Energy-Efficient MAC Protocol for Wireless Sensor Networks - A Review

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Abstract -Energy efficiency is the kernel issue in the designing of wireless sensor network(WSN) MAC protocols. Energy efficiency is a major consideration while designing wireless sensor network nodes. Most sensor network applications require energy autonomy for the complete lifetime of the node, which may span up to several years. These energy constraints require that the system be built such that Wireless sensor networks use battery-operated computing and sensing devices. A network of these devices will collaborate for a common application such as environmental monitoring. Each component consumes minimum possible power, ensure the average successful transmission rate, decrease the data packet average waiting time, and reduce the average energy consumption. Influencing by the design principles of traditional layered protocol stack, current MAC protocol designing for wireless sensor networks (WSN) seldom takes load balance into consideration, which greatly restricts WSN lifetime. As a novel Forwarding Election-based MAC protocol, is presented to prolong WSN lifetime by means of improving energy efficiency and enhancing load balance.

I. INTRODUCTION

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices that use sensors to monitor physical or environmental conditions. These autonomous devices, or nodes, combine with routers and a gateway to create a typical WSN system. Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Systems of 1000s or even 10,000 nodes are anticipated. Such systems can revolutionize the way we live and work.

A WSN system is ideal for an application like environmental monitoring in which the requirements mandate a long-term deployed solution to acquire water, soil, or climate measurements. For utilities such as the electricity grid, streetlights, and water municipals, wireless sensors offer a lower-cost method for collecting system health data to reduce energy usage and better manage resources. In structural health monitoring, you can use wireless sensors to effectively monitor highways, bridges, and tunnels. You also can deploy these systems to continually monitor office buildings, hospitals, airports, factories, power plants, or production facilities.

A. MAC Layer Protocol:

In a wireless sensor network the MAC Layer protocols are supposed to perform the following tasks:

1. To create an infrastructure and establish link for data transfer.
2. To share network communication resources between sensor nodes.

The MAC layer is responsible for access to shared medium. It assists nodes to decide when to access the shared medium. The MAC Protocols [1] can be classified as follows:

1. Scheduled:

This is based on Time Division Multiple Access (TDMA) protocol. In this mechanism the channel is divided into fixed time slots. A complete cycle of these slots is called frame. TDMA Protocols are inherently energy conserving as they reduce wastage due to Collision, Idle Listening and Overhearing.

2. Random:

This is based on Carrier Sense Multiple Access (CSMA) protocol. In random access protocols, the channel is allocated to nodes on demand. i.e. the nodes contend for channel and if they find the channel free, starts transmission else postpone the transmission until the channel becomes idle and

sense the channel to grab the chance to transmit the channel.

II. WSN PROTOCOLS:

1) LEACH: LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) was the first sub-cluster-style routing protocols in WSN. LEACH conserves energy because it uses data compression techniques and sub-cluster dynamic routing technology. In LEACH algorithm each round is consist of two states:

(a) Setup State: during this step a cluster head is selected for that round.

(b) Steady State: In this phase the nodes send data to the cluster head.

The cluster head node is selected at random; it balances the network load and also the rapid death of cluster nodes. The probability of a node being the cluster node is given by:-

$$T(n) = \begin{cases} \dfrac{p}{1 - p * (r \bmod \frac{1}{p})} & if \quad n \in G \\ 0 & otherwise \end{cases}$$

Where P is the percentage of all cluster head, r is the number of current selection rounds, r mod (l/P) is selected the number of cluster head nodes in a cycle, G is not selected cluster head node set.

The deficiencies of LEACH are:-

The probability of a node which was once selected as a cluster head for again becoming a cluster head node becomes 1/p in the next recycling round. Also the initial energy of each node is assumed to be equal and energy consumption is equal when a node is selected as a cluster head. The energy cost is also increased as the algorithm frequently changes the cluster head.

IMPROVED LEACH ALGORITHM:

$$T(n)_{new} = \frac{p}{1 - p \times [r \bmod(1/p)]} \frac{E_{n\_current}}{E_{n\_max}}$$

En-current is current energy of the node, *En-max* is initial energy. Formula is improved so that a lower proportion of energy consumption is selected as cluster head node priority.

This shows that as compared with leach, the proposed protocol considers the influence to route mechanism from the route hop number, node position, and energy consumption of each node.

Furthermore, it can reduce the delay of data forwarding and satisfy the demand of WSN application.

2) MULTI PARENT

Multi-Parent method has the advantage of reducing the delay the data will experience, while at the same time it uses an awake scheduling to reduce energy consumption. On the other hand, determining the parents for any node in the network is an algorithm that requires many processing cycles.

