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RECEIVED SIGNAL STRENGTH BASED ENERGY AND LOCATION AWARE CLUSTER ROUTING PROTOCOL (RSSELACRP) FOR WIRELESS SENSOR NETWORKS

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***Abstract*-This article restores an ensemble of location aware protocol termed as received signal strength, energy and location aware cluster routing protocol (RSSELACRP) based on signal strength and residual energy. Among the wireless sensor nodes, the cluster-head sensor node will be chosen based on the residual energy and received signal strength. Clustering is performed based on the nodes location information conceived from the GPS. Relay node selection is carried out by using chain of cluster-head sensor nodes. An adaptive intercluster mechanism is proposed. The performance metrics such as number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops are taken to considering the performance of RSSELACRP and is compared with the AELAR [13] and ELACRP protocol. Simulation results show that RSSELACRP outperforms AELAR [13] and ELACRP in terms of chosen performance metrics.**

Keywords-Energy and location aware clustering; received signal strength; sensor networks; relay nodes.

I. INTRODUCTION

With the recent development of wireless networking, sensors do play an important role in the application areas of physical, environmental conditions viz., temperature, underwater networking, and surveillance. Wireless sensor networks (WSNs) consist of large populations of wirelessly connected nodes, capable of computation, communication, and sensing [19]. Routing is the process by which data transmission takes place for reliable delivery of packets. This research work aims in development of an on–demand routing protocol. The received signal strength, energy and location aware clustering mechanism is incorporated in the on-demand routing protocol. Wireless sensor networks (WSNs) are decentralized systems by which the sensor nodes are equipped with batteries. It comprises of spatially distributed autonomous sensor nodes equipped with a radio transceiver which is the combination of transmitter and receiver. Battery lifetime is the important restraint that has high impact on reducing the network performance. Hence it is essential to build up energy conservation model for wireless sensor networks. Also, the link quality plays an important role in routing. The proposed paper has the following objectives. The proposed protocol provides a clustering mechanism based on received signal strength and energy based on-demand routing. Also, the proposed routing mechanism must fulfil inter-cluster routing that must result in improved number of packets delivered to the sink, reduced energy utilization rate along with energy standard deviation and decreased average number of hops.

II. LITERATURE REVIEW

The literatures contain various hierarchical energy-efficient clustering algorithms in order to extend the lifetime of the wireless sensor network [2 – 10]. Time of arrival, time difference of arrival and received signal strength indicator metrics are used in the literature [14][17]. LEACH is the routing protocol primarily used for periodical data-gathering applications proposed by Heinzelman et al. [11] that made use of randomized rotation of cluster-heads for distributing energy consumption over all the nodes in the network along with determining optimum number of cluster head nodes. LEACH has data transmission phase in which every cluster-head sensor node (CH nodes are chosen based on the maximum residual energy) forwards packet to the base station. Also it is noteworthy in the assumption that the residual energy will be propagated inside the network.

In [7] the authors' proposed clustering mechanism consisted of two stages. Primarily at the cluster-head electing stage, every sensor node in the network advertises with a random delay to the other sensor node. This process will take place and get cancelled based on the scheduled advertisement. Once when the initial clusters are

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formed, the cluster member sensor node finds a nearby cluster-head in order to establish an energy-saving data relay link.

HEED [8] brought in cluster radius parameter that emphasizes the transmission power to be used for intra-cluster broadcast. Based on the residual energy every sensor node has the initial probability for becoming a tentative cluster-head. The final heads are chosen based on the intra-cluster communication cost. HEED stops its process once when it reaches the constant number of iterations, and achieves fairly uniform distribution of cluster-heads across the network. A voting based clustering algorithm shortly termed as VCA [9] extends from HEED. The sensor nodes among the network vote for their neighbors in order to choose suitable cluster-heads. VCA follows two strategies for poising the intra-cluster workload among the cluster-head sensor nodes.

Cooperation among unknown-location nodes can improve network positioning coverage as well as localization accuracy particularly in the poor electronic conditions [15]. Angle of arrival (AoA) measurements are employed in [16] for calculating the angle differences of two different nodes. The major issue in designing routing protocol for wireless sensor network is the link reliability. Lindgren et al. designed a routing mechanism PROPHET. It utilizes the history of nodes and non-randomness in the nodes' behavior for offering improved packet delivery ratio along with lower overhead [18]. The routing also consistently targeted on making use of probabilistic routing and mobility prediction. On the other hand, most of the probabilistic routing is performed among intermittently connected networks by which probabilistic routing techniques are used for delivering data with minimal delay.

