Implementation of energy saving Isochronous Mac Protocol for Wireless Sensor Networks

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ABSTRACT

Energy Consumption in Wireless sensor networks is one of the main challenges for researchers. Most of the work is done over the MAC layer of network in which different kinds of MAC protocol used by sensor networks. We are implementing the Isochronous MAC protocol which has periodic wakeup time synchronized with the flooding Time Synchronization protocol (FTSP) part of routing layer protocol. We are supporting the performance of proposed approach efficient through our extensive simulation work using the NS2. We will first implement the proposed MAC protocol by modifying the traditional MAC protocol and then do the cross layer simulation using FTSP routing protocol with different kinds of WSN networks and hardware evaluate its energy consumption performances. We have measured the performances in terms of energy consumption, residual energy.

Keywords - WSN, Energy efficient, MAC protocols, Routing protocols.

1. INTRODUCTION

1.1 Wireless Sensor Networks

Wireless Sensor Networks (WSNs) represent a new paradigm in wireless technology drawing significant research attention from diverse fields of engineering. The WSNs comprise of a large number of application-specific wireless sensor nodes spread over varying topographies. This kind of random placement of the sensor nodes does not follow any fixed pattern and the density of nodes is not dependent on any factor. They self-organize themselves by creating multi-hop wireless paths through mutual co-operation. The nodes work collectively and collaborate together on common tasks of sensing/data-collection/communications etc to provide good network-wide performance in terms of network life-time, latency, and uniform density of available nodes for sensing.

1.2 Energy related issues

Energy consumption is the most important factor in determining the life of a WSN as the sensor nodes comprising the network are all battery-powered and thus limited by very low energy resources for tasks involving data sensing, processing and communications. Energy optimization techniques therefore take precedence in WSNs to allow preservation of energy for prolonged network life-times. This can be done by considering energy awareness issues in every aspect of design and operation of each sensor node. Energy saving protocols and techniques also need to be addressed for collective groups of communicating sensor nodes in order to have better overall performance and improved energy efficiency in the entire WSN.

Power management in radios is also a very important issue because radio communication consumes a lot of energy during operation in

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comparison to the overall energy consumption of each node in the WSN as a whole.

2. PROBLEM STATEMENT

The main aim of this paper to present new MAC protocol along with FTSP routing approach with objective of improving the performance of energy utilization and hence consumption. We have designed and implemented protocol architecture for WSNs that achieves low energy dissipation and higher scalability. Since sensor-heads can be replaced as single modules on every single sensor node for serving the purpose of specific applications, our research looks at a cross-layer (at the network/data-link layer) design for a very general application scenario. Specifically so, by working on the protocol architectures for individual nodes we have been able to design a robust, energy-efficient, and scalable scheme for WSNs that can be applied to any generic application that WSNs may be used for. The results of our research show that greater amount of energies can be saved by using the cross-layer design.

3. COMMUNICATION CENTRIC DESIGN

To achieve communication centric design, we introduced an Isochronous-MAC (I-MAC) protocol [1], which has a periodic wakeup time synchronized with the Flooding Time Synchronization Protocol (FTSP). I-MAC reduces the active time of the RF circuits significantly resulting low power characteristics.

3.1 Isochronous-MAC (I-MAC)

An effective way to reduce the energy in MAC is shorten the idle listening, in which the receiver is activated even when no packet is received. The proposed Isochronous-MAC (I-MAC) [3][5] is based on LPL that has a periodic wakeup time. Since a sender can predicts a next wakeup time of an intended receiver with high accuracy, we can minimize the duration of a preamble on the sender. As well as on the receiver side, the receiving time for the preamble can be reduced thanks to the short duration of the preamble.

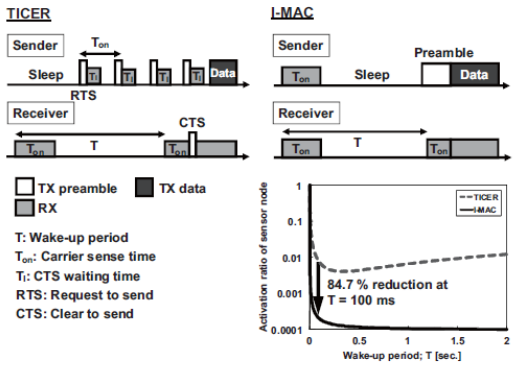

Figure 3.1: Comparison of the TICER and the I-MAC.

