ALGORITHM FOR ENERGY EFFICIENT SENSOR NETWORK IN PRECISION AGRICULTURE (PA)

A project report submitted in partial fulfillment of the requirements for B.Tech. Project

B.Tech.

by

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CANDIDATES' DECLARATION

I hereby certify that the work, which is being presented in the report, entitled **Algorithm for Energy Efficient sensor network in Precision Agriculture**, in partial fulfilment of the requirement for the award of the Degree of **Bachelor of Technology** and submitted to the institution is an authentic record of our own work carried out during the period of **May-2018 to August-2018** under the supervision of **Dr. Anuraj Singh** and **Dr. Yash Daultani**. We also cited the reference about the texts/figures/tables from where they have been taken.

Date: Signatures of the Candidates

This is to certify that the above statement made by the candidates is correct to the best of our knowledge.

Date: Signatures of the Research Supervisors

ABSTRACT

Today, in the era of science and technology; everything is going to be revolutionized. With the increase in population, economic shift is taking place; and so another Green Revolution is needed.

In this 21st century, time saving and energy saving without depleting the yield or output; are two prior requirements for anyone. And this is true for agriculture also. Merging agriculture with technology gives new scope for research scholars and engineers. Precision Agriculture (PA) is going to be a new chapter for farm land owners in upcoming world.

Deploying IoT in agricultural land gives better yield of crops even without working too hard, but as this method of using technology is new and so the approaches. These new approaches gives better performance in terms of crop yield with limited amount of farm land, yet these are not as advanced in terms of energy efficiency. Installing a system of sensor nodes along with charged batteries is called a Sensor Node Network.

We will work with our new proposed algorithm i.e. Master-Slave division with Additive Increase Multiplicative Decrease (AIMD) approach; to make these networks less susceptible to battery limitation problem thus giving more energy efficient solutions.

Keywords: Green revolution, Precision Agriculture, Sensor Node network, Master-Slave division, AIMD, battery limitation.

ACKNOWLEDGEMENTS

It is a great opportunity to be working on a project **"Battery limitation of sensor nodes in Precision Agriculture"** which is related to the life of each one of us. While working on the project it was of great help from our mentors **Dr. Anuraj Singh** and **Dr. Yash Daultani**. We would like to express our gratitude for their guidance and support throughout the project.

This project is of immense importance for the coming energy problems which may arise in the future near or far. This project deals with a novel approach to the available solutions in case of battery limitations of sensor networks.

We have tried our best to collect and work on the available resources available related to our project. We tried to offer an algorithm which is trying to offer some progress in battery limitation issues. There may be some shortcomings in the paper but it can be improved with time.

(Abhay Pratap Singh) (Nishant Sharma)

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ABBREVIATIONS

ADCS	Adaptive Data-centric Clustering using Sensors
AIMD	Additive Increase Multiplicative Decrease
CH	Cluster Head
EASR	Energy Aware Source Routing
IDE	Integrated Development Environment
IoT	Internet of Things
LDR	Light Dependent Resistor
LEACH	Low Energy Adaptive Cluster Hierarchy
LED	Light Emitting Diode
MSN	Master-Slave Node
PA	Precision Agriculture
SN	Sensor Node
SR	Sink Relocation
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION AND LITERATURE SURVEY

This chapter includes the details of previously proposed energy efficient algorithms, our objective, platform used to implement the project and literatures review related to work done in this field.

1.1 INTRODUCTION

1.1.1 Why is precision agriculture needed?

In India, more than half of the population depends on the agriculture. It is either as land farmer or as labour. A shift for economic development and urbanization is significantly shrinking the farming land. As time passes, population is increasing and agricultural land is getting converted into residential plots, which is putting a stress over farm land. Here we need a role of technology to surpass this problem and that is known as Precision Agriculture.

Farmers are the first stewards of the land and they have been knowing much about weather pattern, soil nutrients, climate, temperature etc. As time passes, soil starts degrading and losing its nutrients. For small farm land owners its easy to observe soil moisture, nutrients or temperature manually (however it is not as accurate as technology offers) but for bigger farm land owners its too difficult to do it manually.

Precision agriculture is an IoT based application of technology which helps farmers in deciding what type of crop is needed to harvest? Or when is it needed to harvest? Knowing answers of these type of question makes it definitely easy for farmers. Also using modern machinery in agriculture saves time and energy of farmers, which definitely increases yield without increasing effort.

1.1.2 How easily can it be introduced?

To support those bigger farm land owners, technology can perform a vital role. Using an IoT based network model they can fetch all the information sitting in their comfort place without even spending too much time. Precision agriculture offers a vast area of interest for farmers. Including improved irrigation pattern, special soil nutrients management, crop rotation management etc.

