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DESIGN OF A CLUSTER HEAD SELECTION FRAMEWORK FOR WSN BASED ON SOCIAL SPIDER OPTIMIZATION

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Abstract: Numerous sensor nodes in a Wireless Sensor Network (WSN) have limited power, storage, and processing ability. The performance of these systems can be enhanced by employing clustering. In this work, an energy-efficient routing protocol based on Low Energy Adaptive Clustering Hierarchy (LEACH) and Received Signal Strength Indicator (RSSI) for WSNs is proposed. Data aggregation is also incorporated to decrease the number of transferred messages to the Base Station (BS). It enhances network lifespan. The design of an energy-balanced clustering for peak network lifespan of WSN is a Non-deterministic Polynomial (NP)-hard problem. Recently, several meta-heuristic approaches based on clustering schemes have been proposed to solve NP-hard problems. However, this clustering scheme suffers from power inefficiency. The proposed method is based on Social Spider Optimization algorithms. The proposed charged system Hierarchical Structure (HS) was found to be efficient in terms of energy with a good response. The scheme was able to choose suitable CHs, thus optimizing routing and increasing network lifespan. The system selected efficient CHs with routing optimization with an increase in network lifetime. Results show that the charged system HS has a higher number of clusters formed by 23.25% for 150 number of nodes, by 17.28% for 300 number of nodes, by 15.12% for 30 number of nodes, by 9.09% for 40 number of nodes, by 13.49% for 45 number of nodes and by 11.89% for 50 number of nodes when compared with HS.

***Keywords* - WSN, Security, Sub Carrier, Power Reduction**

I. INTRODUCTION

A group of sensor nodes that can sense, compute and communicate through wireless modem is called a Wireless Sensor Network (WSN). They have a wide range of applications, including environmental, habitat monitoring, and military and industrial surveillance and application (Ammar et al., 2016). Due to limited power, a number of challenges are faced by large-scale networking designs. Because of this, a number of protocols and algorithms have been proposed, which help in utilizing the energy resources of the sensor. Consumption of energy and the distance of communication are directly proportional based on the prototype of energy consumption (Ren et al., 2013); for instance, multi-hop communication is data gathering is a more beneficial data gathering technique for energy conservation; whereas hierarchical routing seems to be advantageous for performance of the network, based on energy consumption and scalability. In general, in a cluster network, single-hop routing is observed in every cluster. Energy can be conserved through one-hop clustering as the communication takes place from the source node to cluster through one hop. But as there is an increase in distance of communication and a single hop require more energy, it seems to be a technique with lower efficiency. The multi-hop communication network is an energy-efficient technique when consideration is being given to inter-node distance. The ultimate aim of cluster-based SNs is to mitigate the delay of the system and improve energy conservation. Regarding cluster-based techniques involving micro sensor networks, LEACH (Low Energy Adaptive Clustering Hierarchy) is the best technique, which is quite efficient with regards to energy, has scalability in routing, and there is fair media access for SNs (Tyagi & Verma 2018). LEACH is one of the early protocols which was designed to use clustering to routing information (Rhim et al., 2018). This is a technique that involves single-hop routing where transmission of data takes place directly from CH to BS, though there are some limitations to this. Firstly, as the distance between CH and BS is more, energy dissipation is more; because of this, the clusters which far off-die faster than the ones which are closer. With regards to large-scale networks, the technique of direct transmission used in LEACH is not applicable, as the distribution of load balancing is affected, and the network's operational lifetime is reduced. Secondly, there is a difference in the data transfer's frequency from one node to another on the basis of the level of significance of the information that is detected in every area. Early destruction of active nodes takes place due to this differentiation in comparison to the ones with average activity, which leads to an imbalance in the energy levels of the nodes in the network.

1.1 Wireless Sensor Network

WSN is a technology that is involved in the communication of information through a network of nodes using wireless links with close monitoring of fields. Multiple hops are involved in WSN, where the data is forwarded to the base station (BS/sink) or through another gateway. The nodes can be static or mobile, with or without the knowledge of the location, and can be either similar or different.

1.1.1 The Architecture of the Wireless Sensor Network

The objective of WSN is to provide effective communication between the ecological systems and the internet world. The SNs are deployed randomly in terrains that are beyond human accessibility, leaving the WSN to be self-organized and also integrate with the other SNs. Data is collected by the SNs, after which they are processed and transmitted to BS, which acts as an interface between the user and the internet. WSNs basically have limited energy, decreased power, network topology that is dynamic, mobility and failure of nodes, broadcast communication with a short-range, multi-hop routing, and deployment at a larger scale.

