Improving Energy Efficiency Using MR-MAC Protocol in Wireless Sensor Networks

C. Benita and P.X. Britto

Abstract--- *Sensor networks are network of nodes working towards a common application such as temperature or light measurement in a field. These sensor nodes are characterized by limited energy resources. Energy in a sensor node is consumed in sensing, data transferring by the microcontroller and communication. For communication, energy is consumed in transmitting and receiving packets. In layered based architecture of WSN, Unified Network Protocol Framework (UNPF) plays an important role for establishing hop by hop network connection. To implement layered based WSN using UNPF, three modules are incorporated: Initialization and maintenance, MAC Protocol and Routing Protocol. The existing protocols like CSMA, SMAC and TRAMA protocols are analysed with various parameters such as average packet delivery rate, average packet delay, energy efficiency with variable traffic and increasing load. A novel protocol called MR-MAC, an energy conserving Medium Access Control (MAC) protocol for WSN is introduced, the core of which is characterized by both random based and scheduling based of sleep-wake up cycle. The nodes in the network do not need to wake up all the times. The node is active only when the data transfer arrives at the scheduled time and also it extends and limits the time according to the data rate using random access. Only the nodes that are going to receive a packet are listening and the rest of the nodes sleep during that period and hence conserve energy. Our simulation results propose that MR-MAC performs well in various topologies with significant energy savings.*

Keywords--- *Wireless Sensor Networks, MAC Protocols, Energy Efficiency, Sleep and Listen Scheduling, Scheduling Access and Random Access*

I. INTRODUCTION

WSN has a powerful base station and a collection of small sensor nodes that are randomly deployed in large numbers to monitor the environment or systems by the measurements of physical parameters such as temperature, pressure or relative humidity. Most wireless sensor nodes are battery operated and usuall1y they cannot be recharged due to its deployment in harsh and remote environment. Each node consists of processing devices such as microcontrollers, may contain multiple types of memory, have a RF transceiver, have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. In Figure 1.1 the nodes communicate wirelessly and often self-organize after being deployed. Sensor organization often involves signal processing techniques and geographical mapping in order to ensure a sufficient coverage using the least possible number of deployed sensors.

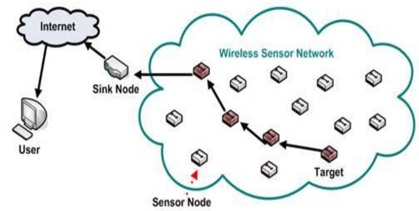

Fig 1.1: Architecture of Wireless Sensor Network

As the hardware for sensor nodes has become affordable, sensor networks have emerged as an ideal solution to a number of applications in both civilian and military scenarios, including monitoring and surveillance of large, remote or inaccessible areas over extended periods of time. Today's sensor networks can be constructed using commercial components on the scale of a square inch in size and a fraction of a watt in power. They use one or more micro controllers connected to various sensor devices and to small transceiver chips. Many researchers have envisioned the network sensors down to microscopic scale by taking advantage of advances in semiconductor processes. This includes having communication integrated on chip with a rich set of micro electromechanical (MEMS) sensors and CMOS logic at extremely low cost. They envision that this smart dust will be integrated into the physical environment, perhaps even powered by ambient energy, and used in many smart space scenarios. Alternatively, others envision ramping up the functionality associated with one-inch devices dramatically. Other research projects are trying to compress this class of devices onto a single chip. In short, sensor networks are an evolving technology that is going to be ubiquitous and quintessential in days to come. In this paper we concentrate on the minimization of energy consumption at the MAC layer through time-based arbitration of the sensor's medium access.

II. SYSTEM DESIGN

2.1 Existing System

In layered based architecture, communication will possible with one hop or multi hop. In case of multi hop communication, more traffic will occur due to channel access. To avoid this problem CSMA protocol was introduced to avoid congestion in network and also reliable. CSMA is a contention-based MAC scheme. In CSMA, each node is required to keep sensing the medium searching for a free

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channel for its transmission. When a node has packet to send, it transmit at the full channel bandwidth. No a priori coordination among nodes or synchronized clocks is required in this scheme[9]. Using CSMA forces nodes to be awake for longer time and consequently boosts their energy consumption. In addition, data transmissions suffer from high collisions in dense networks. Increased collisions among nodes make the transmission delay unpredictable and can lead to high rate of packet drops. On the other hand, CSMA based medium arbitration is autonomous and does not require external control.

