Strategic Trajectory Defined Mobile Sink Scheduling Protocol for Energy Efficient Cluster based Wireless Sensor Network

R. Gopalakrishnan[1], Dr. A.SenthilKumar[2]
Guest Lecturer[1], Assistant Professor[2]
Department of computer Science[1,2]
Arignar Anna Government Arts College, Namakkal[1,2]

Abstract

Heterogeneous wireless sensor network will lead to unequal energy consumption and imbalanced traffic due to limited energy sources of the densely deployed wireless network. Energy efficient approaches has been employed to achieve the higher energy efficiency and increase the lifetime of the network using multiple mobile sink on the heterogeneous sensor network . Despite of much significance of the routing approaches, it leads to hot spot challenges on deployment of the multiple mobile sink as data collection points to acquire the sensed information of the deployed sensor. As multiple mobile sinks frequently changes its locations and distance during data acquisition in multihop manner. To mitigate those hotspot challenges, a new energy efficient routing paradigm named as Strategic Trajectory defined multiple mobile sink scheduling protocol has been proposed. Proposed protocol is capable of enhancing the energy efficiency of the network and improving the lifetime of the network on properly managing the numerous parameter of the network by extracting the node energy, node coverage, data collection location and positions of the mobile sinks, data aggregation constraints of the protocols and data redundancy elimination constraints. Those management increase the transmission rate on generating the trace file to the particular routing principle. Particular configuration of the sensor network achieves high scalability, prolonged lifetime of the network and reduced data collection latency. Further this protocol has been organized initially using energy based clustering technique to represent the sensor node into cluster by establishing the Clusterhead to facilitate the effective data communication. Clusterhead carry out the planning of the data transmission of the collected data from the sensor through mobile sink trajectories to achieve the effective data collection and data transmission. Mobile sink Trajectories can be established using particle swarm optimization as it capable in reducing the energy depletion of the sensor nodes towards data collection and propagation distance on the sink nodes for data transmission. Extensive simulation analysis of the proposed model is carried out using NS2 simulator in order to evaluate the effectiveness. Furthermore, performance results of the proposed model has been illustrated that it achieves large energy consumption per nodes on various traffic of the network using cluster head for data collection through multi-hop relay mechanism on comparing with conventional existing approaches.

Keywords: Heterogeneous Wireless Senor Network, Energy Efficiency, Multiple Mobile Sink, Network Lifetime Maximization, Data Collection, Sink Trajectories

1. Introduction

Wireless Sensor Network is highly projected for next generation technologies on usage of the future internet technologies as it is envisioned as internet of things architecture on incorporation of the heterogeneous devices to achieve major objective with high feasibility [1]. Heterogeneity of the sensor node has been illustrated with respect to energy, traffic and its link connectivity with mobile sink. Basically wireless network has been composed of the large number of small nodes called sensor nodes which collaboratively employed for task of sensing, processing and communicating of the sensed information to base station[2][3].

Typically usage of sensor nodes is growing and configuration of sensor nodes is getting complex due to recent advances in the MicroElectroMechnaical technologies and it makes the implementation of the model more sophisticated for several application based on sensor network[4]. Generally sensor is densely deployed in random manner in the sensing field with nodes unattended, it makes the challenging to recharge the energy or replace the batteries to sensor nodes. It is deployed on autonomous form due to this sensor node near the sink depletes more energy in smaller time than other node due to relaying traffic to the particular node. Balancing the energy, connectivity and coverage of the sensor is not being guaranteed [5].

In order to manage those traffic heterogeneity, various constraints to sensor nodes has been imposed as it considered as important design goals for the energy-efficient data collection. Those design goals achieves the uniform energy distributions, reduced latency and longer network lifetime across the sensing field [6]. Many traditional approaches have been used to address the above mentioned challenges, but some technique is still inefficient in on various perspectives such as data aggregation and sensed data forwarding. Thus, employing the mobile sink may alleviate those energy and latency related issues

In this article, a new source traffic defined multiple mobile sink scheduling protocol has been designed to enhance the energy efficiency and to increase the lifetime of the network. Initially sensors node are self organized as clusters and cluster head is identified based on computation of energy density of among each sensor node in the particular cluster. Generated Clusterhead will take the responsibility of the data forwarding to the mobile sink.

Numerous parameter of the network is managed by extracting the node energy, node coverage, data collection location and positions of the mobile sinks, data aggregation constraints of the protocols and data redundancy elimination constraints. Multiple Mobile sink Trajectories can be established on basis of the data traffic from the data collection points using particle swarm optimization as it capable in reducing the energy depletion of the sensor nodes towards data collection and propagation distance on the sink nodes for data transmission.

