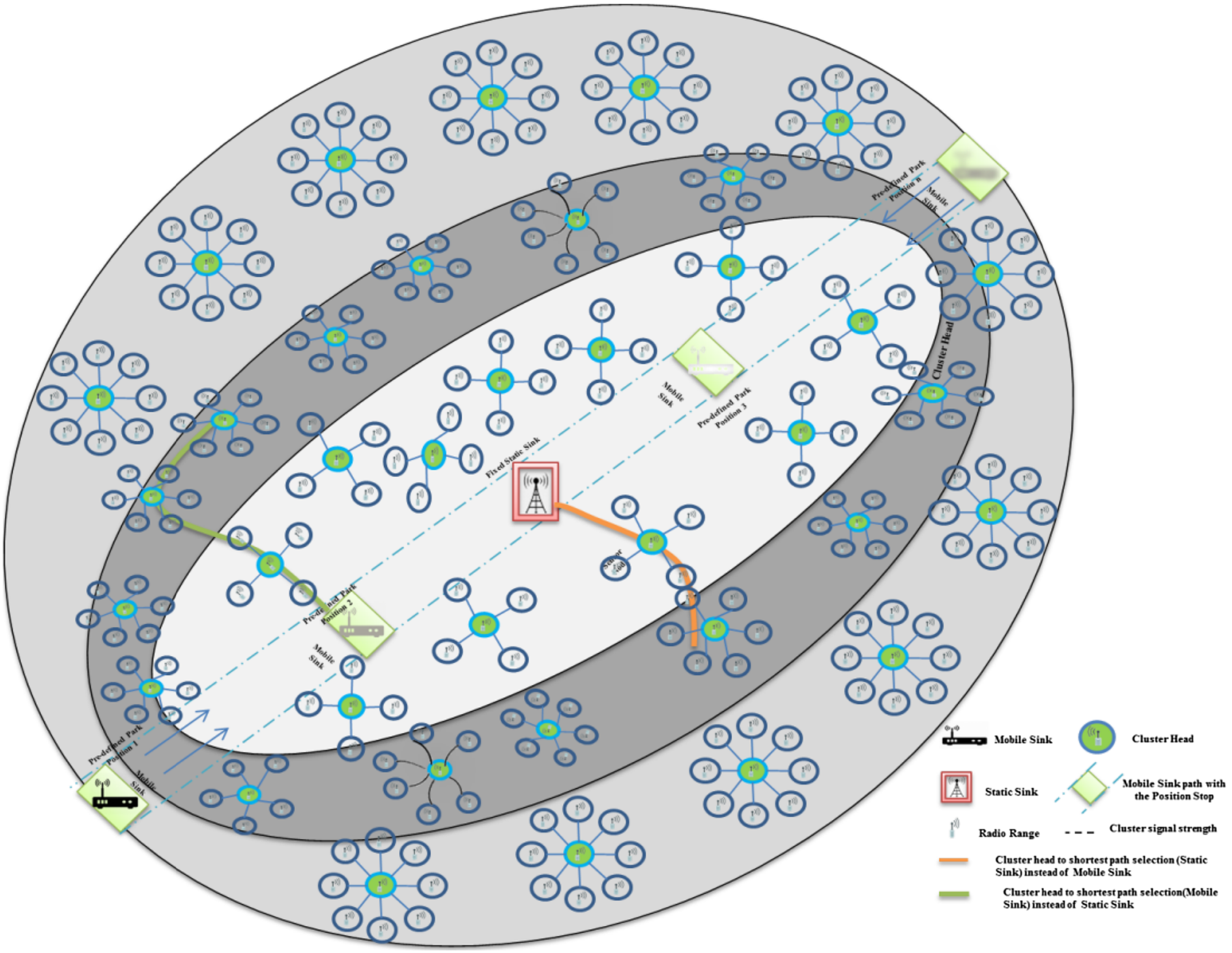

Fig. 1 Proposed system for cluster formation network model

will be assigned less waiting time. This node is selected as the tentative Cluster Head. The selected tentative CH broadcast tentative CH message in its broadcast range and other sensor nodes exits the cluster head selection upon receiving this message before the arrival of its waiting time.

The tentative cluster has been selected based on cluster distance, total energy (E_{total}), trust value (TV). Depending upon the tentative cluster selection parameters, in each round, the process finds the maximum and minimum distance of nodes.

