# Active and Passive Power Conservation Mechanisms in MAC Layer in WSN

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***Abstract*—In recent years, WSNs has become an explorative area, particularly due to its potential merits and applications. In order to realize the WSN, many constraints are associated out of which energy conservation is one of them. As the sensor nodes are powered by batteries, which are hardly rechargeable so it is crucial to conserve the power. In this paper, the need of power conservation and factors responsible for power wastage are reviewed from the literature it has been observed that power conservation techniques can be classified as active and passive. The relative issues and merits of these power conservation mechanisms have been extracted and highlighted in this paper.**

***Keywords: The MAC, Power Conservation Mechanisms, Issues in MAC layer, Active and Passive Power Conservation***

## I. INTRODUCTION

WSN is becoming centre of topic of research, As WSN have a wide range of Important applications including environment monitoring, medical systems, smart spaces and robotic exploration so Performance analysis and optimization of WSNs, especially its Medium Access Control (MAC) protocols, have received an attention of researchers Conventional MAC protocols for wireless ad hoc networks are designed to maximize throughput and minimize delay.

As sensor nodes are generally battery operated and it is very difficult to replace or recharge the batteries so network lifetime is crucial to WSN. To extend network lifetime, there is a need for efficient power control mechanisms to reduce power consumption in sensor nodes [3]. The power conservation mechanisms are categorized in two parts named as active power conservation mechanisms and passive power conservation mechanisms.

This paper is organized as follows. In section II Active and Passive power conservation mechanisms are described. Section III describes the related work done in power conservation mechanisms. Then comprehensive study of issues is done. Section IV contains open issues and future scope and last section provides the conclusion of the paper.

## II. POWER CONSERVATION MECHANISMS

The main aim of the medium access control (MAC) layer is to ensure that the nodes of network efficiently use the physical medium, while providing error free data transfer to the network layer above it. MAC protocols are influenced by a number of constraints. So in protocol design, there is required a trade-off among several, often contradictory factors, such as quality of service, throughput, and energy efficiency. In wireless sensor networks, the MAC protocol must achieve the following two goals [8]:

1. Create the network infrastructure: Because thousands of sensor nodes are densely deployed, the MAC layer must establish the basic infrastructure needed for hop by hop communication and give the sensor network self-organizing ability.
2. Allow fair and efficient sharing of the wireless communication medium between sensor nodes.

### A. *Need of Power Conservation*

In wireless sensor network, the sensor nodes operates on batteries which have limited life and difficult to recharged so there is need to use energy resources efficiently in order to minimize the energy consumed by the sensor nodes and increase the network lifetime. So, energy efficiency must be considered in every aspect of network design and operation, not only for sensor nodes, but also for the communication of the entire network [14]

### B. *Factors Responsible for Energy Wastage*

The main activities that consume the energy the most are data sensing, data processing, and data communication. Of the three factors, data communication utilizes maximum energy. This involves both data transmission and reception with the ratio between energy consumption in data reception and transmission being 1:2.5 [21].

Other factors that are responsible for energy waste are [1] [2]:

#### 1) *Idle listening*

It means listening to receive traffic that is not sent. This is especially true in many sensor network applications. If nothing is sensed, the sensor node will be in idle state for most of the time.

#### 2) *Collisions*

When a transmitted packet is corrupted due to interference, it has to be discarded and require retransmission that increases energy consumption.

#### 3) *Overhearing*

Since the radio channel is a shared medium, a sensor node may receive packets that are destined to other nodes. Overhearing can be a dominant factor of energy waste when traffic is heavy and sensor nodes are densely deployed.

*4) Packet overhead*

Sending and receiving control packets also consumes energy and less useful data packets can be sent. In applications where only a few bytes of data are transmitted in each message, these overheads can be large.

*5) Traffic fluctuations*

A sensed event will lead to a sudden peak in the sensor network traffic and increase the probability of a collision. The follow on random back off procedure will increase latency and consume energy. When the traffic load approaches the channel capacity, the performance can collapse with little data being delivered while the radio is consuming a lot of energy by repeatedly sensing to identify a clear channel.

*C. Classification of Power Control Techniques in WSN [3]*

1. Active power conservation mechanisms
2. Passive power conservation mechanisms

*1) Active power conservation mechanisms*

Mechanisms that achieve energy conservation by utilizing energy efficient network protocols, rather than turning off the radio (or transceiver) interface of a sensor node.