For small farm land owners, precision agriculture can be deployed in their own methods, Like- using temperature sensors, di-electric sensors, optimum crop rotation techniques. Small farm lands are also a problem in this way of precision agriculture. A small network of wireless sensor nodes can be designed to get all the information related to small farm lands.

1.1.3 Where and how much it is implemented?

Much attention has already been drawn in foreign countries, they have already been started using applications of IoT in agriculture. Although in India it is not widely known yet, but it has gained much importance in recent years and many researchers have shown interest in precision agriculture. Several countries are using precision agriculture and showing the world that with small land farms optimum yield can be gained. But in India, we are far behind and we need proper planning to get more and more crop yield. Although we can install proper networks for precision agriculture yet to fight with many problems in this technology. Deploying a network will definitely need a power source to run that network, and achieving better lifetime of that power source and network is desired. Many researchers had put an attention in the use of power saving methods in precision agriculture.

1.1.4 What was the need of our research?

After investigating several given theories and algorithms, we understood that every given algorithm has some pros and cons. And precision agriculture is facing many difficulties in its implementation over the world. One of the biggest problem is energy consumption. Since the sensor nodes used in a network, carry limited power source; Every time, when a network is installed on the field new batteries are deployed and long lifetime of network (in terms of energy consumption) is desired. There is need for solutions which can help us in such a manner so that battery consumption is reduced and network lifetime is increased.

For more lifetime of network we need to work for energy saving algorithms. Some algorithms have already been proposed. We will work with three of those and the combination with our novel approach will try to give more energy efficient results.

1.2 LITERATURE SURVEY

1.2.1 Novel Clustering

The development of extremely small and low-cost sensors, which possess the capabilities of: sensing, signal processing and communicating through wireless channel. Moussaoui and Naimi proposed hierarchical clustering of sensor nodes reduces energy consumption in multiple ways, Moussaoui and M Naimi (2006). This is achieved by putting redundant sensor nodes in sleep mode. The most effective method used in this approach is, Cluster Head (CH) configuration.
For CH configuration, at first select a set of CH sensor nodes in the network then cluster remaining nodes with these CHs. These CHs behaves just like a router behaves in its network; more precisely, all the nodes in cluster sends their data to their respective CHs and these CHs are responsible to communicate with other CHs among the network.

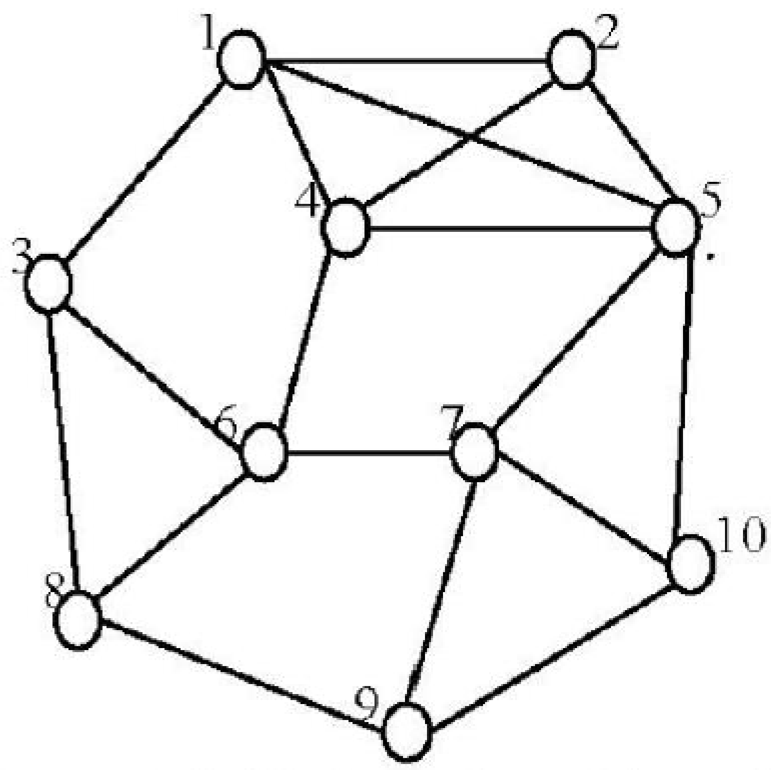

Figure 1.1: Initial Configuration, Moussaoui and M Naimi (2006)

In above figure 1.1; a dummy model is shown for cluster based approach. In this model some nodes will work as CHs and others will assist them as child nodes. While deciding the cluster size; for a given network, higher the cluster size lower the number of nodes in one cluster.

