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IEEE 802.11 Power Saving Mechanism –A Brief Survey

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ABSTRACT

As IEEE 802.11 Wireless Local Area Network (WLAN) becomes the prevailing technology for the broad band wireless Internet access, its power save mechanism which has been discovered to be naturally weak in supporting the mobility of mobile host (MH) when there is no traffic to be served for the MHs has become a key research issue. This paper examined some power save algorithm in literature in the light of their performance and complexity. It also pointed out major limitations with the existing schemes, which calls for more work in this area.

Keywords: *Wireless communication, location management, resource management*

1. INTRODUCTION

Mobility management is the support giving to mobile hosts (MHs), allowing users to roam while simultaneously offering them incoming calls and supporting calls already in progress. Mobility management consists of two components: Handoff management and Location management. In handoff management, the network switches coverage responsibility from one base station to another for an MH that has a call in progress and is moving from one cell to the other. In location management, the network tracks the users between call arrivals i.e. Location registration/Location update; and when connection needs to be established for a particular user, the network has to determine the user's exact location within the network, this is Terminal paging or searching [1]. The network to be searched is a group of network cells in one of which the mobile host is expected to be. As shown in Fig 1, an MH is always in either an active or standby state.

IEEE 802.11 Wireless Local Area Network (WLAN) is becoming the prevailing technology for the broad band wireless Internet access.However, IEEE 802.11 WLAN has been discovered to be naturally weak in supporting the mobility of mobile host (MH) when there is no traffic to be served for the MHs.

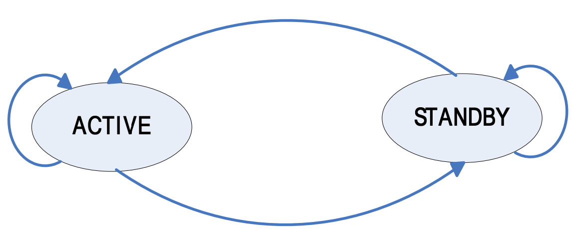

Fig 1: State Transition Diagram of Mobile Host

[Redrawn from Jiang, X. (2005)]

2. SURVEY OF SOME IEEE 802.11 POWER SAVING MECHANISMS

Several algorithms has been proposed to achieve a trade off between conflicting performance measures while still enhancing overall system performance. In what follows, we present a summary of some of the proposals in literature.

In 2006, Sunggeun Jin et al, proposed a Novel Idle Mode Operation in IEEE 802.11 WLANs [2] which comprises paging, idle handoff, and delayed handoff. The new procedure is compatible to IEEE 802.11 WLAN standard, in order to support the Idle Mode. Figure 2 shows the procedure when a wireless network interface card (WNIC) enters and leaves the Idle Mode. After a session completion, the WNIC transmits a Disassociation-Request frame with Power save Mode bit set to '1' in order to enter the Idle Mode. After receiving the corresponding Disassociation-Response from its AP, the WNIC in the IM can move around within the same paging area while the AP, which transmitted the Disassociation-Response, keeps the information for the WNIC to perform a handoff procedure in the future. This AP is referred to as Home-AP. After entering the Idle Mode, the WNIC starts listening to the beacons periodically (e.g., every 1s). Even when a WNIC recognizes the change of AP cell through the beacon information, the WNIC keeps listening to the beacons only as long as the WNIC stays in the same paging area.

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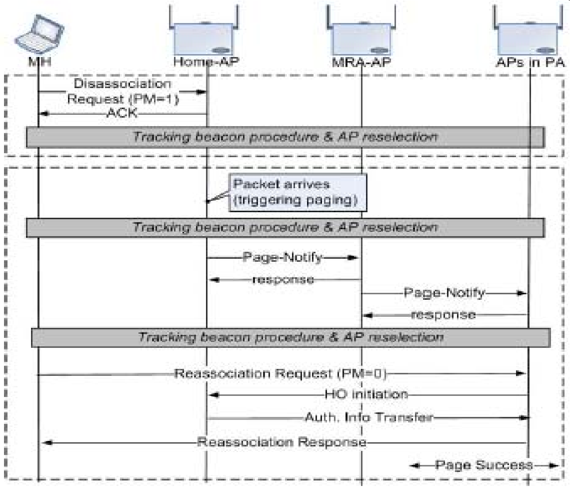

Fig 2: Procedure for the Idle Mode Operation (From Sunggeun Jin et al, 2006)

The proposed protocol was evaluated with an analytical model. The numerical results demonstrated that their proposed IM operation outperforms legacy schemes with respect to the power consumption. As a result, it enables a longer standby time of the 802.11-equipped mobile host.