3.1.1.2 *TCH selection based on trust value* Trust value (TV) is used to detect the node behavior, node quality and node services. It is also used for data aggregation, reconfiguring and routing of sensor nodes. It provides a quantitative way to evaluate the trustworthiness of sensor nodes [8]. In this paper trust value is used to collect data and monitor different events in the node. Along with energy based timer (EBT), the trust value is used to find the tentative cluster head. Tentative CH selection follows two approaches (EBT and TV) to optimize best cluster head selection efficiency. The following Eq. 7 is used to calculate the trust value of nodes.

$$Trust\ value(TV)_{nodes} = \frac{N_{FD}}{N_{REC}} \tag{7}$$

Where N_{FD} denotes number of forwarded packets and N_{REC} denotes number of received packets. The trust values of the individual node are computed and the node with highest trust value is selected as temporary cluster head. After this, final CH process is performed. Finally the EBT and the TV returns the result of TCH selection.

3.1.2 Final cluster head selection

TCH compete to become FCH based on parameters such as competition range, residual energy, node degree and head count. Based on the sensor node's energy consumption, dead and alive nodes of the cluster are identified. Final cluster head is selected based on the following process.

Number of edges incident on a node is called the node degree. Node degree metrics [9–13,16] is used to measure the connectivity of WSN. Here each node cannot reflect the mobility characteristics such as static connectivity. Increasing node degree saves energy [14] by reducing hop-count. To improve the node degree metrics, [15] proposed the maximum node degree to solve the expected node degree and node degree distribution problems. Optimal node degree is determined by evaluating the energy consumption of each node. It aims to observe the effect attributable to variations in node degree that are controlled by transmission range. Broadcasts inadvertently jam the transmission medium with collisions and energy is wasted, for a larger node degree. The cluster head nodes are selected depending on node degree and energy.

The average node degree of N is

$$d_{mean}\left(N\right) = \frac{1}{n}\sum_{n=1}^{N} d\left(n\right) \tag{8}$$

Where d (n) is the degree of a node, ‘n’ is the number of neighbors of node (links). A node of degree 0 has no neighbors. The minimum node degree of a network ‘N’ is defined as

$$d_{min} = \min\nolimits_{\forall n \in N}\left\{d\left(n\right)\right\} \tag{9}$$

The d_{min} and d_{mean} gives efficient results compared to EEUC. Node whose degree is higher is elected as CH. Node degree reduces the overall communication cost for cluster-head selection and thus it increases overall lifetime of the network. Each normal node belongs to only one cluster. Minimizing number of clusters maximizes average cluster size. The advance nodes deployed in dense areas are selected as cluster head (Fig. 2, 3).

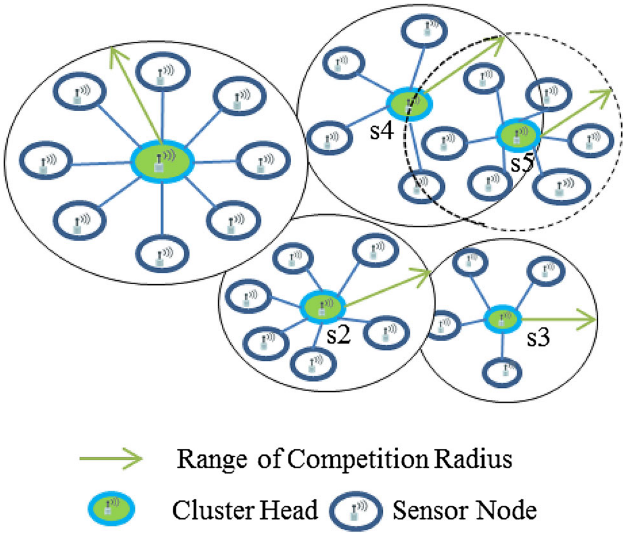

Fig. 2 The competition range among tentative cluster heads

With respect to the chosen TCH, FCH are selected using following process.

Consider S1, S2, S3, S4, S5 are selected as five tentative cluster heads. Each TCH will compute the competition range R_i using the following formulae:

Case 1 Competition range for tentative cluster head (S1)

$$S1(R)_1 = \left(1 - c\frac{d_{max} - d\left(S_1, Static\ Sink\right)}{d_{max} - d_{min}}\right)R_0 \tag{10}$$

Case 2 Competition range for tentative cluster head (S2)

$$S2(R)_2 = \left(1 - c\frac{d_{max} - d\left(S_2, Static\ Sink\right)}{d_{max} - d_{min}}\right)R_0 \tag{11}$$

Case 3 Competition range for tentative cluster head (S3)

$$S3(R)_3 = \left(1 - c\frac{d_{max} - d\left(S_3, Static\ Sink\right)}{d_{max} - d_{min}}\right)R_0 \tag{12}$$

Case 4 Competition range for tentative cluster head (S4)

$$S4(R)_4 = \left(1 - c\frac{d_{max} - d\left(S_4, Static\ Sink\right)}{d_{max} - d_{min}}\right)R_0 \tag{13}$$

Case 5 Competition range for tentative cluster head (S5)

$$S5(R)_5 = \left(1 - c\frac{d_{max} - d\left(S_5, Static\ Sink\right)}{d_{max} - d_{min}}\right)R_0 \tag{14}$$

As the distance $\mathrm{d}\left(\mathrm{S_i}, \mathrm{Static\ Sink}\right)$ increases the competition range $\mathrm{R_i}$ of the tentative cluster head also increases and vice versa. For example, S3 is nearer to the static sink and hence the distance between static sink and S3, {d (S3, static sink)} is small. Hence the competition radius $\mathrm{S3(R)_3}$ will also be small. Thus the communication range of S3 will be small. Hence the sensor nodes in that small range join S3 creating a small cluster with S3 as the final cluster head, as there is no other tentative CH overlapping in the same range.