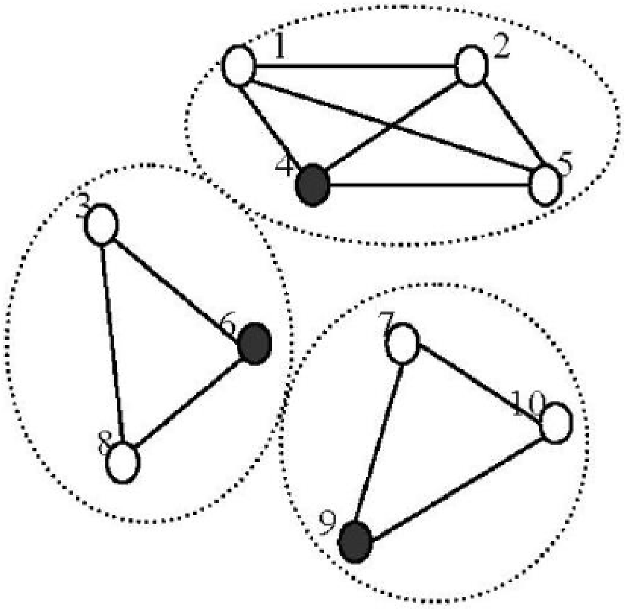

Figure 1.2: Clusters Identified, Moussaoui and M Naimi (2006)

In figure 1.2, after deploying the network, CHs are identified and configured and so the clusters.

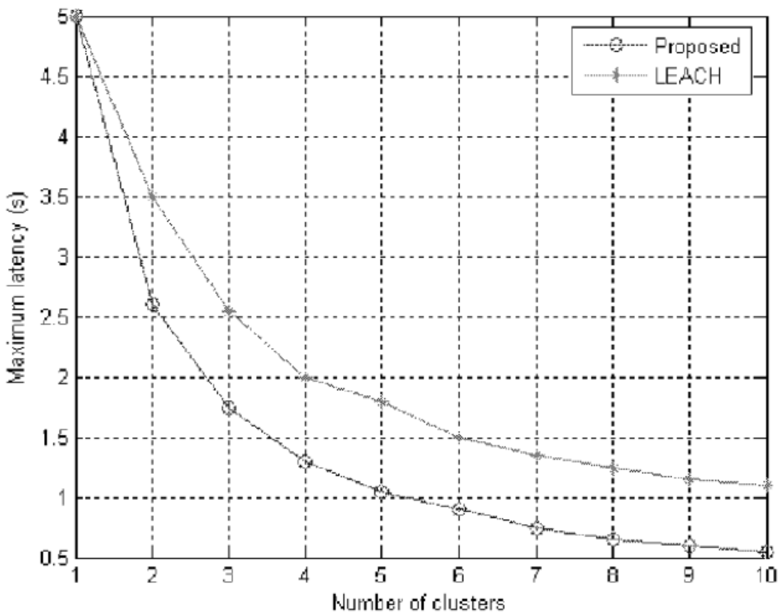

Figure 1.3: Maximum Latency, Moussaoui and M Naimi (2006)

As we can see in graph of figure 1.3, the given clustering algorithm decreases the network latency as compared to other proposed algorithm; hence improve the performance in terms of energy consumption and overhead.

1.2.2 The Adaptive Data Centric Algorithm

The authors gave ADCS algorithm, which works in two levels: Data level i.e. L0 and Location level i.e. L1. During L0 clustering ADCS computes and identifies nodes at similar data-level using dimensionality reduction, Euclidean distance methods, Sanat Sarangi and Srinivasu Pappula (2016). ADCS then performs L1 clustering based on location of the nodes with maximum allowable distance. At the end we get cluster of nodes in which nodes are present in similar data levels and geographically close to each other so that communication consumption is less.