S-MAC, a medium-access control (MAC) protocol designed for wireless sensor networks. S-MAC uses three novel techniques to reduce energy consumption and support self configuration. To reduce energy Consumption in listening to an idle channel, nodes periodically sleep. It achieves good scalability and collision avoidance by utilizing a combined scheduling and contention scheme [4]. Each node goes to sleep for some time, and then wakes up and listens to see if any other node wants to talk to it. During sleep, the node turns off its radio, and sets a timer to awake later. SMAC requires periodic synchronization among neighbouring nodes to remedy their clock drift. All nodes are free to choose their own listen/sleep schedules. Nodes exchange their schedules by broadcasting it to all its immediate neighbours. This ensures that all neighbouring nodes can talk to each other even if they have different schedules.

The traffic-adaptive medium access protocol (TRAMA) is a energy-efficient collision-free channel access in wireless sensor networks [8]. TRAMA consists of three components: the Neighbour Protocol (NP) and the Schedule Exchange Protocol (SEP), which allow nodes to exchange two-hop neighbour information and their schedules; and the Adaptive Election Algorithm (AEA), which uses neighbourhood and schedule information to select the transmitters and receivers for the current time slot, leaving all other nodes in liberty to switch to low-power mode. TRAMA starts in random access mode where each node transmits by selecting a slot randomly. Nodes can only join the network during random access periods. The duty cycle of random- versus scheduled access depends on the type of network. The existing protocols are based on both Contention based and scheduled based approach.

III. MR-MAC

3.1 Protocol Overview

A new protocol called, MR-MAC will be implemented. This MR-MAC protocol switches between both random-access time and scheduled-access time. It avoids assigning time slots to node that has no data to send. It extends and limits the scheduled access time by using random access time until it finishes its transmission, thereby conserving energy. It never loses a packet due to an invalid state assignment (i.e., a node transmitting to a sleeping node). Prolongs the battery life of each node in the network. For example: Scheduled Access Time is 5ms. If the data transfer will take 8ms to transmit, then our protocol will extend its time to 8ms to transmit using random access time and then the node will go to in-active mode. Similarly if the data transfer will take 3ms to transmit, then our protocol will limits its time to 3ms to transmit and then the node will go to in-active mode.

3.2 Hop by Hop Network Setup

In wireless Sensor Network, MAC protocol is responsible for creating the network infrastructure [3].Unified Network Protocol Framework (UNPF) for a wireless sensor network consisting of a few hundred sensors are connected in a layered manner that communicate data to a base station (BS). The framework encompasses network organization, medium access control (MAC) and routing protocols. The network organization protocol is a distributed algorithm which uses localized information to organize the network into a “layered” structure. The MAC protocol, based on Time Division CDMA access, is designed to be collision-free, energy-efficient and fair. The routing protocol is multi-hop and uses a simple layering-based forwarding scheme. This reduces the number of control packets that need to be transmitted thereby reducing energy and computation costs.

3.3 Sleep and Awake Capability

In many sensor network applications, nodes are in idle for a long time if no sensing event happens. If it is given that the data rate during this period is very low, it is not necessary to keep nodes listening all the time. The sleep and wake scheduling method conserves energy as it puts the radio to sleep during idle times and wake it up right before message transmission/reception. The important part for a sleep/wake method is the synchronization between the sender and the receiver, so that they can wake up simultaneously to communicate with other.

3.4 Scheduling Access Period

This period is used for contention free data exchange between nodes and also supports unicast, multicast and broadcast communication.

3.5 Random Access Period

This is used for signalling: synchronization and updating two-hop neighbour information.

3.6 Proposed Algorithm

Step 1: Let $H_1(n_i)$ be the set of neighbors of node n_i and $ST(n_i)$ be the Supreme transmitter of node n_i with highest priority.

Step 2: if node n_i is the Supreme transmitter ($ST(n_i)$) then set node n_i to Transmit TX mode and transmit the packet and update the schedule.

Step 3: when the transmissions starts, the node n_i can extends and limits the schedule time until it completes its transmission.

Step 3: else if $ST(n_i)$ belongs to $H_1(n_i)$ then if $ST(n_i)$ has highest priority but no data to send, then set node n_i to Sleep SL mode.

Step4: else if $ST(n_i)$ has not highest priority but it is in receiving state, then set the node n_i to Receive RX mode.

Step 5: Else set the node n_i to Sleep SL mode and update the schedule for $ST(n_i)$.

IV. PERFORMANCE EVOLUTION

The existing protocols such as CSMA, SMAC, TRAMA are analysed and compared with various parameters such as throughput, packet delay, packet delivery rate and energy efficiency.

