Overview of 802.11 Power Saving Mechanisms

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Abstract: This paper presents overview of 802.11 power saving mechanisms with priority to Distributed Coordination Function (DCF). In the 802.11 power saving mechanism, time is divided into beacon intervals. When each beacon interval starts, each node periodically wakes up for a time period called *ATIM window*. Synchronization is required between nodes so that they remain active at the same time. During ATIM window, nodes exchange control packets to determine whether they need to remain active for the rest of the beacon interval. The size of the ATIM window has a major marked effect on energy savings and throughput achieved by nodes. In the mechanism, the nodes that are involved in the data communication remain active and other nodes go into doze mode.

Keywords: *Power Saving Mechanism, 802.11, ATIM window size, beacon interval*.

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I. INTRODUCTION:

Wireless local area network are a rapidly developing area in networking [9]. This is due to increase in portable devices like notebooks and mobile phones. These devices have limited battery capacity which limits their action. This results in need of power saving mechanisms which lengthen battery lifetime.

In general best way to save power in wireless communication is to switch devices off. But it is not possible to switch devices off without losing capacity to communicate in both directions. If the device is off then it will not know about any packets that will come to the device for communication. Therefore there are two problems are to be solved in power saving.

• How does a station in power save mode accept packets from other stations?

• How does a station forward packet to another station in power save mode?

Within the standard, the general intention is for all stations in power saving (PS) modes to be synchronized to become active at the same time. At this time a window is initiated in which the sender announces buffered frames for the receiver. A station that accepts such an announcement frame stays active until the frame is delivered. This is easy to implement in infrastructure networks due to presence of central access point. The central access point is able to store the packets for stations in doze state and to coordinate all mobile stations. It is more difficult to implement it in ad-hoc networks, where the packets are stored and forwarded and the timing synchronization has to be done in a distributed manner.

Power Saving in IEEE 802.11 therefore comprises a Timing Synchronization Function (TSF) and the actual power saving mechanism. The access point (AP) generate beacons, which contain a valid timestamp in addition to other information. Stations inside the BSS (Basic Service Set - a wireless cell) fine tune their local timers to that time stamp. If the channel is already busy after the beacon interval the AP has to postpone its transmission until the channel is free again.

The situation is more complex for an ad-hoc network (The Distributed Coordination Function). Due to the absence of a trusted controlling authority the timers adjust in a distributed way. Every station is accountable for creating a beacon. After the beacon interval all stations strive to gain superiority over others for transmission of the beacon employing the standard back off algorithm. The first station "wins" the access and all others have to cancel their beacon transmissions and to fine tune their local timers to the timestamp of the winning beacon.

Due to rapid progress in wireless communication and increase in number of wireless devices that are using wireless communication it is worth taking review of 802.11 power saving mechanisms.

The power saving mechanism in principle is shown in figure 1 for distributed coordination function (DCF).

