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# A STOCHASTIC APPROACH FOR OPTIMAL MULTIHOP COMMUNICATION AND DATA TRANSFER IN WIRELESS SENSOR NETWORK

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## Abstract

This project presents a semi-centralized stochastic election approach named Stochastic Election of Appropriate Range Cluster Heads (SEARCH) for design of heterogeneous wireless sensor networks. SEARCH assuring low time cost and optimal number cluster heads for each round. It is by boosting cluster head threshold of a node in a favourable position while deteriorating it otherwise, achieves an aggressive goal on prolonging the round of alive nodes surviving (notably stable period) as well as reducing energy consumption. In addition, we eliminate the unfavourable scenario that no cluster head emerges during some specific rounds, enhancing network performance.

## 1. Introduction

Wireless Sensor Network (WSN) is a system composed of wireless sensors deployed in a region to sense various types of physical information from the surroundings. The information sensed by these sensors is then processed and has been sent to Base Station (BS) for assessment. A wireless sensor network is a collection of nodes organized into a cooperative network`. Each node consists of processing capability, may contain multiple types of memory have a RF transceiver, have a power source and accommodate various sensors and actuators.

The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. The network once established, keeps on sensing the information and the energy of the nodes keep on dissipating whenever, they receive some information and send it further to other nodes or BS [1]. WSNs are used for various applications like habitat monitoring, military surveillances, forest fire detections, transport monitoring, etc.

Wireless Sensor Networks are networks made up of tiny embedded devices and consist of a large number of sensor nodes deployed over a geographical area for monitoring physical phenomena like temperature, humidity, vibrations, and so on. Each sensor node is a tiny device that includes three basic components:

- Sensing subsystem for data acquisition from the physical surrounding environment,
- Processing subsystem for local data processing and storage and
- Wireless communication subsystem for data transmission to a central collection point.

The main characteristics of a WSN include:

- Power consumption constraints for nodes using batteries or energy harvesting
- Ability to cope with node failures (resilience)
- Mobility of nodes
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions

Wireless Sensor Networks (WSN) offers a rich, multi-disciplinary area of research, in which a number of tools and concepts can be applied to address a whole diverse set of applications. A few examples of their applications are listed below.

### Types Of Wireless Sensors

### Specialized Sensor Nodes

Specialized sensors are used in many applications, including asset tracking. These sensors are very small and must operate for a long time on a battery supply. Thousands of sensors are usually involved in this type of application.

### Generic Sensor Nodes

Generic sensors are used in many applications, including security applications such as motion detection in doors and windows. These sensors are very small and must operate for a long time on a battery supply. Not much data processing is required for this application, and low communication rates are required. Hundreds of sensors are usually involved in this type of application.

### High-Bandwidth Sensor Nodes

High-bandwidth sensors are used for video, acoustic and chemical applications that require more resources for communications and computations. Battery power is often not enough for these applications. In order to operate for the long term, they must be plugged in to electrical power.

## 2. Related Work

Topology control is defined as controlling the neighbor set of nodes in a WSN by adjusting transmission range and/or selecting specific nodes to forward the messages [7]. Topology control approaches can be divided into two main categories, namely, homogeneous and no homogeneous. In homogeneous approaches transmission range of all sensors are the same whereas in no homogeneous approaches nodes can have different transmission ranges. There are many topology control methods proposed in literature and they can be classified according to the techniques they use. Many topology control methods [8], [2] are built on the transmit power adjustment technique which depends on the ability of sensors to control their transmit power. Some algorithms [4], [8] use sleep scheduling which aims to decrease energy consumption while nodes are in idle state. Others use geometrical structures, location and direction information and also combinations of these techniques [6]. The difference between these studies and our work is that we try to minimize nodes' total transmission power in two-tiered heterogeneous topologies whereas other works focus on flat homogeneous topologies. In addition we focus on connectivity between a sensor node and super nodes whereas they focus on connectivity between any two nodes.

Clustering can also be considered as another way of topology control, where the aim is to organize the network into a connected hierarchy for the purpose of balancing load among the nodes and prolonging the network lifetime. Hierarchical clustering techniques select cluster heads depending on various criteria and create a layered architecture. These techniques start with a flat topology and end up with a layered one. We start with a layered architecture from the beginning, where the super nodes are already given. Instead of building clusters, we focus on maintaining fault-tolerant connectivity between sensor nodes and super nodes.