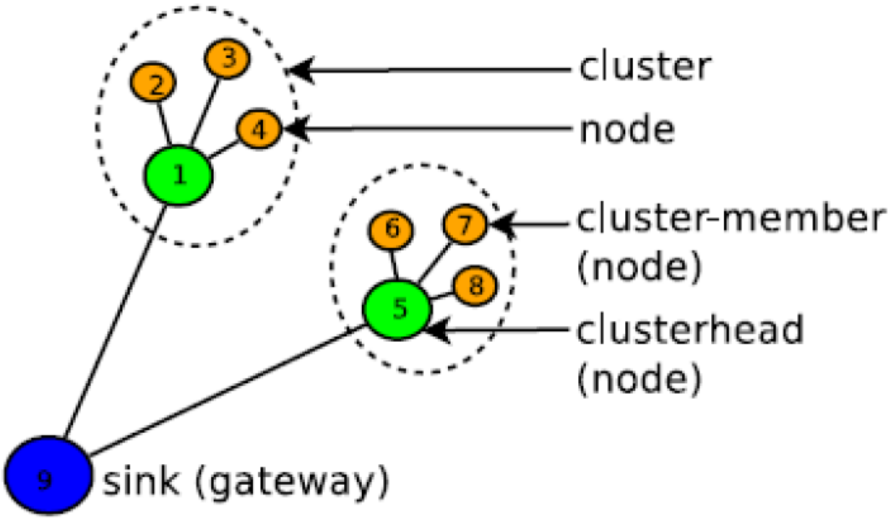

Figure 1.4: A configured WSN with cluster nodes cluster members and sink, Sanat Sarangi and Srinivasu Pappula (2016)

Sarangi and Pappula combined ADCS with already proposed algorithms make those better in terms of energy efficiency, Sanat Sarangi and Srinivasu Pappula (2016). ADCS is combined with DB-SCAN, K-Mean and Agglomerative. Then three variant of ADCS are thus obtained: ADCS-DB, ADCS-KM and ADCS-AG. Each with different characteristics. Agglomerative and K-Mean are uses more balanced clusters as compared to DB-SCAN.

Figure 1.4 is talking about the clusters at the similar data levels. After twenty rounds of clustering each round with a different set of values for dataset P, evaluate performance of ADCS-DB, ADCS-TM and ADCS-AG for each algorithm independently. Nodes in each cluster take turns to send their measurements to respectively CHs and CHs sends the data to the sink. Distances between cluster members and cluster heads are 23.52, 24.55, and 26.38 for ADCS-KM, ADCS-AG, and ADCS-DB respectively.

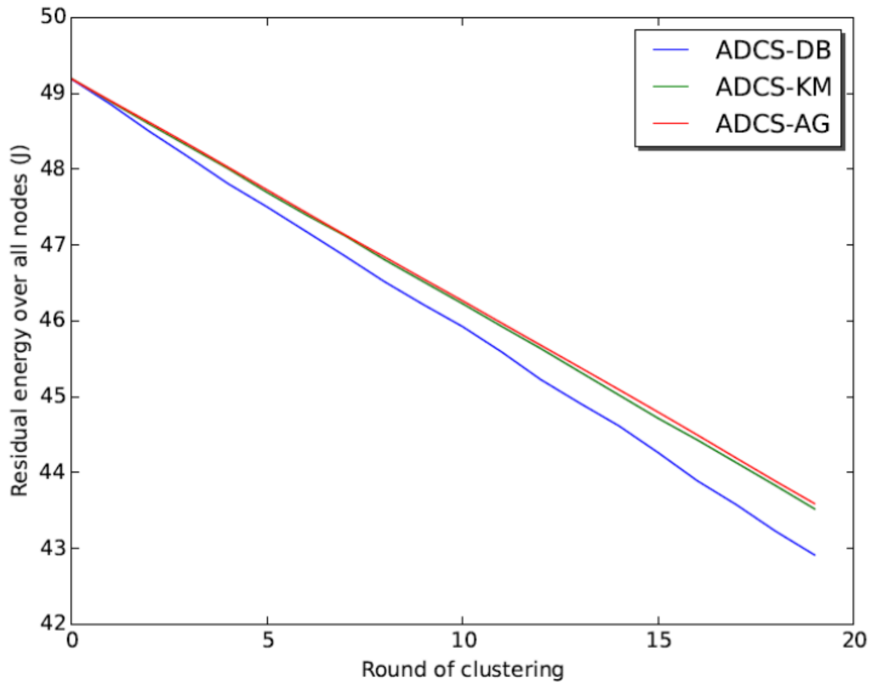

Figure 1.5: Residual energy after each round for 20 rounds, Sanat Sarangi and Srinivasu Pappula (2016)

The above figure 1.5 shows the battery draining of all nodes with respect to the rounds of activation. Analysis shows that ADCS-AG is most energy efficient followed by ADCS-KM. The results of ADCS-DB are not as effective in terms of energy efficiency. Although residual energy with ADCS-DB is less as compared to others but it offers highest level of flexibility in specifying end-user requirements for clustering in terms of maximum allowable distance among cluster members rather than number of clusters.

1.2.3 Sink Relocation Algorithm

In other study the investigators used central processor, a sensing unit, battery, transmitting antenna, receiving antenna, memory unit, and actuator system; these are the components used in deployment of this network, Chu-Fu Wang and Tin-Yu Wu (2014). Energy consumption in sensor nodes may be due to operations like computation, sensing reception, transmission.

