Sink Mobility based Energy Efficient Routing Protocol for Wireless Sensor Network

Diksha Pandita[1], Ravi Kumar Malik[2]

[1,2]Department of ECE, Geeta Engineering College, Panipat, Kurukshetra University, Kurukshetra

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Abstract - *In Wireless Sensor Network (WSN), a small portion of "dead" sensor nodes could directly affect the entire network lifetime, and possibly lead to a huge loss in the network due to the routing path reallocation and failure of sensing and reporting events in the environment. Therefore, in order to prolong network lifetime and guarantee the robustness of the sensor network, efficient energy consumption and energy conservation are of great importance in WSN when designing and deploying networks for practical use. In this work, we proposed a framework which uses mobile sink concept with 4 sojourn locations path patterns in addition with one centralized static sink to improve the network lifetime by diverting the load of sensor nodes to nearby static or mobile sink. Furthermore, the performance of proposed framework is compared with Threshold sensitive Energy Efficient sensor Network protocol (TEEN) protocol respectively. Simulation results demonstrated that proposed framework of sink mobility is more energy efficient and improve the network lifetime.*

Key Words: TEEN protocol, sink mobility, mobile sink, efficient routing.

1. INTRODUCTION

In a wireless sensor network (WSN), sensors are scattered in the field and communicate with each other wirelessly [1]. However, sensor nodes are battery-powered with limited energy supply. Moreover, compared to the sink nodes, computational power of a sensor is also weaker. Depending on the network size and network topology, there could be one or multiple sink nodes and the sink nodes can either be stationary at one position or patrolling in the network area [2]. The sink node with base station functionality is usually supplied with large energy reserve and large computational power as it works as a pivot in the sensor network system. Sensor nodes are electronic devices that are widely deployed throughout the network area to completely cover the environment and are equipped with sensing devices that can monitor a wide variety of ambient conditions. In addition to sensing components, sensor nodes are also capable of data processing and data communication. The workflow of sensor nodes includes generating data packages, which contains the information within the sensing area, and wirelessly transmitting them to the base station or other sensor nodes as shown in figure 1[3].

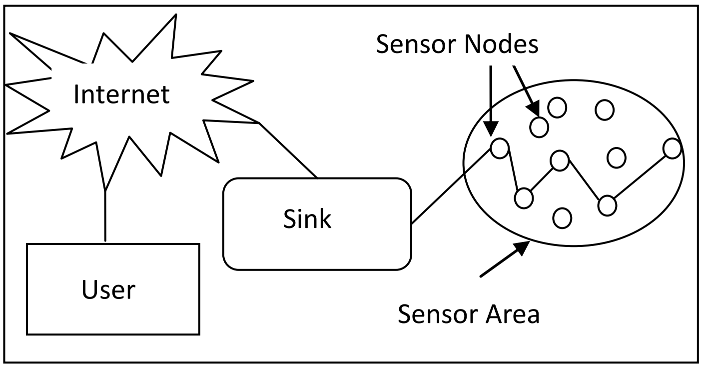

Fig - 1: Architecture of WSN

Due to the limitation of maximum transmission range, data packages from a sensor node may not be able to reach the sink node directly. In this case, other sensor nodes are needed to forward the data to the destination. Thus data transmission may involve multiple sensor nodes to receive the data package and route them back to the sink node(s) [4]. In this scenario each sensor node can be assigned dual roles [5] as both a data generator and a data router (sometimes referred to as a relay node). Sensor nodes which are closer to the sink are typically required to forward data packages from other sensor nodes that are far away from the sink in the network topology [6]. A sensor node consumes energy from the battery and when a sensor node runs out of energy it cannot provide any service, including sensing, data processing or data communication any more. When this occurs, sensor is considered to be "dead" and will be removed from the network topology. The lifetime of a sensor network is defined to be the time interval from its deployment to the time a "critical" number of sensor nodes die, rendering the network unusable [7]. Hence the lifetime of a sensor node depends strongly on the battery power.