*2) Passive power conservation mechanism*

Mechanisms that conserve power by turning off the radio (or transceiver) interface

*D. Active Power Conservation Mechanisms*

*1) Multiple ACCESS with Collision Avoidance (MACA)*

It was one of the first channel access protocols proposed to inform other nodes to stay silent before transmitting the data in wireless networks. It also controls power transmission per frame without using carrier sensing. In MACA, a three layer handshake RTS (ready to send)/CTS (clear to send)/DATA is used, which is based on the RTS/CTS exchange. Sender transmits an RTS frame to the receiver to request transmission. If the RTS frame is received by receiver correctly, it will receive the transmission by sending back a CTS frame. When a mobile node overhears some RTS/CTS frames related to the transmissions of other nodes, it is not necessary to remain silent. [4]

*2) Multiple access with collision avoidance wireless*

It is derived from the CSMA/CA protocol, where RTS/CTS/DS/DATA/ACK handshake signaling (or message exchange) are used and merge different back off algorithms. It is a improved version of the MACA protocol, where link layer acknowledgments (ACKs) are added. In the MACAW protocol, a sender can retransmit a packet that was not received by the receiver successfully. The use of the acknowledgment improves the reliability of a wireless link, and consume less energy in transmitting a packet but it does not generally solve the exposed terminal problem and might not normally behave in multicasting. [5]

*3) Power Controlled Multiple Access(PCMA)*

PCMA is a MAC protocol that achieves power controlled transmission and collision avoidance[6]. The goal of the PCMA protocol is to achieve power controlled multiple access within the framework of CSMA/CA base multiple access protocols. At the sender side, the concept of power control with the RTS/CTS based and busy tone based MAC protocols is used.

*4) Power Adaptation for Starvation Avoidance(PASA)*

It is a simple, effective, and independent mechanism with no control message overhead. The PASA protocol adjusts the transmission power in each sensor node to break capture and achieve higher spatial reuse, thus providing fair access of transmission channel to all sensor nodes. Specifically, PASA adjusts the transmission power in each sensor node according to its current condition, so that all mobile nodes in the network can share the medium channel efficiently. [7]

*5) Intelligent medium access with busy tone and power control*

It is another MAC protocol for saving power in mobile ad hoc networks. The main idea of this protocol is to use the exchange of RTS and CTS packets between two intending communicators to determine their relative distance. This information is then utilized to limit the power level on which a mobile host transmits its data packets. The use of lower power can increase channel reuse and thus channel utilization. It can also save the limited battery energy of mobile (or static) sensor nodes and reduces co channel interference with their neighbours. [8]

*E. Passive Power Conservation Mechanisms*

*1) Power Aware Multi access Protocol with Signaling ( PAMAS)*

Power aware multi-access protocol with signaling is based on the original MACA protocol with the addition of a separate signaling channel. Saving the battery power at nodes by powering off nodes that are not actively transmitting or receiving packets is its main attribute. Another feature of PAMAS is that it requires two independent radio channels. [9]

It provides solution to overhearing but does not provide solution of idle listening. In this, when mobile sensor node start receiving data frames, it transmits a busy tone to make the other mobile sensor nodes aware when to turn off.

Mobile sensor node will be turned off in following cases [9]:

1. If a mobile sensor node does not have data to transmit and if a neighbour starts transmitting to some other node.
2. If it has data to transmit but at least one of its neighbour pairs is communicating.

A mobile sensor node, which has been turned off when one or more of its neighbour pairs started communication, can determine the time period for which it should be turned off by using a probe protocol. In this probe protocol, the sensor node performs a binary search to determine the time when the current transmission will end. However, the loss of probe frames may cause major power wastage. [9]

*2) Sensor-Medium Access Control(S-MAC)*

It is a sensor MAC layer protocol where sensor nodes are allowed to discover their neighbours and organize a network for communication without requiring the existence of master nodes in the network[11]. It is motivated by PAMAS. S-MAC during transmissions of other nodes, it also sets the radio to sleep . Unlike PAMAS, it only uses in-channel signaling. It reduce contention latency by message passing for sensor-network applications that require store and forward processing as data move through the network. [11]

S-MAC supports multi-hop operation. Its key features are:

1. Periodic listen and sleep
2. Collision avoidance
3. Overhearing avoidance
4. Fixed duty cycle

Sensor MAC (S-MAC) uses three new procedures to decrease energy consumption and support self-configuration. It is a contention-based protocol with low duty cycle. For SMAC, neighbouring nodes of transceiver and receiver are allowed to sleep periodically during transmission which reduces the energy consumption in idle listening . By doing so this scheme put nodes into low duty cycle. S-MAC is based on contention. Periodically sleeping is good in low traffic cases. If a node can sleep for longer time it consumes less energy. Nodes in the S-MAC exchange their sleeping schedule and before going to sleep nodes broadcast their schedule to their neighbours as a SYNC packet. Nodes listen to this sync message and follow it. If they do not get the sync message they make their own schedule.

