Automation Using Data Aggregation In Wireless Sensor Network

BY

Parita Oza

11MICT51

GUIDED BY

Dr. Priyanka Sharma

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

AHMEDABAD-382481

May-2014

Automation Using Data Aggregation In Wireless Sensor Network

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Information and Communication Technology

BY

Parita Oza

11MICT51

GUIDED BY

Dr. Priyanka Sharma

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

AHMEDABAD-382481

May-2014

Certificate

This is to certify that the Major Project entitled "Automation using Data Aggregation In Wireless Sensor Network" submitted by Parita Oza (11MICT51), towards the partial fulfillment of the requirements for the degree of Master of Technology in Computer Science and Engineering of Nirma University, Ahmedabad is the record of work carried out by her under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

Dr. Priyanka Sharma
Guide and Associate Professor,
Department of CSE,
Institute of Technology,
Nirma University, Ahmedabad

Prof. Gaurang Raval
M.Tech. ICT Coordinator,
Department of CSE
Institute of Technology,
Nirma University, Ahmedabad

Dr Sanjay Garg
Professor and Head,
Department of CSE,
Institute of Technology,
Nirma University, Ahmedabad

Dr K Kotecha
Director,
Institute of Technology,
Nirma University, Ahmedabad

Abstract

Wireless Sensor Network (WSN) is a variant of Mobile Ad-hoc Network which has strict resource constraints. In WSN sensor nodes are scattered in the sensor field. These nodes sense parameters like humidity, pressure, sound etc and report it to the sink node. These direct form of data transmission takes significant amount of energy also nodes may sense correlated data and may report redundant data back to the sink. The project aims to identify efficient data aggregation protocol and further enhance it for achieving better network life time also to use this aggregation protocol for automation of an application like automation of water sprinklers(where based on the humidity present into the soil water will be supplied automatically). Hardware implementation of data aggregation with very small network of 3 nodes is also done using arduino microcontroller. In these small experimental setup nodes can sense amount of humidity present into the soil, generates results accordingly and report it to the aggregator node. Aggregator node is connected to the laptop via USB which is acting as sink node where analysis of result is done. To use this approach in real time application like automation of garden water sprinklers, model for automation is also presented.

Acknowledgements

With immense pleasure, I would like to present this report on the dissertation work related to "Automation using Data Aggregation in Wireless Sensor Networks". I am very thankful to all those who helped me for the successful completion of the first phase of the dissertation and for providing valuable guidance throughout the project work.

I would first of all like to offer thanks to **Dr. Priyanka Sharma**, Guide & **Prof. Gaurang Raval**,Programme Co-ordinator M.Tech. ICT, Institute of Technology, Nirma University, Ahmedabad whose keen interest and excellent knowledge base helped me to finalize the topic of the dissertation work. Their constant support and interest in the subject equipped me with a great understanding of different aspects of the required architecture for the project work. They have shown keen interest in this dissertation work right from beginning and has been a great motivating factor in outlining the flow of my work.

My sincere thanks and gratitude to **Dr. Sanjay Garg**, Professor and Head, Computer Engineering Department, Institute of Technology, Nirma University, Ahmedabad for his continual kind words of encouragement and motivation throughout the Dissertation work.

I am thankful to Nirma University for providing all kind of required resources. I would like to thank The Almighty, my family specially to my Husband and little Daughter, for supporting and encouraging me in all possible ways. I would also like to thank all my friends who have directly or indirectly helped in making this dissertation work successful.

- Parita Oza
11MICT51

Abbreviation Notation and Nomenclature

WSN .... Wireless Sensor Network

MANET .... Mobile Adhoc NETwork

LEACH .... Low Energy Adaptive Clustering Hierarchy

HEED .... Hybrid Energy Efficient Distributed Clustering Approach

CH .... Cluster Head

AMRP .... Average Minimum Reachability Power

BS .... Base Station

PEGASIS Power Efficient data GAthering protocol for Sensor Information Systems

EADAT .... Energy Aware Distributed heuristic

PEDAP .... Power Efficient Data gathering and Aggregation Protocol

NS .... Network Simulator

Contents

List of Tables

List of Figures

Chapter 1

Introduction

Wireless Sensor Networks consists of small nodes known as sensor nodes and sink node. These nodes are having limited battery power. These nodes are scattered in the sensor fields and are capable of measuring parameters like temperature, humidity, pressure etc.. By sensing their surrounding they report it to the sink node using multi hop infrastructure less network. During these transmission some amount of energy is consumed which needs to be utilized efficiently. Data aggregation techniques can help here where only few nodes directly communicates to the BS thus saving energy of other nodes in a network hence improving network lifetime[2].

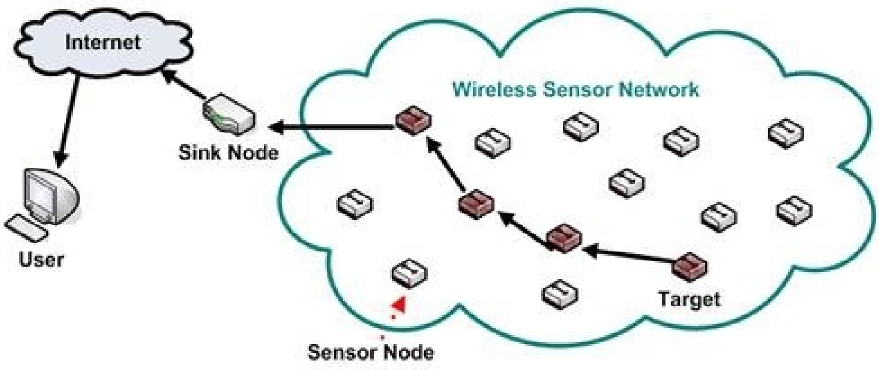


Figure 1.1: Wireless Sensor Network

1.1 Motivation

Wireless Sensor Networks are highly resource constrained they have limited memory, power and computation capabilities. Sensor nodes sense data based on its mechanisms and report it to the sink. These direct communication takes large amount of energy consumption. Network can be designed such that there are few nodes which receives data from various nodes, aggregates them and only few packets are to be sent to the sink. These nodes called an aggregator and process is called data aggregation.

Since hundreds of years our farmers have been watering farms with the traditional techniques and methods. This resulted in the less accuracy, more waste of water and in worst condition over irrigation of the plants. This continued for many years until some modern technologies come forward to rescue the farmers from the irrigation problem. These technologies include modern and efficient equipment for irrigation and water supply, like drip irrigation, water jets, water showers and sprinklers. These technologies prevented the loss of precious water and also helped achieve more efficiency and above all helped farmers bring down the expenses of water in form of taxes. These technologies served modern farmers well. But world is moving forward in fast pace. More efficacy and production are requirement of the todays world. But it comes in cost of the large human labor and precious time. Both are which very expensive.

Here comes the role of automation systems. They serve well to overcome the problem by eliminating the need for the human labor and human intervention and hence saving precious time. Even with less requirements this technologies are capable enough to provide more efficiency and production than before.

As we are speaking of water irrigation, we cannot miss the most important equipment used for irrigation by most of the farmers, water sprinklers. They have been in the use since very long and they evolved with time. They are now more affordable than ever, robust than ever and most importantly easily available. One important thing to notice is that they are mechanically operated. That means that they do not require any electrical power supply to work. Since they are in use we can use modern technologies like sensor networks and automation of mechanical instruments to make our farms and garden more smart and efficient.

