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Dynamic Selection of Cluster Heads for Increasing Lifetime in Wireless Sensor Networks with Bloom Filter

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ABSTRACT

Wireless sensor networks, are a new generation of real-time systems with limited computational, energy and memory. Since in these networks a major challenge is the issue of energy, using of clustering models can be considered as a solution to this problem. In this structure, the sensor nodes are grouped in a set of cluster and a central node is selected as a node of cluster heads. To choose an appropriate cluster heads in these networks is reduced the energy consumption and reducing of energy consumption increases the lifetime of network. In this paper, we choose cluster heads by Bloom filter.
KEYWORDS: Bloom filter, clustering, wireless sensor networks, energy consumption.

1. INTRODUCTION

The Bloom filter is a space-efficient probabilistic data structure that supports set membership queries. The data structure was conceived by Burton H. Bloom in 1970 [1]. The structure offers a compact probabilistic way to represent a set that can result in false positives (claiming an element to be part of the set when it was not inserted), but never in false negatives (reporting an inserted element to be absent from the set). This makes Bloom filters useful for many different kinds of tasks that involve lists and sets. The basic operations involve adding elements to the set and querying for element membership in the probabilistic set representation [2]. Wireless sensor networks (WSNs) rely on a large number of small sensor nodes. It is commonly known as a mote, while they have extremely limited the motes that have low cost and various ability and can be easily deployed. They need to continue their action independently (autonomously) without maintenance that is possible whenever. Many of them are just equipped with a few types of sensors [3, 4]. WSNs consist of a large number of sensor nodes that are deployed randomly to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants at different locations. Advancement in wireless communications, electronics and technological evolution has enabled the development in the field of WSNs due to their low cost and variety of applications such as health, home and military etc. Research is going on to solve different technical issues in various application areas [5,6]. They are extremely limited in terms of processing, memory, radio bandwidth, and the most crisis energy [7]. There are applications for most of the radio communication which largely have the task of compressing more energy. Based on the results of centralized sensor network, it is not surprising [8] that in fact, the lifetime of metric network, plays an important role in performance (proficiency). Recent advances in electronics and wireless communications have been provided the capability to design and manufacture sensors with low power consumption, small size and reasonable price. These tiny sensors, that can perform various actions such as receiving environmental information (depending on sensor) and processing and sending that information, have led to the emergence of the idea to develop networks called WSN wireless sensor networks [9]. Sensor networks are hordes of tiny wireless networks or a set of inexpensive sensors to send environmental data. Wireless sensor networks will help to monitor and control the remote physical environments, with the best accuracy. They have softwares in various fields such as environment monitoring, military purposes and gathering perceptions in improper places. The sensor nodes due to the nature of being cost and depends on deployment method have different computational energy and limitations [10]. These networks that are called wireless sensor network, have become into the appropriate tool for data extraction of surroundings and monitoring the environmental events, and their applications in domestic, industrial and military, are increasing day-to-day [11]. The main challenge in designing and manufacturing of wireless sensor networks is the limitation of the energy resource of sensors. However, due to the large number of sensors in the network and/or not having access to them, it is not feasible to replace or recharge the battery of sensor. Therefore, it is greatly needed to provide methods to reduce energy consumption, which ultimately leads to increase the network lifetime [12]. Meantime transmit and receive the data have the most of energy consumption [13]. The network should be independent and have a framework (skeleton) for effective communication. We use a fully distributed protocol, called Bloom filter for standalone network that by taking advantage of local feedback is generated the hierarchical clustering to gather data. But,

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although our homogeneous networks scale is limited, we are also demanded of our protocol clusters to deploy less of constrained resource of devices. Second, the network should retain the distributed data to guide publication of query forms.

