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Enhanced MC-LMAC: A Multi-Channel MAC Protocol In Wireless Sensor Networks

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ABSTRACT

Wireless Sensor Networks (WSNs) consist of a huge number of small, inexpensive sensor nodes distributed over the target area in order to collect the data of interest. Some of the applications of WSNs are intrusion detection, industrial automation, health care monitoring, environmental/earth sensing etc. The WSN MAC Protocols can be classified into four categories: asynchronous, synchronous, frame slotted and multi-channel. This paper gives a brief description of the multi-channel communication in the WSN and divided the various protocolsused in multi-channel communication in the WSN and divided the various protocols used in multi-channel along with their strengths and weaknesses.

Keywords: MAC Protocol; Multi-Channel Media Access Protocol; Wireless Sensor Networks.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of a large number of autonomous and low cost sensor nodes [1-2]. Each sensor node has a low-power radio trans-receiver, sensors, limited power supply, small amount of memory and processing capability. To collect the information regarding environmental monitoring like landslide detection, forest fire detection , military surveillance, industrial monitoring etc. WSN needs to have a large number of sensor nodes distributed in an ad hoc manner. The designing of MAC protocol is of great importance in WSN to maintain the high throughput in an efficient manner. The other reason is that the most power consuming component in a sensor node is the radio. This component is controlled by MAC protocol only.

A WSN can be divided into two categories: structured and unstructured. A structured WSN is a network in which the deployment of nodes is done in a pre-planned manner. The cost of network management and maintenance is very low in structured networks. On the other hand, in case of unstructured networks, the nodes are deployed in an ad hoc fashion. The maintenance and management of unstructured network difficult as the network is way too large. The nodes in the unstructured network are left unattended for a long period of time.

To maximize node as well as network lifetime is the main objective of the WSN. As most of the energy is consumed due to the communication between the nodes. So, the desired objective should be achieved by minimizing the communication of the nodes.WSN has a large number of applications as it is one of the most emerging technologies in today's world [3]. To support all these applications, a lot of MAC protocols are proposed. MAC protocol takes the decision about when the contending nodes will access the medium. Hence, avoids the collision and increases lifetime of the network [4-5].

In this paper, we address the high end to end delay and higher energy consumption in a multi-channel communication with a trade off in throughput. Enhanced MC-LMAC combines multi-channel technology and dynamic power management to further improve the parameters like end to end delay, energy consumption, and network routing load. Dynamic power management makes the protocol energy efficient by shutting down the nodes when they are idle. The performance of Enhanced MC-LMAC is evaluated and compared with the existing MC-LMAC.

The rest of the paper is organized as follows. In section 2, multi-channelcommunication is explained. In section 3, the related work is given. In section 4,thedesign of Enhanced MC-LMAC is provided. In section 5, we evaluate the performance of Enhanced MC-LMAC and compare it with existing MC-LMAC. In section 6,the paper is concluded.

II. METHODS AND MATERIAL

1. Multi-Channel MAC Protocols

Every multi-channel communication consists of two components viz. channel selection and a MAC method. Channel selection tells how to select idle channels in such a way that the overall performance is optimized. On the basis of frequency channel execution, the channels are divided into static and dynamic. Media access (MAC) decides how and when all the nodes should access the channel so that there would not be any data collisions. Media Access is of two types: TDMA and CSMA. Some of the MAC multi-channel protocols are discussed below:

Y-MAC is a hybrid multi-channel MAC protocol [6]. It is a TDMA based dynamic channel selection scheme where only receiving time slots are provided. So during the beginning of the slot, the transmitters have to contend for the slot. In Y-MAC, each time frame is divided into broadcast period and unicast period. Both of them are further divided into smaller slots. In order to support broadcast, all the nodes are awake during the broadcast period. The nodes who have to send broadcast packets contend during the broadcast period to send in a broadcast slot. The radio can be turned off to save energy when there are no incoming messages. Y-MAC is a light weight hopping mechanism in which multiple node pairs communicate with multiple channels at the same time. The basic procedure is that there is a base channel in every assigned slot. Every node must listen to the base channel of its assigned slot. Whenever a packet is received by a node in its assigned slot, the node will hop to the next channel of the next slot to receive the data. Though the next channel is owned by some other node still there would not be any interference because both of the nodes are on different channels. The advantage of Y-MAC is that it introduces new channels only when there is a necessity. The disadvantage of Y-MAC is that it does not tell a node when to switch to sending instead of receiving .The other disadvantage is that which channel a node should use when all of the channels have been visited once.

