An Enhanced Energy Efficient Hybrid Asynchronous Duty Cycle MAC in Wireless Sensor

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Abstract. Wireless sensor network (WSN) has countless potential application in many areas due to its easy deployment process, lower installation cost, less cabling required, and high mobility. However, limited energy residue (especially deposited in small size battery) is always a major obstacle in WSN. Improving mechanism on MAC layer is one of the potential research that could increase battery lifespan. In the active phase of the MAC layer, a node can receive and transmit packet when awake. Then, a node is in a sleep phase, it switches off the radio automatically to save energy and gives alert. While in idle listening phase, node still using the energy. Duty cycling performed in MAC layer don’t involve turning off their radio and switching sleep mode but repeating off/on process. Therefore, this study proposed mechanism of WSN that used in order to enhance power energy using duty cycle in MAC layer. The proposed of asynchronous duty cycle MAC layer using a hybrid duty cycle MAC in implementation the performance of WSN. In addition, this paper also elaborated the design asynchronous hybrid duty cycle MAC with multi-hop broadcast.

1. Introduction
Nowadays, wireless system is becoming a popular system in industrial technology. It became popular due to their so many applications especially in wireless sensor network (WSN) that can have applied in any environment. The implementation of WSN is considered able to adopt in agriculture business [1], national defence [2], temperature monitoring [3], pollution [4], and so on. WSN provides some advantages including easy deployment process, lower installation cost, less cabling required, and high mobility [5]. It also offers expected transformation infrastructure for building automation, also process control applications [6]. WSN has expected to proper future in market prospective.

WSN is a regular of small networks component that contain of distributed particles called sensor nodes. Compared to mobile device, the coverage and communication range for sensor nodes compared is limited due to low power capacities. It consumes several powers to do the task as the laying of the sensor. Moreover, sensor node has some duties to collect and transmit data obtained by the sensor to other nodes or access point. WSN usually used a large number of nodes across the hostile and unstable environment.

Extending the lifetime of node and sustaining the proper processes of the network are becoming one of issue in this sensor networks. Furthermore, the energy efficiency becomes the first concern and main objective in designing this system, which can be useful if a user uses it properly and effectively. Those processes consist of sending, receiving, processing, forwarding data, and also processing or forwarding some requests. In other way, useless energy consumption consists of collision, overhearing, control overhead, idle listening, and over emitting [7]. It used in order to enhance the power energy that used relevant technique Media Access Control (MAC) layer named duty cycle. Both synchronous and asynchronous are suitable for light traffic loads where frequent excessive traffic load and high traffic loads in wireless system network, such as broadcast [12] or converge cast [13-15] traffic could suddenly increase channel contention in a local neighbourhood. Broadcast process is commonly used for various network wide queries and updates [16], and the converge cast taken when various sensors can be observed under the same conditions by sending the report to the sink node or to the node that
receives the data aggregation [17].

2. Duty Cycle on MAC

There are various low duty cycle protocols that is proposed for WSNs, which differ in aspects of synchronisation, the number of channels required, transmitter- or receiver-initiated operation etc. There are two different types of protocols, which control low duty cycle protocols: asynchronous and synchronous schemes [18-20].

Another variation of low duty cycle protocols such as Queue-MAC, a new traffic adaptive duty cycle MAC protocol considered for event-driven sensor networks [21] uses the synchronization based preamble sampling to deal with low traffic load in a long period and responds to burst events by dynamically dealing the TDMA slots. SVP sampling has high energy efficiency with short channel listening period and dynamically allocated TDMA slots could achieve low transmission delay by making full use of the communication bandwidth according to the traffic load. Moreover Distributed Slot Scheduling Algorithm for Hybrid CSMA/TDMA MAC [22] offered algorithm for hybrid mac to handle collision during communication. This protocol handle a schedule which bridges the gap between a feasible and an optimal schedule to handle the collision during transmission. First, find out two-hop neighbors of each node, then a particular slot is allotted to each node in order to prepare a feasible schedule using the RD-TDMA algorithm. Finally, the feasible schedule is adequate tuned in a novel way to improve the efficiency in handling the collision by reducing the number of allotted slots.

Energy Efficiency TDMA/CSMA Hybrid Protocol with Power Control (TCH-MAC) for WSN reduce the energy consumption and transmission throughput [23].This protocol takes advantages of TDMA and CSMA in the MAC layer by design a novel power control scheme to further reduce the energy consumption and optimize the transmission slots.

