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EFFICIENT CLUSTER HEAD SELECTION AND OPTIMIZED ROUTING IN WIRELESS SENSOR NETWORK (WSN)

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ABSTRACT

Wireless Sensor Networks (WSN) comprises with numerous sensor nodes which are connected with each other through the usage of short distance wireless links. The data transfer among the individual nodes is found to be energy constrained and there is a huge requirement of energy efficient protocol in WSNs. Furthermore, deployment of large number of sensor nodes increases the network size which in turn increases the rate of energy consumption. In this research, an efficient protocol is developed comprising the formation of grid based communication network, selection of efficient path through cluster head selection and data communication. Furthermore, multi stage authentication is implemented to provide security for the data transfer from source node to destination node. Implementation is carried out through NS2 based platform and the result obtained shows that proposed system outperforms other existing techniques in terms of packet delivery and energy utilization through network lifetime.

Keywords: *Wireless Sensor Networks (WSN), Cluster Head(CH) Selection, Replication, Data Communication.*

1. INTRODUCTION

In recent times, the advances in miniaturized scale electromechanical frameworks have facilitated the improvement of small, minimal effort, low control, and multifunctional property embedded sensors, which are fit for performing numerous tasks such as detecting, collection of data and pre-processing, and enabling communication through intermediate devices [1]. The trends of Wireless Sensor Network (WSN) is defined as a distribution network comprising of numerous number of sensor nodes, which are deployed in a geographical region over a widespread land area to track a specific physical phenomenon. There is no requirement for predetermination or engineering requirements for the selection of places that are considered for deployment of WSNs [2]. This empowers the deployment of sensor nodes in a random manner with inaccessible terrains or during the requirement of communication in disaster relief operations. Furthermore, this infers a requirement for effective network protocols and deployment of self-intelligence based organizing abilities. Another distinct feature of the wireless sensor network is its property of collaborative approach among the sensor nodes, in which it is deployed to perform several specific tasks, such as data aggregation and fusion, identification and its measurement techniques [3]. Rather than sending the raw information to the end node, sensor node utilizes their inbuilt processing capabilities to locally perform the computations and transfer just the required and processed information at that particular time. In general, information from every sensor is gathered to create an essential outcome of information database [4].

The application of wireless sensor networks can be extended to an extensive variety of resources and can be used in numerous fields such as medical fields to transfer the data [5], industrial and military applications [6], monitoring the ecological factors [7], analysis of scientific data [8], and home network systems [9]. In particular, WSNs empower medical specialists to recognize predefined indications by observing the physiological information of patients remotely. In the field of military appliances, WSNs can be utilized to distinguish atomic, nuclear, and chemical assaults and to detect the presence of harmful materials, avert foe assaults by means of alarms when adversary flying machines are spotted,

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and keep in touch with the friendly forces through monitoring tools and ammunition. Besides, WSNs are likewise helpful for checking timberland fire, watching natural and organic environments, and recognizing surges and places with earth quakes. As far as non-military personnel uses of WSNs, it is conceivable to decide spot accessibility in determining the public parking lot, track dynamic identification at the working environment, watch security out in the open places such as banks and shopping centres, and screen roadway activity in a certain time. Moreover, WSNs can address the issues for logical applications in terms of space and interplanetary investigation, application of physics with material science, and profound undersea investigation [10]. During these processes, several performance factors also play an active role in determining the capabilities of the sensor network. Such factors are taken care by the management and control units within sensor, which are designed to monitor the usage of resources, distribution of task, end point delivery and so on. From the above mentioned cases, the important concerns which can be considered as generic design characteristic and system objectives 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

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

The main theme considered during the deployment of wireless sensor network is to decrease the energy utilization in the communication system through clustering. In the process of clustering, one node is chosen to be a group head of the cluster. The cluster head handles larger part of the data processing steps in sensor nodes and cluster computation. The clustering technique is seen to be the vital process in system, since information exchange between groups should be transferred in effective and efficient manner. The most imperative limitations of existing techniques in WSNs are to control the rate of energy consumption and keeping up the security in the system. Because of broad utilization of wireless sensor systems, it is important to enhance its security during the transmission of data from source to destination. Furthermore, the WSNs are high prone to the physical attacks, thus some security driven techniques ought to be incorporated during the transmission based on the designed routing techniques and communication strategy. The key necessities of security comprise with verification, secrecy maintenance, trustworthiness, resistance against the capture of node, process of node replication, and so forth and for the process of rate of energy consumption comprises with the process of network connectivity, size of the network and its

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limit, availability of memory storage, low computational and communication overhead.

