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REEH: Residual Energy Efficient Heterogeneous Clustered Hierarchy Protocol for Wireless Sensor Networks

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Abstract—Wireless sensor networks (WSN) are spatially distributed micro sensor systems. WSN is a power constrained system, since nodes run on limited power batteries which shorten the life time of the system. Prolonging the life time depends on efficient communication protocol architecture. LEACH hierarchical homogeneous communication protocol which greatly minimizes the energy consumed in collecting and disseminating data. In this paper, impact of heterogeneity in energy of nodes to prolong the life time of WSN is described. A protocol is proposed, which is heterogeneous in energy than the LEACH protocol, further more residual energy of the network is used in which cluster head(CH) is selected based on the residual energy of the node and the cluster. This research work present a metrics approach, **FND** (first node dies), **HNA** (Half of the nodes alive) and **LND** (last node dies), to define lifetime of WSN. Simulation results using NS-2.27 shows that the proposed Leach- heterogeneous and residual energy based Leach protocol significantly reduces energy consumption and increase the total lifetime of the wireless sensor network compared to the homogeneous LEACH protocol.

Index Terms— Clustering, Energy efficiency, heterogeneous, homogeneous, LEACH protocol, network lifetime, Residual energy, wireless sensor networks.

1 Introduction

Wireless sensor network (WSN) consists of small in size sensor nodes, which form an ad-hoc distributed sensing [4] and data propagation network to collect the context information on the physical environment. WSN is widely used to collect reliable and accurate information in the distance and hazardous environments, and can be used in National Defense, Military Affairs, Industrial Control, Environmental Monitor, Traffic Management, Medical Care, Smart Home [7]-[5] etc. Figure1. Shows μAMPS microsensor network consists of hundreds to thousands of nodes that collaboratively gather environmental observations (footsteps of the jogger) and forward them to a remote base station (within the house). Individual nodes consist of an array of environmental sensors, A/D conversion, digital signal and network protocol processors, and a radio transceiver for two-way communication.

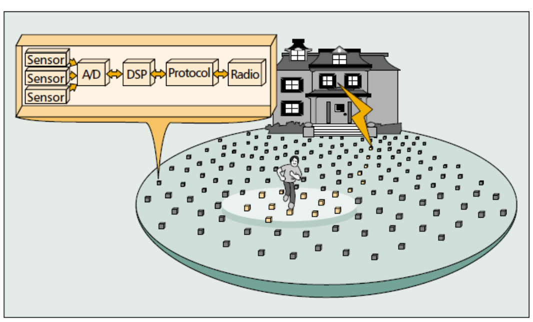

Figure 1: The μAMPS microsensor network

The sensor whose resources are limited is cheap, and depends on battery to supply electricity, so it's important for Routing to efficiently utilize its power in both military and civilian applications such as target tracking, Surveillance and security management. The sensor node has four basic components: sensing unit, processing unit, radio unit, and power unit. With their capabilities for monitoring and control, the sensors are expected to be deployed in vast area.

The main applications of sensor network is to periodically gather data from a remote terrain where each node continually senses the environment and sends back the data to the Base Station (BS) for further analysis, which is usually located considerably far from the target area. The most restrictive factor in the lifetime of wireless sensor network is limited energy resource of the deployed sensor nodes. Because the sensor nodes carry limited and generally irreplaceable power source, the protocols designed for the wireless sensor networks must take the issue of energy efficiency into consideration. Also, the network protocol should take care of other issues [4] such as self configuration, fault tolerance, delay, etc. Another important criterion in the design of a sensor network is data delivery time since it is critical in many applications including battlefield and medical/security monitoring system. Such applications require receiving the data from sensor nodes within some time limit. Communication protocols highly affect the performance of wireless sensor networks by an evenly distribution of energy load and decreasing their energy consumption and thereupon prolonging their lifetime. The paper is organized as follows: A brief introduction with related works of LEACH protocol in homogeneous system is presented in section 2. In section 3 describes the design of our novel proposed LEACH protocol in heterogeneous system in detail. Simulation and results are discussed in section 4. Finally, Conclusions are made in section 5.

