Energy Efficiency S-MAC Protocol for Wireless Sensor Networks

Tran Cong Hung, Tran Van Thao, Huynh Trong Thua.

***Abstract*—One of the most important constraints in traditional wireless sensor networks is the limited amount of energy available at each sensor node. In WSNs, sensors are usually equipped with capacity-unreplaceable battery sources. Therefore, optimizing an effective wireless sensor network to maximizing the lifetime of sensor node in order to minimize energy resource and maximize overall system performance becomes important. The energy consumption is mainly determined by the choice of media access mechanism. Sensor-MAC is a typical access mechanism that has drawn much attention in recent years about minimizing solution energy resource. In S-MAC, a border node is located the least of two virtual cluster, each virtual cluster has private sleep timer, listen timer, wake-up timer. Border nodes can listen more schedules than other nodes, so they need to have more energy consumption which make their power to consume faster, to affect to maintain productive purpose information, data. This paper propose a solution method about energy efficiency when nodes add its SYNC information to their list schedules which only implement one schedule later.**

***Index Terms*—Wireless Sensor Networks (WSNs), Sensor-MAC protocol, Energy efficiency**

I. INTRODUCTION

Wireless Sensor Networks (WSNs) include a lot of sensor nodes which are distributed in determined area. They will conduct to measure parameter of the environment as temperature, humidity, salinity, PH, pressure … to collect this information in the office, warehouse, factory, museum, medical, agricultural, forestry information. A perfect WSNs system is also capable of monitoring and warning level environmental safety or positioning the movement of objects in its area. Depending on the purpose of sensor networks that can design the appropriate network node. The sensor node has processor inside, instead of sending raw data to the destination node it can conduct simple processing and sending of data has been processed as required.

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In many applications, sensor nodes will be deployed as unstructured ad hoc network [1], [2]. They must organize themselves to form a multi-hop wireless networks. Common challenges in wireless sensor networks is the issue of conflict because the two nodes send their data at the same time on the same channel.

The most important difficulty in wireless sensor networks is energy available to each sensor node. Because of the potential replacement or maintenance on site for each sensor node is almost un-impossible, so the saving of energy consumption should be optimized to extend the life of wireless sensor networks. Many recent researches have been researched to design the MAC protocol to save energy. In fact, it was presented in [3], the consumption of energy by using the IEEE 802.11 protocol compete when the nodes in idle mode were researched very much. Some MAC protocols mentioned above include PAMAS, T-MAC, DSMAC, S-MAC, which, S-MAC protocol is particularly interested in this paper and will be described in detail in the next section follow. PAMAS is an improvement of protocol MACA (Multiple Access Collision Avoidance) by adding a separate channel for exchanging signaling packets RTS / CTS. Therefore, more effective protocols MACA protocol, and it can improve the efficiency from 10% to 70% in energy efficiency

In S-MAC [4] or other MAC protocol sensors, nodes go to sleep and maintain this status in an active way to reduce energy consumption. During sleep timer, the nodes will turn off the radio, and set the timer to wake up. The difference between S-MAC is PAMAS and S-MAC using internal signals more efficiently channel private channel as in PAMAS. Based on the idea of S-MAC, T-MAC uses the same cycle sleep / wake. However, the duty cycle is not fixed in T-MAC, T-MAC can automatically end the cycle of operation, should be a significant reduction of energy in idle listening.

The nodes don’t take part in transmission or reception if S-MAC in listening state or other the nodes surrounding related to transfer data. The purpose of the sleeping state in S-MAC protocol to reduce collisions and overheard. The node wakes up at the end of the communication node to forward the packet. This task is performed by the neighbor's node overhearing RTS and CTS exchange and go to sleep node.

To summarize, the core causes of energy wastage in wireless sensor networks:

Collision: Collision is the first cause energy waste. When two packets are transmitted at the same time, they will be conflicted. They corrupted and must be removed.

Retransmission of packet will request and give to rise to the energy consumption. Therefore all MAC protocol tries to avoid conflict in any way.

