

Implementation of IMHT LEACH Protocol for WSN

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Abstract

Wireless sensor network (WSN) consists of sensor nodes, which is divided into multiple levels for efficient communication. In WSN there are lots of protocols developed with different goals, but LEACH (Low Energy Clustering Hierarchy) is considered one of the most important among all other protocols. Lots of protocols are proposed as successors of LEACH but Multi-Hop Technique LEACH (MHT-LEACH) is considered effective one in terms of energy saving. MHT divides the whole network into two levels with reference to the threshold distance. But MHT suffers from area deployment problem when monitored area is considerably large. Improvement for this limitation of the MHT-LEACH, a new protocol is proposed named as Improved Multi-Hop Technique LEACH (IMHT-LEACH). In which the whole network is divided into multiple levels based on the distance between each other, which is proved to be more effective in terms of power saving. This paper illustrates practical implementation of IMHT-LEACH algorithm and parameters related to communication links like multiple hopping of data, response time and connection drop in half an hour in the implemented algorithm.

Keywords

Wireless Sensor Network; Hierarchical Routing; LEACH; Multi-Hopping Technique.

Introduction

In WSN hundreds of sensor nodes are deployed to monitor the specific environment, it has a wide range of applications [1]. Each sensor node has sensors, onboard computing circuitry, communicating device and power source [2]. To minimize the energy consumption and maximize throughput of the network, lots of protocols are developed aiming data transfer from the sensor node to Base Station (BS) [3] [4]. There are two routing techniques first is Network operation based and second is network structure based routing. Further network structure based routing is divided into three categories such as data-centric routing, hierarchical routing and location-based routing [5]. There are various types of hierarchical routing protocols like PEGASIS, TEEN, LEACH, APTEEN, PEDAP. LEACH is one of those hierarchical routing protocols which increases network lifetime significantly. In LEACH whole network is divided into clusters whose function is monitored by Cluster Head (CH) [6]. CH collects information from the sensor nodes and sends aggregated data to Base Station (BS). In LEACH operation of the cluster is divided into two phases i.e. setup phase and steady-state phase. In the setup phase after cluster formation, any node from the cluster member is selected as CH. The selection of cluster head is totally based on probabilistic value [6], as below:

$$T(n) = \frac{p}{1 - p * \left(r * \text{mod} \frac{1}{p} \right)} \quad \forall n = G$$

$$T(n) = 0 \quad \text{otherwise}$$

Where $T(n)$ is a threshold value. p Describes desired percentage of Cluster Heads (e.g. $P=0.05$) or in simpler words, it is the probability of the other nodes to become cluster head in the current round. G is the set of nodes that have not been CHs in the last $1/p$ rounds. (r) is the current round number. (n) is the node number.

In steady state phase data is actually transmitted from CH to BS. Here comes the role of IMHT-LEACH protocol, it is nothing but the modification over MHT-LEACH protocol. In MHT-LEACH protocol the whole network is divided into two levels. CHs in upper level transmit data to BS through lower level CHs which reduces power saving significantly as the distance of transmission is reduced. IMHT further modifies this protocol by dividing the network into multiple levels, which transmits data to BS through multiple hops.

Literature Review

Routing protocols in WSN specifically used to govern the data flow right from the sensor node to base station. Data collected by nodes is sometimes directly transmitted to BS or through CH's or even sometimes through other neighboring nodes. The main objective of WSN is to save energy, it may be through reducing the data to

be transmitted or by effectively transporting it to the base station. Aggregating data is one of the techniques to save energy, as number of resultant bits to be transmitted reduced energy requirement by the transmitter also reduces. Generally, data coming from sensor nodes is aggregated at the CH before transmitting it to the base station, but aggregating data is not considered as an effective technique to save energy. Therefore different routing techniques are implemented to reduce energy cost.

Routing protocols mainly classified in network structure based and network operation based, in which network structure based protocols can be effective in terms of energy saving and operation of the network in WSN. Network structure based routing protocol has three different routing technique i.e. flat routing, hierarchical routing and location-based routing.

In flat routing protocol all the sensor nodes play the same role i.e. sensing and transferring of data, there are no clusters and no node act as a cluster head. Therefore to monitor large network operation basically a query based, BS send requests to certain nodes of which area is to be monitored and wait for the response.

In location-based routing protocols all sensor nodes are identified by their location only, i.e. there is no special identification number present for the nodes. The location of nodes can be fetched by installing low power GPS receiver on the node [7], or through incoming signal strength in which neighboring nodes exchange this information to get the approximate location of the node [8].

