Energy-Aware Architecture for Wireless Ad Hoc Networks

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Abstract

Wireless Ad Hoc networking is a developing new field in technology; that is widely spread in a variety of civil and military applications. Ad Hoc network means a group of mobile terminals connected together wirelessly, and free to move in a bounded area. The battery life of those terminals is limited, therefore the energy efficiency of mobile terminal becomes an important consideration for mobile Ad Hoc wireless networks. Determining a power conservation protocol that minimizes the power consumption, will help the designer of such networks to design more efficient networks with longer life time. This paper presents a simulation study of sleep/ wake up, power save protocol (Modified Multilevel power save protocol MM3) based on IEEE 802.11b standard protocol. This protocol conducted to save more power with the acceptable network performance compared with earlier work; standard IEEE 802.11 power save mode (PSM) and two levels of multi-level power save protocols.

Keywords: *Ad Hoc network, Mobile Ad hoc Network (MANET), Wirless, Energy Aware ,Save Power.*

1. Introduction

Ad Hoc network achieves increased attention, as a means of connecting a group of small devices without infrastructure, because of the explosion of using portable wireless devices. Power management in such devices is extremely needed because they rely on a small battery as a power source. Generaly, the sources of power consumption in mobile devices, can be from computation related which concerned the usage of CPU and main memory or communication related [1] which concerned the use of transceivers to send or receive data.

In communication devices the transceiver is the most important chip, because it plays the significant role in the communication for both transmitter and receiver. Furthermore, any portable device will be on one of four modes: transmitting, receiving, idle, or sleep mode. Transmitting and receiving modes consume the maximum power, sleep mode consume the minimum power, while the idle mode consumes more power than last mode, but lower than the other two but considered as the main power wasting source [2].

The solutions previously investigate the power saving issue in wireless ad hoc networks can be classified in three groups: transmission power control, power aware routing and power mode. At transmission power control solution, for each host the protocol has to regulate the transmission power, to find the best network topology in term of power saving without loosing the network connectivity [3],[4],[5]. Where, in Power-Aware Routing solution the protocol determine the itinerary based on different power cost functions [6],[7]. Whereas, in Low-Power Mode solution, the mobile radio need to be awake periodically. A lot of wireless devices, which are supported IEEE 802.11 [8] can support low-power sleep modes produced by IEEE as PSM (Power Save Mode). This paper studies the power saving modes for IEEE 802.11-based ad hoc networks which fall into the last category of the above classification.

ISSN: 2005-4297 IJCA

This paper is organized as follows, second section talks about the related works. While the third section has defined the paper problem followed by the research objective in section four. After that, the methodology is discussed in section five and the results are shown in section six, then the conclusion is summarized in section seven.

2. Related works

Several low power mode protocols have been proposed for ad hoc networks this section show some of them. In [8], IEEE 802.11 Power Save Mode (PSM) protocol proposed, such that the network is synchronized, and its timeline divided into beacon intervals (BI), when the beacon interval starts all the nodes are waking up and stay on for a period called ATIM (Ad Hoc Traffic Indication Message window). In the period of the ATIM window, each node is listening, and an advertisement via ATIM packets is sending for the messages that have been queued to be send since the previous BI. The sending and receiving nodes stay on if send or receive ATIM packets, but the other nodes will go off. This procedure is illustrated in Figure 1. Node A has a message to node B, so they stay on after receiving ATIM packet, but node C does not receive any message on ATIM period, so it goes to sleep until the next beacon interval.

