A Comparative Analysis of Various Routing Protocols and Performance Comparison of Clustered Routing Protocols in Mobile Sink Scenario

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ABSTRACT:
The concentration of data transfer towards the sink in a wireless sensor network causes nearby nodes exhaust their batteries faster than further nodes, this leaves the sink trapped and disrupts the data reporting communication between sensor nodes. To avoid such scenarios, protocols with mobile sinks were proposed. They helped in achieving load balancing and uniform energy consumption throughout the network. This research aimed to concentrate on the dynamic requirements of the mobile sink by providing an overview of mobile sink protocol concerns, design requirements, and challenges associated with issues of the mobile sink routing. On the other hand, in this research different types of mobile sink protocols are reviewed and compared on the basis of some parameters of the sink protocol. In this paper, the concept of the mobile sink with various protocols that were defined with the static sink is presented. Mobile sink is supposed to be moving in each round and the data collection is done through Coordinator Cluster Head which collects the data through various cluster heads. Simulation results showed that mobile sink concept is increasing the network lifetime.

Keywords: Mobile Sinks, Distributed Routing, Wireless Sensor Networks.

1. INTRODUCTION

Due to the concentration of packages around the sink and the intersection of multi-hop routes, the nodes near to sink node tend to deplete their batteries first. This is called as the Hotspot problem [1]. Death of a node would lead to the isolation of sink node as no sensing data will be received by it. Moreover, it will lead to the disruption in the topology. Therefore, mobile sinks are proposed, to incorporate load balancing [1], [2] and achieve uniform energy consumption [3],4] throughout the network. Distributed and disconnected network can be handled in a better way using mobile sink [3-8]. One major disadvantage of mobile sink comes at cost. Updating the location of mobile sink across the network is quite difficult and this leads to increase in overhead. The overhead should not exceed a certain limit [2]. In Fig. 1, data is being sent from source to mobile sink by using multiple nodes. When the mobile object changes its position data can be sent by choosing other nodes in the path from source to destination.

In WSN, the two categories of sink are static sink and mobile sink. The static sink is stationary on a particular position while mobile sink can move across the network. Due to the increasing demand for energy efficient routing and reliable data delivery, mobile sink's concept became prevalent [1-8]. As the nodes can survive for more time and give better results. In the case of a mobile sink with fixed paths the choice of the mobility path influences energy efficiency [9]. Table 1 showed the comparison between static and mobile sink.

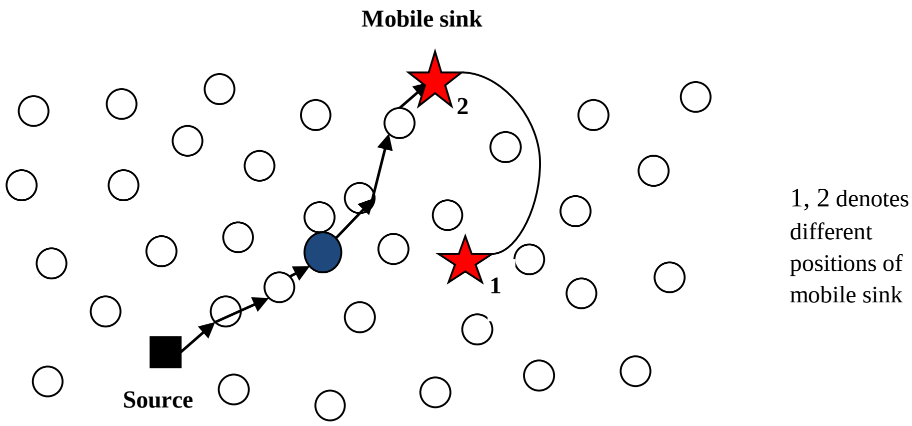

Fig.1. Mobile Sink.

1.1. Sink Mobility Patterns

Depending on the requirement of the application, it could be seen from two perspectives

A. Sink's perspective- It reflects the true motion pattern of the sink.

i) Continuous: In this, the sink nodes follow a particular pattern for e.g. cyclic, straight line etc.

ii) Nomads: Here, the mobile sink doesn't follow a particular pattern, they move here and there like nomads.

B. Sensor's perspective- It tells about the sink mobility with respect to the sensor node's limited knowledge.

Rest of the paper is organized as follows. In section 2, design issues and challenges for mobile sink has been discussed. Section 3 and section 4 illustrates the types of hierarchical and non-hierarchical routing. Section 5 comprised of the clustering technique and various approaches. In section 6, the proposed algorithm of the mobile sink has been proposed. Section 7 presents the simulation table and results. Finally, conclusion and future work are provided in section 8.

2. DESIGN ISSUES & CHALLENGES

Various design issues and challenges for mobile sink are following:

2.1. Extreme Cases

This problem can be defined using 2 extreme cases [10]

A. Naive Approach- In this, the position of the mobile sink is periodically flooded in the network so that, every node gets updated with the new position of the sink.