An active research area where layered and heterogeneous architectures are utilized is wireless sensor and actor networks. WSANs usually have a two-layer architecture where the lower level is composed of low cost sensor nodes and the upper layer consists of resource-rich actor nodes which take decisions and perform appropriate actions. In WSANs, there are usually two type of wireless communication links: actor-actor and sensor actor links [10]. The links between sensors and actors are assumed to be less reliable [11], hence there are several methods proposed for maintaining reliable sensor-actor connectivity. The methods do not employ k-connectivity between sensors and actors and thus they do not guarantee fault-tolerance in case of k - 1 node failures. Although [10] addresses the k-actor connectivity problem, it does not consider the energy efficiency of the resulting topologies. Our approach differs from these works by maintaining k-connectivity and addressing power efficiency at the same time. A prominent work on fault-tolerant topology control for heterogeneous WSNs with a two-layer network architecture is proposed by Cardei et al. [5], addressing both k-connectivity and energy efficiency. As we do, they focus on the k-degree Anycast Topology Control (k-ATC) problem, which aims adjusting the transmission range of the sensor nodes to achieve k-vertex supernode connectivity and minimize the nodes' maximum transmission power.

They propose a greedy centralized algorithm called global anycast topology control (GATC), and also a distributed algorithm called distributed anycast topology control (DATC), which provides k-vertex supernode connectivity by incrementally adjusting the transmission range of the sensor nodes. GATC is mostly of theoretical importance since it is not practical to apply it for large scale WSNs due to the requirement of global topology knowledge. The DATC algorithm [3] is a distributed and hence a more practical solution to the k-ATC problem. This algorithm requires only 1-hop neighborhood topology information, which can also be extended to h-hop. The objective of DATC is to ensure that any neighbor node u, in the reachable neighborhood of any node v, is either directly reachable from node v or there are at least k-vertex disjoint paths from v to u.

Our algorithm differs from DATC by the approach that we adopt for discovering vertex disjoint paths. In DATC, each node starts with a minimal set of neighbors and minimal power level. The power level is increased incrementally and only the paths from the neighborhood that is reachable with that power level can be discovered. The nodes outside of the reachable neighborhood are totally unknown to the node performing discovery and thus they are out of the search scope for discovering paths. This is an important limitation for DATC because it has a low chance to find k-vertex disjoint paths for its neighbors in its reachable neighborhood, which typically has nodes that are in 1 or 2 hops distance from the node performing the discovery. In contrary to DATC, in our algorithm, a sensor node can discover paths including nodes outside of its reachable neighborhood. This is achieved by storing full path information from supernodes to sensor nodes in local information tables. In this way, the DPV algorithm has more chance to discover better k-disjoint paths than DATC. Another difference of our algorithm from DATC is that, we decrese the power level only after deciding the final topology. During path discovery in the DPV algorithm, nodes operate with maximum power, thus, increasing the likelihood of discovering more paths than DATC. Our simulation results are in conformity with this discussion.

## 3. WSN Protocols

LEACH (Low Energy Adaptive Clustering Hierarchy) LEACH Heinzelman et al. Low Energy Adaptive Clustering Hierarchy is one of the most popular clustering algorithms. The main idea behind leach is to form clusters based upon the signal strength of the sensors. Some of the nodes are randomly chosen as the cluster heads (CH) and a node is assigned to the CH based upon the signal strength received by that node from the CH Yadav and Sunitha. CHs have to do a lot more work than the normal nodes; hence they dissipate a lot more energy and may die quickly. In order to maintain a stable network, CHs keep on rotating, in every round. So, a node which had become CH may not get an opportunity to become CH again before a set interval of time.

**SEP (Stable Election Protocol)** Given initial energy diversity, adjusted cluster head threshold according to node type in SEP. It was an improvement over LEACH in the way that it took into account the heterogeneity of networks. In SEP, some of the high energy nodes are referred to as advanced nodes and the probability of advanced nodes to become CHs is more as compared to that of non-advanced nodes. In these networks some of the nodes become cluster heads, aggregate the data of their cluster members and transmit it to the sink. We assume that a percentage of the population of sensor nodes is equipped with additional energy resources this is a source of heterogeneity which may result from the initial setting or as the operation of the network evolves.