In this research, an effective model comprising Authentication based Secure Routing Clustering (ASRC) strategy figure 2 is developed along with the cluster head selection approach for data transmission from source to destination [22]. Furthermore, an efficient hash based authentication strategy is deployed to avoid data loss and counter many potential network attacks. The detailed methodology of the proposed system will be explained in the following section as follows.

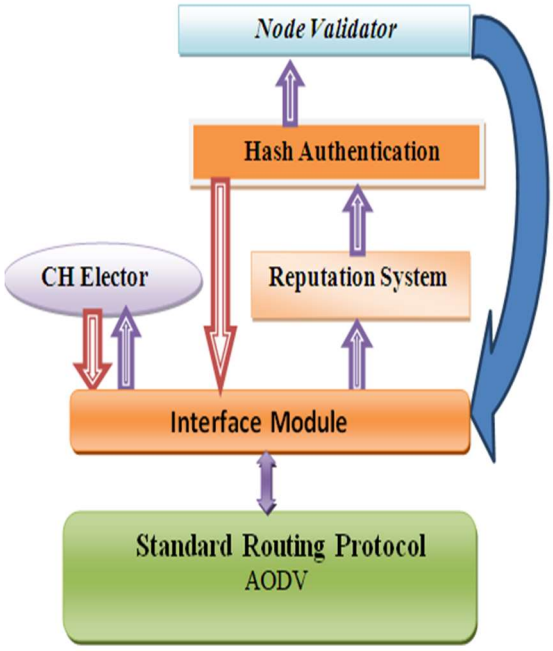

Fig 2. High Level Block Diagram for ASRC-WSN

2. LITERATURE REVIEW

Multimode amount of research along with numerous routing strategies have been developed by number of authors along with the unique techniques. The different routing strategies to enhance the performance of the WSNs along with reduction in the rate of energy consumption will be described in this section.

During the deployment of sensor nodes in WSNs, a huge amount of battery power is consumed along with certain limited capacities such as computing capacity of the sensor node, communication interface and the limited amount of storage capacity. So, there is a requirement of efficient protocol for conservation of energy along with enhancement in the network lifetime of the nodes. Proper selection of cluster head plays a critical role during the deployment of WSNs and an energy efficient cluster head selection protocol on the basis of particle swarm optimization technique is developed by author [13]. During the preliminary analysis, the author has considered the overview of nature inspired particle swarm intelligence-based optimization algorithm. The main objective for the consideration of PSO is to select the best particle position along with the calculation of fitness function to achieve best results. Furthermore, radio framework-based energy model is developed to calculate the value of energy consumption which intern depends on the total amount of data that is to be transmitted along with the distance from source to destination. On the basis of received signal strength, the sensor node can calculate the distance between the adjacent node and helps in selection of efficient data path for transmission. The overall process explains about the cluster head selection which is on the basis of PSO algorithm followed by cluster formulation. Several parameters such as distance among the average intra cluster and average sink distance is considered for the analysis along with energy parameter which is updated along with change in velocity and position. The developed technique is programmed using C language and tested in MATLAB platform. From the study on analysis, it is seen that system is tested using different scenario and better results in terms of energy consumption, number of data transmitted and network lifetime is achieved compared to Leach and LDC algorithm. Furthermore, a novel cluster head election approach through the application of fuzzy theory in order to prolong the lifetime of the WSNs system is developed by author [14]. Initially, the author has conducted review on several cluster head election mechanisms such as random election of nodes, probability-based election technique, game theory-based election approach along with the development of fuzzy based election communication system. The review done by author mainly concentrates on the literature of existing fuzzy logic based election approach and the summary of the study shows that hybrid fuzzy based c means cluster head election approach shows better results in terms of minimal energy consumption, enhancing the vicinity of the nodes along with maximizing the lifetime of the overall system. A novel cluster head