B. Lack of routing protocol- In this approach, simply the sink node collects information from every other node as it passes along their communication range. This could be more energy efficient by using the sleeping mechanism. The node could only play a role when the sink is nearby.

2.2. Performance

There are many performance issues that mobile sinks have to deal with [10].

A. Energy- To achieve uniform energy consumption, the mobile sinks are most suitable because they increase the lifetime of the network by making the batteries more durable. It protects the nodes from early deaths that can cause disruption and disconnectivity of topology.

B. Latency- It is the time taken between generations of sensor data to reception of data. In the mobile sink, the location of the sink might not be updated or the position of the sink is outdated. In this case, the sensor nodes should acquire the sink's position or it must send data through indirect routes. We must use low-latency mechanisms in order to get the position of the sink whenever needed.

C. Reliability- It depends on the ratio of packets delivered to the sink. The packets which are transmitted to the outdated sink are destined to be lost. To avoid the packet loss we must use fruitful mechanism.

3. HIERARCHICAL MOBILE SINK ROUTING PROTOCOLS [11]-

It decreases the load of advertising or broadcasting the position of the sink. It also establishes a virtual hierarchy of nodes that imposes different dynamic roles on the sensors. It consists of two tiers (**high-tier nodes & first-tier nodes**).

In high-tier, nodes in this tier obtain the sink's position while other nodes in first-tier ask the high-tier nodes to acquire sink position information whenever necessary.

This approach can be further classified with respect to structures:

3.1. Grid-Based Approach

In this approach, grid structures are employed as the higher level of the virtual hierarchy. For e.g. square, rectangles, triangles, hexagons etc. Geographic coordinates are required due to the geometric structures used in it; hence position- aware protocols are preferred. Some common protocols used under it are, TTDD (Two tier Data Dissemination in large scale WSNs) [12], GBEER (Grid based Energy Efficient routing) [13], CMR (Coordinate Magnetic Routing) [14].

A. TTDD- This approach is source oriented. In this protocol, each source node creates a grid around itself with other valid nodes and whenever, sinks need data they broadcast a query message that is further relayed to the source nodes. Source nodes solve the queries and send back data to the sink from the same path that was followed by query message.

i) Advantage: The grid based approach is easily accessible because both sink and source can reach the grid covering minimum distance.

3.2. Cluster Based Approach

In this approach, clusters are formed by partition of the networks. The cluster head assigned to these clusters are used as high-tier nodes. Since, clustering is a topology-based mechanism; this approach leads to a more proficient virtual hierarchy. The protocols which follow the same approach are LEACH-C, TEEN, DEEC, SEP, HCDD (Hierarchical Cluster-based Data Dissemination) [15], EEMSRA (Energy-Efficient Mobile Sink Routing Algorithm) [16], MSRP (Mobile Sink-based Routing Protocol) [17] etc.

A. HCDD- This type of hierarchical approach is based on clusters. Clusters are formed to control the second-tier nodes and cluster-heads are elected for the circulation of data. To elect cluster-head Max-Min D cluster formation algorithm is used.

i) Advantage- Position-awareness of nodes is not required and gives an enhanced choice of second-tier nodes.

3.3. Tree Based Approach

This class of protocols creates an overlaying effective tree structure. The sink announcement is usually dissipated from the source towards (roots) the destination (leaves). Some examples are SEAD (Minimum-Energy Asynchronous Dissemination) [18], QDD (Quad-tree Based Data Dissemination Protocol) [19].

A. QDD- It divides the area into quadrants and the center point of these quadrants is considered as second-tier nodes. These quadrants are further divided in a recursive manner until the second-tier node is easily and quickly accessible.

i) Advantage: The main advantage is the reduction of overhead of constructing quadrants.

3.4. Backbone-Based Approaches

The protocols of this class set up a backbone covering the network which classically consists of nodes with diverse roles. Protocols that reside under this category are DDB (Dynamic Directed Backbone) [20], DQM (Data Quality Maximization) [21].

A. DDB- A backbone is constructed for the second tier nodes which is a collection of leader and gateway nodes. The leader nodes form clusters with the neighboring nodes and coordinate the data processing. The leader nodes communicate with each other with the help of gateway nodes. Sink collects data from gateway nodes and this is how data dissemination takes place.

i) Advantage: It minimizes the overhead problem by avoiding hotspots because only immediate neighbors are informed about the update.

3.5. Area-Based Approaches

These approaches assign the nodes in an area of precise boundaries as the high-tier nodes rather than establishing complex structures. To diminish the hotspot problem, rather than altering the structure, the size of the area is specified large enough to extend and reduce the spare load on the high-tier nodes. Nodes under this approach are LBDD (Line-based Data Dissemination) [22], Ring routing [23] etc.

