An Efficient Cluster Head Selection and Routing in Mobile WSN

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Abstract—Wireless Sensor Networks (WSN) includes numerous sensor nodes that are connected to each other through the use of wireless short distance links. The transfer of data between the individual nodes is found to be energy-constrained and the energy-efficient protocol in WSNs is a huge requirement. In addition, the deployment of large numbers of sensor nodes increases the size of the network, which in turn increases the energy consumption rate. An efficient protocol is developed in this research that includes grid-based mobile communication network formation, efficient path selection through cluster head selection and data communication. In addition, multi-stage authentication is implemented to provide security from source node to destination node for the transfer of data. Implementation is performed via NS2-based platform and the result obtained shows that the proposed system outperforms other existing techniques in terms of packet delivery and use of energy through network lifetime.

Keywords—Wireless Sensor Networks (WSN); ASRC Routing; Cluster Head (CH) Selection; Replication; Data Communication.

1 Introduction

Recently, advances in miniaturized electromechanical frameworks have facilitated the improvement of embedded sensors with small, minimal effort, low control and multifunctional property, which are suitable for performing numerous tasks such as detection, data collection and pre-processing, and communication via intermediate devices [1]. Wireless Sensor Network (WSN) trends are defined as a distribution network consisting of numerous sensor nodes that are deployed to track a specific physical phenomenon in a geographical region over a widespread land area. There is no requirement for predetermination or engineering to select places that are considered for WSN deployment [2]. This enables sensor nodes to be deployed randomly with inaccessible terrains or during disaster relief operations communication requirements. In addition, this infers a requirement for effective network protocols and the deployment of organizational skills based on self-intelligence. Another distinctive feature of the wireless sensor network is its property of collaborative approach between sensor nodes, where it is deployed to perform several specific tasks, such as data aggregation and fusion, identification and measuring techniques [3]. Instead of sending the raw information to the end node, the sensor node uses its built-in processing capabilities to perform the computations locally and transfer at that particular time only the required and processed information. Overall, information is collected from each sensor to create an essential outcome of the database of information [4].

Wireless sensor networks can be extended to a wide range of resources and can be used in numerous fields such as medical fields for data transfer [5], industrial and military applications [6], ecological factors monitoring [7], scientific data analysis [8], and home network systems [9]. In particular, by observing patient physiological information remotely, WSNs empowers medical specialists to recognize predefined indications. WSNs can be used in the field of military appliances to distinguish atomic, nuclear and chemical assaults and to detect the presence of harmful materials, to prevent foe assaults through alarms when adversary flying machines are detected, and to keep in touch with friendly forces through monitoring tools and ammunition. In addition, WSNs are also helpful in checking timberland fire, watching natural and organic environments, and recognizing earthquake surges and places. As far as non-military personnel use WSNs, it is conceivable to determine spot accessibility in determining the public parking lot, track dynamic identification in the working environment, monitor security in open places such as banks and shopping centers, and screen road activity in a certain time. In addition, WSNs can address issues related to logical applications in terms of space and interplanetary investigation, application of physics with material science, and in-depth undersea investigation [10]. Several performance factors also play an active role in determining the capabilities of the sensor network during these processes. Such factors are taken care of by sensor management and control units designed to monitor resource use, task distribution, end point delivery, and so on. From the above cases, the important concerns that can be considered as characteristic of the generic design and objectives of the system are shown in Table 1.

Table 1. Parameters and characteristics of WSN along with its limitations

Design characteristics	**Objectives of the system**	**Limitations**
Implementation of sense sensor node	Should be as small as possible along with minimal cost factor	The energy capacity will be limited
Sensors with battery powered	Power consumption should be as less as possible	Depends on the location of sensor nodes
Data storage constraints	Scalability factor and the system should be highly reliable	The hardware resources will be limited with certain constraints
Redundancy in size of data	The system should be self-configurable	Deployment of sensor nodes is found to be in a random manner
Designed system should be Application specific	Developed system should be compatible with numerous faults	Aggregation of data
Frequent change in the topology of the system	Security factors should be ascertained	Scalability of the system varies

WSN location is defined as a process by which the sensor node identifies its current location after network implementation [11]. There are several techniques to identify the specific location of the beacon node and few of them are proximity-based in which the neighboring node is used to determine the exact position of the beacon node and then the same is converted into beacon to transfer the data to the destination node. The synchronization process is primarily concerned with routing methods and energy conservation [12]. The data should be transmitted in a scheduled manner with less collision, distortion and retransmission of conserved power to enhance the lifetime of the overall network.