Based on the energy level of all the members in a cluster, a CH is chosen. The battery of the WS node can be divided into four levels. When a CH goes to the certain level of energy, it gets shifted to neighbour node. The nodes located at far distance is sending

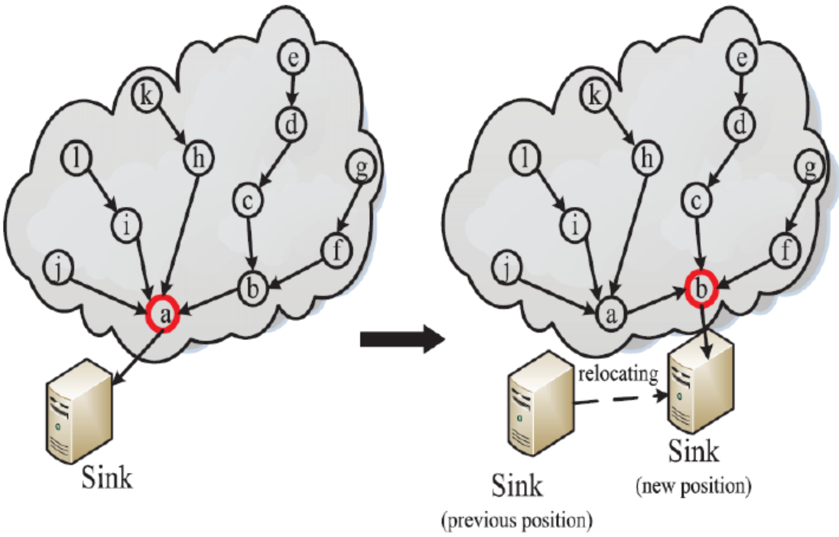

Figure 1.6: Sink relocation in a WSN, Chu-Fu Wang and Tin-Yu Wu (2014)

data node via node to the sink, from here sink transmits it to the base station as shown in figure 1.6. A relocatable sink is another approach for prolonging network lifetime by avoiding staying at a certain location for too long which may harm the lifetime of nearby sensor nodes.

The figure 1.7 showing the more battery drainage problem associated with the nearby

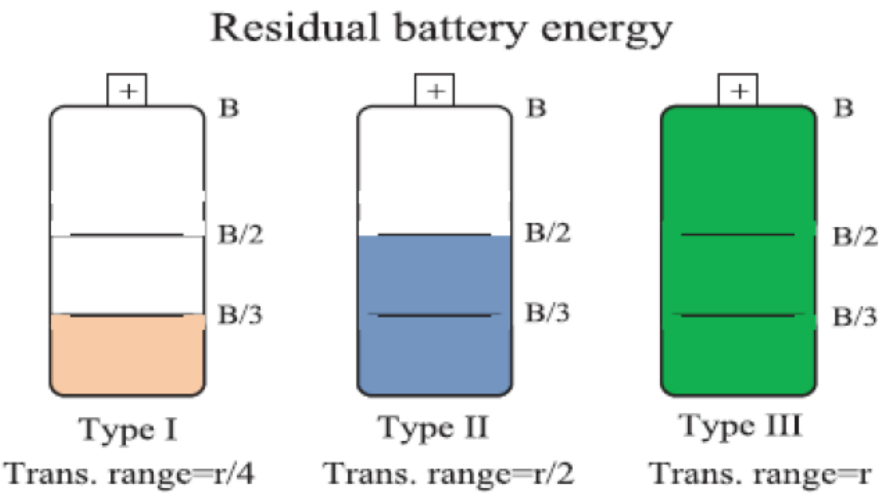

Figure 1.7: Battery residual levels Chu-Fu Wang and Tin-Yu Wu (2014)

nodes to the base station.This was showing the battery drainage as a function of the distance of node from the base station.

1.3 Objective:

After understanding the need of precision agriculture and better results after the implementation of IoT in the agriculture. We observed that in precision agriculture the IoT implementation consists of sensors and actuators where the sensors are sensing the environment and actuators working on the sensed input. The driving force of the implementation is power. That is the battery driven sensors need. There is the volatility associated here because of the need to cope up with the limitations arising from the battery draining over time. This became the motivation for our work to propose an algorithm which can optimally manage and make the networks of nodes battery efficient.

CHAPTER 2

DESIGN DETAILS AND IMPLEMENTATION

To increase the life time of any sensor network we need to make it more energy efficient. To understand the concept of energy efficiency in a sensor network, we have considered the model which is discussed below.

2.1 DESIGN DETAILS

2.1.1 Tools Used:

2.1.1.1 Tinker cad

Tinkercad is the online available tool for implementing the circuit in virtual environment which gives the dimension to our work in a different direction. This implementing in virtual environment is different than the real time measurements of data but it is precise in measuring the results for implementing our proposed naive algorithm. On tinkercad the simulation with implementing the analogy circuit of real time field sensor network is giving the testing data set. The tinkercad was preferred because of arrangement of circuits in a neat fashion.The circuit is made on this environment as shown in figure 2.1 and figure 2.2.

