DESIGN AND ANALYSIS OF SECURITY ALGORITHMS FOR ROUTING IN WSN

Shipra Khurana*

Ashish Gupta**

ABSTRACT

The aim of this master paper is the implementation of simulation models and the simulation of energy-efficient network initialization algorithms. First of all, it is presented a survey of state-of-the-art strategies for network initialization and exploration in wireless ad-hoc networks. Among the routing approaches presented in the survey it has been chosen the clustering-based approach due to it is the most suitable for ad-hoc sensor networks. Following are explained the features and properties of the clustering-based routing algorithms that have been selected for their implementation on this work. These implemented routing protocols are LEACH, LEACH-C, the solaraware extensions of both, HEED and a protocol based on direct transmission just as a reference in the comparison among the rest of them. On the other hand, all these routing protocols have been implemented and simulated. Subsequently, all the protocols have been simulated with different parameters and conditions to prove their functionality and to find out their behavior in different sorts of sensor networks. Next, the simulations of the algorithms are compared among each other especially in terms of communication and energy efficiency. There are presented different comparisons such as LEACH and LEACH-C with their respective solar-aware extensions of both, a comparison between HEED with optimized parameters and non-optimized parameters, and finally a general comparison among One-hop, LEACH, LEACH-C and HEED. To sum up, some conclusions are drawn about the performance of the different protocols and some key points are given for future work. Furthermore, it is presented a brief study of the environmental impact this work may have.

*Lecturer, Department of Computer Science and Technology, RP Inderaprastha Institute of Technology, Bastara, Karnal, Haryana, India.

**Assistant Professor, Department of Computer Science and Technology, RP Inderaprastha Institute of Technology, Bastara, Karnal, Haryana, India.

I. INTRODUCTION

A Wireless Sensor Network or WSN is supposed to be made up of a large number of sensors and at least one base station. The sensors are autonomous small devices with several constraints like the battery power, computation capacity, communication range and memory. They also are supplied with transceivers to gather information from its environment and pass it on up to a certain base station, where the measured parameters can be stored and available for the end user. In most cases, the sensors forming these networks are deployed randomly and left unattended to and are expected to perform their mission properly and efficiently. As a result of this random deployment, the WSN has usually varying degrees of node density along its area. Sensor networks are also energy constrained since the individual sensors, which the network is formed with, are extremely energy-constrained as well. The communication devices on these sensors are small and have limited power and range. Both the probably difference of node density among some regions of the network and the energy constraint of the sensor nodes cause nodes slowly die making the network less dense. Also it is quite common to deploy WSNs in harsh environment, what makes many sensors inoperable or faulty. For that reason, these networks need to be fault-tolerant so that the need for maintenance is minimized. Typically the network topology is continuously and dynamically changing, and it is actually not a desired solution to replenish it by infusing new sensors instead the depleted ones. A real and appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes. Sensor devices in WSNs monitor the same event and report on them to the base station. Therefore, one good approach is to consider that sensors located in the same region of the network will transmit similar values of the attributes. This fact notices inherent redundancy in the node transmissions that may be used by the routing protocol.

Sensor networks need protocols, which are specific, data centric, capable of aggregating data and optimizing energy consumption.

II. ROUTING PROTOCOLS

A routing protocol coordinates the activities of individual nodes in the network to achieve global goals and do so in an efficient manner.

Sorts of Routing Models

One-hop model

This is the simplest approach and represents direct communication. In these networks every node transmits to the base station directly.

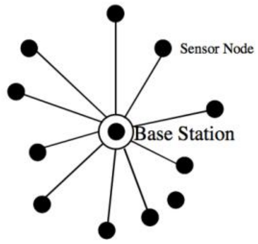


Fig.1 One-hop Model.

Multi-hop Planar Model

In this model, a node transmits to the base station by forwarding its data to one of its neighbors, which is closer to the base station.

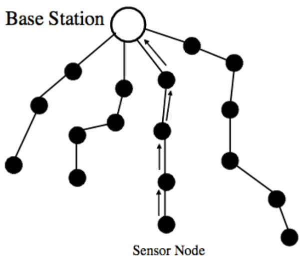
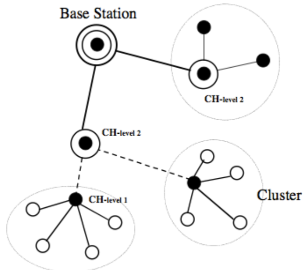


Fig.2 Multi-hop Model.

