

SURVEY ON ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORK USING MAC PROTOCOL WITH NETWORK PROTOCOLS

By

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Abstract—The main objective of this survey paper is to provide a detailed description of Wireless Sensor Networks with Medium Access Control layer and Routing layer. In the medium access control layer, Event Driven Time Division Multiple Access protocol is studied and in Network layer, two routing protocols Bellman-Ford and Dynamic Source Routing are studied.

General Terms- Routing, Protocol, Routing layer, Medium Access Control layer.

Keywords—Wireless Sensor Networks, Event-Driven Time Division Multiple Access, Bellman-Ford, Dynamic Source Routing.

1. INTRODUCTION

Recent technological advances have enabled the development of low cost, low power & multifunctional sensor devices. These nodes are autonomous devices with integrated sensing, processing, and communication capabilities. Such nodes are called Sensor nodes. A sensor is an electronic device that is capable of detecting environmental conditions such as temperature, sound, or the presence of certain objects.

Wireless Sensor Network (WSN) is currently an active research area as it has a huge range of applications out of which some are machine health monitoring, natural disaster prevention, health-care monitoring and structural health monitoring. The network consists of the sensor nodes which can be imagined as small computers which are extremely basic in terms of their interfaces and their components. They carry a processing unit with limited computational power and limited memory, sensors or MEMS (Micro Electro Mechanical Systems) [5], a communication device and a power source in the form of battery. A WSN typically consists of large number of small size, low cost, low power multi-functional sensor nodes equipped with sensors, microprocessors and radio transceivers [2]. They communicated over a short distance via a wireless medium and

collaborate with each other to accomplish a common task. The WSN have the following unique characteristics :[2]

- Dense Node Deployment
- Battery Powered Sensor Nodes
- Severe Energy, Computation and Storage Constraints
- Self-Configurable
- Application Specific
- Unreliable Sensor Node
- Frequent Topology Change
- No Global Identification

2. ENERGY IN WSN

Energy has been the scarcest resource of WSN nodes and it determines the lifetime of the network. WSN may be deployed in large numbers in various environments such that in most cases ad-hoc communication is mandatory. Therefore algorithms and protocols need to address issues like lifetime maximization where the energy/power consumption of the sensing device should be minimized and the sensor node should be energy efficient since their limited energy resource determines their lifetime. To conserve power the nodes normally turn off the radio transceiver when not in use.

MAC is one of the critical issues in the design of WSN. As in most wireless network, collision, which is caused by two nodes, sending data at the same time over the same shared medium is a great concern in WSN. To address this problem a sensor network must employ MAC protocols to arbitrate access to the shared medium in order to avoid data collision from different nodes at the same time to fairly and efficiently share the bandwidth among multiple nodes.

3. PROTOCOL STACK IN WSN

The Protocol Stack used by sensor nodes and Base Station consists of five layers: Application layer, Transport layer, Network

layer, Data link layer, and Physical layer. Protocol stack also consists of several management planes: Power Management Plane, Mobility Management Plane and Task Management Plane.

MAC Protocols reside at the Data link layer of the network protocol stack. It is used to arbitrate the access of wireless medium among sensor nodes efficiently and effectively with the aim to reduce the collision that occurs when more than one node sends at the same time.

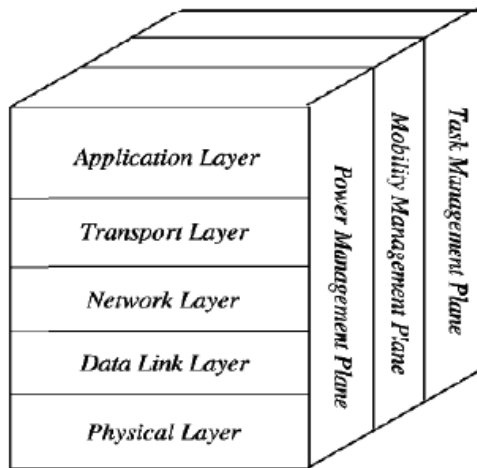


Fig 1: Protocol Stack in Wireless Sensor Network

Source: G. Pottie, W. Kaiser, "Wireless Integrated Network Sensors, Communication of ACM", Vol.43,N. 5, pp. 51-58, May 2000.

4. TYPES OF MAC PROTOCOLS AND ROUTING PROTOCOLS IN WSN

There are two type of MAC protocols: Contention-Based and Contention-Less.

4.1 Contention-Based – In contention-based MAC protocols, all nodes share a common medium and contend for the medium for transmission. Thus collision may occur during the contention process.

