Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, July, 2021: 4979 – 4993

Research Article

Source Traffic Defined Multiple Mobile Sink Routing Protocol for Energy Efficiency & Lifetime Maximization in Wireless Sensor Network

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Abstract

Heterogeneity of the sensor nodes with limited energy sources will lead to uneven energy consumption and traffic imbalanced across the densely deployed network. On employment of the energy efficient algorithm could try to achieve energy efficiency among the heterogeneous sensor nodes to prolong the network lifetime using mobile sink. However despite of many advantageous of routing algorithm, it introduces hotspot problem on deployment of the multiple mobile sink for data gathering by set of data collection points as it frequently updates sink location information to all the sensor nodes in multi hop manner. In order to mitigate the hotspot problem, a new source traffic defined multiple mobile sink routing protocol has been employed to mitigate the hotspot issue towards improving the energy efficiency and network lifetime on extraction of multiple parameter including energy, coverage, data collection points, data fusion degree, schedule patterns, data redundancy transmission success ratio in the trace file of the particular topology. Particular network topology achieves good scalability, long network lifetime and low data collection latency. In addition, Source traffic defined Clustering techniques projected in this work will self organize the sensor nodes into effective clusters on generation of multiple cluster head to facilitate the data transmission. Cluster head along with information of data collection points plans the trajectory of the multiple mobile sinks for effective data collection from the sensor nodes. Trajectory of the multiple mobile sinks can be enabled using particle swarm optimization to reduce the energy depletion and moving distance of the sink nodes for data collection. Extensive simulations are conducted using NS2 simulator to evaluate the effectiveness of the proposed scheme. The performance results show that proposed model achieves more energy saving per node and energy saving on cluster heads on large traffic while comparing with data collection through multi-hop relay to the single mobile data sinks using existing state of art approaches.

Keywords: Wireless Senor Network, Energy Consumption, Multiple Mobile Sink, Lifetime Maximization

1. Introduction

Wireless Sensor Networks (WSNs) are the key enablers for the future Internet that is often envisioned as Internet of Things on interoperability among heterogeneous devices to

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achieve common objectives has become feasible[1]. Node heterogeneity in WSNs can be expressed in terms of energy (energy level), computation (traffic), link connectivity, and other heterogeneities such as mobility scenarios. Wireless Sensor Network (WSN) is a network comprising of huge number of tiny nodes called sensor nodes. These sensor nodes collaborate together in sensing, processing and communication [2][3]. As the sensors in WSN are getting better and more complex due to the recent advancement in MicroElectroMechnaical systems technology, makes it promising to implement them for sophisticated applications [4].

Sensors are generally densely deployed and randomly scattered over a sensing field and left unattended after being deployed, which makes it difficult to recharge or replace their batteries. After sensors form into autonomous organizations, those sensors near the data sink typically deplete their batteries much faster than others due to more relaying traffic. When sensors around the data sink deplete their energy, network connectivity and coverage may not be guaranteed[5]. To cope with traffic heterogeneity constraints among sensor nodes, it is crucial to design an energy-efficient data collection scheme that consumes energy uniformly across the sensing field to achieve long network lifetime with low data latency[6]. Many states of art approaches has been employed to address the above mentioned constraints, but some inefficiencies have been identified on intra-cluster aggregation and inter-cluster data forwarding. On employment of the mobile sink, it may alleviate non-uniform energy consumption and unsatisfactory data collection latency.

In this paper, a new source traffic defined multiple mobile sink routing protocol has been proposed to improve the energy efficiency and network lifetime. Initially sensors node are self organized into clusters and cluster head is selected based on energy density to take the responsibility for forwarding data to the data sink. Further multiple parameter including energy, coverage, data collection points, data fusion degree, schedule patterns, data redundancy, transmission success ratio in the trace file of the particular topology has been extracted to establish the data transmission utilizing the mobile sink. Multiple Mobile sink has been employed in this work. Hence the trajectory of the multiple mobile sinks has been computed on basis of the traffic from the data collection points using optimization technique named particle swarm optimization. It is effective in reduce the energy depletion and moving distance of the sink nodes for data collection. Finally data redundancy on data aggregation is eliminated indexing approach.

, The rest of this paper is organized into following section which is as follows: In Section 2, the traditional algorithm on the energy efficient routing and throughput improvement has been analysed along strategies to mobile sink scheduling framework. Detailed specification of proposed framework for energy efficient data transmission in wireless sensor network is given in Section 3. The simulation results and performance evaluation of proposed framework using various performances metric against state of art approaches are presented in Section 4. The article has been concluded in Section 5 with providing final remarks and future research directions.