3. Proposed Hybrid Asynchronous MAC

Generally, this protocol is designed to achieve energy efficiency and delay WSN applications that combined technique time division multiple access (TDMA) with CSMA Asynchronous. Here TDMA concept used LMAC protocol [19] and then CSMA concept is used like WiseMAC Protocol [17].

The free timeslots of each channel are calculated by performing the OR operation between its local vector and the vector found from its neighbour. A node is allowed to transmit by using its controlled timeslots and receive from any timeslot of any channel by switching the interface between different free timeslot as well. Therefore, the transmitter has the option to choose the best timeslot between the two and hence the delay of packet advancing decreases dramatically. Figure 1 shown the idea of Hybrid Duty Cycle MAC WSN done in this paper.
Free wakeup node implemented to do clear channel assessment (CCA) to find free channel. If the channel busy, it uses to wait until there is a free channel do preamble. In preamble, package initiates the readiness of their neighbour to send the data. Then after sent the data, it waits for an acknowledgement to confirm that the data has been send successfully. If the package received the acknowledgement then the package become free, otherwise it will redo the sending process. Furthermore, in Fig. 2 shown that when the node is not wakeup yet, thus wait control will schedule the slot for package that being transmit, then continue to CCA. If the slot had been used by other package, then wait control will try to find another free slot.

**Figure 1:** Flowchart of Porposed Enhanced Hybrid Duty Cycle MAC

Based on Figure 1 is shown flowchart has been formulated to enhance the energy efficiency and reduce delay in this new model of Hybrid Duty Cycle MAC. When the package needs to send data, this model finds a free wakeup node. If all nodes are busy, then the package needs to wait in WAIT_CTL and schedule its turn. If the package cannot get their free slot in WAIT_CTL. Therefore, it expectedly goes back to sleep in order to save the energy.

**Figure 2:** Wait control (WAIT_CTL) Mechanism
4. Operational Cycle of the Proposed Hybrid Protocol

This operational cycle in begin when a node wants to send the data. All nodes start from sleep state then it will indicate priority slot which already wakeup. If the wakeup slot is not for the node, then it will wait their scheduled slot in WAIT_CTL. If the wakeup slot is for the node, thus it will do clear CCA in order to find free channel. If the channel is busy, it will wait their turn in wait package then going back to sleep. If the channel free, then it will do preamble to send the data. Then it will check the acknowledge status. If the ack is true, means that the wait ack does not receive any acknowledgement then it will go back to sleep. If the ack is false means it will broadcast, then go to sleep. It shown in Figure 3 as follows:

![Figure 3: Overall Operational Cycle Hybrid Asynchronous Duty Cycle MAC](image)

5. A Hybrid Asynchronous Duty Cycle MAC with Multi-hop Broadcast

Multi-hop broadcast is an important network service in WSNs, especially for applications such as code update, remote network configuration, route discovery, etc. Although the problem of broadcast that is studied in always-on networks such as wireless ad hoc networks, where neighbour connectivity is not a problem. The broadcast is more difficult in duty-cycled WSNs where each node stays awake only for a fraction of time slots and neighbourhood nodes are not simultaneously awake for receiving data. It becomes more difficult in asynchronous and heterogeneous duty-cycling scenarios.

EMBA [18] is the multi-hop broadcast protocol that uses asynchronous duty cycle. It allows nodes to periodically give-and-take link quality information with neighbour nodes. With this procedure, EMBA can significantly lessen duty cycle of nodes and also provide a considerable broadcast efficiency for networks with burst traffic. Hybrid Asynchronous Duty Cycle MAC integrated EMBA techniques to reduce the number of transmissions, thus it minimizes the active time of nodes.

6. Conclusions

This paper presents about the development in designing model in hybrid asynchronous duty cycle MAC WSN as the guidance of the point. One of point in development is to measure the power energy in term improve or delay process. It elaborates operational cycle of hybrid mac protocol that consist with several stages such as: INIT, SLEEP, CCA, WAIT_PKT, WAIT_CTL, PREAMBLES, and SEND_DATA. It is condition that through the transmission in hybrid asynchronous duty MAC. In future work, the study about how to compare the protocol in asynchronous duty cycle MAC that used based on the proposed design mode.

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