Clustering-based Hierarchical Model

A hierarchical approach for the network topology breaks the network into several areas called clusters. Nodes are grouped depending on some parameter into clusters with a cluster head, which has the responsibility of routing the data from the cluster to other cluster heads or base stations.



. **Fig.3 Hierarchical Clustering-based Model.**

III. PROTOCOLS IMPLEMENTED

After having finished a survey of the state-of-the-art it was necessary to select the protocols that would be implemented. Firstly, LEACH, i.e. LEACH-distributed, was selected due to the fact that is the first well known clustering-based routing protocol and all the subsequent clustering-based protocols are based on it or are referred to it somehow. Therefore, it was a good first step to start with.

Other interesting protocols that were selected to be implemented were LEACH-C, i.e. LEACH-centralized, created by the same authors of LEACH and also the solar-aware extensions of both. Finally, a more complex protocol, which is called HEED, was chosen since it is currently one of the most well known and mentioned routing protocols. The implementation of HEED is based on the pseudo-code that is provided in the original paper. Therefore, different protocols were selected for their implementation and simulation. These protocols differ in their complexity, the strength and number of assumptions they make and the goals they have. Once the programming of all these protocols was finished it was necessary to create and implement one basic protocol to compare the rest of them with it. The simplest approach for routing protocols is the One-hop that has been implemented for this work since it is a good simulation to see whether the compared protocols are energy efficient or not and how much they elongate the batteries lifetime. Therefore, in this work is presented a comparison among four protocols, i.e. One hop, LEACH, LEACH-C and HEED, and two solar-aware extensions, i.e. Solar-aware LEACH and Solar-aware LEACH-C.

1. One-hop

This protocol is the easiest and simplest routing approach and has been implemented to establish a reference for the comparison among the different protocols. It is based on the assumption that every node is able to reach the base station, otherwise it would be impossible the communication between every node and the base station. The operation of this protocol is quite simple. In every round the base station receives a status message from all nodes, which points out to the base station the position and parameters of the node. Once the base station has received all the messages it creates a TDMA schedule telling each node when it can transmit the data and how many times this process is repeated. Once all nodes have sent all the data packets regarding to the current round, they send another status message in order to start the next round.

2. LEACH-distributed

LEACH-distributed or LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network.

LEACH makes some assumptions about both the sender nodes and the underlying network, being some of them very strong. LEACH assumes that all sensor nodes can adapt their transmission range. Furthermore, energy consumption during transmission scales exactly with the distance and every sensor node is able to reach a base station (BS). Moreover, nodes support several MAC layers and perform signal-processing functions.

LEACH uses a distributed algorithm to determine the cluster heads in the set-up phase whereas in the steady phase nodes send their data according to the time schedule provided by their cluster heads. This operation of LEACH is divided into rounds.

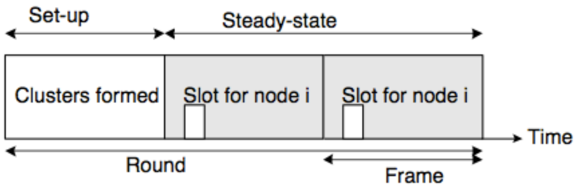


Fig.4 LEACH operations

- Advertisement Phase
- Cluster Set-Up Phase
- Schedule Creation
- Data Transmission

3. LEACH-centralized

Though there are some advantages using LEACH-distributed cluster formation algorithm, this protocol offers no guarantee about the placement and/or number of cluster heads. LEACH-centralized (LEACH-C) is a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. This method to form the clusters may produce better clusters by dispersing the cluster head nodes throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using a GPS receiver) and energy level to the BS. The BS needs to ensure that energy load is evenly distributed among all the nodes besides of determining good clusters. With this aim, the BS computes the average node energy and whichever nodes have energy below this average cannot be cluster heads for the current round. Using the remaining nodes as possible cluster heads, the BS finds clusters using the simulated annealing algorithm to solve the NP-hard problem of finding k optimal clusters. This algorithm attempts to minimize the amount of energy for the non cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distances between all the non-cluster head nodes and the closest cluster head. Since the authors of LEACH do not present the detailed algorithm the BS uses to choose k cluster heads, it is used simple heuristics. The process consists of three steps: In step 1, the k+3 nodes with the highest remaining energy are selected. In step 2, the potential cluster head with the minimal sum of the distances to all other potential cluster heads is removed. In step 3, it is removed one of the two potential cluster heads that have the closest distance to each other. If one of these two nodes is close to the border of the sensor area network, this node is removed. Otherwise the node closer to the centre of the sensor area network is removed. When removing the third node, the total sum of the square distance between non-cluster heads and their potential cluster head is minimized.