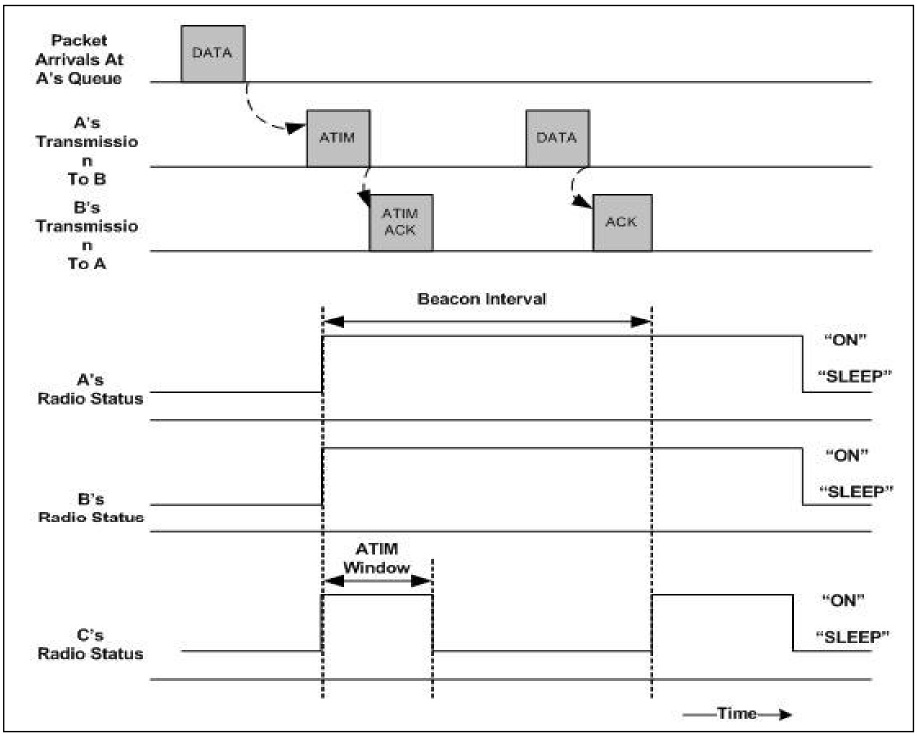

Figure 1: IEEE 802.11 Power Save Mode (PSM) [9]

In [4], an Ad Hoc routing for multi-level power save protocols proposed, this protocol based on IEEE802.11 PSM [8] with k save power levels. As seen in PSM, every node turn on at the beginning of every beacon interval, then turn off if there is no transmitting or receiving, but in this protocol, k levels of saving power are achieved by increasing the off state time for each level by a ***factor of 2***.

The protocol assumes that PS0 corresponds to the ‘‘always on’’ state where the nodes do not sleep and receive any packet immediately, but consume more energy. The next level, PS1 matches the implementation of the 802.11 PSM standard. In PS2, nodes wake up at the beginning of two beacon intervals, which save about twice energy than the level PS1 but doubling the latency to transmit or receive a package. If there is no transmission on PS2, the wake up time will increase to reach level PS3 and wake up every four ATIM windows, etc.. Figure 2 presents the idea clearly.

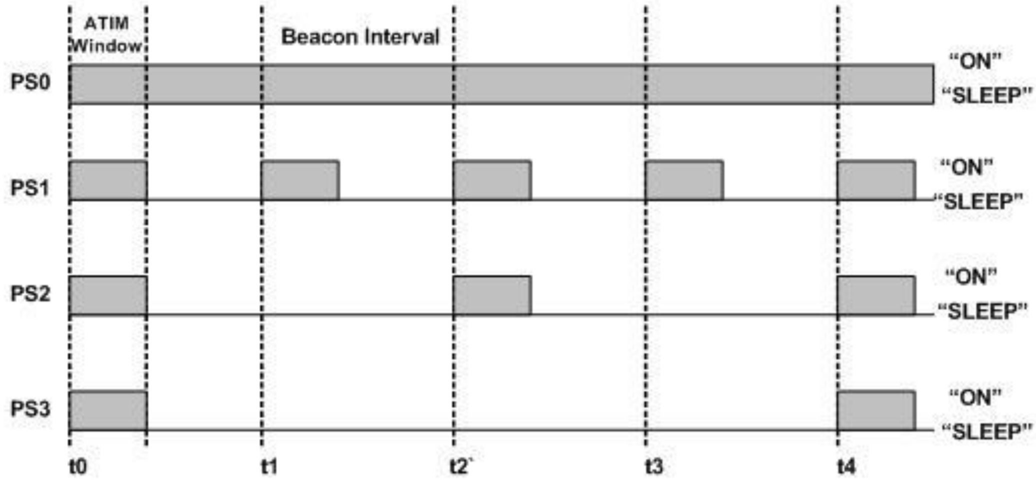

Figure 2: Multilevel Power Save Protocol [9]

