IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 5, Oct-Nov, 2013
ISSN: 2320 - 8791
www.ijreat.org

The Power Control MAC Using RIMA in Ad-Hoc Networks

Vikhyath K B[1] , Chethan B K[2] and Dr. K Karunakara[3]

[1]**Department of Information Science & Engineering, Sri Siddhartha Institute of Technology, Tumkur-572105, India.**

[2]**Department of Information Science & Engineering, Sri Siddhartha Institute of Technology, Tumkur-572105, India.**

Abstract

An Ad Hoc wireless is a collection of mobile hosts that communicates via wireless links in a multi-hop fashion without the aid of any established infrastructure or centralized servers. Mobile hosts are usually powered by batteries which provide a limited amount of energy. Power plays an important role in energy saving and network performance enhancement.

This paper addresses the issue of transmission power control (TPC) schemes in wireless Ad Hoc networks. In BASIC scheme of power control MAC protocol maximum transmit power is used for RTS-CTS and minimum transmit power is used for DATA-ACK in order to save energy. But this protocol is more prone to collisions and degrades network throughput. Hence, an improved power control MAC protocol PCM is proposed to achieve power saving and to overcome the shortcomings of BASIC scheme of power control MAC protocol. In this PCM to save energy and to overcome collisions DATA-ACK are transmitted with maximum power periodically. The PCM protocol still does not solve the problem of collisions thus leading to degraded network throughput and delay at higher level. And also these schemes face hidden and exposed terminal problems.

To overcome hidden and exposed terminal problem a novel distributed power control protocol, Receiver Initiated power control Multi-Access (RIMA) protocol is proposed. And also an enhanced version of RIMA is proposed where RTS power transmission is reduced to improve the spatial reuse of wireless channel. Thus the proposed protocol yields energy saving which increases network throughput by eliminating hidden and exposed terminal problem and improves the spatial reuse by reducing collisions.

Keywords: *Ad-Hoc, Wireless, Throughput, Power control.*

1. INTRODUCTION

Wireless hosts are usually powered by batteries which provide a limited amount of energy. One way to conserve energy is to use power saving mechanisms. Power saving mechanism allows a node to enter a doze state by powering off its wireless network interface when deemed reasonably [2, 8]. Another alternative is to use power control schemes which suitably vary transmit power to reduce energy consumption [1, 4, 5, 6]. In addition to providing energy saving, power control can potentially be used to improve the spatial reuse of wireless channel.

A simple power control protocol has been proposed based on RTS-CTS handshake in the context of IEEE 802.11[1, 6, 10, and 15]. Different power levels among different nodes introduce asymmetric links. Therefore in the above scheme, RTS and CTS are transmitted using the highest power level and DATA and ACK are transmitted using the minimum power level necessary for the nodes to communicate. But this scheme has a shortcoming, which increases collisions and degrades network throughput. Therefore a new power control protocol which does not degrade throughput is proposed. PCM periodically increases the transmit power to maximum power during DATA packet transmission. With this change, nodes that can potentially interfere with the reception of ACK at the sender will periodically sense the channel as busy and defer their own transmission. The PCM protocol still does not solve the problem of collisions, thus leading to degraded network throughput and delay at higher network load. It also suffers from hidden and exposed terminal problems.

In order to resolve hidden terminal problem and reduce the exposed terminal problem, we present a new power control protocol called Receiver Initiated power control Multi-Access (RIMA).

2. Related Work

A power control mechanism can be incorporated into the IEEE 802.11 RTS-CTS handshake proposed in [10, 15]. The scheme in [15] allows a node, A, to specify its current transmit power level in the transmitted RTS, and allows receiver node B to include a desired transmit power level in the CTS sent back to A. On receiving the CTS, node A then transmits DATA using the power level specified in the CTS. This scheme allows B to help A choose the appropriate power level, so as to maintain a desired signal-to-noise ratio.

A similar protocol is utilized in [6], wherein the RTS and CTS packets are sent at the highest power level, and the DATA and ACK may be sent at a lower power level. We refer to this scheme as the BASIC power control MAC protocol. We found that the basic scheme has a shortcoming that can degrade the throughput furthermore the BASIC scheme may potentially increase the energy consumption, instead of decreasing.