2.1.1.2 Arduino UNO R3

The UNO board of the Arduino family is the very less complex tool available to implement the sensors network for collecting data and processing on the data set. The available digital pins and analogue pins are used as giving output and reading input from the implemented sensors respectively. The coding of the algorithm was done in C++ derived language in Arduino IDE (Integrated Development Environment) and

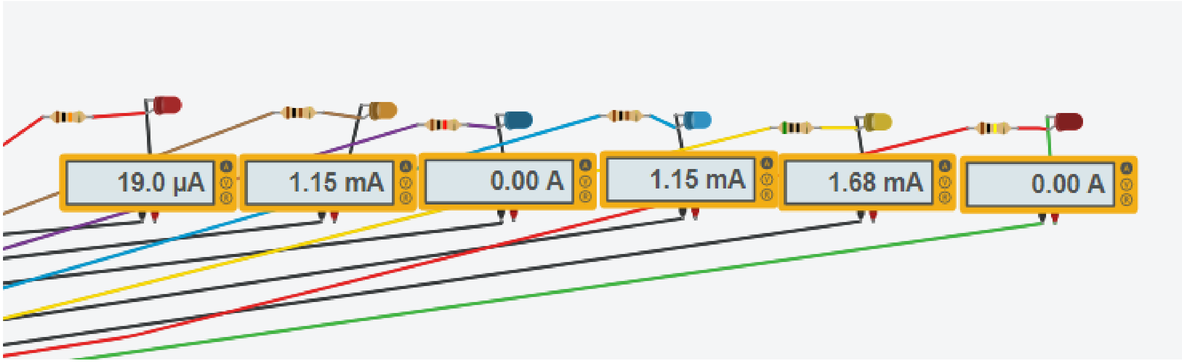

Figure 2.1: Analogy of the sensors using LEDs and resisiors

the same was implemented with the analogy circuit implemented on the online coding platform available on tinkercad.

2.1.1.3 LEDs

Light Emitting Diodes are the light source working on the semiconductors p-n junction diode and activates when a suitable potential difference is given at its two ends. The cathode of the LED is connected to the ground and the anode is connected to the output pin of the Arduino UNO R3.
Multiple connections of the sensors involved taken analogy with the LEDs are assisted with the breadboard.

2.1.1.4 Resistors

Resistors are the passive element of the circuit offering resistance to the current flow and hence varying the resistance varies the current flowing in the circuit.

2.1.1.5 Multimeter

The multimeter is used to measure the potential difference and current flows in the circuit. To measure the current it is to connected in series in the circuit.

2.1.2 Sensor Work

2.1.2.1 LDR sensor

LDR sensor measures the intensity of the light and tells the available intensity of light in the environment. For a large field we may require deploying of multiple sensors at many different location independent of each other.

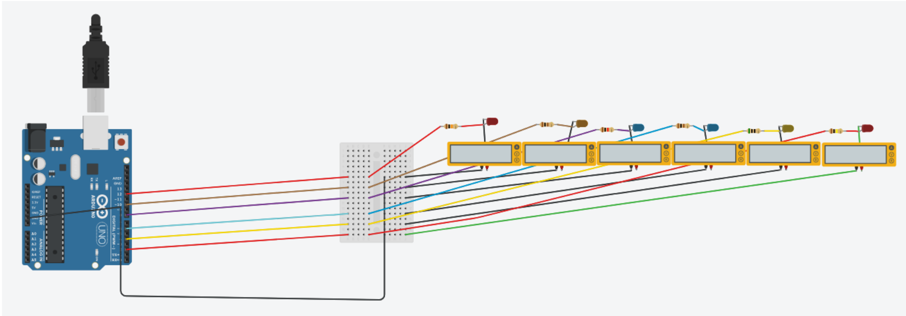

Figure 2.2: Analogy of the network using Arduino UNO R3 LEDs Ammeter and Resistors

2.1.2.2 Di-electric sensor

Also known as Moisture sensor. Moisture sensor measure the humidity in the soil. That measures the quantity of water required in the field for the crop. And helps in deciding the optimum time for irrigation.

2.1.3 Analogy Used

The circuit implementation of the problem circuit is done online on virtual environment tinkercad. The problem circuit considered is taken as analogy to the real time circuit. The sensors deployed in the field require battery (power supply) to work and that creates the issue for the battery availability. Thus the different types of sensors used in any implementation of the precision agriculture offers different resistance and consume power as per their resistance offered.