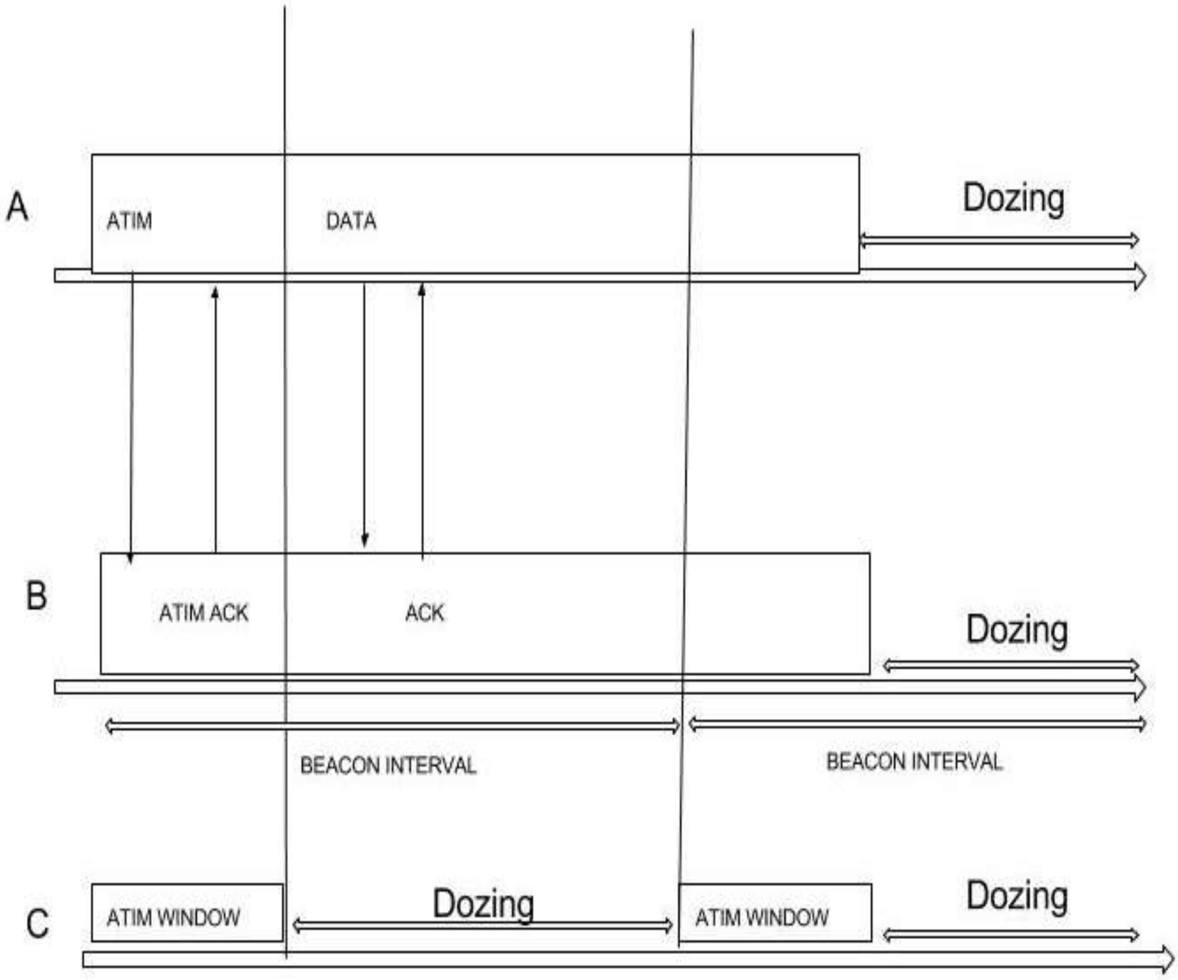

Figure 1: PSM: When the ATIM window is in progress, node A sends an ATIM frame to node B to announce buffered packet. Node B replies with ATIM ACK package. Both node A and B stay awake during beacon interval. After ATIM window A transmits data to B and B replies with ACK.As node C is not participated in data transmission it goes to doze state after ATIM window.

II. OVERVIEW OF POWER SAVING MECHANISMS:

Several power saving mechanisms have been proposed in the literature for increasing energy efficiency. Some of the power saving mechanisms have been overviewed below

Reference [1] presents a TDMA based multi-channel MAC protocol called TM MAC for Ad Hoc Networks. In this protocol time interval is divided into beacon intervals. Each beacon interval is divided into two parts as ATIM window and Communication window. The ATIM window size is dynamically adjusted.

Two data structures are used in TMMAC; channel usage bitmap (CUB) & the channel allocation bitmap (CAB). The CUB is maintained at each node & stores current usage information of each channel. So if the radio receiver has M channels then there are M CUBs in each node. The CAB has same data structure as CAB but is used for negotiation & describes which channels are allocated by the current negotiation. So CAB is used in negotiation process.

Unicast & Broadcast negotiations are supported & priority is given to broadcast negotiation. Control messages are exchanged in the ATIM window & communication is carried out in data window.

An analytical model to compute throughput of TMMAC is presented. A model is validated by making simulation in GloMoSim, a scalable discrete event simulator developed by UCLA.

The ATIM window size is adjusted based on the whether network is saturated or not. If the network is saturated, corresponding rules are applied. If all the available bandwidth is used for data communication and the scheduled bandwidth is more than the accommodate bandwidth then ATIM window size is decreased by one level to leave more bandwidth for data communication. If opposite is true then the ATIM window size is increased by one level to leave more bandwidth for negotiation.

If the node does not get opportunity to transmit its current ATIM window size or it does not have packet to send then node resets its ATIM window size to ATIM minimum.

The protocol is compared with 802.11 DCF which uses single channel and MMAC which is a typical multi-channel MAC protocol using a single radio transceiver. TM MAC attains up to 113% higher communication throughput while 74% less packet energy consumption over multi-channel MAC protocols using a single half-duplex radio transceiver.

Reference [2] has proposed a hybrid and adaptive protocol, named H-MMAC. It uses IEEE 802.11 PSM. In H-MMAC, nodes exchange control messages on default channel to come to an agreement with the data channel during the ATIM (Ad hoc traffic Indication Message) window. The difference of HMMAC compared to other multi-channel MAC protocols is that the other nodes can transmit data packets on data channels based on the network traffic burden.

The protocol uses two modes of transmission. Normal mode & extended mode. Extended mode of transmission transmits in the current beacon interval as well as next beacon interval. The extended mode of transmission is longer than normal mode.

