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Energy Efficiency Improvement Using IEEE 802.15.4 in Cooperative Wireless Sensor Networks

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ABSTRACT : *Wireless Sensor Networks is an emerging technology in modern communication. The rapid and increased use of these networks results in the decreased lifetime of the sensor nodes. The life time reduction is due to the increased battery drain. As a result many methods have been developed to cope this. One such technique is the cooperative routing scheme. Compared to the present existing schemes cooperative routing scheme was found to give around 40% improvement in energy efficiency. As a modification to the original cooperative routing scheme the Mac protocol was changed from IEEE 802.11 to IEEE 802.15.4. The result obtained shows much greater energy efficiency for all the nodes in the network.*

Keywords - *cooperative routing scheme, energy efficiency, IEEE 802.11, IEEE 802.15.4,* wireless sensor networks

1. Introduction

Wireless sensor networks, an emerging technology are made up of sensor nodes which are distributed and autonomous in nature. These sensor nodes can vary in number from a few to thousands depending on the situation in which they are being used. These sensor networks are used in military, monitoring applications etc. they are also used in hostile environments such as disaster struck areas. Depending on the application or the area in which such a network is used the energy utilization of the individual nodes can vary. In such hostile environments the fast reduction of the battery is not feasible and recharging or replacement is not applicable.

A sensor node is made of a sensing system, a communication system, a computational system and a power unit. The sensing system senses the environment in which they are being placed. The sensed data are passed to the computation system. The nodes can pass the sensed data to other nodes or can perform some computations and pass only the required information. The selected information is then passed to the neighboring nodes if the present node acts as an intermediate router or is stored within if is the destination. All these operations are supported by the power unit which consists of the battery. As a result it is certain the charge gets reduced. Therefore energy efficient routing schemes have to be developed for retaining the battery charge.

One such technique is the cooperative routing scheme. The routing schemes are basically classified into cooperative routing schemes and non cooperative routing schemes. The non cooperative routing schemes is further classified into one path scheme and disjoint path scheme whereas the cooperative routing schemes is classified into cooperative along non cooperative path (CAN) and the proposed cooperative routing scheme. The cooperative routing scheme is found to give much higher energy efficiency than the other schemes.

The usual cooperative routing scheme is designed based on IEEE 802.11 scheme. As a modification the Mac protocol is changed to IEEE 802.15.4. This is used for higher secure services and allows for many features that is useful in communication.

2. Related Work

The work in paper [1] gives an idea of the cooperative network and their working. This concept is used in developing the cooperative routing scheme of this work. Paper [2] shows the working of IEEE 802.11 and its classification into two working modes. Also it proposes the use of a back off algorithm called the Linear/Multiplicative Increase and Linear Decrease (LMILD). This suggests the process of varying the contention window during collisions or overhearing. The work in [3] shows the different parameters in IEEE 802.11 and its tenability. The various IEEE parameters are added in this work and its effect is noted. The RTS/CTS parameter is studied and the advantages and disadvantages are cited in this paper. The work in [4] proposes the importance of WSN MAC protocols. According to the problems faced within the WSN the Mac protocols are classified and the classification is also given in this work.

The working of beacon mode slotted CSMA-CA working is proposed in paper [5]. Beacon mode CSMA-CA is used for broadcast transmissions in WSN. Also beacon modes have greater flexibility compared to non beacon mode. In this work we are using non beacon mode for simplicity. Many differentiation services to improve the performance of IEEE 802.15.4 beacon enables CSMA-CA is discussed in paper [6]. The work of IEEE 802.15.4 along sleep wake scheduling protocols is given in paper [7].

3. Cooperative transmission protocol

The cooperative routing schemes consists of the cooperation of all the nodes in the sensor network. It involves the formation of clusters based on the formation of cluster heads. The cooperative routing scheme is divided into two phases "the routing phase" and "the recruiting and transmitting phase"

1) Routing Phase: - a path is determined from source to the destination which is selected based on Adhoc On Demand Distance Vector (AODV) routing protocol.

2) Recruiting and transmitting phase: - the selected nodes on the initial path acts as cluster heads. They recruit additional nodes from the neighborhood based on the remaining energy. These selected neighboring nodes along with their cluster heads forms clusters.