Once the cluster heads and associated clusters are found, the BS broadcasts a message that contains the cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a cluster head; otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data. The steady-state phase of LEACH-C is identical to that of LEACH.

4. HEED

HEED (Hybrid, Energy-Efficient, and Distributed) clustering protocol considers a hybrid of energy and communication cost. This approach only assumes that sensor nodes are able to control their transmission power level and does not make assumptions about the distribution of the nodes or their capabilities. A node only knows about the other nodes within its reachable range, which implies that nodes base their decisions only on local information. Further explanations about the requirements HEED must meet. HEED bases cluster head selection primarily on the residual energy of each node, which can be estimated, and intra-cluster communication cost as a secondary clustering parameter. In the latter case, cost can be a function of neighbor proximity or cluster density. The transmission power level used for intra-cluster announcements and during clustering determines the cluster range or radius. This level is referred as cluster power level and it dictates the amount of clusters in the network.

IV. SIMULATIONS OF THE PROTOCOLS

All the models of the protocols have been simulated just as all the simulations have been done on it.

One-hop

This protocol is the simplest approach for the communication of a wireless sensor network. The implementation has been completely done from scratch for this master thesis.

LEACH-distributed and Solar-aware LEACH-distributed

Both simulations presented in this work are based on the Solar-aware LEACH distributed simulation found. The original implementation of the protocol mentioned above had to be migrated. This implied to change a large number of functions and parameters as the original ones were deprecated. First of all is necessary to follow the migration file that can be found and afterwards the file provided by the INETMANET distribution since this simulation model is used in the implementations. Once the migration process has finished, it is still necessary to make some other changes that include the connections between each node and the base station, the connections among all nodes or some other parameters such as the functions regarding to simulation time.

LEACH-centralized and Solar-aware LEACH-centralized

Both simulations are based on the Solar-aware LEACH-centralized simulation found in as creation for the paper.

Firstly, was also necessary to follow the migration files provided and the INETMANET distribution, and later to make the necessary changes of functions and parameters directly on the code.

Furthermore, the handover function was completely done for this work since it was not included in the original code. This function outperforms the results since it forces the solar-driven nodes to become cluster heads for the next round. This function improves energy-efficiency since solar-powered nodes consume less amount of energy than the ones that run on their battery.

HEED

It has been created from scratch for this master thesis and based on the pseudo code. The intra-cluster communication cost parameter, which is the secondary parameter for the cluster head election process, is based on the closest node. However, it may be pretty easy to modify this parameter in order to take into account the average minimum reach ability power (AMRP) instead of the current one. In order to synchronize the end of the cluster election process in all nodes it has been used a function, which sends the status of each node to all nodes that are within its cluster range. This implies a further waste of energy and instead of this, in a future implementation could be used a synchronization technique such as RBS as is pointed out.

The inter-cluster communication is based on a simple multi-hop strategy, which allows all cluster heads to send the data directly to the base station or to send it to a cluster head even closer to the base station, otherwise.

V. RESULTS

Evaluation of the results

The results of the simulations done with the different protocols implemented in this work are shown

Simulation parameters

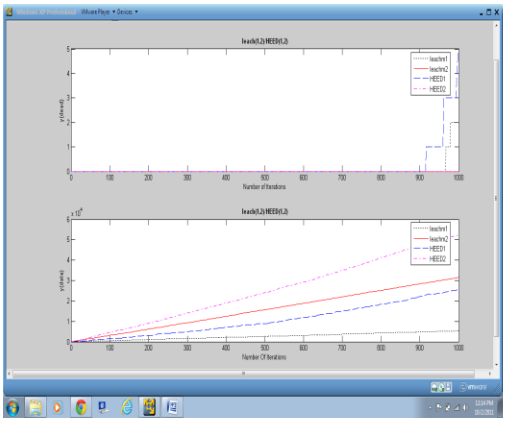
In table 6.1 are shown the parameters that have been used for the simulations of the implemented protocols.