The protocol works on the following assumptions:

Time is divided into beacon intervals which contains two subintervals as ATIM window and data window.

There are N non overlapping channels of is one is control channel and other are data channels.

All nodes are time synchronized and operate the IEEE 802.11 DCF mechanism.

Nodes have priori knowledge of how many channels are available.

Each node has single half duplex transceiver such that it can transmit or receive but not simultaneously.

It is observed that H-MMAC can utilize the channel resources more efficiently. The simulation results show that the suggested H-MMAC improves the network performance significantly in terms of aggregate throughput, average delay and energy efficiency. The nodes that are not involved in control message exchanges in ATIM window can perform data communication.

Reference [3] proposes an adaptive mechanism to dynamically choose an ATIM window size according to network conditions. There are two rules for increasing the ATIM window size as given below

(a) When a node transmits an ATIM frame, an ATIM ACK may not be received as a reply. In such cases nodes retransmits its ATIM frame. The ATIM frame retry limit is set to three. That is, ATIM frame is transmitted three times before retry limit is reached. If the ATIM ACK is not received after three transmissions the dispatched packet is "marked" & re buffered for another try & that too for three times in the next beacon interval. The node increases its ATIM window size to next higher level when a node receives a marked packet.

(ii) When a node receives an ATIM frame, it retrieves the transmit time, calculates the Round Trip Time (RTT) & compares calculated RTT with round trip time in its neighbor list. If the value of the new calculated RTT is greater than its neighbor list, a node increases its ATIM window size.

During an ATIM window, if a node has successfully declared one ATIM frame to all destinations having pending packets & no window increasing rule defined above is satisfied, it means that current ATIM window size is big enough. In such cases the node decreases ATIM window size to ATIMmin.

To implement the protocol each node keeps a neighbor's list in which each entry has the fields as shown in Table 1

TABLE 1: FIELDS IN AN ENTRY IN A NEIGHBOR LIST

node id	round trip time	schedule

The neighbor discovery procedure works as follows:

Whenever node wakes up, it broadcasts a beacon piggybacking its own id, the transmit time & other information subject to channel contention or resolution. A new entry is added whenever a new neighbor is discovered.

Simulation results show that the proposed scheme performs better than the IEEE 802.11 power saving mechanism in terms of amount of power consumed and the packet delivery ratio.

Reference [4] proposes an energy efficient with controlled overhearing medium access control protocol for multi-hop mobile Ad hoc Networks (MANETs). In the 802.11 power saving mechanism (PSM) not all the packets are forwarded by the neighbors but also overheard even if it is not destined to itself. Allowing zero overhearing may affect the performance of path detection. Hence the proposed medium access protocol curbs the amount of overhearing in transmitter vicinity.

The protocol allows the sender to prefer controlled overhearing & unconditional overhearing for its neighbors. It is defined in the MAC management frame & neighboring nodes know the details during ATIM window.

The scheme uses unused subfield 1110_2 to state the controlled overhearing & subfield 1001_2 for unconditional overhearing.

The protocol working is given below

Upon receiving ATIM frame

If the node is intended destination /* then continue to wake up and receive*/

Else if /* controlled overhearing*/

For the distance is greater than set distance & remaining battery power is greater than threshold power then continue to wake up & receive

Otherwise

Switch to sleep state

Else if /* unconditional overhearing */

Upon being ready to send a frame

If control frame then unconditional overhearing

If data frame then conditional overhearing

The simulation is carried out in network simulator NS2 & performance is evaluated in terms of Packet Delivery ratio, Energy Utilization, Throughput & Delay. The protocol not only reduces the overall energy consumption but also improves the energy stability among nodes leading to network longevity.

Reference [5] presents a mechanism that improves the energy efficiency of Power Saving Mechanism specified for Distributed Coordination Function (DCF) in IEEE 802.11.

The protocol allows nodes to enter doze state in the middle of the beacon interval if they have completed all the transmissions that are explicitly announced during the ATIM window.

The terms used are CIT (Channel Ideal time) & CITThreshold (Channel Idle time Threshold). Current channel idle time is measured at the end of the ATIM window. The protocol works as follows:

Each node begins with ATIMmin.

When node finishes ATIM, node makes comparison of CIT with CITThreshold. If CIT is less than CITThreshold then node increases its ATIM window size by ATIMmin & restarts the ATIM window for ATIMmin. If CIT is greater than CITThreshold, the channel is ideal long enough to take it granted that no node transmits an ATIM frame. Thus in this case it is not necessary to increase its ATIM window size.

Simulation results show that proposed solution improves performance and energy savings over PSM in IEEE 802.11.