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selection approach comprising an energy efficient algorithm on the basis of flower pollination is developed by author [15]. Wireless sensor networks serve as a backbone of communication network with its numerous real time applications and it is necessary to use efficient algorithm for data transfer from the source to destined path. The author has employed evolutionary characteristics of the flower pollination to enhance the optimization problems arise in the communication network. As per the survey by the author, deployment of flower pollination technique has shown better results in terms processing speed along with easy modification and robustness. The author has considered several assumptions such as unique identity will be assigned to the individual sensor node and the nodes should be static in nature. Efficient path should be considered to transmit the sensed data to the destination. The sensor nodes are randomly deployed in the system with equal initial energy source from all the nodes. During the development of algorithm, the cluster formation is done by employing Euclidean distance between each node and the order of cluster head selection are done in accordance with node ID number. Several developed methods like, LEACH and K-means algorithm are used for the analysis and the results obtained from the study shows that FPA algorithm outperforms other existing techniques in terms of rate of energy consumption, energy efficiency and packet drop ratio. The author has summarized the study by stating that in future, further network lifetime can be enhanced along with optimization in the cluster time.

An efficient data replication protocol along with adjustable grid technique for the application of WSN is developed by author [16]. During the development of WSN environment, the energy of the nodes are depleted when more number of sensor nodes are employed for the data transmission. The author has developed adjustable data replication scheme (ADR) on the basis of virtual grid technology in order to enhance the performance and lifetime of the sensor nodes. In individual grid process, the head node of the particular process is considered as a manager and the same is in charge for data reception and transmission to the other nodes in virtual grid. The head nodes will determine and select the path for data transmission on the basis of selected beacon and it repeatedly develops a replica node across the query node to provide balance between the overhead and the rate of energy consumption in the sensor network. The author has considered NS2 based simulation platform for the experimental analysis and the study on results show that a reduced energy consumption in terms of metrics comprising number of replica nodes is achieved from the developed technique. Another novel energy efficient data dissemination scheme for the purpose of distributed storage in Internet of Things (IoT) is developed by author [17]. In the field of IoT, deployment of WSNs plays an active role for data sensing, collection from the external environment. In general, there is a requirement of large-scale monitoring system to provide internet connection to the entire village areas. In this research, the author has developed a replica and distribution-based scheme to enhance the rate of data storage in WSNs and minimize the data loss probability. During the deployment, it is observed that the WSN is constrained with certain amount of resources in the sensor nodes. To overcome this limitation, a low complex distributed data replication system has been developed along with enhancement in distributed storage through data replication mechanism and optimized communication with reduction in the energy utilization. During the development stage, it is assumed that the sensor network nodes are continuously collecting the data along with periodic recycling in which the data is removed from the memory to avoid limited memory usage. Through the comparative analysis from the study, it is observed that there is a relative improvement in the energy usage along with enhancing the lifetime and providing balance among the storage of data in the neighborhood nodes. There arises a limitation during the process of node replication such as security threats in which the data traffic is redirected to the sensor node which really does not exist in the communication system. During the process of finding the shortest path, the node can select any analogous node in the network irrelevant of whether it belongs to the same network of different group and this process is found to be a major issue during the data transmission. In order to overcome this problem, the author [18] has developed a modified algorithm to identify the replication of nodes along with the prevention of data loss in WSNs. The author has reviewed the different effects of replication attack along with the exploitation of security protocol during the development of WSN network. Adhoc On Demand Distance Vector (AODV) mechanism has been developed along with the adoption of distributed clustering algorithm for cluster head selection. Furthermore, a trust mechanism has been deployed to enhance the routing process. An experimental analysis is carried out through network simulators along with effective parameters such as packet delivery ratio (PDR), end to end delay and NS2

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platform is used for implementation. From the study done on findings, it is seen that better results in terms of performance parameters such as PDR, end to end delay and efficiency is achieved compared to other existing techniques.

