TDMA based Energy Conservation in Wireless Sensor Networks

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ABSTRACT

Energy conservation is a very critical issue in wireless sensor networks. Energy consumption in WSN occurs in three domains: sensing, data processing, and communications. Among these, radio communication consumes more energy. MAC protocols play a vital role in controlling the energy consumption in a WSN. It tells the network when and how to access the medium. In this paper a TDMA based MAC protocol is used to conserve the energy in wireless sensor networks which is used in a irrigation system. Here the base station is collecting the moisture level and temperature of the soil in a particular area of the fields using the sensor nodes which are deployed over there. Each node is assigned with a unique address and the sink/base station will decide which node to send the data(temperature and moisture level of the soil) at a particular interval of time by sending the address of that node. Only the addressed node is sending data during that allotted time and all other nodes will be in an idle state. Based on the data collected from each node the sink/base station will inform the controller by setting the corresponding bit in it. In this paper two algorithms based on TDMA scheduling is used. First one is a single hop method. Second method uses data aggregation method in which a considerable amount of energy can be saved. From the analysis and simulation it is observed that aggregation method is saving more amount of energy compared to the single-hop method.

Keywords: TDMA scheduling, wireless sensor networks, energy efficiency, irrigation.

1. INTRODUCTION

An agricultural country like India has been following the traditional methods for irrigation. These irrigation methods were able to meet the rapidly growing food requirements of the nation. But in majority of the case, the knowledge regarding the optimum conditions for a particular crop is not known to a farmer. This causes a huge loss in terms of utilization of land in our country.. Availability of energy is one of the important factors in the irrigation system.

This paper is basically on automated irrigation system with electronic controls and monitoring that uses energy efficient TDMA methods for data transfer. It can be mainly divided into two; automatic irrigation system and an energy efficient wireless sensor network. Automatic irrigation is done with the help of 2 sensors and solenoid valves. The data given by the sensors are interpreted by microcontroller and it turns on the motor according to the need of soil. The water-fertilizer composition is determined by microcontroller as it is programmed. Wireless sensor networking is an emerging technology that has a wide range of potential applications including environment monitoring, agriculture, vehicle monitoring, smart spaces, medical systems and robotic exploration etc. It can sense the physical conditions such as temperature, pressure, moisture, vibrations etc. These networks are deployed in an ad-hoc manner with the nodes in the network sharing the same communication medium. Sensor nodes are usually battery operated and are unattended after deployment. Sensor life time depends mainly on the life time of battery. So power saving is a critical issue in WSN. The main functions of a wireless sensor network are sensing; processing; and communication . The sensing circuitry consumes less power than the processor. But the power consumption of the radio communication is much more than that of the processor. Several energy saving schemes have been proposed for the WSN which includes power saving hardware design, Power saving topology design, power efficient MAC- protocols, and network layer protocols.

MAC protocols plays a vital role in the energy saving process of a WSN. It is required in the sensor networks to co-ordinate the sensor networks' access to the shared medium. MAC schemes for sensor networks can be fundamentally categorized into contention-based or scheduling-based schemes. TDMA schemes have a distinct advantage over the other methods. Except for the transmission, receiving and sensing durations, nodes can be put to sleep and highest amount of power savings possible. The main disadvantage of the TDMA scheme is that it requires time synchronization.

The report consists of six sections. Section 1 deals with the introduction of the present work and its objective. Section 2 is the literature survey which include the details of papers referred regarding energy conservation in the WSN. Different energy conservation algorithms are discussed and their performances are evaluated in the section 3. Section 4 deals with the results and analysis of the proposed algorithms. Comparison between two different methods are explained in the section 5. The conclusion and future work are presented in section 6.

2. RELATED WORKS

Presently rural irrigation depends on the natural resources and experience of skilled farmers. There is a frequent electric supply failure and rectification of the same takes weeks together in rural areas which adversely affects the irrigation and farmers may have to adopt for other sources of electricity and it is costly too.

Presently there is no efficient and controlled utilization of water or fertilizer.