2. REVIEW OF LITERATURE

We have a developed protocol for autonomic systems to facilitate the internal processing of network and deliver messages. Distribution of Asynchronous Clustering [14] is the topology of generating efficient energy. While hierarchical clustering in other tasks, such as generating energy has been caused to reduce generating energy of adaptive cluster hierarchy (LEACH), [15, 16]. DAC protocol is caused to produce cluster heads in the distributed network evenly and consistently. Into the protocol generating of random clusters, shows the small percentage of volunteer random points without regard to local events. Against, two close nodes in the DAC clusters never become into cluster heads. As a result, the logical hierarchy of the cluster heads is known to maintain and uses the distributed data structures on Bloom filters for routing, storage, and making-decision. Given to the correct trend in hardware development for sensor networks, their memory capacity steadily is increased from Motes but severe constraints to generate energy are remained [17]. In this paper, we use the installed techniques on Bloom filter to suppress the radio transmissions. These techniques are for taking advantage of offline trade (trade-offs) between the calculations and the radio costs and the expenses between the radio and memory to reduce latency and energy consumption. As a result, the network respond to queries get faster and also the longevity of network increases.

2.1 LEACH Protocol

In this section we address the overview of LEACH algorithm and compare it with the proposed algorithm. Why we use of clustering algorithms, is to reduce the energy consumption. LEACH is one of the most popular clustering algorithms in wireless sensor networks. This algorithm forms clusters on the basis of received signal's strength and uses the nodes of cluster heads as a route to main base. All data processing operations, such as composition and aggregation of data are doing within a cluster. LEACH constitutes clustering using distributed algorithms, where nodes make decision independently (autonomous) and without any centralized control. Initially, a node decides to be cluster heads and transmit (send) its decision. Nodes that are not cluster heads, determine their cluster by selecting the cluster heads which is connected it with the least consumption of energy. The role of cluster heads is periodically loading among the cluster nodes in order to balance.

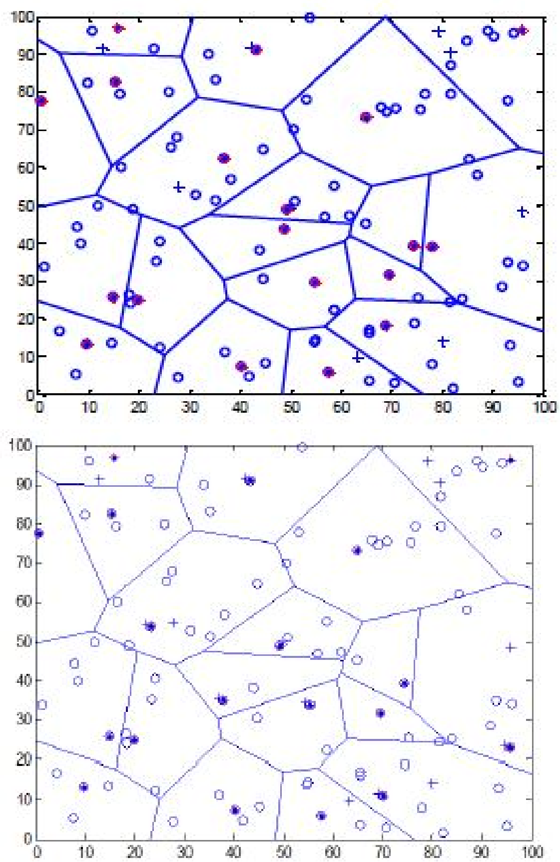


Fig. 1: Two examples of performing the LEACH algorithm

In this algorithm, the cluster heads periodically change and thereby it is resulted in balancing the load on the network. LEACH algorithm is divided into rounds which at the beginning of each round the LEACH algorithm is executed once and destroys the previously created compounds (But keep it in memory) and again, the new combination of cluster heads and cluster members is created.