Hierarchical routing is basically a multi-level routing scheme in which nodes in the network performs a different role. Some protocols divide the network into clusters. Each cluster is represented by CH, it collects the data from nodes in the cluster and sends it to the BS. Protocols in hierarchical routing are basically on the cluster formation, CH selection and propagation of data from node to BS. In hierarchical structure nodes having higher energy i.e. CHs, processes and sends the data collected by nodes having lower energy i.e. nodes. Cluster formation and information handling play important role in the lifetime of network, scalability of sensing the data.

There are various protocols under hierarchical routing scheme like PEGASIS, LEACH, TEEN, etc. In which PEGASIS performs well in terms of power saving [5]. It uses a collaborative technique that communicates with a neighboring node only and thus reaching the data to BS, this extends the network lifetime by dividing energy consumption uniformly [9]. But as it is chain based protocol and data propagates through one another, this increases the delay in the network and it becomes sluggish.

To minimize the delay parameter, Threshold-sensitive Energy Efficient Network Protocol (TEEN) is proposed for time critical application [10]. In TEEN, CH sets two values soft threshold and hard threshold; whenever the sensed attribute crosses soft threshold transmitter is turned on to transmit data to CH. And hard threshold is to inform BS that the sensed parameter has changed significantly. But if threshold values are not received, the node will not send any data to CH.

By highlighting the limitations of all the protocols there seems to be one protocol that can overcome all the requirement is Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. In LEACH information collected by sensor nodes is transmitted to CH and CH transmits it to BS. CH is selected on the basis of residual energy of the node and its role is rotated among the nodes of the cluster. When energy falls below the threshold level CH gives its role to another node in the cluster, and cannot become CH unless all the nodes in the cluster had become CH at least once. The author demonstrated that only 5% of cluster nodes have to perform the role of CH throughout the network lifetime [6].

In a modification to LEACH, various protocols are proposed some of which increases scalability of the network, some makes a more robust network or some add security to the network. But in the case of energy saving, MHT technique performs better. This technique is used in two protocols, in MHT-LEACH followed by IMHT-LEACH. In MHT-LEACH data transferred from CH to BS in hops through CH only. MHT divides the whole network into two levels; upper level and lower level. These levels are separated by threshold distance (d_0), the threshold distance is decided by how much distance BS can communicate [11]. Lower level CH's transmits their data directly to the BS, whereas CH's in upper level communicates to BS through CH's in the lower level. This greatly reduces power requirement, as required power is directly proportional to the square of the distance between transmitter and receiver and thus increasing network lifetime. But it suffers from a problem known as an area of deployment if area to be monitored is considerably large. Because of this most of the CH's are located at distance greater than the threshold distance (d_0) and therefore has to communicate directly to BS, draining the battery in a very short time. As an improvement to MHT-LEACH new protocol IMHT-LEACH is developed, unlike MHT it divides the network into multiple levels rather than two levels.

The IMHT-LEACH Protocol

As MHT-LEACH adds a new feature to CH that directly routing its data to BS or to another CH, but it suffers area of deployment issue which leads early death of nodes present at distance greater than d_0 . This limitation is overcome in IMHT-LEACH protocol. IMHT divides the network into multiple levels, therefore, nodes at far distances can communicate to BS through other CH's by multiple hopping of data [12]. The maximum length of every level is $d_0/2$.

IMHT differentiate CH's based on distance from BS. It has three phases: setup phase, routing phase and data transmission phase. IMHT-LEACH supposes that clusters are formed and CH's are selected. In the setup phase, all the CH broadcast announcement message to all the CH's in the network. CH's which are in the range of BS respond to announcement message by giving acknowledgment signal. CH's of which acknowledgment messages are not received, BS request other CH's which are in range to send announcement message on behalf of itself. After receiving a response of all CH's in the network routing table is created this is known as routing phase. When the setup of the network is done completely next stage is to transfer actual data. In data transmission phase data sensed by nodes are transmitted to BS through various CH's. This phase also decides network lifetime because data transmission requires more energy. Sometimes data transmission is periodic or sometimes it is query based and this decides battery usage.

Proposed System

Here in this paper, a modification in the existing protocol is proposed in which the master will advertise for the nearest path depending upon the nearest neighbor protocol. Once the shortest path is set the communication commences through the fixed path. Since the master is advertising for the shortest path there are fewer queries like multiple paths.

The Improved IMHT-LEACH protocol is a 3-stage protocol as sensor nodes use three types of messages ADV, REQ and DATA to communicate. ADV is used to advertise new data, REQ to request data, and DATA is the actual message itself. The protocol starts when a CH obtains new data that it is willing to share. It does so by broadcasting an ADV message containing destination ID. The Advertisement Frame is flooded on the network. Using the shortest Path algorithm the Base station finds out the shortest path and then the Request frame containing the data request and a fixed path is sent which is then responded by the destination node with sensor Data.