Allen (2000a) evaluated an irrigation management system that can provide continuous real-time or near real-time soilwater content information to the irrigation system operator. This system used two different data loggers to collect and store data from Watermark® soil moisture sensors (Irrometer Co., Riverside, CA, USA). The data loggers were installed in the field in close proximity to the sensor and wired to the sensors. However, this system required the operator to visit the data loggers for data downloading and thus did not provide a wireless solution. Shock et al. (1999) used a similar approach but transmitted data from the data loggers to a central data logging site via radio. This system allowed up to 16 Watermark® soil moisture sensors to be wired into apropriętary data logger/transmitting box. But, unless all the sensors were placed in close proximity to the data logger, this system still required extensive cabling. The expense of the data loggers prevents a dense population of sensors in the field.

Sensor-based irrigation systems have been studied for many applications (Stone et al., 1985; Jacobson et al., 1989; Zazueta and Smajstrla, 1992; Meron et al., 1995; Testezlaf et al., 1997). Stone et al. (1985) presented a computer-based monitoring system for continuous measurements of soil water potential. Zazueta and Smajstrla (1992) compared indirect estimates with direct measurement of soil moisture. Meron et al. (1995) used a control system for apple tree irrigation management using tensiometers. Testezlaf et al. (1997) used an automated irrigation control system for management of greenhouse container plants. A well-designed irrigation system is an essential requirement for a profitable and environmental friendly irrigation (Abreu and Pereira, 2002). Wireless radio frequency technology has provided opportunities to deploy wireless data communication in agricultural systems (Oksanen et al., 2004; Zhang, 2004; Lee et al., 2002). Software design for automated irrigation control has been studied by Abreu and Pereira (2002). They designed and simulated solid-set sprinkler irrigation systems by using ISADIM software that allowed to the design of a simplified layout of the irrigation system. However, their software provided limited control due to the lack of feedback in-field sensors.

Energy conservation in WSN is very important. Different types of algorithms have been proposed for the sensor networks. *C. Srisathapornphat, C.C. Shen,(2002,)* has proposed a co-ordinated power conservation(cpc) algorithm to facilitate power conservation for ad hoc networks. CPC uses a set of backbone nodes selected over an ad hoc network to coordinate power conservation.

W. Ye, J. Heidemann, D. Estrin(June 2002.) has proposed An energy-efficient MAC protocol for WSN – SMAC. This protocol tries to reduce energy consumption from all the sources that have identified to cause energy waste. Although, SMAC saves more power than 802.11, it does not adapt to network traffic very well since it uses a fixed duty cycle for all the sensor nodes. Another drawback in both SMAC is that, they group the communication during small periods of activity. As a result, the protocols collapse under high traffic loads. Energy efficiency in wireless sensor networks using sleep mode TDMA scheduling is proposed by *Nikolaos A. Pantazis et al(2008).* This method balances energy-saving and end-to-end delay. This balance is achieved by an appropriate scheduling of the wakeup intervals, to allow data packets to be delayed by only one sleep interval for the end-to-end transmission from the sensors to the gateway. The only problem in this scheme is that, there is a wastage of energy when all the nodes are listen to Wake Up messages for the whole Wake Up period.

3. PROPOSED SYSTEM

The automatic irrigation done with the help of highly accurate sensors makes irrigation system a unique product. Man power requirement is very less; this could reduce the manpower requirements for farming which is one of the major factors holding back the farmers. As the number of farmers are decreasing day by day this would help the agricultural area to keep up with the other industries. One of the most important benefits of the product is that a single farmer can manage more than one field. This makes the product truly unique in its kind.

Automatic irrigation is done with the help of 2 sensors, solenoid valves and a pump. The data given by the sensors are interpreted by microcontroller and it activates the motor according to the need of soil. The main objective of this paper is to provide an energy efficient algorithm for the wireless sensor communication used in an automated irrigation system. The wireless communication can be of two types- single hop or multi hop. In this paper we are using a single hop communication between the source and sink. Data aggregation method is providing better performance. Here we are using this concept to give a better energy efficiency in single-hop communication. In order to provide a good energy conservation a distributed TDMA based scheme which leads to a collision free transmission over the data channel is used. Using this method we can reduce the energy consumption by each node and thereby reducing the overall energy consumption. This method is robust and the failure of single node will affect only the data intended for that node.