Idle Listening: the second reason is the energy consumption caused hearing problems when idle listening. It occurs when the radio components try to listen to see if data channel to receive. This consumption is particularly high in the sensor network applications, where no data is exchanged during the event without sensors. Many MAC protocols (like CSMA and CDMA) always hear despite of active channels even though there is no data to send. Exact cost of hearing problems as salvation depends on hardware and operating mode radio components. Most of the sensor network is designed to operate for long periods and the sensor nodes in the state will also hear when idle for a long time. In such case, listening at leisure is a major factor in the energy consumption problem of radio components.

Overhearing: the third reason is the problem of overhearing when a node receives the packet that is intended for the other nodes. Must overhear unnecessary information that's not for its which could be a major factor in energy consumption when traffic, communicate to load in order to increases and high node density distribution.

Overhead: Fourth cause us to consider is the control packet processing. The sender, receiver, and control packets of heard is also energy consumption causes. When the package does not directly control the data carrier, they also reduce the "*goodput"*. MAC protocol for sensor networks designed to achieve energy savings required by the control component radio to avoid or reduce the energy wasted by these reasons. Turning off the radio components when it is not necessary to be an important strategy for saving energy. A schema complete energy management must consider all sources of energy wasting.

In this paper, we mentioned the problems of the energy losses in S-MAC protocol. Based on limited issues, we propose innovative solutions S-MAC protocol with synchronization method before and after the selected node own schedule while ensuring proactive nodes at least one schedule so that the existence of the border nodes is at least. The rest of the paper will be presented as follows. Part II introduces the issues remaining restrictions of S-MAC protocol and related works. Part III introduces the proposed reasons and proposed solutions. Part IV simulate and evaluate the results. The last part is the conclusion and development.

II. S-MAC PROTOCOL AND RELATED WORKS

S-MAC was introduced by the authors [4] [5] in 2002. To be built on the foundation of competitive protocols such as 802.11, S-MAC tries to inherit the flexibility, availability of communication variables knowledge-based competitiveness while improving the energy efficiency in multi-hop networks. There are three large energy consumption of S-MAC is mentioned at part I such as collision, overhearing, listen to idle. Collision of results in waste of energy due to retransmit packets that have collided. Overhearing happens when a node without having transmitted listen for it. Finally, listen to idle that occurs when a node receives hear any data that can't be sent. To achieve the purpose as designed, S-MAC [6] is designed with three main issues: cycle - duty; avoid collision and overhearing; overhead.

The operation of a node is scheduled at a specific amount of time, called *"frame"*. The rest of the time frame reserved for sleep time and listen time to the channel of a node. The ratio of around listening / total duration of the frame is denoted duty cycle. During sleep, the radio's node turn-off to save energy. Meanwhile, specific nodes are also removed from the network.

2.1. Duty cycle

Duty cycle of sleeping and listening is introduced to reduce idle listening. The operation of each node is stored in the frame. Each frame consists of two intervals, listen and sleep. The listening period is divided into two time periods called SYNC and DATA. In applications of sensor networks, sensor nodes often in idle state most of the time if no sensor event occurs. Actual speeds very low data exchange is thus not necessary for the sensor nodes in the wake-up state of all time. S-MAC is designed to reduce time by letting mode sensor nodes periodically switched to a sleep state. For example, in cycles per second, the sensor nodes may remain dormant for half a second and listen state in half seconds remaining operating cycle reduced by 50%. So can save 50% of energy.

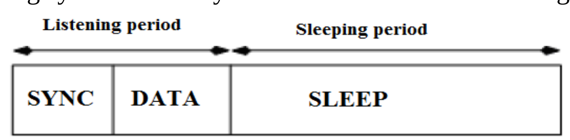

Fig 1: Listening and sleeping time in S-MAC

2.2. Operation and SYNC

Before each node starts cycle wake-up / sleep, it needs to choose a work schedule and tourist exchange with neighboring nodes. Each node maintains a schedule table to store all the timetables of neighboring nodes that it knows.