All the communication is done using the nearest neighbor concept and Co-operative communication. If the CH's are out of range then the master will send a Frame which contains the destination ID which will then travel through the WSN and return back with the desired data using the shortest path algorithm.

Simulations and Results

Experimental Setup

The embedded kit developed as in figure 1, has PIC18F4520 microcontroller, temperature sensor, fire sensor, gas sensor and RF module. The on-board sensor collects data from surrounding environment and with the help of UART this data is fed to the controller, further the controller compiles a frame for communication adding 'source ID' and 'destination ID', which help to direct the data at the destination.

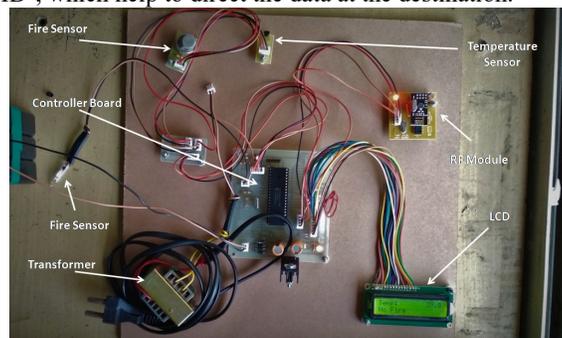


Figure 1: Experimental Setup

Initially master will broadcast the advertisement signal to which all slave's response with the response signal. Master will observe all the response frames and if response from any one of the slave is missing then it forwards the advertisement frame through the sensors which are in the range of it, if got the response of missing slave then the connection is established through hopped communication and the routing table of that node is created.

Both master and slave both use the same frame format as shown in figure 2. The frame contains frame ID which indicate if it is advertisement frame or data frame, sender ID, router ID, destination ID, command bit i.e. if it is request or response frame, path type if it is direct or hopped and if hopped then the path which is through frame is hopped is added in to router ID's.

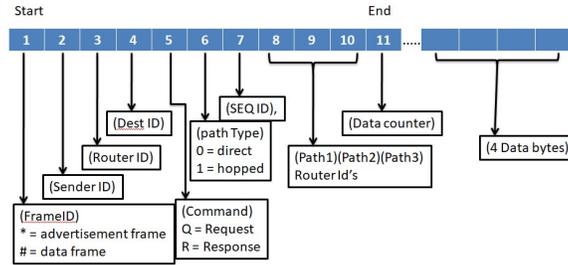


Figure 2: Frame Format

Algorithm

- Step1:- Start
- Step2:- Initialize system.
- Step3:- Read ADC, Store Temperature & Gas and display it on LCD.
- Step4:- If request received then go to step 5 else go to step 3.
- Step5:- If destination matched then go to step 6 else go to step 3.
- Step6:- Send response to BS and go to step 9.
- Step7:- Forward the frame with Request and include router ID.
- Step8:- If destination matched then go to step 5 else go to step 3.
- Step9:- If response frame received then go to step 10 else go to step 3.
- Step10:- If destination matched then go to step 12 then go to step 11.
- Step11:- Forward the frame with Response and include router ID and go to step 2.
- Step12:- Store values & display results.
- Step13:- End.

Simulations

Basically, as embedded kit is developed for experiment, therefore most of the results are real-time based and may differ with practical simulations. For the development of IMHT program for PIC microcontroller, we used microchip MPLAB IDE v8.91 simulation tool, which supports code editing, programming and debugging. To load program into microcontroller there is tool known as PICKIT 3, it communicates controller serially using UART. MPLAB converts code written in assembly language in to '.hex' file that can be loaded in to microcontroller.

For the designing and simulation of the circuit, we used circuit simulation tool 'Proteus 8'. In proteus simulated circuit, actual input signal can be given from virtual terminal and output can be observed on simulated 'LCD display'.

The operation of the whole system can be monitored from computer through visual basic software. The parameters measured such as temperature, gas, fire can be displayed on monitor screen through visual basic. It also displays the data coming directly from sensor node or through hopped from another node. Figure 3 shows data directly coming from the sensor node and figure 4 shows data of sensor node 1 received by one hop through sensor node 2, whereas getting data of node 2 directly.