In [6], TICER [7] is implemented as a MAC, in which a sender node periodically repeats wakeups and sleeps in a preamble operation when establishing communication with receiver nodes (Figure 3.1). In the figure, T is a receiver's wakeup period, and Ton is a carrier sense time; as T becomes larger, the power of TICER becomes larger, since a number of preambles must be tried.

3.2 Time synchronization

In [1] [5], the time on sensor nodes are adjusted to the actual time using the long-wave standard time code. However, external hardware is required for this method, and it does not work indoors. In contrast, packet exchanging methods do not require external hardware or signal, although a communication overhead is required. Flooding Time Synchronization Protocol (FTSP) [8] is one of the packet exchanging method and it correct the time by using time stamp packet communication. As the time synchronous technique of the proposal sensor node, we chose FTSP in consideration of the cost of hardware and power overhead. Figure 3.2 shows the synchronization method of the FTSP algorithm. First, the synchronous packet is flooding

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from the root node. At this time, the time stamp of T1 is send to the receiver node. Next, the receiver node records the time stamp of T2 at the end of the synchronous packet. Then the propagation delay is calculated from T2 - T1. However, note that, until the synchronous packet is recognized by a system, there is a time of Tb as a byte alignment time. This can be calculated by the data rate, and after that, the time error is corrected with T2 - T1 – Tb in the receiver node. The time lag among sensor nodes is suppressed within 250 μseconds, when the nodes synchronize 50 times, in a day. From [1], time lag of 250 μseconds is sufficiently small value in order to operate IMAC.

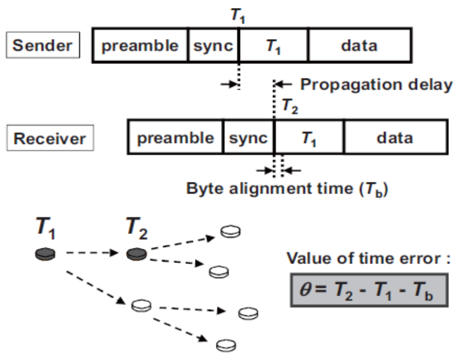

Figure 3.2: Synchronization method of the FTSP.

In addition to the above, there are two other reasons why we chose the FTSP for our system. The first reason is that the I-MAC does not need to synchronize the time of the entire network. Only by synchronizing the time between a node and its one-hop neighbor, the I-MAC can organize communication.

Moreover, although the power consumption of the I-MAC is dependent on a preamble length, its length can be determined only by the time drift over a one-hop neighbor [1][5].

The second reason is that we assume data collection type application in this research. In order to collect sensing data, it is necessary to construct routes from a base station to each node in the network. In many routing protocols, the route is constructed by using flooding. (E.g. Directed Diffusion [19] and Tiny Diffusion [10]). Therefore, since the time synchronization by using FTSP and the construction of a route can be executed simultaneously, the flooding operation does not become overhead.

3.3 Mathematical Model

We will next use a model to identify, analytically, those parameters that would be associated most closely with the power consumption. To do so the model is simplified where packet collisions are ignored [1]. The power consumption P total to obtain for IMAC is definable with the active time period, Ttotal, and the total consumption energy, E total, as expressed in the following equation.

Ptotal = Etotal/ T total (1)

We will proceed with the modeling process separately for the energy consumption at sending and receiving times and at the idle time, as well as to obtain the E total value. First we will describe the consumption energy at the data sending and receiving times. Now we define N as the average number of nodes within the Transmission range from any one node, and M as the average number of data transmissions made during the period of Ttotal. Because every node residing in the transmission area is expected to send data M-number of times,it is concluded that any one node is expected to receive data NM-number of times on average, during which time neither packet collisions nor retransmissions are presumed to be made. From the NM-number of data receptions, M-number of packet receipts are assumed to be made by the own node, and the other (N -1) M-number of times by other nodes. Here, we respectively define each pair of Esend and Tsend, Erecv-own and Trecv-own, and Erecv-other and Trecv-other, as thee of data transmission, for one piece of data receiving by the own node, and for one piece of data receiving by other nodes. Using these variables, the energy Ecomis consumed by data

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sending and receiving; the time Tcom is required to accomplish that. The entire process happens during Ttotal. They are represented as the following equations.