Similarly S1 and S2 calculate the competition range. The range is decided based on the distance to the sink. As S1 and S2 are far from sink, their competition range should be larger than the S3. They do not have competition or overlap as no other tentative CH is present in their range. Hence S1 and S2

Fig. 3 Pseudo-code for tentative CH selection and final cluster head selection

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Pseudo-code for Tentative CH and Final Cluster Head Selection
Initialization:
Energy (E), Temp_CH(Sj), Total Energy ($E_{total}$), Forwarded packets ($N_{FD}$),
Total Number of Packets ($N_{REC}$), non-cluster set of nodes (G),
Number of Node (N)
Case 1: Tentative CH Selection ∀node (i)∈ [Within Network Region]
energy(i)←Energy level of node i
initialize timer (i)←'k', neighbor node, $i_n$ $n^{th}$ neighbor node with sensor node $S_i$
elect cluster head as 'n'
if n become the cluster head
process checks the cluster distance of
        $d_{max}$= max ($d_{max}$, distance) and $d_{min}$=min($d_{min}$, distance)
Calculate the average energy
$Avg\ Energy\ (i) = \begin{cases} \frac{1}{k}\sum_{n=1}^{k} Energy(i_n) & k > 0 \\ 0 & k = 0 \end{cases}$
until end of the node in non-cluster set of nodes (G)
Wait Time ($S_i$)=  (Average Energy of $S_i$  Neighbor node)/(Energy of $S_i$ )
repeat process to reach successive tentative Cluster Heads with high probability
Case 2: depends on the Random node (n) and non-cluster set of nodes (G)
if 'n' sends advertisement and join request to G
Non-cluster set of nodes checks and verifies the cluster head
        $d_{max}$ and $d_{min}$with the total energy $E_{total}$=$E_{total}$+ E
else
        Create cluster head (CH) for new cluster
form the remaining non-cluster set of nodes
perform case 1: and case 2:
calculate the trust value, $(TV)_{nodes}$=$N_{FD}/N_{REC}$
Result: tentative cluster head selection
Case 3: find final cluster head selection
compute the node degree by
$d_{min} = \min_{\forall n \in N}\{d(n)\}$ , average node degree by
$d_{mean}(N) = \frac{1}{n}\sum_{n=1}^{N} d(n)$
  $for\ all\ dense\ area$
Calculate competition range of tentative cluster head by
        $R_i = \left(1 - c\frac{d_{max} - d(S_i, Static\ Sink)}{d_{max} - d_{min}}\right) R_0$
                If distance $d(S_i, Static\ Sink)$ is increases
        Competition range $R_i$ increases
else if distance $d(S_i, Static\ Sink)$ is decrease
        Competition range $R_i$ decrease
Condition 1:  cluster size w.r.t. sink by near → small
Condition 2:  cluster size w.r.t. sink by far → large
                Select the CH as FCH;
Result: FCH selection
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become FCH. Hence the nodes in the competition range of S1 and S2 join them.

In another case, the TCHs S4 and S5 overlap in a cluster. S4 and S5 compete to become FCH. S4 can hear the broadcast message of S5 and vice versa as their ranges overlap. The competition between S4 and S5 to become Final CH is explained below:

1. If S5 belongs to S4($S5 \varepsilon S4$). S4 compares its energy with the energy of S5
2. E (S4> $S5$), then S4 broadcast itself as final CH. S4 receives a quit election message from S5. S4 removes S5 from its overlap region. Thus S4 will become the FCH for the cluster in transmission range. Other sensor nodes in S4 range will join S4 as its cluster members

3. E (S5>S4), then S5 sends FCH message to S4. After S4 receives the message from S5, it gives up and sends a quit election message to the nodes in overlap region. Hence S5 will be the final CH for the cluster in its range. All nodes in S5 range will join S5 as its cluster members.
4. If the energy of S4 and S5 are equal (tie), then the node with smallest id will become the final cluster head.