Figure 1.2: Why Automation

Chapter 2

Literature Survey

In WSN nodes are battery driven. To use network for a longer time efficient use of power is an essential requirement. Using data aggregation redundant data transmission can be eliminated also it enhances lifetime of network.

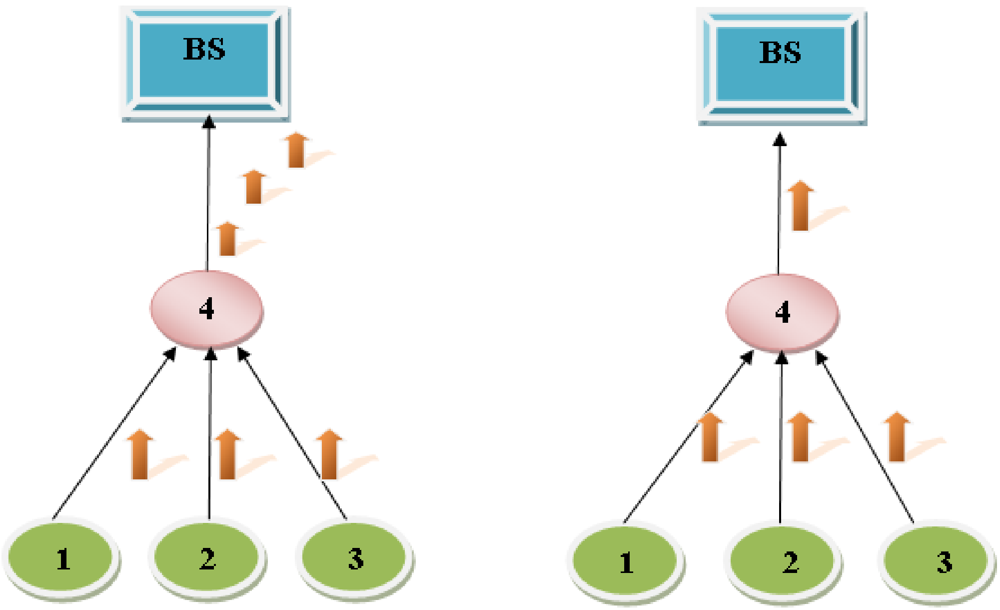


Figure 2.1: Data Aggregation Model vs Non Data Aggreggation Model

Figure shows two models one is non data aggregation model and second is data aggregation model where sensor nodes 1, 2, 3 are regular nodes which collects data and send them back to forwarder which is node 4.In this model total 4 packets travels in the network. These packets may have correlated data so same data is received by sink node. But if we use data aggregation and we make node 4 as aggregator then this node will receive data from all other nodes then apply some aggregation function on received data and finally only one packet is sent to the sink node[1].

2.1 Comparison of WSN Architectures

The architecture of the sensor network plays an important role in the performance of different data aggregation protocols. This section explains about two basic architecture of WSN.

Hierarchical Networks	Flat Networks
Data Aggregation performed by cluster head or a leader node.	Data Aggregation is performed by different node along the multi hop path.
Even if one cluster head fails, the network may still be operational.	The failure of node may break down the entire network.
Lower latency is involved since sensor node perform short range transformations to the cluster head.	Higher latency is involved in data transmission to the sink via a multi path.
Node Heterogeneity can be exploited by assigning high energy node as cluster head	Does not utilize node heterogeneity for improving energy efficiency.

Figure 2.2: Hierarchical Networks vs Flat Networks[4]

- Flat Networks:

  In flat networks, Every sensor node has same role and has same energy. Data centric routing is used to do data aggregation. Sink node does query to the sensor node using flooding approach and sensor with appropriate data respond the query.

- Hierarchical Networks:

From the comparison, Hierarchical data aggregation is chosen as data fusion at particular node improves significant energy efficiency.

2.2 Hierarchical data aggregation approaches

2.2.1 Chain Based Data Aggregation

In chain based data aggregation, each node transmits its data to the its closest node only. Here nodes are arranged in chain for the aggregation. Chain formation uses greedy algorithm for that every node should have global knowledge of the network[4]. **Disadvantage:** Global knowledge of all node position is required. One more disadvantage is that, crashing of leader node will loss all aggregated data of the network.

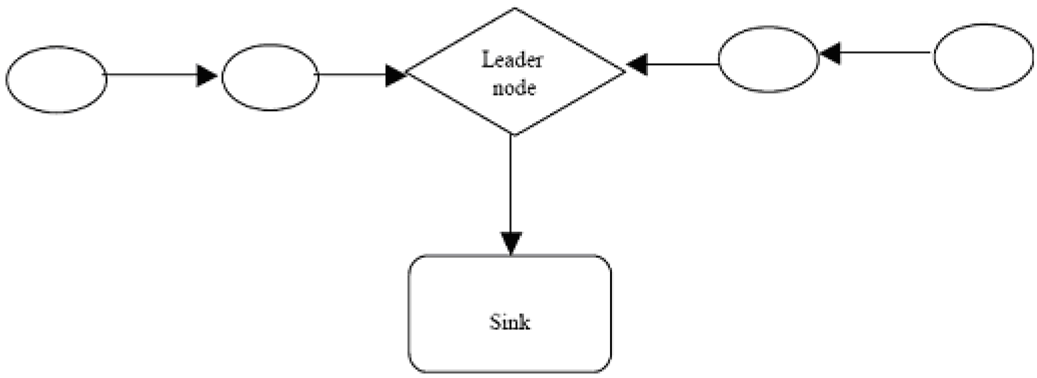


Figure 2.3: Chain Based Data Aggregation

2.2.2 Tree based data aggregation

This approach form an aggregation tree. It type of tree to be constructed is minimum spanning tree where sink node is act as root of the tree and source nodes are considered to be leaves. information flow is from downwards to the sink.

Disadvantage: If ata all data packet loss at any level of tree, the data will be lost not only for single level but for whole related sub tree as well[1].

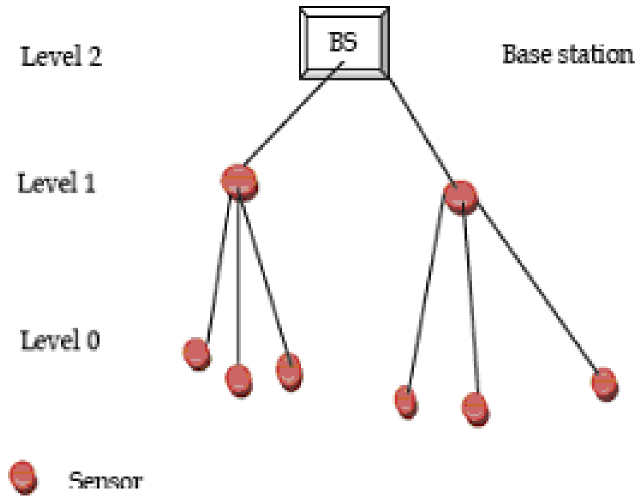


Figure 2.4: Tree Based Data Aggregation

2.2.3 Cluster Based Data Aggregation

In cluster based approach entire network is divided in to small small region called cluster. Every cluster has one leader node called cluster head. CH is the only node which directly communicates to the sink. All other nodes in a cluster send their data to the CH. CH performs role of aggregator[1].