3) P_MAC (PENDULUM-MAC)

In this, the system is organized into layers and in each layer the nodes are assigned time slots in which they can be awake to report the data to the BS. Sensor nodes scattered in the geographic area for monitoring follow an awake scheduling. That means, the sensor nodes will determine when to wake up and when to go to sleep based on the current location of the node. But a major disadvantage lies with this technique that is the delay in collecting data for extended periods of time. Also it needs a certain density to operate that is, it cannot work on 250 node, it needs a denser network to work on so that a connected network is created. Thus it is not suitable for a small network.

4) TMAC(Timeout-MAC)

In T-MAC all the messages are transmitted in a burst of variable length and there is gap between the bursts called sleep/sleep time. This is to reduce the idle listening. The node awakes periodically to communicate with neighbors and it uses RTS and CTS, Data Acknowledgement (ACK) scheme, which provides both collision avoidance and reliable trans-mission.

In this the messages are stored in a buffer and then a frame is made to transmit containing messages during the active time as shown in fig. The active time ends when there is no active event for a time period TA and the node goes to sleep mode. At the time of high load nodes communicates continuously without sleeping.
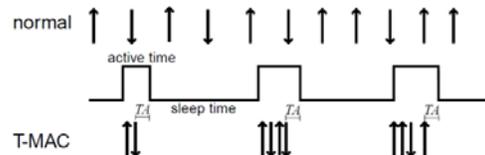
The major disadvantage with this technique is "The early sleep problem". i.e. the node goes to sleep mode even if it its neighboring node have something to send to it.

It has been found from previous research papers that T-MAC is more efficient than the traditional protocols, Pendulum and Leach protocol.

III.   MAJOR ISSUES OF ENERGY WASTAGE:

1.   Idle listening

When nodes have nothing to send or receive, the nodes still remain in active state and do idle listening to the network. This process consumes equal amount of energy as during transmitting or receiving process. Thus resulting into wastage of energy.

2.   Collision or Corruption
Normally collision may occur when neighbouring nodes contend for free medium and lossy channel will result in corruption of transmitted packets. When either of two cases happens corrupted packets should be retransmitted, which increases energy consumption.

3.   Overhearing
which happens when a node receives some packets that are destined to other nodes.

4.   Control Packet Overhead
Exchanging control packets between sender and receiver also consumes some energy.

5.   S-MAC(Sensor-MAC):

Sensor MAC (S-MAC) [3] is a contention based protocol specifically designed for wireless sensor networks. Its basic principle is CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance).It introduced a periodic "Listen and Sleep" method to avoid idle listening & to reduce the energy wastage. Each node follows a periodic sleep and listen schedule as shown in fig. In listen period, the node senses the network, if found idle, the node performs listening and communicate with other nodes. When sleep period comes, the node will try to sleep by turning off their radios. This significantly reduces the time spent on idle listening. In this protocol the nodes use the RTS (Ready to send), CTS (Clear to send) and Data Acknowledgement (ACK) to communicate. When a node finds a RTS or CTS packet destined for some other node, it goes to sleep mode. This is a periodic process. At the end of sleep mode the node wakes-up and look for some event, if not found it again go to sleep mode.

S-MAC proposes a low-duty-cycle operation which reduces energy consumption.
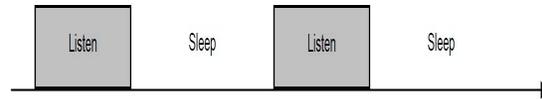

Fig. Periodic listen and sleep

A complete cycle of listen and sleep period is called a frame. During sleep period, the node will turn off its radio if possible. In this way, a large amount of energy consumption caused by unnecessary idle listen can be avoided especially when traffic load is light. The nodes in the network make a virtual cluster with its neighboring node and share a synchronization schedule for listen and sleep period. Thus there may exist more than one cluster in a network. In different clusters the nodes use periodic SYNC packet to find its neighbor. This process is called PND (Periodic Neighbor Discovery).

The S-MAC protocol uses the following to reduce or avoid the four major issues of energy wastage discussed above:

- The scheme of periodic listen and sleep reduces energy consumption by avoiding idle listening.
- The overhearing problem is avoided by using the in-channel signalling to put each node to sleep when its neighbour is communicating to another node.
- A complete synchronization mechanism, including periodic SYNC packets broadcast is used to avoid collision.
- S-MAC uses only a pair of RTS/CTS for one message passing but requests an ACK for each fragment. This reduces the control packet overhead to a great extant.

The S-MAC protocol essentially trades used energy for throughput and latency. Throughput is reduced because only the active part of the frame is used for communication. Latency increases because a message-generating event may occur during sleep time.

IV. CONCLUSION

This paper gives the performance analysis of all the protocols that have been proposed for wireless sensor networks till date. As compared to Leach and the Pendulum techniques MAC techniques are considered to

be better as far as efficiency and performance of wireless sensor networks is concerned. Also the MAC.

Protocols have an interesting property that it has the ability to make trade-offs between energy and latency according to traffic conditions. But the problem of early sleep is observed in T-MAC and energy wastage issues are being observed in S-MAC. So further work will include the analysis of these issues.

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