3.1Single Hop Method

3.1.1 Basic Scenario

The basic scenario consists of a base station/sink and twenty sensor nodes. Each sensor node has a range of 1km. Thus we can cover up to 1acre area of the field using this method. Each sensor node will measure the temperature and the moisture level of the soil. For initializing the network, the base station will assign each node with a unique address. Then each node will switch to the idle state. In the idle state each node will be in receiving mode only. When the base station requires to collect the temperature and moisture level of a particular area, it will broadcast the address of the sensor node which has deployed over there.

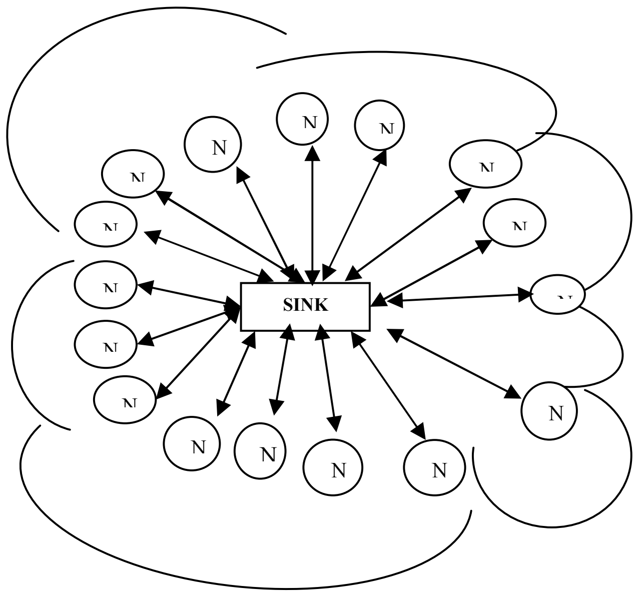

Figure 1. Basic scenario for the single hop method

All the nodes are receiving this address but only the addressed node will respond to this request by sending back the present value of the moisture and the temperature of that region. The other nodes will continue in the idle state. After sending the required data the node will go back to the idle state. This process will repeat for all the nodes.

3.1.2. Sensor Node

Each node consists of a moisture sensor and the temperature sensor. The node's microcontroller program (programmed in C language) corrected and formatted sensor values then output results to the onboard transceiver. Out of this 20byte data is used for storing the temperature and 5 bytes are used for the moisture level. The remaining 11bytes are reserved for the future use. The basic format is shown in the table 1

Table 1 Format of the data from the sensor node

Temperature data	Moisture data	Unused bytes
4 Byte	5Byte	11 bytes

Most of the time the sensor node will be in the receive only mode so that the energy consumption is minimised. The sensing of environment and data transmission will occur whenever it is requested by the base station

3.1.3 Soil Moisture Sensor:

The Soil Moisture sensor is used as a tool to optimize irrigation and to warm of plant stress at the dry or wet ends of the scale. The Soil Moisture sensor is a high performance and accurate soil moisture sensor. The VG400 series soil moisture sensor probes from Vegetronix enable precise low cost monitoring of soil water content. Because the probe measures the dielectric constant of the soil using transmission line techniques, it is insensitive to water salinity, and will not corrode over time as does conductivity based probes. The probes are small, rugged, and consume under a milliamp of power.

3.1.4 Temperature Sensor

Thermistors are temperature sensitive resistors. All resistors vary with temperature, but thermistors are constructed of semiconductor material with a resistivity that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature. That's due to the properties of the semiconductor material that the thermistor is made from. For some, that may be counterintuitive, but it is correct. Not only is the resistance change in the opposite direction from what we expect, but the magnitude of the percentage resistance change is substantial.

3.1.5. Base Station

The base station consists of a transceiver, processor, and LCD display. After getting the value of the moisture level and the temperature, the base station will compare this value with the threshold value which is already stored in the database. If the measured value is less than the required value the controller will do the necessary actions. The same procedure is repeated for all the nodes.

3.1.6. Solenoid Valve:

A solenoid valve is an electromechanical valve for use with liquid or gas controlled by running or stopping an electrical current through a solenoid, which is a coil of wire, thus changing the state of the valve. The operation of a solenoid valve is similar to that of a light switch, but typically controls the flow of air or water, whereas a light switch typically controls the flow of electricity. Solenoid valves may have two or more ports: in the case of a two-port valve the flow is switched on or off; in the case of a three-port valve, the outflow is switched between the two outlet ports. Multiple solenoid valves can be placed together on a manifold. Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design. We are using these valves to control the flow of fertilizers and water to the mixer. Besides the plunger-type actuator which is used most frequently, pivoted-armature actuators and rocker actuators are also used.