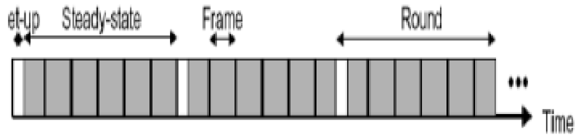


Fig. 2: Steps of performing the LEACH algorithm

The main purpose of LEACH, is to have a local base stations (cluster heads) to reduce energy consumption rising of transmitting data to a remote base station. LEACH, select randomly a few sensor nodes as cluster heads and organize the local nodes as local clusters. Assignment of nodes to the related cluster heads is based on proximity (distance). Nodes of non-cluster heads (which are called normal nodes) transmit their data to the cluster heads. Thus the only overload for them is Intra-cluster communication. Nodes of cluster heads require more energy than the normal nodes. There for selecting the fixed cluster heads nodes is leading to early depletion of energy and premature death. Balance of the energy of cluster heads is appointed by intermittent rotation the role of cluster heads between different nodes. Also using of community/composition in cluster heads, reduce the volume of messages sent to the base station and is resulting in energy saving. The performance of LEACH protocol is divided into several rounds. Each round begins with the installation (the clusters) which is organized in those clusters. Following the installation stage, there is a stage of data transfer, in which normal nodes send their data to the cluster heads and cluster heads after performing community/composition of data send their centralized packets into the base station to reduce the amount of information that must be sent to the base station. In LEACH, timing the sending of sensor data is done by protocol of code division multiple access (CDMA)[1] or time division multiple access (TDMA)[2]. Cluster heads are elected by a probability function. Each node chooses a random number between zero and one, and if the selected number is less than T (n), that node is selected as the cluster heads of the current round:

$$T\ (n) = \begin{cases} \dfrac{P}{1 - P\left(r \bmod \frac{1}{P}\right)} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where P is the probability of cluster heads, r is the number of the current round, and G is the set of nodes which in the 1/P of recent round were not cluster heads. According to the simulation model it has been demonstrated that only five percent of the nodes are required to be cluster heads. Strength of LEACH in the mechanism is the rotation of the role of cluster heads and community of data and it is able to increase the network lifetime, but it has disadvantages as well:

First, it assumes that all nodes in the network have enough strength to send the data to the base node and have sufficient computational power to support different MAC protocols. Therefore it is not applicable to large-scale networks. It also assumes that the nodes always have data to send, and the nodes close to each other have data dependent to each other. This protocol assumes that all nodes in each round of selection, begins with the equal amount of energy capacity, given to the consumption that the cluster heads almost consume energy as much as of the other nodes. The main disadvantage of LEACH is that it is not clear that a pre-determined number of cluster heads (i.e. P) how would uniformly be distributed in the network. In fact it does not provide any guarantees about the location or number of cluster heads in each round. Thus, it is possible that the selected cluster heads have been focused in part of network. The solution of this problem can be using a concentrated clustering algorithm.

[1] Code Division Multiple Access
[2] Time Division Multiple Access

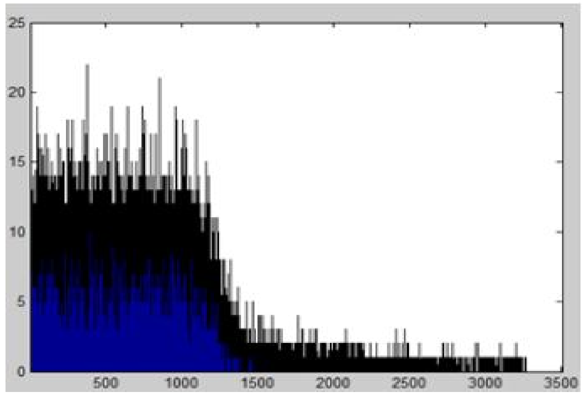


Fig. 3: Steps of performing LEACH algorithm based on clusters

2.2. The proposed methods for clustering

If the nodes have the minimum distance to their neighbors (centrality), other nodes will consume less energy to send data to the node. Therefore, the centrality is also one of the efficient parameters in clustering. So we define the centrality formulation as the sums of differences between each two neighbors distance of a node, the lower the number, the greater the centrality of nodes. If the nodes are in the focus, i.e. if more signals pass through that to get a cluster, it's better the node become into the cluster heads. Also if longer rounds take time and the node does not become into the cluster heads, to supply distribution of energy in the entire network, nodes are more likely to be cluster heads.

