A SURVEY ON ENERGY EFFICIENT ASYNCHRONOUS WISEMAC PROTOCOL FOR WIRELESS SENSOR NETWORKS

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ABSTRACT
This paper presents a review on energy efficient WiseMAC Protocol for wireless sensor networks. Among various MAC layer protocol WiseMAC is a known as one of the most energy efficient protocol. Non-persistent carrier sense multiple access (np-CSMA) and the preamble sampling technique are the main techniques used in basic WiseMAC protocol, they are used to reduce the consumption of power when energy is wasted in listening to idle medium. Here we investigate the WiseMAC protocol with the different important schemes that used in implementation of WiseMAC in sensor networks, these schemes are basically emphasizing on energy saving methods in WiseMAC, various modifications are done in original WiseMAC to make them more energy efficient; with the same motive of more energy efficiency, we propose adaptive WiseMAC protocol with dynamic duty cycle and the adaptive Contention Window.

KEYWORDS: *Adaptive Contention Window, CSMA, Dynamic Duty Cycle, MAC Layer Protocol, Preamble Sampling.*

I. INTRODUCTION

A Wireless Sensor Network (WSN) defines a system that contains a number of sensor nodes to collect information over a wide interested area. Sensing and communication are the main activities used by sensor nodes to collect and pass the information to the interested users. Sensor nodes can be used in various modes such as visual, thermal, infrared and radar; they are used to observe a wide variety of area, according to the specific applications, like to check the movement of Vehicles, to check the Lightning condition, sense the temperature [5].

Applications areas of Wireless sensor network is very vast and serve to different categories of different fields such as the healthcare, military area monitoring, environmental sensing, homecare and other commercial areas. When we are concern about lifetime and energy efficiency in wireless sensor network then the role of MAC layer come into existence. There is a long list of MAC layer protocols proposed by different authors for better life time and energy saving in sensor networks. Among the various reasons of energy wasting some important reasons are overhearing of the data packets, listening of the idle medium, collisions that increase the energy wastage because of retransmissions .primarily division of MAC protocol gives two basic kind of categories , these are slotted MAC (or synchronous) and random access MAC (or asynchronous) Protocols.

In this paper we present a review to one of the main asynchronous MAC protocol, WiseMAC (Wireless Sensor MAC), for wireless sensor networks. We review the important contribution of WiseMAC protocol and propose some modifications in Original WiseMAC to make it more energy efficient. The rest of the paper is organized as follows--Section II describes the related with different asynchronous MAC Protocols for wireless sensor network. Section III describes the WiseMAC protocol. Section IV presents different schemes used in implementation of WiseMAC. Section V and VI provide a discussion of future work and conclusion.

II. RELATED WORK

A plentiful MAC Protocols are proposed to obtain the objective of energy efficiency. In synchronous MAC protocols energy consumption of sensors are reduced by synchronizing the sensors' wakeup and sleep times. These protocols are not efficient in case of variable traffic rates because of fixed sleep times and listen times. S-MAC [11] and T-MAC [10] are example of synchronous MAC protocols. In Asynchronous MAC Protocols synchronization is not required. As they use randomization and Contention process called as Random Access MAC Protocols. In Asynchronous MAC Protocols a simple technique is used to reducing the problem of idle listening, in that technique all the cost of receiver is transferred to sender by using extended MAC header, this is also consider as preamble. By using this technique nodes can check channel periodically and to save the energy the node can go to the sleep state most of the time.

Asynchronous MAC protocols can also be divided in either sender initiated or receiver-initiated. In sender initiated approach, a sender added a preamble in packet header before the packet transmission to inform the receiver for the upcoming packet. In contrast, in receiver-initiated approach, sender replaces its preambles with the receiver's wakeup beacons. With this approach Collisions can be reduced because as compare to preamble beacon is significantly short. WiseMAC protocol is a part of long list of asynchronous MAC protocols, the other protocols in that particular category are C-MAC [2], B-MAC [8], and X-MAC [7]. B-MAC protocol is a combination of CSMA and Low power listening (LPL) technique. In LPL technique senders use the long preambles to sure that receiver will wake up for upcoming authentic packet. Unsynchronized duty cycling is used in B-MAC with the long preambles to wake up the receivers. To increase the reliability of channel assessment B-MAC uses a filter technique. B-MAC also uses the adaptive preamble sampling and clear channel assessment (CCA) to minimize the problem of idle listening. In comparison to the B-MAC, X-MAC uses the short preamble and efficiently minimize the idle listening, packet overhearing. In X-MAC [7] target address information is embedded in the short preamble to provide the low power communication.