A. Ring Routing- In this, a ring structure is formed in which the center is considered as the head. Whenever sink wants to announce its position it forwards the packet to the center with the help of geographic routing. Source node also queries for the sink position in the same manner.

i) Advantage: This structure is easily accessible and it has low overhead which altogether makes it an efficient protocol. Due to the rapid and easy acquire of sink position, data delivery takes less time.

3.6. Agent-Based Approaches

This category of protocols chooses an agent to pass on the traffic from source to the sink. These selected representatives are considered under high-tier nodes. Sometimes, flooding is done to make the nodes aware of agent's location. Protocols under this class are DHA (Data Dissemination Protocol Based on Home Agent and Access Node) [24], OAR (Optimized Agent-based Routing Protocol) [25].

A. DHA- Footprint mechanism is used to handle the sink mobility patterns and data dissemination. Specialized nodes are employed that are Home agents and Access nodes. Only these nodes are affected by sink positions. Sink chooses access nodes and forwards the packet containing its current position.

Then, access nodes further pass it on to the Home Agents. Home agents represent sink to the sensor nodes.

i) Advantage: The main advantage of this protocol is its straightforward and simple approach.

3.7. Hybrid Approaches

As the name suggests, these protocols take up a grouping of two or more fundamental structures. Protocols that reside in this category are MGRP (Multi-tier Grid Routing Protocol) [26], EGRR (Real-Time Routing Protocol Based on Expect Grids) [27].

A. MGRP- It is a combination of Grid based approach and cluster based approach. A recursive grid structure is formed such as QDD. Inside each grid cell clustering mechanism is performed, by selecting cluster heads which act as data aggregators.

i) Advantage: The combination makes this protocol easily accessible.

Here, we have compared different hierarchical based routing protocols according to the different studies done on these protocols. These types of protocols are found to be very effective in load balancing, because this somehow helps in increasing the lifetime of network. Most of these protocols, support multi-sink and provides mobility. As they follow a hierarchical structure, most of these protocols share a strong bond i.e., they have good communications between their nodes. But, when we consider the main parameter i.e., energy efficiency these protocols fail. As they are inefficient in providing increased lifetime, for this reason researchers proposed non-hierarchical protocols.

4. NON- HIERARCHICAL MOBILE SINK ROUTING PROTOCOLS

In these types of protocols, high tier structure is not utilized. The nodes are not imposed to form a hierarchy. This helps in minimizing the overhead of constructing a virtual structure and eliminates the problem of hotspots. Mechanisms that are employed to advertise the mobile sink's position are selection of agents, flooding, overhearing.

4.1. Flooding Based Approach

These types of protocols are based on the transmission of broadcasts across the sensor nodes. This is done to announce the sink and to bring back data to sink. This approach has strictly confined areas avoiding unnecessary broadcasts. Some widely used protocols under this approach are GRAB (Gradient Broadcast) [28], ER (Efficient Routing) [29], DEEP (Density based proactive data dissemination) [30] etc.

A. DEEP- Probabilistic flooding is used to lower the widespread broadcasting. The data packets are flooded in a random manner that is further aggregated by nodes across the network. To further reduce unnecessary transmissions, duplicate packets are detected and deleted. Data compression is done in order to increase bit efficiency. Sink travels randomly across the network to collect data from sensors in its vicinity.

i) Advantages: It has the ability to work without position-awareness. It helps the mobile sink to collect the aggregated data through minimal movement. It is an efficient method to control flooding.

4.2. Overhearing Based Approach

Overhearing is an ineffective but unavoidable property which describes the reaction of transmitted packets by the neighboring nodes in addition to the intended recipient. The information contained in the overheard packets is used to advertise the sink. Some common protocols are DDRP (Data Driven Routing Protocol) [31], Elastic Routing [32] etc.

A. Elastic Routing- In this protocol, overhearing is a primary mechanism. The sink position is recursively updated on sensor nodes starting from nearest to farthest. When the sink moves its neighborhood changes and it informs the last source node it has received the packet from. This announcement is overheard by the nodes near its path which helps other nodes to get updated.

i) Advantage: It is easy to design and implement. It has the ability to propagate sink's position to a large number of nodes which makes it an efficient protocol.

4.3. Approaches Exploiting Geometric Properties

Sensors are deployed on a flat surface which is considered as a two-dimensional plane. Geometric properties are utilized to make sure the junction of different types of packets. Protocols that lie in this category are GHT (Geographic Hash Table) [33], Double Cross [34] etc.

A. Double Cross- It extends the idea of RLW by exploiting plane's simple geometric property. The probability of intersection of two orthogonal lines on a level surface is more than 99%. When a node has data to send, it sends it along the two orthogonal lines leading to four directions. Similarly, sink sends queries issued by it in four directions. According to the geometric property, query and data are tend to meet at a point and data dissemination takes place by sending it on to the reverse path of the query.

i) Advantage: The most considerable advantage is that it does not require position- awareness.