2. Related work

In this section, Energy efficient routing model for wireless senor network has been examined in details on basis of deployment of mobile sink, clustering of the sensor nodes and optimal path finding of the mobile sink for data collection from sensor node to base station. Each of those energy efficient techniques which follows some kind of better performance effectiveness on the evaluation of the model has been represented in detail and few which performs nearly equivalent to the proposed model is described as follows

2.1. Ring Routing – Energy Efficient Routing Protocol

In this architecture, ring routing has been employed to wireless senor nodes and mobile sinks on utilizing the greedy geographic routing solutions and asynchronous low power MAC protocols as it is scalable and energy efficient. It requires knowledge of the node inside the cluster to carry out the data transmission with mobile sink to ease the data collection efforts and to exhibit superior performance in the heterogeneous nodes[7]. Further it achieves fast data delivery on establishing a virtual ring structure which allows fresh sink position to regular nodes.

2.2.Hybrid Adaptive Routing Protocol for Energy Efficient Routing

In this architecture, adaptive routing protocol has been dealt in sparse wireless sensor network with multiple mobile sink on achieving reliable and energy efficient data transmission. As Mobile sink propagating in the network is random, it becomes unpredictable for data transmission to sink on minimum energy data delivery[8]. In order to achieve the minimum energy data delivery, erasure coding with automatic repeat request has been used to cope with message losses and ability to adapting the level of redundancy based on feedback send by the mobile sink.

3. Proposed Architecture

In this section, network topology of the wireless sensor network and inclusion of multiple mobile sink for data transmission through data collection points has been constructed as effective infrastructure. In addition, source traffic defined strategies employed to model the framework has been discussed with optimization technique using Particle swarm optimization towards generating trajectory for data collection from sensor by mobile sinks has been represented with details is as follows

3.1.Network Infrastructure

Sensor Nodes and Mobile Sinks used for data communication to base station on details of the specified infrastructure has been provided as follows

- **Sensor Node Deployment**

In this work, Wireless Heterogeneous Sensor Networks which consist of a set of n static sensors which is represented as $S = \{s1 , s2 , \dots , sn\}$. Different sensors may be embedded with different sensing elements, each of which undertakes different sensing tasks. All sensors are distributed over a given rectangular region R. The sensing and communication radiuses of each sensor are r and $2r$, respectively.

- **Mobile Sink**

Mobile Sink which consist of a set of mobile sinks sink intended to visit sensors and collect data from the sensor which is represented as M = {m1, m2, …, mn}. The mobile sink is battery powered and it is intended to visit each sensor in round passion. A round begins when the mobile sink leaves the base station and ends when the mobile sink returns to the base station. Let $p0$ denote the base station. Tree topology will be formed for data collection from sensor node and transmits to the collection point which acts as root.

- **Collection Point**

Let $P = \{p1, p2, \cdots, pm\}$ denote the selected list of collection point to gather the data or information from the sensor node through mobile sink. Let $\pi = (p0, p1, \ldots, pm, p0)$ denote the constructed path which passes through each $pi \in P$ and returns to the base station $p0$. The m collection points will be responsible for collecting data from other sensor and transmit the collected data to the mobile sink when the mobile sink visits them. The data will be transmitted from sensor node to collection point in hop by hop manner.

3.2. Clustering of the Wireless Sensor Network

In this section, Clustering of sensor nodes has been carried out. Sensors are organized into clusters on basis of residual energy and link quality using K Means clustering[9]. Each sensor decides to be either a cluster head or a cluster member in a distributed manner on basis of residual energy. In this model, sensors with higher residual energy would become cluster heads and each cluster has at most C cluster heads, where C is a system parameter. Cluster generated using k means algorithm is represented as follows

$$D_v = \sum_{v \varepsilon N(v)}^{n} \{\mathrm{dist}(v, V|))\}$$

Where D_v is the sum of distance between all neighbours

The multiple cluster heads within a cluster are called a cluster head group with each cluster head represented as a peer of others. Cluster generation using k means model utilizing sensor node has been described in the figure 1