, The remaining of this article has been organized into subsequent section is as follows: Section 2, represents the relate works of the conventional energy efficient routing approaches on the energy mobile sink and throughput enhancement has been analysed in addition to multiple strategies to mobile sink scheduling architecture. Detailed design specification of proposed model for energy efficient data transmission in wireless sensor network is specified in Section 3. The simulation outcomes and performance evaluation of proposed architecture employing different performances metric against conventional approaches are illustrated in Section 4. The article has been summarised with brief findings in Section 5 with highlighting the major objectives and research suggestions for future directions.

2. Related work

In this section, various Energy efficient routing approach for wireless senor network has been analysed in details on various aspects such as deployment of sensor node and multiple mobile sink, clustering technique used for sensor nodes and data processing employed for optimal path estimation to the trace information data collected from of the mobile sink. Detailed performance analysis of the mentioned energy efficient techniques which related to proposed model is described as follows

2.1. Ring Routing Protocol– Energy Efficient Multiple Mobile sink Scheduling Architecture

In this architecture, ring routing protocol has been analysed in depth as it is employed to wireless senor nodes along the multiple mobile sink for data transmission to base station on establishing the ring structure by refreshing the sink position in regular manner. It utilizes the greedy routing technique and asynchronous MAC protocols for low power sensor nodes due to its performance on scalability and energy efficiency. Further it obtains the information of the sensor node and cluster the node based on energy and distance towards effective data collection and data transmission to base station via mobile sink [7]. Finally it exhibits the superior performance on the heterogeneous wireless sensor nodes with high throughput in data transmission.

2.2. Energy efficient adaptive routing protocol for heterogeneous wireless sensor network

In this architecture, adaptive routing architecture has been analysed to the wireless sensor network along multiple mobile sink for data collection to achieve high reliable and scalability towards data transmission in addition to increasing energy consumption and reducing the routing latency. Due to propagation of the sink in the network for data collection, it trajectories is considered as random. Hence it becomes traversing of the sink becomes unpredictable for data collection and it leads to high energy depletion on the sensor nodes [8]. Further, minimum energy consumption of sensor node and sink nodes is achieved with erasure coding approaches with automated repeat request to sin node by sensor nodes as it is efficient in managing the data loses and redundancy based on the feedback by mobile sink.

3. Proposed Architecture

In this section, topology design of the wireless sensor network along its incorporation of multiple mobile sink towards energy efficient data transmission with projection of efficient data collection points has been established as energy efficient network infrastructure. Further, sensor node traffic defined mobile sink trajectory strategies has been employed to design the architecture has been illustrated with routing optimization technique termed as Particle swarm optimization. It provides the sink trajectory for data collection. Details of architecture is as follows

3.1. Energy Efficient Heterogeneous Wireless Sensor Network Model

In this model, wireless Sensor Nodes and Multiple Mobile Sinks employed for sensed data transmission to base station has been represented with its design specification as follows

- **Deployment of wireless Sensor Node**

In this section, Heterogeneous wireless Sensor Networks composed of n static small sensors is illustrated as N = {n1 , n2 , … , nn}. Various sensors node has been integrated various sensing elements for sensing of the environment. Those sensors are randomly distributed over a represented region R. The area of sensing and its communication radius of the each sensor node is highlighted as r and $2r$, respectively.

- **Deployment of Multiple Mobile Sink**

Multiple Mobile Sink which composed of set of data collecting sink is intended to visit each sensors and collected sensed data of the sensor is illustrated as S = {s1, s2, …, sn}. The mobile sink is considered as battery powered intended to visit each sensor in circle manner. A trajectory of the sink starts and ends near base station. Let b_0 represents the base station.

Network is represented in Tree topology as mobile sink collects the sensed data of the sensor node on the specified collection point is termed as root and child.

- **Sensed data collection Point**

Sensed data collection point is represented position of the mobile sink. It is represented as $C = \{c1, c2, \cdots, cm\}$ as it represents the list of collection point on trajectory mobile sink to collect the sensed data or information from the sensor node. Let $p = (p0 , p1 , \ldots , pm, p0)$ represents the trajectory path of sink with condition that $ci \in P$ and path of data collection terminates in the base station $p0$. The c collection points will be manage the data collection from sensor nodes and transmits those collected data to the mobile sink during the mobile sink traversing. Hop by Hop communication paradigm is set to the data transmission from sensor node to collection point.