III. PROPOSED WORK

A. Assumptions

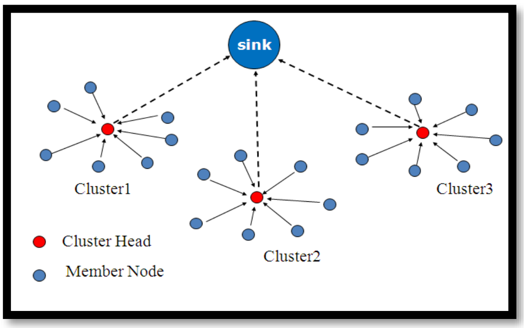

Figure 1. CLUSTERING IN WIRELESS SENSOR NETWORKS

In this research work a heterogeneous and hierarchical wireless sensor network is chosen. The hierarchical wireless sensor network system consists of three types of devices namely sink node which is base station, cluster-head nodes shortly termed as CH, and the sensor nodes. The heterogeneity of the network is deployed by varying the transmission range of the sensor nodes. The three types of nodes have varying transmission range. The sink node has the transmission range of 200 meters. The base station sensor nodes have 300 meters of transmission range. The rest of the nodes in the sensor network have 150 meters of transmission range. The system is placed into a two-dimensional area. The algorithm for cluster formation is depicted in 3.3. It is assumed that once when the clusters are established and the cluster-head is elected, there is an exchange of messages. The device types exists on the network, and residual energy of the sensors pertaining to their clusters. Only one sink node is placed in the network system which communicates with cluster-heads through wireless connections. The cluster-heads are distributed around the sink node and each cluster-head can communicate with other cluster-heads directly using one-hop communication along with the sensors inside the cluster that is located in the middle of each cluster. The cluster-head mechanism depicted in 3.3 chooses the cluster-head which is a device with more residual energy, than ordinary sensor nodes. Each cluster is composed of a set of static and homogeneous wireless sensor nodes with single omni-directional antennas forming a multihop network. Each sensor node can perform both computation and communication task simultaneously. All the sensor nodes are identical to their processing time. Also, all the sensor nodes have the same communication range and transmission time. The communication link works at half duplex mode fashion, which means the transmission is in one direction at a time. The communication channel does not allow transmitting and receiving data simultaneously, since full duplex communication channel cost is high in deployment among sensor nodes.

It is noteworthy to assume that the cluster-head nodes CHs always know the geographical position using Global Positioning System (GPS) devices inbuilt on it. GPS is a space based satellite navigation system. GPS offers location of the sensor node along with the time information. It is to be noted that the GPS works well in almost all weather conditions. GPS will function as an unobstructed line of sight to four or more GPS satellites. The GPS satellite has steady atomic clocks. The clocks are synchronized to one another with the clocks on ground. The drift that can happen from true time is maintained on the ground and corrected periodically. Also the locations of the satellite are also monitored in a precise fashion by the GPS device placed on the sensor network. The GPS devices do have clocks and it transmits the current time and position to the satellite. The GPS receiver keeps an eye on multiple satellites and it determines the exact position of the receiver sensor node. It is to be kept in mind that at least four satellites need to be in the view of the sensor node in order to compute four quantities (three position coordinates and clock deviation from satellite time).

Each GPS satellite continually broadcasts a signal that has pseudorandom code and a message. The pseudorandom code contains 0s and 1s which is well known to the receiver. By time-aligning a receiver generated version and the receiver measured version of the code, the time of arrival (ToA) of a defined point in the code sequence shortly termed as Epoch is found in the receiver clock time scale. The message contains time of transmission (ToT) of the code Epoch and the satellite position at that time.

B. Energy Consumption Model

The energy model used in this research work is adopted and described precisely in this section [1]. Ecomp denotes for energy consumption caused by a task running on a sensor. The energy consumption of executing N clock cycles with CPU speed f as

$$E_{comp}(V_{dd}, f) = NCV_{dd}^2 + V_{dd}\left(I_0 e^{\frac{V_{dd}}{nVr}}\right)\left(\frac{N}{f}\right) \quad (1)$$

$$f \approx K(V_{dd} - c) \quad (2)$$

Where VT denotes the thermal voltage and C, I0, N, K, C are processor-dependent parameters. It is considered that a sensor node will consume different energy within its communication range, Etx(l,d) and Erx(l), where l represents the size of the data and d represents distance. The duty cycle and sleep cycle of sensor nodes is followed as per the above said energy consumption model, where sensor nodes switch to sleep mode for reducing energy consumption and when no communication and computation tasks are allocated for them. Also, the energy consumption model that has been adopted will eliminate energy consumptions of a radio in other possible states (e.g., idle listening) for sensor nodes.