In the process of development of wireless sensor network, the sensor devices deployed will be of limited amount of energy which dissipates the battery energy in the system. Hence, the energy efficiency metric is the key design constraint during the deployment of WSNs. The process of multipath data transfer is considered to search for the multipath or smallest route to transfer the beacon. A security aware energy efficient protocol for the selection of shortest route to transfer data from source node to destination node is developed by author [19]. The overall process is divided into two main parts, in the first part in the algorithm concentrates about the selection of an efficient route which maximizes the overall lifetime of the sensor network with its novel metric. The second part concentrates on providing the optimal security level to the selected path on the basis of risks that can be observed on that particular path. It is observed that the developed protocol is both evaluated and compared with the existing technique in both analytical and extensive simulation process. NS2 based simulation platform is considered for the analysis and the result obtained from the study shows that better network lifetime is achieved from the developed technique along with increase in lifetime and packet delivery ratio. Furthermore, a novel design comprising the dynamic clustering along with the embedded hashing technique for the application of WSNs is developed by author [20]. Through the process of clustering, the data will be transmitted only to the selected nearby cluster head within the range of the cluster radius and irrelevant to the size of the network. In the application of military networks, there is a huge requirement of data security when the data is transferred among the operational groups. This introduces high amount of impact on both the node mobility within the groups and traffic among intra group. In this research, the author has mainly concentrated on the data aggregation problem along with data security. A new Hash based data authentication is developed by author namely DCSHT. The Hash based key authentication scheme is modified along with the SHA-1 based hash functions and ECDH based secret key sharing algorithm for pre-shared secret key exchange. Furthermore, a secured oneway Hash function is deployed to enhance the security in military applications. The main features is to track the target location of the destination node along with its distance on the basis of cluster head. The results obtained from the study shows that the developed scheme does not have any overhead with less processing time making it suitable for the application of sensors with limited resources. In order to provide tradeoff amongst the data security and energy model, a novel methodology comprising secure paradigm is developed by author [21]. Through this deployment, the security acts as an optimal tradeoff between the resource utilization and data transfer. The author has introduced two types of sensor nodes with different capabilities and deployed novel protocol namely model of secure paradigm to enhance the security in the WSN network. The developed algorithm make use of Hash based authentication code along with the pairwise key establishment for the data segregation. MTALAB based numerical platform is considered for the experimental analysis and the results obtained from the study outperforms other existing techniques in terms of processing time along with the rate of energy consumption.

From the above-mentioned literature review, it is seen that major limitations in WSNs are observed in terms of rate of energy consumption, authentication and total packet deliver ratio which will be ascertained in this research.

3. RESEARCH METHEDOLOGY

In this research, an efficient cluster head selection algorithm along with efficient data routing will be developed to ensure secure, fast data transfer from source to destination node between or within cluster members. At the initial stage, a preliminary study has been carried out followed by the development of intelligent protocol for selection of cluster head along with deployment of ASRC based replication technique and data communication among the nodes.

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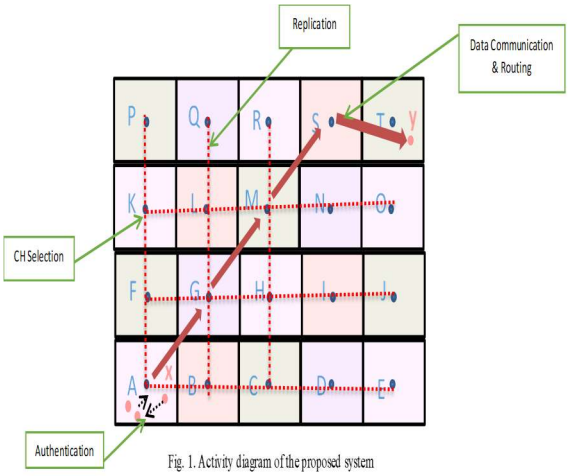

Fig. 1. Activity diagram of the proposed system

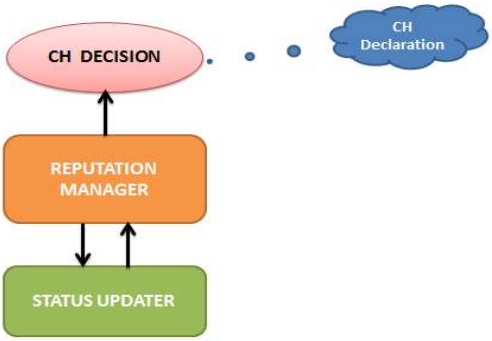

Fig. 3. CH Election modules

The overall Activity diagram of the proposed system is shown in Fig. 1. The overall process of the proposed system is divided into four stages as CH selection, authentication, replication and data communication using routing. In the first stage, all the sensor nodes engage in selecting a suitable CH, which can command the network. In the second stage, an effective hash based multi stage authentication mechanism ensures the genuine identity of the participating sensor members within a cluster. In the third stage, a data replication mechanism is deployed among CHs of different clusters and the last deals with the data communication through the route established by proposed ASRC routing. The individual steps will be explained in the following sections as follows:

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 sensors just start exchanging control information to recognize each other. The CH election procedure is well managed with four designed modules in our proposed work as shown in Fig.3.

