S-MAC PROTOCOL FOR WIRELESS SENSOR NETWORKS- A SURVEY

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Abstract— **Wireless sensors nodes are made up of small electronic devices which are capable of sensing, computing and transmitting data from harsh physical environments like a surveillance field. These sensor nodes majorly depend on batteries for energy, which get depleted at a faster rate because of the computation and communication operations they have to perform. However, as they are spread in zones with troublesome landscape and to accomplish full coverage of zone there are suitable number of remote sensors utilized, it is difficult to replace their batteries once exhausted. Medium Access Control (MAC) plays an important role in wireless sensor network as MAC controls the radio signal in channel of communication between two or more sensor nodes. S-MAC is one of the base protocol of MAC layer protocols which with slight modifications result in various protocols. In this paper we discuss the survey on S-MAC protocol which is popular MAC layer protocols. It also provides a brief analysis of these protocols which could be helpful in future work in this direction. This paper also provides a reference for further research in this area giving an insight on energy conservation at MAC layer.**

Index Terms— **Wireless Sensor Network (WSN), Media Access Control (MAC), Sensor MAC (S-MAC)**

I. INTRODUCTION

Wireless Sensor Networks (WSN) has evolved, over the last decade, as a major research area due to its significance in a wide range of applications in monitoring and control. These include environmental, structural and healthcare monitoring in addition to industrial and military applications [5]. A number of protocols have been developed specifically for WSNs to address the various challenges at System level as well as at different layers such as Media Access Control (MAC) [3].

MAC layer protocols receive a lot of attention due to their impact on the life of WSN. Sensor nodes are operated by batteries which have a limited lifetime. The major issues in deploying wireless sensor nodes are that there reliance of limited battery power. Also these nodes are deployed in the environment where their replacement becomes difficult. Energy efficient designs of MAC protocol can minimize the battery consumption and increase network lifetime to a great extend [7]. MAC protocol's objective is to reduce energy consumption. The major resources of energy waste are collision, overhearing and idle listening. In MAC layer protocols S-MAC is one of the basic protocol, which is designed for wireless sensor networks [10].

Rest of the paper is organized as follows. Related research work is discussed in the next section. Section II provides a brief description and theoretical framework of Sensor-MAC protocol, Section III merits and demerits of S-MAC and Section IV finally gives the conclusion and future scope of related survey [6, 9, and 10].

II. BRIEF DESCRIPTION AND THEORETICAL FRAMEWORK OF S-MAC

S-MAC is a medium-access control (MAC) protocol designed for wireless sensor networks. 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. We expect sensor networks to be deployed in an ad hoc fashion, with individual nodes remaining largely inactive for long periods of time, but then becoming suddenly active when something is detected. These characteristics of sensor networks and applications motivate a MAC that is different from traditional wireless MACs such as IEEE 802.11 in almost every way: energy conservation and self-configuration are primary goals, while per-node fairness and latency are less important. Sensor MAC uses three novel techniques to reduce energy consumption and support self-configuration [2, 6, and 10]:

A. Periodic listen and sleep.
B. Collision and overhearing avoidance.
C. Message passing.

A) Periodic Listen and Sleep

- One of the main objectives of design S-MAC is to reduce energy consumption by avoiding idle listening.
- Each node goes into periodic sleep mode during which it switches the radio off and sets a timer to awake later When the timer expires, it wakes up Selection of sleep and listen duration is based on the application scenarios
- Neighboring nodes are synchronized together. Nodes exchange schedules by broadcast. Multiple neighbors contend for the medium
- Once transmission starts, it does not stop until completed.

- During sleep time node turn-off its radio to save energy.

The basic periodic listen and sleep scheme is show in Figure (a):