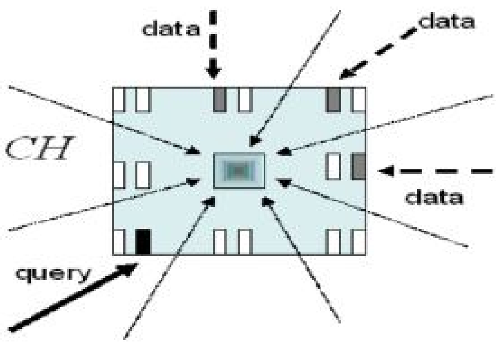


Fig. 4: Cluster heads in the Bloom filter

And inform him their remaining energy. It follows a lot of send and receives and consumes a lot of energy and it does not seem logical. We reached the conclusion that involves the number of packets sent to each of the neighbor nodes into the making decision rather than the remaining energy of that node. A node will allocate a mark or value to send packets for each of its neighbors which the value is the chance of that neighbor to pass the packet through that. It can be run easily by a Bloom filter. The first step in the Bloom filter, as you can see, is filtering the input values. This operation is performed easily by the membership functions. We need to have two membership functions, the one to conversion the number of addresses to that node and the other to transmit the packets' address to the next node.

2.3. Determine the percentage of cluster heads in entire network

We should use a parameter named "percent" of cluster heads for clustering the sensor networks which usually can be shown with P. P value indicate that how much of the available sensors in a network at a time are cluster heads, in other words, in clustering algorithms how many sensor can be introduced as cluster heads at any stage. It has been the subject of many researches and many experiments have been conducted and the results of these investigations are shown in the following chart. In chart of Figure 5, several experiments have been performed using N = 100 value of sensors which show whatever the number of cluster heads will move towards zero or N figure, the status of the entire network is not desirable, so that the entire network will have the maximum amount of energy wasting.

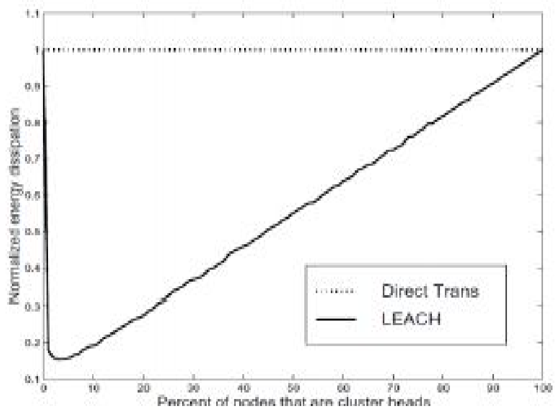
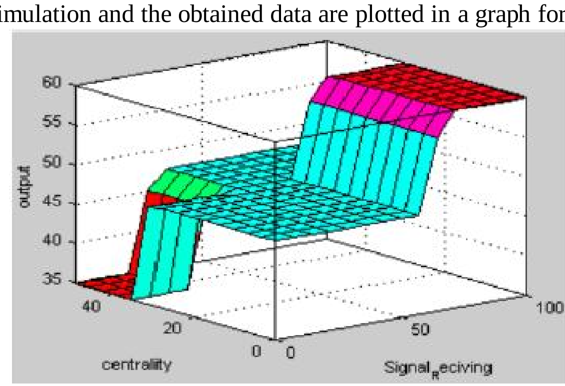