Status Updater: This lower level module will run inside every sensor's firmware to update all sensor related parameters to other peer sensors over the network. This module helps the participating sensors within a cluster to know about each other and gather neighbor status information. The critical sensor status such as packet transmission statistics, energy status, location, transmission power will be exchanged over the wireless link.

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

CH Decision: This module performs the key operation of electing a Cluster Head within a cluster by consulting the feedback from the earlier reputation manager module. So, initially or at later stage, when there is no CH present in a particular cluster, every node applies the cluster election procedure on all neighbors within a cluster by comparing the reputation and position information of its peers, which will be available through reputation manager. In this process, a peer who will be found to have highest reputation and energy and also located about the center position of the cluster will considered to be the most acceptable candidate for CH entity. The center location for CH is preferred because of uniform coverage and maximum reachability throughout the cluster, which ensure

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enhanced coordination and communication between CH node and other sensors.

CH Declaration: Once the CH entity inside each cluster is determined, every participating sensor node broadcasts this information throughout the cluster in the form of a declaration message. This message is received by all other cluster members including CH node within that cluster. Now every node analyses this declaration message by comparing the self-node id with the declared CH ID to check if it's the newly elected CH. In this mechanism, whenever the actually selected CH node receives multiple such declaration message from other cluster member, it found the declared node id to be equal with self id. It then declares itself as the CH in that cluster and acknowledges it's new identity by replying the original declaration message. Upon receiving this declaration reply, and all sensor nodes assumes that a stable CH node is selected and stops the ongoing CH election procedure further.

In this research, the arrangement of sensor node will be done in the form of grid. The selected head node of any particular cluster is responsible for monitoring and controlling the rate of energy consumption in that particular grid area of cluster. When the sensor node is considered in the network systems, then each grid of the sensor node should have a cluster head or head node to sense the input data, receive and transmit the data to the destination node.

3.2 Authentication

At the initial step, it is assumed that both the source node (S) and the destination node (D) will be assumed to be secured with hash-based authentication algorithm. The topology of the network will be discovered and all the number of data paths between the source node (S) and the destination node (D) will be authenticated among themselves. The sensor nodes present in the WSNs will know their particular physical locations and it estimates their distance with the adjacent nodes along with the amount of time consumed to transfer the data between them. Hence, it can be assumed that sensor nodes have all the details about their particular location along with the time synchronization. Furthermore, the sensor node has an idea about the preconfigured parameters such as Hash authentication interval, maximum number of iterations consumed by the node along with their reputation data. After elapse of each hash authentication interval, a cluster member figure outs the list of reputed nodes from the reputation database as their first level validator. The verification or authentication request will be initially sent to these reputed nodes. In this cycle, an irregular or random number is picked with the end goal that it picks an arbitrary hash work for hashing the demand information for sending towards the reputed neighbor. A node produces another packet for verification to the reputed node along with hash function. After accepting this data, the adjacent reputed entity validates the authenticity of WSN user by comparing the received hash value with the already stored hash value from its table. If these two value matches, then the requesting sensor is authenticated for further communication with cluster head node.

3.3 Replication Scheme

The replication scheme in this research is considered for efficient routing of data packets with less overhead and traversal time. The replication procedure comes into effect after a CH is selected in the network and each sensor node is well authenticated with the CH. In this context, each CH will maintain two databases for information storage and fetching at any stage of network communication. These will be local database (to store all the sensor member details within local cluster) and global database (to store all the sensor member details of all other clusters located horizontally and vertically across a CH's location). The purpose of the data replication will be to make all the CHs aware of other existing clusters in the network, which includes mostly various cluster members and their location information. In order to achieve this, each CH node will maintain a replication timer, which indicates the approximate time interval after which a CH can initiate the replication process on periodic basis. There may be chances of collision in the replication process, when all CH starts transmitting simultaneously to replicate their database information to other CHs. To avoid replication packet loss due to such collision, a TDMA based unique slot assignment technique has been considered. This unique slot ($TDMA_{schedulin\ slot}$) is computed by adding some random uniform time with the replication interval timer and it would be unique for each CH. In each such $TDMA_{scheduling_{slot}}$, the scheduler module located inside a cluster head starts the replication of its local database across the network. The replication packet contains all local cluster members' info