C. Received Signal Strength, Energy and Location Aware Cluster Routing Protocol (RSSELACRP)

A clustering architecture offers fault tolerance along with network scalability that will give the outcome of exploiting the network resources. Clustering can be applied effectively for resource management, routing and location management and also drastically lessen both communication overhead and computational time complexity. Initially the proposed RSSELACRP form a cluster by selecting the cluster-head among the eligible nodes. Clustering is the instrumental way of segmenting the collection of wireless sensor nodes into clusters. Each cluster will have one cluster-head sensor node and some common sensor nodes with less energy, signal strength and bandwidth as its member nodes. The cluster-head selection is primarily based on the residual energy (RE) and received signal strength of the sensor nodes in the cluster. Considering the number of sensor nodes present in the WSN as

NoN = {N1, N2, N3, …., Nn}. (3)

In wireless sensor network, it is possible to measure the quality of the signal. It is used by the physical layer to specify to the upper layer, when a packet is received from a wireless sensor node that is sending with a signal lower than a specific value. Thus, using the received signal strength from physical layer, link quality can be predicted and links with low signal strength will be discarded from the route selection. The received signal strength can be measured by using the below mechanism.

$$RSS = P_t * \left(\frac{\lambda}{4\pi d^2}\right) * G_t * G_r \quad (4)$$

Where λ the wavelength carrier, d is is the distance between the sender wireless sensor node and receiver wireless sensor node, Gr is the unity gain of the receiver sensor node and Gt is the unity gain of the sender sensor node. The cluster-head node will be chosen based on the below said criteria,

CH = Max [RE &RSS{N1, N2, N3, …., Nn}] (5)

Once after receiving the received signal strength, every sensor node among the network measures the distance from the base station. The distance will be calculated using GPS.

Calculating distance between nodes using GPS

GPS methods are related to measuring light propagation time indirectly. Distance is measured by sending a pulse and measuring using the time it takes to travel between two points. This method [20] is to reflect the signal and the time between when the pulse was transmitted and when the reflected signal returns.

Selecting Cluster Head nodes

Among the sensor nodes, the node which has maximum of residual energy and received signal strength will become the cluster-head as said in Equation (5). If the two clusters are in the same distance for base station, the cluster-head which sends back clear-to-send (CTS) packet will be chosen. During the intra-cluster data processing, it is well known that the clusters nearer to the base station will comprises of less number of member sensor nodes which results in less energy consumption. It will also perform some amount more energy consumption for the inter-cluster relay traffic. Inter-cluster is the communication happening between the clusters. Each cluster has its own cluster_id. Cluster-heads which is geographically nearer to the base station will support smaller cluster sizes, that results in creating more clusters nearer to the base station.

Once when the cluster-heads are elected / chosen, each cluster-head broadcasts a cluster-head advertisement message (CHAM) over the wireless sensor network. Every common sensor node selects cluster-head based on the nearest location along with the largest received signal strength. It notifies the cluster-head sensor node by sending a join cluster message (JCM). Every cluster-head node first collects the data from its member sensor nodes and through multihop route the data will be sent to the base station.

D. Inter-cluster Routing in RSSELACRP

The cluster-head creates a TDMA schedule informing each node when it can transmit. The schedule is broadcast to the nodes in the cluster. In order to avoid collision, each sensor node is permitted for transmitting packets in its allotted time slots. During the data transmission process, the cluster-heads are only eligible to communicate with the base station directly. In case of the cluster-heads that are far away from the base station, direct communications will consume additional energy than the cluster-heads nearer to the base station. Hence RSSELACRP constructs a chain among the cluster-heads so that each cluster-head will receive from and transmit to an adjacent cluster-head.

The chain of cluster-heads is formed using the following method. Distance of cluster-head is grouped to form a Distance-set. Distance-set is calculated using the GPS method. GPS methods are related to measuring light propagation time indirectly. Distance is measured by sending a pulse between two cluster-head nodes and measuring using the time it takes to travel between two points. This method [20] is to reflect the signal and the time between when the pulse was transmitted and when the reflected signal returns.

Distance set between cluster-head i and the other cluster-heads is represented as CHCHi={CHCHi1,CHCHi2,…,CHCHi(i-1),CHCHi(i+1),…,CHCHiK}. CHCH denoted distance between the cluster-heads. CHBS represents distance between cluster-head and base station.