A distributed Multichannel Medium Access Protocol (MAC) for Multichip Cognitive Radio Networks is suggested in [6]. Sensing costs are evaluated & shown to contribute only 5 % of the energy cost. The protocol uses common control channel (CCC).

Each Cognitive Radio (CR) maintains two types of data structures. The SIP vector is called spectral image of Primary (SIP) Vector. The SCL vector is called secondary user's channel vector.

The SIP vector contains node local view. It has three types of entries.

No Primary user is active on the channel.

(SIP[c] =0),

Primary user is active on the channel. (SIP[c] =1),

The spectral image of the channel C is uncertain. (SIP[c] =2),

Fast scan is carried out in the data window when SIP value of the channel is uncertain.

Expressions are derived for following parameters

(a)False Alarm Probability

(b)Missed detection Probability

(c)Channel Vacate time (CVT)

(d)Channel Open Time (COT)

(e)The Probability of Channel is free for communication

(f)Throughput of Single Hop CR network

Simulation results demonstrate that simulation result significantly improve network performance by borrowing licensed spectrum band & primary user is protected from interference & even in hidden terminal situations. The scanning cost is compensated by reduction in overhearing cost to achieve 40% decrease in global energy consumption for the reference scenario.

Reference [7] presents TDMA based energy efficient multichannel medium access control (MAC) protocol called ECR-MAC for wireless Ad Hoc Networks. The protocol uses single half duplex radio transmitter receiver at each node. The protocol integrates spectrum sensing at physical layer and packet scheduling at MAC layer. The conventional MAC protocols adopt explicit frequency negotiation. In addition, this protocol introduces lightweight explicit time negotiation.

This two dimensional approach allows ECR-MAC to exploit advantage of both multiple channels & TDMA. It achieves aggressive power saving by allowing nodes that not involved in communication to go into doze mode.

The 802.11 MAC protocol is designed for single channel. A single channel MAC protocol does not works in multi-channel environment due to multichannel hidden terminal problem. This protocol gives solution to multichannel hidden terminal problem.

The secondary users identify and use unused frequency spectrum in such a way that it limits level of interference to primary user. The principal working methodology is based on communication segment which is function of channel & time slot. The communication segments are assigned based on data rate requirement of the session.

Simulation results show that ECR-MAC achieves high throughput, low end to end delay in an energy efficient way.

Reference [8], proposes an energy efficient cognitive radio protocol for Quality of Service (QOS) provisioning, and called ECRQ-MAC which is similar in principle to reference [7]. The protocol considers providing quality of service guarantee to CR users as well as to maintain the most efficient use of insufficient bandwidth resources. In the ECRQ-MAC structure sensing window occurs before control channel ATIM window. It avoids out of date spectrum sensing results. The system throughput of proposed MAC protocol is analyzed with mixed delay sensitive traffic and non-real time data traffic flows in a single hop network. The mathematical equation for total network throughput is derived.

Reference [10] considers three techniques to improve the power save protocol. In the first technique , CS-ATIM(carrier sensing), nodes use a short carrier sensing period at the beginning of each beacon interval to indicate whether there are any packets to be advertised or not and hence which decides whether ATIM window is necessary or not. When there are no packets to be advertised CS-ATIM uses much less energy in listening to the channel than 802.11 PSM.

In the second technique, D-ATIM nodes dynamically extend their ATIM window as long as ATIMs and ATIMACKs exist. Extension limit is imposed on ATIM window to avoid excessive ATIM window size. When no ATIMs and ATIMACKs are heard, nodes can either go to sleep mode or start sending and receiving data depending upon the situation. ATIM window size is reduced when there are no or very few packets are to be send. Larger ATIM window size is allowed when traffic is heavy. In D-ATIM improves packet latency by starting to send packets earlier than 802.11 PSM.

The third techniques is introduced by augmenting first two techniques viz. CS-ATIM and D-ATIM. Per link beacon interval is established between sender and receiver. The sender and receiver can separately schedule their wake up times different from other nodes in the network based on past packet arrival history. Simulation result show that such technique can improve per packet latency while maintaining low energy consumption.

III CONCLUSION:

Wireless devices need more energy efficient protocols. Such protocols are necessary to improve life of the battery and allow the devices to remain untethered as long as possible. The major disadvantage of 802.11 PSM is static ATIM window size irrespective of traffic pattern. This approach is not efficient practically. The ATIM window size needs to be adjusted depending on traffic pattern. Hence 802.11 PSM mechanisms are overviewed here with special priority to Distributed Coordination Function (DCF). The work throws light on dynamic ATIM window adjustment. This work will go long way in providing platform for anyone who wants to delve into 802.11 PSM for making ATIM window more dynamic and increasing energy efficiency.

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