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collected from local database mentioned earlier, such as, CH id, packet timestamp etc. After this replication packet is published in the network by any CH, its turn for all the horizontal and vertically located CHs to subscribe this replication info and update their CH global database. In the proposed grid based cluster arrangement like, a CH is enabled to calculate whether a replication packet is coming from horizontally or vertically located CH of other cluster, by knowing the sender CH's position info which is embedded in the sender CH's replication packet. Finally, the replication info is updated into each CH's Global database. At the end of replication, a global view of the entire WSN is acquired within the scope of each CH.

3.4 Data communication and Routing

In order to achieve effective and efficient data communication, the sensor node will be deployed in wireless network in the form of grid as shown in Fig.1. After the selection of cluster head and replication, the source node 'S' identifies all the designated paths through which the data can be transferred from source to the destination using proposed ASRC routing. During the process of data communication, the data packets will be transmitted through the selected head node of the virtual grid. The cluster head captures all the data from the adjacent nodes which will take part in the transmission process along with their node degree and the residual energy data from source node. These information is considered to be authenticated and frequently updated if there is any additional changes in the communication network.

The sensor nodes take advantage of the geometrical properties of the grid as shown in Fig.1, where the individual cube represents a cluster in the network, in which the cluster head of the particular node will be placed at the center of the grid. The individual node will be registered to the cluster head of that particular group and the registration details will be shared among the adjacent home cluster in a horizontal and vertical direction.

The data transfer and routing mechanism among the sensors of the same cluster (Intra Cluster) or among the members of different clusters (Inter Cluster) follows a state machine in the purview of current research design. This state machine is depicted in Fig. 4.

Whenever any originating source node feels the need of data transfer, a transmission request is generated in the cluster from the source node for discovering the route of the destination of data. This transmission request is received by multiple enroute node and they switch to the receive request stage. In this way, as soon as the response message is received by the actual destination of data, ASRC response is generated by that node.

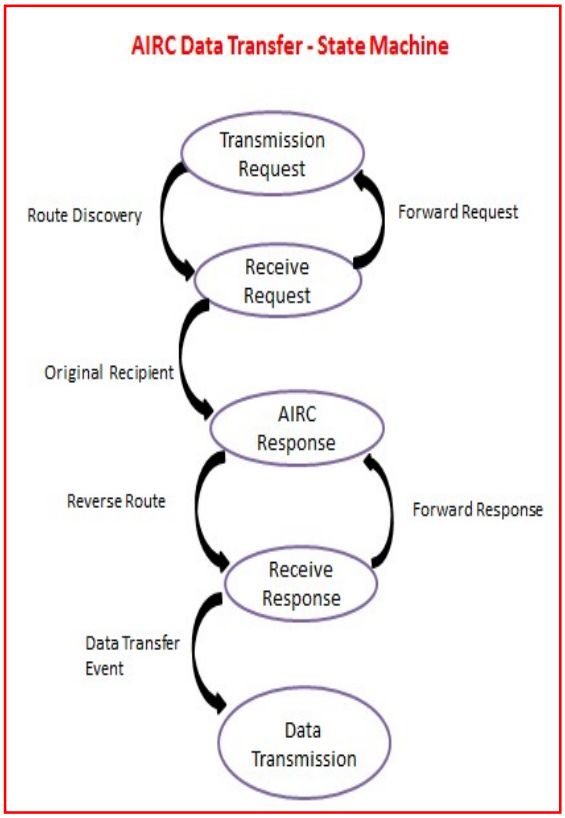

Fig.4. Data Transmission State Machine for WSN

This ASRC response is dispatched to the original source node via the reverse route of data request and finally data transmission is initiated now between the source and destination via the discovered route.