Sukyoung et al proposed a Power-Efficient Interface Selection Scheme using Paging of WWAN for WLAN in Heterogeneous Wireless Networks [3]. When a WLAN interface card is connected to the wireless local area network, the interface card is usually idle for around 70% of the overall time excluding the time during which the interface is turned off [3]. They made known that the power consumption level for a WLAN interface card is greater than a WWAN interface, with and without power saving. Each cell in a WWAN may contain more than one WLAN hotspot because the service area of a Base Station (BS) is generally larger than that of a WLAN hot spot. Thus, in the idle state, the WWAN interface is assumed to listen continuously to Power Efficient Communication Protocol (PCP) to detect messages directed to all APs in its cell in addition to the messages addressed to it. This assumption is valid since the WWAN interface has to support the operation of frequent traffic compared with data traffic in WLAN. The proposed PCP scheme aims at limiting the WLAN power consumption, where the WLAN is made to consume power only when transmitting or receiving data. This is accomplished by turning off the WLAN interface without any periodic wake up during the idle period. This work focuses on the downlink traffic. According to PCP system, the Paging Channel (PCH) of a cellular network is utilized to provide information about all APs in its current cell. It assumed that serving GPRS support node (SGSN) (or the packet Control Function (PCF) in the CDMA can acquire the IP addresses and Service Set Identifiers (SSIDs) of all APs in its coverage area. In the PCP system, the IEEE 802.11 gateways serving the APs have a direct link to the SGSN either when the BSs are initialized or when APs are installed in the SGSN coverage area. Thus the SSID and the MAC address of each AP in an IEEE802.11 access network are registered with the corresponding SGSN during the initialization phase of the BS.

In a 3GPP system, the Radio Network Controller (RNC) is responsible for controlling user traffic between a user and the core network with buffers for different users. The PCP scheme uses a similar approach. Thus, for down link transmission, the BS notifies the mobile host when the number of packets in a per-user-buffer at the RNC reaches a certain threshold n (usually, less than the maximum buffer size) so that the mobile host does not consume its power due to frequent turn-on and off actions.

The expected number of packets at the RNC buffer is computed as:

$$E[i] = \sum_{i=0}^{N} ip_i = \frac{\alpha}{\alpha+\beta}\left\{\frac{1-p^N}{(1-p)^2} - \frac{Np^N}{(1-P)}\right\} \quad (1)$$

The numerical and simulation results obtained shows that the power consumed in a non communication state for PCP system is lower than a typical WLAN system.

Ved Kafle, Sangheon et al, in 2003, proposed the Performance Analysis of IP Paging Protocol in IEEE 802.11 Networks; they observed that in the next-generation mobile networks, the so called all-IP networks, the paging function will be supported in the IP layer [4]. They also observed that “when IP paging protocol is deployed in the IEEE 802.11 wireless networks, it may utilize the power saving mechanism supported in the IEEE 802.11 Standard for more efficient power management” [4]. Hence they carried out the performance analysis of IP Paging Protocol in IEEE 802.11 Networks. In evaluating the performance of IP paging protocol in the IEEE 802.11 networks they defined two types of cost: wake-up cost and paging delay cost. In IEEE 802.11 power save mode (PSM), MH in sleep mode wakes up periodically to check whether there are some incoming packets. In the current IEEE 802.11 PSM, the wake-up period is the same as beacon interval (typical values are in the order of 100 ms). However, when there exist a long idle period, waking up every beacon interval is unnecessary. In their analysis, they investigated the impact of the wake-up interval on the wake up cost ($C_{wake-up}$). They assumed that the minimum wake-up interval is a beacon interval and that the adjusted wake-up interval is an integer multiple of the beacon interval. If a paging request packet arrives during the sleep period then the MH can receive the paging request packet only at the next wake-up time. In other words when the IEEE 802.11 PSM is deployed in the wireless / mobile networks supporting IP paging, delay can occur. To represent this delay, they defined the paging delay cost (C_{delay}). Also, if the delay associated with a paging request packet is no longer than the given delay constraint, the session may be blocked. Therefore, the paging delay is related to the session blocking probability (P_B)

$$C_{total\ cost} = C_{delay} + C_{wake\text{-}up} \quad (2)$$

The wake-up cost, $C_{wake\text{-}up}$ is proportional to the number of wake-ups which occur during the inter-session time. The analytical results obtained indicated that the total cost is largely dependent not only on the session arrival rate but also on the length of wake-up interval.