C-MAC [2] is an asynchronous MAC layer protocol, which reduce the latency and improves the energy efficiency. C-MAC uses three main phases such as Aggressive RTS, Anycast Based Forwarding and Converging from anycast to Unicast .It uses cooperation of aggressive RTS and double channel to minimize the latency. Here we only present a review on WiseMAC protocol, that is one of important protocol in energy efficient asynchronous MAC Protocols.

III. WISEMAC

To minimize the energy consumption WiseMAC protocol used the preamble sampling technique [3]. In WiseMAC protocol a preamble is used to add in front of each data packet just to aware the receiver node not to go to the sleep mode upon reception of the current frame, but be in wakeup mode for the upcoming frame transmission. Listen to the wireless channel for short amount of time is considered as the Sampling of medium. TW denotes the constant period in which all sensor nodes sample the medium in sensor network. In sampling process sensor nodes periodically sense the medium to check the availability of the channel to send the data, if the sampled medium is busy, a sensor node again listens to the channel till a data frame is received or the medium becomes idle. At the transmitter side, a wake-up preamble of equal size to the sampling period is added in the front of every data frame to make sure that the receiver will be awake when the data segment of the packet arrives.

Wise MAC protocol provides an idea to learn the sample schedule of its direct neighbors that is used to reduce the size of the wake-up preamble. If any node does not have any idea about its neighbors' wake pattern, it can send a preamble of duration T, in order to get to the sampling interval of the neighboring node. After receiving the frame successfully, receiver node wake-up pattern is piggybacked in its acknowledgement message, then one table is maintained to keep the neighboring nodes' relative schedule offset from nodes own wake pattern. Based on this table, a node can determine the next wake-up of all its respective neighbors, and reduce the preamble length for all upcoming future frames. This simple scheme provides a considerable improvement to the basic preamble sampling protocols.

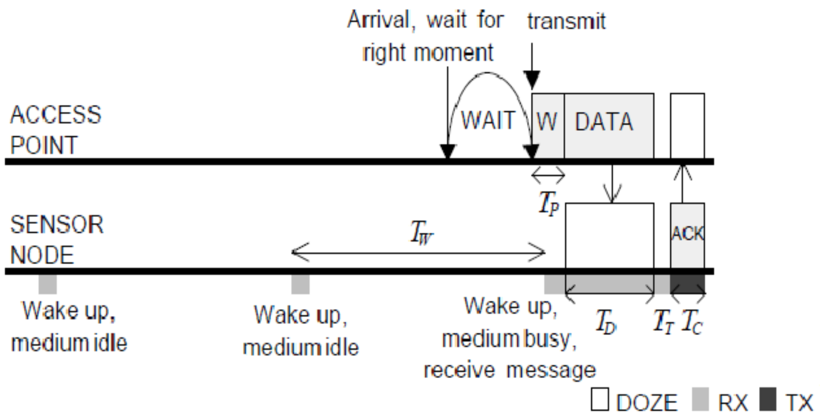

Figure 1. WiseMAC

In WiseMAC, random duration preamble denoted as a medium reservation preamble (TMR) is appended in front of the wake-up preamble that is to avoid the collisions between different nodes that need to send a data frame to same target. After the wake-up preamble, the WiseMAC data frame includes a bit synchronization preamble (SYNC) and a start frame delimiter (SFD).In WiseMAC the duration of the wake-up preamble is denoted by TP. The wake-up preamble is composed of two parts: the clock drift compensation preamble of duration TCDC and the medium reservation preamble of length TMR. Then we have