Table 2. Comparison of Hierarchical Mobile Sink Protocols.

Protocols	Classification	Data Aggregation	Multi-sink support	Strength	Control Manner	Mobility	Energy Efficiency	Load Balancing	Complexity
TTDD [12]	Grid based (Rectangular)	Yes	Yes	Strong	Distributed	Yes	Very low	Good	Low
HCDD [15]	Cluster based (Max-min)	No	No	Weak	Distributed	Yes	Low	Good	Low
QDD [19]	Tree based (Quad-tree)	No	Yes	Weak	Centralized	No	Very Low	Good	High
DDB [20]	Backbone based	No	Yes	Strong	Distributed	Yes	Low	Moderate	Moderate
Ring Routing [23]	Area based (one-node width)	No	No	Strong	Distributed	Yes	Moderate	Good	Moderate
DHA [24]	Agent based (Two agent)	Yes	No	Weak	Distributed	Yes	Very low	Bad	High
MGRP [26]	Hybrid (Grid& cluster)	Yes	No	Strong	Distributed	Yes	Higher than others	Moderate	Very high

Table 3. Comparison of Non-Hierarchical Mobile Sink Protocols.

Protocols	Classification	Data Aggregation	Multi-sink support	Strength	Control Manner	Sink Mobility Pattern	Energy Efficiency	Complexity
DEEP [30]	Flooding-based	Yes	No	Strong	Distributed	Random	Medium	Less
Elastic Routing [32]	Overhearing based	No	No	Very Strong	Distributed	Random	High	Very Less
Double Cross [34]	Exploitation of geometric properties	No	Yes	Moderate	Distributed	Random	High	High

In this comparison, we compared various non-hierarchical protocols according to the different parameters that define a protocol. These types of protocols are found to be less complex and the sensor nodes in it have very strong connections. They do not support multi-sink, this is a major drawback. But, the purpose for which these protocols were proposed was successfully fulfilled, that is energy efficiency. These protocols proved to be very much energy efficient.

In the next section, we have proposed a mobile sink strategy to improve the network lifetime by electing a CCH to communicate with the mobile sink.

5. CLUSTERING

Clustering means dividing of large sensor network into small manageable units called clusters which do data aggregation tasks as shown in Fig. 2.

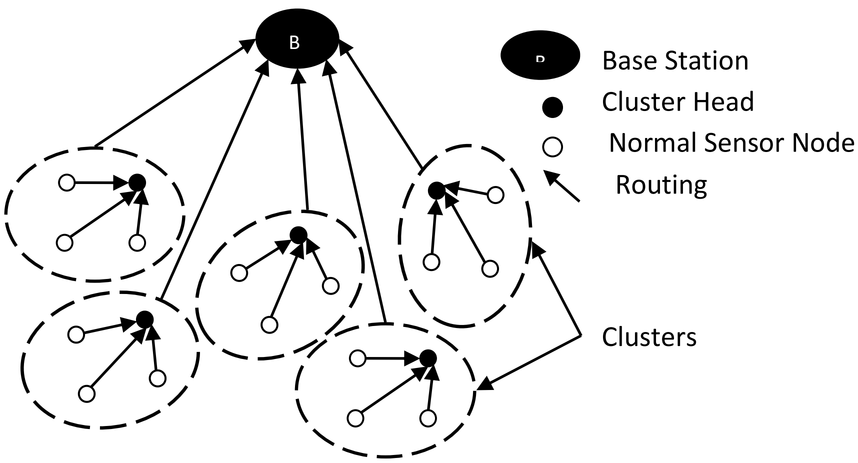

Fig. 2. Traditional Clustering Routing.

5.1. Leach Protocol

Low Energy Adaptive Cluster Hierarchy (LEACH) [35] based protocol is first hierarchical clustering energy efficient routing protocol that reduces the energy consumption of node by cluster formation so it directly increases network life. LEACH Algorithm contains a periodic process in which each round has two phases: setup phase and steady state phase. Every node x in the network chooses a random number j between 0 and 1. If j <T (x) for node x, the node becomes a cluster-head. The selection of cluster heads will be done by the following equation (1):

$$T(x) = \begin{cases} \dfrac{prob}{1-prob\left[r*mod\left(\frac{1}{Prob}\right)\right]} & \text{if } n\epsilon G \\ 0 & \text{Otherwise} \end{cases} \tag{1}$$

where prob = the desired percentage of cluster heads (e.g., prob= 0.05), r=the current round, and G is the set of nodes that have not been cluster-heads in the last $\frac{1}{prob}$ rounds.

5.2. Leach-C Protocol

When designing protocol architectures for wireless micro sensor networks, it is important to consider the function of the application, the need for ease of deployment, and the severe energy constraints of the nodes. These features led us to design LEACH, a protocol architecture where computation is performed locally to reduce the amount of transmitted data, network configuration and operation is done using local control, and media access control (MAC) and routing protocols enable low-energy networking. LEACH-C protocol [36] uses centralized sink for CHs selection as shown in Fig. 3.