This section explains about various data aggregation protocols.

LEACH[4]

Perhaps the first network protocol that is specifically designed for wireless sensors is the Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol [1].

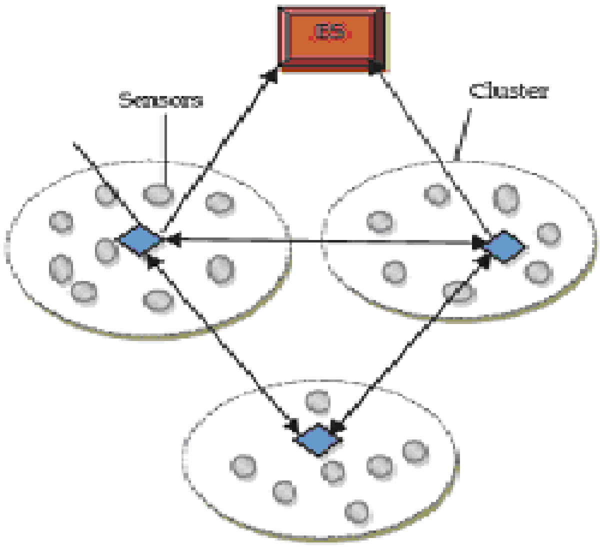


Figure 2.5: Cluster Based Sensor Network

Clusters Formation in LEACH: LEACH minimizes power consumption by dividing network in to clusters. For a network where large number of nodes generates a node clustering achieves two objectives, first, it reduces total data sent to the BS and second it reduces energy consumption. Operation of these protocol is called round. It uses distributed fashion where each node elects it self as CH independently. For doing these each node choose a random number between 0 and 1.

This number is then compared to the network wide threshold.In round 0, all nodes are eligible to elect themselves as cluster heads. During subsequent rounds, the number of eligible nodes decreases, consequently, the threshold probability must increase to maintain the required percentage. This protocol is divided into rounds; each round consists of two phases; Set-up Phase and Steady Phase.

Independent of each other each node decides whether it will become a CH or not. In the advertisement phase, CH inform their neighboring node using advertisement packet that they are CH for the round. non CH node, based on the signal strength

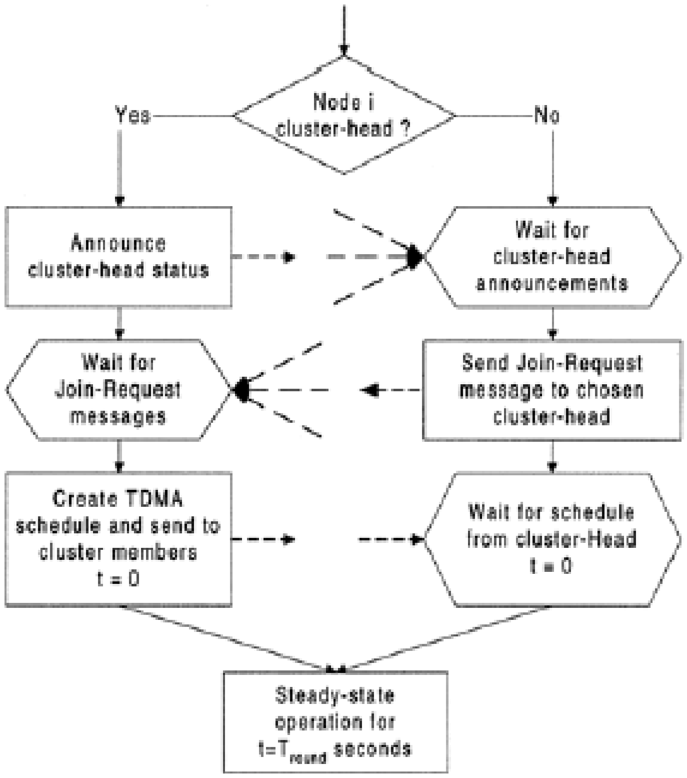


Figure 2.6: Setup Phase in LEACH

decides which cluster head to select. CH then creates TDMA schedule and broadcast in the cluster. non CH node then send their data in a given TDMA schedule this is called steady phase.

LEACH-C

LEACH protocol has several advantages but still it does not gives guarantee to the placement also number of CH nodes. It uses distributed approach for cluster formation so CH and cluster selection is not efficient. Use of central control algorithm to form a cluster may produce better clusters. This is the base of LEACH-C protocol. It uses the centralized clustering algorithm. Data transmission phase of LEACH-C is same as LEACH. In the beginning of round every node send there energy and location to the BS. BS then make use of simulated annealing algorithm to find out optimal clusters.

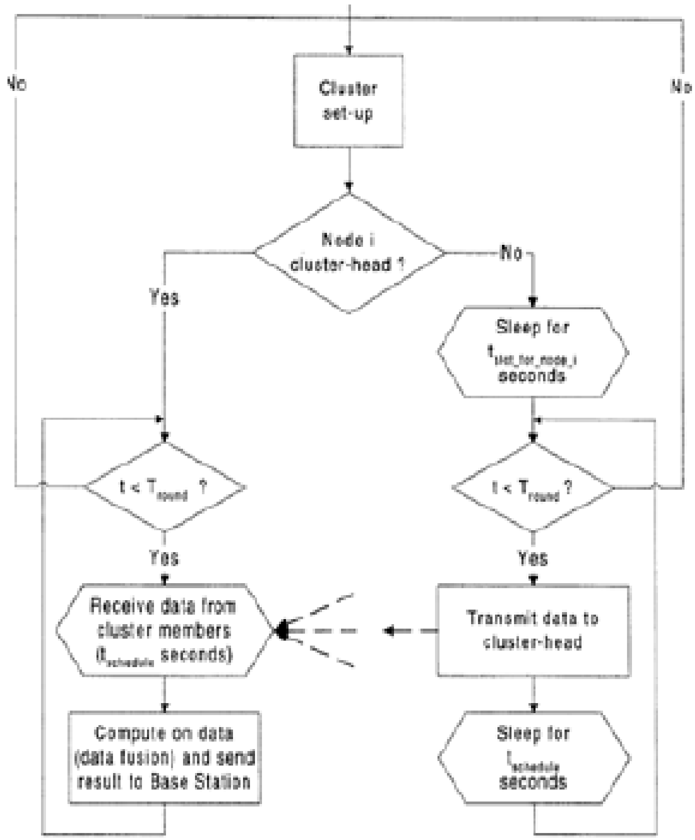


Figure 2.7: Steady Phase

Once the CH and clusters are decided,the BS then broadcast a message which comtains CH ID. Every node then matches its own ID with cluster head ID. if there is a match then that node is cluster head. The steady-state phase of this protocol is same as LEACH.

Chapter 3

Tools and Technique

3.1 Network Simulator

Networks simulator is tools which is used to analyze different network scenarios. Network simulator version 2.35 is used for analyzing said data aggregation protocol.