$$T_P = T_{MR} + T_{CDC}$$

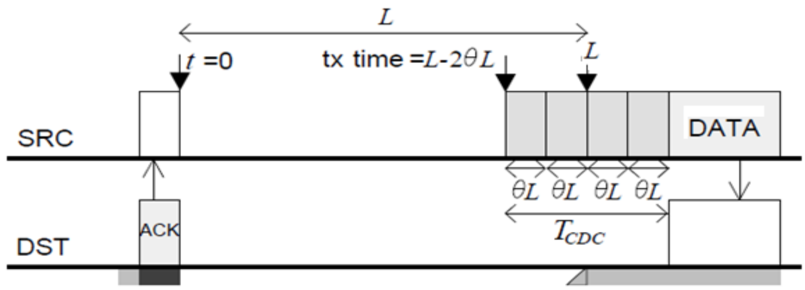

Figure 2 Clock drift compensation

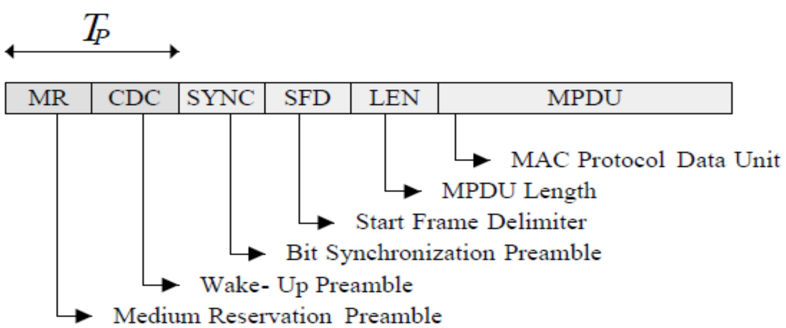

Figure3 WiseMAC frame

In simple preamble sampling technique (long) wake-up preambles cause a limitation on throughput and increase the overhead of extra power consumption in reception and transmission. In comparison to the simple preamble sampling technique, WiseMAC protocol reduces the length of the long wake-up preamble that reduces the cost and energy of the node. With the reference of different reviewed papers we can give some advantages and limitations of WiseMAC [6].

Advantages of WiseMAC:

- Performance of WiseMAC is much better than SMAC in variable traffic conditions.
- WiseMAC provides improved life time for battery because of low power consumption.

- In variable traffic rates WiseMAC provides good throughput relatively to other MAC layer protocols.
- The external time synchronization requirement is mitigated by the protocol by handling the clock drift very well.
- WiseMAC easily can be combined with other MAC protocols for better results in different applications.

Limitations of WiseMAC:

- Decentralized sleep–listen scheduling scheme in Wise MAC outcomes in different sleep and wake-up times for each neighbour of a node.
- Different packets are buffered for neighbors in broadcast-type communication in sleep mode and delivered many times as each neighbour wakes up, this causes higher latency and unnecessary power consumption.
- Due to hidden terminal problem collision occurs at beginning of transmition of the preamble to a node.

IV. DIFFERENT SCHEMES USED IN IMPLEMENTATION OF WISEMAC

4.1 Minimized Wake-Up Preamble

In Basic Medium Access Mechanism of WiseMAC all nodes in the network sample medium with a common basic cycle duration T, but their wake-up schedule patterns are always independent. At the time of transmission of a frame, a preamble of variable length is prepended to alert the receiving node in its wake-up interval not to go to the sleep state. Preamble is a simple bit sequence indicating an upcoming transmission to nodes neighborhood. In WiseMAC Protocol acknowledgement packets are used to carry the acknowledgement for the received data packet, as well as they also used to inform other party of the remaining time until next sampling time [4]. By using this scheme, a node can have a table of the sampling time offsets of all the common destinations up-to-date. Because a node will have only limited direct destinations, so the table is very easy to manage even with limited memory resources. By using the information of that table , a node can transmits a packet just at the correct time, with a minimize wake-up preamble as shown in Fig.3, In the given fig, the duration of the wake-up preamble is denoted with TP .WiseMAC Protocol minimizes the preamble and calculates its duration as follows [4]:

$$T_{Preamble} = \min(4\theta L, T)$$

Where L denotes the time since the last update of the neighbour’s wake pattern, T denotes the common basic cycle duration and θ denotes the quartz oscillator clocks drift.