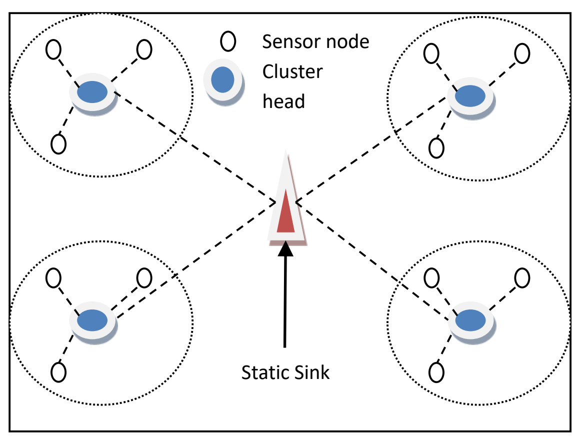

Fig. 3. LEACH-C Protocol using Static Sink.

5.3. Teen Protocol

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [37] uses both hierarchical technique and data-centric approach. Transmission of data is done less frequently so it saves energy efficiently. It is a reactive protocol in which nodes are sensitive to certain activities like temperature weather etc. so reactive protocols are best suited for time critical activities. So, data transmission happen only in two conditions either the sensed data value is larger than the hard threshold value or changes in the value of the sensed attribute is greater than/ equal to the soft threshold value.

5.4. Heed Protocol

Hybrid Energy Efficient Distributed clustering Protocol (HEED) [37], CH selection is based on two parameters residual energy of node and network topology. It includes three steps for selection of the CHs which are initialization phase, repetition phase and final phase. In the initialization phase each node sets its probability of becoming a cluster head, *CHprob*, can be defined by the equation (2):

$$CH_{prob} = (C_{prob} \times \left(\frac{E_{residual}}{E_{max}}\right) \tag{2}$$

In repetition phase node keeps on discovering the node with lower communication cost. When node does not find an appropriate node then it selects itself as a CH. In the final phase, nodes are selected CH. Where, *Cprob* is the initial percentage of cluster heads among n nodes, while *Eresidual* and *Emax* are the residual and the maximum energy of a node (fully charged battery), respectively [37].

5.5. Sep Protocol

In a heterogeneous sensor network, initial energy of all nodes is not the same. The WSN contain various types of heterogeneous protocol like SEP [38] DEEC [39], using these energy efficiency protocols we can save the energy of the nodes and improve the network lifetime. So for heterogeneous purpose in terms of energy, Stable election protocol (SEP) [38] was proposed which carried two level heterogeneity for sensor network.

Nodes which are having more energy power are known as advanced nodes. Suppose sensor network composed of total N number of sensor nodes and each node is equipped with E_0 initial energy. For heterogeneity, let M×N be the number of advanced nodes where M is a fraction of the total number of nodes. Let advanced nodes have A times more energy than rest of nodes. Therefore, the initial energy of each advanced node in the network is Eo×(1+A). Thus total initial energy of two level heterogeneous networks could be represented by equation (3).

$$Etotal = N \times (1 - M) \times Eo + N \times M \times E_0$$
$$Etotal = Eo \times (1 + A \times M) \tag{3}$$

For a node to become a CH it should have optimal probability P_{opt}, defined as in equation (4):

$$Popt = \frac{K_{opt}}{N} \tag{4}$$

Here k_{opt} is optimal number of constructed clusters. When distance of a population of nodes to the sink is less than d_o where $do = \sqrt{\frac{e_{fs}}{e_{mp}}}$, then value of k_{opt} given by the equation (5):

$$K_{opt} = \sqrt{\frac{N}{2\pi}}\frac{X}{D} \tag{5}$$

When distance of a population of nodes to the sink is more than d_0 then value of kopt defined by equation (6):

$$K_{opt} = \sqrt{\frac{N}{2\pi}}\sqrt{\frac{e_{fs}}{e_{mp}}}\frac{X}{D^2} \tag{6}$$

Let area of network=X×X, D=Average distance from a CH to the sink node, N=no of nodes in network. e_{fs} and e_{mp} depend on the transmitter amplifier model [38]. For every round, the average number of constructed CH should be N×*Popt* and its fix (constant) to minimize the energy consumption of nodes. SEP protocol assigns a weight to the optimal election probability (Popt) to maintain the fixed number of CH per round. Thus weighed election probabilities for normal and advanced nodes are shown by equations (7) and (8) respectively:

$$Pnrm = \frac{Popt}{1 + A \cdot M} \tag{7}$$

$$Padv = \frac{\text{Popt}}{1 + \text{A} \cdot \text{M}} \times (1 + A) \tag{8}$$