In 2008, Anastasia et al, proposed a Power-Saving Mode for Mobile Computing in Wi-Fi hotspots…. They presented an analysis, in which they considered the typical Wi-Fi hotspot scenario, where a mobile user accesses the Internet through an Access Point [5]. They focused on best-effort Internet applications, such as Web browsing, e-mail, file transfer. This choice is motivated by the evidence that the traffic generated by these applications represents the lion's share of the today Internet traffic, and they are very likely to be the dominant applications also in the near-future Internet. However, the traffic model is general enough to represent also other best-effort applications, as well. They also investigated a broad range of the scenario parameters when evaluating PSM and XEM. Hence they believe their results are not valid only in the Web case. Furthermore, as far as the XEM definition, it is not heavily tied to the Web case, and can work with different applications.

Their main results can be summarized as follows. During traffic bursts PSM is quite effective and able to save up to 90% of the energy spent without energy management and it is able to significantly reduce the negative effect on energy consumption of low transport-level throughput and MAC-level contention. However, PSM is not very fit to deal with User Think Times between bursts; this originates from the fact that PSM switches the wireless interface to the sleep mode during any type of idle time.

Their results also shows that during long idle times, such as UTTs, switching the wireless interface to the off mode proves to be more energy efficient hence they proposed and evaluated XEM, a Cross-Layer Energy Manager that uses PSM during bursts, and switches it off during UTTs. XEM is able to achieve energy saving between 20% and 96% with respect to the standard PSM.

Eun-Sun Jung et al, in 2004 proposed an Improved Power Saving Mechanism (IPSM). The proposed scheme has two major differences from PSM. First, in IPSM, a node can adjust its ATIM window size based on observed network conditions. Second, IPSM allows a node to enter the doze state in the middle of beacon interval if it has completed all the transmissions that are explicitly announced during the ATIM window [6]. The latter is achieved by piggybacking the number of pending packets inside data packets. In their proposed scheme, a node uses only one ATIM frame to announce pending packets for the same destination during the same beacon interval". [6]. When the node transmits the actual data packets it includes the number of packets still pending for the destination. This information allows the destination node to determine when it has received all the packets pending at the source node at the time of data transmission. If the source node could not deliver all pending packets that were previously announced to the destination and the current beacon interval expires, both the source and destination stay up in the next beacon interval. During the next beacon interval the source transmits the remaining packets without additional ATIM frame. After that they may enter the doze state if they have no other announced pending packets to transmit or receive. Results obtained shows that the ATIM window size, which is a significant factor for both throughput and the energy consumption, is fixed in PSM and hence as the network load gets heavier; the desirable ATIM window size becomes large. However, in their proposed scheme, a node can adapt its ATIM window size based on observed network conditions. The scheme also allows a node to power off its wireless network interface whenever it has finished transmitting packets. Thus IPSM outperforms PSM with respect to energy savings.