3.2. Wireless Sensor Network-Clustering

In this part, Sensor node Clustering has been achieved on basis of the energy density. Sensors are grouped into clusters with respect to its residual energy and transmission link quality between the sensor nodes through K Means clustering technique [9]. Each sensor node is represented in a distributed manner as cluster head or a cluster member with respect to its residual energy. Further, sensors with large residual energy will be generated as cluster heads and other sensor is considered as cluster members. On processing, it generates C cluster heads, where C is considered as system parameter. Cluster obtained employing k means approach is illustrated as follows

$$d_v = S \sum_{i\varepsilon N(v)}^{n} \{\mathrm{dist}(Ni, Ni - 1|))\}$$

Where d_v is the sum of distance among the neighbour nodes in the particular region

Multiple cluster heads can be generated for large cluster member group and representing it as cluster head group. Further each cluster member for cluster head is illustrated as a peer of neighbour peer. Cluster representation employing k means approach utilizing sensor node has been illustrated in the figure 1

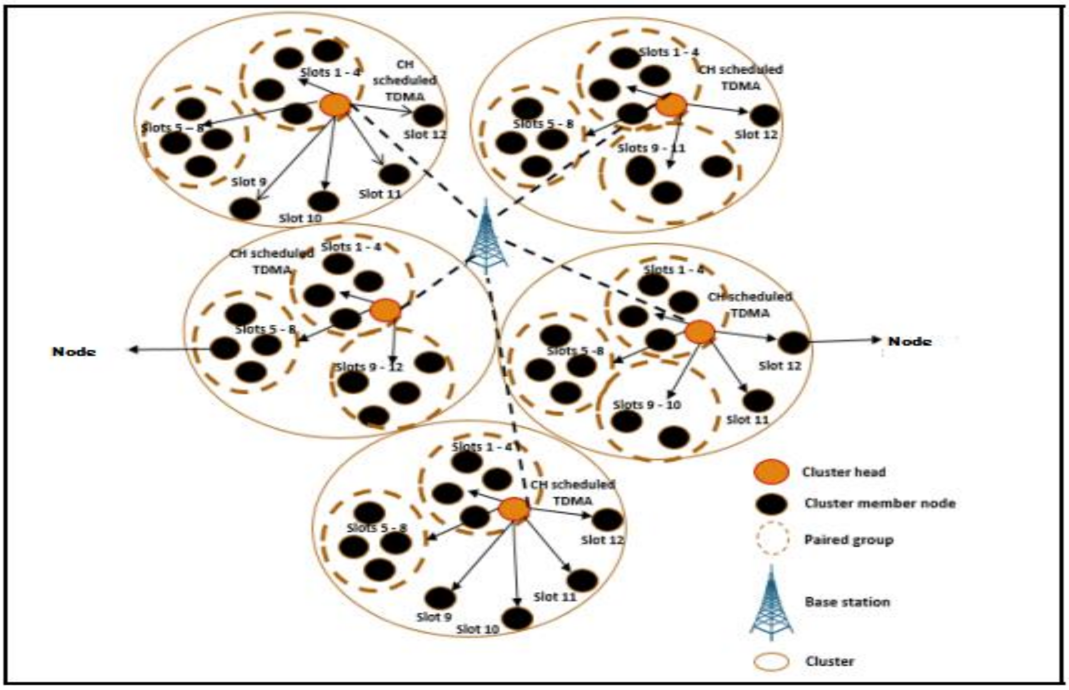


Figure 1: Cluster Representation of Heterogeneous Wireless Sensor Network

The current algorithm generates clusters composing sensor in manner of hop by hop with single cluster head. The significance of designing the cluster and cluster head is to aggregate the sensed data in single hop communication. The residual energy of the cluster is calculated through following expression

$$E_r = (\frac{1}{Ki+1} \sum_{j=1}^{Ki} E_{is}$$

Where E_r denotes the average residual energy of sensor nodes among the node i's transmission range . E_i considered as residual energy of node i respectively, K_i represents the number of neighbor nodes to the particular cluster. Cluster head is selected on condition,

If (E_i>E_{i+1}) in particular cluster

Consider N_i as cluster head to C_i cluster

Cluster is updated periodically with change of the residual energy of the cluster heads among cluster members to avoid depletion of energy in the cluster heads [10]. Moreover, cluster heads can also change their output energy for a specified transmission range to maintain a certain degree of connectivity among clusters.

3.3. Sensed Data Aggregation

Cluster Head each cluster is applied with time-division-multiple-access (TDMA) technique to correlate the data communications among the sensor nodes and to eliminate the data collision during cluster head data aggregation. Especially Distributed Randomized TDMA Scheduling [11] is considered as efficient and employed to collect the sensed data from the each cluster members. Further local synchronization of the nodes is enabled with TDMA scheduling towards reliable and effective data collection. Figure 2 illustrates the Distributed Randomized TDMA scheduling architecture towards data gathering.