3.1.7. Pump

The pump is used for the purpose of pumping water in the storage tank to the field. It works according to the instruction of micro controller. So it can pump the water whenever it is needed.

3.2 Data Aggregation Method

Data aggregation plays a major role in reducing the energy consumption by the sensor nodes and there by increasing the network life time efficiently. The difference between the data aggregation and data accumulation is that, in data accumulation the header node collects the data from all the nodes and it will just bypass them to the base station without altering the data. But in case of data aggregation the header node collects the data from all the nodes and aggregate them depending on different techniques.

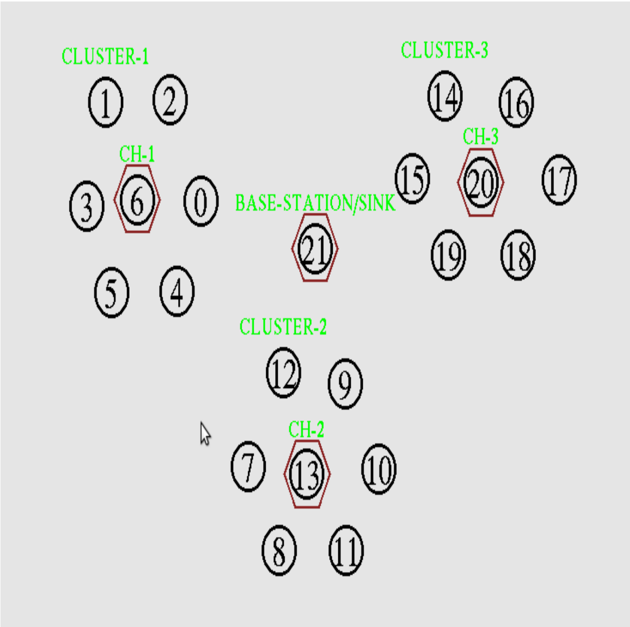

Figure 2. basic scenario for the data aggregation

For data aggregation nodes are designed in such a way that if the transmitting node fails it will not affect the network performance and also due to the presence of error bound the header will transmit the data only if the aggregated data is beyond the limit. In this paper, a sink/ base station acts as the super cluster head. All the sensor nodes are grouped into 3 clusters , each contains six nodes and a cluster head. The basic scenario is shown in the figure 2. The communication between sink and cluster heads is based on the TDMA. The communication within each cluster is also based on TDMA method. The sink/base station is sending a request to each cluster head in a particular time slot which is assigned to it and on receiving the request each cluster head will collect the data from the nodes in its cluster and send it back to the sink/base station.

Basically, data aggregation can be done using four methods; Sum, Minimum, Maximum, Averaging. In the case of averaging technique, the header node collects the data and it will just find out the average of all the data that are got from remaining nodes and it will inform the average value to the base station. The major advantage in this method is that, since the header node performs averaging technique, it will be very useful for the base station to find exactly how many nodes have transmitted their data and also how many nodes failed during transmission. Also in this method because of averaging, the exact temperature and the moisture distribution in the corresponding area can also be found easily, due to these advantages we are following maximum approach for efficient data aggregation.

4.RESULTS AND ANALYSIS

In this paper two different energy conservation mechanisms have been analyzed based on the TDMA scheduling for the real time application – automatic solar irrigation systems. Both the methods provide good energy conservation compared to other conventional methods. The single – hop method provides a collision free data transmission. Network simulator-2(NS-2) has used for the analysis of both the algorithms. The matrices used here for the performance analysis are average energy and the throughput of the network. Graphs are plotted for the energy of the network over the time. It shows that, the energy of the network decreases as a function of time. Then the throughput of each node is calculated and plotted. For the simulation purpose the initial energy of each node has been selected as 100 joules. From the real time system it is found that the energy needed when the node is in transmission mode is 1 j/sec and for receiving mode is 0.5 j/sec.

4.1. Single – Hop Method

The simulation results shows that the amount of energy consumption can be reduced using the single hop method.