In 2002, Yu-Chee Tseng et al, proposed a Power-Saving Protocols for IEEE 802.11-Based Multi-Hop Ad Hoc Networks [7]. In their work they presented three asynchronous power-saving protocols that allow mobile hosts to enter PS mode in a multichip MANET and derived several guidelines in their design. In other to prevent the inaccurate-neighbor problem, they proposed that a mobile host in PS mode should insist more on sending beacons. Specifically, a PS host should not inhibit its beacon in the ATIM window even if it has heard others' beacons since this will allow others to be aware of its existence. Hence, their protocols will allow multiple beacons in a ATIM window". [7]. As the proposed protocol do not count on clock synchronization, the wake-up patterns of two PS hosts must overlap with each other no matter how much time their clocks drift away. When a host hears another PS host's beacon, it should be able to derive that PS host's wake-up pattern based on their time difference. This will allow the former to send buffered packets to the later in the future. They also propose three power saving protocols, each with a different wake-up pattern for PS hosts. PS hosts' wake-up patterns do not need to be synchronous. For each PS host, it divides its time axis into a number of fixed-length intervals called beacon intervals. In each beacon interval, there are three windows called active window, beacon window, and MTIM window. During the active window, the PS host should turn on its receiver to listen to any packet and take proper actions as usual. The beacon window is for the PS host to send its beacon, while the MTIM window is for other hosts to send their MTIM frames to the PS host. Their MTIM frames serve the similar purpose as ATIM frames in IEEE 802.11; MTIM is used to emphasize that the network is a mutil-hop MANET. Excluding these three windows, a PS host with no packet to send or receive may go to the sleep mode. They were able to address the power management problem in a MANET which is characterized by unpredictable mobility, multi-hop communication, and no clock synchronization. Their results obtained shows that the proposed power-saving protocols can save lots of energies with reasonable route establishment probability.

In 2002, Eugene Shih et al, in their article titled "Wake on Wireless: An Event Driven Energy Saving Strategy for Battery Operated Devices" worked towards eliminating the power consumed when an IEEE 802.11b-enabled UCoM device is idle [8]. It was clear from their work that when a second, low-power channel is added, the proposed work is able to shut the rest of the system off and reduce the idle power. "At the same time, out-of-band control information can be sent to maintain connectivity and wakeup the UCoM device when necessary". [8]. They evaluated a concept, called wake-on-wireless that addresses Power consumption of battery-powered devices and were able to deduced that the lifetime of an iPAQ used in phone applications can be significantly improved by utilizing a wake-on-wireless technique with which they achieved a standby time of 30 hours, which is an improvement of almost 115% over an unmodified iPAQ with a wireless card in power save mode.

In 2011, Xavier P´erez-Costa et al, proposed a Static IEEE 802.11e Unscheduled Automatic Power Save Delivery. The U-APSD specification provided in the IEEE 802.11e standard introduces different mechanisms to control the QoS and power saving provided to a station for each different AC [9]. The specific implementation of these mechanisms to actually deliver the desired QoS is though, as usual, left open to allow differentiation between vendors. For the design of the U-APSD algorithm they assumed that the EDCA QoS parameters are properly set by a QoS algorithm at the AP to provide the required bandwidth and delay guarantees for the applications. Hence, they observed that upcoming mobile devices including wireless LAN access capabilities introduce new technological challenges that need to be addressed. They identified the combination of the 802.11e mechanisms EDCA and U-APSD as a key element toward the introduction of wireless LAN capabilities in the short-term in battery limited mobile devices. The main conclusions drawn from their results are: i) U-APSD significantly outperforms 802.11 power save mode in all considered performance metrics ii) the U-APSD performance metrics improvement results not only in better QoS and power saving but also in a considerable higher number of users/applications that can be accepted for the same channel capacity and iii) the usage of U-APSD for ACs which are not expected to have frames buffered frequently at the AP presents some particularities that have to be considered or otherwise use 802.11 power save mode.

In 2007, Xavier P´erez-Costa et al, proposed a Protocol Enhancement for IEEE 802.11 Distributed Power Saving Mechanisms. [10]. Unscheduled Automatic Power Save Delivery (U-APSD) is the distributed APSD method defined in 802.11e to improve the QoS provided to stations accessing the channel using the EDCA mechanism. The U-APSD design uses data frames sent in the uplink by stations (STA →AP) as indications of the instants when the power saving stations are awake. When such an indication is received at the AP from a power saving station, the AP takes advantage of it for delivering any data frames buffered while the station was in sleep mode. The Method has a specific functionality and hence it is specially suited for bi-directional traffic streams even though it provides alternative methods for its usage in other cases [10, 11]. "APSD has been designed such that it provides backwards compatibility to legacy terminals implementing the 802.11 power save mode only" [10, 11]. Therefore, all new functionality has been built on top of the already available 802.11 power save mode one re-using as much as possible without altering the original power save mode specification [10, 11]. The main difference between the power saving method defined in the 802.11 standard and APSD is that with APSD a station is awake during a Service Period instead of being awake from the transition to the awake state for receiving a Beacon until the return to the sleep state after acknowledging receipt of the last frame buffered at the AP through PS-Polls [10, 11]. The main conclusions from their work reveals that: NDAck significantly reduces the power consumption of stations running real-time applications and the larger the power consumption due to the congestion in the wireless channel the larger the power consumption reduction with NDAck and NDAck results in a considerable QoS improvement for real-time applications.