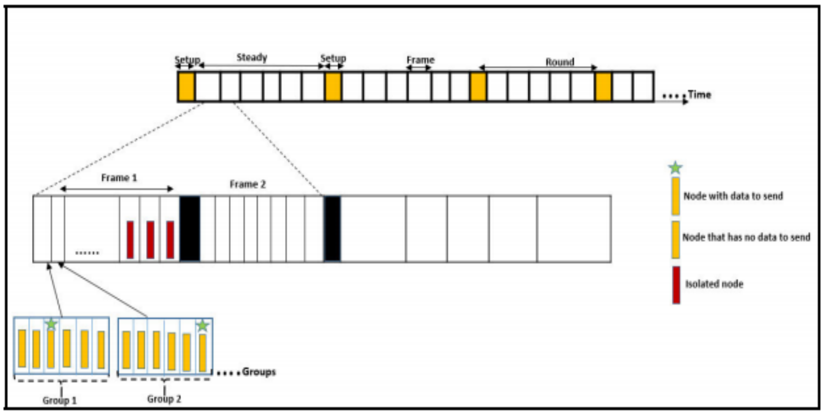


Figure 2: Data Aggregation architecture using Distributed Randomized TDMA Scheduling

In the cluster heads, each cluster member will synchronize the clock using via beacon messages during the data uploading with buffered data to various data collection point of the multiple mobile sink [12]. Each cluster member in cluster head generation will dynamically configures with clocks with other member to achieve the highest residual energy. Cluster member scheduled by cluster head to the data transmission on the available trajectory strategies of sink. Further it is used to schedule the aggregated sensed data to mobile sink on the trajectory to forward data to base station. Algorithm1 representing the procedure of Strategic Trajectory scheduling for multiple mobile sink.

Algorithm 1: Strategic Trajectory Scheduling

Assign

N as Sensor Nodes

S as sink nodes

C as clusters

Compute Node Residual energy with nodes with specified distance

Establish cluster C =(n1,n2...nn)

Compute Cluster head on cluster members with highest residual energy

If (ne_i> ne_{i-1})

Assign n1 in the cluster as cluster head

Apply TMDA scheduling for data aggregation

for i = 1 to n && J=1 to k

Synchronize the Nodes and aggregate the data of each cluster member

Compute Mobile sink Trajectory ()

Path = {p1,p2,p3....}

Path P1={m1,m2,m3..mn}

If (Cluster 1 has largest data aggregation)

Traverse Node to particular path

Else

Select the optimal path using PSO

3.4. Distributed optimal Trajectory of Mobile Sink

It is to compute the Optimal trajectory of the sink node with data collection point to acquire data from cluster head is carried out using dynamic strategies of the sink propagation and it is carried to establish high energy consumption and reduces the data collection latency as it is considered as potential for data transmission and reception services. In order to collect the data from the sensor node, multiple mobile sink will be employed dynamic fast constraints. In this strategies, mobile sink should scheduled at appropriate location on the various cluster to achieve maximum capacity of the mobile sink [13].

In optimization of the trajectory of sink, it is mandatory to select the optimal location of the data collections points to particular sink. However, it is infeasible to compute the channel conditions as it is very complex in practice Thus, optimal set of locations has been computed using Metaheuristics approaches on analysis of the trace files. Further it is possible to reduce the impact of the dynamic channel conditions, mobile sink quantify channel state information prior to data collection trajectory to compute candidate data collection locations.

3.4.1. Trajectory Path Optimization -Particle Swarm optimization

In this model, reliable data collection point has been computed on the available path traversing of the mobile sink using PSO technique effectively. In this, mobile sink propagating around the available paths is considered as search space in the PSO containing the trajectories and fitness function is employed to determine the optimal path for sink traversing [14]. In this mobile sink is termed as particle on the search space containing the positions of the Clusterhead and cluster members of various sensor nodes. Velocity of sink is considered in the particular model as it support in computing g best and p best for the mobile sink traversing using fitness function. Algorithm 2 describes the optimal trajectory path using PSO model on the specified path

Algorithm 2: Optimal Trajectory of sink for data collection using Particle Swarm Optimization

S : Search space containing trajectory of the mobile sinks

p_i : Position of sink for data collection in the search space

f : Fitness function

v_i : Velocity of mobile sink towards data collection

$V(a_i)$: Velocity of Neighborhood mobile sink

- c_1: weight of local information
- c_2: weight of global information
- pBest: local position of the sink position for data collection
- gBest: global position of the sink position for data collection

```
P = Position of the data collection();
For i=1 to M
  Assign each psoition to  p in P do
    Fitness of the data colkection point = f(p);
    If fp > f(pBest)
        Assign pBest = fp;
    Else
  Assign  gBest =Fp;
```

Mobile sink propagates through collection points with respect to computed pbest and gbest values. Instead, it computes different accessible collection points for various sink. In addition, fitness function computes the propagation sequence for various mobile sink toward data collection with minimized data collection latency. Implementation of PSO approach, mobile sink projected with path for locations of collection points and provides the shortest route to collect the sensor information to base station.