3.1.1 Installation Procedure

Step 1: Download and install following files:

- NS-2.34 package
- ns-2.34 - gcc410.patch
- MIT's LEACH
- Makefile patch for LEACH

step 2: modify NS 2 source code.

step 3: Run protocol using ./leach-test command

There are two programming languages, which are essential for developing NS2 simulation programs. These include Tcl/OTcl which is the basic building block of NS2 and AWK which can be used for post simulation analysis. NS2 uses OTcl to create and configure a network, and uses C++ to run simulation. All C++ codes need to be compiled and linked to create an executable file. Since the body of NS2 is fairly large, the compilation time is not negligible.

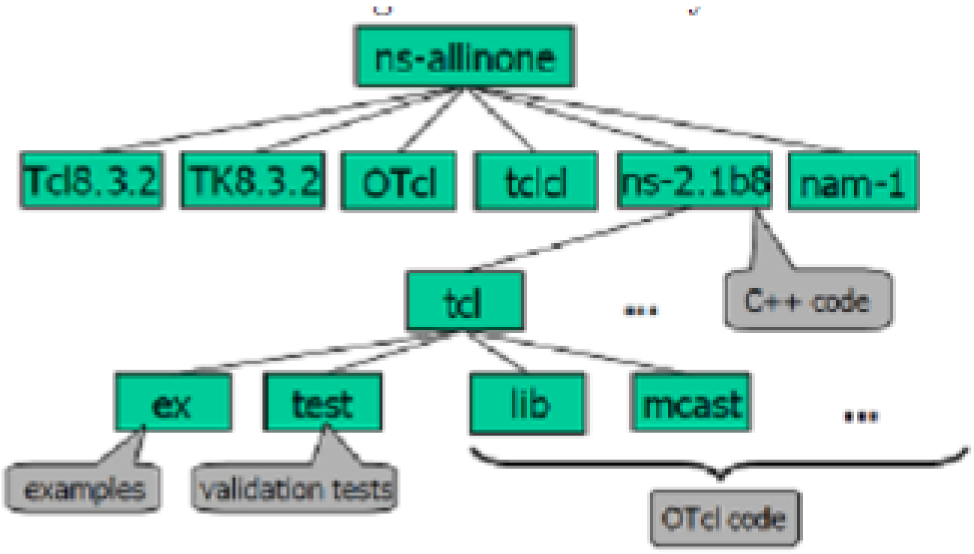


Figure 3.1: structure of NS2

Chapter 4

Simulation of Existing Protocols and Result Analysis

4.1 Simulation Environment

For doing simulation of a protocol some parameters needs to be decide. standard parameters are taken for the simulation shown in the following table.

Table I: Simulation Parameters

Parameters	Value
Node Distribution	100 X 100m
Number of Nodes	50,100,150,200
Initial Node Energy	2J
Simulation Time	3600s
Desired number of cluser-heads	5 percentage

4.2 Simulation Results

In figure 4.1 and figure 4.2 graph gives information about the energy consumption and life time of network. It is clearly seen that LEACH-C has short life span as compare to the LEACH and also it consumes more energy as compared to LEACH .This is because in every round all the nodes of network send their location and energy to the base station.

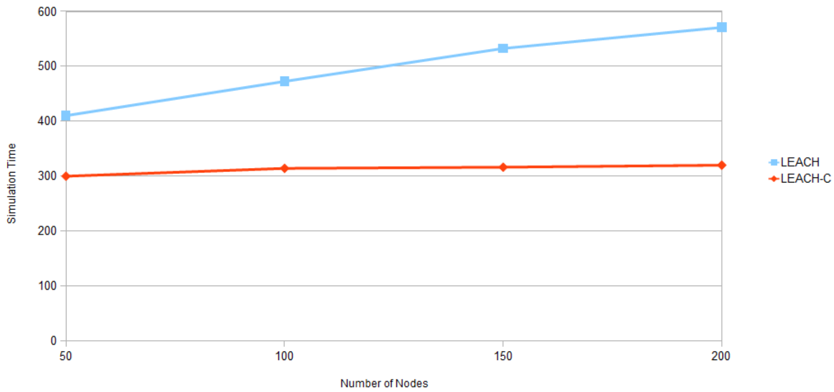


Figure 4.1: Network Lifetime

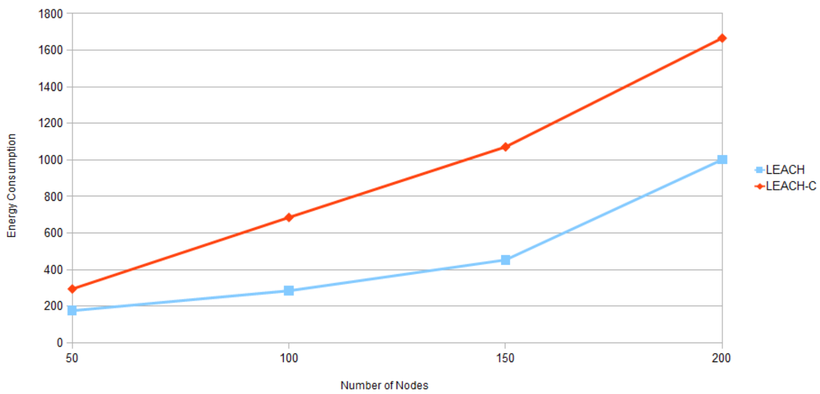


Figure 4.2: Energy consumed

In Figure 4.3 and Figure 4.4 LEACH and LEACH-C evaluated in terms of the amount of data received at base station. The result shows that LEACH-C has higher data transmitting capacity that to in less time as compared to LEACH.

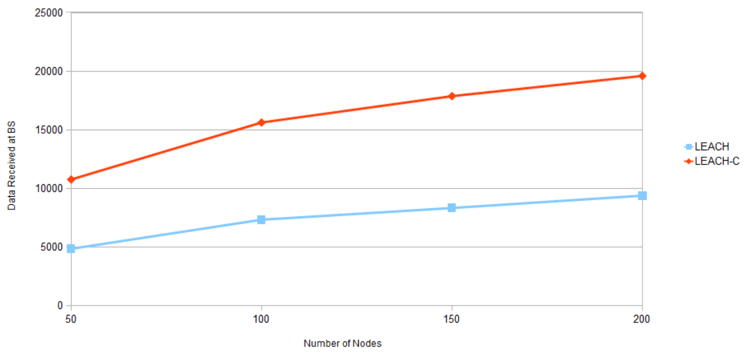


Figure 4.3: Data received at base station

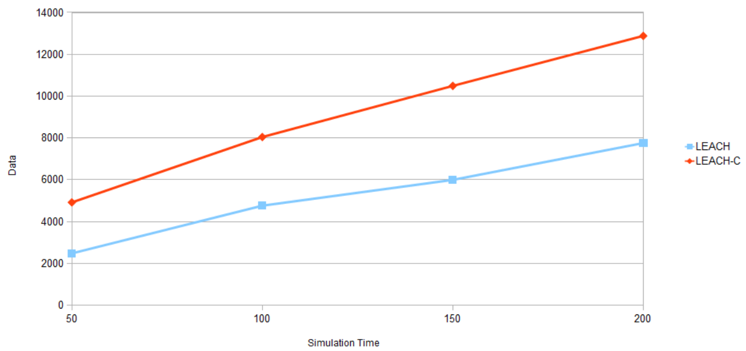


Figure 4.4: Data received at base station

Chapter 5

Problems and Proposed Approaches

5.1 Problems

During Literature survey and based on the simulation results of standard LEACH-C some drawbacks in LEACH-C are identified.