3.2 Energy consumption

The residual energy (RE) of proposed algorithm is measured in each round, which starts from the current Round, Round+1 and Round+ 2 until final node is reached. The energy consumption rate of proposed system is shown in Eqs. 15 to 18. The energy consumption measured in various rounds is as follows,

In current round, the energy consumed by CH is given in Eq. 15.

$$Residual\ energy = RE + S(i) * E \tag{15}$$

From this, the average residual energy (ARE) is calculated using,

$$ARE\,(Round + 1) = \frac{RE\,(Round + 1)}{2} \tag{16}$$

The total energy consumption (TEC) on each rounds are calculated using the following equation.

$$TEC\,(Round + 1) = E_0 * n - RE\,(Round + 1) \tag{17}$$

In case are ‘n’ layers available in the network, the average energy consumption of node can be defined as

$$AEC\,(Round + 1) = \frac{TEC\,(Round + 1)}{n} \tag{18}$$

The AEC is calculated with respect to the total energy consumption. TEC consists of the average of all transmitted energy, received energy, idle energy and sleep mode energy. The result shows the total dead and alive nodes present in the system. For this scenario, each node has an ability to transfer 2000-bit data packet to the sink. At this time, when transmission distance [6] is lesser and/or the radio energy is higher, then equal amount of energy is used for transmitting and receiving.

The above pseudo-code in Fig. 3 for CH selection using unequal clustering algorithm gives the efficient energy balance in the network. The energy based timer (EBT) and trust value are used to choose TCH. The FCH is selected based on the node degree, competition range, residual energy and head count**.**

3.3 Dual sink for data transmission

Usage of dual sink in continuous monitoring applications reduces hot spot problem. The proposed dual sink used for aggregated data transmission network model is based on the static and mobile sink. At the center of the network, the static sink is fixed to collect data from nearby CH and mobile sink moves in a straight line on the network region toward the static sink.

3.3.1 Static sink in network model

Sensor nodes are used in continuous monitoring applications for monitoring, sensing and reporting gathered data to the static sink which is fixed at the center of the network.

The coordinates of static sink is given by Eqs. 19 and 20

$$Sink.Xfixed = 0.5 * Xm \tag{19}$$

$$Sink.Yfixed = 0.5 * Ym \tag{20}$$

In continuous monitoring application, the CHs gather data from their cluster members. This data can be sent directly or through intermediate CHs to the static sink. As a result, the static path is created and hot spot problem may occur due to energy dissipation. Hence mobile sink is also used to collect data so as to avoid hotspot problem.

3.3.2 Mobile sink in network model

Mobility pattern of a sink node could be classified into random mobility pattern and predefined mobility pattern. In random mobility pattern, the position and speed of mobile sink movement are done in random manner and therefore it is simple and unpredictable. In predefined mobility pattern, movement of the mobile sink node is predictable and it moves along a predetermined trajectory. From the predefined moving patterns such as random, circular, diagonal and linear, linear movement incurs the least energy consumption [17].

The coordinate of mobile sink for linear path is given by Eqs. 21 and 22

$$Sink.Xmobile = 0.5 * Xm \tag{21}$$

$$Sink.Ymobile = 0 * Ym \tag{22}$$

Hence, the recent studies focus on the mobile sink that could travel in a straight path across the entire network. Dynamic paths and delay constraints need to be taken care while using mobile sink.

3.3.3 Communication over the cluster head by using dual sink

Every final cluster head will compare the distance to the both mobile and static sink. The transmission of the data packet to the sink depends on minimum distance between CH to mobile or static sink. If the distance of CH to the mobile sink node is lesser than static sink node, FCH transmits aggregated data packet to mobile sink. Otherwise the aggregated data packet will be transmitted directly to static sink or through neighbor CH nodes to the static sink node.

The operational view of proposed ECH-DUAL is shown in Fig. 4. The process repeats until the residual energy become empty with respect to inter and intra cluster communication transmission. This process returns efficient data transmission and reduces energy consumption as well as increases the network life time. Direct transmission Energy routing protocol is used for Intra-Cluster communication. It is the process of collecting local data from the network and sending only to its corresponding CH. The CHs further proceed with Inter-Cluster communication (Fig. 5).

4 Simulation results and discussion

During experimentation, the characteristics of each node in the network and its performance are analyzed based on efficient cluster head selection and, data transmission using dual sink Energy based cluster head selection unequal clustering algorithm. The proposed methodology is tested using MATLAB; MATLAB is common and well known simulation tool. In this work, the terrain area of 1000*1000 is simulated with 100 nodes. The Maximum competition range (R_0) 40m is assumed as the network region. The following discussion shows the MATLAB R2011a with bundled JVM 1.6.0_17 of simulation.