4.2 Contention-Less – In contention-less MAC protocols a shared medium is divided into a number of sub-channels in terms of time, frequency or orthogonal pseudo-noise codes. The sub-channels are allocated to individual nodes with each node occupying one sub-channel. This allows the nodes to access the shared medium without interfering with each other hence effectively avoiding collision from different nodes. The most typical types of Contention-Less MAC protocols are Time Division Multiple Access(TDMA), Frequency Division Multiple Access(FDMA), Code Division Multiple Access(CDMA).

TDMA divides the shared channel into fixed number of time slots and configures these time-slots into frames that repeats periodically. Each node is allocated a time-slot and is allowed to transmit only in that times lot in each frame. TDMA divides the channel in N time slots. The 'N' time slots comprise a frame and this frame repeats cyclically. The TDMA based MAC protocols can be classified into two types: Centralized TDMA protocols and Distributed TDMA protocols.

In centralized category of the protocols the base station centrally schedules different slots to different nodes. Every node uses this slot for communication. Examples of centralized TDMA are:

- a. Bit-Map assisted MAC protocols(BMA)- it is an intra-cluster communication MAC protocol for large-scale cluster-based WSN, BMA is intended for event-driven applications where the sensor nodes transmit data only when significant events are observed.
- b. Event Driven TDMA- it improves channel utilization by changing the length of TDMA frame according to the number of source nodes and saves energy.
1. c. Mobility tolerant TDMA based MAC- it is a new TDMA based MAC protocol which can be used in mobile wireless sensor network .

In the distributed category scheduling is done by the nodes itself based on the local information they have. Examples of distributed TDMA are:

- a. Self Organizing Medium Access Control-is a distributed MAC protocol which enables a collection of nodes to discover their neighbours and establish schedules for communicating with them without the need for any local or global master nodes. This protocol allows the sensor to turn its radio on and off, and tune the carrier frequency to different bands as per the requirements.
- b. Power Aware Clustered TDMA - it is normally used for large population. It adapts the duty cycle of the nodes to user traffic.
- c. Distributed Energy Aware MAC- it exploits the inherent features of TDMA to avoid energy waste caused by collision and control overhead and employs a periodical listening and sleeping mechanism to avoid idle listening and overhearing.

A. Event-Driven TDMA (ED-TDMA) Protocol

Event Driven TDMA[2] is an energy efficient TDMA protocol for event driven application WSN. It improves channel utilization by changing the length of TDMA frame according to the number of source nodes. It also employs intra-cluster coverage to prolong network lifetime and to improve system scalability. The operation of ED-TDMA protocol is divided into rounds. Each round begins with a set-up phase followed by a steady phase. The Set-up phase [5] includes clustering and time synchronization. It begins with a reservation phase, followed by a TDMA schedule and data transmission. The reservation phase consists of m mini-slot where m is the number of members in the cluster. The members occupy the mini-slot according to their ID.

Node with maximum ID occupies the first mini-slot while node with minimum ID occupies the last mini-slot. If a node has data to send in the current frame it sends a 1-bit RSV (Reservation) message to the cluster head. The length of the reservation phase is m bit. In TDMA schedule phase, the cluster head broadcasts a schedule packet according to the RSV packet received in the reservation phase. It consists of two parts. The first k-bit parts it represents piggybacking reservation of the previous frame. The second m-bit part represents the reservation in the current frame. In the transmission phase a node sends data to the cluster head during its data slot. If it has more data to send in its next frame, it can book a data slot in the next frame by piggybacking a flag in the data packet.

Advantages: the energy consumption is reduced in each node thereby network lifetime is prolonged. This protocol performs better for event-driven application with high-density deployment and under low traffic in WSN [5].

Disadvantage: Energy consumption of ED-TDMA depends on the monitoring area. The larger the area is, the more is the average energy consumption of ED-TDMA. So, energy utility efficiency of ED-TDMA decreases drastically with the enlargement of monitoring area [5].

B. Bellman Ford Routing

Bellman Ford Routing algorithm is used as distance vector routing protocol. The basic concept of Distance Vector Routing(DVR) is that each node in the network maintains a vector(table) of minimum distances to every node[3]. This table helps the packet to be routed to the proper node by showing the next stop in the route. Nodes using this algorithm, share its routing table with its immediate neighbors periodically and when there is a change. Each node initially can know the distance between itself and its immediate neighbors, those directly connected to it. The distance of any node which is not a neighbor is considered as infinite. This forms the basic routing table. When a node shares its routing table with its neighbors, the neighbors can re-compute the shortest path to the nodes and update their routing tables accordingly.