Ecom = MEsend + MErecv-own + M(N - l)Erecv-other (2)

Tcom= MTsend + MTrecv-own + M(N-1)Trecv-other (3)

The energy consumed to send and receive one piece of data and the necessary time for that are obtained next. Using Sack as the ACK size, Sdata as the data length, and R as the channel rate, we define Tack as the time to send and receive an ACK, and Tdata as the time to send and receive the data. We represent them in the form of

Tdata=Sdata / R (4)

Tack=Sack / R (5)

Defining Tpreamble as the preamble transmission time,followed by Ptx, Prx, and Psleep, which respectively represent thepower consumption at the times of transmission, receiving, andsleeping, Esend and Tsend are given as

Esend =Ptx (Tpreamble + Tdata) + PrxTack (6)

Tsend = Tpreamble +Tdata + Tack (7)

The average time period spent for each node to startreceiving data after it detects a preamble is Tpreamble / 2.Therefore, Erecv-own and Trecv-own can be expressed as

Erecv-own =Prx(Tpreamble/2 +Tdata)+PtxTack (8)

T recv-own= (Tpreamble/2)+ Tdata +Tack (9)

When receiving the data that are addressed to the othernode, the node is assumed to enter into an idle state withoutsending an ACK. With this fact in mind, Erecv-other and Trecv-otherare given as

E recv-other = P rx(T preamble/2+T data) (10)

T recv-other = T preamble/2 + T data (11)

The energy consumption at an idle time is discussed next.With T given as a wakeup period, the energy ET that isconsumed during time T is provided as follows during the idletime.

ET = P rx Ton + P sleep(T-Ton) (12)

Then the energy Eidle that is consumed at an idle timeduring Ttotal, can be represented by the following equation.

Eidle= ((Ttotal-Tcom)/T)ET (13)

I-MAC is dependent on the maximum clock drift D and the number of synchronizations C, it can be represented by the following equation, where F is the maximum error from the absolute time at the time synchronizations, and the clock drift varies linearly with time.

Tpreamble = 4D/C + Ton + 4F (14)

Defining P sync as the power consumed during time synchronization, C as the number of synchronizations made during Ttotal, and Tsync as the time required for one synchronization, the energy E sync that is consumed by the time synchronization made during Ttotal is Psync Tsync C.In conclusion, the total energy consumption E total-imac of I-MAC is given as the following equations.

Etotal-imac=Ecom-imac+Eidle-imac+Esync (15)

4 PERFORMANCE METRICES

4.1 Energy Consumption

The metric is measured as the energy consumed by a node with respect to its initial energy. The initial energy and the final energy left in the node, at the end of the simulation run are measured. The energy consumed by a node is calculated as the energy consumed to the initial energy. And finally the energy consumed by all the nodes in a scenario is calculated as the average of their individual energy consumption of the nodes.

1) 802.11 with FLOODING

2) IMAC with FTSP

Scenario

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Number of Nodes	10
Traffic Patterns	CBR (Constant Bit Rate)
Network Size	1000 x 1000 (X x Y)
Max Speed	10 m/s
Simulation Time	30s
Transmission Packet Rate Time	10 m/s
Pause Time	2.0s
Routing Protocol	FLOODING/FTSP
MAC Protocol	802.11/IMAC

5 SOFTWARE REQUIREMENTS

For the simulation of this work we have to need the following setups requirement for the same

1) Cygwin: for the windows XP
2) Ns-allinone-2.31: FLOODING/ FTSP

6. RESULTS AND DISCUSSION

We have implemented the protocols namely FTSP routing protocol and IMAC Mac Protocol using NS-2 tool in order to perform the cross layer functionality. This network scenarios used with two approaches to claim effectiveness of proposed methods:

1. Existing Methods: 802.11 as Mac protocol and Flooding as Routing protocol. First we have used these two protocols with all four scenarios and measured their energy consumption and residual energy performances.

2. Proposed Methods: IMAC as Mac protocol and FTSP as Routing protocol. Once we have readings of all above existing methods, further we simulate the above same network scenarios with these two protocols and then noted energy consumption.