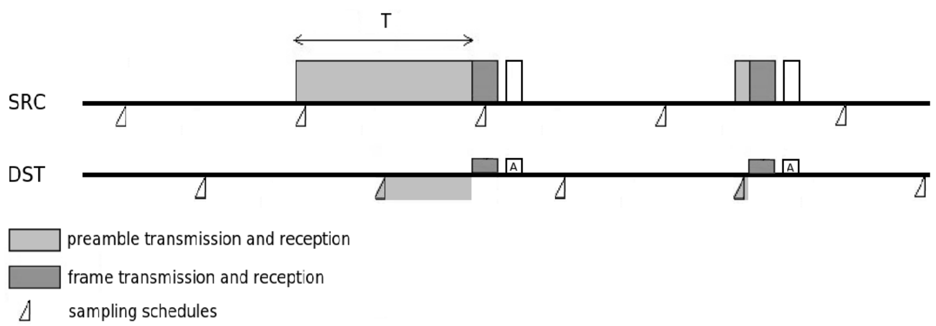

Figure 4 Medium Access Mechanism of WiseMAC

4.2 More bit Scheme

WiseMAC suggests an elective fragmentation scheme, to increase the throughput in the condition of packet bursts and higher traffic loads, that scheme is referred as more bit scheme [4]. More bit scheme provides same functionality as the fragmentation scheme used in S-MAC. In More bit scheme whenever a node has the more packets to send, it sets a flag bit in a unicast MAC frame. That more bit in the frame header signals to receiver node that it will not turn off its transceiver after receiving the frame, but switch back to the receive mode again in order to receive the next packet. Throughput is increased because a sender does not have to wait for the next wakeup of the receiver to transmit their next frame. With the variable traffic load and in case of packet bursts generated by the single node the more bit scheme is proved to be very efficient.

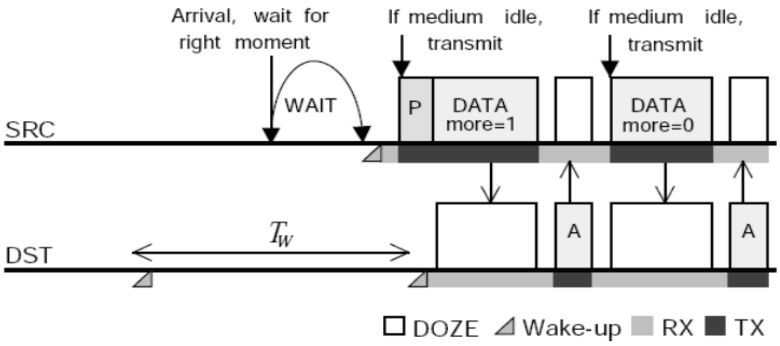

Figure5 More bit Scheme

4.3. Extended More Bit Scheme

More bit scheme only serves to improve the traffic adaptivity between one sender and one destination, and for that reason it has limitations. To overcome the limitations of More bit scheme, extended more bit scheme is used [12]. In this scheme two sources Source1 and Source2 are simultaneously trying to transmit some packets to same node Destination. If Source1 and Souece2 both try t o reach Destination in same wake interval, then decision who is first is taken by medium reservation preamble. If Source1 wins contention then it sends its first two frames with more bit set. The more bit in ACK packet is acknowledges by the destination node so the destination node is in stays awake position for at least some a basic wake interval T. Because Source2 has lost contention, it has to wait and overhear the transmission to the Destination. Because the promise of stay awake in the ACK packet, Source2 identifies that it can start sending its own data frames just after the Source1 has completed its transmissions.

The key objective of using this scheme is that we can save the waiting time, because the transmission of Source2 can start without any delay after the transmission of node Source1.The extended more bit mechanism is only activated when there is a node buffering more than one frame that requests to its destination to stay awake for the one next packet, which is a sign of increased load. The extended more bit scheme is not applied after the every unicast transmission, because it would lead to the huge energy consumption.

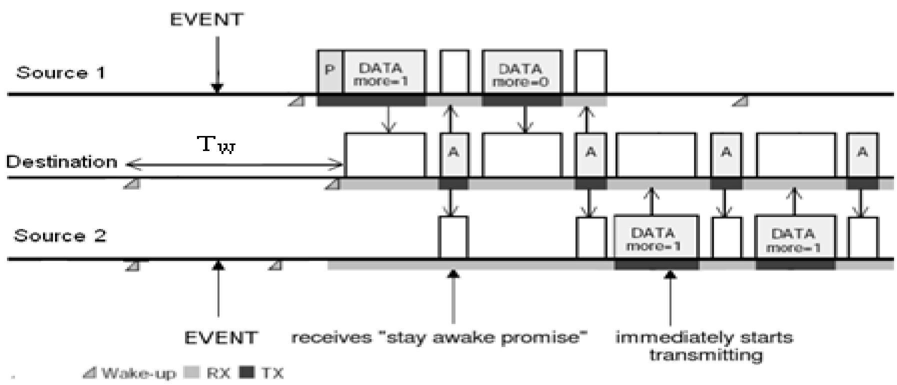

Figure 6 Extended More Bit Scheme

4.4. Medium Reservation

In WiseMAC synchronization mechanism can lead a possibility of systematic collision. In Wireless sensor network, a number of sensor node sending data through a multi-hop network to a sink. In this situation, many nodes are working as relays along the path towards the sink. If a number of sensor nodes try to send the data packets to the same relay, at the same scheduled sampling time and with approximately identical sizes of wake-up preambles, there are high possibilities to find a collision [1].