3.4.2. Optimizing Energy Consumption

Energy consumption is the considered as computation factor in computing the network lifetime of the model. In this section, optimizing the energy consumption each mobile sink towards and sensor node for data communication has been achieved using various node scheduling constraints [15]. In a multi-hop wireless communication system, the less difference in transmission distance among the propagating hop provide the best the energy efficiency. Figure 3 represents the calculation of the trajectory for the mobile sink for data collection by PSO optimization technique yield better energy efficient data transmission.

The effective distance for data collection is considered as the transmission distance between each sensor node or mobile sink. Let us assume that a data link among sensor node and the cluster head is separated by distance D is partitioned by x hops by $(x - 1)$ data collection points. Provided the distance D of the sink from cluster head and the number of hops x to the sensor nodes to sink, the total energy utilized for data collection on the specified path can be computed and it provides the less energy consumption to the transmission distance $d = D/x$. In order to compute the optimal data collection point, effective distance d by providing the total energy consumption E_{total} of the path is computed as follow

$$TE_{total} = xME_T(k) + (x-1)RE_R(k)$$

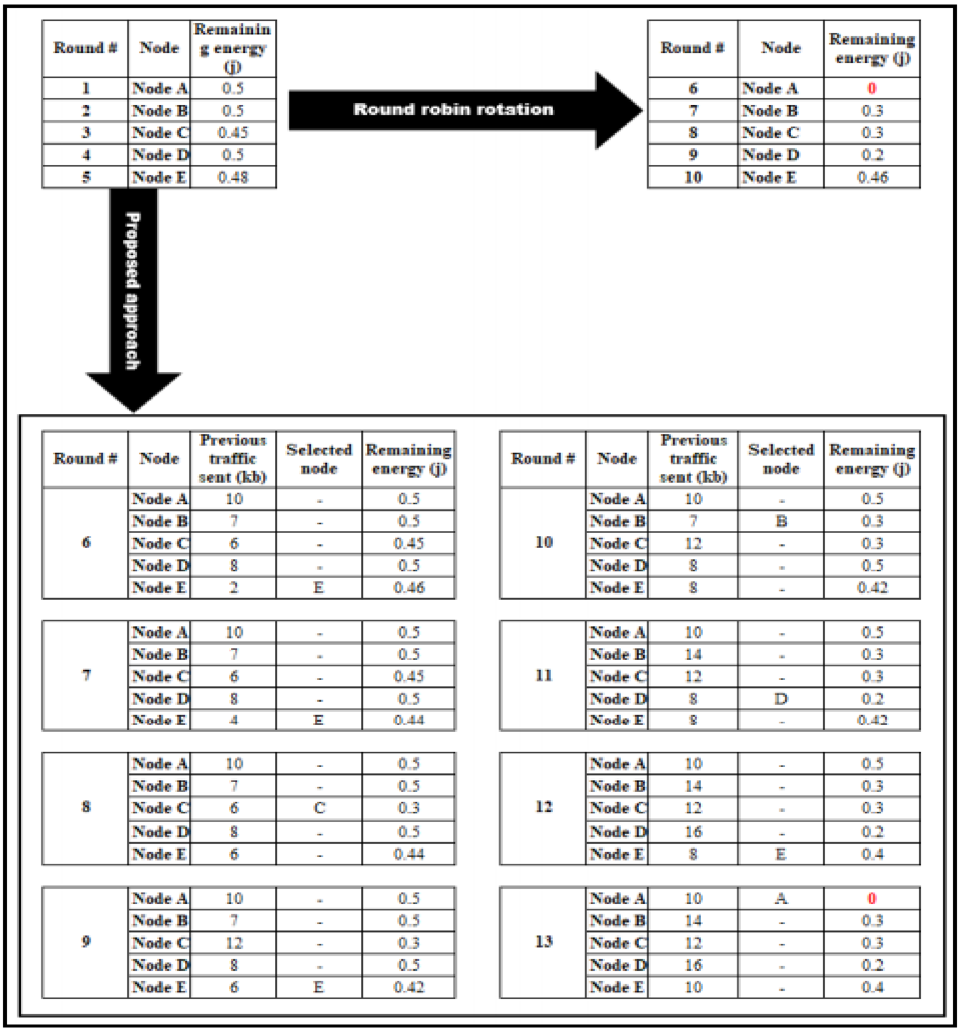
$$= x(kE_{elec} + k\varepsilon_{ampd}\,\gamma) + (x-1)k(E_{elec} + E_{DA})$$