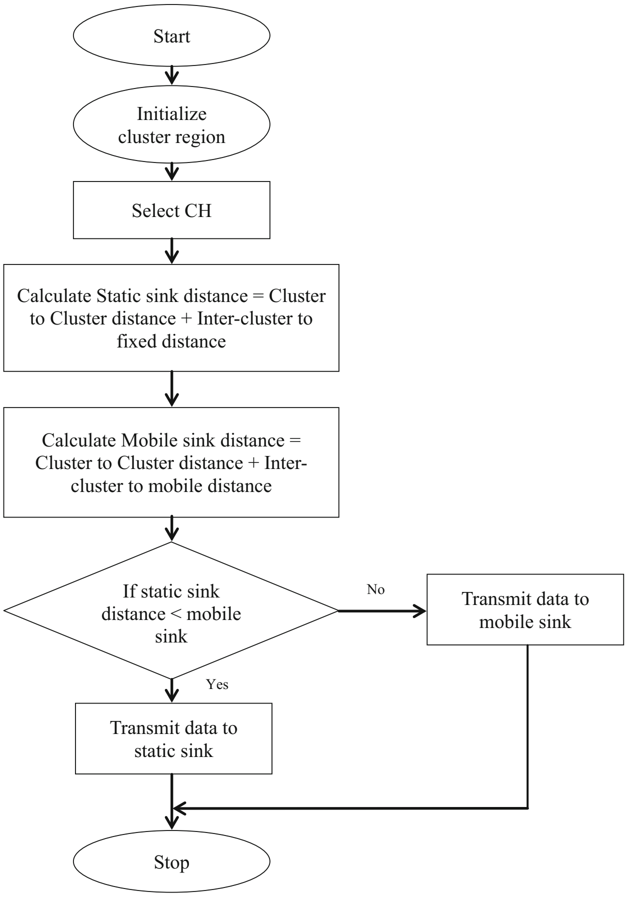


Fig. 5 Flowchart for inter-cluster communication

Fig. 4 Energy based cluster head selection unequal clustering algorithm with DUAL sink (ECH-DUAL)

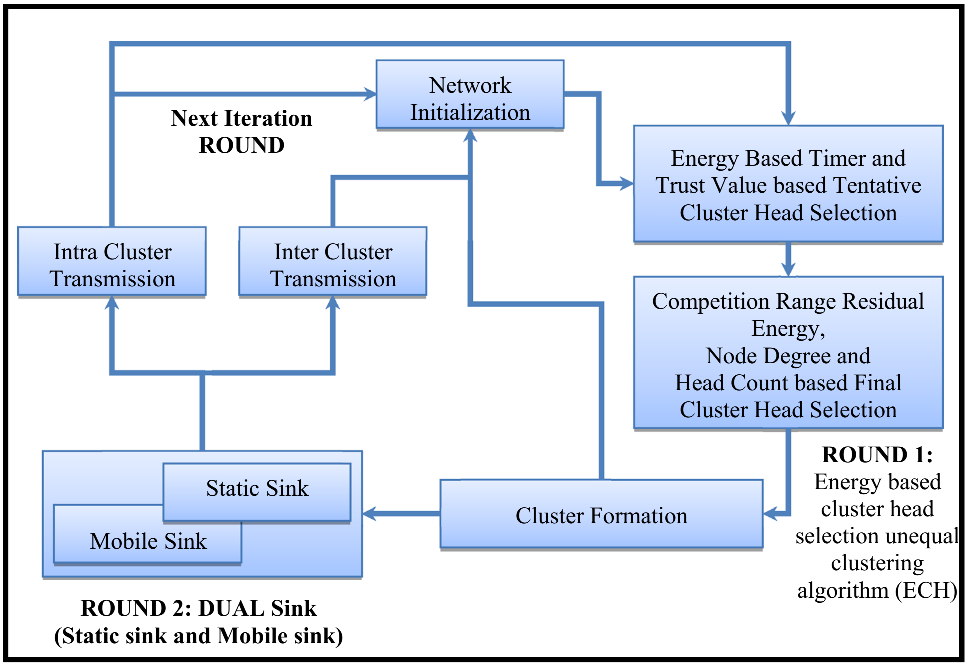


Table 1 WSN simulation parameters

Parameter	Value
Network field	(1000*1000) m
X dimension of topography	1000
Y dimension of topography	1000
Number of sensor nodes, N	100
Initial energy, E_0	0.5 Joules
Data aggregation energy, EDA	5 nJ/bit
Transmit amplifier free space propagation model, ϕ_{fs}	10 pJ/bit/m^2
Transmit amplifier two-ray ground propagation space model, φ_{mp}	0.0013 pJ/bit/m^4
Percentage of tentative cluster heads, PCH	0.2
Maximum competition range, R_0	40 m
Constant coefficient	0.3
Cross-over distance	87.7058 m
Data packet size	4000 bits
Antenna model	Omni antenna
Simulation time	200 s (minimum: 200s, maximum: 10000s)
Channel type	Wireless_Channel
Radio-propagation model	Two_Ray_Ground
Network interface type	Wireless physical layer
MAC type	802_11
Interface queue type	DropTail/PriQueue
Link layer type	LL
Mobility	/tclfiles/speed5

In this simulation result, we discuss the performance of the proposed system using dual sink for continuous monitoring application in wireless sensor network. In each round the energy consumptions are calculated with respect to data transmission. The proposed ECH –DUAL using (static and mobile sink) [18,19] is compared with the existing EEUC technique. In addition to this, the experiments are conducted to determine the number of alive nodes, dead nodes, residual energy, average residual energy, total energy consumption, average energy consumption and the network lifetime. The simulation iteration rounds vary from round 1 to 4250. The simulation is carried out by using the parameters given in Table 1.