2.1.4 Why Analogy?

The analogy is used to eliminate the physical errors possible and to measure the results of the proposed approach algorithm in simpler manner. The measuring of current in circuit is easier and efficient and the arrangements of multiple circuits is much easier and very systematic.

2.1.5 Working of the analogy?

The problem circuit taken as with the Arduino UNO working as the central node and the led in series circuit with the different resistors giving analogy to real time sensors.
The difference in the resistance with each led is giving the difference in current consumed by each node LED. Thus resulting in power consumption differently. Like the different sensors applied in precision agriculture environment setup offer different resistance, in the same manner the LEDs combination with the different resistances do the

same work to measure collect the data set for testing the proposed solution. The glowing of the LEDs reflects the working of the sensor of that node and turn of condition of the led shows the off condition of that sensor node.

SENSOR STATE WITH THE LED STATE:
Glowing LED=TURN ON SENSOR
Not Glowing LED= TURN OFF SENSOR

2.2 IMPLEMENTATION

2.2.1 Proposed Methods

2.2.1.1 Master-Slave Node division (MSN)

Among the nodes,one node considered master and others as slaves at a time Master's sensing, more frequent than that of slaves Smallest interval:Master, Largest interval:Slave.Slaves activated at a time on the platform is shown in figure 2.1.

2.2.1.2 Master Node Rotation

The master node is rotated among the nodes where one among the slaves become master and the master becomes the slave.The making of slave to master is considered by checking the battery level of the node because of the battery drainage more in case of master. Hence slave having battery level less cannot be made to master.The code implementing this is shown in figure 2.3.

2.2.1.3 Additive Increase Multiplicative Decrease (AIMD)

In AIMD, we increase frequency of measurement if any change outlies to threshold in sensed data. And if no changes are within limits, we increase duration of measurement accordingly.

2.2.1.4 MSN with AIMD

AIMD is implemented using Master Slave division. This gives better efficiency and increased network lifetime.

```
for(int i=2;i<=6;i+=2){battery[i]-=10;}
for(int i=8;i<=12;i+=2){battery[i]-=15;}
 for(int i=2;i<=12;i+=2){
   if(battery[i]<=batterythreshold){digitalWrite(pin[i],LOW);
   else{digitalWrite(pin[i],HIGH);}
```

Figure 2.3: Battery residual checkup

2.3 USED PARAMETERS

2.3.1 THRESHOLD CONDITION:Historical data consideration

The long term measurements of the sensed data inputs gives the results of the optimal condition of the field which is calculated by taking the average on that long term data sets. This average calculated gives the threshold for each sensor node.

2.3.2 BATTERY THRESHOLD:Residual energy check

It is above said too that each node require battery for its working thereby makes the necessity of changing the battery after some time period. The battery discharge with time and the remaining time for its working is lessen. Hence there arose the need to check for the remaining energy of the power source of that node. There is associated threshold battery level of the node which on reaching it becomes necessary to optimise the working of the network.

2.3.3 Last data check first at node level

Each node cannot be allowed to active all the time for all the day for sensing the environment and reaching the result. So the sensing need to be distributed of the node in time slots where the sensor node is working for the time allowed it to work. The node works for the time it is allowed to work where it will sense and send it to the central node.
Since the microcontroller offer the memory advantage, the table is created associated, for each node with the input of the sense data. When the next data input comes if it is compared with the table entries.

2.3.4 ALGORITHM

Our proposed algorithm works in following manner:

- We have divided the nodes into two type master node and slave nodes. At a time one node is the master node and the remaining are the slave nodes.

- Among all the nodes, the node working of a node as a master node is rotated with the equal intervals of time is given for each node to work as master node.
- The master node is given time slots for activation less than slave nodes. That means the master nodes senses the environment more frequently than the slave nodes.
- While the other slave nodes at the same time are sensing the environment and the data is being verified with the table data set. The master nodes senses and works as the activation switch for the remaining slave nodes.
- The increment and decrement in the time slot of the master node is done on the basis of the threshold value of the type of sensor considered.
- If master node sensed **input>condition threshold**, then it activates the remaining node to verify that whether the condition has become different from the optimal conditions or not. And the next slot time to check the condition is decreased by a small factor.
- The time decrement is multiplicative decrease. The decision of condition changed or not is taken on the majority of nodes data input.
- But if master node sensed **input<condition threshold**, then the time slot for each check by master node is increased by a small factor. The time increment is additive increase.
- Also the battery value is used for determining the node working as master node. When the node gets the time slot for its working as a master node it checks for its battery level if battery **level>battery threshold**, then, the node will be selected as the master node.
- But if battery **level<battery threshold**, then, the node will not be selected as the master node and the next node will be the master node.