The sensor nodes exchange information with each other schedules by radio to all existing neighboring nodes. This ensures that all nodes in the area can still contact to each other even though we have different schedules. If node A to node B wants to talk, it simply waits until B in the waking state. If there are multiple nodes in the neighborhood want to talk to a node, we need competitive conduct occupied line when receiving node in the waking state, using packet RTS (Request to Send) and CTS (Clear to Send) . RTS node sends out packets before will gain access and receive node will respond with a CTS packet. Then we start the data transfer, this time we did not follow the previous schedule their work until they finish data transfer.

Schema wake-up / sleep requires a synchronization between the nodes in the neighborhood. The nodes in the vicinity of each other periodically update their timeline is necessary to prevent the deviation of the cycle time listening / sleep. The updated timetable is done by exchanging synchronization packets SYNC. SYNC very short packets, and include the address of the sending node and the time switch next sleep state of it.

To a node receives all asynchronous packets and packets, we share some knowledge (active time) of it into two parts. The first section to get the packet synchronization, the second to receive a packet RTS.

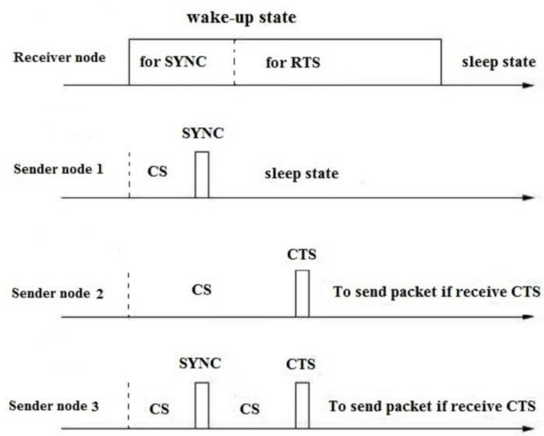

Fig 2: The relationship between nodes time to receive and to send

2.3. Virtual Cluster

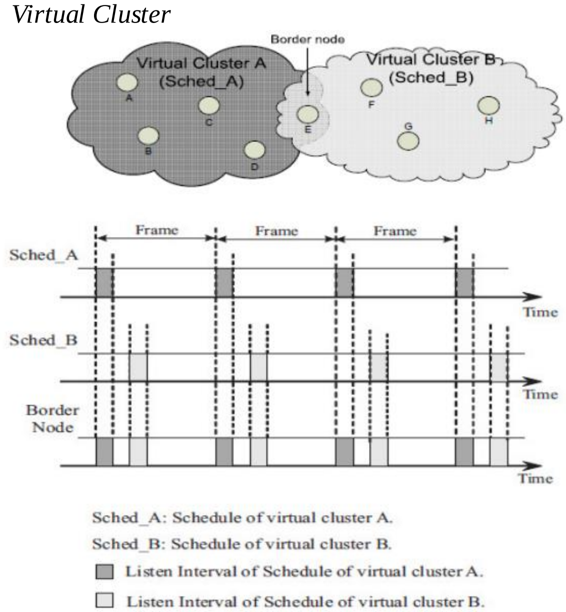

Fig 3: Virtual cluster in S-MAC

As shown in Figure 3, there are two virtual cluster is set to cluster A and cluster B with two different schedules. Each virtual cluster will contain the frame interval to sequentially for different sensor nodes. Border node E is a dispute between two virtual cluster 2 should be saved for their own schedule. Border node will listen to intervals sequentially scheduled to wake-up and listen to their own virtual cluster A, this same edge node will still wake up and listen own schedule virtual cluster B. This leads the border node will almost would have listened most all the sequential period of two virtual clusters. Even then listening to interval of the boundary nodes may be more if it does not synchronize the time to listen to this phrase. As a result, it may happen this node will store a lot of marginal own schedule various unnecessary, listening and node own schedule unnecessary proportional energy consumption. This led to a period of life of the shorter border node other sensor nodes.

With these advantages compared to the access protocol environments, the authors [4], [5] described the method of their S-MAC. In particular, the authors [6] proposed model energy saving MAC protocol for wireless sensor network, there by optimizing S-MAC protocol .Since then, the node to manually synchronize follow time. On the other hand, the cycle time and listen to different sleep too much. Some nodes may follow a schedule of more than one group or multiple groups of their own neighborhood. The authors describe a structure only be synchronized like in a cluster of its own.