Transmit power is controlled according to packet size in [4, 5]. The proposed scheme is based on the observation that reducing transmission power can result in energy savings, but can also result in more errors. A higher bit error rate can lead to increased retransmissions, consuming more energy. Thus, the protocol in [4, 5] chooses an appropriate transmission power level based on the packet size.

The hidden and exposed terminal problem been used to solve busy tone signal from the receiver using a separate channel with or without power control .The dual channel approach improves the network utilization.

A single-channel MAC protocol has been proposed in [16] allows more than one power control transmission within the transmission vicinity of a node by staggered handshake approach. After a transmit-receive pair decides on data transmission the transmitter waits for certain duration to allow a nearby transmitter to do handshake for a parallel transmission. This approach helps increase network throughput and possibly reduce per bit energy consumption with respect to 802.11 DCF without power control. However this protocol does not eliminate the hidden and exposed terminal problem completely.

3. IEEE 802.11 Mac Protocol

IEEE 802.11 specifies two medium access control protocol PCF (Point Coordination Function) and DCF (Distributed Coordination Function). PCF is centralized scheme where as DCF is fully distributed scheme.

We now define the terms Transmission range, Carrier sensing range and Carrier sensing zone.

1) Transmission range: When a node is with in transmission range of sender node, it can correctly decode packets from the sender node.

2) Carrier sensing range: Nodes in the carrier sensing range can sense the sender’s transmission. Carrier sensing range is typically larger than the transmission range, for instance, two times larger than the transmission range[9].Note that the carrier sensing range and transmission range depend on the transmit power level.

3) Carrier sensing zone: When a node is with in carrier sensing zone, it can sense the signal but cannot decode it correctly.

Figure 1 shows the transmission range carrier sensing range and carrier sensing zone for node C. When a node C transmits a packet B and D can receive and decode it correctly since they are in transmission range.

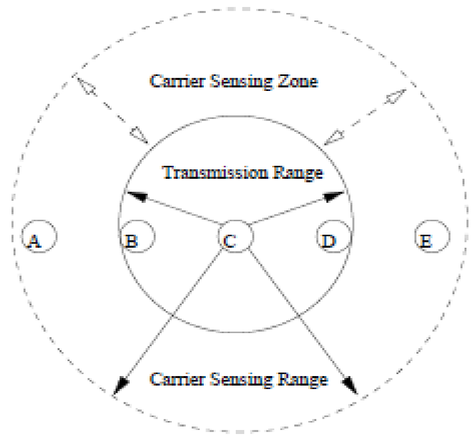

Fig1.Nodes in different transmission ranges.

However, A and E only sense the signal and cannot decode it correctly because they are in carrier sensing zone.

4. Basic Power Control Mac Protocol

4.1 Protocol Description

As mentioned earlier, power control can reduce energy consumption. However power control may introduce

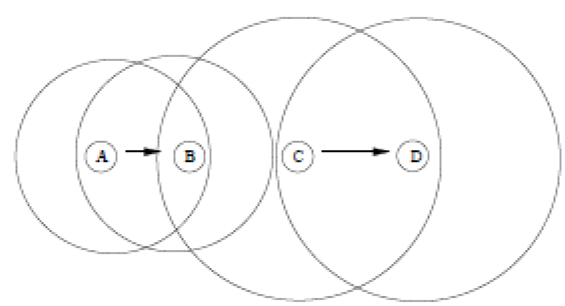

Fig 2.Differences in transmit power can lead to increased collisions.

different transmit power levels at different hosts, creating an asymmetric situation where a node A can reach node B, but B cannot reach A.