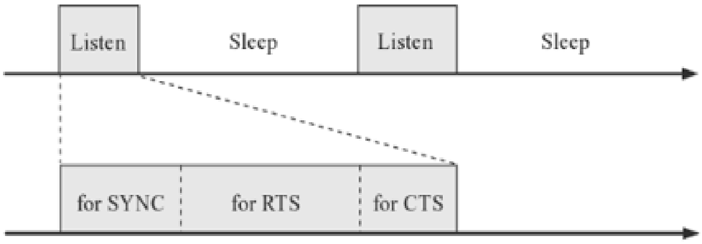

Fig: (A) S-MAC period listens and sleeps modes of operations

a) **Schedule selection and maintenance**

- The neighbouring nodes coordinate their listen and sleep schedules such that they listen at the same time and all sleep at the same time.
- To coordinate their sleeping and listening, each node selects a schedule and exchanges it with its neighbours during the synchronization period. Each node maintains a schedule table that contains the schedule of all its known neighbours.
- To select a schedule, a node first listens to the channel for a fixed amount of time, at least equal to the synchronization period. At the expiration of this waiting period, if the node does not hear a schedule from another node, it immediately chooses its own schedule.
- The node announces the schedule selected by broadcasting a SYNC packet to all its neighbours. It is worth noting that the node must first perform physical carrier sensing before broadcasting the SYNC packet. This reduces the likelihood of SYNC packet collisions among competing nodes. If during the synchronization period the node receives a schedule from a neighbour before choosing and announcing its own schedule, the node sets its schedule to be the same as the schedule received [].
- It is worth noting that a node may receive a different schedule after it chooses and announces its own schedule. This may occur if the SYNC packet is corrupted by either collision or channel interference. If the node has no neighbour with whom it shares a schedule, the node simply discards its own schedule and adopts the new one.
- On the other hand, if the node is aware of other neighbouring nodes that have already adopted its schedule, the node adopts both schedules. The node is then required to wake up at the listen intervals of the two schedules adopted. This is illustrated in Figure (a). The advantage of carrying multiple schedules is that border nodes are required to broadcast only one SYNC packet.
- The disadvantage of this approach is that border nodes consume more energy, as they spend less time in the sleep mode [10].

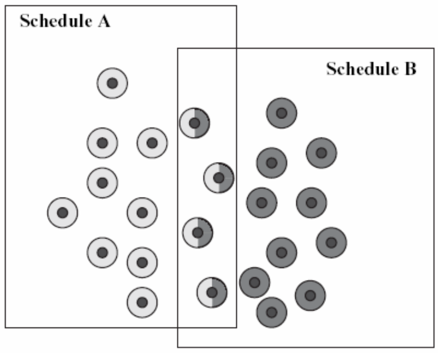

Fig. (a) Border node schedule selection and synchronization

- It is to be noted that neighbouring nodes may still fail to discover each other, due to the delay or loss of a SYNC packet.
- To address this shortcoming, S-MAC nodes are required to perform frequent neighbour discovery, whereby a node listens periodically to the entire synchronization period. Nodes that currently do not have any neighbours are expected to perform neighbour discovery more frequently.

(b)**Schedule Synchronization:**

- Schedule updating is continuous process and this is accomplished by sending a SYNC packet. For a node to receive both SYNC packets and data packets, the listen interval is divided into two subintervals as depicted in Figure (b).
- This figure illustrates three cases. In the first case
    - The sender sends only a SYNC packet;
    - Sender sends only a data packet; and
    - Sender sends a SYNC packet in addition to the data packet.

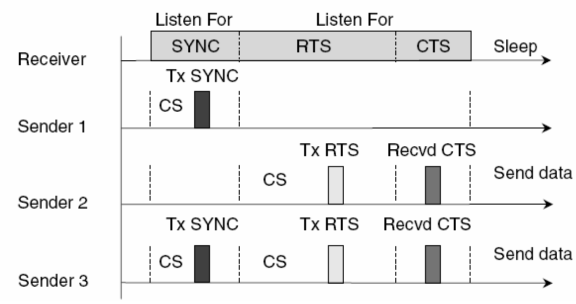

Fig. (b) Timing relationship between a receiver and senders

- Access to the channel by contending node during these subintervals is regulated using a multi slotted contention window.
- The first subinterval is dedicated to the transmission of SYNC packets; the second subinterval is used for the transmission of data packets. In either of these subintervals, a contending station randomly selects a time slot, performs carrier sensing, and starts sending its packet if it detects that the channel is idle.
- Transmission of data packets uses the RTS/CTS handshake to secure exclusive access to the channel during transmission of the data. This access procedure guarantees that the neighbouring nodes receive both the synchronization and data packets [10].

(c) Adaptive Listening

- A closer look at the periodic listen and sleep scheme reveals that a message may incur increased latency as it is stored and forwarded between adjacent network nodes. If a sensor is to follow its sleep schedule strictly, data packets may be delayed at each hop.
- To address this shortcoming and improve latency performance, the protocol uses an efficient technique referred to as adaptive listening.
- Based on this technique, a node that overhears, during its listen period, the exchange of a CTS or RTS packet between a neighbouring node and another node assumes that it may be the next hop along the routing path of the overheard RTS/CTS packet, ignores its own wake-up schedule, and schedules an extra listening period around the time the transmission of the packet terminates.
- The overhearing node determines the time necessary to complete the transmission of the packet from the duration field of the overheard CTS or RTS packet.
- Immediately upon receiving the data packet, the node issues an RTS packet to initiate an RTS/CTS handshake with the overhearing node. Ideally, the latter node is awake, in which case the packet forwarding process proceeds immediately between the two nodes. If the overhearing node does not receive an RTS packet during adaptive listening, it renters its sleep state until the next scheduled listen interval.