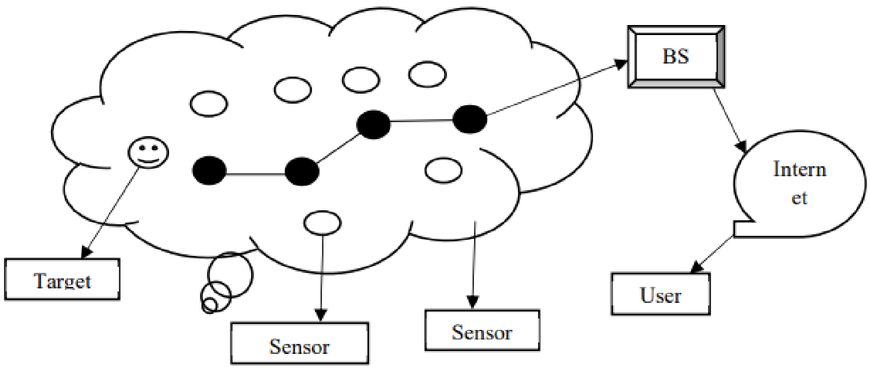

Figure 1 - Architecture of the WSN

WSN is an integrated system with both hardware and OS platform. An OS based on a component called Tiny OS is designed in such a manner that it can be operated in wireless devices which have resource limitations. It aids the protocol developers and applications through mechanisms with fine-grained concurrency and an organized communication primitive. Generally speaking, Tiny OS is used in event-based programming along with component protocol that is increasingly efficient. An optimization that is system-wide is enabled by Tiny OS, which closely interacts with both hardware and software. It is assembled to run on a general marketecture, where there is only one CPU which is shared between the processing of the protocol and application. WSN's basic design is shown in Figure 1, where the SN that is deployed in the sensor fields interact with one another; the information is collected from the environment and is sent directly to BS, which is the gateway. Data is transmitted to the internet through the gateway, as the user is connected directly to the internet (Maraiya et al., 2011).

1.2 Related Work

WSNs operate in human-inaccessible terrains. The information from the sensor nodes should be routed efficiently and the energy saving measures are required. The aim of cluster-based routing in WSNs is to minimize the energy consumption and maximize the network's lifetime. This chapter discusses in detail the research work carried out by various authors for the efficient cluster-based routing in WSN. The CHs, GW nodes and routing path selection in cluster-based approaches available in the literature survey can be classified into three categories as follows:
(i) Clustering and cluster head selection approach
(ii) Gateway node and routing path selection approach
(iii) Mobile sink-based routing and data gathering approach

II. CLUSTERING AND CLUSTER HEAD SELECTION APPROACH

Routing protocols in cluster-based WSNs depend on clustering and the CH selection. Hence, it is the basic and the most important service that helps in finding the efficient routing path to reach the sink. A survey on the CH selection for cluster-based WSNs is discussed below. Clustering mechanism is a key to achieve energy efficiency in WSN. Heinzelman et al. (2000) have proposed the basic clustering protocol for WSN called LEACH (Low Energy Adaptive Clustering Hierarchy). It is the most popular energy efficient clustering protocol which deals with distributed cluster formation. The main objective of this scheme is to achieve energy efficiency by minimizing the energy consumption, and to ensure even distribution of the load to all the sensor nodes. LEACH protocol function is broken up into rounds. Each round contains two phases, namely, the setup phase and the steady state phase. In the setup phase, the nodes are deployed, the clusters are formed and the cluster heads are selected. The cluster head selection is based on the predetermined value p (the desired percentage of cluster heads in the WSN). In this phase, each node could be a cluster head or a cluster member. All the wireless sensor nodes select a random number p between 0 and 1. The node with random number less than the desired threshold value T(n) becomes the cluster head for that specific round. The threshold value is determined using the percentage of a particular node for becoming a cluster head in the current round and the set of other nodes that have not been selected as cluster heads in the last (1/p) rounds. In the steady state phase, the data is gathered and communicated between the source node and the sink. During the steady state phase all the sensor nodes initiate sensing and transmit the data to the cluster head.