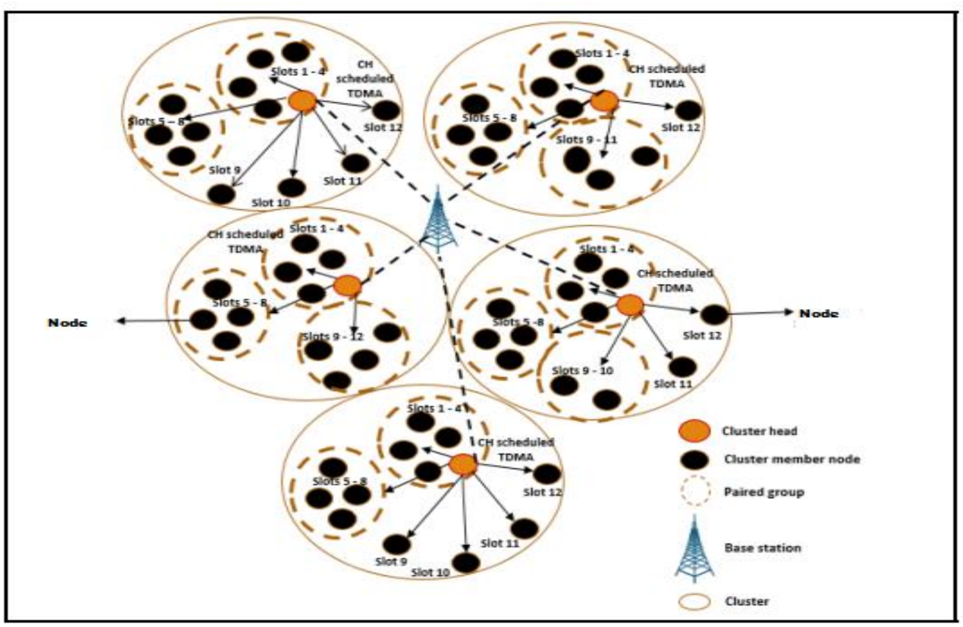


Figure 1: Cluster Structure of Wireless Sensor Network

The particular algorithm constructs clusters composed of sensor with 1 hop away from at one cluster head. The advantage of modelling is that the intracluster aggregation is limited to a single hop. The residual energy of the cluster is computed using

$$E_a = \frac{1}{Ki+1} \sum_{j=1}^{Ki} E_{jr} + E_{ir}$$

Where E_a is the average residual energy of all nodes within node i's transmission range Rc, E_{ir} and E_{jr} are the residual energy of node i and node j respectively, Ki is the number of neighbor nodes of the node i. If $E_{ir} > E_{ia}$, the node is the candidate source routing node. Cluster is periodical updated to rotate cluster heads among sensors with higher residual energy to avoid depletion of energy from cluster heads[10]. Moreover, cluster heads can also adjust their output power for a desirable transmission range to ensure a certain degree of connectivity among clusters.

3.3.Data Aggregation

Cluster Head group adopts time-division-multiple-access (TDMA) based technique to coordinate communications between sensor nodes and to avoid the collision on data aggregation. Especially distributed Randomized TDMA Scheduling[11] is applied to gather the data from the cluster members. Further local synchronization is carried towards effective data collection. Figure 2 represents the distributed Randomized TDMA scheduling towards data gathering.

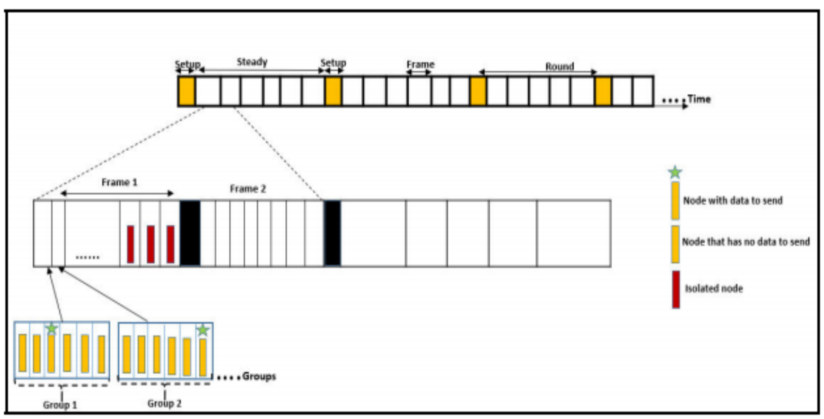


Figure 2: Distributed Randomized TDMA Scheduling

On cluster heads, the nodes synchronize their local clocks via beacon messages upon uploading buffered data to data collection point via mobile sink[12]. The nodes in a CHG could adjust their local clocks based on that of the node with the highest residual energy. Scheduling of the node using DRTDMA is to cluster for data for mobile sink. Algorithm1 describes the working of DRTDMA scheduling.

