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Research Analysis on Optimization of Energy Consumption in Wireless Sensor Networks*

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Abstract

Wireless Sensor Networks need more research to satisfy the today's energy demands in real time applications. Energy consumption is one of the most challenging aspects of the Sensor Networks because of its limited storage capability. The objective is to provide the analysis of various research methodologies and protocols to achieve the optimized energy consumption in WSN. A notable work done by many scientists in this area , but all the previous research have concentrated in either few layers or few protocols, In this paper we present a detailed analysis of previous research in Wireless Sensor Networks.

Keywords: Wireless sensor networks (WSN); Sensor node; Lifetime; Energy optimization; MAC protocols; Cross layer.

I. INTRODUCTION

Sensor nodes used in WSN collects the information as shown in figure 1.These sensor networks using in real time applications to monitor and control the events [1-3]. Sensor node performs processing, gathering sensory information and communicating with other connected nodes in the network and the architecture of the sensor node is shown in figure 2.

The protocol stack of sensor node is shown in figure 3. The Physical layer takes care of modulation, encryption, signal detection and Frequency selection. Data link layer provides Medium access control and error control and synchronization. The network layer is responsible for routing the data and the transport layer does the multiplexing, splitting or segmenting. Application layer does login or password checking. The power management plane manages the power level of node. The mobility management plane detects and registers the movement of the nodes. The task management plane balances and schedules the sensing task at the same time. These planes work together and for using the power efficiently.

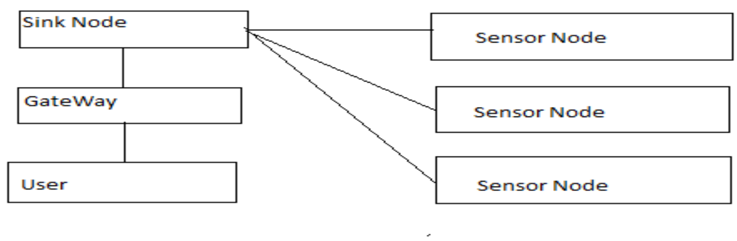

Figure 1: Wireless sensor Network

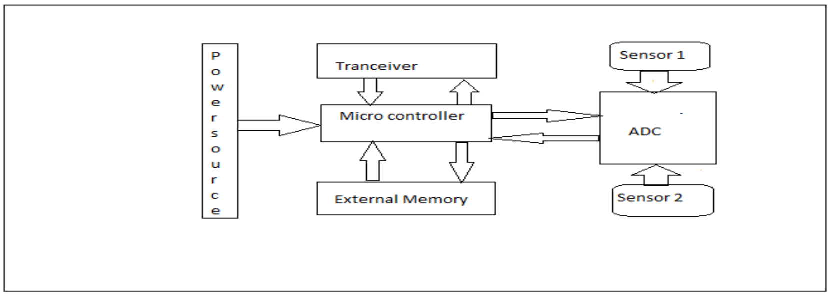

Figure 2: Architecture of sensor node

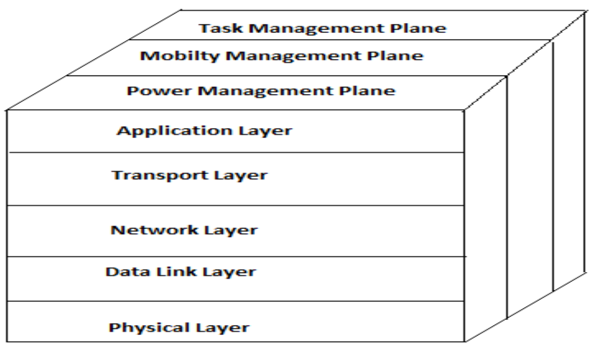

Figure 3: Protocol stack used by sensor node

II. MATHEMATICAL CALCULATIONS FOR ENERGY CONSUMPTION IN SENSOR NODES

Sensor node has limited power source (<0.5 Ah, 1.2V), the energy consumed by a sensor node can be attributed to seven main basic energy consumption sources. They are micro controller processing, radio transmission and receiving, transient energy, sensor sensing, sensor logging and actuation [4]. The energy used in transmitting or receiving one bit and is found by using the power value [5]. Let us calculate the energy to transmit one bit and the battery lifetime of a sensor node.

If the transmission rate is 2 Mbps and power is 1024mw.

The Time to send or receive one bit = 1/2 Mbps= 0.5 µsec

Energy to transmit one bit = power x Time

= 1040 x 10-3x0.5µs

= 0.52µJ/bit.

If the Transmitter is at 20 mA, Battery at 880mAh, Node lifetime= 880 mAh/[(20 mA)x 24] days.

= 1.8 days.