3. Problem Definition

As we see in the related work, multilevel power saves [9] protocol adds k power levels to PSM which may arise some problems:

• Respectively sleep and wake up process: since the multi-level power save protocol assume that the nodes traverse from level to level respectively if there is a transmission or not, which mean that the response time of the network will increase and the performance will decrease. If the node has a packet to send, it will wait until next ATIM window which is mine so far because the node is in level k.

• Node sensitivity: as many as the node going into a deep sleep (level k), the node sensation about the outer environment changes will decrease, which is a critical issue in Ad hoc network which is working in a cooperative manner.

• Moving from power level to another by a factor of 2: at k=1, the standard ratio between ATIM window interval and beacon window interval is 10%. By moving to level k=2, this ratio will be 20%, and for k=3, the ratio will be 40% and so on. The difference between the first and second ratio is very large, which will affect the performance of the network.

According to the above discussion, we develop several strategies in the proposed plan:

• Determining the k level of multilevel power save protocol into two levels: to save more power than standard PSM, with acceptable performance.

• Move from level to level by a factor of 1: to decrease the latency of the network.

• Wake up immediately if there are packets to send: by benefit from the point of some of the network nodes work at level 1 and some of them work at level 2 and so on.

Based on the above strategies we propose a protocol called Modified Multi Level Power Save Protocol with k=3 (MM3). The essential idea of this approach is derived from multi-level power save protocol with k=3 (moving from level to level by a factor of one). This protocol is developed as follows; Each PS (Power Save) host divides its time axis

ISSN: 2005-4297 IJCA

into beacons, those beacons are fixed equal time periods, with an ATIM window at the beginning. Going from level 1 to level 3 without entering to level 2 (not respectively); if there is the transmission the PS host will move to level 1 if not the PS host will go to level 3.

If the PS host is at level 1; then the PS host wakes up at the ATIM window of every beacon interval, but if PS host is at level 3 the wake up process will base on beacon sequence number. If the beacon sequence number is divided by the station level, wake up else continue sleeping.

The proposed idea is compared with the first two levels of multilevel power save protocol (k=2, 3 which called (M2, M3) moving from power save level to another by a factor of one) and the standard PSM protocol.

4. Research Objectives

As wireless devices rely on battery power source to work properly, and this battery need to recharge frequently. The power management can provide a battery with long lifetime, which is better for wireless networks. This paper conduct a protocol to save more power with the acceptable network performance compared to the earlier works.

5. Methodology

To evaluate the performance of the proposed protocols, the scenarios were created by QualNet simulator, which verify the proposed characteristics (addressed in section 3) and then compare the protocols. Four factors are adjusted in the simulations; Host density, Beacon interval, Mobility and Auto multi-rate capability.

Each scenario for this comparison is created as follows: 30 nodes randomly distributed over a 1000m x 1000m terrain; each node has a total energy of 100 MJ. Fifteen nodes are randomly picked to send CBR (Constant Bit Rate) packet, to another randomly picked destination at a rate of 10 packets per second for 100 seconds.

The usesd routing protocol is AODV (Ad Hoc On-Demand Distance Vector) [11] to send each CBR from the origin to the destination. The 802.11 MAC and physical wireless parameter were adjusted to match the published specification of Cisco Aironet 802.11A/B/G Wireless CardBus Adapter [12].

Four factors are adjusted in the simulations:

- **Host density:** between 30 to 50 hosts, where the network area is fixed.
- **Beacon interval:** the beacon period is last for 100 ms to 400 ms.
- **Mobility:** mobility of the hosts follows the random waypoint model. When moving, the node will move at a velocity between 0 and 20 ms, with pause time set to 30s.
- **Auto multi-rate:** we use auto multi rate capability (already implemented in the simulator) with the proposed power saving protocol and compare it with a fixed rate protocol (2Mbps).