The main theme considered during the deployment of the wireless sensor network is to reduce the use of energy in the communication system through clustering. One node is chosen to be a group head of the cluster in the clustering process. The cluster head handles much of the data processing steps in sensor nodes and cluster computation. The clustering technique is seen as the vital process in the system, as the exchange of information between groups should be effectively and efficiently transferred. The most imperative limitations of existing WSN techniques are to control the rate of energy consumption and maintain system security. Due to the wide use of wireless sensor systems, it is important to increase its security during the transmission of data from source to destination. In addition, the WSNs are highly prone to physical attacks, so some security-driven techniques should be incorporated during transmission based on the designed routing techniques and communication strategy. The key security needs include verification, secrecy maintenance, trustworthiness, node capture resistance, node replication process, and so on, and for the energy consumption rate process includes network connectivity process, network size and limit, memory storage availability, low computational and communication overhead.

An effective model comprising Authentication-based Secure Routing Clustering (ASRC) strategy figure 1 is developed in this research along with the cluster head selection approach for data transmission from source to destination [22]. In addition, an efficient hash-based authentication strategy is deployed to prevent data loss and counter many potential network attacks. The detailed methodology of the proposed system will be explained as follows in the following section.

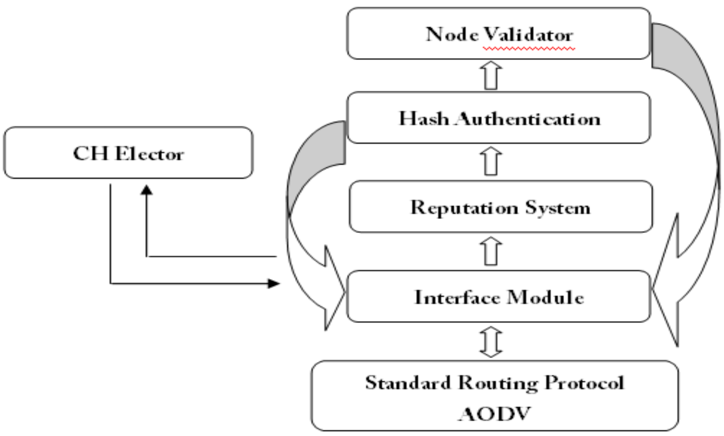

Fig. 1. High Level Block Diagram for ASRC-WSN

2 Literature Review

Multimode amount of research along with various routing strategies was created by number of authors along with the unique techniques. This section will describe the different routing strategies for enhancing the performance of the WSNs along with reducing the rate of energy consumption.