2. LITERATURE REVIEW

B. Khalifa et. al. [1] proposed a novel distributed algorithm called neighbor intervention by farthest point that repairs coverage holes using mobile sensor nodes in the immediate vicinity. Participating nodes collaborate to approximate the area of the hole, then consider their coverage redundancy, residual energy, and moving distance to select a suitable replacement to cover it. The results showed that the proposed algorithm substantially outperforms the baseline algorithms. In order to provide an improved performance amongst the existing, a routing algorithm called Cluster-Chain Mobile Agent Routing (CCMAR) is proposed in this work [2]. It makes full use of the advantages of both low energy adaptive clustering hierarchy (LEACH) and power-efficient gathering in sensor information systems (PEGASIS). The results demonstrate that the proposed CCMAR outperforms LEACH, PEGASIS and other similar routing algorithm, energy efficient cluster-chain based protocol. X. Yang et al. [3] proposed a MAC layer protocol based on a CSMA/TDMA hybrid transmission scheme for mobile WSN. The authors divide the sensor nodes into subsets for efficient transmission and design the transmission slot in the protocol. The main contribution of CTh-MAC is reducing the energy consumption in high-speed mobile transmission model. In addition, the authors improve the throughput of the networks compared with the LDCMAC and HTC-MAC. According to the simulation results, the CTh-MAC efficiently improves the throughput and reduces the energy consumption in mobile WSNs. In this paper [4], the authors focused on how to plan a traveling path that meets the delay requirement of time-sensitive applications for data collection and reduces the amount of relay packets in the WSNs. The proposed algorithm is called Timeliness Traveling Path Planning (TTPP) algorithm. Based on the least squares curve approach, the proposed TTPP algorithm can find the best-fitting curve for any given set of sensors by reducing the amount of relay packets in the WSNs. The effectiveness of the proposed TTPP algorithm is confirmed through extensive simulations. In the IEEE 802.15.4 technology, both of the Beacon Order and the Superframe Order helps in controlling the node's activity duration. Authors present work has put forward a novel energy-consumption method, along with a new energy control approach, named Adaptive Beacon Enabled Mode, relevant to monitoring the node battery remaining power, through intervening with the node associated duty cycle [5]. This paper presents the existing work on monitoring the FoI and connectivity in WSNs. Based on the requirement of monitoring of the targets, coverage can be classified into three categories: area coverage, point coverage, and barrier coverage. The authors mainly focused on area coverage of the FoI in this work [6]. In this paper, the authors propose a sparsest random sampling scheme for cluster-based compressive data gathering in WSNs [7]. Specifically, sensor nodes are organized into clusters. In each round of data gathering, a random subset of sensor nodes sense the signal field and transmit their measurements to the corresponding CHs. Extensive simulations are performed, and results demonstrate that SRS-CCDG can significantly reduce the energy cost of data gathering and improve the system robustness to unavoidable node failures. Compressive data gathering (CDG) has been recognized as a promising technique to collect sensory data in wireless sensor networks (WSNs) with reduced energy cost and better traffic load balancing. Besides, clustering is often integrated into CDG to further facilitate the network performance. The authors presented in [8] a regular hexagonal-based clustering scheme (RHCS) and a scale-free topology evolution mechanism (SFTEM) for WSNs, which increases network survivability as well as maintains energy balance. RHCS uses a regular hexagonal structure for clustering sensor nodes, which satisfies at least 1-coverage fault-tolerance. The authors proposed a novel strategy by using random beamforming (e.g. ASM) in [8]. The authors analysed the strategy in terms of reliability, security, and network lifetime. For the lifetime analysis, the authors developed a lower bound on the network lifetime of the proposed strategy. Through simulation results, the authors demonstrated the proposed strategy improves the network lifetime, compared to the conventional one, while achieving the same reliability and perfect secrecy. A novel energy-efficient cluster selection algorithm for multi-level heterogeneous WSNs based on AP has been proposed in [10], named as PECBA. Simulation results have shown that the PECBA has a better performance in balancing the energy consumption and prolonging the network lifetime compared with DEEC. The authors have proposed a fast, adaptive, and energy-efficient data collection protocol in multi-channel-multi-path WSN [11]. A new quaternary interconnect scheme was presented in [12]. The scheme modifies the transmission of data in a WSN from binary symbols to quaternary ones. Upon transmission, each two bits are modulated as one symbol, and upon reception the symbol will be demodulated producing the original binary bits. This scheme has been simulated with SPICE, and the simulation results have shown that it can increase the life span of a WSN.