- In every round each node sends energy/location to BS
- BS is not receiving data from some nodes

5.2 Approaches

Listed above problems needed to be solved. So to overcome it some solution approaches are given.

- Allow Static nodes to send their location only once: In LEACH-C protocol,at each round all the sensor nodes sends their location and energy to the BS. But for static network nodes are stationary so there location is fixed. So protocol can be modified such that it also works for stationary nodes.

- Send negative-ACK to nodes whose energy is not received at BS for reliable com- munication: During simulation it is found that BS does not receives initial parameters like energy and location from some nodes. As we talk about static network BS has global information about the network so on not getting said parameters from a node BS should send negative acknowledgement to that specific node so that it can resend its data.

Chapter 6

Simulation and Results of Proposed Approach

Standard Simulation Parameters are considered for performance evaluation of standard LEACH-C and modified LEACH-C Protocol.

6.1 Simulation Results

Fig. 6.1 shows the energy consumed by nodes during simulation. Fig 6.2 shows network lifetime. Fig. 6.3 shows the No. of nodes alive during simulation.According to the simulation results in modified LEACH-C there is significant improvement over standard leach for the said performance parameters.

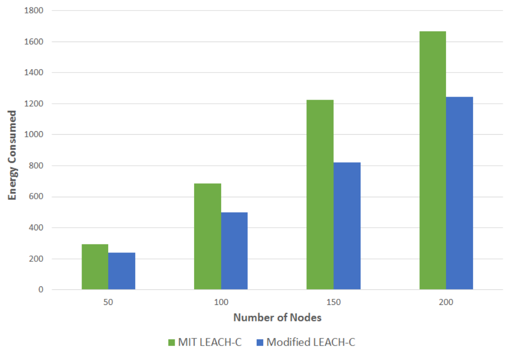


Figure 6.1: Energy Consumed

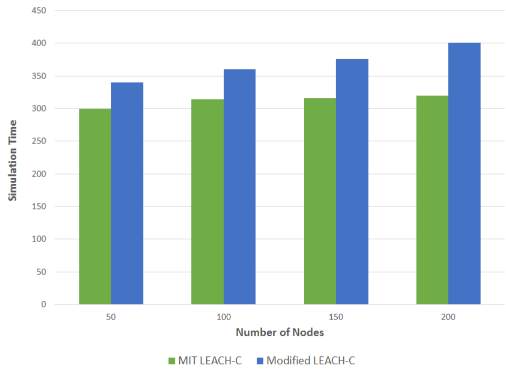


Figure 6.2: Network Lifetime

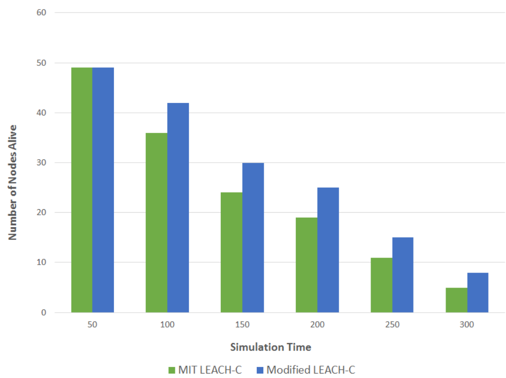


Figure 6.3: Nodes Alive

Chapter 7

Hardware Implementation

Soil moisture sensors measure the water content in soil. A soil moisture probe is usually made up of multiple soil moisture sensors.

7.1 Implementation of Soil Moisture Sensor

7.1.1 Working: Probe

This basic cheap soil moisture sensor consists of two probes (the metal rods) held apart at a fixed distance by some insulating material. The two probes are attached with some insulating material to keep other electronics apart from soil and water. These two probes/wires are then attached to the wires going to microcontroller (Atmega168). The type of sensor proposed here is a resistive sensor. The resistive type of moisture sensor is the most crude. It uses the two probes to pass current through the soil, and then we read that resistance to get the moisture level. More water makes the soil conduct electricity more easily (less resistance), while dry soil conducts electricity more poorly (more resistance).

7.1.2 Working: Controller Circuit

There is still a single sensor read wire (Arduino analog in), and the resistor is still part of a voltage divider with the soil between the probe wires. Usually 10 Kohm resistors are sufficient. But higher the value batter the result.Two probes are then connected as shown in the diagram beside. One probe is connected to the digital pin of the microcontroller (ATmega168) and other probe is connected to ground with parallel to the voltage divider circuit and in series with analog input pin to measure the resistance between two probes. Then wires connected to the probes are then connected to the respective pin of the microcontroller (ATmega168). Microcontroller (ATmega168) can read analog signal natively so no Analog to digital converters needed to be used. And we have moisture reading inside Microcontroller to be processed.

7.2 ATmega168 microcontroller

Name of the controller board: Arduino diecimila
Name of processor on the board: Atmega168
Features

- 2.7V - 5.5V working voltages
- 8 bit
- RISC architecture
- 32 8 bit general purpose register
- 4 KB Flash Memory
- 256 bytes EEPROM
- 512 KB SRAM
- 1 instruction per Hz i.e if frequency = 20MHz then 2 Million instruction per second

- 23 programmable I/O lines

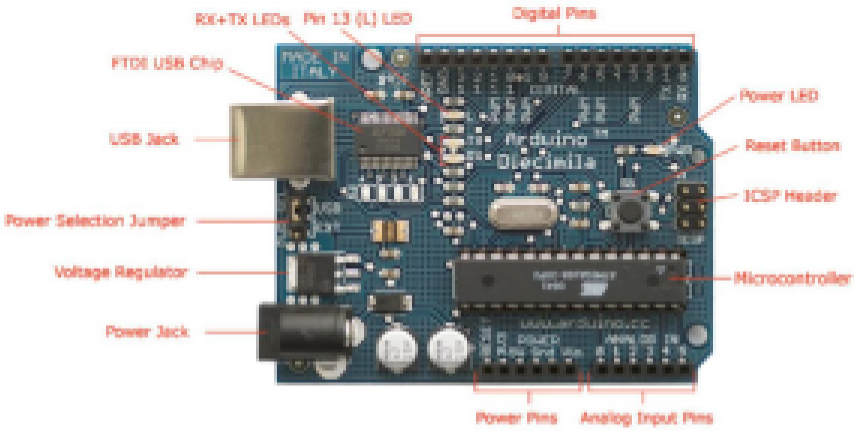


Figure 7.1: Arduino microcontroller

Number of Digital pins used in project (Without transmitter and Receiver): 2 This digital pins are used with 5v electronics,i.e. they can emit or read 5 volt.

- Pin number 12: for data read indication LED
- Pin number 9: for data send indication LED

Number of Analog pins used in project (Without transmitter and Receiver): 1

- Pin number 0 : for Input/ Read value from nail

Code for Arduino micro-controller is written such that it measure the moisture value is written such that it takes readings from analog pin 0 of the controller and then send it to the device via USB interface. The controller will take reading from input pin at every one second and add those reading to one variable. Then on 6th second the average of those reading will be taken and then average will be transferred to respected device connected to the USB interface of the micro-controller. This process will be running infinitely. The average value will range from 0 1200 (Approximately). Where 0 means extremely dry soil and 1200 means extremely moist soil.