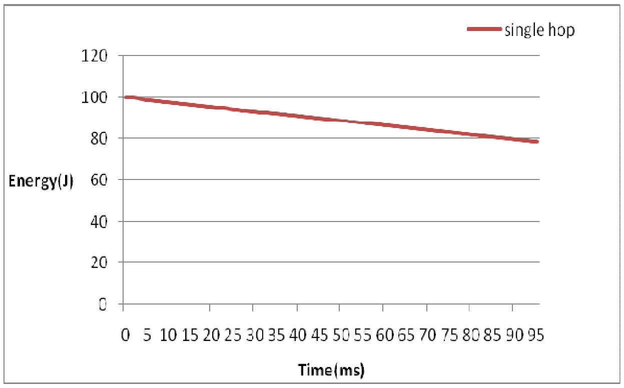

Figure 3. variation of energy over time.

Figure 3 shows the relation between energy and time for the network. From graph it is clear that the energy decreases as a function of time. In this method the final energy reaches up to 78.5 joules from the initial energy of 100 joules. It shows that Energy decreases as time increases.

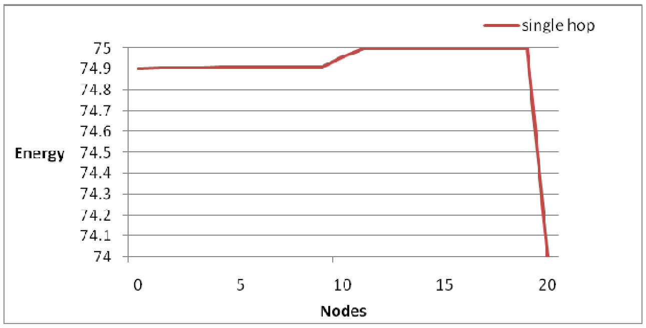

Figure 4. Node vs energy graph. It showing the final energy of each node

The final energy of each node is found and Figure 4 shows the graph between the node and final energy of each node. It is giving us the value of final energy in each node after the end of simulation. From the graph it is clear that the node 21 which is the sink node has the minimum energy as it is always taking part in communication. All other nodes are having higher energy than the sink node because they are going back to the idle state after the time slot which is allotted for them. So we could save some amount of energy by switching the nodes back to the idle state while it is not taking part in the communication. `

Another parameter for performance evaluation is the throughput of the network. It is the number of packets successfully received divided by time. Figure 5 shows the throughput of the network.

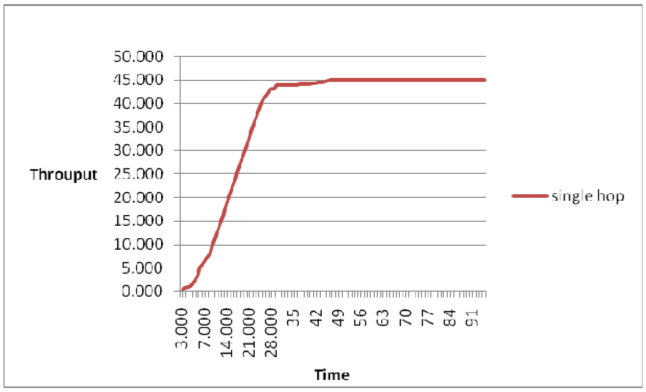

Figure 5. Time vs throughput graph. It shows the throughput of the network

4.2. Aggregation Method

The main objective of the aggregation method is to reduce the energy consumption and to increase the network throughput . The simulation results show that the objective could be met by reducing the consumption of energy and by increasing the throughput of the network.

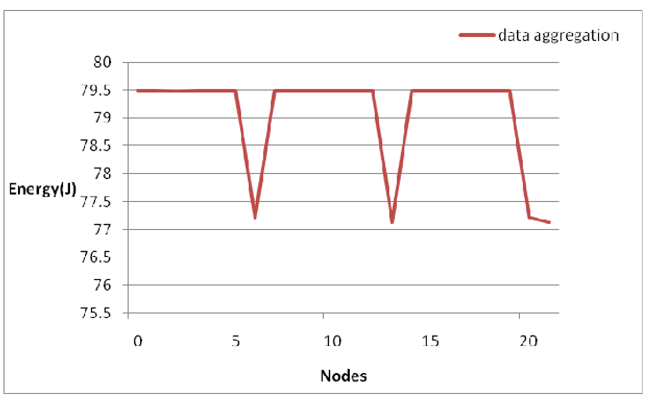

Figure 6. Node vs energy grapgh showing the final energy of each node

Figure 6 shows the final energy of each node. Three dips are seen in the graph. They correspond to the final energy of each cluster heads.(ie, node 6,13,20) in the scenario shown in the figure 6. The reason is that the active time of the cluster heads are more compared to other member nodes in the networks. But it is seen from the result that even the final energy of cluster head is more than the final energy of each node in the single – hop method.