Summed up the idea of the authors above would look like if the nodes have more than one schedule?

- There is a higher duty cycle
- Consume more energy
- Making rapid battery depletion
- Routing harder

III. PROPOSED IMPROVEMENTS

With the analytical limit survivor of S-MAC protocol in part II, section III we outlined the reasons for the proposal and solution algorithm improvements proposed S-MAC protocol (MAC Sensor Modified Proposal) as follows:

3.1 Reasons for proposal

Mote-Carlo simulations

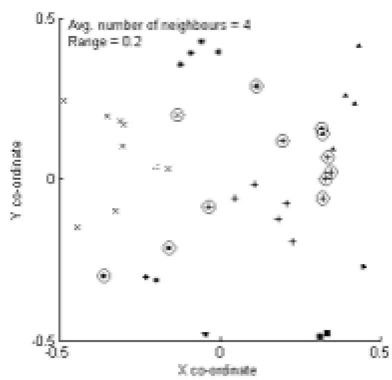

Fig 4: Mote-Carlo simulation

Monte-Carlo simulation has 40 nodes. Twelve of the 40 nodes in two schedules. The nodes that follow a shared schedule an icon. The nodes that are required to wake up in time more than one schedule drew a small circle around. In other words, the average number of the schedule followed by a node in the wireless sensor network is 1.3. When the node to follow that schedule will have much higher energy consumption, and therefore a shorter lifespan.

Listening period

When selecting and maintaining the regime time to listen and sleep, some even to maintain node mode during waking listen more to a schedule. This happens when a node see the nodes around it in some different schedule, then start the process of sharing schedule. The share node after schedule is considered formed a virtual cluster.

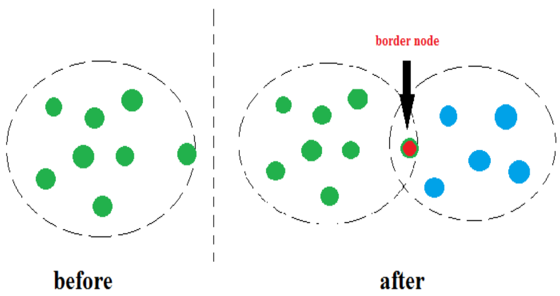

Fig 5: Listening mechanisms of border node

Pictures mechanisms of listening is an example of border nodes clearest description. Initially, the first boundary node of schedule is his own schedule (green color). The circle around the node to know their own schedule. Then, schedule 2 (blue color) send connected signals to border nodes, synchronization time is set. Now, despite of previous first schedule, border node still listens to signals connected from 2nd schedule in S-MAC. Because the S-MAC is no mechanism that border node must cancel, or received any previous schedule will be better in this period, border node will store the two schedules in sync frame as its own schedule. Thus marginal node will have a higher mission, this leads to greater energy consumption of a normal node.

Would be like if all the nodes do not schedule more than one ? The nodes follow different schedules, it will deplete its battery sooner than the other nodes. Therefore, the number of larger schedule will directly proportional to the ability to consume more energy, which leads to depletion of the battery more quickly.

3.2 Proposed solutions

S-MAC protocol can have a high rate of nodes wake up in time more than one schedule. This has negative impacts on the life and connectivity of a WSNs with limited power node. In this section are recommendations for improvement MPS-MAC (Modified Proposal Sensor - MAC) of S-MAC protocol.

When the connection is established between two (or more) virtual cluster are isolated (each an independently selected schedule) by the introduction of a new node in the cluster, all of the cluster nodes convert a single cluster because of a schedule in the cluster. The process of merging the cluster to ensure short time except when the cluster is set to merge, the nodes must follow a precise cycle, avoiding the problems associated with multiple schedules.

All the cycle start node, similar tasks. In particular, the nodes can increase the duty cycle by increasing the duty cycle when the load observed increased or reduced latency. Conversely, the node can also reduce duty cycle when necessary by removing the additional operating cycle when there is less traffic. Note, uptime never been changed, the nodes are only allowed to add new activities scheduled in the middle stage of sleep when necessary. The process of merging the cluster requirements is scheduled next individual clusters were identified.