From the above calculations, we can observe that the sensor lifetime is very short and replacing the sensor nodes frequently in all the applications is not possible hence we need to optimize the Energy in wireless sensor networks. A notable work done and detailed breakdown of work distribution and energy consumption across each layer for packet transmission and reception is discussed [6]. This paper reveals the impact of architectural changes in microcontrollers would make a significant performance impact. In our paper we are presenting the detailed survey of various protocols and the future scope of the research to optimize the Energy in Wireless Sensor Networks.

III. RESEARCH IN INDIVIDUAL LAYERS OF SENSOR STACK

Energy optimization in Wireless Sensor Networks can be done in two ways, Firstly optimizing the individual layer protocols in traditional protocol stack or otherwise using cross layer designs. Many researchers have done a notable work in different layers of traditional protocol stack to improve the performance.

A. The Physical layer

The Energy Optimization in physical layer is possible by using efficient modulation scheme, efficient encryption methods, proper signal detection and Frequency selection, minimum hop distance and transmits power. The comparative analysis of various research works are shown in Table 1 [7-13].

Table 1: Comparison of various Physical layer protocols

Ref No.	Parameters considered	Limitations
[7]	Optimization is performed over modulation and coding parameters.	Unique for WBAN applications.
[8]	Power aware protocols in each layer.	Results are not compared.
[9]	physical layer aware protocols, algorithms, and applications that minimize energy consumption of the system and individual nodes	In order to meet the system lifetime goals of wireless sensor applications, considering the parameters of the underlying hardware are critical.
[10]	Proposed a hybrid TH/FH PPM UWB for wireless sensor networks.	The trade-off between diversity and multiplexing gains should be considered.
[11]	Energy-per-Useful-Bit (EPUB) metric for evaluating and optimizing WSN PHYs	Qos is not considered.
[12]	Symbol Error Rate (SER)	Variations in average delay are significant at very large path loss values.
[13]	Transmit Energy and total energy.	Lifetime improved under optimal conditions.

B. The data link layer

The data link layer includes Medium Access Control (MAC) and error control protocols. MAC protocol creates network infrastructure by defining appropriate communication channels, and shares available communication media among nodes. Since transmission is the most energy consuming task in a sensor node, MAC protocols should be properly designed. The major sources of energy waste are Collision, Overhearing, Control packet overhead, Idle listening.

MAC protocols can be broadly divided into contention-based, schedule based protocols and Hybrid protocols. TDMA, FDMA and CDMA are the schedule based MAC protocols in which TDMA has been reviewed to be best during high traffic condition but it needs global synchronization, inadaptability to changes in network topology and interference irregularity. Comparison between different schedule based MAC protocols are shown in Table 2 [14-22].

Table 2: Comparison of various schedule based MAC layer protocols

Name of the Protocol	Achieved parameters	Limitations
Bit-map-assisted (BMA) MAC Protocol [14]	Significant energy savings is possible in BMA. The nodes have average packet latency and utilize the bandwidth efficiently.	Applicable for only the cases of low and medium traffic loads.
Self-Organized TDMA protocol (SOTP) [15]	SOTP is energy efficient due to its pure TDMA and non-clustering architecture. It reduces transmission delay efficiently.	Data aggregation and compression is left to the upper layers and it is assumed that such aggregation and compression will not add to the delay of multi-hop transmission.
Event Driven TDMA Protocol (ED-TDMA) [16]	The energy consumption is reduced in each node thereby network lifetime is prolonged.	Energy utility efficiency of ED-TDMA decreases drastically with the enlargement of monitoring area.
Mobility tolerant TDMA-based MAC Protocol [17]	Relatively very less delay as compared to other traditional TDMA-based MAC protocol	This protocol assumes the network to be static during its setup phase and can tolerate less mobility of the cluster heads.
Self-organizing medium access control for sensor networks (SMACS) [18]	Significant energy savings can be achieved	Low bandwidth utilization
Power Aware Clustered TDMA (PACT) [19]	It adapts energy consumption to user traffic.	As clustering is unavoidable in PACT, an amount of overhead, it may be very less, is still there due to clustering.
The distributed energy -aware MAC (DE - MAC) [20]	Increases network lifetime.	End-to-end delay to be more as compared to other TDMA based MAC protocols.
The traffic-adaptive medium access (TRAMA)[21]	Less collision probability is achieved.	Suitable for applications that are not delay sensitive, but require high delivery throughput and energy efficiency.
Busy Tone On-Demand Scheduling (BTODS) and On-Demand Scheduling (ODS) [22]	Reduces energy consumption due to collision, overhearing, idle listening and control overhead.	BTODS requires the hardware capability to provide two non-interfering channels, ODS requires longer time-slot and less time is devoted to data transmission.