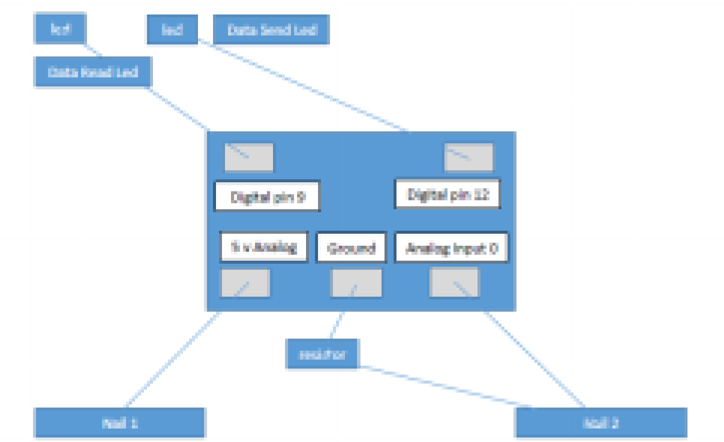


Figure 7.2: Connections done using pins

7.2.1 Initial Setup and Results

Figure 7.1 and 7.2 shows initial setup where Sensor node is connected to the laptop via USB. Figure 7.3 shows necessary steps to run program which measures moist in the soil and generates readings accordingly.

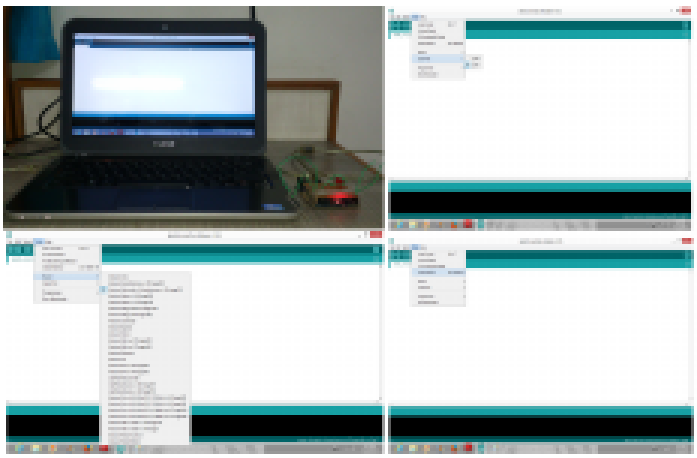


Figure 7.3: Initial Setup

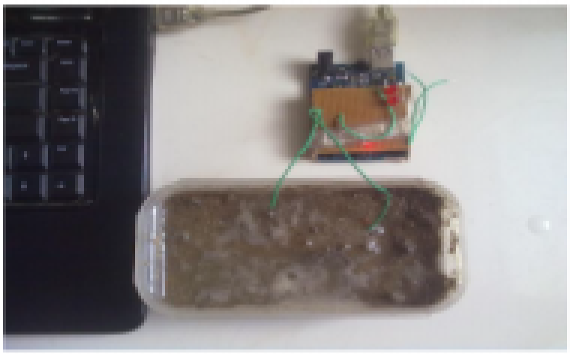
Figure 7.4 shows setup with dry soil and results for the same. This program basically

Readings for dry soil
11
20
19
12
16
16
13
11

Figure 7.4: Results of dry soil

generates results in the range from 0 to 500 if there is not enough moist in the soil that indicates this area is dry and needs water to be supplied.

Figure 7.5 shows setup with moist soil and results. this program basically generates results in the range above 500 if the soil is enough wet that indicates this area is having enough moist and does not need water to be supplied.



Readings for wet soil
634
663
679
677
683
730
732
750

Figure 7.5: Results of Moist Soil

7.3 Data Aggregation using Hardware

7.3.1 Setup and Results for Dry Soil

Figure 7.6 shows variation of simple communication technique. In this technique, sensors with moisture sensing capabilities are deployed in the field of functioning. Each sensor is equipped with simplex wireless communication equipment for sending data from the point of source (itself) to a point of destination (receiver). Destination is a special node called Aggregator, collecting data from various nodes. And then sending data to sink node. Sink node is not having moisture sensing capability and is only collecting data from aggregator nodes. An aggregator node collects data from moisture sensors and then creates a single data packet containing moisture information regarding that logical cluster and then sends this packet to the sink node.

Figure 7.6: Aggregated Results of dry Soil

As shown in the figure if soil is absolutely dry then each of this sensor is sending reading 0 to the aggregator. aggregator then apply aggregation function on all the readings coming from various sensor nodes and then forward it to the sink node. sink node is connected to the laptop via USB to see the readings.

7.3.2 Setup and Results for Moist Soil

Figure 7.7: Aggregated Results of moist Soil

Figure 7.7 shows the same setup for the moist soil and results for the same. As shown in the figure if soil is moist then each of this sensor is sending readings above 500 to the aggregator. aggregator then apply aggregation function on all the readings coming from various sensor nodes and then forward it to the sink node. sink node is connected to the laptop via USB to see the readings.

7.4 Hardware Implementation of DA for Different Moisture Level

7.4.1 Data Packet Format

Here again same communication technique is used for data aggregation. a small network with 3 nodes is created where one node is aggregator. code is modified such that now it can aggregates different moisture level data too. data packet format shown in figure 7.8 is also changed. there are 8 bits in data packet sent by aggregator node to the sink. bits p0, p1 and p2 represents id of aggregator node. so this code can work with total 7 aggregator node. it can further be expanded by changing the code. bit p3 shows data from aggregator node itself. value 1 represent wet soil and 0

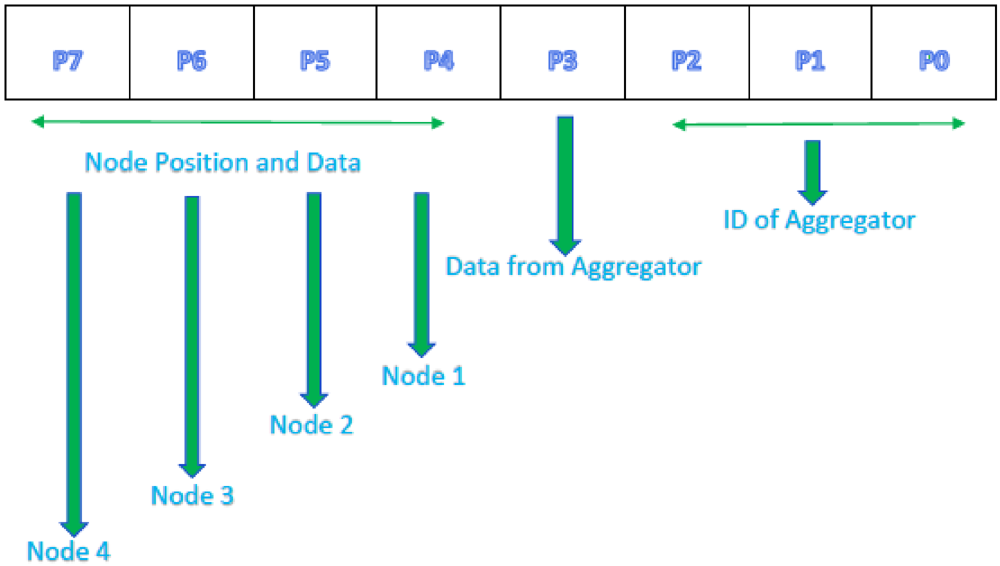


Figure 7.8: Data Packet Format

represents dry soil. bits p4, p5, p6 and p7 represents nodes id 1,2,3 and 4 also data from that node. for example if bit p4 is 0 it means node 1 has sent dry results and similar for other 3 nodes.