Algorithm 1: DRTDMA Scheduling

Initialize

// N is number of nodes in the network

// K is number of required clusters

```
Assign n =N/K
Compute ()
   for i 1 to n
{
      for j = 2 to n
         Synchronize the Nodes in the Cluster
If (node (node (i) ID == node (j) ID)
   node i and node j are Synchronized
      count++
Else
   node i and node j are unpaired
          countl++
endif
 endFor
   endFor
total slot= (count + countl) −1
Broadcast TDMA according to the total slot to n−1 nodes
```

3.4.Distributed optimal Movement prediction of Mobile Sink

Optimal Movement strategies of the mobile sink establishes great energy saving and shortened data collection latency, which has the potential for different types of data services. To collect data as fast as possible, multiple mobile sink has been employed with some strategies to gather sensor information. In this mobile sink should stop at positions inside a cluster that can achieve maximum capacity[13].

In optimization models, mobile sink is considered as mobile, it has the freedom to choose any preferred position for data collection. However, this is infeasible in practice, because it is very hard to estimate channel conditions for all possible positions. Thus, we only consider a finite set of locations. To mitigate the impact from dynamic channel conditions, mobile sink measures channel state information before each data collection tour to select candidate locations for data collection. We call these possible locations mobile sink can stop to perform concurrent data collections prediction path using particle swarm optimization

3.4.1.Particle Swarm optimization

In this model, Effective collection point and path for traversing for mobile sink can be computed effectively. In this, mobile sink moving around the available path is considered search space is looking for best solution for path traversing[14]. In this mobile sink is considered as particle in the search space composed of cluster and cluster members of sensor nodes. Particular model compute the g best and p best for the mobile sink traversing on basis of fitness function. In addition, velocity of mobile sink is also computed to determine the solution. Algorithm 1 describes the working of PSO model towards identifying the effective path

Algorithm 1: Optimal Path Prediction using Particle Swarm Optimization

A : Population of mobile sink containing sensor nodes
$\mathbf{p_i}$: Position of mobile sink $\mathbf{a_i}$ in the solution space
f : Objective function
$\mathbf{v_i}$: Velocity of mobile sink $\mathbf{a_i}$

V(a_i) : Neighborhood of mobile sink a_i (fixed)

- p: particle's position
- v: path direction
- c_1: weight of local information
- c_2: weight of global information
- pBest: best position of the particle
- gBest: best position of the swarm

```
P = Particle_Initialization();
For i=1 to it_max
  For each particle p in P do
    fp = f(p);
    If fp is better than f(pBest)
        pBest = p;
    end
  end
  gBest = best p in P;
  For each particle p in P do
     v = v + c1*rand*(pBest – p) + c2*rand*(gBest – p);
     p = p + v;
  end
end
```

Mobile sink that visit all the collection points can be computed on basis of pbest and gbest best values. Instead, it calculates some collection points which are accessible. In addition, fitness function determines the sequence for mobile sink to visit these selected collection points such that data collection latency is minimized. On employment of the algorithm, mobile sink has pre-knowledge about the locations of collection points and it can determine a good trajectory with the shortest route to collect the sensor information.

3.4.2. Optimizing Energy Consumption

Energy consumption is the most important factor in determining the lifetime. In this section, optimizing the energy consumption of sensor node and mobile sink against data communication has been carried out using constraints[15]. In a multi-hop wireless transmission system, the smaller the difference in transmission distance between each hop, the best the energy efficiency of wireless transmission system can be obtained. Figure 3 represents the computation of the mobile sink by PSO optimization technique for energy efficient data transmission.