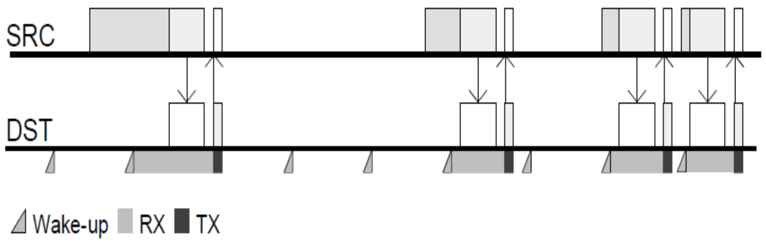

Figure. 7 Per-Packet Overhead to the Traffic

To avoid such collisions, a key is to add a medium reservation preamble of randomized length TMR in front of the wake-up preamble. The sensor node will start its transmission earlier which has picked the longest medium reservation preamble and thus reserve the medium.

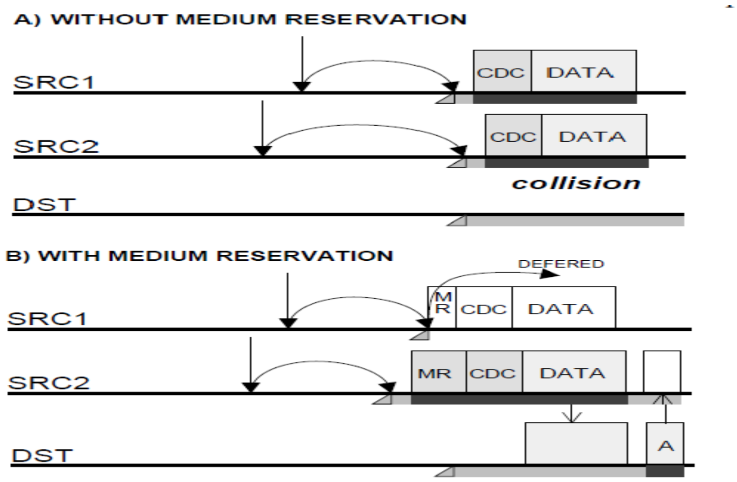

Figure.8 Collision between two nodes without medium reservation (A) Medium Reservation Scheme (B)

4.5. Overhearing Mitigation

When traffic is high overhearing is naturally avoided, in WiseMAC protocol that is because of combined use of the minimization of the wake-up preamble length and preamble sampling scheme. In WiseMAC, sensor nodes are not synchronized among themselves but their relative sampling schedule offsets are independent. Let TD and TP be the duration of a data packet and length of the wake-up preamble respectively. When the traffic conditions are high, the length of the wake-up preamble TP becomes small. Let us assume that the total length TD+ TP of wake-up preamble and the data packet is then much smaller than sampling period TW [1]. Because the nodes have independent sampling offsets, this much short transmissions are supposed to fall in between sampling moments of potential overhearers. if the wake-up preamble is larger than the data message; a overhearing avoidance mechanism holds in repeating the data message in the wake-up preamble, as illustrated in Fig.9 When there are repetitions of data messages in the wake-up preamble, overhearers can go to the sleep after reception of only one copy of data message.