$$= (2x-1)\,kE_{elec} + x(k\varepsilon_{ampd}\,\gamma + kE_{DA}) - kE_{DA}$$

Consequently, sink node with higher traffic rate (packet size) will have higher average traffic rate (TR) for the particular path for each transmission or trajectory. The average traffic rate (TR) of sink node i at the particular round is given as

$$ET_R(i) = EMbx(i)/R$$

Where number of messages transmitted by node with energy iss Mbx(i) & particular round is represented by R



Round #	Node	Remaining energy (j)
1	Node A	0.5
2	Node B	0.5
3	Node C	0.45
4	Node D	0.5
5	Node E	0.48

Round #	Node	Remaining energy (j)
6	Node A	0
7	Node B	0.3
8	Node C	0.3
9	Node D	0.2
10	Node E	0.46

Round #	Node	Previous traffic sent (kb)	Selected node	Remaining energy (j)
6	Node A	10	-	0.5
	Node B	7	-	0.5
	Node C	6	-	0.45
	Node D	8	-	0.5
	Node E	2	E	0.46
7	Node A	10	-	0.5
	Node B	7	-	0.5
	Node C	6	-	0.45
	Node D	8	-	0.5
	Node E	4	E	0.44
8	Node A	10	-	0.5
	Node B	7	-	0.5
	Node C	6	C	0.3
	Node D	8	-	0.5
	Node E	6	-	0.44
9	Node A	10	-	0.5
	Node B	7	-	0.5
	Node C	12	-	0.3
	Node D	8	-	0.5
	Node E	6	E	0.42

Round #	Node	Previous traffic sent (kb)	Selected node	Remaining energy (j)
10	Node A	10	-	0.5
	Node B	7	B	0.3
	Node C	12	-	0.3
	Node D	8	-	0.5
	Node E	8	-	0.42
11	Node A	10	-	0.5
	Node B	14	-	0.3
	Node C	12	-	0.3
	Node D	8	D	0.2
	Node E	8	-	0.42
12	Node A	10	-	0.5
	Node B	14	-	0.3
	Node C	12	-	0.3
	Node D	16	-	0.2
	Node E	8	E	0.4
13	Node A	10	A	0
	Node B	14	-	0.3
	Node C	12	-	0.3
	Node D	16	-	0.2
	Node E	10	-	0.4

Figure 3: Trajectory of the Mobile Sink for Energy Efficient Transmission

Each node determines the average traffic rate with respect to previously transmitted sensed data on various traffic rate with the average traffic rate and node evaluates its energy status according to the threshold value (the minimum energy node is required to survive in the network). The threshold value is calculated according to the computed energy consumption in the entire network per iteration [16]. To determine the energy consumption in each iteration (E_{round}), the sensor nodes are uniformly distributed is assumed as in K × K as

$$TE_{round} = \text{Sensed data size} \ast 4(N_{tslot}E_{elec} + TN_{tslot}E_{DA} + Tk\varepsilon_{mp}d^4_{t\_BS} + TN_{tslot}\varepsilon fsd^2_{t\_CH})$$

4. Simulation Results

In this Section, proposed model titled as strategies based trajectory defined multiple mobile sink routing architecture towards energy consumption in the heterogeneous Wireless Sensor Network has been simulated using NS2 Simulator [19]. Extensive simulation is exploited using different performances on its comparison with traditional techniques. The performance of the proposed model has been evaluated against the various properties of the network with respect to data Throughput, Packet delivery ratio, Network Overhead and latency. The proposed protocol outperforms the traditional routing architecture such as Ring Routing protocol through incorporation of Traffic handling and Redundancy elimination Constraints to the mobile sink. In the network Simulation, network set up with it parameter is represented in the following table 1

Table 1: Simulation Parameters

Simulation Parameter	Value
Network Simulator	NS2
Network Topology Size	500m *500m
Node Energy	0.75joules
Total Node deployed	100
Network Bandwidth	3Mbps
Data Traffic to Sink	Constant Bit Rate
Sensed data size	1028 bytes
Simulation Time	45 minutes

Transmission time of mobile sink's trajectory on the specified data collection path on the sensor field has been partitioned into several respective time slots on synchronization with the cluster head. No of hop for data collection m = 1 is represented and it employs the K nearest neighbor technique to determine the effective path and effective node for clustering of the sensor nodes in the particular location [20]. Node energy consumption of the sink node at various location is computed as various transmission rates for sink selection, transmission, acquiring, idle state and sleep state has been computed for evaluation of the proposed approach.

