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ENHANCING NETWORK LIFETIME IN WIRELESS SENSOR NETWORKS USING ADAPTIVE THRESHOLD BASED CLUSTERING

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ABSTRACT

With the advent of the Internet of Things (IoT), clustering algorithms for wireless sensor networks have gained unprecedented importance. A collection of wireless sensor networks constitutes the IoT framework. A Wireless Sensor Network (WSN) is a collection of numbers of connected sensor nodes. The paper proposes an optimized energy efficient routing protocol for the enhancement of network lifetime in Wireless Sensor Networks. The essence of the protocol lies in the fact that it changes the cluster size as well as the cluster head dynamically at the beginning of every iteration. Both heterogeneous and non-heterogeneous networks are considered. Moreover, a threshold based approach is used so as to reduce the total number of transmissions thereby bringing down the energy consumption. A delay time is introduced to re-transmit the data in case the transmission thresholds are not exceeded. This adds a point of safety to the algorithm. The obtained results show that the proposed system renders higher network lifetime compared to previous approaches.

Keywords: Internet of Things (IoT), Wireless Sensor Networks (WSN), Clustering, Routing, Network Lifetime.

I. INTRODUCTION

Wireless Sensor Network can be defined as collective set of multiple sensor nodes. Sensor nodes are responsible for gathering the sensory information and to interact with other nodes in the networks. A sensor node comprises of a microcontroller, transceiver, external memory and sensors. Increasing the network lifetime is of paramount importance in Wireless Sensor Networks since once the sensors are dead, the entire network goes down and any ongoing process needs to be halted till the network's energy resources are not replenished. WSNs find their applications in several fields such as defence and surveillance, automation, robotics, chemical industries, maritime research etc. For increasing networks performance and capability, the process of clustering is applied.**[3]** Different protocols have their own pros and cons, yet it is envisaged to design a protocol which fulfils two basic criteria:

1) Lesser Energy Consumption per iteration of the transmission of the data.
2) Reliability in gathering and transmitting data

The modes of communication in a WSN are twofold, one being between cluster head and base station and other being between clusters. The scenario is depicted in the figure below.

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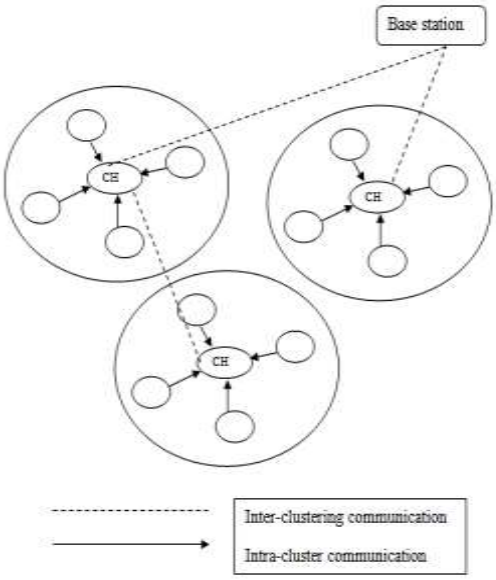

Fig.1. Communication in a clustered WSN

II. CHALLENGES IN CLUSTERING PROTOCOLS

The major challenges involved in cluster based routing in WSNs are:

1) Effectively deciding the cluster configuration in every iteration of data transmission so as to minimize energy consumption.
2) Reducing the decay in average energy of nodes with respect to iterations
3) Avoiding dead nodes with respect to iterations so as to increase the Quality of Service (QoS) of the proposed system
4) Increasing the network lifetime of the system

Fixing the cluster size or cluster head results in large energy consumption and hence yields lesser network lifetime.[6] Hence the clustering and routing algorithm needs to be adaptive in searching for cluster heads in every iteration and deciding the cluster boundaries. Apart from the aforesaid challenges, some other issues to be considered while designing clustering algorithms are:

- Cluster establishment: The CH determination and cluster creation techniques ought to create the best conceivable clusters (decently adjusted, and so forth.). Then again they ought to additionally protect the amount of exchanged messages low and the aggregate time unpredictability ought to (if conceivable) stay consistent and free to the development of the system. [6]This yields an extremely difficult trade-off.
- Application Dependency: When planning clustering and directing conventions for WSNs, application robustness must be of high necessity and the planned protocols ought to have the capacity to adjust to an assortment of use prerequisites.[8] Secure correspondence: As in conventional networks, the security of information is characteristically of equivalent significance in WSNs as well. The capability of a WSN clustering plan to save secure communication is regularly paramount when considering these networks for military applications.
- Synchronization: Slotted transmission methods, for example, TDMA permit nodes to regularly schedule sleep intervals to minimize energy utilized. Such plans oblige comparing synchronization instruments and the viability of this systems must be considered. [7]
- Data Aggregation: Because this methodology makes energy improvement conceivable it remains a principal configuration challenge in numerous sensor network schemes these days. Be that as it may its successful execution in numerous applications is not a direct system and must be further advanced as indicated by particular application prerequisites.[8]

III. PROPOSED APPROACH

The proposed approach is based on two vital characteristics v.i.z. adaptive clustering and a threshold based approach for data transmission.