The effective distance as the transmission distance between each hop, and assume that a data link between the source node and the destination node at distance D is divided into x hops by (x − 1) intervening collection points. Given the distance D and the number of hops x, the total energy usage along the path can achieve the minimum when each hop shares the same transmission distance d = D/x. In order to determine the optimal collection point, we calculate the effective distance d by giving the total energy consumption E_{total} of the path as follow

$$E_{total} = xE_T(k) + (x-1)E_R(k)$$

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

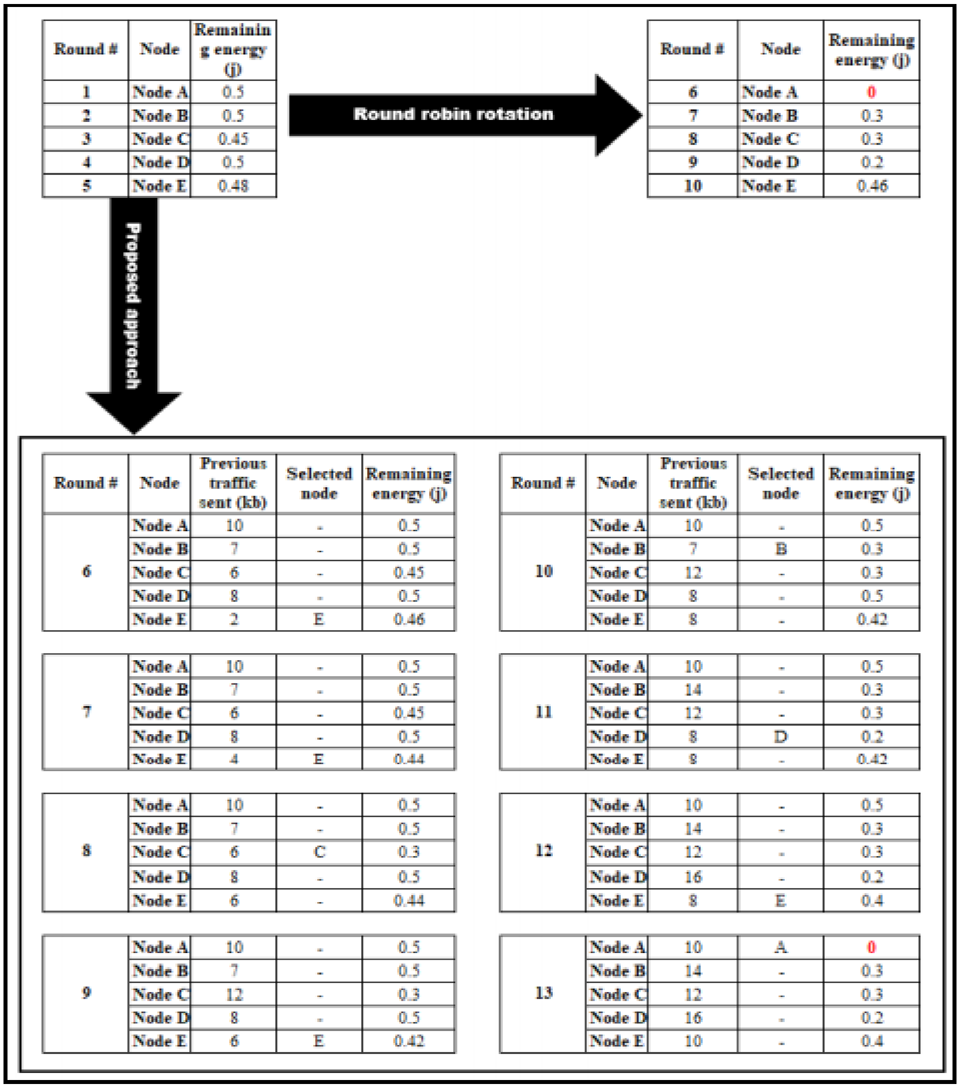
$= (2x - 1)\, kE_{elec} + x(k\varepsilon_{ampd}\, \gamma + kE_{DA}) - kE_{DA}$

Consequently, node with larger traffic rate (packet size) will have larger average traffic rate (TR) with respect to previous rounds. The average traffic rate (TR) of node i at the current round is given b

$T_R(i) = Mbx(i)/R$

Where number of messages transmitted by node i is Mbx(i)

Current 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: Mobile Sink selection for Energy Efficient Transmission

Each node computes its average traffic rate with respect to previously sent messages and compares its traffic rate with the average traffic rate and node checks its energy status according to the threshold value (the minimum energy node is required to survive in the network). The threshold value is computed according to the estimated energy consumption in the whole network per round[16]. To estimate the energy consumption in round (E_{round}), we assume that the sensor nodes are uniformly distributed in K × K as

$$E_{round} = packetsize * (2N_{tslot}E_{elec} + N_{tslot}E_{DA} + k\varepsilon_{mp}d^{4}_{t\_BS} + N_{tslot}\varepsilon fsd^{2}_{t\_CH})$$