In addition, neighboring nodes can add synchronization information (SYNC) on their packets. When synchronizing, the node will remain the highest point in the original schedule. To synchronize the whole WSNs a quick, solution that we propose be done from the boundary nodes and data packets can be relayed more different between virtual cluster. The structure of a message sent or received node includes its own ID, storage slots remaining time until the node to switch to sleep mode, or listening mode.

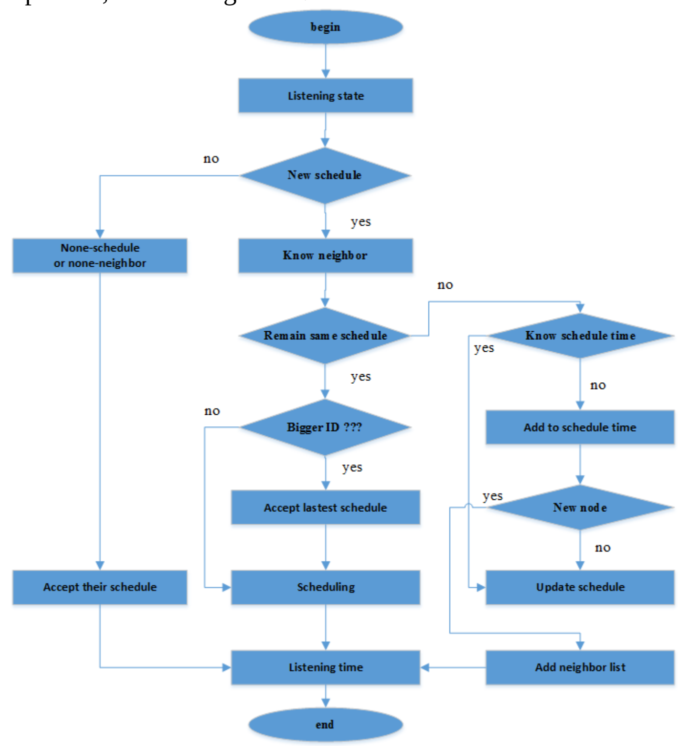

Fig 6: Flowchart of MPS-MAC processing flow

Begin MPS-MAC

1 Listening state

2 To have known neighbor

3 *If (None-schedule Or None Neighbor)*

4 To accept their schedule

5 Step to 30

6 *Else*

7 To know and SYNC its neighbor

8 *If (!Source node remain same schedule)*

9 *If (Source node has bigger ID)*

10 To accept last schedule

11 To update schedule

12 Step to 29

13 *Else*

14 Step to 29

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        End If
    Else
        If (! does it know schedule time)
            To add to schedule time
            If (that's new node)
                To update schedule
            Else
                Add it to neighbor list
                Step to 30
            End If
        Else
            To update schedule
        End If
End If
SYNC and Schedule
Listening time
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End MPS-MAC

First of all, if a node has its own schedule and still be other nodes send packets larger ID SYNC to its ID (or ID of the schedule previous calendar) it will accept greater schedule ID This. The cause is accepted by the larger ID (mean that node has just entranced to the network), it will exist in the network in a smaller period of time, resulting in shorter time to wake up node of listening are declining. After the merger schedule is set, the list of the "neighborhood" will be updated again for operation of the "neighbors". Second, signaling the schedule coordinated package will be made after have "excluded" border nodes into a normal sensor node. A "excluded" border node will take place during the time to listen and will perform the duties as shown in the algorithm on how to survive the boundary nodes is the least. Third, the entire synchronization takes place during the period of listening so that the list of neighboring nodes is fully updated and accurate operation. After the list of border nodes are "excluded" and set as the other sensor node, the next strategy is to establish a common agenda on the network to all nodes under a unified calendar only single process.

IV. SIMULATION AND EVALUATION OF RESULTS

For sensor nodes, consumption measured in reality about 20µA in sleeping, 4mA in receiving and 10mA in the transmission. Since the power supply for each sensor node is constant 3V, the simulation time is determined, so can easily calculate the average power consumption when determining the average electrical current consumption.