A huge amount of battery power is consumed during the deployment of sensor nodes in WSNs along with certain limited capacities such as sensor node computing capacity, communication interface and limited storage capacity. There is a requirement for an efficient energy conservation protocol along with an enhancement of the node's network lifetime. Proper cluster head selection plays a critical role during the deployment of WSNs and the author develops an energy-efficient cluster head selection protocol based on particle swarm optimization technique [13]. The author considered the overview of nature-inspired particle swarm intelligence-based optimization algorithm during the preliminary analysis. The main objective for PSO consideration is to select the best particle position along with the fitness function calculation to achieve the best results. In addition, a radio frame-based energy model is developed to calculate the value of the internal energy consumption depending on the total amount of data to be transmitted along with the distance from source to destination. The sensor node can calculate the distance between the adjacent node on the basis of the received signal strength and helps in selecting an efficient data path for transmission. The overall process explains the selection of the cluster head based on the PSO algorithm followed by the formulation of the cluster. For the analysis, several parameters such as distance between the average intracluster and average sink distance are considered along with the energy parameter being updated along with velocity and position change. The technique developed is programmed using C language and tested in the MATLAB platform. From the analysis study, the system is tested using various scenarios and good results are achieved in terms of energy consumption, number of data transmitted and network life compared to the Leach and LDC algorithms. In addition, the author develops a novel cluster head election approach by applying fuzzy theory to prolong the lifetime of the WSN system [14]. The author initially conducted a review of many cluster head election mechanisms such as random node election, probability-based election technique, game-based election approach along with the development of a fuzzy-based election communication system. Author's review focuses primarily on the literature of the existing fuzzy logic-based election approach and the study's summary shows that hybrid fuzzy-based c means cluster head election approach displays better results in terms of minimal energy consumption, enhancing node proximity and maximizing the overall system's lifetime. Author develops a novel cluster head selection approach consisting of an energy-efficient algorithm based on flower pollination [15]. WSN's serve as the backbone of the communication network with its numerous real-time applications, and it is essential to use an efficient algorithm to transfer data from the source to the destined path. The author has employed evolutionary characteristics of flower pollination to enhance the communication network's optimization problems. According to the author's survey, the deployment of flower pollination method has shown better results in terms of processing speed along with easy modification and robustness. The author has considered several hypotheses such as the assignment of unique identity to the individual sensor node and the nodes should be static in nature. To transmit the sensed data to the destination, an efficient path should be considered. The sensor nodes are deployed randomly from all nodes in the system with the same initial source of energy. During the development of the algorithm, the formation of the cluster is done by employing Euclidean distance between each node and the selection order of the cluster head is done in accordance with node ID number. Several methods developed such as the LEACH and K-means algorithm are used for analysis, and the results obtained from the study indicates that the FPA algorithm outperforms other existing methods in terms of power consumption rate, energy efficiency and packet drop ratio.

Author develops an efficient data replication protocol along with adjustable grid technique for WSN application [16]. When more sensor nodes are employed for data transmission, the energy of the nodes is depleted during the development of the WSN environment. The author has developed an adjustable data replication scheme (ADR) based on virtual grid technology to improve the performance and lifetime of the sensor nodes. The head node of the particular process is considered as a manager in the individual grid process and the same is in charge of receiving and transmitting data to the other nodes in the virtual grid. The head nodes will determine and select the path for data transmission on the basis of the selected beacon and repeatedly develop a replica node across the query node to provide a balance between the overhead and the rate of energy consumption in the sensor network. The author has considered NS2-based simulation platform for experimental analysis and the study of results shows that the developed technique achieves reduced energy consumption in terms of metrics consisting of number of replica nodes. Another novel energy-efficient data dissemination program for distributed storage in the Internet of Things (IoT) is created by the author [17]. WSN deployment plays an active role in data sensing, collecting from the external environment, in the field of IoT. In general, a large-scale monitoring system is required to provide internet connection to the entire village area. In this research, the author has developed a replica and distribution-based scheme to improve data storage rates in WSNs and minimize the probability of data loss. During deployment, it is observed that the WSN is restricted in the sensor nodes with a certain amount of resources. To overcome this limitation, a low-complex distributed data replication system was developed along with improved distributed storage through data replication mechanism and optimized communication with reduced energy utilization. During the development phase, the sensor network nodes are assumed to continuously gather the data along with periodic recycling in which the data is eliminated from the memory to stop limited memory use. Through the study's comparative analysis, it is observed that there is a relative improvement in energy usage along with lifetime enhancement and balance between data storage in neighborhood nodes. During the node replication process, there is a limitation, such as security threats, in which the data traffic is redirected to the sensor node that does not really exist in the communication system. During the process of finding the shortest path, the node may select any analog node in the network irrelevant to whether it belongs to the same network of various groups and this process is found to be a major issue during data transmission. To overcome this problem, the author [18] has developed a modified algorithm to identify node replication along with prevention of data loss in WSNs. During the development of the WSN network, the author reviewed the various effects of replication attack along with the exploitation of security protocol. Adhoc on Demand Distance Vector (AODV) mechanism was developed along with the adoption of a distributed clustering algorithm for cluster head selection. In addition, a trust mechanism was deployed to improve the routing process. An experimental analysis is performed through network simulators along with effective parameters like packet delivery ratio (PDR), end-to-end delay, and the implementation of NS2 platform. From the study of findings, it is seen that better results are achieved in terms of performance parameters such as PDR, end-to-end delay and efficiency compared to other existing techniques.