3.4.3. Estimating Uniform Data Gathering Delay

The network lifetime highly depends on the sensor node that has the lowest remaining energy. Let ξ_i denote the lifetime of the sensor , and $Ei\ t$ denote the energy consumption of sensor si in the t-th round. Let $E0$ denote the battery capacity of each sensor node. The data reporting delay is another important metric which affects the WSN performance[17]. Reporting delays are largely affected by the overall traffic in the network and the number of hops data packets travel from the source to the sink Uniform delay of the data gathering by mobile sink is given by

$$\sum Ei\ t \leq E0 \leq \sum Ei$$

The data generated by each CP should be sent to the mobile sink on basis data flow constraints is given as

$$n_{CPi}{}^{send} = \sum(n_{i,j}{}^{store} \times \lambda_{i,j})$$

Where $n_{CPi}{}^{sen}$ is the data size sent from CPi to the mobile sink.

Therefore, the node's energy consumption is mostly affected by traffic rate on the distribution of heterogeneous sensor nodes. It is assumed that each sensor node is using free-space energy model to send data to CH as stated earlier.

3.4.4. Redundancy Elimination in Data Aggregation

Redundancy of data collected by the mobile sink has been eliminated before data aggregation using data indexing structure in the base station or analysis of the trace file on collection point[18]. It is computed to eliminate the traffic, overhead and latency. Further elimination of redundancy improves the throughput and energy consumption. Constraints to determine the redundancy in the collection point is given by

$$Rd = Packet\ P.\ Index(i)\ \varepsilon\ tracefile(m_i)$$

In above constraint, packet for the sensor is verified for redundancy estimation in the trace file of the mobile sink. It further eliminated against the transmission in the network to the base station for storage and data uploading time can be greatly reduced. Finally it makes possible for multiple cluster heads in a CHG to transmit distinct data simultaneously.

4. Simulation Results

In this Section, we simulate detail description of proposed source traffic defined multiple mobile sink routing protocol towards Throughput Maximization in the Wireless Sensor Network using NS2 Simulator[19]. Extensive experiment explores various performances on its comparison with existing techniques. The performance of the work has been demonstrated with the properties and measures of the network performance in terms of Throughput, Packet delivery ratio, Network Overhead and Packet Loss. The STDMMS protocol extends the Ring Routing protocol through inclusion of Traffic and Redundancy management Constraints. In the Simulation, the set up of the network along its parameter is described in the following table 1

Table 1: Simulation Parameters used to build a protocol

Simulation Parameter	Value
Simulator	NS2
Topology Size	1000m *1000m
Initial energy Bound	0.5joules
Number of Nodes	200
Bandwidth of the Network	2Mbps
Traffic Type	CBR
Pause Time	10s,20s
Data Packet length	512 bytes
Buffer Size	30 packets
Simulation Time	30 minutes

The duration of mobile sink's moving trajectory on the various path of sensor region has been divided into several consecutive time slots on reference to the cluster head. The data collection hop count m = 3 is defined and use the nearest neighbor algorithm to find the shortest path and clustering the sensor nodes [20]. Node energy consumption at different rates during mobile sink selection, transmission, reception, idle waiting and sleeping has been calculated for evaluation of the proposed model.

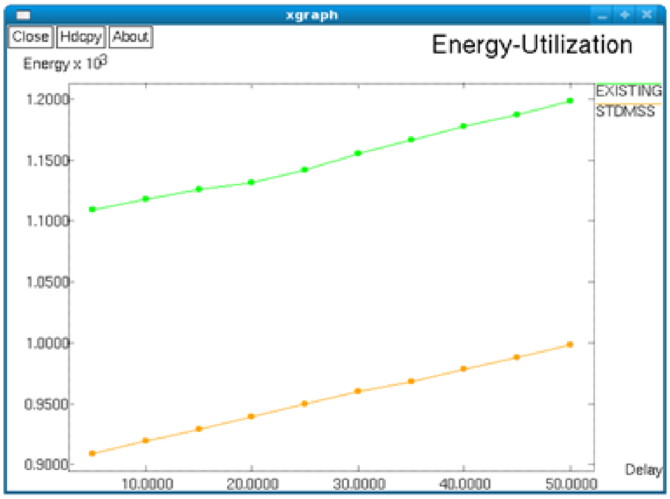


Figure 2: Performance Analysis of Proposed Framework against Existing Technique through Energy Utilization

The sensor nodes generate different types of traffic depending on its sensing capacity and configuration in terms of number of packet size. The evaluation of the proposed multiple mobile sink data gathering and scheduling on bandwidth requirement against the different network traffic on the heterogeneous sensor nodes is demonstrated and its comparison in terms of energy utilization and network utility is described in the figure 2. Energy utilization is important to ensure the operation of the network in the sense that no sensor would have drained its battery energy during data transmission. There is excessive energy consumption of 0.03mJ per data in transmission.