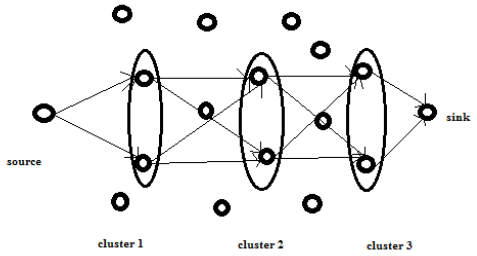

Fig 1: cooperative transmission protocol

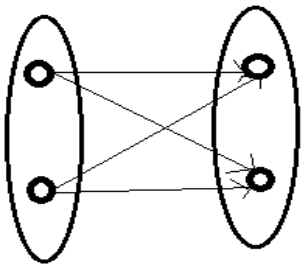

Fig 2:- cooperative reception protocol

The working of cooperative routing scheme is as follows. The source first transmits information to a preselected number of nodes in the first cluster closest to it. The nodes then forward information to the next cluster on the path. Every node in the first cluster should transmit information to every node in the receiving cluster. The number of nodes selected in each cluster should be the same. This process continues till the final cluster is reached. In the last stage the nodes in the final cluster transmits information to the sink. Thus information from the source reaches the destination. This is a many to many communication.

4. IEEE 802.11

The commonly used Mac protocol is IEEE 802.11. a wireless LAN uses a common media for transmission . So for the coordination the stations are coordinated by the MAC protocol. This is achieved through the control messages travelling in the medium. A set of physical standards for WLAN is provided by IEEE 802.11. IEEE 802.11 has several features. Some of them are within time delivery, service continuity, authentication services, etc.

There are two modes of operation for IEEE 802.11. They are the Point Coordination Function (PCF) and the Distributed Coordination Function (DCF). In PCF, a voting technique is used by the nodes to enquire if any nodes have data to send. In the DCF mode the nodes directly tries to transmit information with the use of Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) scheme. Two important features of CSMA/CA are physical and virtual carrier sensing. This is done with the help of optional Request-To-Send/Clear- To-Send (RTS/CTS) messages. These were designed to overcome the exposed node and hidden node problem.

In wireless networks, the exposed node problem occurs when a node is prevented from sending packets to other nodes due to a neighboring transmitter. RTS/CTS mechanism helps to solve this problem only if the nodes are synchronized and packet sizes and data rates are the same for both the transmitting nodes. When a node hears an RTS but not the corresponding CTS from a neighboring node, that node can deduce that it is an exposed node and is permitted to transmit to other neighboring nodes. If the nodes are not synchronized problem may occur that the sender will not hear the CTS or the ACK during the transmission of data of the second sender.

Hidden nodes in a wireless network refer to nodes that are out of range of other nodes or a collection of nodes. As a result each node can hear its neighbor's transmission nut not of other nodes in the network. RTS/CTS handshake and acknowledgement are used to solve this problem.

5. IEEE 802.15.4

IEEE 802.15.4 is a standard used for WLAN's. Important features include reservation of guaranteed time slots, collision avoidance through CSMA/CA and integrated support for secure communications. Devices with IEEE 802.15.4 also include power management functions such as link quality and energy detection.

IEEE 802.11 has two operating modes. One is the beacon enabled mode and the other is non beacon enabled mode. There is s PAN coordinator in the beacon enabled mode. Beacon frames are sent periodically by the PAN coordinator. The active period is called superframe is a frame divided into 16 equal slots. Transmissions are allowed only in this frame. The time between two frames is called beacon interval. It includes an active and an inactive period. The nodes use the basic CSMA/CA technique for accessing the media.

The non beacon enabled mode also works on CSMA/CA. There is no transmission of beacons. The CSMA/CA works on the non persistent protocol. To prevent collisions the non persistent scheme introduces a random back off scheme to prevent nodes within the same range start their transmission together. The node first checks whether the channel is busy. If the channel is available the node is given access to the medium otherwise it has to wait. Retransmission attempts can be done. If the node cannot transfer after a number of retransmission attempts the packet is dropped.

6. Simulation Experiment

A experiment is done to compare the performance of the IEEE 802.11 and IEEE 802.15.4 Mac protocols in cooperative networks. 35 nodes are taken and arranged in a random manner such that the nam contains 5 clusters. 6^{th} node is taken as the source and 34^{th} as the destination. A single cooperative node is selected for cooperation such that the cluster contains only two nodes. The nodes are given random movement. The range of the nodes is 250m and the simulation area is 1100x700m². Figures 3 show the final nam windows.