*3) Timeout-Medium Access Control( T-MAC)*

Timeout-MAC (T-MAC) protocol is an extension to S-MAC protocol in order to improve its performance with respect to latency and throughput under variable traffic load [22]. It uses a timer to indicate the end of the active period instead of relying on a fixed duty cycle schedule. This removes the burden of selecting duty cycle by the applications. It also saves energy by lowering the amount of time spent in idle listening. It is adaptable to traffic conditions changes. The adaptive duty cycle allows T-MAC to automatically adjust to variations in network traffic. But it has the problem of synchronization of the listen periods between nodes within the virtual clusters, due to which early sleeping problem may occur that limits the number of hops a message can travel in each frame time.

*F. Disadvantages of Passive Power Conservation Mechanisms*

As most of the energy is utilized by radio so to conserve energy, it must be turned off whenever not required. But this is not the complete solution as it increases energy consumption rather than decrease. As sensor nodes communicate using short data packets, the data communication energy is dominated by the radio start up energy in most deployments. So, turning the radio off during each idle period will result in negative energy gains. This requires that a well-designed MAC protocol should achieve energy efficiency by finding the right balance between smart radio control and efficient protocol design.

## III. RELATED WORK

Syed Jawad Ali and Partha Roy [10](2008) described different protocol for wireless sensor networks and reviewed some proposed MAC protocol like S-MAC to make the network more power efficient. They also discuss benefits and drawbacks of each method. S-MAC has low packet delivery ratio due to adaptive sleeping mechanism, but delay is increased when traffic is high because one node has to wait for others to receive data and latency is also low for periodic sleeping.

Wei Ye, John Heidemann, Deborah Estrin[11] (2008) proposed the S-MAC and analyses the trade-offs between the energy savings and the increased latency due to nodes sleep schedules by comparing S-MAC with protocols that do not have periodic sleep such as the IEEE 802.11, for a packet moving through a multi-hop network. They have used the motes and TinyOS platform to test the S-MAC and concluded that the S-MAC has the ability to make trade-offs between energy and latency according to traffic conditions.

Liqiang Zhao, Le Guo, Li Cong, Hailin Zhang [12] (2009) modeled the problem of energy-efficient MAC protocols in WSNs as a game-theoretic constraint optimization with multiple objectives. They provided an auto digressive back off mechanism to implement the game in current WLANs.

N. Dimokas, D. Katsaros, Y. Manolopoulos [13](2010) considered the problem of energy efficiency and multihop communication and proposed an energy-efficient distributed clustering protocol for wireless sensor networks called called GESC (GEodesic Sensor Clustering) that was based on a metric for characterizing the significance of a node. The protocol achieves small communication complexity and linear computation complexity. Experimental results attest that the protocol improves network longevity.

Suraiya Tarannum [14] (2010) discusses the WSNs, their characteristics, issues, Energy Conservation Challenges in Communication Protocols and Design Issues in WSNs and applications. The energy conservation challenges and related issues emphasize the need for energy saving and optimizing protocols to increase the lifetime of sensor networks

Ines Slama, Badii Jouaber, Djamal Zeghlache [15] (2010) introduced an adaptive hybrid medium access protocol called I-MAC for wireless sensor networks .IMAC uses adaptive prioritization mechanism in order to have more chances of accessing the radio resources by the sensor node and to reduce the chances of collision. They also evaluated the performance of IMAC through simulations over NS2 and concluded the improvement, compared to Z-MAC, mainly in energy efficiency, channel utilization, loss ratio and delay.

Wen-Hwa Liao, Hung-Chun Yang [16] (2012) provide a data storage scheme that supports energy-efficient mechanism and scheme was based on grid based architecture. They evaluated the network lifetime and residual power percentage of sensors by varying the number of sensor nodes, storage events and concluded that both network lifetime and residual power of their scheme increases with the increase in the number of sensors and decreases with increase in data storage events.

Amir Esmailpour, Moataz Alfaraj, Jamal Alfaraj, and Gelareh Kokabian [17] (2013) Proposed solar rechargeable system that checks the radiation level in the area and dynamically adjusts the recharging cycle of the sensor node battery based on the level of radiation .They designed two methods where they calculated electrical energy and battery lifetime with 11%, 15%, 20% and 25% cell efficiencies in two different areas having different solar radiation environment and concluded that battery lifetime is longer in stronger radiation area than in weak radiation area and battery lifetime varies diversely by adjusting PV efficiencies and radiation levels within the same area as well as in different areas.

Dharam Vir, S.K. Agarwal, S.A. Imam [18] (2013) discuss two mechanisms that effect energy consumption: power control and power management. They analysis power control mechanisms of MAC Protocol for wireless sensor network using QualNet simulator and made modifications in the virtual carrier sensing scheme of 802.11 MAC in order to reduce the power consumption and to increase total throughput.