III. GATEWAY NODE AND ROUTING PATH SELECTION APPROACH

In multi-hop communication, the sensed data need to be routed over a long distance to reach the sink which reduces the strength of the information and consumes more energy. Hence the GW nodes are required to send the information efficiently to the sink using multiple hops. The routing path selection is an important factor for achieving energy consumption in WSN, since the link or path failure causes large number of packets drops in the network. Hence the dynamic path selection is required for the achievement of a high packet delivery ratio. The following section analysis the various reviews based on GW node selection and dynamic routing path selection. Wang & Chen et al. (2013) have proposed a Link-Aware Clustering Mechanism (LCM) to achieve energy efficient routing for cluster-based WSN. In this protocol, energy efficiency is achieved through a proper selection of cluster head and gateway with the help of Predictable Transmission Count (PTX). This scheme achieves reliability and energy efficiency, but the CH selection criteria considers the residual energy of the node and distance of the node which is not enough for the selection of the best cluster head or gateway node in WSN. A Passive Clustering (PC) scheme for WSN has been developed by Kwon & Gerla (2002). This mechanism describes all the nodes in the network with their own state. The receiver node changes its state depending on the sender node state and all the nodes update the new state to their neighbors, with the knowledge of the current cluster state. This passive clustering technique has reduced additional load by reducing the control packets in the network. This passive clustering uses the random CH selection procedure to reduce the battery power very quickly making the CH selection and the routing scheme inefficient.

Tarhani et al. (2014) have proposed SEECH (Scalable Energy Efficient Clustering Hierarchy). This protocol is sub divided into two phases, start phase and steady-state phase. In start phase, the distance of each node from the sink and the number of neighbors in a particular radius are calculated. The highest distance node is selected as the CH. This scheme also made analyzes of the gateway node selection scheme which has distance as its criterion. In the steady-state phase, data is gathered from the nodes and communicated to the sink using a selected topology, CH and GW node, based on the distance criteria alone which leads to an inefficient CH selection. Abbasi & Younis (2007) have given a survey on clustering algorithms for WSN which analyze the various clustering algorithms, need for clustering, highlights the clustering objectives, features and clustering complexity.

IV. MOBILE SINK-BASED ROUTING AND DATA GATHERING APPROACH

In mobile sink-based WSNs, the position of the mobile sink is always in an ad-hoc manner, making the routing and data gathering more challenging. Hence the following section presents a survey of the mobile sink-based WSNs. Zahhad et al. (2015) have proposed (MSIEEP) Mobile Sink based adaptive Immune Energy-Efficient Clustering Protocol which avoids the energy hole problem by minimizing the total dissipating energy in communication. The above scheme uses AIA (Adaptive Immune Algorithm) in order to reduce the communication overhead control packets in the network and optimizing the required number of CH in the network. AIA identifies the location of the CH and also the mobile sink which leads to the reduced energy consumption while communicating between the CH and mobile sink. Rani et al. (2016) presented a BDEG (Big Data Efficient Gathering Algorithm) for real time data gathering using RSSI (Received Signal Strength Indicator) data communication methodology. The static approach is followed, for determining the clusters. The CH and the relay node selection considers the residual energy of the node. The data gathering in various nodes is indicated through RSSI. This scheme achieves load balancing and incWOes the lifetime of the sensor nodes. In this scheme, the CH selection is based only on one parameter and the total distance for data transmission is high leading to an inefficient mobile sink based routing scheme for WSN. Takaishi et al. (2014) have proposed a methodology which describes the sink mobility utilization to assist data gathering in a densely distributed WSN. This scheme describes the modified maximization technique and the cluster optimization for reducing energy consumption. This algorithm groups the nodes based on their communicating ability. To gather the data from all the sensor nodes in the network, the number of clusters must be high in the network, this is achieved through the connectivity value of the node which is based on the sensor node's location. This scheme deals mainly with clusters of an optimal number.