The sensor devices deployed will be of limited amount of energy that dissipates the battery energy in the system in the process of developing the wireless sensor network. Thus, the energy efficiency metric is the key design constraint during WSN deployment. Multipath data transfer process is considered to search for the multipath or smallest route to transfer the beacon. Author [19] develops a security-conscious energy-efficient protocol to select the shortest route to transfer data from source node to destination node. The overall process is divided into two main parts, focusing on selecting an efficient route in the first part of the algorithm that maximizes the overall lifetime of the sensor network with its novel metric. The second part focuses on providing the selected path with the optimal level of security based on the risks that can be observed on that particular path. It is observed that in both analytical and extensive simulation process the developed protocol is evaluated and compared with the existing technique. NS2-based simulation platform is considered for analysis and the study results show that improved network lifetime is achieved from the developed technique along with increased lifetime and packet delivery ratio. In addition, the author develops a novel design consisting of the dynamic clustering along with the embedded hashing technique for the application of WSNs [20]. Through the clustering process, the data will only be transmitted to the selected nearby cluster head within the range of the cluster radius and irrelevant to the network size. There is a huge data security requirement when the data is transferred among the operational groups in the application of military networks. This introduces high impact on both node mobility within groups and intra-group traffic. In this research, the author focused mainly on the issue of data aggregation along with data security. Author develops a new Hash-based data authentication, namely DCSHT. The Hash-based key authentication scheme is modified for pre-shared secret key exchange along with SHA-1-based hash functions and ECDH-based secret key sharing algorithm. In addition, a secured one-way hash function is deployed to improve security in military applications. The main features is to track the destination node's target location along with its distance based on the cluster head. The results obtained from the study show that there is no overhead for the developed scheme with less processing time making it suitable for the application of sensors with limited resources. A novel methodology comprising a secure paradigm is developed by author [21] in order to provide tradeoff between data security and energy model.

3 Research Methodology

An efficient cluster head selection algorithm along with efficient data routing will be developed in this research to ensure secure, fast data transfer from source to destination node between or within cluster members. A preliminary study was conducted at the initial stage, followed by the development of intelligent cluster head selection protocol along with the deployment of ASRC-based replication technique and data communication between nodes.