Step – 1: The minimal value among distances between the cluster-heads and the base station is chosen. In case, when the length of the chain is less than minimal value then LoC = CHBSi.

Step – 2: The minimal value from the set of distance between cluster-head and the other cluster-heads is chosen. In case, cluster-head x has the shortest distance to cluster-headi, then CHCHix is the minimal value in the set CHCHi, then LoC = CHBSi+ CHCHix.

Step – 3: The minimal value from the set of distance between cluster-head x and the other cluster-heads is selected. In case, CHCHxy is the selected minimal value in the set CHCHx, then LoC=CHBSi+ CHCHix+ CHCHxy.

The above mentioned process continues until all the cluster-heads are included in the chain. The cluster heads are connected with other cluster head nodes using the gateway as depicted in the Figure 2.

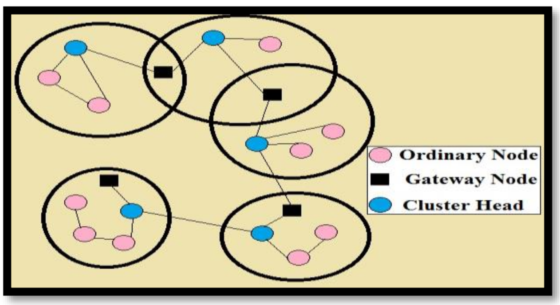

Figure 2. INTER-CLUSTER ROUTING IN WIRELESS SENSOR NETWORKS

IV. SIMULATION SETTINGS AND PERFORMANCE METRICS

TABLE I. SIMULATION SETTINGS

Parameter Name	Value
Number of nodes	600 nodes to 1100 nodes
Initial energy / node	50 joules
Simulation time	1500 seconds
Baseline node power	6mW
Simulation runs	10
Packet size	300 bytes

The simulation has been done using the NS-2 Simulator. The WSN nodes were randomly and uniformly deployed with varied node density of 600 to 1100. The packets are allowed to transfer in constant bit rate fashion. It is assumed that all sensor nodes are homogeneous that have the same ability of communication and also know their neighbor nodes and their own location information by GPS [12]. The performance metrics taken are number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops. The aim of the simulation is to determine the performance of the RSSELACRP with AELAR [13] and ELACRP. The simulation parameters are shown in Table 1.

V. RESULTS AND DISCUSSION

From the Figure 3 it is to be noted that the RSSELACRP delivers more number of packets to the sink than that of AELAR and ELACRP. Since received signal strength is calculated and incorporated for constructing the cluster head nodes and chain is created for inter-cluster routing the proposed mechanism attains better packet delivery ratio.

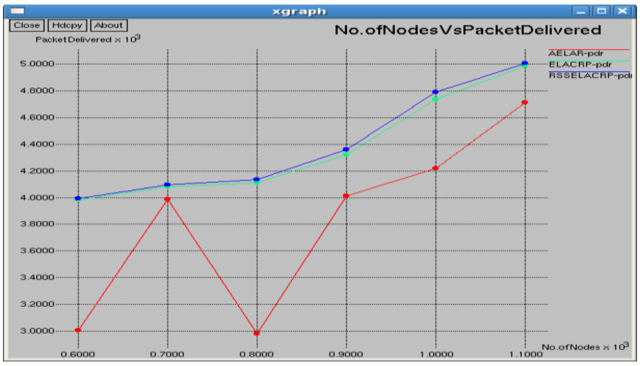

Figure 3. NUMBER OF NODES VS PACKET DELIVERED TO THE SINK

Also it is shown in the Figure 4 that RSSELACRP utilizes lesser amount of energy when compared with AELAR and ELACRP. This is because of the energy consumption model incorporated in RSSELACRP. Even though ELACRP has the same energy consumption model, using the inter-cluster mechanism the energy is consumed less in RSSELACRP.

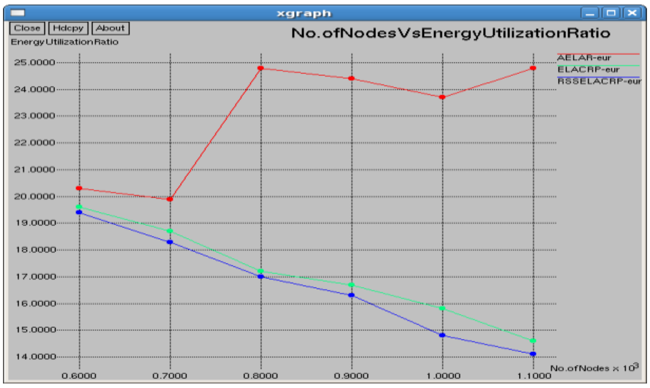

Figure 4. NUMBER OF NODES VS ENERGY UTILIZATION RATIO

It is depicted in the Figure 5 that RSSELACRP has lesser energy standard deviation when compared with AELAR and ELACRP. This is because of the energy consumption model incorporated in RSSELACRP. Even though ELACRP has the same energy consumption model, using the inter-cluster mechanism that has chain of cluster-heads the energy standard deviation is lesser in RSSELACRP.