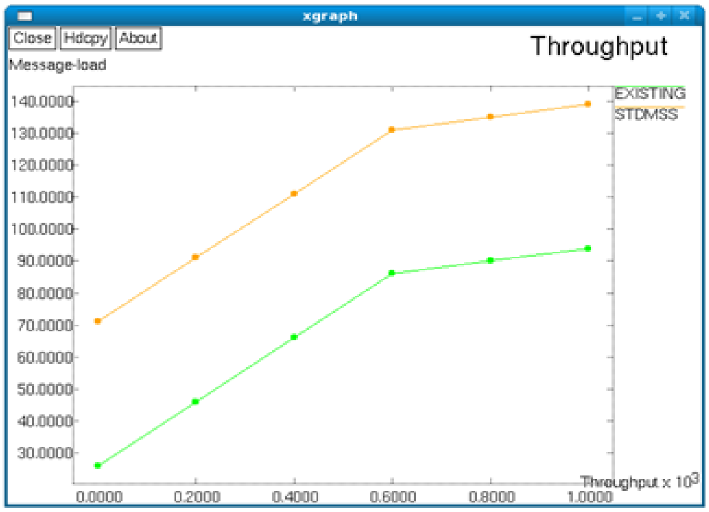


Figure 3: Performance Analysis of Proposed Framework against Existing Technique through Throughput

The observations indicate that the proposed protocol can find predict optimal states in short span of time in case of sudden node failure, they aspect increase the throughput of the system. Therefore, the number of participating node for data sensing and transmission in a cluster towards throughput is calculated. Throughput refers to the total number successful bits transmitted to the destination in a period of time. The throughput defines the effectiveness of the network capacity. The network throughput can be computed as follows

Throughput = NR/ NS

Where NR is the total packet received by the destination and NS is the total number of packets transmitted by the source.

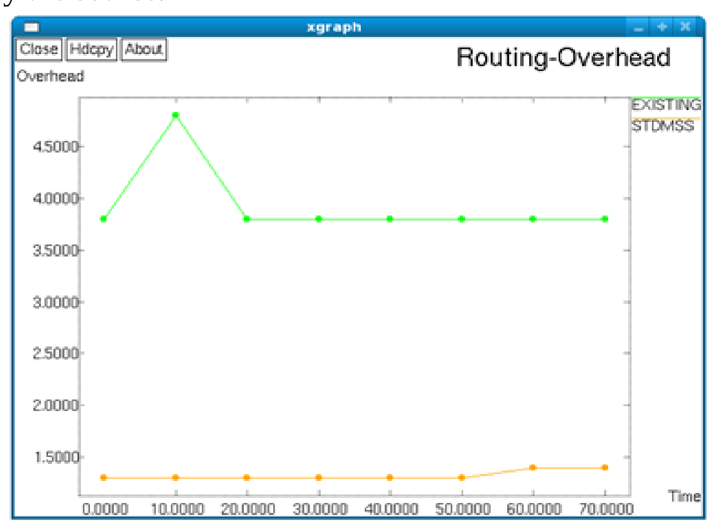


Figure 4 : Performance Analysis of Proposed Framework against Existing Technique through Routing overhead

The evaluation of the throughput is described in the figure 3.The unit of network throughput, the total collected data by the sink, is also mbps. The routing overhead is the ratio of the No of time for Sensor Data to be delivered to the destination. The total energy consumed by all sensor nodes which have participated in data delivery. The average energy consumption for each sensor and the maximum energy consumption in the network have been compared. The routing overhead is given in the figure 4

Routing overhead $R_d = 100\% * \frac{nd - ne}{nd}$

The reason is that in dense deployment, the ratio of loosing contribution in data transmission to sink remains same with larger difference in the number of nodes compared to sparse deployment. The time delay from the generation of the packet to its delivery to the destination has been computed. Further data latency is equivalent to the time duration of a data collection tour which comprises of the moving time and data transmission time. Table 2 concludes the performance values of the different metrics on evaluating the mobile sink data collection.