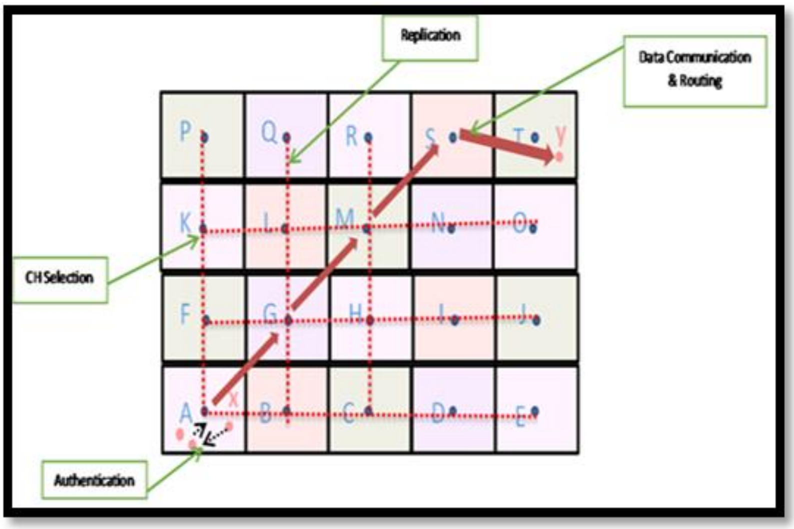

Fig. 2. The proposed system's overall activity diagram

The proposed system's overall activity diagram is shown in Fig. 2. The proposed system's overall process is divided into four stages as CH selection, authentication, replication, and routing data communication. In the first phase, all sensor nodes are engaged in choosing a appropriate CH that can control the network. In the second phase, an efficient hash-based multi-stage authentication system guarantees the real identity of the participating sensor members within a cluster. In the third phase, a data replication mechanism is implemented among CHs of separate clusters and the last one deals with data communication through the path created by the suggested ASRC routing. The individual steps will be described as follows in the following parts:

3.1 Cluster head selection

Initially when all the sensor nodes power on it's assumed that there is no CH in a cluster and all the sensors just begin exchanging control data to acknowledge each other. As shown in Fig.3, the CH election procedure is well managed with four designed modules in our proposed work.

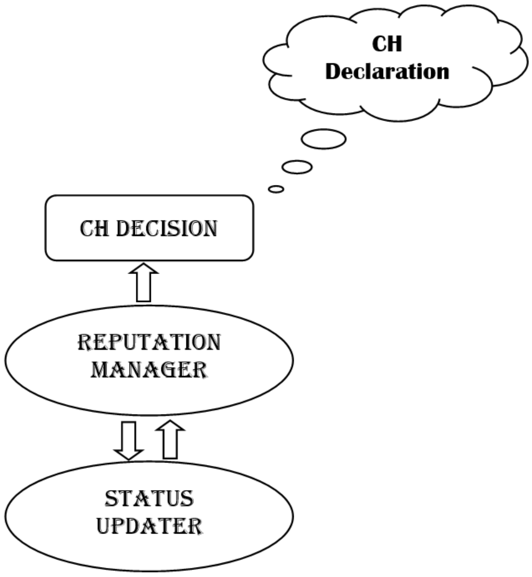

Fig. 3. CH Election modules

Status Updater: This lower-level module will operate in the firmware of each sensor to update all sensor-related parameters to other peer sensors over the network. This module enables the participating sensors in a cluster to understand each other and collect data about their neighbor status. The critical sensor status such as statistics on packet transmission, energy status, place, transmission power will be exchanged over the wireless connection.

Reputation Manager: This module takes input from the status updater and manages the reputation information of a sensor node's nearby neighbours. It maintains a mini light weight database known as the reputation database to store data related to the reputation of all peers. The reputation mechanism is a continuous process and the reputation of all the sensors is updated to their neighbors on a periodic basis. While this process continues for a while, each sensor node accumulates enough information about all nearby neighbors in their reputation database.

CH Decision: This module conducts the main procedure of selecting a cluster head within a cluster by consulting the feedback from the previous reputation manager module. So, first or later, when there is no CH present in a particular cluster, each node applies the cluster election procedure to all neighbors within a cluster by comparing their peers' reputation and position information, which will be available through reputation manager. A peer found to have the highest reputation and energy and also located about the cluster's center position will be considered to be the most acceptable candidate for CH entity in this process. Center location for CH is chosen due to uniform coverage and maximum reachability throughout the cluster, which ensures improved coordination and communication between CH node and other sensors.

CH Declaration: Once the CH entity within each cluster is determined, each participating sensor node transmits this data in the form of a statement message throughout the cluster. All other cluster members, including CH node within that cluster, receive this message. Now each node analyzes this declaration message by comparing the self-node Id with the declared CH ID to check if it is the freshly appointed CH. Whenever the actual selected CH node receives multiple such declaration messages from other cluster member, it found the declared node I d equal to the self Id in this system. It then presents itself as the CH in that cluster and recognizes its fresh identity by replying to the initial statement message. Upon getting this statement response and all sensor nodes assume that a stable CH node is chosen and further stop the continuing CH election operation.