C. Dynamic Source Routing

Dynamic Source Routing(DSR) [6] is a reactive routing protocol that uses a concept called source routing. DSR divides the task of routing into two separate problems [6]:

- **Route Discovery:** A node only tries to discover a route if it has something to send to the destination and there is no known route for that destination in route cache currently.
- **Route Maintenance:** If a node is continuously sending data via a route, it has to make sure that the route is held upright. Upon detecting a problem a node needs to find an alternative route.

Dynamic Source routing eliminates all periodic routing updates and works as follows. If a node needs to find a route, it broadcasts a route request (RREQ)packet with a unique identifier and the destination address as parameters. Any node that receives a route request does the following:

- If the node has already received the request, it simply the request packet.
- If the node recognizes its own address as the destination, the request has reached the target. The route request packet already contains the route by which the request reached this host from the initiator of the route request. A copy of this route is returned in a route reply (RREP) packet to the initiator.
- Otherwise, the node appends its own address to a list of traversed hops in the packet and then the node broadcasts this route request packet.

In this approach, the node's route request packet collects a list of address to the destination. Once the packet reaches the destination, it can return the request packet containing the list in reverse order to the receiver. Here, the links are assumed to work bi-directionally. DSR assumes the network to be lightly loaded and less mobile.

5. Factors Influencing WSN MAC Design

- 5.1 Energy-Efficiency
- 5.2 Scalability and Adaptivity
- 5.3 Latency

- 5.4 Channel Utilization
- 5.5 Throughput
- 5.6 Fairness

6. DESIGN CONSTRAINTS FOR ROUTING IN WSN

WSN are expected to fulfill the following requirements:

- 6.1 Autonomy
- 6.2 Energy-Efficiency
- 6.3 Scalability
- 6.4 Device Heterogeneity
- 6.5 Mobility Adaptability

7. Related Works

1. G. Pottie, W. Kaiser (2000)[1] provided a detailed survey on the issues on which WSN have been categorized or classified and also explored the issues that are actually challenges that must be considered while selecting or designing an algorithm for routing purpose in WSN. The study clearly brought forth important finding that were very useful and presented enough valuable contents related to wireless sensor network protocol design issues and existing classification.
2. Anastasi, Giuseppe, Marco Conti, Mario Di Francesco, and Andrea Passarella(2009) [3] reported on the effects of low-power listening, a physical layer optimization, in combination with the MAC protocols. The comparison was based on extensive simulation driven by driven by traffic that varies from over time and location: sensor nodes are inactive unless they observe some physical event or send status updates to the sink node providing the connection to the weird world. The key issue that needed to be addressed is the efficient operation of the radio link to foster collaboration between individual resource scarce sensor nodes on the one hand and to minimize the energy consumption on the other. They had compared the three approaches for saving energy in sensor network: low power listening at the physical layer and MAC protocols operating at medium access layer. These three approaches have in common that they introduce duty cycle to mitigate idle listening, the dominant cause of energy consumption in typical sensor network scenarios.
3. Ye, Wei, John Heidemann, and Deborah Estrin(2002) [2]proposed S-MAC an energy efficiency 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 the nodes periodically sleep. S-MAC sets the radio to sleep during transmission of the other nodes. S-MAC applies message passing to reduce contention latency for sensor-network applications that require store-and-forward processing as data move through the network. Another important property of the protocol is that it has the ability to make trade-offs between energy and latency according to traffic conditions.
4. Haigang Gong, Ming Liu, Lingfei Yu, Xiaomin Wang (2009)[4]proposed to deploy multiple, mobile base stations to prolong the lifetime of the sensor network. Their method made use of an integer linear program to determine new location for base station and flow-based routing protocol to ensure energy efficient routing during each round. They proposed four evaluation metrics and compared their solution using these metrics.
5. A.K. Dwivedi and O.P. Vyas (2010) [5] performed an analysis of S-MAC and TDMA using Castalia. Their study was oriented towards the comparison of these protocols in some real world environments. Through the implementation perspective it was raised that the S-MAC was easier to implement and the results were good. The S-MAC protocol was concluded to be better in certain aspects like

latency and number of control packets sent while TDMA performed better in low load condition with high energy efficiency and high network lifetime.

8. CONCLUSION

The use of this Wireless Sensor Networks has introduced big changes in data-gathering, processing, and dissemination for different environments and specific applications. In recent developments, the use of simulations for networks offers a viable way to design, execute, analyze and enhance routing protocols.

9. REFERENCES

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