Different transmit powers used at different nodes may also result in increased collisions, unless some precautions are taken. Suppose nodes A and B in Figure 2 use lower power than nodes C and D. When A is transmitting a packet to B, this transmission may not be sensed by C and D. So, when C and D transmit to each other using a higher power, their transmissions will collide with the on-going transmission from A to B. One simple solution (as a modification to IEEE 802.11) is to transmit RTS and CTS at the highest possible power level but transmit DATA and ACK at the minimum power level necessary to communicate, as suggested in [1, 6, 10, 15]. We refer to this as the BASIC scheme. Figure 3 illustrates the BASIC scheme. In Figure 3, nodes A and B send RTS and CTS, respectively, with the highest power level so that node C receives the CTS and defers its transmission. By using a lower power for DATA and packets, nodes can conserve energy.

The BASIC scheme, the RTS-CTS handshake is used to decide the transmission power for subsequent DATA and ACK packets. This can be done in two different ways as described below. Let P_{max} denote the maximum possible transit power level.

Suppose that node A wants to send a packet to node B. Node A transmits the RTS at power level Pmax. When B receives the RTS from A with signal level P_r, B can calculate the minimum necessary transmission power level, Pdesired, for the DATA packet based on received power level Pr, the transmitted power level, Pmax, and noise level at the receiver B. Node B then specifies Pdesired in its CTS to node A. After receiving CTS, node A sends DATA using power level Pdesired. Since the signal-to-noise ratio at the receiver B is taken into consideration, this method can be accurate in estimating the appropriate transmit power level for DATA.

In the second alternative, when a destination node receives an RTS, it responds by sending CTS as usual (at power level Pmax). When the source node receives the CTS, it calculates Pdesired based on received power level, Pr, and transmitted power level (Pmax), as Pdesired= (Pmax/Pr)*Rxthresh*C Where Rxthresh is the minimum necessary received signal strength and C is a constant. We set C equal to 1. Then, the source transmits DATA using a power level equal to Pdesired. Similarly, the transmit power for the ACK transmission is determined when the destination receives the RTS.

This method makes two assumptions. First, signal attenuation between source and destination nodes is assumed to be the same in both directions. Second, noise level at the receiver is assumed to be below some predefined threshold. This approach may result in unreliable communication when the assumptions are wrong. However, it is likely to be reliable with a fairly high probability. This alternative does not require any modification to the CTS format. As we now explained, the BASIC scheme can lead to increased collisions, degrading throughput.

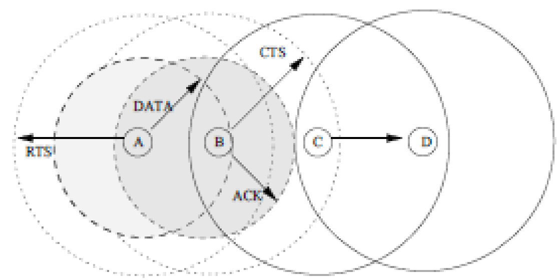

Fig 3.BASIC scheme RTS-CTS are transmitted in highest transmission power level.

4.2 Deficiency of the BASIC Protocol

In the BASIC scheme, RTS and CTS are sent using P_{max}, and DATA and ACK packets are sent using the minimum necessary power to reach the destination. When the neighbor nodes receive an RTS or CTS, they set their NAVs for the duration of the DATA-ACK transmission. For example, in Figure 4, suppose node D wants to transmit a packet to node E. When D and E transmit the RTS and CTS respectively, B and C receive the RTS, and F and G receive the CTS, so these nodes will defer their transmissions for the duration of the D-E transmission. Node A is in the carrier sensing zone of D (when D transmits at P_{max}) so it will only sense the signals and cannot decode the packets correctly. Node A will set its NAV for EIFS duration when it senses the RTS transmission from D. Similarly, node H will set its NAV for EIFS duration following CTS transmission from E. When transmit power control is not used, the carrier sensing zone is the same for RTS-CTS and DATA-ACK since all packets are sent using the same power level. However, in BASIC, when a source and destination pair decides to reduce the transmit power for DATA-ACK, the transmission range for DATA-ACK is smaller than that of RTS-CTS similarly, the carrier sensing zone for DATA-ACK is also smaller than that of RTS-CTS.