7.4.2 setup and results

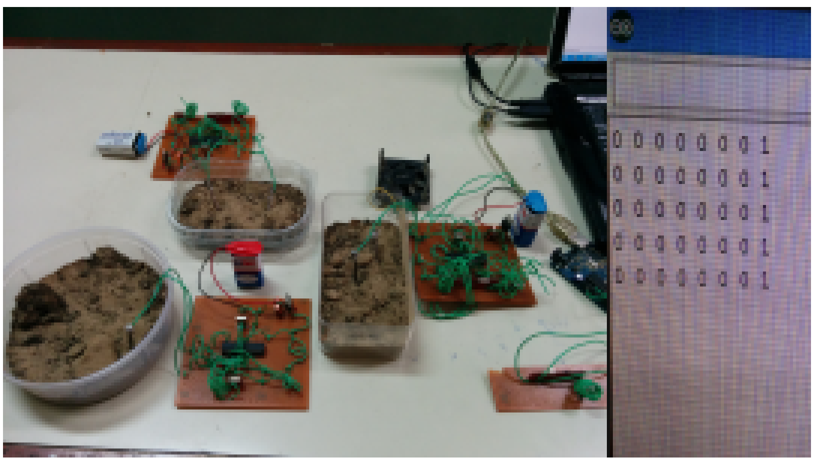


Figure 7.9: Results: dry Soil

Figure 7.9 shows aggregated results for dry soil where all nodes senses dry soil and terminal nodes sends results to the aggregator. finally, aggregation is done at aggregator node and results is send to the sink node.

Figure 7.10: Results for node 3: wet soil

Figure 7.10 shows experimental setup and results also where node 3 is deployed in the area which is wet and other 2 are deployed in the dry area.

Figure 7.11 shows experimental setup and results also where node 3 as well node 1 is deployed in the area which is wet and aggregator node is deployed in the dry area.

Figure 7.12 shows experimental setup and results also where all three 3 nodes are deployed in the area which is wet and accordingly results are created by aggregator.

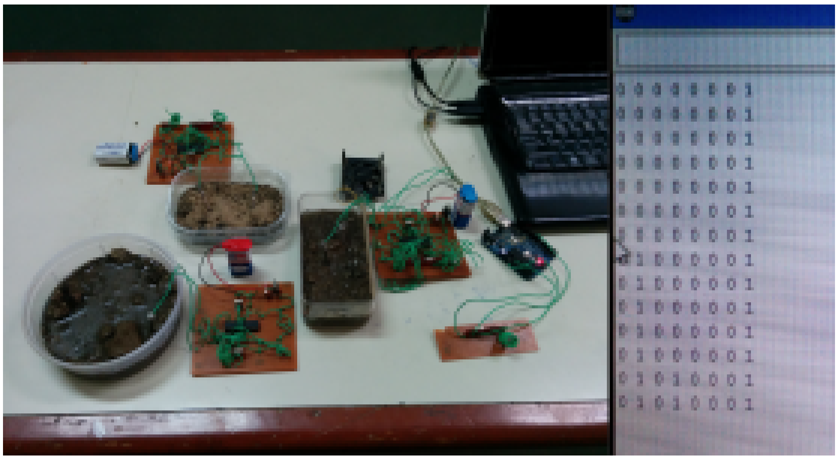


Figure 7.11: Results for node 3: wet soil

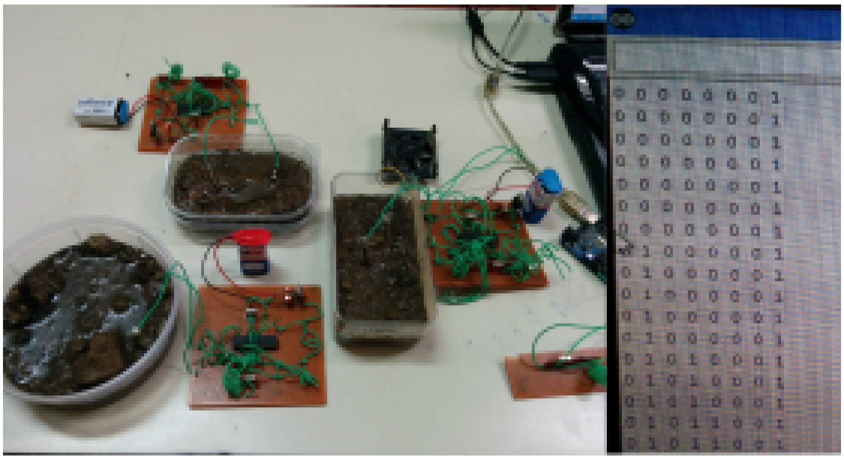


Figure 7.12: Results: wet soil

Chapter 8

Proposed Model for Automation

8.1 Proposed Model for Automation

Here Arduino Microcontroller and GSM are used for the automation and also to monitor the field and gives the accurate results to the end user (farmer). Figure shows the proposed model for automation. Here soil sensors will send the input data to the Microcontroller via aggregator node. Here the microcontroller controls the operation using some commands those commands were written in the program and are used easily by the end user (farmer) through the mobile phone services. Through those commands the Microcontroller gives the desired output.

In general, the sensors will give analog output but our processor will accept only the digital data. Arduino Microcontroller does this conversion internally so no extra circuit is required. LCD can be used to display the readings and specific action. Apart from soil sensors to monitor the field condition various other sensor can also be used like Temperature, Humidity in the air, Leaf sensor, PH sensor, Level sensor, Phase sensor etc.. A specific set of command words are used to operate the corresponding devices connected to the micro-controller, forming an embedded system. GSM module can also be used through which end user can send command to the controller and