**DEEC (Distributed Energy-Efficient Clustering Algorithm)** In DEEC, Took node type and residual energy into consideration, refining the threshold of each node respectively. In DEEC protocol all nodes use the initial and residual energy level to define the cluster heads. DEEC estimate the ideal value of network lifetime to compute the reference energy that each node should expend during each round. In a two-level heterogeneous network, where we have two categories of nodes,m. N advanced nodes with initial energy equal to Eo.(1+a) and (1 −m).N normal nodes, where the initial energy is equal to Eo. Where a and m are two variable which control the nodes percentage types and the total initial energy in the network Etotal.

## 4. A Stochastic Approach For Optimal Multihop Communication And Data Transfer

In proposed system implementation of presents a semi-centralized stochastic election approach named Stochastic Election of Appropriate Range Cluster Heads (SEARCH) for design of heterogeneous wireless sensor networks using MATLAB. Note that, SEARCH does not blindly pursue a seemingly lasting lifespan, but striving for enduring stable period, the most valuable stage. It also eliminates hurt network performance. It is worth mentioning that SEARCH assures optimal number cluster heads for each round, which is unfeasible for LEACH, SEP and DEEC. A detailed description on SEARCH protocol is elaborated. We assume that, BS could preliminarily acquire position information of each node and handle the cluster head selection process.

### 4.1 Refined Updating Rule

It guarantees that, in each round, there always exists k or more candidates for cluster head selection. In LEACH-like protocols, every alive node has a G value. Each time a node serves as a cluster head, its G value decreases 1. When G value falls to 0, the node could not be chosen as a cluster head during current poch. Zero G value does not update until next epoch starts. An unfavorable scenario that no cluster head emerges would occur in LEACH, SEP and DEEC.Our protocol updates G value timely so that there always exists ample cluster head candidates. In SEARCH, maximal G value of a normal node is 1, while top limit of G value for an advanced node reaches $1 + \beta$ assuming that the additional energy factor of an advanced node is $\beta$, and the initial energy of a normal node is E0, then the initial energy of an advanced node is $(1 + \beta)*E0$). In the refined updating assuming that the optimal number is k, which has been deduced in.

And there are t nodes possessing nonzero G. At the beginning of each round, if $t < k$, BS would select t existing candidates as cluster heads then update the G value of unselected alive nodes. Remaining $k - t$ cluster heads could be chosen from updated nodes. If $t \geq k$, BS would pick up k cluster heads immediately.

**4.2. Calculated Average Residual Energy**

It offers a more accurate value in terms of average residual energy estimation. Then, the value contributes to build a more precise cluster head threshold. In DEEC, the average residual energy e(r) aids to adjust Cluster head probability of node i.

P is initial cluster head probability, $\beta$ represents the additional energy factor, m denotes the fraction of advanced nodes, and Ei(r) describes the residual energy of node i in round r. DEEC predicts E(r) in a linear manner, indicating that each round boast uniform energy consumption. That would mislead cluster head probability to a certain extent. DEEC predicts E(r) in a linear manner, indicating that each round boast uniform energy consumption. That would mislead cluster head probability to a certain extent. In SEARCH, during the WSNs operation sector of each round, member nodes would report its survivorship along with sensed data to cluster heads. Cluster heads then gather death toll as well as aggregated data and transmit them to BS.

BS collects alive node number n and the residual energy of each node Ei(r) without much extra overhead. And then, we could calculate the exact value $E(r + 1) = \Sigma n\ i=1Ei(r)$ n, introducing it to (1) for next round operation. Notably, $E(1) = n \cdot (1-m) \cdot E0+n \cdot m \cdot (1+\beta) \cdot E0\ n = (1+\beta m)\ E0$. And node i would count as an alive one if only $Ei(r) > 0$. Heinzelman et al. Have defined cluster head threshold of node i. SEARCH follows that model. Pi stands for cluster head probability of node i, and r represents current round number. Evidently, a node with little residual energy Ei(r) would get much harder to become a cluster head due to its low threshold T (i). Meanwhile, for there is no limit on lifespan prediction, SEARCH could operate till the last alive node exhausts.