Each experiment run's last for 100 seconds. But, when evaluating the survival ratio of the hosts in the network, the simulation will stop when all hosts run out of energy.

6. Results and Discussion

This section presents the outcome of each measured parameter separately as follow:

6.1 Impact of Beacon Interval Length

The node's must be sensitive to the environment changes but that affecte by the length of beacon intervals . To detect its effect, we change the beacon length from 100 ms to 400 ms as figure 3 shows, longer beacon will decrease the throughput, and we can see that the throughput of MM3 is closer to the standard PSM, These results confirmed with the proposed idea in this paper. Likewise, we can see in figure 4 that the energy will save with longer beacon as expected. Figure 5 shows that longer beacon interval extent the network lifetime, because the ratio of wake up period for each node becomes smaller.

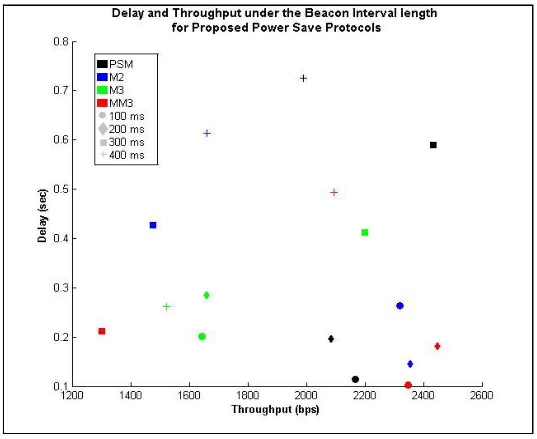

Figure 3: Impact of Beacon interval length On the total throughput and Delay

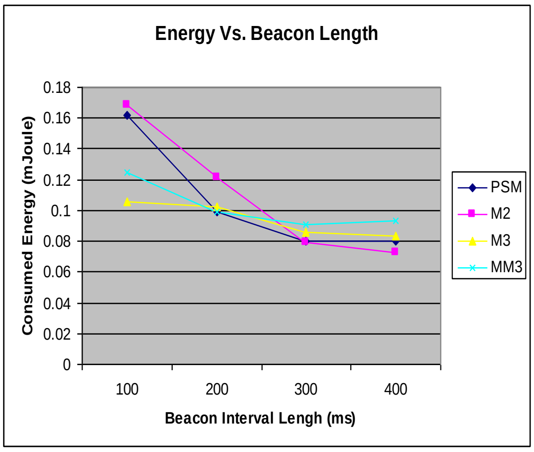

Figure 4: Consumed energy vs. beacon interval length (30 hosts, mobility 10 m/s)

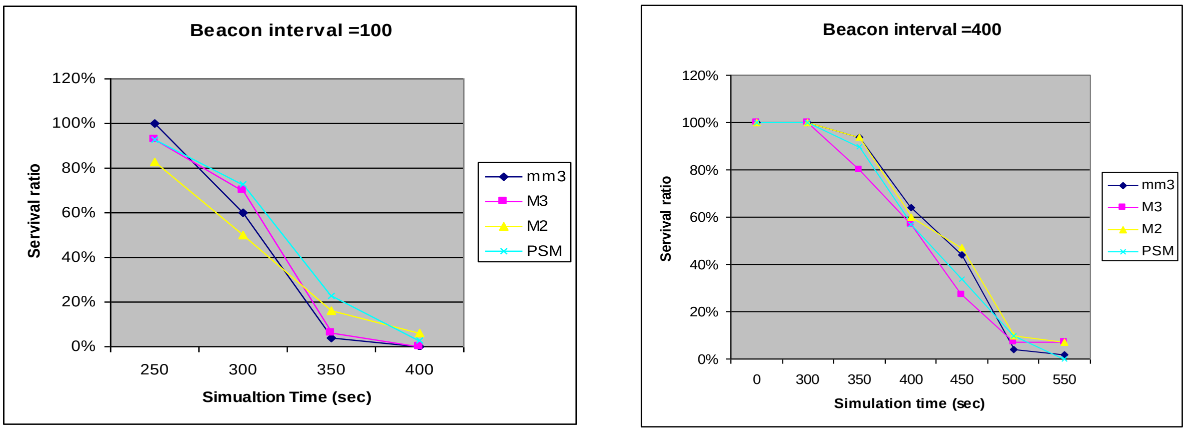

Figure 5: Host survival ratio vs. beacon interval length (30 hosts, mobility 10 m/s) Energy Vs. Beacon Length