MLMAC stands for multi-channel low latency MAC protocol [7]. It solves inter-flow interference problems by exploiting multiple channels. It has an enhanced reservation mechanism by which a node can handle multiple reservations in a single transmission cycle. By using multi-channel and enhanced reservation technique, the end to end latency and power consumption is reduced. A node can respond to multiple reservation requests by using MLMAC protocol. If a time slot reserved by sender is overlapping with the receiver's NAV then MLMAC allows the receiver node to select some other channel for data transmission. It solves the two problems viz. Parallel interference and congestion control in RMAC. To overcome these two problems a control packet called Enhanced Multi Channel Reservation Frame (EMRF) is used to set up multi-hop transmission path. A multi value NAV is maintained by each node in this protocol. The communication of all the nodes is done in a data period in a designated channel. The multi-channel NAV possessed by nodes is set according to EMRF they hear. When a source node wins a contention then the source node selects a channel as well as time slot in such a way that the selected parameters will not interfere with the neighbouring nodes with respect to the multi-channel NAV and EMRF packet is sent. After receiving the EMRF packet, the destination node checks the availability of the slot and the channel. In case the time slot is already to some other source node then the destination node will be busy receiving the data from the source node. To overcome this problem, another free time slot and channel is chosen by destination node with the help of NAV. If in case the destination node is not busy then it sees whether the source node is free in that particular time slot. If it's a no. then another free slots are seen. After all this, an EMRF packet is sent to the source node with chose channel and slot. During the sleep time, the transmission of the data is done on the selected slots and channels. The advantage of this protocol is that it has improved the end to end delay and energy consumption.

DMMA stands for dynamic multi-channel media access control. It makes the network robust from the external interferences by choosing the channel dynamically with respect to the changing environment [8]. In order to

reduce energy consumption, a sleeping based mechanism is used. It uses the concept of multiple radios to dynamically negotiate for the correct channel. DMMA can be seen from two aspects viz. Multiple radio multiple channel negotiation and multiple radio sleeping mechanism. In multiple radio multiple channel negotiation, DMMA uses the carrier sense ability of the RF chips which sense the surroundings and the channel is decided depending upon the availability of channels. DMMA can use two radios: control radio and data radio as per its design. The purpose of control radio is to work on the control channel and transmission of control message. On the other hand, the transmission of data is done by data radio. In multiple radio sleeping mechanism, DMMA uses control radio as wake up radio and it adopts periodically sleeping schedule. Data radio remains in sleep state until data needs to be transmitted or received. The mechanism is a bit complex. The main motive in this mechanism is to reduce the energy consumption of the nodes which is done by making nodes asleep for the maximum time. The advantage of DMMA is that it needs light weight synchronisation because of the separation of control radio and data radio.

MMSN is a multi-channel MAC protocol which is contention based [9]. It is based on CSMA with time divided into various time slots. Each slot consists of two periods i.e. broadcast contention period (T_{bc}) and transmission period (T_{tran}). Receiving frequency is assigned to each node. In order to maximize the parallel transmission in the surrounding area the nodes co-operate with each other. Nodes compete for the same broadcast frequency $f_0$to provide proper broadcast during the T_{bc} period. On the other hand, nodes compete for shared unicast frequencies during the $T_{tran\ period}$. Every node's behavior depends upon two factors . One of them is whether a node has any packet to transmit or not. Second factor is whether the transmission is broadcast or unicast. If a broadcast packet needs to be transmitted then the broadcast frequency is checked by each node. If there is not even a single broadcast packet for transmission then unicast packet transmission and reception are considered. If a node does not want to transmit any packet then receiving is done. After the completion of T_{bc}period, if there is not any broadcasting then node goes to another frequency f_{self}which is the frequency assigned to the node in case of unicast packet reception. If there is any signal in the duration of frequency f_{self}then the node receives the packet in the remaining time slot .On the other hand, if there isn't any signal then the node waits in the whole T_{tran}period. A random back-off is taken by the node if there is a unicast packet and no broadcast packet for transmission. During this back-off period, the node oscillates between two frequencies. There are two frequencies i.e. $f_{dest}$and f_{self}. For an incoming unicast packet, the node goes to f_{self}.It also oscillates to f_{dest}which is the destination node's frequency in order of data reception of its unicast period.