Next the throughput of the network can be seen in the figure 7. Graph shows that the throughput of the network also has increased by a considerable value. It has increased from the 22 to 58 while we are moving from single – hop method to data aggregation method.

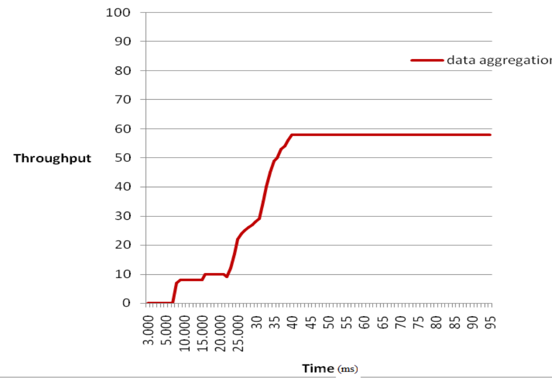

Figure 7. Time vs throughput gragh showing the throughput of the network

5. COMPARISON BETWEEN SINGLE – HOP AND DATA AGGREGATION METHOD

In this paper two methods have proposed for the conservation of the energy in the WSN. Both the methods are working according to the principle of TDMA.

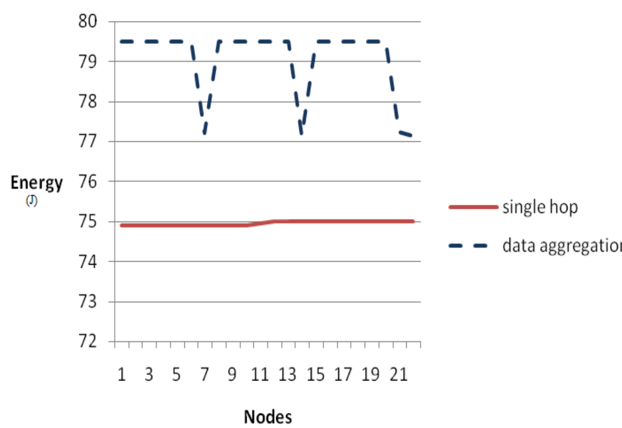

Figure 8. Comparison of final energy for the single – hop method and data aggregation method

From the analysis and the simulation results it is clear that aggregation method is having better performance compared to the single-hop method. The metrics used for the analysis are the average energy of the nodes and the throughput of the network. It is clear from the figure 8 that the final energy of the network in the aggregation method is greater than that of the single-hop method. For the throughput comparison the throughput of the base station vs time for both the methods have plotted. It is shown in the figure 9. From the figure we can understand that, the throughput of the base station in aggregation method is 58 and for the single – hop method is 45.

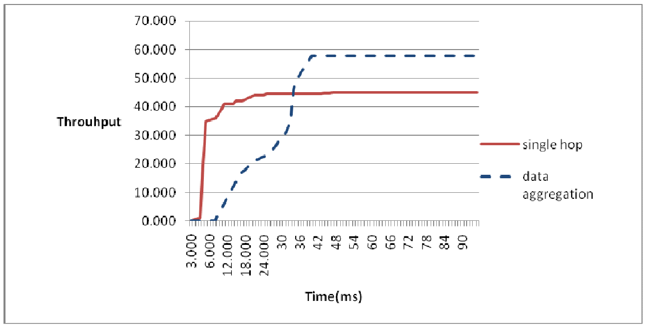

Figure 9 comparison of throughput in single-hop method and aggregation method

6.CONCLUSSION

In this paper two different energy conservation mechanisms have been analyzed based on the TDMA scheduling for the real time application – automatic irrigation systems. Both the methods are providing good energy conservation compared to other conventional methods. The single – hop method is providing a collision free data transmission. From the simulation results it is found that the aggregation method is showing better performance than the single hop method in terms of average energy and the throughput of the network.

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