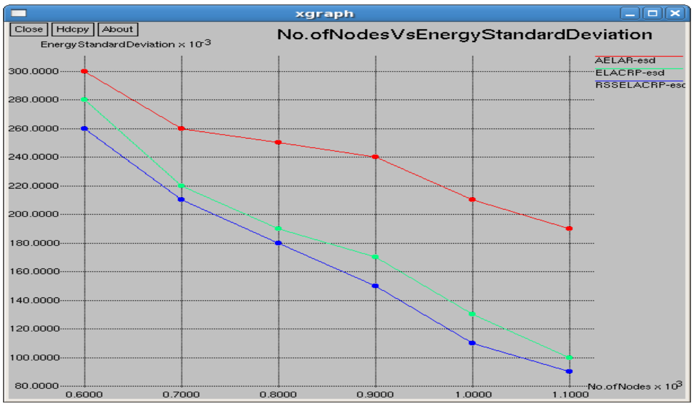

Figure 5. NUMBER OF NODES VS ENERGY STANDARD DEVIATION

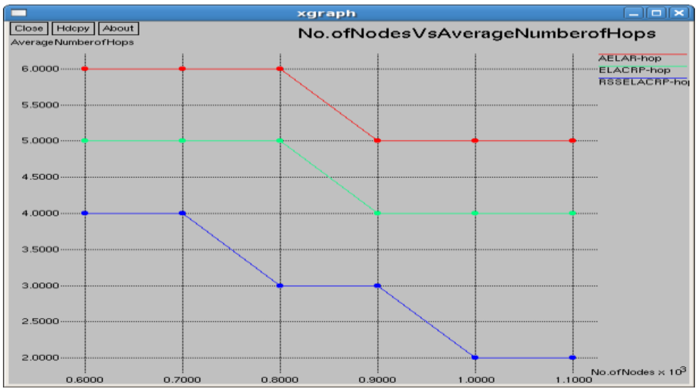

Figure 6. NUMBER OF NODES VS AVERAGE NUMBER OF HOPS

It is shown in the Figure 6 that RSSELACRP makes use of less number of hops when compared with AELAR and ELACRP. This is because of the cluster-head chain formation mechanism that is present in RSSELACRP.

From the simulation results it is evident that by using residual energy, received signal strength, location aware and adaptive inter-cluster routing mechanism proved that the RSSELACRP outperforms AELAR and ELACRP in terms of packet delivery, energy consumption, energy standard deviation and average number of hops. The simulation results are also depicted in Table 2.

TABLE II. SIMULATION RESULTS

	Packet Delivered to the Sink			**Energy Standard Deviation**		
Number of Nodes	**AELAR**	**ELACRP**	**RSSELACRP**	**AELAR**	**ELACRP**	**RSSELACRP**
600	3003	3976	3992	0.3	0.28	0.26
700	3987	4112	4153	0.26	0.22	0.21
800	2978	4176	4198	0.25	0.19	0.18
900	4015	4299	4383	0.24	0.17	0.15
1000	4218	4764	4791	0.21	0.13	0.11
1100	4710	4912	5003	0.19	0.1	0.09
	Energy Utilization Ratio			**Average Number of Hops**		
Number of Nodes	**AELAR**	**ELACRP**	**RSSELACRP**	**AELAR**	**ELACRP**	**RSSELACRP**
600	20.4	19.8	19.6	6	5	4
700	19.9	18.9	18.6	6	5	4
800	24.9	17.1	16.9	6	5	4
900	24.3	16.8	16.3	5	4	3
1000	23.7	15.9	14.9	5	4	3
1100	25.9	14.8	14.1	5	4	3

VI. CONCLUSION

This paper proposed received signal strength, energy and location aware cluster routing protocol (RSSELACRP) for wireless sensor networks. By adapting the location information model and energy consumption model the cluster-head selection mechanism is performed based on the residual energy and received signal strength of the wireless sensor nodes. The metrics such as number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops are taken to compare the performance of the ELACRP with AELAR protocol and the results proved that RSSELACRP outperforms AELAR.

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