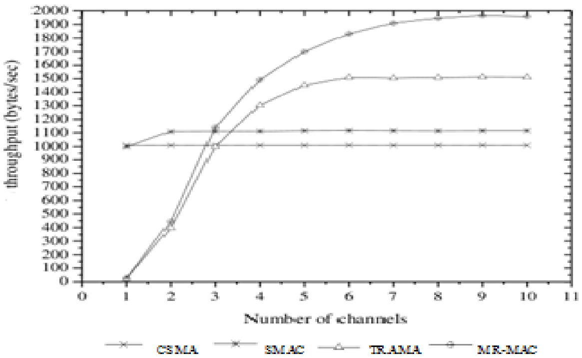

Fig 4.1: Average Throughput (bytes/sec)

The average throughput increases as the number of channels increases from 1 to 10 except CSMA where the number channels is fixed to 1 (Fig 4.1). A significant improvement is achieved using our proposed MR-MAC protocol compared to CSMA, SMAC, TRAMA.

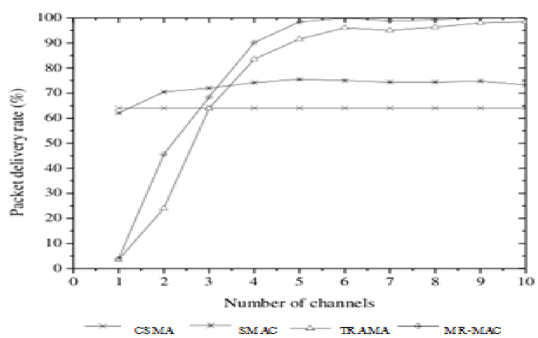

Fig 4.2: Packet Delivery Rate (%)

The packet delivery rate is the ratio between the number of packets received by the sink and total number of packets generated by the nodes. The performance is better than both protocols and achieve to deliver more than 99% of the packets shown in fig 4.2.

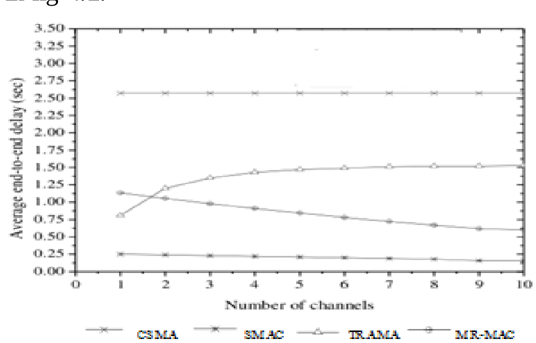

Fig 4.3: Average End-to-End Delay (sec)

Average end-to-end delay is the time between the transmission of a packet at the source node and reception at the sink node. Our proposed MR-MAC protocol achieves much lower delay than the TRAMA protocol fig 4.3.

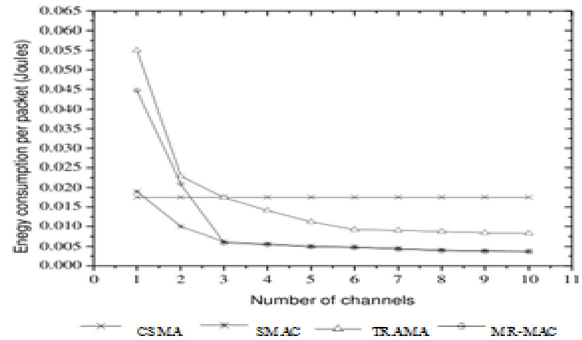

Fig 4.4: Energy Consumption

Energy spent to receive and transmit as well as energy spent for electing the Supreme transmitter in the two hop neighbourhood nodes are considered. Energy spent per delivered packet is quite high with TRAMA when there is only a single channel fig 4.4

Table 1: Advantages & Disadvantages of MAC Protocol

MAC Protocols	Advantages	Disadvantages
CSMA	prevent collision and retransmission	Increases system delay
SMAC	reduces idle listening and prevents time synchronization overhead	increases latency and predefined constant time periods
TRAMA	improvement in delivery ratio, traffic adaptive and prolongs the battery life	complex election algorithm, overhead due to explicit schedule propagation and higher queuing delay
MR-MAC	extends and limits the scheduled access time, reduces delay	Not yet found

V. CONCLUSION

This project proposes a novel MAC layer protocol, which improves energy efficiency in WSN. MAC layer Protocol shows better performance rather than TRAMA. Another major property of the protocol is that, it has the ability to prolong the battery life of the node in the network. A novel protocol called MR-MAC, an energy conserving Medium Access Control (MAC) protocol for WSN is introduced, the core of which is characterized by both random based and scheduling based of sleep-wake up cycle.

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