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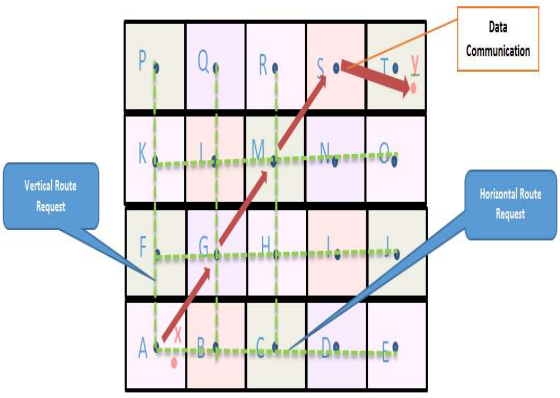

Fig.5. Data Communication Process

A Cluster head node plays a vital role in discovering the route for ASRC routing. When any route request packet is generated from local cluster member, it reaches to the corresponding CH node at first. The CH will check their local database at first to determine, if the destination node is located within the same cluster i.e. intra cluster routing or it's outside the scope of current cluster i.e. inter cluster routing. For outside cluster routing, the CH consults its global database and determine if the destination node is placed in any of its horizontal or vertically located cluster and form the route in case the node is found in such position. In case, the destination node is not located around the vertical or horizontal clusters, then the CH moves one step further by approaching to the diagonally located CH by requesting him about the information of destination node. The diagonally located CH again searches the destination in its horizontal and vertically located clusters and this process goes on until the actual destination node is found. The above mentioned process is depicted in Fig.5.

4. RESULTS AND DISCUSSION

In this research, an efficient cluster head selection algorithm along with the double stage authentication, replication and routing is utilized to enhance the communication performance between the source node and destination. The algorithm is programmed using C++ language and implemented through NS2 based platform. The results obtained through the experimental study are as follows:

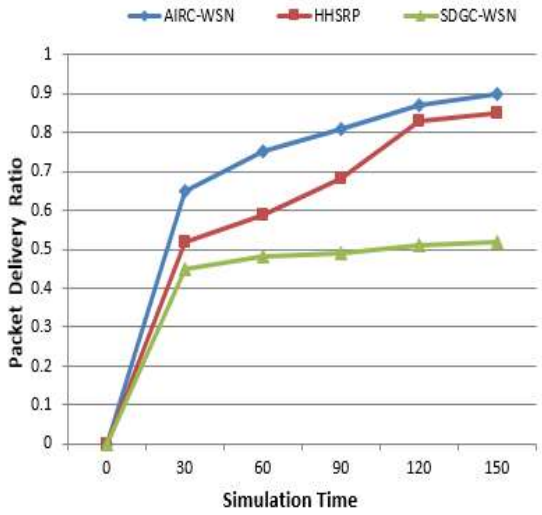

Fig. 6. Evaluation of proposed system in terms of packet delivery ratio

The results captured from the proposed system as shown in Fig. 6 shows that better packet delivery ratio is obtained for data transfer compared to other existing protocols and techniques. Fig.7. represented the statistics for network lifetime. This brings out the fact that, for the same network size, the proposed ASRC-WSN routing yields better network lifetime due to improved energy efficiency than the existing protocols.

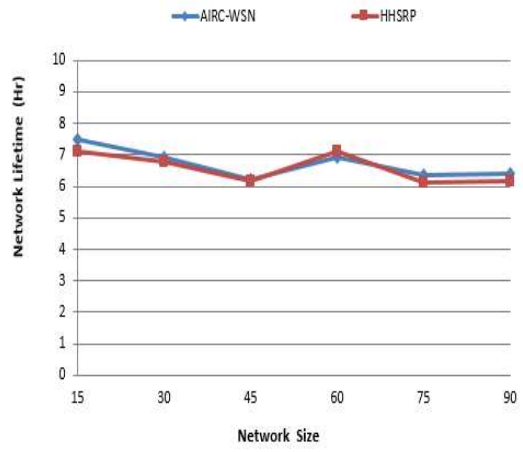

Fig. 7. Performance analysis with respect to the network lifetime

5. CONCLUSION

The selection of effective route along with the cluster head plays a critical role in determining the

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network lifetime. The existing routing protocols are primarily dependent on the residual energy and calculation of transmission power to capture the shortest path. In this research, an efficient cluster head selection algorithm is deployed to select the shortest path for data transmission from source node to destination node. Moreover, each sensor node is authenticated beforehand in order to participate in the routing procedure, ensuing security of network against many attacks. Furthermore, the advantage of grid based network will be considered during the data transfer process by using data replication. The results obtained from the study shows that the proposed technique outcomes other existing techniques in terms of packet delivery ratio and energy statistics. In future, the proposed protocol can be used in IoT based systems for data storage and transfer because of its high end security aspects.

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