V. PROBLEM STATEMENT

The special and unique characteristics of a WSN are that it is infrastructure-less, and self-organized with limited energy sources, memory and bandwidth. Most of the WSNs have real time applications with deadlines. The challenges facing WSN are briefly stated below.

i. Energy Efficiency: The WSN requires high energy efficiency, the sensor nodes are powered by limited batteries, and the main causes of battery drainage include, continuous sensing, data gathering, processing, buffering, transmission and reception of data. More energy is consumed by these functions, which is a major challenge in the WSN.

ii. Deployment: WSN nodes are deployed in two categories on the basis of the sensor node movement, namely, the deterministic node deployment and random node deployment methods. The deterministic node deployment method is used mostly when the deployment region and the requirements are known earlier and the location of the sensor nodes remains static. In the random node deployment method, the sensor nodes are spread randomly forming an ad-hoc infrastructure. The random node deployment method is used mostly for real time applications in critical environments without any prior information about the deployment region, environment requirement and communicable range.

iii. Topology: The wireless sensors are deployed mostly randomly. They are required for the achievement of high network reliability, network coverage, network connectivity and energy efficiency. Hence, the network topology requires an efficient designing.

iv. Sensor Localization: Sensor localization is a vital issue for WSN management and functions. In most of the real time applications, the wireless sensors are deployed randomly without any infrastructure. The determination of the location of the sensors in real time applications is an another important challenge.

VI. METHODOLOGY

A WSN is a self-configurable group of spatially dispersed and dedicated sensors, which can sense, process and communicate among themselves using radio signals. It can be deployed in various environments for monitoring and measuring physical conditions such as temperature, sound, pollution levels, humidity, wind velocity and so on. The data sensed from various sensor nodes are routed to the sink minimizing the energy level of the sensor nodes, which constitute the primary issue in the WSN that degrades the network's performance significantly. Cluster-based routing is one of the approaches in the area of efficient use of energy in WSNs. In cluster-based routing, the CH selection procedures are usually based on the residual energy of the node or random selection. But this is an inefficient methodology since some nodes contain high energy but the distance from the node to the base station is high, which results in early depletion of energy. In the random selection procedure, the node that contains minimum energy which is selected as the CH quickly drains the energy level, thereby reducing the lifetime of the network. In the GW node selection procedure, the nearest node to the sink is frequently selected as the GW node. But that node receives heavy messages compared to other nodes, which minimizes the energy of such nodes easily leading to error-prone situations in WSNs. So, the GW node is also very important and requires careful selection. Hence, the CH and the GW node selection is an important issue in the energy efficient cluster-based routing protocol for the WSN. In this chapter SSO Protocol is proposed for WSN through strategic selection of the CH, GW node and the shortest path from the source node to the sink.

In SSO Protocol, energy-efficiency is achieved through efficient selection of the CH and the GW nodes along the shortest path from the source node to the sink. WO consists of two phases, namely, the setup phase and the steady-state phase to enable achievement of an efficient routing. In the setup phase, clusters are formed using the CMs, the CHs and GW nodes and the shortest routing path is determined. In the steady-state phase, data is collected from the CMs and routed to the sink through the CH and GW nodes. The protocol assumes all the sensor nodes and the sink as stationary, with the sink located far away from the sensing field, all the sensor nodes' energy levels are equal and they have an unique ID. All the sensor nodes are equipped with the GPS device to measure their own geographical position, the sensor nodes are capable of performing in the inactive mode and the sleeping mode. All the sensor nodes have the same fixed energy and rate, and each round consists of a complete cycle for forming clusters, selecting the CH, and the GW node and sending the data to the sink. The block diagram of SSO Protocol is shown in Figure 6. The various stages of SSO Protocol, such as CH selection, algorithm for CH selection, GW node selection, algorithm for GW node selection, cluster formation, WO message formats, operation of SSO Protocol, and intra-cluster and inter-cluster routing are discussed in the following sections.