Fig. 5: Chart of setting clusters percent, P

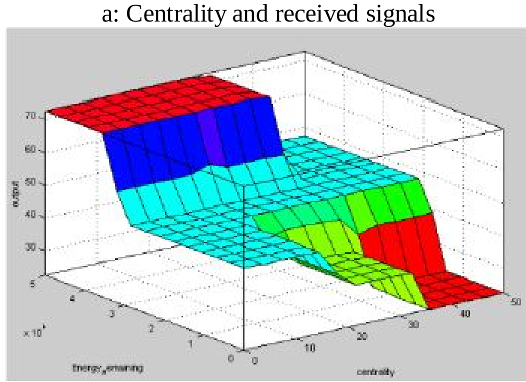
In this chart, as much as the number of cluster heads gets closer to 4 or 5 digits and the network conditions get very favorable, the amount of energy dissipation in the whole network will be slowed noticeably. The experiments have been done for different numbers of sensors (for different Ns) and the obtained results indicated that in all of these experiments if the ratio of the number of cluster heads to the total number of network sensors (N) close to 0.05 the desired result is achieved and the reducing of energy waste will be minimized. So in performing the clustering algorithms if need to know the percentage of cluster heads (P), it is commonly used of the value of P = 0.05 and P = 0.04. It is possible that in some clustering algorithms it needs to be reduced or increased slightly.

3. SIMULATION RESULTS

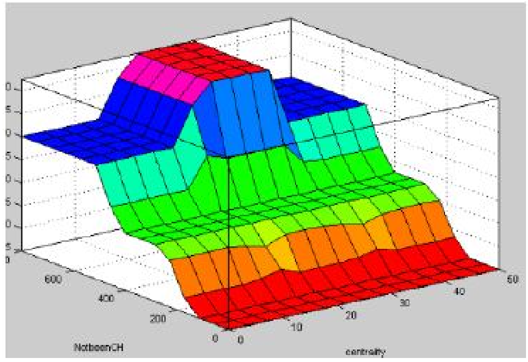
We have used NS-2 software to simulation and the obtained data are plotted in a graph form in the content.



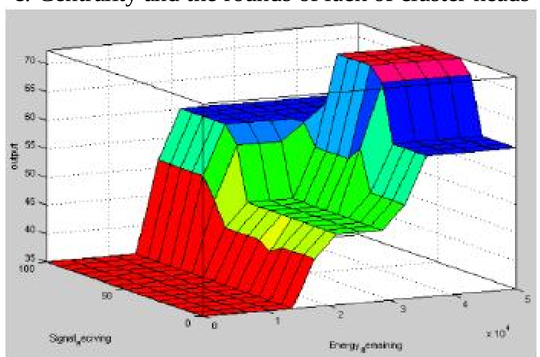
a: Centrality and received signals



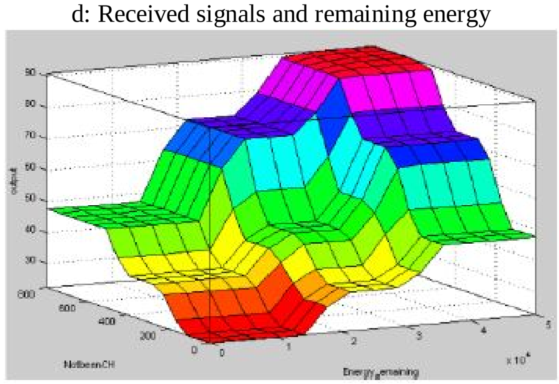
b: Centrality and remaining energy



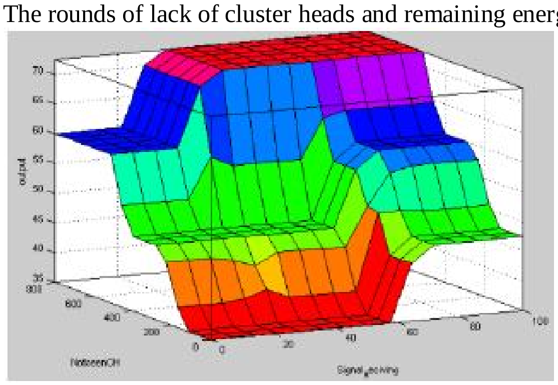
c: Centrality and the rounds of lack of cluster heads