Here we have considered six nodes with one Arduino UNO working as the central node for all of them. The first three nodes are working as the LDR sensor nodes. The other three nodes are working as the di-electric based humidity sensor nodes. For each triplet common sensors:

- The time division is done for the day twenty-four hour time period.
- Master node time period=6 hour
- Master node time slot=1 hour

After every 6 hour the next node in the three nodes is allotted as master node Slave node time slot=2hr

CHAPTER 3

RESULTS AND DISCUSSION

3.1 RESULTS

For testing we have considered three nodes of a type (say for instance- LDR sensor nodes). The measurement for all the nodes is considered to be the best case. The best case implies that the next slot measurement is less than the conditional threshold. The best case makes the implementation of AIMD more efficient.
The calculation is done on the basis of the total no of times the node is getting activated. Because when the node is activated, this state is where it is consuming power.
The day time period = 24 hour is divided into four master node time period. So when node A is master node for the first master node time period. Then time slot of Node 1 will be of 1 hour. The nodes 2 and 3 are the slave nodes so, the time period of sensing data for slave nodes is of 2 hr. For the first master node time period 6 hour (0:00 to 6:00) Additive increase = 20 minutes Multiplicative decrease = to 1 hr

CASE 1:
The node (1) measures at 0 : 00, 1 : 00, 2 : 00, 3 : 00, 4 : 00, and 5 : 00 o'clock:

- No. of times 1 gets activated = 6
- At the same time the nodes 2 and 3 gets activated for 6 times in a 6 hour time period.
- No. of times 2 gets activated = 6
- No. of times 3 gets activated = 6
- Total no of times nodes get activated = 6 + 6 + 6 = 18

Cases	Approach	Node 1	Node 2	Node 3	Total
A	!D !R !A	6	6	6	18
B	!D !R A	4	4	4	12
C	D !R !A	6	3	3	12
D*	D !R A	4	3	3	10
E	D R !A	6	3	3	12
F*	D R A	4	3	3	10

Table 3.1: Number of times each node gets active within a period of 6 hrs

CASE 2:
The node (1) measures at 0 : 00, 1 : 00, 2 : 00, 3 : 00, 4 : 00, and 5 : 00 o'clock:

- No. of times 1 gets activated = 6
- At the same time the nodes 2 and 3 gets activated for 3 times in a 6 hour time period.
- No. of times 2 gets activated = 3
- No. of times 3 gets activated = 3
- Total no of times nodes get activated = 6 + 3 + 3 = 12

CASE 3:
An additive increase in time period of master node is given. Now, master node (1) measures at 0 : 00, 1 : 00, 2 : 20, and 4 : 00 o'clock:

- No. of times 1 gets activated = 4
- At the same time the nodes 2 and 3 gets activated for 3 times in a 6 hour time period.
- No. of times 2 gets activated = 3
- No. of times 3 gets activated = 3
- Total no of times nodes get activated = 4 + 3 + 3 = 10

3.2 EFFICIENCY:

For CASE 1 and CASE 3:
The efficiency of third case with respect to the first case comes out to be approximately 45%.
So the application of both AIMD and master slave division of nodes is giving the

favourable results with respect to when there is neither AIMD nor Master-Slave division.

For CASE 2 and CASE 3:
The efficiency of third case with respect to the first case comes out to be approximately 17%.

CHAPTER 4

CONCLUSION AND FUTURE SCOPE

4.1 Conclusion:

From past literature, we are getting an idea to go one step forward to those energy efficient algorithms. Thorough study of Novel Clustering by Moussaoui and M Naimi (2006) ; gives the approach of Master Slave division, while Sink relocation by Chu-Fu Wang and Tin-Yu Wu (2014); gives idea of Master node rotation. Using analogy we implemented new algorithm of Additive Increase Multiplicative Decrease with above algorithms and we get network lifetime enhanced.
But our algorithm is not foolproof, we considered best possible cases in all scenarios but these are ideal conditions. In real world implementation, non-ideal conditions will be encountered. Arduino like microcontroller required to work on the data from a cluster. This makes it economically less feasible.
The analogy used may have different results from that of the real time implemnetations with the sensors but approach towards making the solution energy efficient remains same.

4.2 Future scope:

The algorithm we designed and implemented is working on the last end of the network. This is manging the sensing time activation and deactivation of node in an efficient manner. Here it is implemented considering one cluster. In future this can be stretched to multiple clusters in the network. And also among the networks the sending of data from nodes to the base station along with the sensing efficiently can be managed. The implementation of algorithm in the real time scenario with different types of sensors and different type of thresholds is also can be done in future scope.

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