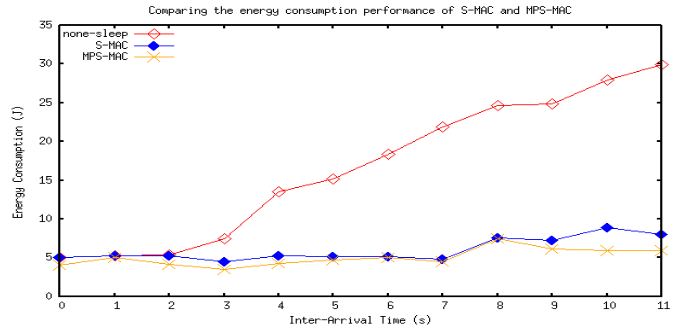

Fig 7: The average power consumption for each protocol

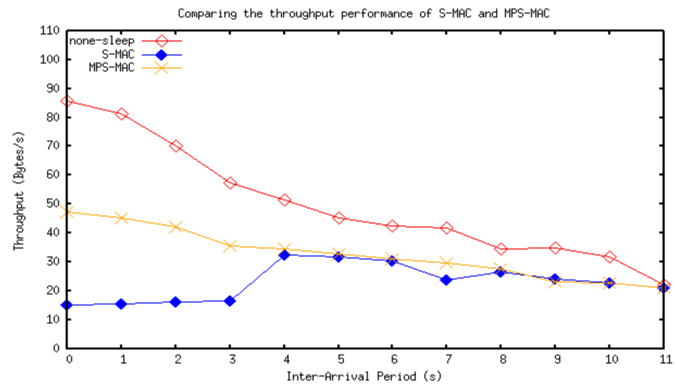

Fig 8: The average throughput for each protocol

From Figure 7 shows the power consumption of none-sleep, S-MAC and MPS-MAC in 2 seconds part of the chart is almost same. The reason is that the nodes wake up the signal to transmit or receive from neighboring nodes. From about 2 seconds on, there was marked as the highest energy levels near 30J of none-sleep, and the lowest close of MPS-MAC is 4J. In the diagram in Figure 8 average throughput of none-sleep initially are very high (about 85 bytes / s), while the same starting point, the MPS-MAC are quite low (about 45 bytes / s). Although the first 4 seconds of chart, the MPS-MAC throughput seems higher than S-MAC, but from the 4th sec on throughput MPS-MAC and S-MAC are equivalent. In summary, the latest three mechanisms tend to lower gradually, because of sending / receiving of three mechanisms above are quite stable so tend almost equal. However, in general, the improved MPS-MAC has more advantages in energy consumption and throughput in the period to interval.

MPS-protocol eliminate the need for any more nodes follow the multiple schedules which causes energy depletion. The goal of the paper is to compare the S-MAC with improvements proposed for MPS-MAC protocol on energy efficiency, part traffic information. All sensor nodes in sensor network protocol wireless MAC compare energy efficiency and resulting simulation model of WSNs is presented in conditions that compare energy performance. Energy efficient sensor nodes is defined by the total energy consumption / total number of bits transmitted.

V. CONCLUSION

Based on the comparison results from Figure 7 and Figure 8 showed the energy efficiency of the mechanism's environmental penetrate the MAC protocol. Despite these different MAC layer protocol is proposed for wireless sensor networks, but the efficiency with which they provide is very possible. From above all the protocols and [7] are compared on the main criteria as energy efficiency, throughput. From the results of the comparison [8], [9] protocol enhancements proposed MPS-MAC is better than traditional S-MAC protocol and some other protocols because it provides efficient features necessary for designing wireless sensor networks. With the proposed solutions to improve part energy which can't replace the sensor node, the subject will be hereby opened for the protocol proposed solutions.

In addition, the authors have proposed two solutions more energy efficient S-MAC protocol:

The first, when the neighboring node synchronization information at the packet, received node to manually synchronize mechanism that is called "piggy-backing"

Second, the node gets information about its neighboring cluster, the cluster will operate while the other clusters in the phase of sleep. During this time, the nodes are in the stage of sleep will automatically synchronize yourself until the start of the stage listening.

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