1) Decide the spatial dimensions (x, y), number of nodes (N), initial energy of nodes (E), location of the base station, optimal election probability (p), hard threshold (H_T) and soft threshold (S_T).

2) Initially, decide the cluster (CH) randomly. Subsequently, the cluster head is decided by differential measure between the residual energy of the nodes and the average energy of the nodes. The average energy of the nodes on every iteration is computed as:

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \qquad (1)$$

Here, it's assumed that there are N nodes in the WSN.

3) Decide the cluster head for each iteration based on the following relation:

$$R_i(t) = \frac{E_{initial} - E_i(t)}{r-1} \qquad (2)$$

Here R represents the residual energy available with a node as a function of time. Needless to say, the residual energy as well as the average energy of nodes will monotonically decrease with increasing number of iterations of data transfer. The probability threshold of a node becoming a cluster head is given by:**[3]**

$$T(S_i) = \begin{cases} \frac{p_i}{1-p_i(r mod \frac{1}{p_i})} & if\ s \in G \\ 0 & otherwise \end{cases} \qquad (3)$$

Here,
G represents the set of nodes which are qualified to become a cluster head at any given iteration 'r'.
p_i represents the individual probability of a node becoming a cluster head of the n nodes of the network. It is given by:

$$p_i = 1/n_i \qquad (4)$$

The cumulative probability distribution function for all nodes becoming cluster heads at some iteration can is given by:

$$\sum_{i=1}^{N} P_i = \sum_{i=1}^{N} P_{opt}\frac{E_i(r)}{\bar{E}(r)} = \sum_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)} = Np_{opt} \qquad (5)$$

It can be clearly seen that the gradient of energy is given by:

$$\frac{dE_i}{dE_r} = g \qquad (6)$$

4) In case there exist heterogonous nodes wherein the initial energies are not constant, then the probability of a node to be a cluster head is given by:

$$p_{adv} = \frac{P_{opt}}{1+am}, P_{nrm} = \frac{P_{opt}(1+a)}{1+am} \qquad (7)$$

Here,
Padv denotes the probability of an advanced node to be adjudged a cluster head.
Pnrm denotes the probability of a normal node to be adjudged a cluster head.
'a' and 'm' are parameters for computing the weighted probabilities.

Thus the overall combined probability of any node (normal or advanced) being a cluster head is given by:

$$(P_i) = \begin{cases} \frac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ normal\ node \\ \frac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \end{cases} \qquad (8)$$

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5) Often the WSNs sensor operate in environments where the normal values reach after some time lag, and remain stabilized in a range. Hence a lot of energy is consumed in transmitting data till the values in the vicinity of the ideal range are reached. Hence a hard threshold **(H_T)** is decided pior to which no transmission takes place

Decide Hard Threshold **(H_T)**
If it so happens that the parameter value reaches the ideal range of operation and says there due to the regulation of system controlling parameters, then transmitting data at every fixed interval would not yield significant information but would only increase the transmission power needed. The idea is presented by the basics of information theory :

$$I = \log_2(1/P_i) \qquad (9)$$

Here,
I denotes the information contained in an event
P denotes the probability of occurrence of the event.
It can be clearly seen that the saturation of sensor values to a particular level does not yield much information.
Hence decide Soft Threshold **(S_T)**

Delay Time (T_d) : It may so happen that the transmission form the cluster head to the base station or control station stops if the soft threshold is not exceeded. Further, a prolonged period of non-transmission results in security and reliability threats. Hence even if the soft threshold is not exceeded, the data is to re-transmitted after the delay time is exceeded.
Hence deicide Delay Time **(T_D)**

6) Compute average energy of nodes iteratively and the network lifetime. The network lifetime is calculated as the number of rounds possible to transmit with respect to a variation in the number of nodes in the network.