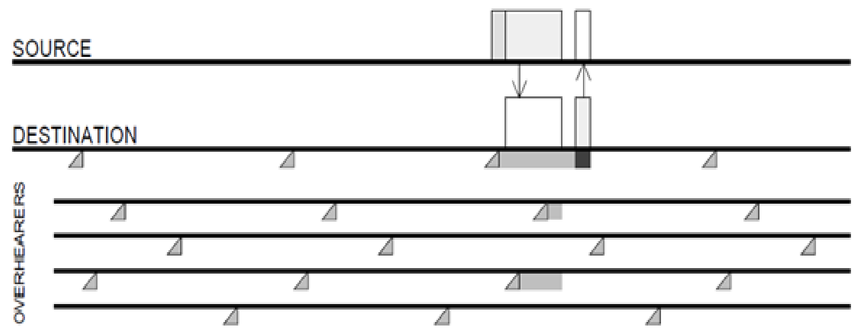

Figure 9 Overhearing Avoidance

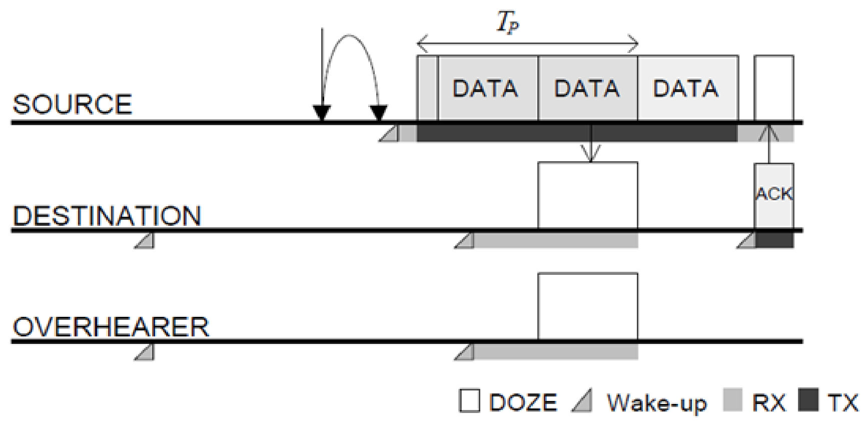

Figure 10 Data message Repetition within wake-up preamble

4.6. Random backoff

When the medium is found busy after sampling, a slotted random backoff procedure is used. In this procedure selecting a uniformly distributed random backoff and decrement the backoff counter by one for every slot that is detected idle. The backoff procedure can also be invoked after a transmission; just to give a fair chance to other nodes to grab the channel [9] .The backoff window is reset to its minimum size, if the transmission was successful. The backoff window is doubled up to a maximum size, if the transmission was not successful. The exponential increase of the backoff window is to avoid or minimize the congestion. In WiseMAC the random backoff procedure is invoked before every unsynchronized transmission and it is not necessary to invoke the backoff after transmissions. , it is suitable to use a slotted random backoff procedure, because the nodes may be synchronized by an external event.

4.7. Inter-frame spaces

There is an idle period between the end of the data message and the start of the acknowledgement, caused by the time needed to turn around transceiver. This delay is called SIFS (Short Inter-Frame Space). Short Inter-Frame Space is computed as the sum of the baseband processing delay, turn-around time, and the propagation delay [1]. If any another station attempts a transmission during the period between an acknowledgement packet and a data, the medium will found idle and that initiate the transmission, which will cause a collision with the acknowledgement message. By presenting a compulsory waiting time after the end of a busy period, before which any transmission attempt is prohibited the problem of collision can easily be avoided. This waiting period is called DIFS (Distributed Inter-Frame Space).In WiseMAC; a node does not observe the medium to find the end of a busy period. To confirm that a data-acknowledgement transaction is not interrupted, a node attempting a transmission and finding the medium idle waits TDIFS and senses the medium again. If the medium is then busy, the transmission attempt is deferred.

V. FUTURE WORK

High energy efficiency is the main concentration point in wireless sensor networks. Low power consumption arise the problem of limiting the throughput in original WiseMAC. We propose some modification to the original Wise-MAC to enhance the performance especially in terms of energy efficiency with the help of dynamic duty cycles and the adaptive contention window in wireless sensor networks. We propose modification in WiseMAC such as change in sensor's duty cycle according to sensor's traffic utilization, for this purpose proposed protocol will be design to adjust its duty cycle dynamically based on the variation of the traffic. This will reduce the power consumption of node. Further we will implement adaptive contention window. Contention window with original WiseMAC is static. Here we will make that adaptive. The use of adaptive contention window is dependent on traffic characteristics such as traffic flow and speed. It will help to increase the throughput and reduce the end to end delay.

VI. CONCLUSION

Low power consumption and better lifetime for nodes are the key requirements in wireless sensor networks. Due to wide application area of wireless sensor networks, to design an efficient and application oriented MAC layer protocols are still a challenging task. In synchronous MAC layer protocols a lot of energy is consumed on periodic synchronization messages and in asynchronous MAC layer protocols a problem of high latency is arises due to lack of synchronization. In this paper we presented a survey on WiseMAC protocol with protocol description, features and various different schemes that are used to them energy efficient. This protocol is an expansion of CSMA with preamble sampling. Existing WiseMAC protocol results in high energy efficiency but with the limited throughput. As a future work we propose some modifications to the original WiseMAC to avoid the problem of limited throughput.

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