6.2 Impact of Mobility

Figure 6 plots throughput and delay vs. mobility (30 hosts, beacon 100s). It shows the impact of mobility on throughput and delay, which is a negative impact because the link broke between nodes because of mobility and the need to retransmission and drop of some packets. While, figure 7 shows that mobility has a positive effect on the consumed energy which is identical to the result of the survival ratio in figure 8.

ISSN: 2005-4297 IJCA

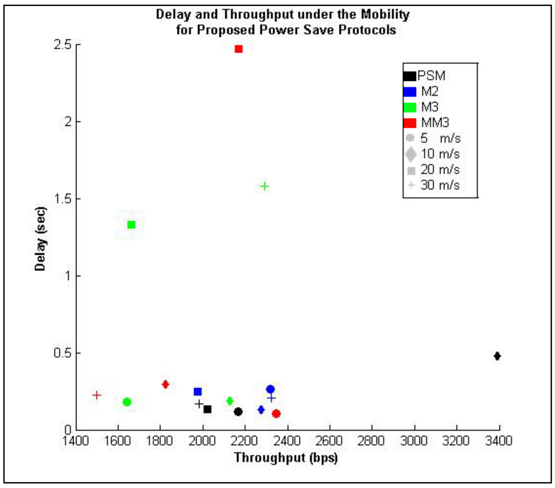

Figure 6: Throughput and delay vs. mobility (30 hosts, beacon 100s)

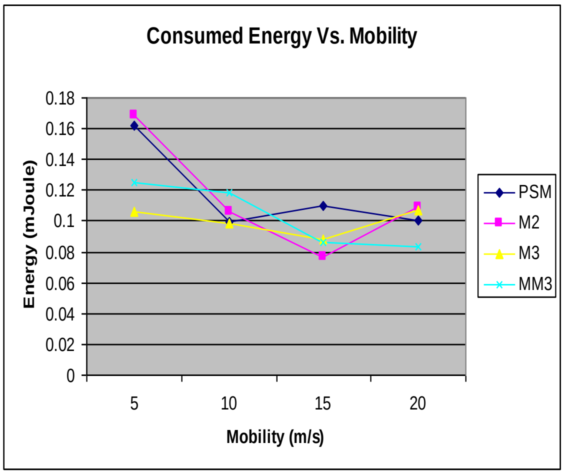

Figure 7: Consumed energy vs. mobility (30 hosts, beacon 100s)

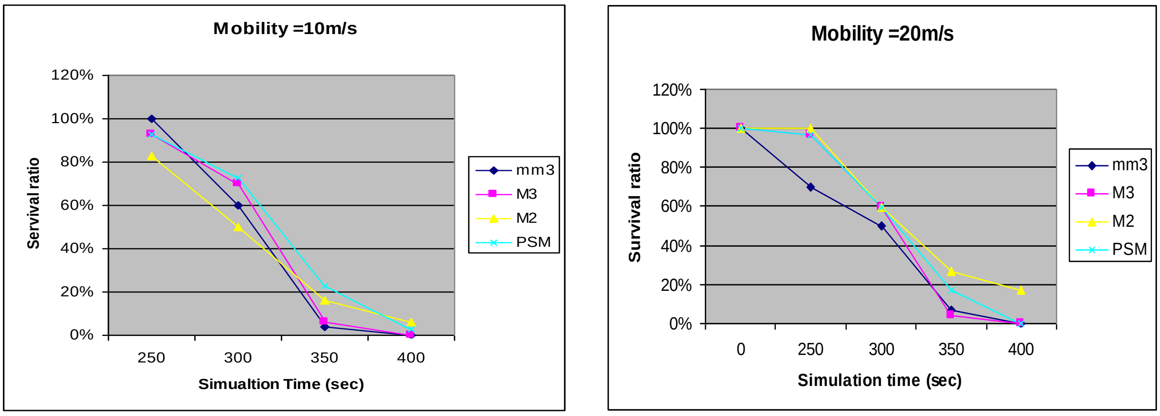

Figure 8: Host survival ratio vs. mobility (30 hosts, beacon 100s)

