Psuedo Randomised Cluster Head Selection Algorithm for Wireless Sensor Network

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Abstract: Recent developments in sensor networks are generally aimed at making wireless sensor networks (WSNs) more viable for implementation in real life scenarios like disaster management, battlefield and border security surveillance etc. Comparable to other wireless networking devices, sensor nodes face acute shortage of battery energy. Many famous existing technologies consider a randomized and distributed clustering strategies to reduce energy consumed by the network, as a whole, and a sensor node, in particular; thereby prolonging the network lifetime of WSNs. Off late concerns have been raised against use of such random approaches. Thus, we came with an idea of redesigning this concept of randomization by including supplementary parameters. This resulted in a pseudo-random scheme wherein network energy decay rate and node depletion rate are decreased by 10-20%, as compared to prevalent policies.

Keywords—Heterogeneous wireless sensor networks, Clustering, Energy Efficiency, Pseudo-random, Cluster Head.

I. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors or MEMS (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery.

A wireless sensor network (WSN) is formed by one or more base stations and a large number of sensor nodes to monitor the objects of interest or environmental conditions such as sound, temperature, light intensity, humidity, pressure, motion and so on through wireless communications. Recently, the advance in micro-electro-mechanical systems (MEMS), embedded processing, and battery technology have facilitated the development of low-cost and low-power sensors with the functions of sensing, wireless transmission, computation and data processing.

A. Characteristics of WSN
(i) Resource Constrained Computing Environment: It is difficult, rather impossible, to replace or recharge the batteries. In fact, it is easier to place another SN and simply discard the previous one. In colloquial language, we may call SNs as use-and-throw commodity. Also, the sensor nodes communicate over wireless links with limited bandwidth and noisy radio links. Additionally, sensor nodes operate with limited processing ability and memory capacity.
(ii) Dynamic Topology: The network topology is prone to frequent changes due to mobility of nodes, failure of nodes or links, power running out etc. New nodes may be added and old nodes may be removed from the sensor networks. As a result, techniques such as dynamic route changing are needed to adapt to network topology change.
(iii) Unpredictability: It refers to the uncertainty in the correctness (accuracy) of sensor data, the reliability of the communication links, and the connectivity of networks. The correctness of sensor data can be affected by the node status and transmission situations.
(iv) Limited Network Security: WSNs are generally more prone to physical security threats than other wireless networks because the sensor network is a distributed system and all the security threats relevant to such a system are pretty much present, as a result, there is an increased possibility of eavesdropping, spoofing, masquerading, and denial-of-service type attacks.
B. Routing Protocol and Approaches

Data-centric Routing: In data-centric routing,[5] the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. SPIN is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy.

Hierarchical Routing: The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of messages transmitted to the sink. LEACH [3,6] is one of the first hierarchical routing approaches for sensors networks.

Location-based protocols: Most of the routing protocols for sensor networks require location information for sensor nodes. In most cases, location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated.

Network flow and QoS-aware protocols: Although, most of the routing protocols proposed for sensor networks fit our classification, some pursue somewhat different approach such as network flow and QoS. In some approaches, route setup is modeled and solved as a network flow problem. QoS-aware protocols consider end-to-end delay requirements while setting up the paths in the sensor network.

II. CHALLENGES/ISSUES

Many applications of WSN have several restrictions, such as limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting SNs. Some of the design challenges in WSNs are summarized below:

- Energy efficiency: It is not possible to replace or recharge the battery of the deployed SNs. This further poses the challenge of scaling WSN to hundreds or thousands of SNs.
- Unattended Nature: In an application where WSN are deployed in hostile environment and left unattended allows adversaries greater access and freedom to physically tamper with the SNs.
- Data aggregation: The data aggregation technique allows reduction of redundancy in transmission by statistically evaluating the frequency of occurring samples and their trend direction.
- Collisions and latency: Insensitive application, concentration of SNs is very high. This causes collision and latency in packets. However, unlike in traditional networks, the energy limitation of SNs makes it unfeasible to resend packets in case of collision.
- Node deployment: More often than not, SNs are scattered randomly creating an infrastructure in an ad hoc manner. If the resultant distribution of SNs is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.
- Node/Link heterogeneity: In many recent studies, SNs were assumed to be having different competence in terms of computation, technical issues related to data routing.

III. ENERGY AWARE STRATEGIES IN WSN

Low-Energy Adaptive Clustering Hierarchy (LEACH), [6] proposed by Heinzelman et al, divides a wireless sensor network into a number of clusters, and a sensor node decides which cluster to join based on the strength of received signals. This cluster formation is done randomly. Since the cluster head will consume more energy than other nodes, it has to be replaced regularly to balance the power consumption.

Energy Efficient Heterogeneous Clustered Scheme (EEHC) [2] proposed by Dr. R. B. Patel et al is an improvement over LEACH using a heterogeneous network with nodes having varied initial energy. Advanced nodes having more initial energy have a higher probability to become cluster heads. Both the above schemes are based on probabilities that are decided at the time of network deployment. Thus, these strategies fail to adapt to the changing network scenario and their assurance of balanced energy consumption stalled.

HEED proposed by O. Younis [4] sets an initial probability of cluster-heads among all nodes (Cprob), assuming that an optimal probability cannot be computed a priori. In every round, a noderesets its probability of becoming a cluster-head, CHprob, as in [4]

\[
C_{\text{prob}} = C_{\text{prob}} \times \frac{E_{\text{residual}}}{E_{\text{max}}}
\]

This protocol creates a problem of no-CH-made in the later stages of the network when the energy of each
node starts depleting. Thus, this shall be beneficial only until first one-fourth of the total network lifetime and shall become equally hazardous in the last three-fourth.