**4.3 Balanced Influential Factor**

In boosts cluster head threshold of a node in a favourable position while deteriorating it otherwise. Here, i is current alive node mark, j is current cluster head mark, distavg_toBS represents the average distance from alive node to BS, disti_toBS denotes the distance from node i to BS, distavg_min toCHs stands for the average distance from alive node to its closest cluster head, and disti_min toCHs describes the distance from node i to its closest cluster head. LEACH transmission model here, d is transmission distance, while wireless standard parameters are listed.

This segment employs reverse thinking. A node close to existing cluster heads would suppress this quadratic ratio and tend to be a member node rather than a cluster head. Note that appropriate range among cluster heads contributes to create reasonable cluster formation, which would alleviate burdens on part I. And then, T (i) • ψi (CHj) determines the final threshold of node i. If its G value is larger than 0 and the assigned random number is less than its threshold, node i becomes a cluster head. In each round, BS stochastically picks up cluster heads one by one, till the optimal number deduced. Thus, SEARCH operates as a semi-centralized clustering protocol.

## 5. Performance Analysis

In this project adopts LEACH energy model in Yadav, Sunitha (2014). Entire experiments have been simulated by MATLAB R2014a. The experimental field is a 100 × 100 square. BS locates in (50, 50). The optimal cluster head ratio P is 0.05. Note that, considering real-time applications, our research only makes comparisons among low time cost clustering protocols (LEACH, SEP, DEEC, PSCND and SEARCH). For each situation as follows, we run experimental simulation 10 times (within different random topologies), to know about number of alive nodes for each round, reduce energy consumption.

### Nodes In Search Protocol

Node details such as

- xd, yd: node placed in x axis and y axis.
- Type- type of node
  1. N- Normal node.
  2. A-Advanced node.
  3. S-Super advanced node.
- E-energy.
- CH-cluster head.
- Distance-Distance from node to base station.
- min_dis-distance from cluster head.
- Min_dis_cluster-minimum distance from cluster head.

```
 >> S (10) Ans =
          xd:   79.2207   yd:
          95.9492
           G: 0
        Type: 'S' % S-Super advanced node
           E: 0.5103
          CH: 0
     Distance:            54.4535
     min_dis: 22.9332
min_dis_cluster: 12
>> S (25) Ans =
xd:  70.9365  yd:
75.4687
```

```
             G: 0
           Type: 'N' % N-normal node
             E: 0.0499
            CH: 0
        Distance:          32.9695
        min_dis: 22.1024
   min_dis_cluster: 12
   >> S (90) Ans =
   xd:  64.7745  yd:
   45.0923
              G: 0
            Type: 'A' % A- node
              E: 15.5683
             CH: 0
         Distance:      15.5683
         min_dis: 15.5683
    min_dis_cluster: 1
```

Simulation parameters of SEARCH protocol is listed in table 5.1 Compression of Deec and search protocol is given in table 5.2.

| PARAMETER | VALUES |
|---|---|
| Eelec | 50 nJ/bit |
| $E_{DS}$ | 5 nJ/bit |
| Ɛfs | 10 pJ/(bit.m$^2$) |
| Ɛmp | .0013 pJ/(bit.m$^4$) |
| Eo | .25 J |
| L | 2000 |
| N | 100 |
| M | .2 |
| B | 3 |
| Number of rounds | 200 |
| First death node in round | 0 |

**Table 5.1 Simulation Parameters of SEARCH protocol**

| PARAMETER\PROTOCOL | DEEC | SEARCH |
|---|---|---|

| | | |
|---|---|---|
| Eo | .5 J | .25 J |
| L | 2000 | 2000 |
| N | 100 | 100 |
| Base station | 50*50 | 50*50 |
| No of alive node at last round | 28 | 100 |
| Number of rounds | 200 | 200 |
| First death node | 26 | 0 |

**Table 5.2 Compression of DEEC and SEARCH protocol**

## 6. Conclusion and Future Work

This project presents SEARCH, a semi-centralized stochastic election approach for heterogeneous WSNs. Given node type, residual energy, position information as well as cluster head energy dissipation, SEARCH makes much easier a node in a favourable location to serve as a cluster head, while worsening the threshold of a node locating in a disadvantaged position. It is remarkable that SEARCH pursues a stochastically sub-optimal solution, assuring optimal number cluster heads for each round. Our protocol, thereby, features enduring stable period, energy consumption and low time cost.

In future work to design Threshold sensitive data transfer implementation. Data is transferred only when the sensing data changes above a threshold.

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