6.3 Impact of Node Density

To investigate this impact, we fix the network area as (1000*1000) and vary the total number of hosts between 30 and 50 nodes. The Impact of throughput and delay vs. node density (mobility 10m/s, beacon 100s) is in figure 9. It shows that when the node density becomes higher, the throughput is down and so is the delay. In denser networks, collision and congestion may become the reason that causes throughput and delay to become down. Overall, we can see that the performance of MM3 is stable in denser networks while other protocols perform worse in the same state. On the other hand, figure 11 shows that by maximizing the node density the total network lifetime is maximized because there is lower throughput, which preserve the energy of receiving packets, which is supported also by figure 10.

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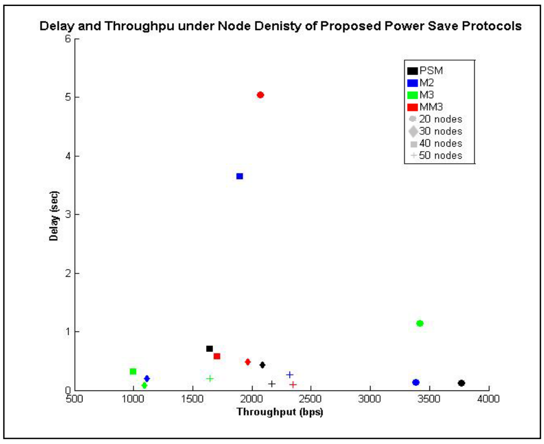

Figure 9: Throughput and delay vs. node density (Mobility 10m/s, beacon 100s, 100s simulation)

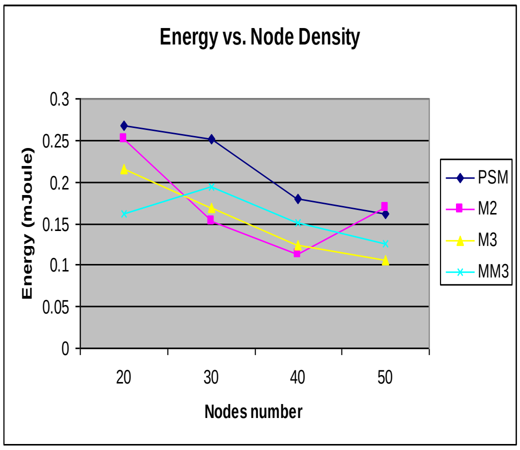

Figure 10: Consumed energy vs. node density (Mobility 10m/s, beacon 100s, 100s simulation)

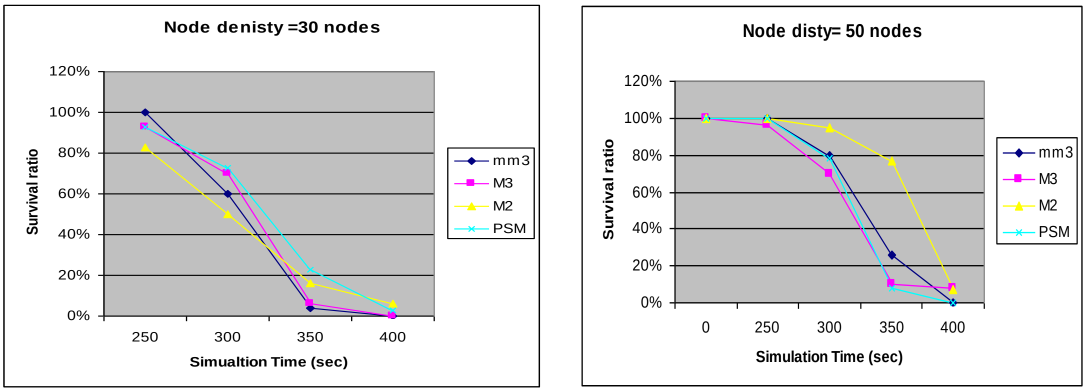

Figure 11: Survival ratio vs. node density (mobility 10m/s, beacon 100s)