3. CONCLUSION

This article presented different proposals aimed at minimizing the power consumption by a mobile node in the IEEE 802.11 which is very vital to the overall functioning of the network and that of the mobile node. The works reviewed among others include: paging, idle handoff, and delayed handoff, Paging of WWAN for WLAN in Heterogeneous Wireless Networks, ATIM window size adjustment based on observed network conditions in IPSM, asynchronous power-saving protocols that allow mobile hosts to enter PS mode in a multihop MANET, "Wake on Wireless, the Unscheduled Automatic

Power Save Delivery and the Distributed Power Saving Mechanisms with no Data Acknowledgement. Another possibility is to employ the IEEE 802.11 network to solely search a mobile node based on the activities of the node so long as the node is within the paging area of the network and hence optimally minimizing the power consumption by the node.

REFERENCES

[1] Jiang, X. (2005). User Independent Paging Scheme for Mobile IP. Wireless Networks 12, 145–158, 2006: Springer Science + Business Media, Inc. Manufactured in the Netherlands.DOI: 10.1007/s11276-005-5262-2.

[2] Sunggeun, J.; Kwanghun, H. and Sunghyun C. (2006). A Novel Idle Mode Operation in IEEE 802.11 WLANs. Seoul, Korea: Seoul National University, School of Electrical Engineering and INMC.

[3] Sukyoung, L. and Nada, G. (2006). Power-Efficient Interface Selection Scheme using Paging of WWAN for WLAN in Heterogeneous Wireless Networks. Gaithersburg, MD, USA: National Institute of Standards and Technology Gaithersburg

[4] Ved, K. S. and Yanghee, C. (2003). Performance Analysis of IP Paging Protocol in IEEE 802.11 Networks. Seoul, Korea: Seoul National University, School of Computer Science & Engineering

[5] Anastasia G., Contib M., Gregorib E. & Passarellab A. (2008). 802.11 Power-Saving Mode for Mobile Computing in Wi-Fi hotspots: Limitations, Enhancements and Open Issues. Journal of Wireless Networks, Volume 14 Issue 6, Kluwer Academic Publishers Hingham, MA, USA.

[6] Eun-Sun J. and Nitin H. V. (2004).Improving IEEE 802.11 Power Saving Mechanism Department of Computer Science, Texas A&M University, College Station, TX 77843, USAEmail: esjung@cs.tamu.edu. Technical Report.

[7] Yu-Chee T., Chih-Shun H.&Ten-YuengH. (2002). Power-Saving Protocols for IEEE 802.11-Based Multi-Hop Ad Hoc Networks.INFOCOM 2002, Twenty-First Annual Joint Conferences of the IEEE Computer and Communications Societies. Proceedings. IEEE

[8] Eugene S., Paramvir B. & Michael J. S.(2002). Wake on Wireless: An Event Driven Energy Saving Strategy for Battery Operated Devices. Proceedings of the 8th annual international conference on Mobile computing and networking ACM New York, NY, USA.

[9] Xavier P., Albert V. and Daniel C. (2011) SU-APSD: Static IEEE 802.11e Unscheduled Automatic Power Save Delivery. 12th European Wireless Conference- Enabling Technologies for Wireless Multimedia Communications (European Wireless), Athens, Greece.

[10] Xavier P. and Daniel C. (2007) A Protocol Enhancement for IEEE 802.11 Distributed Power Saving Mechanisms No Data Acknowledgement.Proceedings of IST Mobile Summit 2007 Conference, Budapest, Hungary.

[11] Xavier P., Daniel C., and Albert V. (2006) On the Distributed Power Saving Mechanisms of Wireless LANs 802.11e U-APSD vs 802.11 Power Save Mode. NEC Network Laboratories, Kurf¨urstenanlage 36, 69115, Heidelberg, Germany