4.1 Performance evaluation

Dual sink is implemented in the proposed unequal clustering algorithm used in continuous monitoring applications for efficient data transmission. The outcome produces less energy consumption and increases network lifetime and also avoids hot spot problem.

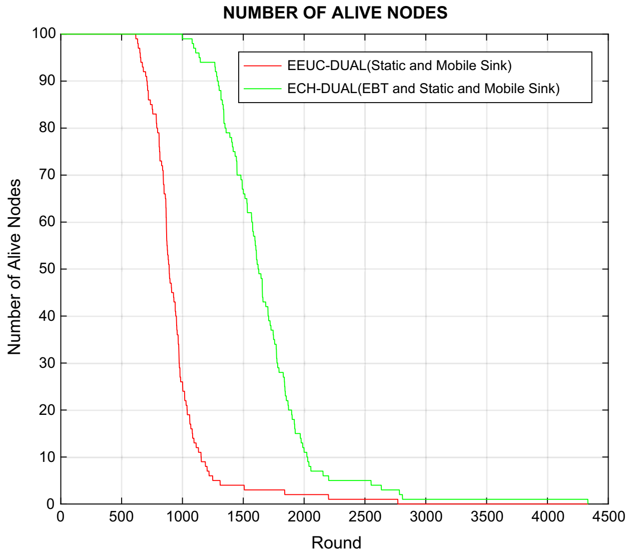


Fig. 6 Number of alive nodes

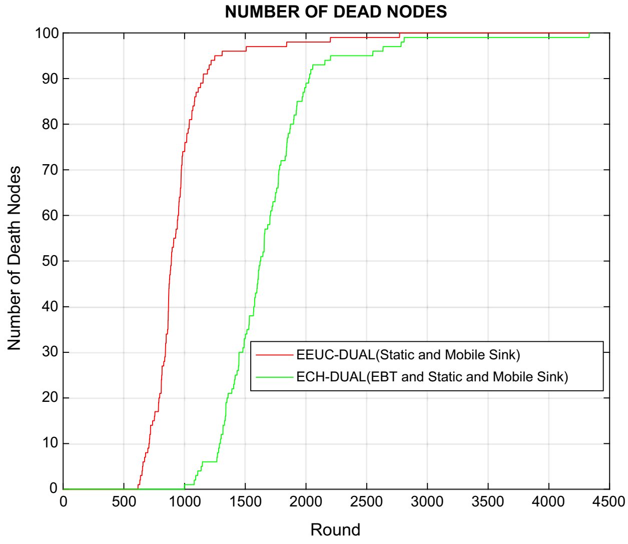


Fig. 7 Number of dead nodes

At the time of simulation, each node has its own power or energy. The energy is used to communicate with the neighbor node for data transmission. This type of nodes is called as the Alive Nodes. Alive nodes are identified based on balanced energy distribution and nodes lifetime. When the energy of a node become empty, the node becomes dead. The alive nodes with 4250 randomly selected rounds is shown in Fig. 6. The proposed ECH-DUAL is compared with the EEUC-DUAL. The proposed algorithm maintains the alive node count high until the system reaches 4250 rounds. Figure 7 reveals the number of dead nodes for different number of rounds and the dead node count is low for proposed system. Network lifetime defines the round when the first node loses its complete energy. From the Fig. 7, it is clear that the first