2 Core of LEACH Protocol

2.1 Low-Energy Adaptive Clustering Hierarchy Protocol (LEACH)

LEACH, which was presented by Heinzelman in 2000[14], [13] is a low-energy adaptive clustering hierarchy for WSN. the sensor nodes from the entire network are shown in figure. 2

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are divided into several clusters, cluster-head nodes communicate with the local base station, then the local base station feed data to the entire network of base stations, and terminal user can access useful information

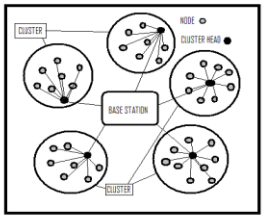

Figure.2: LEACH Protocol

The operation of LEACH can be divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady state phase where several frames of data are transferred from the nodes to the cluster head and on to the base station. During the set-up phase, each sensor node tries to select itself as a cluster head according to probability model. Figure.3 demonstrates the LEACH protocol Phases.

Figure 3: LEACH Protocol Phases

The different phases involved in LEACH protocol are as follows:

2.2.1 Advertisement Phase

Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node ***n*** choosing a random number between 0 and 1. If the number is less than a threshold ***T(n)***, the node becomes a cluster-head for the current round. The threshold is set as:

$$T(n) = p/\{1-p*(r \bmod 1/p)\} \quad \text{if } n \in G \qquad \ldots(1)$$
$$0 \quad \text{otherwise}$$

Where **p =** the desired percentage of cluster heads (i.e. 5% as suggested by LEACH), **r =** the current round, and **G** is the set of nodes that have not been cluster-heads in the last **1/p** rounds.

2.2.2 Cluster Set Up Phase

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits this information back to the cluster-head again using a CSMA MAC protocol. During this phase, all cluster-head nodes must keep their receivers on.

2.2.2 Schedule Creation Phase

The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster.

2.2.2 Data Transmission Phase or Steady-state Phase

Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement).

2.3 Radio Model for Energy Calculation

In this paper, we use the first order radio model. Here are some assumptions for our mechanism [10].

- All sensors are within the wireless communication range when they communicate with each other or with the BS.
- All sensors have homogeneous sensing, computing and communication capabilities.
- All sensors are randomly deployed in WSN.
- Network lifetime is defined as the time span from the deployment to the instant when the first sensor dies (or when the entire sensors die). According to [5], all the sensors would exhaust their energy resource at the same time.
- Both the energy dissipation of sensing data and the energy dissipation for clustering are neglected. Compared with the power consumption of CPU and Radio, the power consumption of sensor part is so small that can be neglected.
- The time span that BS collects the information from all the sensors once is defined as a round. In a round, each sensor has only one sensed data with the same packet size.
- The sensors that receive the data combine one or more packets to produce a same-size resultant packet, and by this way, the number of data that need to send by radio is reduced.
- The energy dissipation of fusing one bit data is a constant value.

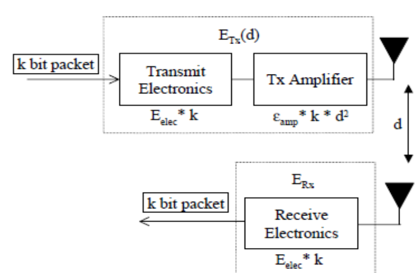

Figure 4: First Order Radio Energy Model

$$\mathbf{E_{Tx}(k, d) = E_{Tx\text{-}elec}(k, d) + E_{Tx\text{-}amp}(k, d)} \qquad \ldots (2)$$
$$\mathbf{E_{Tx}(k, d) = E_{elec} * k + \epsilon_{amp} * k * d^2}$$

The first item presents the energy consumption of radio dissipation, while the second presents the energy consumption for amplifying radio. Depending on the transmission distance

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both the free space εfs and the multi-path fading εmp channel models are used. When receiving this data, the radio expends: *ERx (L) = L*Eelec*. Additionally, the operation of data aggregation consumes the energy as EDA.

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2.4 Disadvantage of LEACH protocol

It assumes that the energy of all the nodes is same and remains so with time, further assuming that the energy usage patterns across the network are identical as the cluster-head activity is rotated among the nodes. These assumptions are too much restricting, and on relaxing these assumptions the LEACH protocol is found wanting as the decision of becoming a cluster head is totally unrelated to the residual energy of a node. Thus, nodes with little energy are as likely to become cluster heads as the nodes with abundance of energy. This will make the energy deficient nodes to die down fast and will gradually render the network useless even though there might be numerous nodes still having enough energy to be functional.