As election probabilities are changed so the threshold value for normal and advanced nodes can be defined by equation (9) and (10) respectively:

$$T(snrm) = \begin{Bmatrix} \frac{Pnrm}{1-Pnrm.\left(rmod\frac{1}{Pnrm}\right)} & if snrm \epsilon G' \\ 0 & if snrm \epsilon G' \end{Bmatrix} \tag{9}$$

$$T(sadv) = \begin{Bmatrix} \frac{Padv}{1-Padv.\left(rmod\frac{1}{Padv}\right)} & if sadv \epsilon G'' \\ 0 & if sadv \epsilon G'' \end{Bmatrix} \tag{10}$$

where, r is the current round, G' is the set of normal nodes that have not become CHs within the last 1/Pnrm rounds of the epoch, *G''* is the set of advanced nodes that have not become cluster heads within the last 1/*Padv* rounds of the epoch [38].

Finally, the excellence of SEP protocol is that it does not requires any global knowledge of nodes in the network for data routing. But SEP cannot perform well for more than two-level heterogeneity in terms of energy of sensor node.

5.6. DEEC PROTOCOL

In Distributed Energy Efficient Clustering (DEEC) [39], selection of CHs is not only based on the election probability. In addition DEEC protocol merges a ratio of residual energy of each node and the average energy of network to the election probability. The nodes with high initial and residual energy will have more chances to become the CH than the other nodes with low energy. In DEEC protocol election probability of each node include residual energy and average energy of network. Let $\bar{E}(r)$ denote the average energy at round r of the network, which defined as in equation (11):

$$\bar{E}(r) = \frac{total\ residual\ energy\ of\ all\ nodes\ at\ round\ r}{no\ of\ nodes} \qquad (11)$$

For two levels heterogeneous network by adding residual and average energy concept we get election probability formula as in equation (12)

$$pi = \begin{Bmatrix} \frac{P_{opt}E_i(r)}{(1+AM)\bar{E}(r)} & if\, s_i\ is\ the\ normal\ node \\ \frac{P_{opt}(1+AM)E_i(r)}{(1+AM)\bar{E}(r)} & if\ s_i\ is\ advanced\ node \end{Bmatrix} \qquad (12)$$

As DEEC consider multilevel heterogeneity in terms of node's energy then we get election probability for CH selection as in equation (13):

$$pi = \frac{P_{opt}N(1+A)Ei(r)}{(N+\sum_{i=1}^{N} A_i)\bar{E}(r)} \qquad (13)$$

Let Eavg(r) represents the average energy at round r of the network that is defined in equation in (14):

$$Eavg(r) = \frac{1}{N}Etotal(1-\frac{r}{R} \qquad (14)$$

Here R denotes total no round of network which can be calculated by the equation (15):

$$R = \frac{Etotal}{Eround} \qquad (15)$$

Eround is the total energy dissipated in the network during a round, is equal to the equation (16):

$$Eround = L\big(2N\text{Eelec} + NE_{DA}ke_{mp}D^4{}_{toBS}Ne_{fs}D^2{}_{toCH}\big) \qquad (16)$$

where, k: number of clusters,

L: no of bits in data packet,

E_{DA}: Data aggregation cost expended in the cluster heads,

D_{toBS}: Average distance between the cluster-head and the base station,

D_{toCH} : Average distance between the cluster members and the cluster-head,

Eelec: Energy dissipated per bit to run the transmitter or the receiver circuit [27].

5.7. Energy Consumption Model

A sensor node is typically small in size and capabilities of a sensor node, in terms of processing power, memory, communications and energy provisioning are limited. A sensor node typically consists of a sensing circuit, a digital signal processor, and a radio transceiver. The communication parts in a sensor are responsible for the majority of energy consumption [35]. To compute the energy dissipation in wireless transmission, this work uses radio energy dissipation model present in [35] as shown in Fig. 4: -

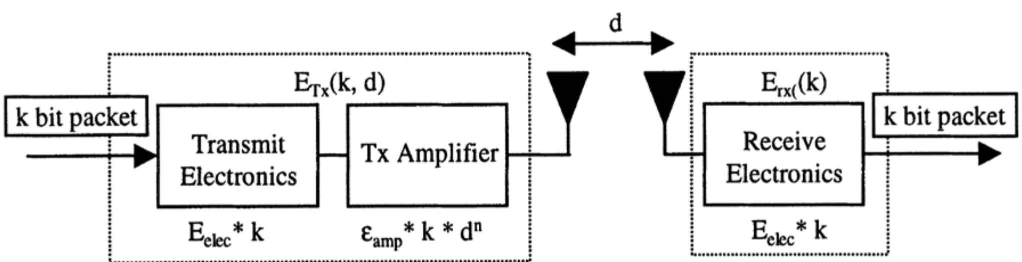

Fig. 4. Radio energy dissipation model

If the distance of the node to the base station is greater than d_0 than the energy required to transmit and to receive the data is given by equation (17) and (18) -

$$E_{trans}(K,d) = E_{elec} * K + E_{emp} * K * (d)^p \qquad (17)$$

$$E_{recv} = E_{elec} * K * (d)^p \qquad (18)$$

where, p: Path loss exponent taken to be 4,

K: Size of message being transmitted and received,

E_{trans} : The amount of energy required to transmit the data packets,

E_{recv} : The amount of energy required to receive the data packets.