CSMA (Carrier Sensing Multiple Access) is a contention based MAC Protocol which provided fine results during less traffic levels whereas experienced hidden terminal problems and hence chance of packet collision is more. The comparison of the various contention based MAC Protocols are shown in Table 3 [23-27].

Table 3: The Comparison of the various contention based MAC Protocols.

Name of the Protocol	Achievements	Limitations
S-MAC [23]	Good Energy Efficiency, good Fairness.	Good Energy Efficiency, good Fairness.
T-MAC [24]	Good Energy Efficiency, good Fairness.	Good Energy Efficiency, good Fairness.
B-MAC [25]	Better Energy Efficiency, Low Latency	Better Energy Efficiency, Low Latency
Wise- MAC [26]	The packet overhead decreases as per increase in traffic, Energy Efficient.	Energy consumption in WiseMAC is less than any other MAC protocol but greater than XMAC.
XMAC [27]	XMAC introduces a shortened preamble approach, reduce a lot of energy consumption and latency.	Analysis and experimentation of the adaptive optimization are needed to clarify the scenarios (i.e. different types of traffic patterns or application requirements) for which it is appropriate.

Hybrid MAC Protocol is a combination of both contention based and schedule based approach of MAC protocols which is having better performance than the others [28]. Optimum Error control protocols to be used for the better performance, stronger codes works well with end to end error control strategy while simple codes are best for node to node error control strategy [29]. This paper shows that the stronger codes provides good performance but are energy inefficient in contrast performance of simple codes is poor but are most energy efficient. This work can be extended by using LDPC codes to improve the performance.

A mathematical analysis for energy efficiencies of ARQ and FEC has been done in paper [30], and a comparison between them in terms of energy efficiency in underwater environment is presented. Error Detection & Correction in Wireless Sensor Networks by Using Residue Number Systems is discussed in [31]. In this paper by reducing the traffic rate power consumption of sensor nodes is optimized. Additionally, RNS has the ability to detect and correct errors in data transmitted with the using minimum redundancy. Energy efficiency of error control schemes in wireless sensor networks is discussed in [32]. In this paper, energy efficiency based on different communication distances and packet lengths is calculated by using optimum techniques.

Error control coding (ECC) is a classic approach used to increase link reliability and to lower the required transmitted power [33]. In this paper simulations are taken considering various error control codes and finds the optimum code which provides better Bit Error rate and power consumption.

C. Network Layer

The main responsibility of the Network layer is to provide energy efficient routing protocol for prolonging the network lifetime [34]. In this paper, they gave a survey of routing protocols for Wireless Sensor Network and compare their strengths and limitations.

Wireless sensor network consists of various sensor nodes which sense the environment and forward the sensed data to the sink node. Static routing suffers from hot spot problem in which sensor nodes near the sink consume all its. Dynamic routing uses 1-hop communication technique increases the network lifetime. In this paper various types of wireless sensor network are presented, various routing protocols in wireless sensor network using mobile sink is also presented. At the end of the paper a detailed comparison of surveyed routing protocols is also presented [35]. In another paper [36] the comparison of Data Centric Routing (Flooding), Hierarchical based routing (clustering) and Location based routing (Geographic) on the basis of network structure is explained. Multi-hop path routing protocols are energy efficient than Single-path routing, Many issues and challenges still exist that need to be solved in many applications of sensor networks [37].

D. Transport layer

The main responsibility of the transport layer protocol is to provide reliability, efficient congestion control, and energy efficiency. The reliability can be packet reliability or event reliability. Packet reliability requires successful transmission of all packets or at a certain success ratio and in the event reliability an event to be reported to the base station in efficient manner [38]. A detailed comparative Analysis of Reliable and Congestion Aware Transport Layer Protocols for Wireless Sensor Networks is presented in [39].A reliable and energy efficient transport protocol (REETP) is introduced, which mainly focuses on the reliability and energy efficiency [40].

E. Application Layer

Application layer includes a variety of application layer protocols that performs sensor network applications, such as query dissemination, node localization, time synchronization and network security [41]. Energy efficient network operation is also possible by defining several application layer protocols. Typical application layer protocols can be categorized into three types, Sensor Management Protocols (SMP), Task Assignment and Data Advertisement protocols (TADAP) and Sensor Query and

Dissemination protocols (SQDDP) [42].

We have seen the various power optimization methods in individual layers. Since all layers of protocol architecture influence the energy consumption, exploiting synergies between these layers by a cross layer design will result in an efficient energy utilization of the system [43-44].

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CONCLUSION

Wireless sensor networks have the maximum research scope to improve its performance because of the energy constraints. We have discussed the detailed research in different layers of Wireless sensor networks and cross layer architectures in wireless sensor networks.

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