6.4 Impact of Using Auto Multi-rate Protocols

To investigate this impact, we use the auto multi-rate ability to send the data between network nodes and calculate the network performance in term of throughput and delay, which is plotted in figure 12 (mobility 10m/s, beacon 100s, 30 nodes). It indicates that the throughput increases using auto multi-rate for all protocols and so does the delay. This is expected because if the throughput is high the delays in wireless networks are unavoidable, according to the effect of propagation time and multipath problem.

Figure 13, plots consumed energy vs. auto multi-rate. It shows the impact of using auto multi-rate protocols on the consumed energy which is expected to be lower than using fixed rate. This is because sending with a higher rate at some links will be consuming more energy, but sending more data will keep the node idle for more times, which save the energy. This energy may be required to send and forward data than sending with a fixed rate. The total network lifetime is virtually the same as shown in figure 14, which plots the survival ratio vs. auto multi-rate.

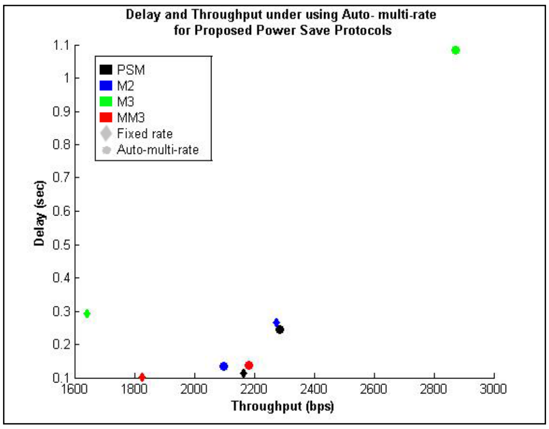

Figure 12: Throughput and delay vs. Auto multi-rate (10m/s, beacon 100s, 30 nodes)

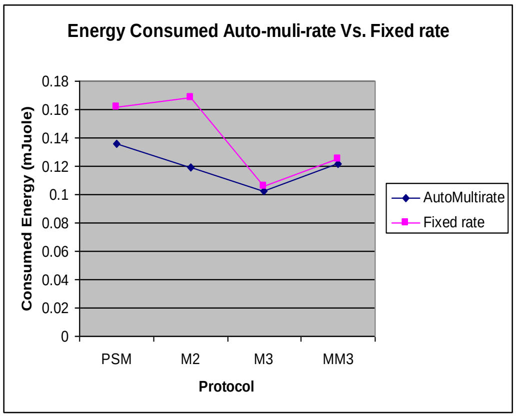

Figure 13: Consumed energy vs. Auto multi-rate, (10m/s, beacon 100s, 30 nodes, fixed rate= 2Mbps)