3 PROPOSED PROTOCOL

In this section we describe the proposed communication protocol which employs the Leach-Heterogeneous system in the network. Here the same procedure as in the normal LEACH protocol is followed. By taking the number of sensor nodes the formation of the clusters is same in this heterogeneous system. In this Leach-Heterogeneous system 0.10 percentages of nodes are having more initial energy than the other nodes in the wireless sensor networks. For this case of Leach-Heterogeneous system 10 nodes are having 4 Joule of initial energy out of 100 nodes in the network. The remaining 90 nodes are having 2 joules of initial energy. Secondly concept of residual energy [14] also used to select the CH with more energy than other nodes. The threshold for residual energy is given as

$$T(n)_{new} = \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)}\left[\frac{Ecurrent}{E_{\max}} + \left(r_s div \frac{1}{P}\right)\left(1-\frac{E_{current}}{E_{\max}}\right)\right] \quad ..3$$

When we increase the additional amount of energy to the nodes in the heterogeneous system of wireless sensor networks ultimately the additional energy are going to lost their energy in the end of the round. Depend the application, the number of advanced nodes can be increased and the total system lifetime can be increased significantly.

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4 SIMULATIONEXPEIMENT & RESULTS ANALYSIS

4.1 Constructing simulating platform

The experimental platform in this paper is NS-2(Network Simulator) version 2.27, which is installed on Linux ubuntu OS. In order to perform simulations for wireless sensor networks LEACH protocol is installed on NS-2.27. we make direct use of protocol simulation package from downloaded package ***mit.tar.gz*** and extract it in order to simulate our work.

4.2 SIMULATING & ANALYZING RESULTS

In this section, we evaluate the performance of the proposed approach through the simulations. A code for LEACH and proposed protocol is implemented in NS-2.27 in order to investigate the energy efficiency with lifetime extension of the mentioned protocol. Simulation parameters are as follows:

- In the range of (100,100), distributing 100 sensor nodes randomly and the file recording spread of nodes is ***100nodes.txt*** (it is used as a working standard in simulating the protocols.).
- The initial energy of each node is 2J.
- The percentage of cluster head nodes to the total number of surviving nodes is 5% in each round.
- The total length of simulation duration is 3600s.
- The effective signal transmission distance is 175 m.

Regarding the network lifetime, there are following regulations: without considering other unpredictable factors, when a node's energy value is less than 0, we think that it's dead; when surviving nodes within the network are less than 4, i.e. 96 nodes are dead, we consider that the network is out of work [1].

Parameter name	Values
Network area	100*100
Number of nodes	101(one BS)
Initial Energy	2J
BS position	50*175
Eelec	50nJ/bit
Etx=Erx	50nJ/bit
εfs(friss-amp)	10pJ/bits/m2
εmp (two-ray-amp)	0.0013pJ/bit/m4
do=sqrt(εfs / εmp)	
EDA	50nJ
Packet size	4000 bits

Table 1: Used parameters details

Based on the simulation results a table 2 is formed which shows **FND** (first node dies)**, HNA** (half nodes alive)**, LND** (last node dies) time in seconds for leach homogeneous, leach heterogeneous, residual homoleach, residual heteroleach.

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	FND	HNA	LND
Homo Leach	170	370	422.2
Hetro Leach	340	570	619
Residual Homo Leach	350	450	513.2
Residual Hetro Leach	430	590	662.2

Table 2: network lifetime for different protocols

The numbers of protocols are simulated and results are compared in terms of network lifetime. The graphs for different protocols are shown below- In order to investigate energy efficiency with lifetime extension, the performances of the proposed protocols are evaluated through simulations.which shows improvement in energy efficiency and lifetime of the network as follows:-

Hetroleach and homoleach: in hetroleach protocol the energy efficiency increased and network lifetime increased by 46.3% than homoleach protocols shown in fig. 5. For hetroleach protocol FND increased by 100%, HNA by 54% and LND by 46.6% than homoleach protocols shown in table 2.