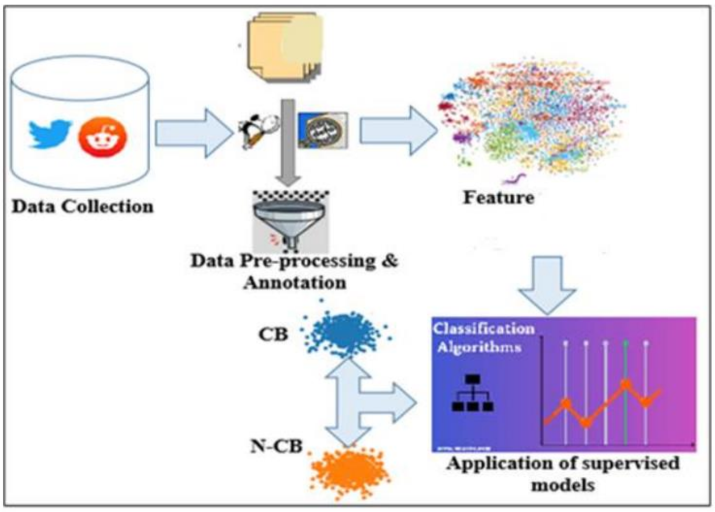

Figure 6 - Proposed Architecture

6.1 Cluster Head Selection Mechanism

In cluster-based routing, CH which is the backbone of the cluster performs all the required functions in the network, such as cluster formation, CM insertion, CM deletion and communication. Hence, the CH must be selected efficiently. In SSO Protocol, CH selection parameters, such as the residual energy of the node, and the angle and distance between the node and the sink have been used in the CH selection procedure. The n number of sensor nodes are distributed in the network area. The source node is considered as the tentative CH (TCH) for each round. All the sensor nodes execute a CH selection algorithm to select the CHs. For example, consider node j to be the CH. Then node j calculates CHs which determines its chance for being a CH.

6.2 Algorithm for CH Selection

The CH sends the CH advertisement message CHs (j) to all the sensor nodes within the region. The nodes receive the message and reply with the join message (JOIN_MSG) to that particular CH. After successfully receiving the join message from the sensor nodes in the network, the CH accepts the nodes as CMs for that particular CH. The CH sends the reply message (REP_MSG) to all CMs. Each CM sends the sensed data to the corresponding CH. The CH searches for the shortest path towards the sink and transmits all the gathered data to the sink using single-hop or multi-hop routing through the GW nodes.

The various steps involved in CH selection process are described below:
Step 1: All the sensor nodes are deployed randomly in the specified area and networks are formed.
Step 2: Initially the source node is selected as the tentative CH (TCH).
Step 3: All the sensor nodes estimate their residual energy, angle and distance between the node and the sink to select the CHs.
Step 4: The node which contains the maximum value becomes the CH in the network for that particular region.
Step 5: The selected CH sends the CH advertisement message to all the sensor nodes within the region in the network.
Step 6: The sensor nodes in the network receive the CH advertisement message
Step 7: The sensor nodes respond with a reply message (JOIN_MSG) to the CH.
Step 8: CH receives the JOIN_MSG from the various sensor nodes within the region and forms the clusters and CMs.
Step 9: The CH sends the reply message (REP_MSG) to all the CMs.
Step 10: The CM respond to the selected CH and sends the sensed data to the CH.
Step 11: The CH gathers all the data and sends it to the sink using the shortest path.

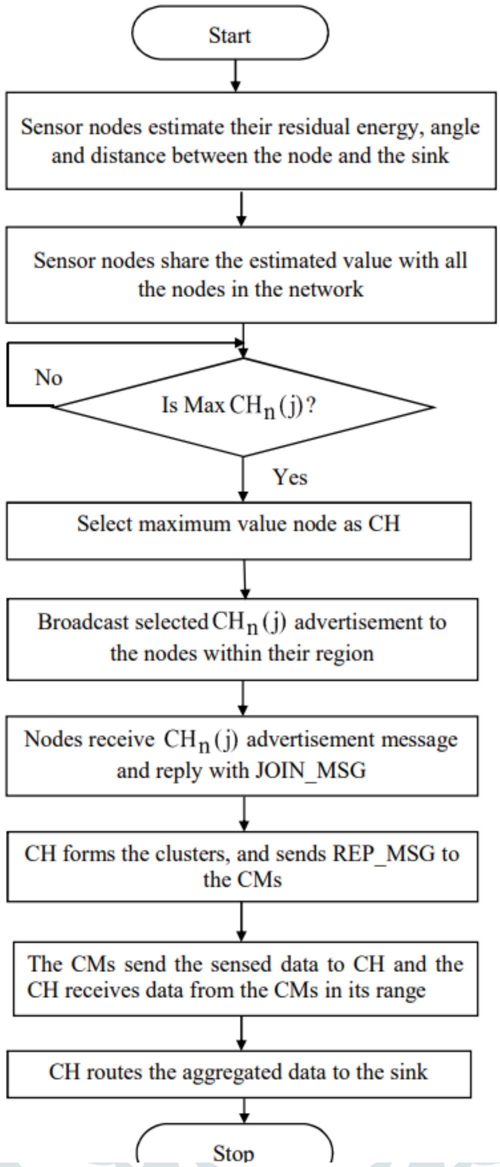

Figure 6.2. Proposed Algorithm Flow Diagram

Efficient routing methodology of SSO Protocol has been proposed. Energy efficient routing is achieved with the help of an efficient selection of the CH, GW node and the shortest path, by strategically selecting parameters, such as residual energy, angle and distance between the node and the sink. The simulation results of SSO Protocol are implemented using NS2. WO achieves higher residual energy, higher lifetime, higher packet delivery ratio, higher energy efficiency and lower end-to-end delay compared to ARPEES and SEECH protocols. SSO Protocol is also suitable for all environments. However, the proposed WO does not provide a solution for link or path failure. In case of any link failure, SSO Protocol needs to search the alternative path again, which leads to incWOe the end-to-end delay in the network.