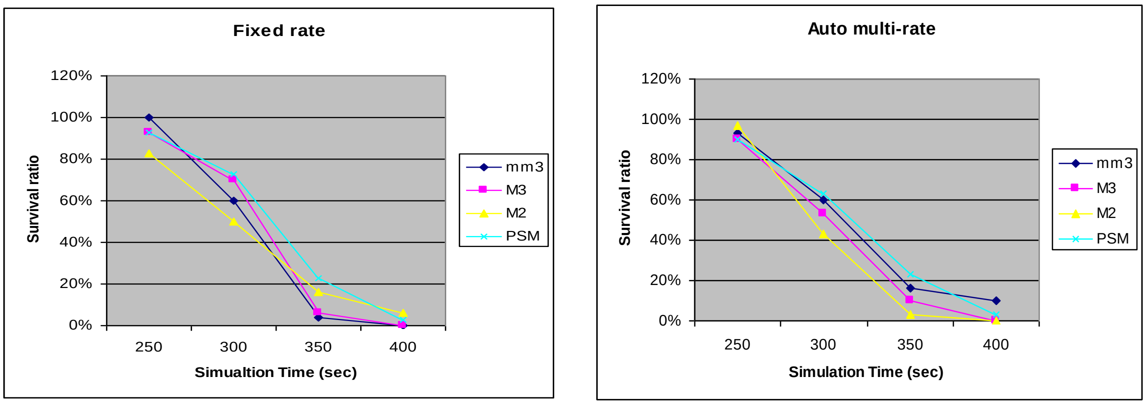

Figure 14: Survival ratio vs. Auto multi-rate, (mobility 10m/s, beacon 100s, 30 nodes, fixed rate= 2Mbps).

7. Conclusion

This paper addresses the power saving problem in wireless ad hoc networks, which is considered by multi-hop communication. As a solution, we have proposed a power saving protocol and compare it with three other power saving protocols. These protocols are; IEEE Power Save mode, and two levels of the Multi level power save protocol (level 2, and 3).

Simulation results have shown that the proposed power saving protocol Modified Multilevel power save protocol (MM3) can save lots of power compared with two levels of the Multi level power save protocol (level k=2, 3) with good performance closer to PSM standard protocol. Likewise, we find that using auto multi-rate protocol, the performance will increase, and the consumed power will diminish. Transmission in the wireless network affected by the channel characteristics, the good channel characteristics the more data can be sent at a shorter time, which save power for a longer time. Finally, we recommend activating auto multi-rate protocol, and to specify the level of multi power level protocol to just two levels because when the node go into more than 2 level the performance will decrease and it is not fitting with the Ad Hoc network. Also, we recommend the proposed power save protocol (MM3) because it presents good performance on the experiment.

References

[1] C. E. Jones, K. M. Sivalingam, P. Agrawal, and J. C. Chen, "A survey of energy efficient network protocols for wireless networks," *wireless networks*, vol. 7, pp. 343-358, 2001.
[2] L. M. Feeney and M. Nilsson, "Investigating the energy consumption of a wireless network interface in an ad hoc networking environment," in *INFOCOM 2001. Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, 2001, pp. 1548-1557.
[3] S.-L. Wu, Y.-C. Tseng, and J.-P. Sheu, "Intelligent medium access for mobile ad hoc networks with busy tones and power control," *Selected Areas in Communications, IEEE Journal on*, vol. 18, pp. 1647-1657, 2000.
[4] L. Hu, "Topology control for multihop packet radio networks," *Communications, IEEE Transactions on*, vol. 41, pp. 1474-1481, 1993.
[5] R. Ramanathan and R. Rosales-Hain, "Topology control of multihop wireless networks using transmit power adjustment," in *INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, 2000, pp. 404-413.
[6] S. Singh, M. Woo, and C. S. Raghavendra, "Power-aware routing in mobile ad hoc networks," in *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking*, 1998, pp. 181-190.
[7] I. Stojmenovic and X. Lin, "Power-aware localized routing in wireless networks," *Parallel and Distributed Systems, IEEE Transactions on*, vol. 12, pp. 1122-1133, 2001.
[8] I. L. M. S. Committee, "Wireless LAN medium access control (MAC) and physical layer (PHY) specifications," *IEEE Standard*, vol. 802, 1999.
[9] M. J. Miller and N. H. Vaidya, "Ad hoc routing for multilevel power save protocols," *Ad Hoc Networks*, vol. 6, pp. 210-225, 2008.
[10] Scalable Network Tech. Qualnet, http://www. scalable-networks.com.
[11] C. Perkins, E. Belding-Royer, and S. Das, "Ad hoc on-demand distance vector (AODV) routing," 2070-1721, 2003.
[12] C. Aironet, "802.11 a/b/g Wireless CardBus Adapter," *Data Sheet [on line at http://www. cisco. com]*, 2007.

ISSN: 2005-4297 IJCA