a) If the distance of the node to the base station is greater than d0 than the energy required to transmit and to receive the data is given by equation (19) and (20) –

b)

$$E_{trans}(K,d) = E_{elec} * K + E_{emp} * K * (d)^p \qquad (19)$$

$$E_{recv} = E_{elec} * K * (d)^p \qquad (20)$$

where p: Path loss exponent taken to be 2,
K: Size of message being transmitted and received,
E_{trans} : The amount of energy required to transmit the data packets,
E_{recv} : The amount of energy required to receive the data packets.

6. PROPOSED ALGORITHM

1. For each round (x-axis and y-axis are defined coordinates of the region)
2. (x, y is the current position of mobile sink)
3. (CCH – Coordinator Cluster Head that is nearest to the Mobile Sink)
4. If (x<x-axis and y=0)
5. Then
6. x= x+ (x-axis/10)
7. Mobile sink receives packets from CCH
8. Else if (y<y-axis and x= x-axis)
9. then
10. y= y+ (y-axis/10)
11. Mobile sink receives packets from CCH
12. Else if (y=y-axis and x>0)
13. then
14. x= x- (x-axis/10)
15. Mobile sink receives packets from CCH
16. Else if(x=0 and y>0)
17. then
18. y= y- (y-axis/10)
19. Mobile sink receives packets from CCH
20. End

The algorithm of the technique is described below:

1. Firstly we simulate an area of x*y and no. of nodes (n) are deployed randomly.
2. The area is partitioned into clusters. The nodes choose their clusters according to their position. Then goto step 3.

% The area which is divided into clusters is called virtual network structure.

3. Location of mobile sink is decided.

% Position of sink is dynamic as it moves around the area. The data dissemination will take place after each round and from a new position of sink as defined in the pseudocode.

4. Initial energy is appointed to each node as every node requires some amount of energy.
5. The cluster head is elected in each cluster with respect to different protocols.
6. Once the cluster heads are selected, the distance between cluster head to cluster head and cluster head to base station is calculated by using equation (21).

Temp = min(min_dis,sqrt((Sink.x-CCH.x)^2+ (Sink.y-CCH.y)^2)) (21)

7. The nearest cluster head to the base station is denoted as CCH; and all other cluster head establishe their routes towards CCH. CCH directly transmits data to base station.
8. Total energy of the network is calculated by using the same formula as used in the existing protocols.

% It is calculated according to the distance in cluster heads

% Energy consumption during data aggregation from CCH to BS, CH to CCH as well as nodes to CH.

Goto step 9.

9. The different protocols are compared as the conclusion is found out by checking the best performance of protocols.

7. SIMULATION TABLE AND RESULTS

Table 4. Simulation Table.

Parameters	Value
Diameters of sensor network	xm=100, ym=100
Initial position of mobile sink	sink.x=0*xm, sink.y=0*ym
No. of nodes	n = 250
Probability of a node to become cluster head	p=0.05
Energy supplied to each node	E=1 Joule
Transmitter energy per node	E_{TX}=50 nJ/bit
Receiver energy per node	E_{RX}=50 nJ/bit
Amplification energy when d is less than d_o	E_{fs}=10 pJ/bit/m^2
Amplification energy when d is greater than d_o	E_{amp}=0.0013 nJ/bit/m^2
Data Aggregation Energy	EDA=5 nJ/bit
No. of rounds	rmax=6500
Threshold distance	sqrt(E_{fs}/E_{amp})

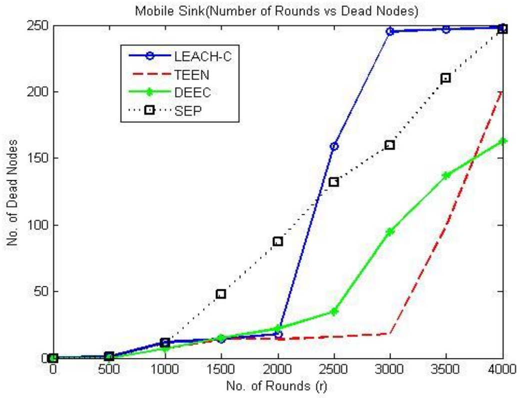

Fig. 5. Lifetime of Network using Mobile Sink.