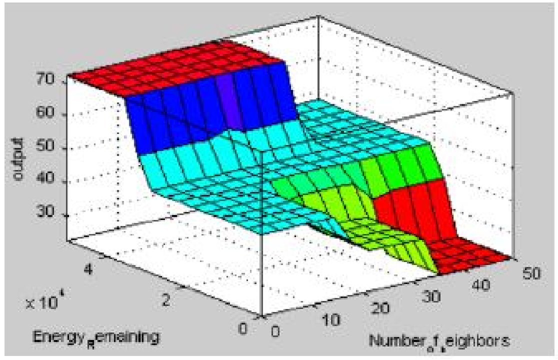
d: Received signals and remaining energy



e: The rounds of lack of cluster heads and remaining energy



f: The rounds of lack of cluster heads and received signals



g: Number of neighbors and remaining energy

Fig. 6: Impact of input and output parameters

This figure shows that the impact of remaining energy and the number of rounds of lack of cluster heads on the output is more than the other parameters.

We choose a network with 100 x 100 perimeters by selecting 20 nodes to compare with LEACH algorithm. Coordinates of the wells are (200, 50).

Table 1: Energy parameters

Initiat energy	0.5J	E_{elect}	50nJ/bit
ϵ_{fs}	$10pJ/(bit*m^2)$	ϵ_{amp}	$0.0013pJ/(bit*m^4)$

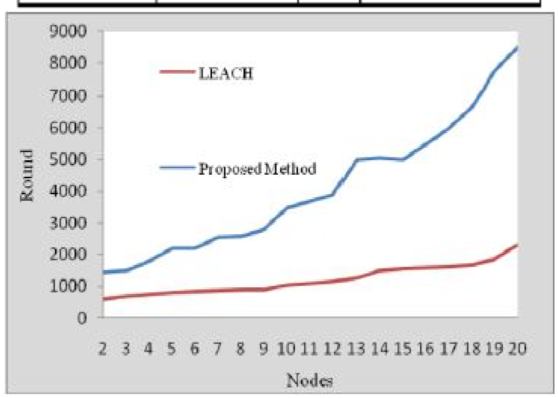


Fig. 7: Alive nodes

3.1. Energy Consumption

Figure 8 shows the difference of energy consumption between the proposed method of Bloom filter and LEACH. You can see that the Bloom filter uses less energy than the LEACH method, and thus the network lifetime is greater. Using the scalable techniques based on Bloom filters leads to reduce the communication costs. The combination of fully distributed protocol for autonomous systems by using of local feedback mechanism and central data communication and a Bloom filter, provide a scalable solution with efficient energy. A bloom filter is an efficient space which refers to the possible structure of the set of elements. A set of hash functions is used a set of elements in the filter to test the elements. While, false positives may be reduced by allocating memory.

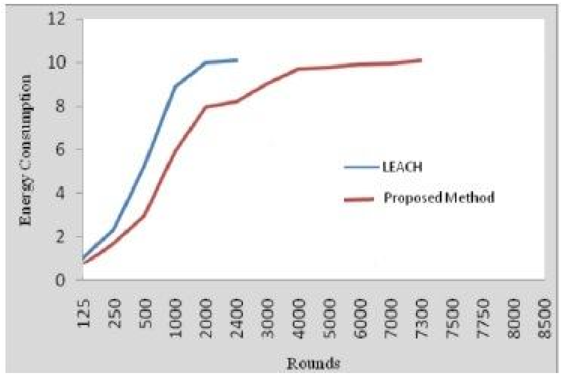


Fig. 8: Energy Consumption

4. Conclusion

Our main objective of this paper is to achieve an efficient and convenient method of routing and also clustering for wireless sensor networks. In this design, the node sends the packet to a neighbor that has a greater chance of being selected. Bloom filter is determining the chance of a node. Bloom filters have advantages such as it works well with non-precision and heterogeneous inputs and does not require heavy processing. Since our scheme uses the parameters of transmit number to a node instead of remaining energy, it can prevent wasting a lot of energy to get the remaining energy of nodes.

Acknowledgment

The authors declare that they have no conflicts of interest in this research.

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