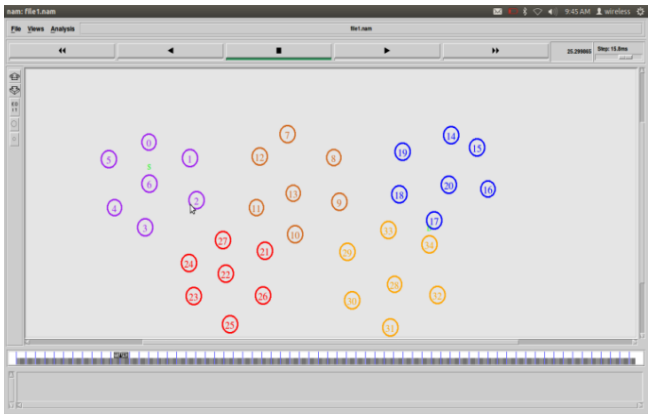

Fig 3:- final set up

The simulation parameters are given in Table 1.

Table1:-parameters for simulation

Various parameters for experiment	Value
Number of nodes	35
Simulation time	85ms
Routing protocol	AODV
Simulation model	Two ray ground
MAC Type	802.11
Link layer type	LL
Interface type	Queue/Pri queue
Traffic type	CBR
Packet size	50
Queue length	50
Node speed	10m/s
channel	Wireless channel
Network interface type	Wireless physical
Antenna	Omni antenna
Initial energy of node	1000J

7. PERFORMANCE ANALYSIS

The performance analysis concentrates on the energy efficiency of the nodes with the low Mac protocols. The results are shown in figure .the results shows that greater energy efficiency is obtained with IEEE 802.15.4. For each node the efficiency is greater with 802.15.4 protocol. The results are shown in figures 4 and 5. Fig 4 shows a graphical comparison of the energy efficiency of the used 35 nodes using IEEE 802.11 and IEEE 802.15.4. Fig 5 shows its bar graph comparison.

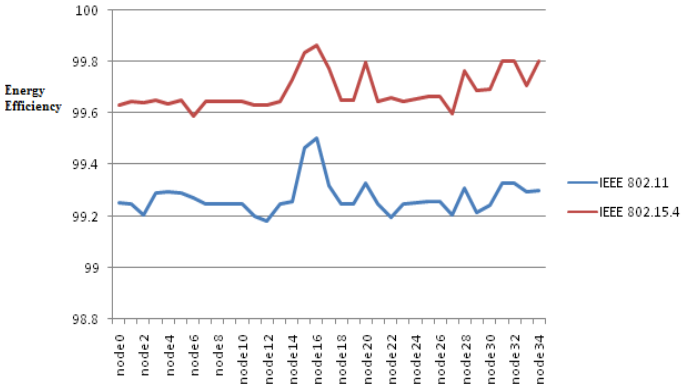

Fig 4:- energy efficiency comparison graph

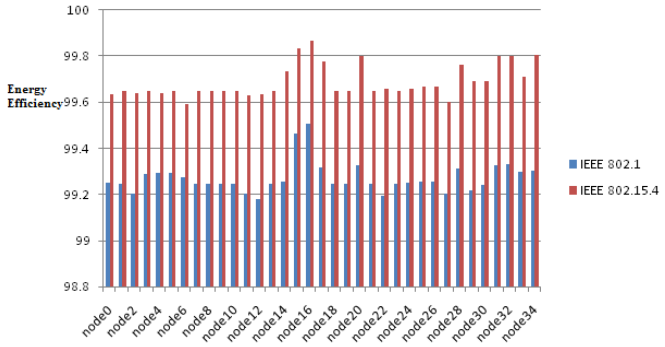

Figure 5:- bar chart showing energy efficiency comparison

8. Conclusion

Cooperative networks had been developed as a method to improve the life time of the sensor nodes. Normally sensor nodes work with the IEEE 802.11 Mac protocol. As a method to improve the energy efficiency the Mac protocol is varied from IEEE 802.11 to IEEE 802.15.4 protocol. It is seen that with IEEE 802.15.4 Mac protocol there is an approximately 40% improvement in energy efficiency compared to IEEE 802.11 protocol. As a result much battery savings and hence lifetime improvement is achieved with IEEE 802.15.4 Mac protocol.

9. Future Work

Several other Mac protocols can be introduced into cooperative networks. Also the effect of directional antennas can be studied.

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