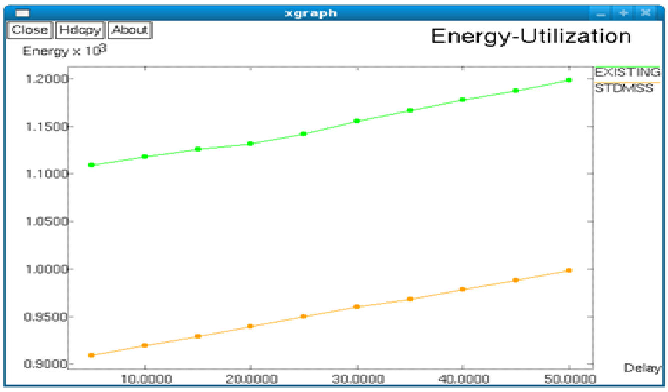


Figure 2: Performance Analysis of Sink scheduling techniques with respect to Energy Utilization

The sensor nodes produces the various types of traffic which is based on its sensing field and sensor and sink configuration to the sensed data considered as packet size. The evaluation of the proposed multiple mobile sink scheduling architecture for data collection and transmission to base station on sink bandwidth on the varied data traffic by cluster head is illustrated and its comparison in with respect to data throughput is described in the figure 2.

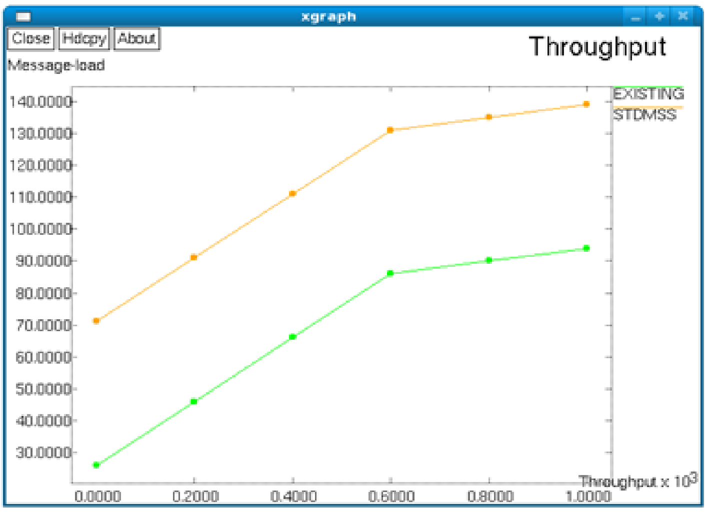


Figure 3: Performance Analysis of Mobile Sink Scheduling techniques with respect to Throughput

The outcome represents that proposed model can determine predict optimal data collection point in short span to reduce the data latency and it increase the energy consumption and throughput ,. Therefore, the sensing node with aggregated data on the Clusterhead transmits the data through mobile sink on computed trajectory. Routing overhead refers to the total number of data transmitted by sink to the base station in a specified period. The routing overhead is given in the figure 4.

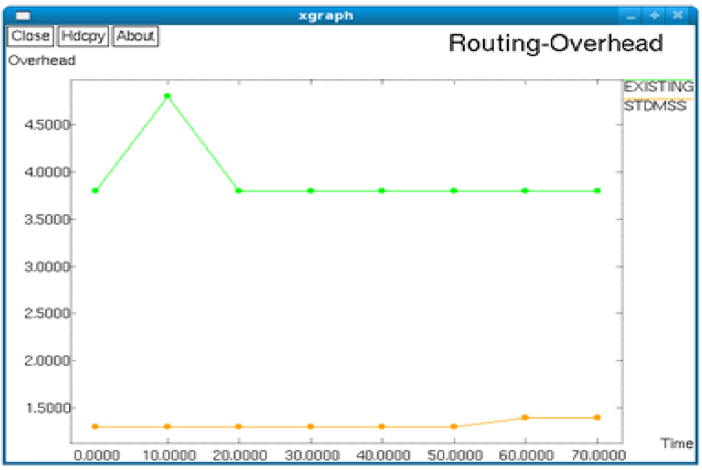


Figure 4 : Performance Analysis of mobile sink Scheduling architecture with respect to Routing overhead

Due to dense deployment of the sensor node and its data collected by sink nodes will lead to the high transmission ratio of with high variation in the number of sensor nodes differentiated with sparse deployment. The time delay is computed from the data sensing to transmission of the data to the delivery in the base station. Further data latency is similar to the time consumed to the data collection trajectory. Table 2 provides the performance of the mobile sink scheduling architectures on evaluating the mobile sink data collection.