In this study, the arrangement of the sensor node is performed in the form of a grid. The chosen head node of any specific cluster is responsible for tracking and controlling the level of energy consumption in that specific grid region of the cluster. When the sensor node is considered in the network systems, each sensor node grid should have a cluster head or head node capable of sensing the input data, receiving and transmitting the data to the destination node.

Authentication: In the initial step, both the source node (S) and the destination node (D) are assumed to be secured with the hash-based authentication algorithm. The network topology will be found and all the information routes between the source node (S) and the destination node (D) will be authenticated among themselves. The sensor nodes present in the WSNs will understand their specific physical places and estimate their distance with the adjacent nodes along with the quantity of moment it takes to transfer the information between them. Therefore, it can be assumed that along with the time synchronization, sensor nodes have all the details about their particular location. The sensor node also has an idea of the preconfigured parameters such as the Hash authentication interval, the maximum number of iterations consumed by the node along with their reputation information. A cluster member figures out the list of reputed nodes from the reputation database as their first level validator after elapse of each hash authentication interval. The request for verification or authentication will be sent initially to these reputed nodes. In this cycle, an irregular or random number is selected with the ultimate goal of selecting an arbitrary hash job to hash the demand information for sending to the reputed neighbor. A node produces another packet with a hash function to verify the reputed node. After accepting this information, the adjacent reputable entity validates the authenticity of the WSN user by comparing the received hash value with the already stored hash value from its table. If these two values match, the requesting sensor is authenticated for further communication with the head node of the cluster.

Replication Scheme: In this study, the replication system is regarded for effective routing of data packets with less overhead and traversal time. After a CH is selected in the network, the replication procedure comes into effect and each sensor node is well authenticated with the CH. In this context, at any stage of network communication, each CH will maintain two databases for information storage and retrieval. These will be local database (to store all the information of the sensor member within the local cluster) and worldwide database (to store all the information of the sensor member of all other clusters situated horizontally and vertically across the place of a CH). The aim of the data replication will be to make all CHs aware of other current clusters in the network, which involves mostly different cluster members and their location information. To achieve this, each CH node will maintain a replication timer, indicating the approximate time interval after which a CH may periodically initiate the replication process. There may be chances of collision in the replication process when all CH begins transmitting their database data to other CHs simultaneously. To prevent replication packet loss owing to such collision, a distinctive slot assignment method based on TDMA was regarded. This distinctive slot $(TDMA_{scheduling_{slot}})$ is calculated by adding the replication interval timer to some random uniform time, and it would be unique for each CH. In each of these $(TDMA_{scheduling_{slot}})$, the scheduler module situated inside a cluster head begins replicating its local database across the network. The replication packet contains all the info collected by local cluster members from the previously mentioned local database, such as, CH Id, packet timestamp, etc. After any CH publishes this replication packet in the network, its turn for all horizontal and vertically situated CHs to subscribe to this replication details and update their worldwide CH database. In the proposed grid-based cluster arrangement such as, a CH is enabled to calculate whether a replication packet comes from another cluster's horizontally or vertically located CH, by knowing the position information of the sender CH that is embedded in the replication packet of the sender CH. Finally, the replication info is updated to the Global database of each CH. A global view of the entire WSN is acquired within the scope of each CH at the end of replication.

Data communication and Routing: The sensor node will be deployed in the wireless network in the form of grid as shown in Fig.1 in order to achieve effective and efficient data communication. After selecting the cluster head and replication, the source node 'S ' defines all the specified routes through which the information can be transmitted from source to destination using the suggested ASRC routing. The information packets will be transferred through the chosen head node of the virtual grid during the information communication phase. The cluster head captures all the information from the adjacent nodes that will take part in the transmission cycle along with their node degree and source node residual energy information. If there are any extra modifications in the communication network, this data is regarded to be authenticated and frequently updated.

The sensor nodes take benefit of the grid's geometrical characteristics as shown in Fig.1, Where the individual cube represents a cluster in the network in which the cluster head of the specific node is positioned in the middle of the grid. The individual node will be recorded with the cluster head of that specific group and the information of the registration will be distributed horizontally and vertically between the adjacent home cluster. The information transfer and routing system between the sensors of the same cluster (Intra Cluster) or between members of distinct clusters (Inter Cluster) follows a state machine in the purview of present research design. This state machine is shown in Fig. 4.