With lower traffic, MMSN provides smaller latency and higher throughput. When the traffic increases, the collision as well as contention also increases. It eliminates the missing terminal problem . But due to the frequent switching between the channels, this protocol increases energy consumption.

2. Enhanced MC-LMAC & Results

A. Enhanced MC-LMAC Design

Enhanced MC-LMAC is a combination of MC-LMAC and Y-MAC. The main design of Enhanced MC-LMAC is based on MC-LMAC. However for energy conservation it uses the concept of Y-MAC. The main aspects of MC-LMAC are written below:

1) Self Configuration: MC-LMAC is a self-configured protocol i.e. no centralized scheduler is required for MC-LMAC.

2) Adaptable: MC-LMAC is an adaptable protocol. If there is any change in the topology then the nodes themselves can adapt to the changes without the requirement of any centralized scheduler.

B. Organisation of Protocol

As Enhanced MC-LMAC is a scheduled protocol, so initially the nodes will synchronize so that they can send and receive the messages as per the correct timings. There are five stages in which nodes will transit : initialization, synchronization, discovery, time-slot channel selection and medium access. The time slot and frequency is chosen by the sink node when the network is initialized for the first time. In MC-LMAC nodes choose the slot as well as frequency. These node transition stages are explained below:

1) Initialization: In this state, the sampling of medium for an incoming packet is done in order to synchronize with the network. Nodes are in initialization state in two cases viz. one is if there is recent deployment of the network or if any node rejoin the network.

2) Synchronization: If the required packet is received, then the network will move into the synchronization phase. Here, synchronization is done with the help of the information contained in the received packet. In case a node wants to actively join the network and send the packets then a random wake up frame is selected by the node to select a time slot within the channel. A node enters into the discovery state before the wake up frame so it can get a list of conflict free slots and channels in the neighborhood

3) Discovery: In this state, it is checked that whether timeslot and channel pair are occupied or not. It can be occupied in two conditions: either if the received level of the transmissions during the timeslot on the channel is above threshold or if there is already a transmission is occurring on the same timeslot and channel.

4) Time slot and channel selection : After collecting all the information regarding the frame duration, node enters into time slot and channel selection state. Here the frequency and time slot will be selected for the transmissions.

The node simply transmits on the selected frequency and timeslot at the end of the discovery state.

C. Media Access Control

After the synchronization is done, the node comes into the media access state. In this state the messages are exchanged. The time slot and channel selection allows the parallel transmission as all of the nodes will listen to the control channel first in each slot. Apart from control channel each slot consists of Common Frequency (CF) period which notifies receivers of data reception. This CF period further consists of m small slots where m defines the total number of available channels. As there is a unique channel/slot pair that's why the multiple nodes can control the same current time slot with different channels. After the CF period, each pair of sender and receiver switch to the sender's controlled channel for data transmission. The control information transmission like acknowledgement to the sender and the occupied slot vectors information is done in the Control Message (CM) period.

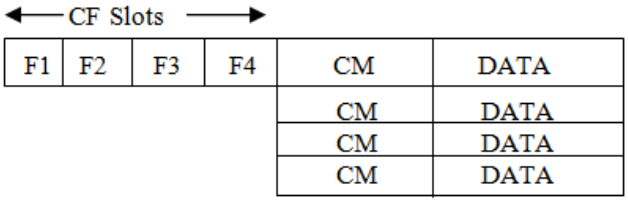

Figure 1: Time slot structure in MC-LMAC

D. Hybridisation of Protocols

The disadvantage of MC-LMAC is that it focuses only on maximizing throughput. While maximizing throughput, the energy consumption and end to end delay parameters were neglected. So, in order to make an energy efficient protocol, the protocols MC-LMAC and Y-MAC are joined together in order to form enhanced MC-LMAC. This enhanced MC-LMAC is more energy efficient than MC-LMAC. The reason being Y-MAC is an energy efficient protocol which uses dynamic power management. Basically in the MC-LMAC the nodes were always awake. So there is continuously consumption of energy in the active mode that is why MC-LMAC is not energy efficient. After combining with Y-MAC, the nodes that are not working i.e. idle nodes are sent to sleep mode. The energy consumption of sleep nodes is very less than the nodes in the active mode. In this way , our enhanced MC-LMAC performs better than the existing MC-LMAC.