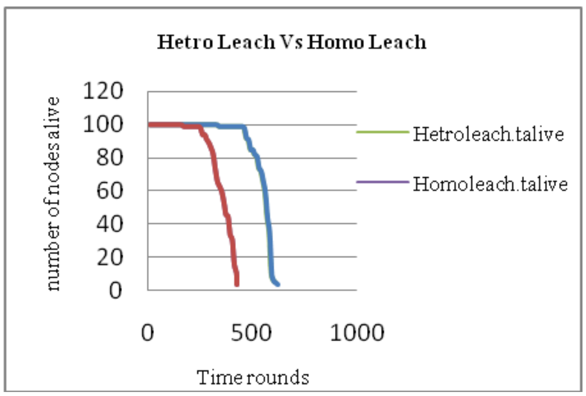

Figure 5: comparison hetroleach and homoleach

Residual homoleach and homoleach: in residual homoleach protocol the energy efficiency increased and network lifetime increased by 22% than homoleach protocols shown in fig. 6. For residual homoleach protocol FND increased by 105%, HNA by 22% and LND by 22% than homoleach protocols shown in table 2.

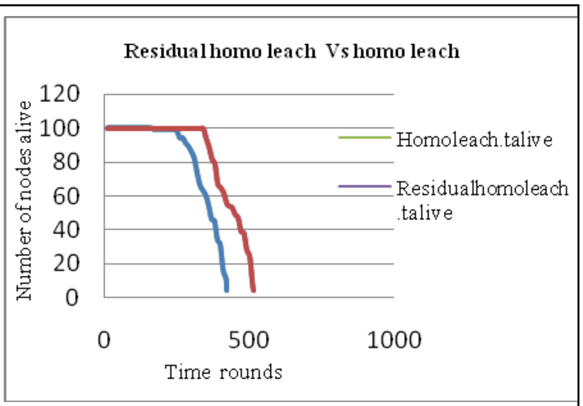

Figure: 6 comparison residual homoleach and homoleach

Residual hetroleach and hetroleach: in residual hetroleach protocol the energy efficiency increased and network lifetime increased by than homoleach protocols shown in fig. 7. For residual hetroleach protocol FND increased by 26.4% than hetroleach protocols shown in table 2.

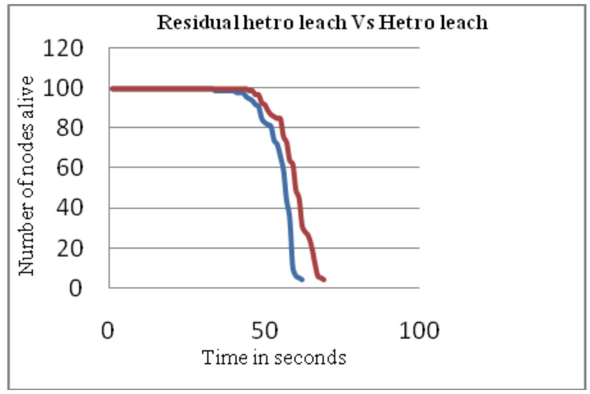

Figure: 7 comparison residual hetroleach and hetroleach

Residual hetroleach and residual homoleach: in residual hetroleach protocol the energy efficiency increased and network lifetime increased by 18% than homoleach protocols shown in fig. 8. For hetroleach protocol FND increased by 14%, HNA by 17.7% and LND by 18% than homoleach protocols shown in table 2

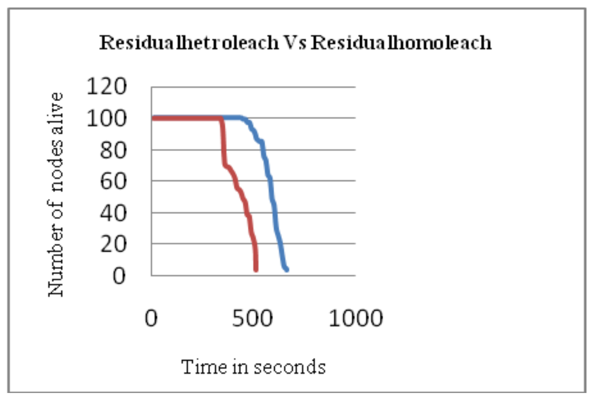

Figure: 8 comparison residual hetroleach and residual homoleach

4 Conclusion

In this paper, we have presented the proposed Leach-heterogeneous, Residual-homoleach, Residual-hetroleach protocols in the individual clustering of the whole network, which are energy efficient method for WSNs and compared it with the normal Leach- Homogeneous system. Results from our simulations using NS-2.27 are shows that the proposed protocols provides better performance in energy efficiency

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and increasing level in lifetime of the wireless sensor networks. We conclude that the heterogeneous and Residual wireless sensor networks are more suitable for real life applications as compared to the homogeneous counterpart.

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