Whenever any originating source node feels the need for information transfer, a request for transmission is produced from the source node in the cluster to discover the information destination path. This request for transmission is received via multiple enroute node and they switch to the stage of receiving request. Thus, as quickly as the answer message is received by the real location of the information, that node generates ASRC response.

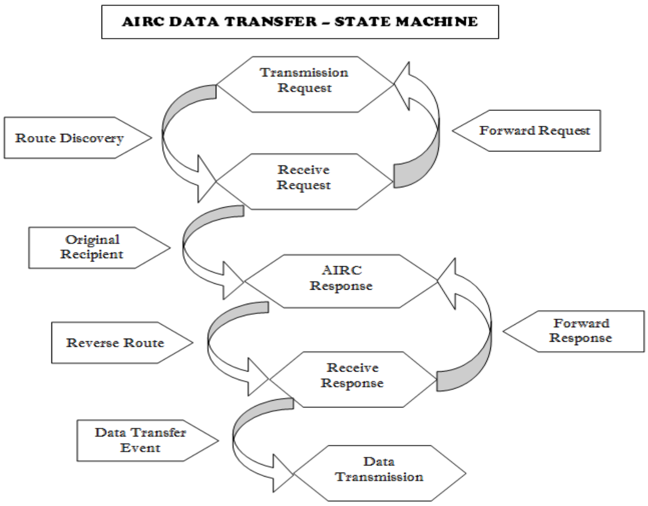

Fig. 4. Data Transmission State Machine for WSN

This ASRC reaction is dispatched via the inverse path of information request to the original source node and lastly data transmission is now initiated via the found path between source and destination.

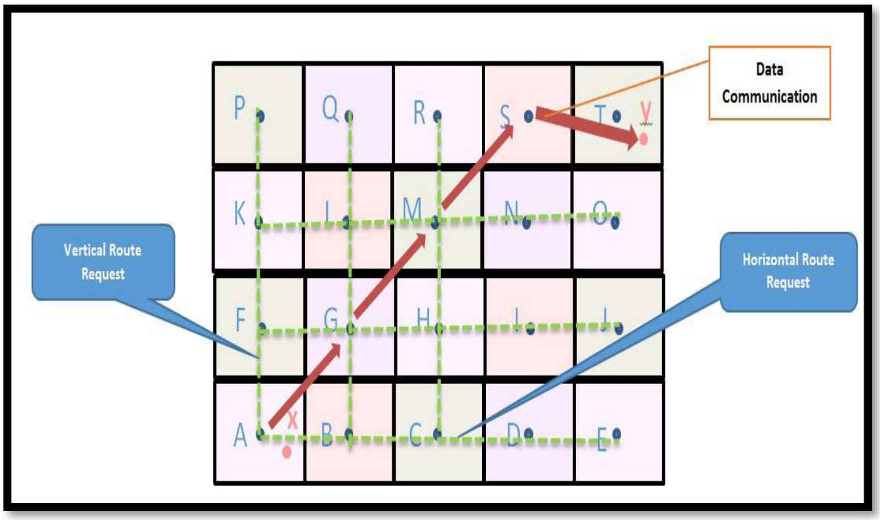

Fig. 5. Data Communication Process

A Cluster head node plays a crucial role in finding the ASRC routing path. When any route request packet is produced from a local cluster member, it first reaches the respective CH node. At first, the CH will inspect their local database to determine whether the target node is situated within the same cluster, i.e. intra-cluster routing, or outside the range of the present cluster, i.e. inter-cluster routing. For external cluster routing, the CH will consult its worldwide database and determine if the target node is placed in any of its horizontal or vertically situated cluster and form the path if the node is discovered in that situation. If the target node is not situated around the vertical or horizontal clusters, then the CH moves one step further by approaching the diagonally situated CH by asking him about the target node data. The diagonally placed CH searches the target again in its horizontal and vertically situated clusters and this method continues until the real destination node is discovered. The above mentioned process is shown in Fig.5.