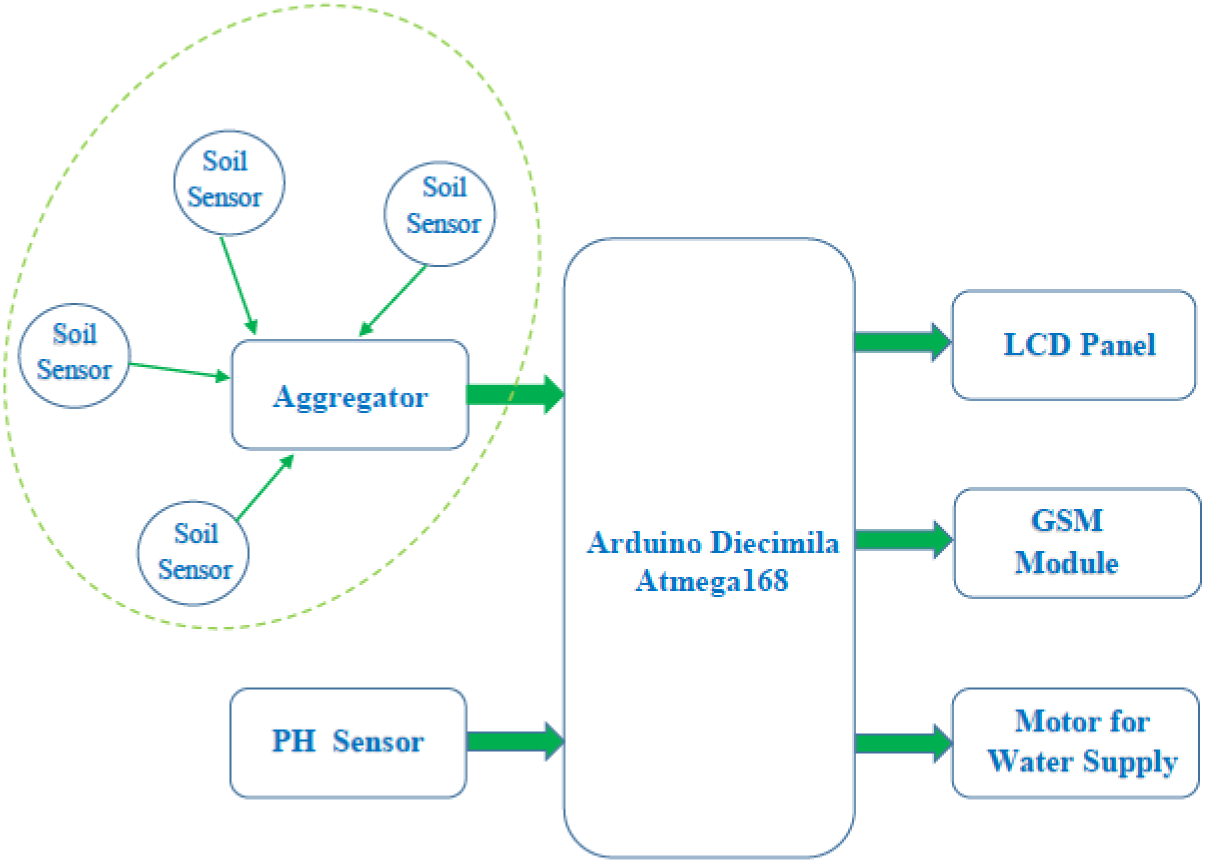


Figure 8.1: Proposed Model

corresponding action will be sent to the end user by the microcontroller. For eg. if micro controller is getting dry results from the aggregator then motor will be switch on automatically and message can also be send to the end user. The PH sensor is used to monitor the soil condition, weather the soil having harmful acidic nature or normal base nature. If acidic nature is present means we have to dilute the content and neutralize it or we will provide the necessary fertilizer.

Chapter 9

Conclusion and Future Scope

9.1 Conclusion

The cluster head selection and the energy consumption are the most important factors when discussing the hierarchical,clustering routing algorithms for WSNs. Centralized Low Energy Adaptive Clustering Hierarchy (LEACH-C) is the fundamental clustering protocol for WSN and is taken as a benchmark solution basis for the newly proposed findings. In this project work, during survey of different data aggregation approaches in wireless sensor networks cluster based data aggregation is chosen and by focusing on optimizing important performance measures such as network lifetime, data received and energy consumption LEACH-C protocol has been selected. Brief description of chosen LEACH-C modifications is presented. LEACH-C protocol is implemented according to the proposed algorithm. Simulation results and analysis of these protocols are presented. The presented LEACH-C protocol improvements represent major trends in LEACH-C development. They are proved to overcome the shortcomings of the original protocol and significantly enhance the original protocol efficiency. Hardware Implementation of Data Aggregation using Soil Moisture Sensors for very small network is also done also proposed model for automation is presented.

9.2 Future Scope

Future work will cover more detailed simulation scenarios, along with additional versions of LEACH modifications, especially the newly proposed. This improved version of LEACH-C can also be executed on sensor nodes deployed in the field and accordingly results can be used to automate any existing irrigation system.Proposed model for automation can also be implemented for the automation of garden sprinklers.

References

1 Kiran Maraiya, Kamal Kant, Nitin Gupta "Wireless Sensor Network: A Review on Data Aggregation" International Journal of Scientific & Engineering Research Volume 2, Issue 4, April -2011 ISSN 2229-5518

2 Vaibhav Pandey, Amarjeet Kaur and Narottam Chand, "A review on data aggregation techniques in wireless sensor network", Journal of Electronic and Electrical Engineering, ISSN: 09768106 and E-ISSN: 09768114, Vol. 1, Issue 2, 2010, pp-01-08 Copyright 2010

3 Nandini. S. Patil, Prof. P. R. Patil , "Data Aggregation in Wireless Sensor Network" IEEE International Conference on Computational Intelligence and Computing Research, 2010

4 ramesh rajagopalan, pramod k. varshney "data aggregation techniques in sensor networks : A survey"

5 Hiren Thakkar, Sushruta Mishra, Alok Chakbarty, "A Power Efficient Cluster-based Data Aggregation Protocol for WSN(MHML)" International Journal of Engineering and Innovative Technology (IJEIT) Volume 1, Issue 4, April 2012

6 V.B.Thakar, C.B.Desai, S.K.Hadia, "Performance Evaluation and Improvement of LEACH - A Wireless Network Protocol Using a Novel Algorithm for Clustering", Journal of Information, Knowledge and Research in Electronics and Communication Engineering,Volume 2, Issue 2, ISSN:6779, Page 638, November 2012

7 Lalit Kumar Chourse, Deepa Chaurse, Priyanka Chourse, "A Review on Energy Efficient of Clustering-based Routing Protocol in Wireless Sensor Network", International Journal of Computer Applications(0975-8887), Volume 50-No.16, July 2012

8 Shilpa Chauhan, Dr. Sona Malhotra, Yogesh Chauhan, "Survey of Hierarchical Routing Protocols in Wireless Sensor Network", International Journal of Emerging trends in Engineering and DEvelopment, ISSN 2249-6149, Volume 5, Issue 2, July 2012

9 Linlin Wang, Jie Liu, Wei Wang, "An Improvement and Simulation of LEACH Protocol for Wireless Sensor Network", First International Conference on Pervasive Computing, Signal Processing and Applications, 2010.

10 Yogesh V Patil, Pratik Gite and Sanjay Thakur, "Automatic Cluster Formation and Assigning Address for Wireless Sensor Network", International Journal of Computer Engineering and Technology (IJCET), Volume 4, Issue 4, 2013, pp. 116 - 121, ISSN Print: 0976 - 6367, ISSN Online: 0976 - 6375.

11 Preetee K. Karmore, Supriya S. Thombre and Gaurishankar L. Girhe, "Review on Operating Systems and Routing Protocols for Wireless Sensor Networks", International Journal of Computer Engineering and Technology (IJCET), Volume 4, Issue 3, 2013, pp. 331 - 339,ISSN Print: 0976 - 6367, ISSN Online: 0976 - 6375.

12 Wendi B. Heinzelman,, Anantha P. Chandrakasan,Hari Balakrishnan, "An Application Specific Protocol Architecture for Wireless Microsensor Networks" .IEEE Transaction on wireless communications, Vol. 1, No. 4, October 2002.

Index