E. Performance Evaluation

In this section, we evaluate the performance of Enhanced MC-LMAC protocol by extensive simulations with ns2. The four performance metrics: throughput, energy efficiency, packet delivery ratio and end to end delay are studied. The performance is seen by increasing the number of nodes from 30,50 ,60,80 and 100. The performance of Enhanced MC-LMAC is compared with the existing MC-LMAC[10].

III. RESULTS AND DISCUSSION

The simulation parameters used in the evaluation are shown in the following table:

TABLE I
SIMULATION PARAMETERS

Terrain Size	150*150 m^2
Number of Nodes	30,50,60,80,100
Placement of Nodes	Random
Bandwidth	250kbps
MAC protocol	Enhanced MC-LMAC,MC-LMAC

1) Energy Consumption: Energy consumption means energy consumed per successfully delivered packet. The energy spent in transmitting, receiving and relaying the packet is considered. When the number of nodes are increased in MC-LMAC, the energy consumption is increasing as the duration of the CF period increases with increasing the number of channels. On the other hand, in the Enhanced MC-LMAC, the energy consumption is very less than that of MC-LMAC. The reason being the non-participating nodes are going to sleep mode. This also shows that our enhanced protocol is quite scalable. The results obtained are shown in the following table:

TABLE II
VALUES OF ENERGY CONSUMPTION FOR MC-LMAC AND ENHANCED MC-LMAC

Number of Nodes	MC-LMAC	Enhanced MC-LMAC
30	785.739	723.993
50	791.237	724.21
60	791.224	724.31
80	791.203	724.39
100	793.31	724.89

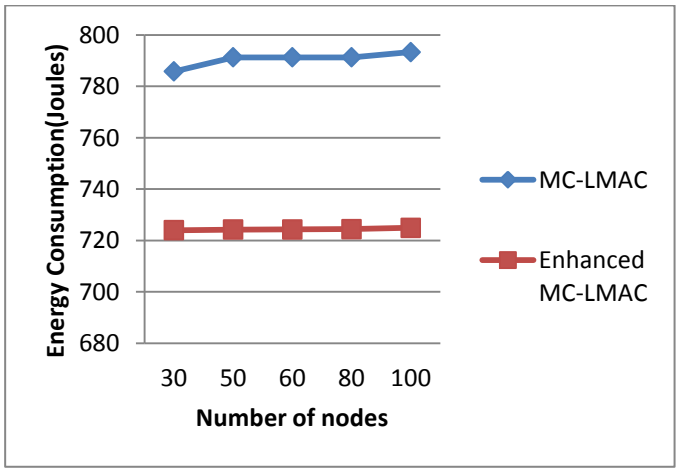

Figure 2: Energy Consumption with different number of channels

2) End to End Delay: The end to end delay is the total time taken by the packet to reach from source to destination. The end to end delay in the MC-LMAC increases immensely with increasing the number of nodes. But in Enhanced MC-LMAC outperforms it because bandwidth occupancy decreases significantly so the waiting time of the packets reduces as well which in turn reduces the end to end delay.

TABLE III
VALUES OF END TO END DELAY FOR MC-LMAC AND ENHANCED MC-LMAC

Number of Nodes	MC-LMAC	Enhanced MC-LMAC
30	43.2804	23.705
50	44.4451	25.97901
60	50.5226	27.94231
80	55.9338	28.95768
100	60.81	37.94513