2.1 RESEARCH GAP

Well balanced distribution of the energy load among sensors does not guaranteed by the direct transmission to sink. To perform balanced distribution of the energy load among sensor nodes in WSN and to improve data aggregation mechanisms, number of clustering protocols have been specifically designed for WSNs [5]–[10]. These protocols use static sink for data transmission which leads to energy hole problem [12].

3. PROPOSED WORK

Conventional clustered routing protocols like LEACH-C have been using single centralized static sink as which leads to energy hole problem. To overcome this problem in our framework, a controlled mobile sink is used that guided based on minimizing the dissipated energy of all sensor nodes. Apart from mobile sink, we also include one centralized sink for data collection so that if any one of sink fails, sensor node still can send data to the other sink. For energy preservation purpose, fewer hops for data transmission is preferable so network field is partitioned into R identical regions. Hence, packet latency and the number of dropped packets can be reduced as mobile sink rotates along the sojourn path and stops at sojourn position when it is nearer to sensor nodes in each region in the network. Furthermore, partitioning the network into small regions provide better connectivity between CHs and BS. Here, two rectangular patterns are considered with 4 and 8 sojourn positions for the mobile sink as illustrated in Figure 1 (a) and (b), respectively. The method of the proposed procedure is broken up into rounds, where each round starts with a set-up phase after that steady state phase are performed with some advancement.

i. Set-up phase

In which the cluster heads (CHs) formation and its member assignment are performed. Here, before sending the aggregated data to the sink node first CH calculates two distance parameters:

a) Centralized distance (CD) is distance between the CH and the network's centralized sink.
b) Region distance (RD) is distance of CH to current region mobile sink in which the CH present. After this, CHs compare these distances and choose the minimum distance sink for data transmission.

ii. Steady State Phase

Where the member node transferred data to CHs and aggregate the data; then transferred these aggregated data to the sink. In proposed framework after formation of CHs the mobile sink moves to its predefined sojourn location. When mobile sink enters into a region then the sensor nodes in this region wake up, where as in remaining regions(R) node are sleep. The sensors start collecting the data; CHs create TDMA schedule for its member nodes to send the sensed data. Then, each node transmits its sensed data to its CHs or the sink (centralized static sink/ mobile sink) if it is close to the sink than CH. When all sensor nodes send their data to their respective CHs, CHs perform data aggregation operation after that CHs sends their aggregated data to the minimum distance sink node. After a predefined time called sojourn time, mobile sink moves to the next region sojourn location for collection of data in this region. Until all the R regions are visited this process is repeated. After completion of all regions, first round of the mobile sink completed then to begin the new round the mobile sink again starts with the first region. Here, Firstly sensor network divided into four equal regions to perform the routing as shown in Figure 2.