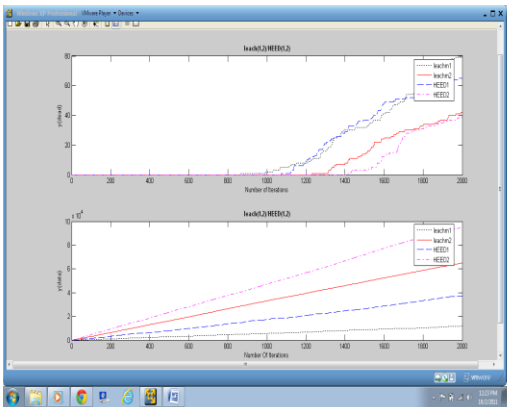
Type	Parameter	Value
Network	Network grid	From (0,0) to (100,100) (1), to (200,200) (2) and to (300,300) (3)

	Sink (BS)	For (1), At (50,150), (50,200), (50,250)
		For (2), At (100,250), (50,200), (50,250)
		For (3), At (150,350), (150,400), (150,450)

	Initial energy	0.5 J/battery
Application	Cluster radius (only for HEED)	R_c = 25 / 100 / 150; R_t = 50 / 100 / 150 / 200 / 250
	Data packed size	100 Bytes
	Broadcast packet size	25 Bytes
	Packet header size	25 Bytes
	Round (frames)	5 / 10 / 20 TDM frames
Radio model	Eelec	50 nJ/bit
	Efs	10 pJ/bit/m^2
	Efusion	5 nJ/bit/signal

Table 1. Parameters used in simulations





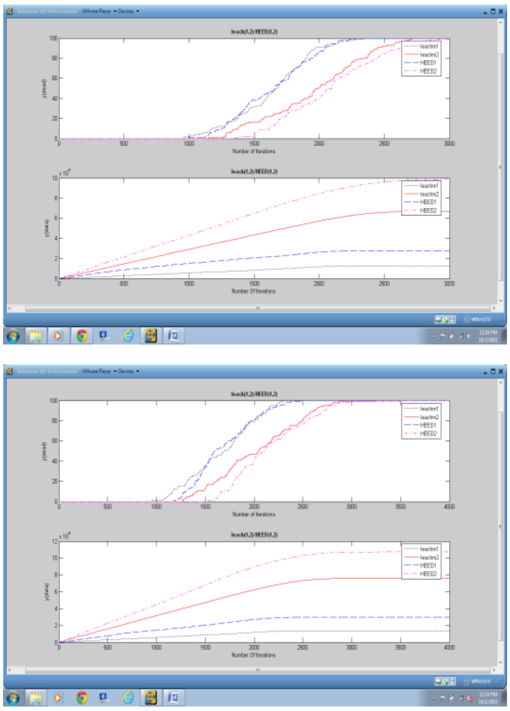


Fig. 5 LEECH and Comparison Graph

VI. CONCLUSIONS

After having carried out and finish this work some conclusions can be drawn. First and foremost, the studied clustering-based routing protocols have proved to be more energy-efficient than the One-hop routing approach, which could be considered the simplest one. The implementation of HEED that has been done for this work shows to be any energy-efficient protocol and has a balanced clustering formation. The former assertion can be observed, where the protocol that gets the longest lifetime is clearly and the highest number of rounds achieved until half of the nodes are already dead. The later assertion is justified looking at the graphical display of the network while the simulation is running, which always denotes clusters with quite similar number of cluster members and well distributed throughout the network. Furthermore, HEED also shows to be a good solution to implement in a wide sort of wireless ad-hoc networks due to its constant behavior that can be seen in the results of the simulations. On the other hand, LEACH and LEACH-C are good enough routing protocols for networks with high density of nodes according to the results obtained with the simulations. Despite of this assertion, it has to be taken into account that these protocols have strong assumptions such as every node can reach each other including the base station, what it is not feasible in most of cases. Another interesting conclusion is the improvement achieved using the solar-aware extensions of LEACH and LEACH-C in networks composed by nodes that are provided with a solar-collection module. The results obtained by these protocols show that these protocols are a really desirable option to consider in such a network since they achieve even the double of network lifetime than the original protocols.

VII. REFERENCES

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