Fig. 8 Residual energy of each node with respect to the round

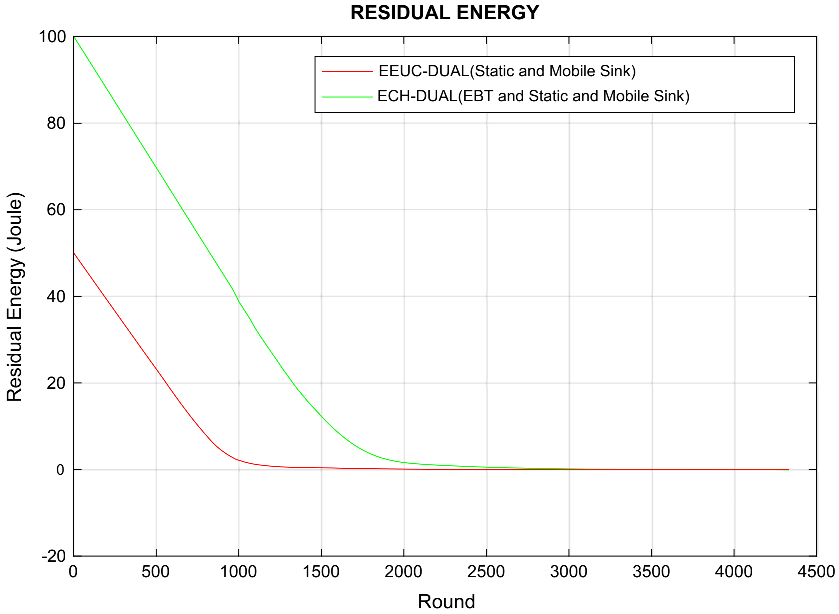
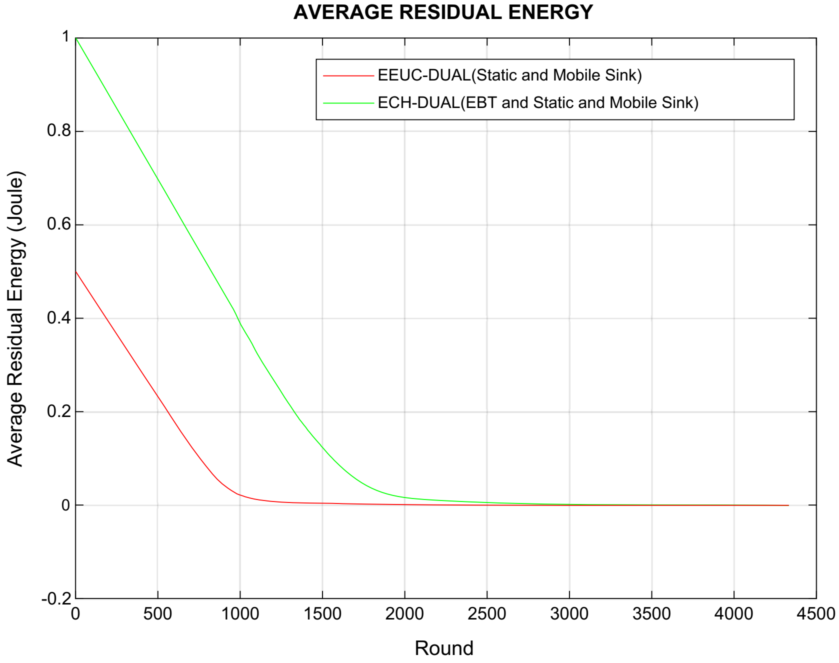


Fig. 9 Average residual energy of each node with respect to the round (1–4250)



node dies at 1120 round and hence the network lifetime is 1120.

Figure 8 shows the Residual energy for the proposed ECH-DUAL and EEUC-DUAL methods. Residual energy has been varied for each node with respect to energy level, network lifetime and transmission range of node. The energy loss of cluster node for an average of 4250 nodes is balanced and near-minimal.

From Fig. 9, the Average residual energy is analyzed in different round (1–4250 rounds).

Figure 10 shows a comparison of total energy consumption with our proposed scheme for the cases where TCH and FCH schemes are considered. The optimal energy configuration is used when our balanced energy consumption scheme is considered. Figure 10 reveals that the energy consumption balanced by our scheme increases with the transmission rate of each sensor node. When a node gets high energy, the execution time becomes low. With this consideration of nodes, the energy consumption is low at each sensor node. We analyzed the total energy consumption with different rounds (from 1 to 4250 rounds). It is measured in joule.

Fig. 10 Total energy consumption of each node with respect to the round (1–4250)

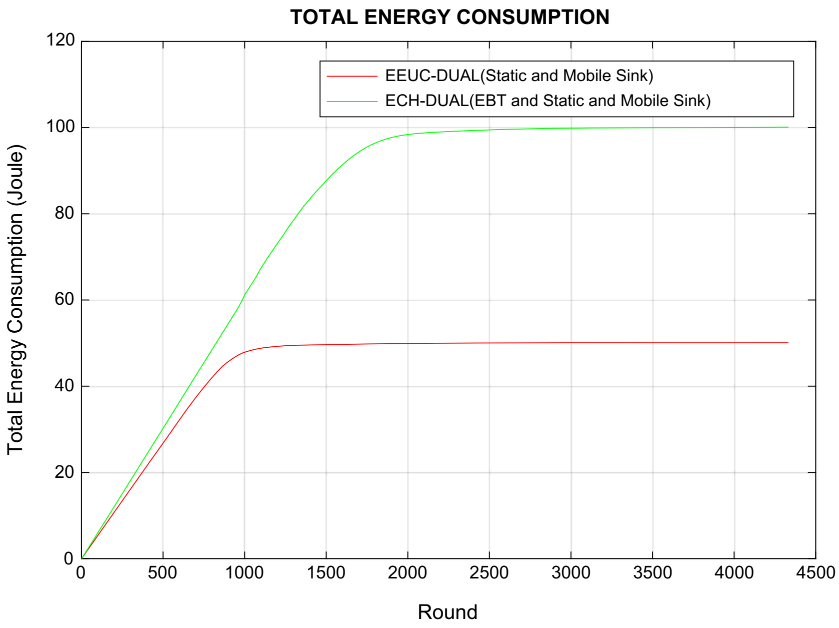


Fig. 11 Average energy consumption of each node with respect to the round (1–4250)