4 Results and Discussion

In this study, an effective cluster head selection algorithm along with double phase authentication, replication and routing is used to improve communication performance between source node and destination. The algorithm is programmed using C++ language and implemented via NS2-based platform. The findings acquired through the experimental study are as follows:

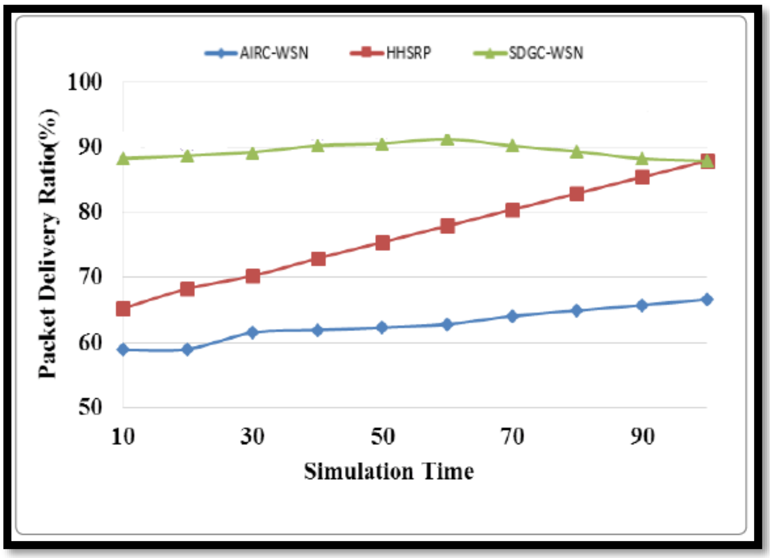

Fig. 6. Evaluation of proposed system in terms of packet delivery ratio

The results captured from the suggested scheme as shown in Fig. 6 show that a better packet delivery ratio is achieved for information transfer relative to other current protocols and methods. Fig.7. depicted the network lifetime statistics. This brings the fact that the proposed ASRC-WSN routing yields better network life due to improved energy efficiency than the existing protocols for the same network size.

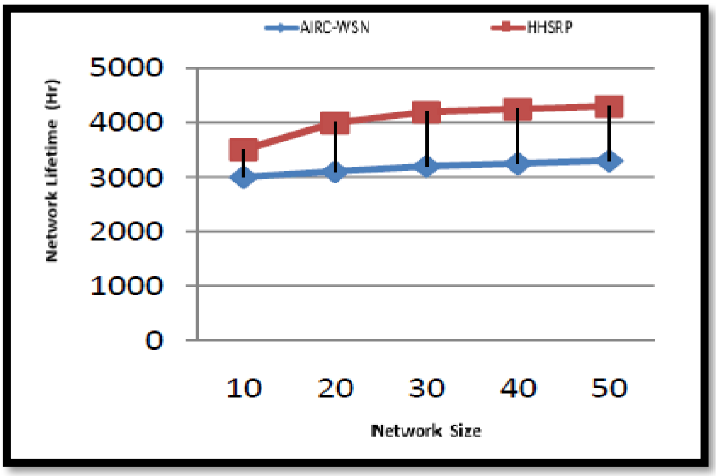

Fig. 7. Performance analysis with respect to the network lifetime

5 Conclusion

The choice of efficient path along with the head of the cluster plays a critical role in determining the lifetime of the network. The existing routing protocols are mainly dependent on the remaining energy and transmission power calculation to capture the shortest route. In this study, an effective cluster head selection algorithm is implemented to select the shortest route from source node to target node for data transmission. In addition, each sensor node is authenticated in advance to participate in the routing process, resulting in network security against many attacks. In addition, the benefit of grid-based network will be regarded through data replication during the information transfer phase. The findings obtained from the research show that the suggested method results from other existing methods in terms of the packet delivery ratio and energy statistics. Due to its high-end safety elements, the suggested protocol can be used in IoT-based information storage and transfer systems in the future.

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