6.3 Cluster Formation

In WO, CHs and GW nodes are selected efficiently, all the CHs introduce themselves to the network using a CHs (j) message. sensor node chooses the nearest CH depending on the strength of the CHs (j) signal. Subsequently, it informs the CH about its choice by transmitting a JOIN_MSG message, which contains the sensor node ID and cluster head ID. All the CHs count the CMs according to the JOIN_MSG messages and use the TDMA scheduling scheme to communicate the information without congestion in the network. The CHs transmit the number of TDMA time slots to all the CMs for data transmission and reception. The steady-state phase selected CHs starts gathering the information from the CMs using intra-cluster communication and the CHs transmit the gathered information to the sink directly, and for long distance communication the CHs transmit the gathered information through GW nodes using inter-cluster communication.

VII. PERFORMANCE EVALUATIONS

In this section, the performance of SSO Protocol is studied in terms of residual energy, lifetime, packet delivery ratio, energy efficiency and end-to-end delay. WO is implemented by using Matlab. The performance of WO is compared with that of ARPEES (Adaptive Routing Protocol with Energy efficiency and Event clustering for Wireless Sensor Networks) and WCH (Social spider Clustering Hierarchy) protocols under varying number of rounds. Hundred nodes are randomly distributed in a 100 m x 100 m area. The initial energy is kept at 2 joules. The simulation parameters used to implement SSO Protocol are listed in Table 7.1.

Table.7.1: Simulation parameters of Proposed protocol

Parameters	Value
Number of nodes	100
Network size	100 m x 100 m
Communication range	80 m
Application Type	Event driven
Initial energy	2 J
Simulation Time	20 sec
Packet Size	512 bytes
Antenna	Omni Directional Antenna

The various metrics used to study the performance of SSO Protocol are defined as follows:
(i) Residual Energy: It is the mean value of the remaining energy of all the alive sensor nodes when simulation ends.
(ii) Lifetime: It is the ratio of the number of alive nodes to the number of rounds.
(iii) Energy Efficiency: It is the ratio of the total number of data delivered by the node to the total energy consumed by the node.
(iv) Packet Delivery Ratio: It is the ratio of the total number of data packets received by the sink to the total number of data packets sent by the source node at a specific time period.
(v) End-to-end delay: The time required for a data packet to be transmitted across the sensor network from the source node to the sink.

VIII. CONCLUSION AND FUTURE WORK

This research has proposed SSO Protocol for minimizing the energy consumption and maximizing the lifetime of the network through efficient selection of the CHs, GW nodes and the shortest routing path in the WSN. In this protocol, strategic selection of the CH and GW nodes has been made using parameters, such as the residual energy of the node and angle and distance between the node and the sink. WO uses two phases, namely, the setup phase and the steady-state phase for achieving efficient routing of information from the source node to the sink. In the setup phase, the clusters are formed using the CMs, CHs and GW nodes, and the shortest routing path is determined. In the steady-state phase, the data is collected from the CMs and routed to the sink. The performance of WO is studied in terms of residual energy, lifetime, packet delivery ratio, energy efficiency and end-to-end delay. SSO Protocol has been implemented using Network Simulator 2 (NS2) version 2.34. The performance of SSO Protocol has been compared with ARPEES and SEECH protocols by varying the number of rounds. SSO Protocol achieved 13.1 percent and 6.1 percent higher residual energy when compared to ARPEES and SEECH protocols respectively, 13.9 percent and 7.6 percent higher lifetime compared to ARPEES and SEECH protocols respectively, 12.7 percent and 7 percent higher packet delivery ratio when compared to ARPEES and SEECH protocols respectively, 13.8 percent and 7.6 percent higher energy efficiency compared to ARPEES and SEECH protocols respectively and 13.4 percent and 7.1 percent lower end–to-end delay compared to ARPEES and SEECH protocols respectively.

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