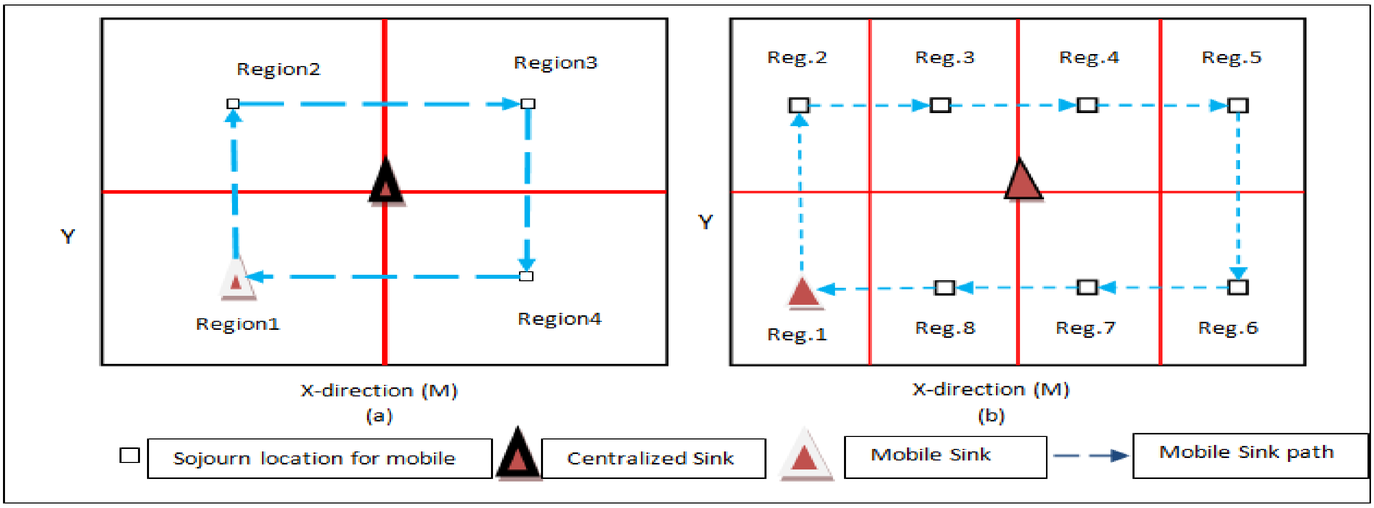

Fig - 2 (a) Sensor network with 4 sojourn locations Mobile Sink (b) Sensor network with 8 sojourn locations Mobile Sink

4. SIMULATION RESULTS

Performance analysis of TEEN protocol with mobile sink is performed using MATLAB. The simulation has been performed on a sensor network of size 500m x 500m with randomly deployed 500 sensor nodes. Here, we considered three cases for sink position in both homogenous and heterogeneous network protocol-

1) Stationary sink placed at middle of the network field (Centralized static network sink).
2) 4 sojourn positions movable sink with 1 centralized stationary sink.

In the first case, all the cluster head directly send the aggregated data from their members to the centralized stationary sink. In the second and third case, cluster head firstly compare the distance to the network's centralized sink with the distance to the region's centralized sink in which the cluster head is present. After the selection of sink with minimum distance, CHs send aggregated data to the selected sink. The radio parameters used in our simulations are shown in Table 1.

Table 1- Network Parameter

Parameters	Values
Area	500m × 500m
No of Nodes	500
Initial Energy Per Node	1 J
Total Energy	150 J
Transmission energy, E_{TX}	50nJ/bit
Receiving Energy, E_{RX}	50nJ/bit
Data Aggregation Energy, E_{DA}	5 nJ/b/message
Probability of Becoming Cluster Head Per Round	0.1
Size of Data Packets	4000 bits
Threshold distance, d0	87.7m
Transmit Amplifier Energy	
Energy for Free Space Loss, E_{FS}	0.0013 pJ/b/m^4
Energy for Multi-path Loss, E_{MP}	10pJ/b/m^2

Simulation for TEEN Protocol
First we considered a network in which all 500 sensor nodes are equipped with the 1 Joule of initial energy.

i. Number of Alive Nodes per Round: The number of nodes that have not yet finished all of their energies.