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

Technique	Throughput in mbps	Overhead in mbps	Packet Delivery Ratio	Energy Utilization	Routing Latency
Ring Routing-Existing	65.58	15.23	97.78	36joules	0.35
STDMSS-Proposed	69.26	12.59	99.85	48joules	0.26

Packet delivery ratio is defined as the ratio of the number of Sensor information successfully received by the destinations of the mobile sink to the destination to the number of data packets generated by the source node in the network. The proposed model considers the residual energy of the node and the optimal effective distance to achieve optimal transmission, which ensures the reliability of the next hop node in terms of residual energy. This is because all of them can find more efficient paths for data delivery, and the probability of packet loss due to node death will decrease.

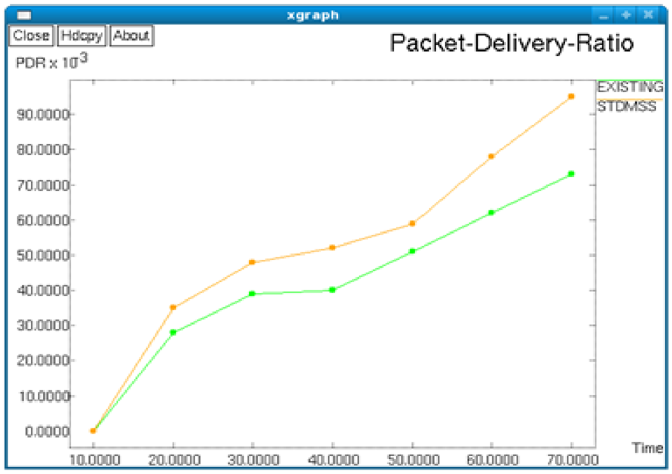


Figure 5: Performance Analysis of Proposed Framework against Existing Technique through Packet Delivery Ratio

The Figure 5 demonstrates the performance of the packet delivery ratio on mobile sink scheduling. The Routing Latency are largely affected by the overall traffic in the network, hence it is controlled by inclusion of the effective constrainst in the mobile sink data collection on the senor node. In parallel, data routing mechanism is defined strong to handle additional complication of the node. The figure 6 describes the evaluation of the routing latency against various techniques towards large sizes of data transfers.

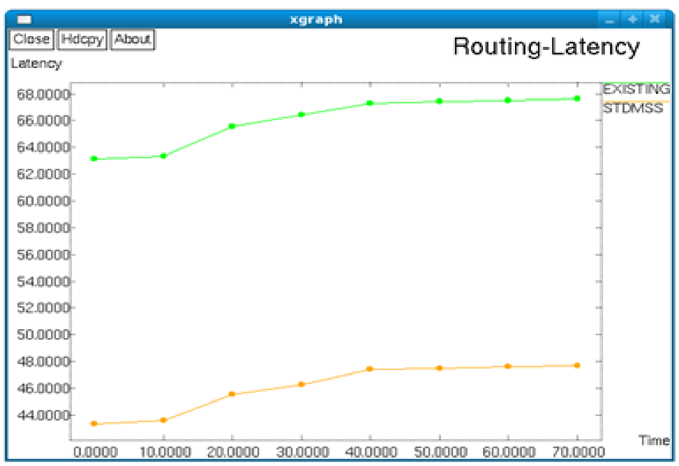


Figure 6: Performance Analysis of Proposed Framework against Existing Technique through Routing latency.

From Simulation analysis it is proved that energy utilization and throughput maximization through employment of optimal solution for multiple mobile sink has improved as compared against state of routing protocol and also performance evaluation depicts the scalability and reliability of the evaluated framework. The network size in terms of the number of deployed sensor nodes also affects the WSN performance significantly since the density of the network and the total traffic loads depend on the network size.

Conclusion

We designed and implemented a high throughput and energy efficient protocol named as Source traffic Defined Multiple Mobile Sink Routing protocol through consideration of the cluster based routing time slot and energy factors. It employs K means model for cluster configurable based on residual energy and link quality. The multiple mobile sink moving trajectories has been computed using particle swarm optimization. The Proposed solution mitigates the routing overhead observed in large sensor deployment scenarios on generating constraints for energy consumption. Finally performance of the model has been evaluated on basis of varying network size, Sink Speed and energy factors. The Simulation results prove that proposed framework outperforms state of art technique in terms of throughput, energy utilization and network latency.

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