Fig. 5 shows the lifetime of the network w.r.t rounds using Mobile Sink. The mobility of the sink is changing w.r.t. rounds. Around 3000 rounds, TEEN protocol showed much more stability as compared to other protocols, but after that number of dead nodes increased drastically. DEEC showed that only half numbers of nodes are dead when TEEN and LEACH-C did not have any live nodes. Fig. 6 depicts the packet transferred to CCH w.r.t. rounds. In SEP, CH transferred much more packets to CCH as compared to other protocols such as LEACH-C, DEEC and TEEN. LEACH-C and TEEN showed similar packet transfer to CCH, but DEEC showed comparatively better. Fig. 7 depicts consumption of power w.r.t. rounds. TEEN and DEEC showed that the consumption of energy in these protocols are much more stable as compared to LEACH-C and SEP.

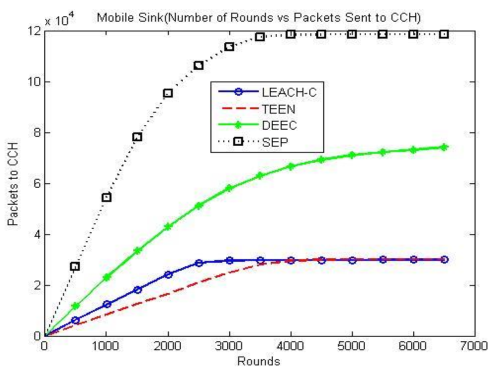

Fig. 6. Packets sent to Coordinator Cluster Head by Cluster Heads.

7.1. Comparison between Static and Mobile Sink

When the area is 500 m x 500 m and number of nodes are 1000, Fig. 8 and Fig. 9 showed the network lifetime comparison by using static sink and mobile sink. When the static sink is used, around 70%-80% of the nodes are dead around 500 rounds. SEP does not perform better in mobile sink scenario. But, LEACH-C, DEEC and TEEN outperform SEP protocol in mobile sink scenario. Thus, the concept of mobile sink considerably enhances the lifetime of the network when routing protocols such as LEACH-C, DEEC and TEEN have been used.

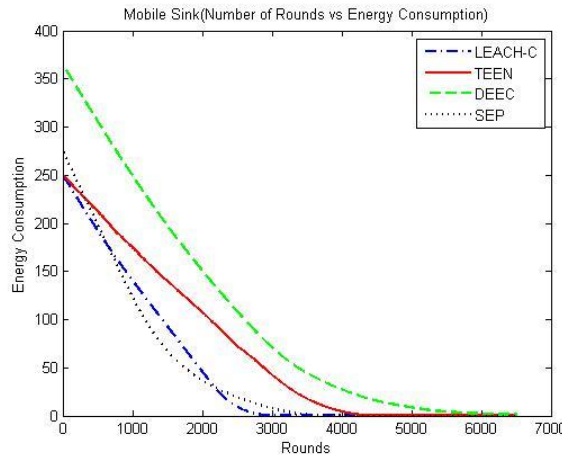

Fig. 7. Energy Consumption per Round.

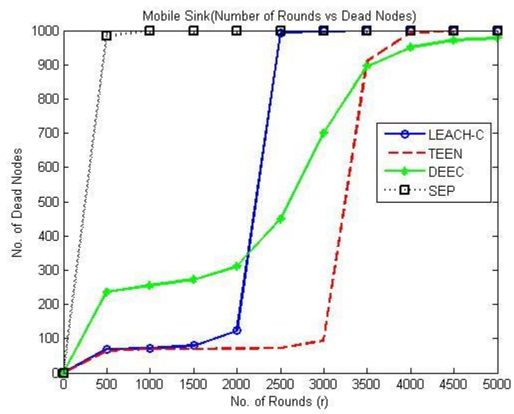

Fig. 8. The network Lifetime using Mobile Sink.

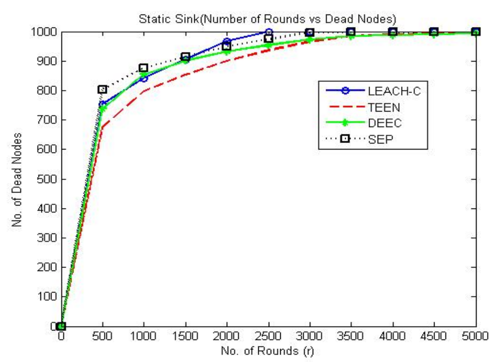

Fig. 9. The Network Lifetime using Static Sink.

8. CONCLUSION AND FUTURE WORK

In this work, various existing distributed mobile sink routing protocols with their design issues and challenges have been discussed. A precise classification of the hierarchical and non- hierarchical protocols is given and in addition various examples of these types were compared. A comparison was done on the basis of various important factors that define a protocol. Simulation results showed that the concept of mobile sink increases the network lifetime as compared to static sink.

But, there is still scope of more improvement like distribution of area into equal sized grids to decrease the work load and random replacement of nodes after some rounds can be done.

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