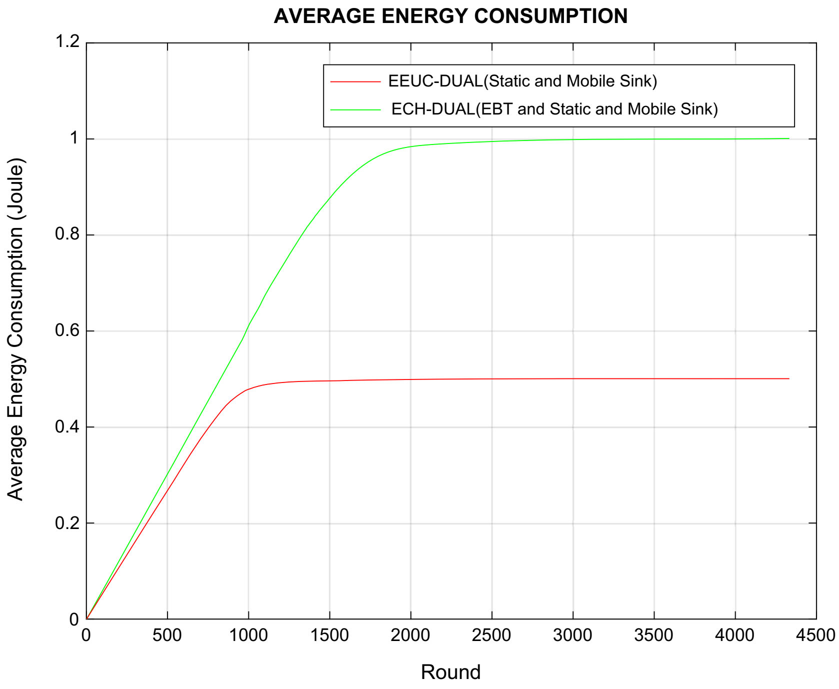


Figure 11 provides the average energy consumption of each node with 4250 randomly selected rounds. The proposed ECH-DUAL is compared with the EEUC-DUAL and the proposed system maintains less Average Energy Consumption compared to the existing system.

The Network lifetime for EEUC-DUAL and ECH-DUAL is given in Table 2 and it is observed that ECH-DUAL method returns higher network lifetime.

Figure 12 shows comparison of lifetime of network (energy consumption) for two algorithms with fixed dimension 1000 × 1000 sq.m. From the figure, proposed ECH-DUAL obtains high network lifetime when compared to EEUC-DUAL.

Table 2 Network lifetime comparison

Algorithms	Network lifetime (rounds)
EEUC-DUAL	513
PROPOSED-ECH-DUAL	1120

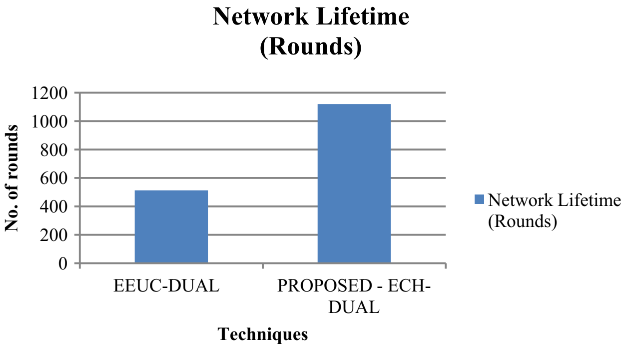


Fig. 12 Comparison of network lifetime in terms of (ROUND)

5 Conclusion

The work discusses the energy based cluster head selection unequal clustering algorithm with dual sink (ECH-DUAL) for data transmission in continuous monitoring applications. This paper mainly focuses on selection of tentative cluster head by energy based timer and trust value and final CH selection by using node degree, competition range and residual energy. The uneven clustering method using dual sink is employed to balance the energy consumed by CHs and improve node lifetime in WSNs. The dual sink (i.e. static and mobile sink) enhances the node lifetime in network. Experimental result shows that proposed system achieves better results in terms of number of alive residual energy, average residual energy, total energy consumption, average energy consumption compared to EEUC-DUAL.

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