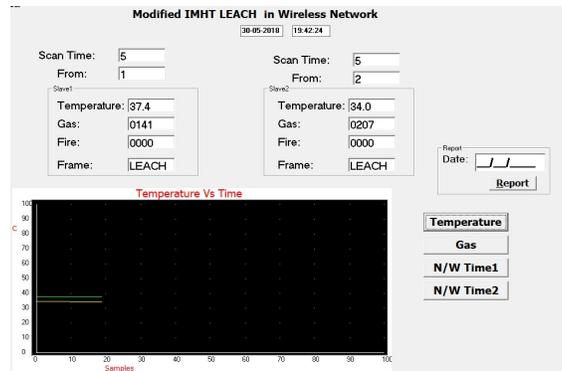


Figure 3: Data of both Sensor Node Directly.

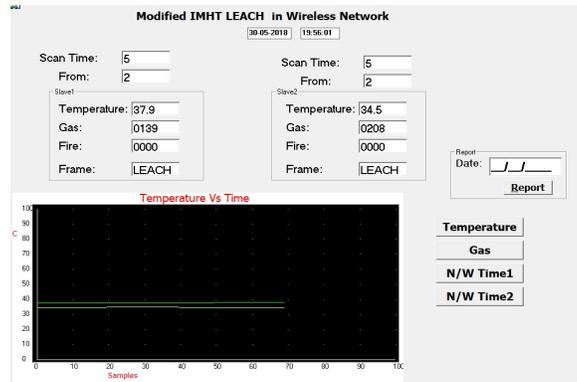


Figure 4: Getting Data of One Node Directly Whereas Another Node Through Hop.

Timing Results

To get timing results like response time and connection drop both the kits are operated simultaneously at different distance. For the sake of simplification response time of only one kit is observed, for this the kit first kept at a 0-meter distance that is very close to the master and then gradually increasing the distance allowing slave to communicate with master directly when in the range and then through hop when it moves out of range. An average of 20 readings is taken to get response delay for a particular distance. Figure 5 shows graph of response time Vs distance.

As the communication range of each node is 5 meters (say threshold distance) only one node is kept constant at a 5-meter distance, while another node whose response is to be observed kept moving at different distances. When node is at a lower distance that is less than the 5 meters it will be in the range of master and can communicate directly, therefore, time required to respond to request is less, in this case graph of response time is near remains constant.

When the node moves through threshold distance connection link breaks down therefore it tries to communicate through another node which is in the range. As request sent by master and response to that request is now coming through a node rather than directly the average response time increases compared to direct communication. Graph shows the results of response time versus distance between node and master.

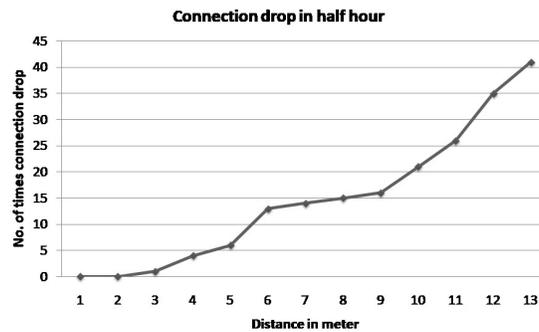


Figure 5: Response Time Vs Distance of the Node

Another parameter to be observed in the system is connection drop during the particular interval of time as in figure 6. For the experiment, number of times the connection drop in half an hour has been observed. As experiment is performed in a closed room there is miss-hearing of the request occurs and because of echoing of the wave through wall the same request can be received multiple times and node cannot give the response to these unusual signals and hence the link between the node and master is breaks down and the connection drops. The network hardly requires 3-4 seconds to establish a new connection link on itself.

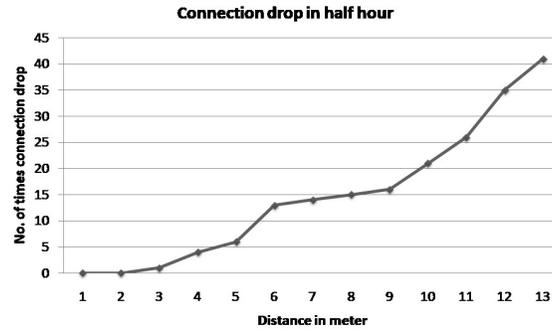


Figure 6: Connection Drop in Half-Hour Vs Distance in Meter

Conclusions

In this paper, the IMHT-LEACH protocol with one master and two slave nodes has been successfully implemented. The master communicates directly with two nodes when both are in range. When one node is moved out of range the connection is set automatically through the node which is in the range. In addition to this, the graphical results are obtained which shows network characteristics such as delay time and connection drops remains same when the routing phase is complete and both nodes are operating in range. The response time graph get stabilizes for two different range of distance and it is separated by small region which shows there is time difference in response when data comes directly and through one hop. That means designed system performs well when the master and slave are in the specified range.

In future GPS module or method of triangulation can also be used in this system so that the accurate position of the sensor node can be obtained and more energy can be saved by controlling transmission power.

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