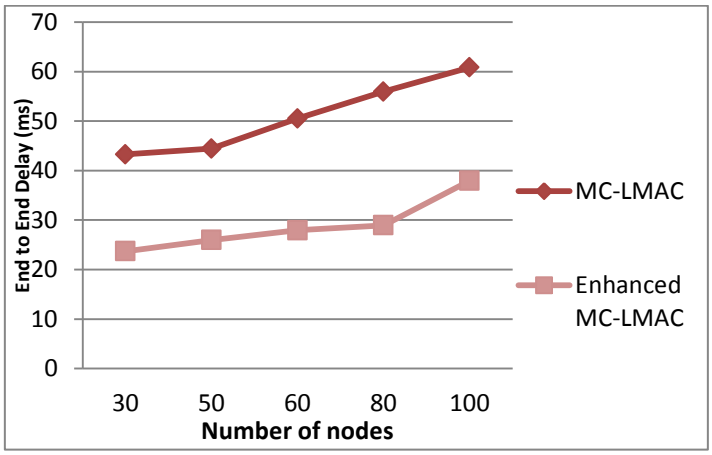

Figure 3: End to End Delay with different number of channels

3)Throughput: Average throughput is a measure of the total number of data packets successfully received at the node, having the total number of bits is computed over the simulation runtime. There is a trade-off between the above two parameters with the Throughput. To decrease the end to end delay and energy consumption, throughput decreases a little bit. The throughput of MC-LMAC is higher than the throughput of Enhanced MC-LMAC. The reason being in MC-LMAC assigns slots to each node so there will not be any kind of packet loss. In case of enhanced MC-LMAC, until the event doesn't

occur the nodes will not come to wake up mode. During packet transmission the source node will wait for acknowledgement. But if neighbour node's condition is not good, the source node will not get acknowledgement so the source node will not transfer the packet. So there are some packet losses in Enhanced MC-LMAC.

TABLE IV
VALUES OF THROUGHPUT FOR MC-LMAC AND ENHANCED MC-LMAC

Number of Nodes	MC-LMAC	Enhanced MC-LMAC
30	290.17	286.51
50	155.47	154.67
60	155.47	153.7
80	155.47	151.68
100	152.19	151.68

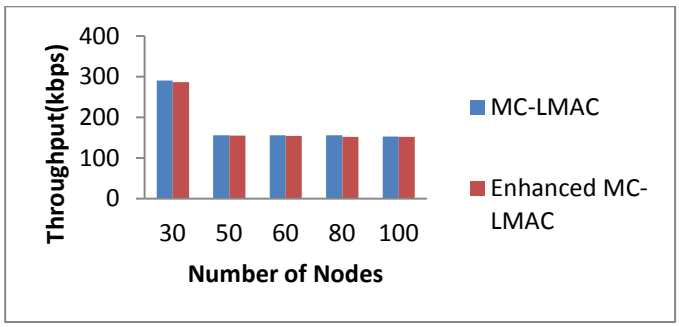

Figure 4: Throughput with different number of channels

4) Packet Delivery Ratio: Packet Delivery Ratio means the total number of packets delivered to the total number of packets generated in the simulation period. The packet delivery ratio in both MC-LMAC as well as Enhanced MC-LMAC is almost 99 % i.e. both the protocols are quite reliable and the packet loss is very less even after increasing the number of nodes.

TABLE V
VALUES OF PACKET DELIVERY RATIO FOR MC-LMAC AND ENHANCED MC-LMAC

Number of Nodes	MC-LMAC	Enhanced MC-LMAC
30	98.81	99.87
50	100	100
60	100	100
80	100	99.3
100	97.89	99.24

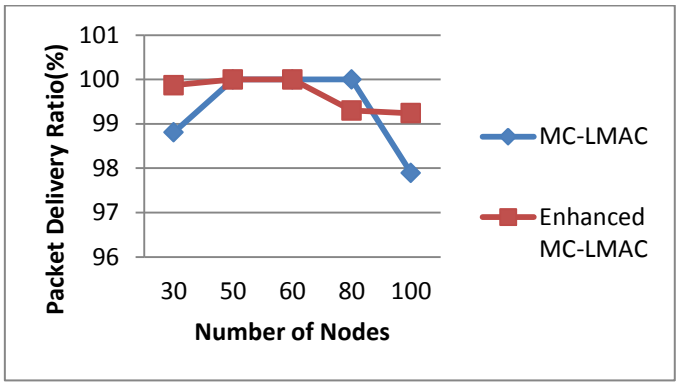

Figure 5: Packet Delivery Ratio with different number of channels

IV. CONCLUSION

The proposed payment system combines the Iris recognition with the visual cryptography by which customer data privacy can be obtained and prevents theft through phishing attack [8]. This method provides best for legitimate user identification. This method can also be implemented in computers using external iris recognition devices.

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