Abayomi M. Ajofoyinbo[19](2013) proposed the novel energy-efficient MAC protocol based on the use of duration value in transmitted packets to setup varying sleep/wake-up schedules for neighbouring nodes of the receiver. The effectiveness of this proposed Packet Duration Value based MAC (PDV-MAC) protocol was tested via Simulation implemented in Visual C# and MATLAB.

Mahir Meghji, Daryoush Habibi [20] (2014) extended the previous research by investigating transmission power control(TPC) in single hop and multi hop WSN using typical Telosb platform to describe the benefits of single hop TCP over multihop TPC and concluded that transmitting in single-hop networks at lower transmission power levels reduced energy consumption by up to 23 %while maintaining reliability.

TABLE 1 COMPREHENSIVE SUMMARY OF ISSUES

| Paper | Issues | Remarks |
|---|---|---|
| Energy Efficient MAC Protocols for Wireless Sensor Networks [11](2008) | To analyses the trade-offs between the energy savings and the increased latency due to nodes sleep schedules. | Researchers reported that Future work can be done in system scaling studies and parameter analysis. More tests can be done on larger test beds with different number of nodes and system complexity. |
| An Energy-Efficient MAC Protocol for WSNs: Game Theoretic Constraint Optimization with Multiple Objectives [12](2009) | To provide simple method to address the sleeping probability in WSN. | Researchers concluded that based on G-Conopt, each sensor node can achieve optimal performance independently under limited energy consumption. |
| Energy-efficient distributed clustering in wireless sensor networks [13](2010) | Issues of network node clustering. | GESC is very efficient clustering protocol and it is able to show significant performance gains in terms of communication cost (few transmitted messages) and also in terms of network longevity. |
| Energy Conservation Challenges in Wireless Sensor Networks: A Comprehensive Study [14](2010) | 1. Energy control<br>2. to satisfy the QoS parameters | The energy conservation challenges and related issues emphasize the need for energy saving and optimizing protocols to increase the lifetime of sensor networks. |

*Table 1 (Contd.)…*

*…Table 1 (Comprehensive Summary of Issues)*

| Paper | Issues | Remarks |
|---|---|---|
| Priority Based Hybrid MAC for Energy Efficiency in Wireless Sensor Networks [15](2010) | To develop novel communication protocols and algorithms that efficiently tackle the resource constraints and application requirements | Researchers look forward to achieve further enhancements over I-MAC through the proposal of a more dynamic and efficient mechanism for priority adaptation and to implement it over TinyOS to validate the simulation results they provided. |
| An Energy-Efficient Data Storage Scheme in Wireless Sensor Networks [16](2012) | As Data storage schemes cannot perform well based on energy-efficient protocols. So, the issue was to propose a data storage scheme to support energy-efficient mechanism. | Both network lifetime and residual power of scheme increases as the number of sensors increases and decreases with increase in data storage events. |
| Energy Conservation for Wireless Sensor Networks Using Solar Rechargeable Power Source [17](2013) | To improve the power Conservation of a sensor node by adjusting the recharging cycle of the solar-fed batteries based on the geographical areas and radiation levels of the areas and to increase the battery lifetime. | Researchers plan to study and try various types of batteries and adjust different environmental conditions such as temperature and humidity and see their effect on the battery lifetime. they also expect different newly proposed Cluster-based protocols and algorithms to be investigated and compared with other approaches to save the energy in WSN |
| Analysis of Power Control Mechanisms of MAC Protocol for wireless Sensor Networks [18](2013) | To analysis a Power Control MAC protocol for WSN with overall power consumption and improve the throughput of the network. | Judge different mobility modes of the nodes to make it more suitable for mobile ad hoc networks. |

## IV. Open Issues and Future Scope

Based on the extensive literature survey done in the previous section, the major issues have been extracted that includes eliminate collision, idle listening in order to conserve energy and sensor network lifetime which need immediate attention of the research community. Another important issue is to implement different types of batteries in different environmental conditions so as to check the effect on the battery lifetime. Also it requires focus on other aspects in wireless sensor network like latency, throughput, cross layer protocol design etc.

## V. Conclusion

WSN has many issues but power conservation is one of the most important issues. Here various active and passive power conservation MAC protocol for wireless sensor networks to make the network more power efficient are discussed. We also consider various issues described by the researchers. Different applications of WSN have different requirements like in environment monitoring application such as checking pressure, temperature, and humidity etc, where the use of power is more sensitive to make network more energy efficient. It is hoped that survey done here in this paper will prove to be helpful to researchers working in the area of WSN in general and power conservation in particular.

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