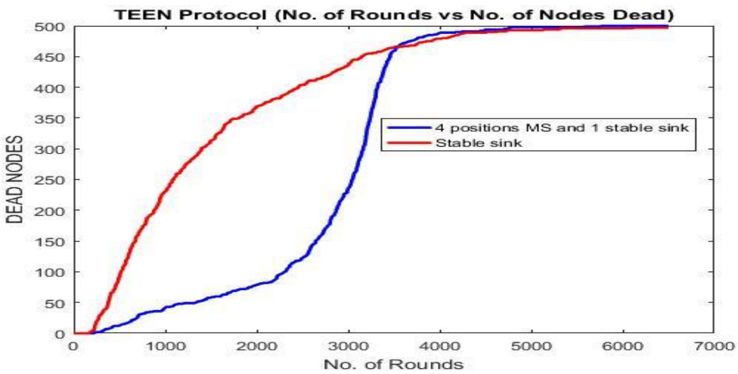

Fig - 3: Comparison of dead nodes with stable and mobile sink in TEEN protocol

The comparative result of number of nodes dead with respect to number of rounds of TEEN protocol with static sink, 4 positions MS are shown in Figure 3 Clearly, less number of nodes are dead in case of mobile sink which scattered the load of nodes around the network and directly extends the network lifetime.

ii. Number of Cluster Heads per Round: The number of nodes which collect data from their cluster members and directly send aggregated data to the sink node.

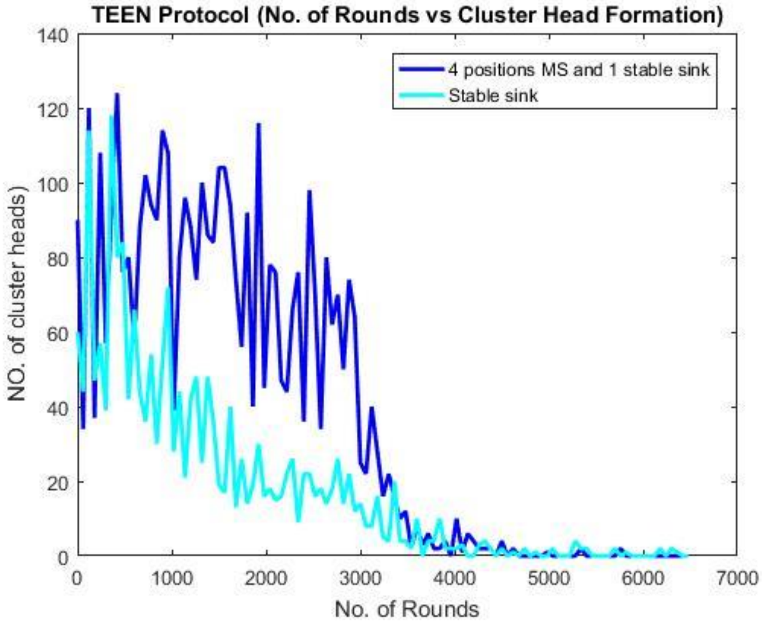

Fig - 4: Comparison of number of cluster head over number of rounds with stable and mobile sink in TEEN protocol

Figure 4 depicts number of cluster head (CH) formed over the number of rounds in TEEN protocol using static sink and mobile sink. It is noticed that the number of CHs for the static sink case is gradually decreased while the number of CHs for 4 positions MS is approximately uniform.

iii. Packets send to BS per Round: The number of data packets sends by cluster head nodes in the network.