IV. PROPOSED SCHEME

CHs are selected by scrutinizing among the candidates on the basis of mutual distance as well as residual energy of each node. The scheme is implemented in three stages. At first phase, the candidates are selected. Scrutinizing among those candidates is done in second phase to find the successful candidate. All such successful candidates play the role of Cluster-Head in third stage i.e. data aggregation phase.

A. Procedure

PHASE 1 (Candidate Selection): A node declares itself as a candidate to become CH on the basis of the probability calculated for each node type as:

\[ P_a = \frac{1}{Q} \]

\[ P_n = \frac{P_{ap}}{Q} \cdot (1 + n) \]

\[ P_e = \frac{P_{ep}}{Q} \cdot (1 + e) \]

Each candidate node sends its id and remaining energy to BS.

PHASE 2 (Scrutinizing): Using the information of residual energy of each candidate and the location of these nodes, BS constructs a graph G'; the candidate nodes are the vertices and links joining the vertices (those that lie within a defined minimum range, say 50 meter) are the edges. Finally, a connected component graph is developed by the BS. Among each component, the node with maximum remaining energy is nominated as CH, while others are asked to behave as associates to their nearest CH.

PHASE 3 (Data Aggregation): Every non-CH node associates itself to the nearest CH available. CHs receive data from each of their associates in a TDMA fashion predetermined by the CH of the cluster. Data, thus received from the associates, are aggregated and eventually sent to BS. After every round, CH is re-nominated in the similar manner.

B. Proposed Algorithm

Initialize parameters such as initial_energy, location of SN, type of SN, radio model, round_max , Round=0, dead=0 etc.

Calculate probability, p(i), corresponding to each type of SN (as in equations 2,3,4)

Do

\{ Generate a random number, Random(i), for each node
If (Random(i)<p(i))
Then candidate(i)=true
Make a graph G for all nodes i in the network such that candidate(i)=true
Call G’=graphconncomp(G)
For each component in G’ thus formed
max_residual_energy(component)=id of winning node
For each winning node
SN.type=’Cluster-head’
For each node in the network
If(SN.type==’normal’) Then find nearest cluster-head
And send data to corresponding CH
Else if(SN.type==’cluster-head’) Aggregate data and send to BS
For each node in the network
If (SN.residual_energy<0) then dead=dead+1
\}

V. SIMULATION AND RESULTS

A. Performance Metrics

Cluster Stability: A cluster is said to be Stable if the CH of the cluster, under consideration, has enough energy to perform all its duties assigned in that particular round. Thus, cluster stability ratio is the number of unstable clusters formed to that of the total clusters formed during the lifetime of the network.

Number of live nodes per round: This measure reckons the total number of nodes who are still left with enough energy to be an active and effective part of the network.

Network Energy Decay Rate: It is the rate by which the total energy of the network decays due to dissipation of energy in the process of communication. The higher the network decay rate, the lesser is the lifetime of the network. It is measured in joules per round.

Average CH to CH distance: The closer the CHs will be to each other, the more will be the overlapping of
clusters, and the greater will be the wastage of resources. The lesser the common area among two clusters, the more efficient will the network become.

B. Simulation Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field dimension</td>
<td>200*200 m$^2$</td>
</tr>
<tr>
<td>BS location</td>
<td>(200,100)</td>
</tr>
<tr>
<td>Numbers of Sensors</td>
<td>100</td>
</tr>
<tr>
<td>Sensor Range</td>
<td>87 m</td>
</tr>
<tr>
<td>$E_{INITIAL}$</td>
<td>0.5 J</td>
</tr>
<tr>
<td>$E_{ELEC}$</td>
<td>50 nJ</td>
</tr>
<tr>
<td>$E_{AMP}$</td>
<td>10 pJ</td>
</tr>
<tr>
<td>$E_{DA}$</td>
<td>5 nJ</td>
</tr>
<tr>
<td>Package Length</td>
<td>4000 bits</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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Table: Simulation Parameters used

We have compared the proposed scheme with another energy efficient protocol EEHC [1,2] (which already have advantages over LEACH) and found that the network lifetime, packet delivery ratio and time-to-first-dead node has increased, while the network energy decay rate and node depletion rate decreases by 10-20%. The graphs below show the results obtained on comparisons.

The mean distance between CHs has been increased drastically. The CH to CH distance determines what areas of two clusters are overlapping on each other. The more the mean distance between CHs, the lesser will be the overlapping in the clusters formed and the lesser will be the overhead in the cluster formation. An average CH-to-CH distance of 110 m is a huge achievement over a mean value of 8m. This indicates that a CH having the cluster radius of 87 units (m) shall now be more efficient in its job due to lesser interference and also lesser cluster density shall prevail, thereby decreasing the load on a specific node.

This protocol is able to maintain a consistently higher performance than the previous protocols. Along with network lifetime, cluster stability has also been increased by 30%.

Energy dissipation per round has shown a positive trend in the beginning. Overall, the average energy dissipation per round has been more stable than EECH over the entire lifetime of the network.

VI. CONCLUSION AND FUTURE SCOPE

LEACH was a breakthrough in the field of WSN for coining a different approach to energy efficiency. Much work has been done since then to improve LEACH. The heterogeneity scheme proposed in EEHC is too rigid to be followed because it believes in making CHs on a totally random basis. On the other hand HEED ensures that probability of each node decreases as the energy of the network decreases. We have proposed a flexible
scheme that relies on the comparative energy of a node among all the live nodes rather than the absolute of the residual energy itself.

Further, we are still trying to make the network more energy efficient by introducing node degree as an additional parameter for CH selection along with residual energy and mutual distance. We have yet tried only a single more factor than randomness to generate a pseudo-random code for CH formation. More factors may be identified and integrated in this process.

REFERENCES