(B) Collision and Overhearing Avoidance

- To regulate access to the communication channel among contending sensor nodes, S-MAC uses a CSMA/CA-based procedure, including physical and virtual carrier sensing and the use of RTS/CTS handshake to reduce the impact of the hidden and exposed terminal problems.
- Virtual carrier sensing is achieved through use of the network allocation vector (NAV), a variable whose value contains the remaining time until the end of the current packet transmission. Initially, the NAV value is set to the value carried in the duration field of the packet transmitted.
- The value is decremented as time passes and eventually reaches zero. A node cannot initiate its own transmission until the NAV value reaches zero. Physical carrier sensing is performed by listening to the channel to detect ongoing transmission. Carrier sensing is randomized within a contention window to avoid collisions and starvation. A node is allowed to transmit if both virtual and physical carrier sensing indicate that the channel is free.
- To perform virtual carrier sensing effectively, nodes may be required to listen to all transmissions from their neighbours.
- As a result, nodes may be required to listen to packets that are destined for other nodes. Packet overhearing may lead to significant energy waste. To avoid overhearing, S-MAC allows nodes to move into sleep mode after they hear the exchange of an RTS or a CTS packet between two other nodes.
- The node initializes its NAV with the value contained in the duration field of the RTS or CTS packets and enters the sleep state until the NAV value reaches zero.
- Since data packets are typically larger than control packets, the overhearing avoidance process may lead to significant energy savings. The scheme used by S-MAC to avoid collisions is illustrated in Figure (B)

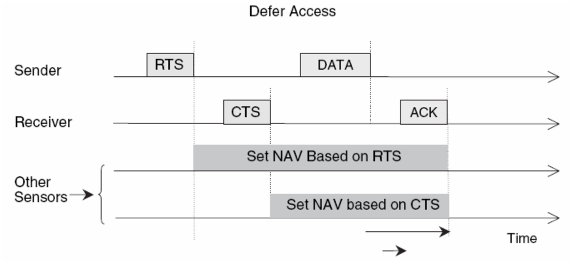

Fig. (B) Collision and Overhearing avoidance scheme

(C) Message Passing:

- To improve application-level performance, S-MAC introduces the concept of message passing, where a message is a meaningful unit of data that a node can process.
- Messages are divided into small fragments. These fragments are then transmitted in a single burst.
- The fragments of a message are transmitted using only one RTS/CTS exchange between the sending and receiving nodes.
- At the completion of this exchange, the medium is reserved for the time necessary to complete the transfer of the entire message successfully.
- Furthermore, each fragment carries in its duration field the time needed to transmit all the subsequent fragments and their corresponding acknowledgments. This procedure is depicted in Figure (C).

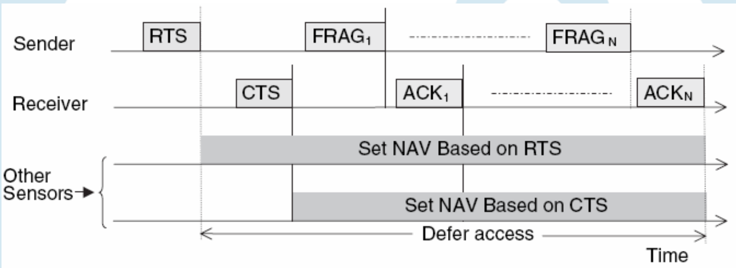

Fig. (C) S-MAC Message Passing

- Upon transmitting a fragment, the sender waits for an acknowledgment from the receiver. If it receives the acknowledgment, the sender proceeds with transmission of the next fragment.
- If it fails to receive the acknowledgment, however, the sender extends the time required to complete transmission of the segment to include the time to transmit one more fragment and its corresponding acknowledgment and retransmits the unacknowledged frame immediately.
- It is worth noting that sleeping nodes can hear about this extension only if they hear extended fragments or their corresponding acknowledgments.
- Nodes that only heard the initial RTS and CTS packet exchange remain unaware of the transmission extension.
- The S-MAC has the potential to achieve significant energy savings. It is well suited for applications where fairness is not a critical design goal and increased latency is tolerable [10].

III. MERITS AND DEMERITS OF S-MAC

Energy waste caused by idle listening is reduced by sleep schedules. This protocol is simple to implemented, long messages can be efficiently transferred using message passing technique [6].

Sleep and listen periods are predefined and constant which decreases the efficiency of the algorithm under variable traffic load, if the message rate is less, energy is still wasted in idle listening. RTS/CTS are not used due to which broadcasting which may results in collision. Adaptive listening causes overhearing or idle listening resulting in inefficient battery usage. Science sleep and listen periods are fixed variable traffic load makes the algorithm efficient [6]. Similar to TMAC but with fixed duty cycle. Not efficient in handling continuously varying data rates.

IV. CONCLUSION AND FUTURE SCOPE

In this paper presented the survey on S-MAC protocol. The main target of this protocol is to reduce the power consumption of nodes in any wireless sensor network and increase the life of networks which id depends on battery usage. S-MAC has extremely well vitality monitoring properties it has capacity to make exchange offs between vitality and latency according to traffic conditions.

Future work incorporates framework scaling studies and parameter examination. More tests will be done on large testing structure with various numbers of nodes and framework multifaceted nature.

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