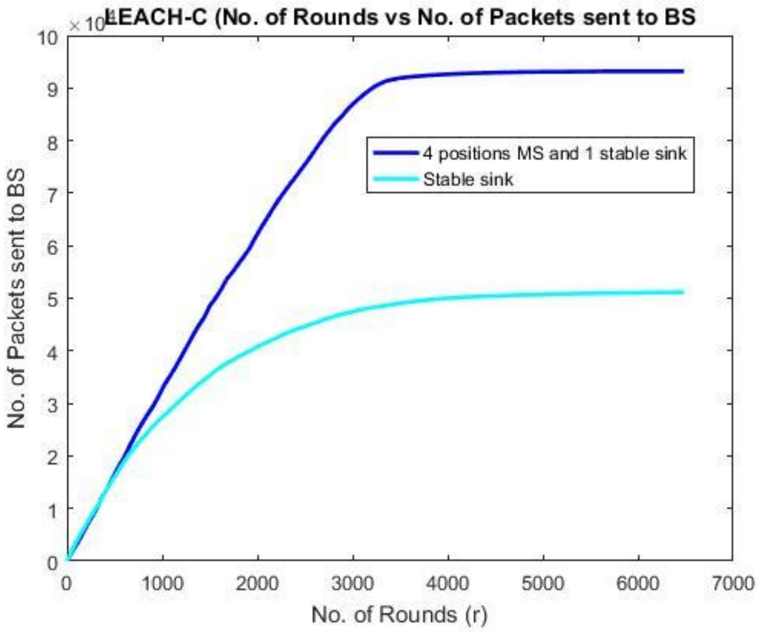

Fig - 5: Comparison of number of packets sent to BS per round with stable and mobile sink in TEEN protocol

In the network, number of packets sent by CHs and by sensor nodes in number of rounds to the sink node defines the throughput of system. Figure 5 showed the simulated throughput of TEEN protocol by using static sink and using proposed mobile sink framework.

iv. Energy consumption per Round: The amount of energy consumed.

Figure 6 shows the energy consumption at number of rounds with 500 sensor nodes by TEEN protocol using static and mobile sink. It is noticed that most nodes of our proposed mobility TEEN protocol on the energy consumption better than that of the static sink TEEN protocol.

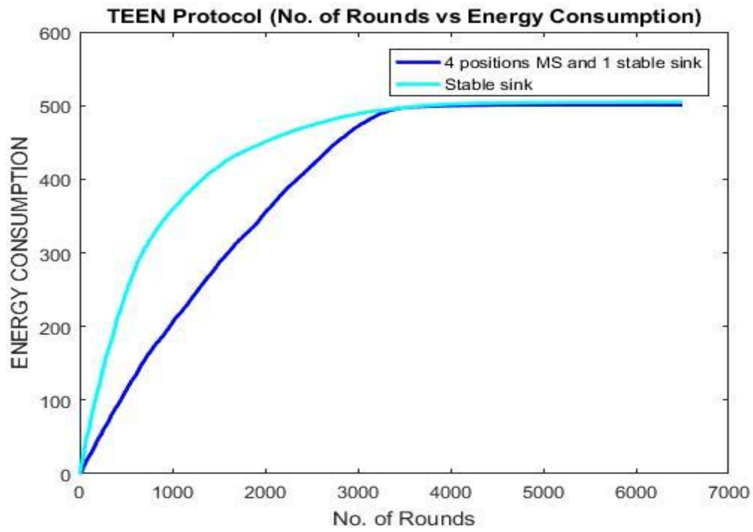

Fig - 6: Comparison of amount of energy consumed per round with stable and mobile sink in TEEN protocol

5. CONCLUSION AND FUTURE WORK

As sensor nodes near the sink quickly died which creates energy hole in network. Furthermore, advantage of mobile sinks over static one and its applications are also explained. We used mobile sink sojourn path patterns with centralized sink to collect the data from CHs and from sensor node by comparing their distance to CHs. The proposed framework is applied to TEEN. The comparison of these protocols with their respective static sink protocol is done using MATLAB. Simulation results showed that by using mobile sink in the network the energy depletion reduced which enhances lifetime of the network as well as it improves throughput of the network.

In future, there is requirement of merging advance methods like optimization techniques named as genetic algorithms, PSO, ACO by which we can form energy efficient clusters and increase the network life time.

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