We have got following results to our simulation study; the results are recording in terms of:

- Average Energy Consumption
- Total Energy Consumption
- Residual Energy

Following graphs 6.1 and 6.2 respectively showing above three performances and comparative analysis against the existing methods in order to claim efficiency of proposed approach:

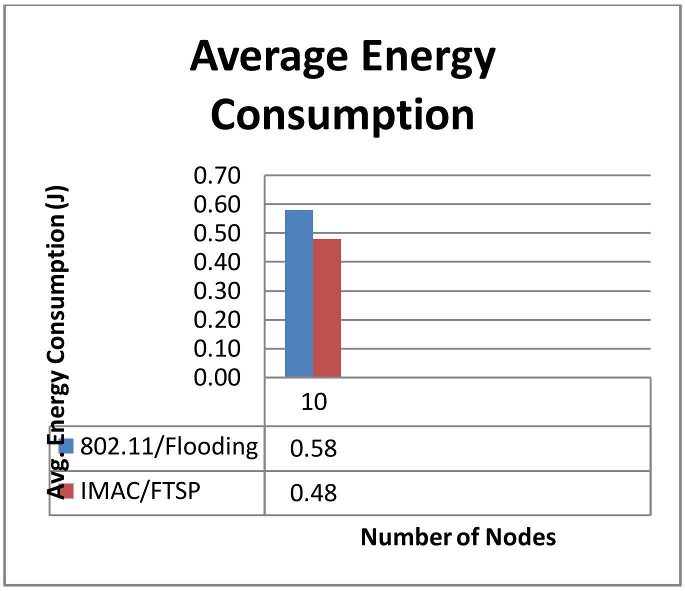

Figure 6.1: Average Energy Consumption Performance Analysis

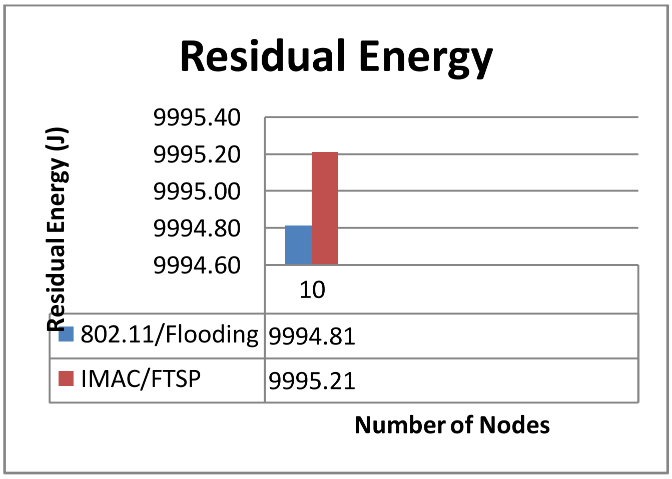

Figure 6.2: Residual Energy Performance Analysis

From the above results, it's clear that our invested method for energy performance improvement showing better utilization of energy as compared to the existing MAC protocols and Routing protocol.

ISSN: 2278 – 7798

7. CONCLUSION AND FUTURE WORK

We have proposed a cross-layer design that exploits the characteristics of sensor networks to meet improved power-aware, scalable and fault-tolerant requirements of WSNs. Paper presents a method for increased scalability and network wide energy-efficiency in WSNs. Each time the nodes in the network configure – new/mobile/hibernating nodes get discovered by the local search performed as a part of the dynamic clustering scheme – an interesting feature of our paper – giving a relatively superior scalability capability to WSNs in comparison to existing procedures. We have used the IMAC approach with FTSP in order to improve the energy consumption. The savings in power is achieved by avoiding the overhearing effect through the elimination of the reception of all the packets inside the transmission range of the cluster, by putting nodes to sleep more often according to the IMAC and FTSP methods. Based on the simulations that we have carried out to support our proposed methods, we observe that energy consumption using our scheme for low traffic is very low – this is very good as WSNs generally operate under event-driven detections, and traffic during the entire lifetime of the network is generally very low.

Therefore protocol architectures need to be developed that support QoS (Quality of Service) issues along with the unique considerations of these networks. This will be particularly useful when energy is highly-varying, such as in self-powered systems (e.g., systems that convert vibration into electrical energy.Such energy-quality scalability constraints add new parameters to the design of protocol architectures. Finally, it will be important to develop secure communication for WSNs.The importance of mobility in sensor networks and schemes focused on the energy implications of node mobility (which none of the schemes have proposed to date) will also need to be addressed.

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