Table 2 – Performance Evaluation of the Multiple Mobile Sink Scheduling against Various data traffic of the network

Technique	Network Throughput in mbps	Network Overhead in mbps	Packet Delivery Ratio in percentage	Energy Utilization in joule	Routing Latency in mbps
Ring Routing-Existing	85.58	25.23	98.78	38	0.39
STDMSS-Proposed	62.26	14.59	99.89	50	0.21

Packet delivery ratio is referred as no of aggregated data from Clusterhead is transformed to base station through optimal path of the mobile sink. The proposed model compute the residual energy each sink node to evaluate the optimal distance for sink trajectory to achieve optimal data transmission to sink on ensuring the data reliability and flexibility.

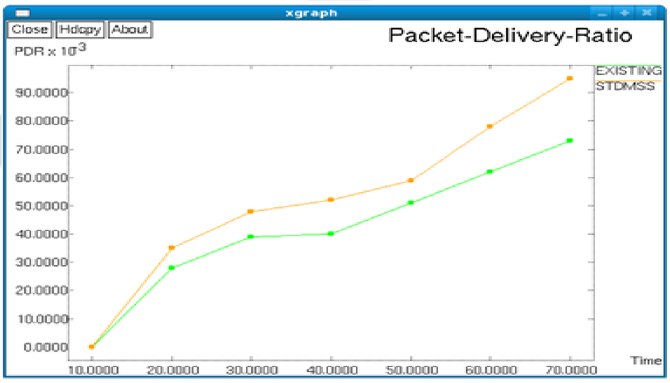


Figure 5: Performance Analysis of multiple mobile sink scheduling architecture with respect to Packet Delivery Ratio

The Figure 5 illustrates the the performance of the packet delivery ratio on mobile sink scheduling and routing Latency is highly changed due to data traffic of the sink in the network, hence it is managed by incorporation of the effective constraints of the mobile sink towards data collection of cluster head. In parallel, data routing approach is represented to manage extra complication of the node. The figure 6 illustrated the evaluation of the routing latency against traditional approaches on various data sizes.

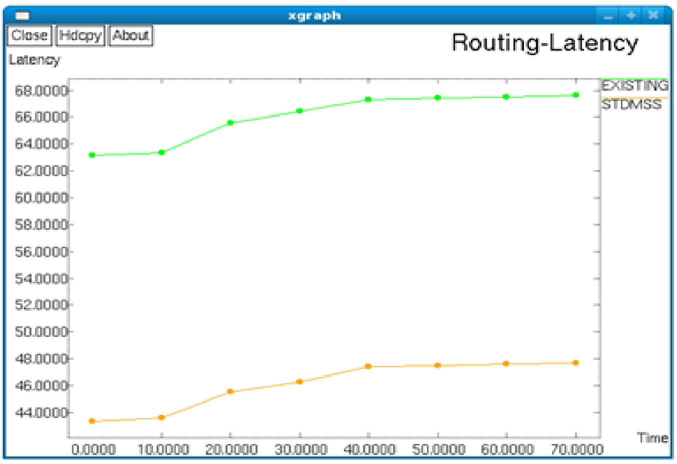


Figure 6: Performance Analysis of mobile sink scheduling with respect to Routing latency.

On Simulation analysis it has been proven that energy consumption and network throughput has been maximized through incorporation of constraint to achieve of the optimal path for trajectory of multiple mobile sink. Proposed mode has enhanced as compared with respect to traditional routing protocol and also performance evaluation represents the high scalability and data reliability. The network size in terms of the number of deployed sensor nodes also changes performance of the WSN significantly against the network density and the data traffic to the sink.

Conclusion

The proposed model has been designed and implemented as enhanced throughput and energy efficient architecture entitled as strategy Defined Multiple Mobile Sink scheduling approach on incorporation of various constraints for clustering and data aggregation on basis of network factors. Clustering is carried out using K means approach and Clusterhead is determined using the residual energy and link quality of the cluster members. The optimal path for multiple mobile sink trajectories for data collection has been calculated using particle swarm optimization. The optimal solution reduces the routing overhead obtained in dense deployment scenarios on producing the constraints for energy consumption. Finally performance of the proposed model has been evaluated on basis of varying network size, energy and link factors. The Simulation results prove that proposed architecture outperforms conventional technique in terms of throughput, energy utilization and network latency.

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