IV. RESULTS

The designed system is simulated on MATLAB 2017a with the following network parameters:
Network Area = 100m x 100m
Number of Nodes (n) = 200
Optimal Election Probability (p) = 0.2
Initial Energy of Nodes (E_i) = 0.1 J
Hard Threshold (H_T) = 200
Soft Threshold (S_T) = 2
Distance of base station (d) = 150m

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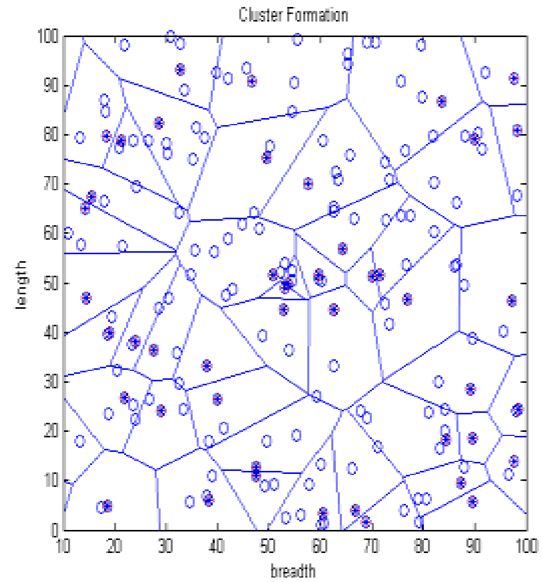

Fig.2 Cluster formation

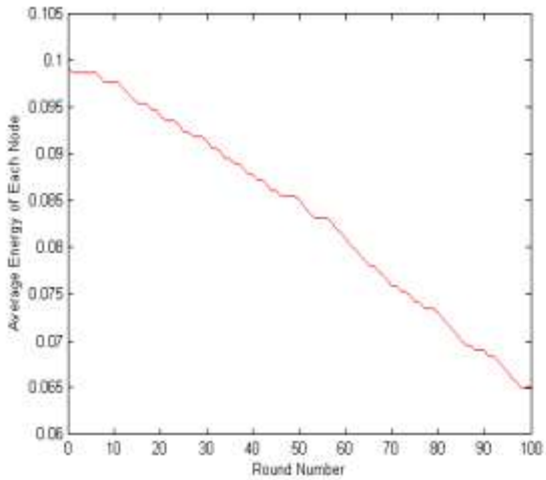

Fig.3 Average Energy of nodes w.r.t. number of rounds

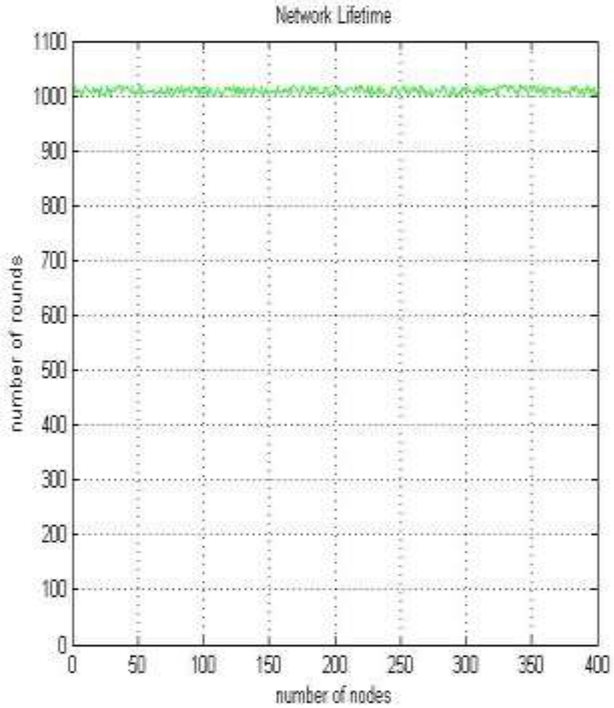

Fig.4 Network Lifetime (rounds w.r.t. nodes)

The number of rounds that can be transmitted using the proposed algorithm is around 1000 for a node range up to 400, which is significantly more than conventional techniques **[1].**

V. CONCLUSION

From the results, it can be observed that the proposed approach outperforms conventional techniques.[1] This can be attributed to the fact that the proposed approach intertwines adaptive clustering, cluster head selection with a threshold based approach to minimize both energy consumption per transmission as well as the total number of transmissions. It can be employed to both heterogeneous as well as non-heterogeneous networks increasing its avenues of applicability. The proposed system not only attains more network lifetime, but also is more secure due to the fact that re-transmissions occur in case the delay time is exceeded and updated data is not received at the control station. A comparative analysis can be made with the grid based routing algorithm proposed in [1] which attains a maximum of 800 rounds of transmission for 400 sensor nodes in the network.

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