When D and E in Figure 4 reduce their transmit power for DATA and ACK transmissions respectively, both transmission range and carrier sensing zone are reduced. Thus, only C and F can correctly receive the

DATA and ACK packets, respectively. Furthermore, since nodes A and H cannot sense the transmissions, they consider the channel to be idle. When any of these nodes (A or H) starts transmitting at the power level p_{max}, this transmission causes a collision with the ACK packet at D and DATA packet at E. This results in throughput degradation and higher energy consumption.

As discussed in Section 3, IEEE 802.11 also does not prevent nodes in the carrier sensing zone (node H in Figure 4) from causing collisions with the DATA packet at the destination node (node E in Figure 4). However, BASIC makes the situation worse by introducing interference with the reception of an ACK at the source node. Using BASIC, node A in Figure 4 cannot sense

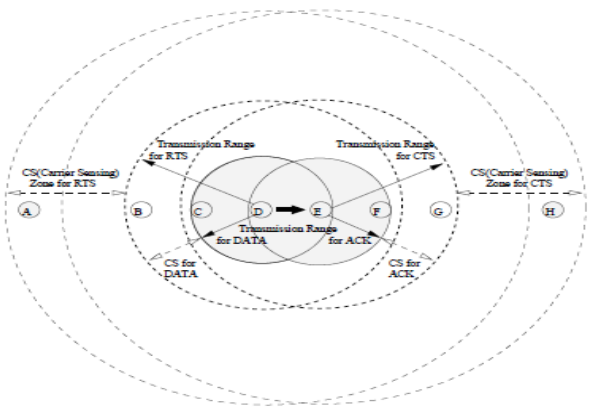

Fig.4 BASIC scheme

D's DATA transmission at the lower power level, so a transmission from A can interfere with the reception of the ACK at D.

The above discussion indicates that the BASIC scheme is more prone to collisions, degrading throughput . The BASIC scheme has been considered for saving energy [1, 6, 10, 15]. However, past work did not identify the above deficiency of the BASIC protocol.

5. Proposed Power Control Mac Protocol

Proposed Power Control MAC (PCM) is similar to the BASIC scheme in that it uses power level P_{max} for RTS-CTS and the minimum necessary transmit power for DATA-ACK transmissions. We now describe the procedure used in PCM.

1. Source and destination nodes transmit the RTS and CTS using P_{max}. Nodes in the carrier sensing zone set their NAVs for EIFS duration when they sense the signal and cannot decode it correctly (similar to the variation on IEEE 802.11 described earlier).

2. The source node may transmit DATA using a lower power level, similar to the BASIC scheme.

3. To avoid a potential collision with the ACK (as discussed earlier), the source node transmits DATA at the power level P_{max}, periodically, for just enough time so that nodes in the carrier sensing zone can sense it.

4. The destination node transmits an ACK using the minimum required power to reach the source node, similar to the BASIC scheme.

5. Periodic transmission of pulsed busy tones at maximum power by the receiver (during which the transmitter does not send data to the receiver) to eradicate the hidden terminal problem. We call this approach as basic RIMA (or b-RIMA).

6. Reduced power RTS transmissions to minimize the exposed terminals problem and hence increase spatial reuse. We call this approach as enhanced RIMA (or e-RIMA).

Figure 5 shows how the transmit power level changes during the sequence of an RTS-CTS-DATA-ACK transmission. After the RTS-CTS handshake using P_{max}, suppose the source and destination nodes decide to use power level p1 for DATA and ACK. Then, the source will transmit DATA using p1 and periodically use P_{max}. The destination uses p1 for ACK transmission.

The b-RIMA protocol

The transmitter and the receiver transmit the RTS and CTS at Pmax. If a node in the carrier sensing zone receives but fails to decode a signal, it sets its NAV (network allocation vector) to an EIFS duration.

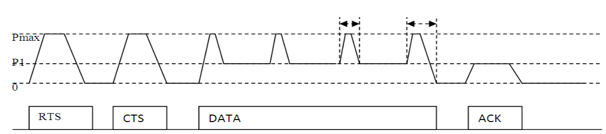

Fig.5The data frame.

The transmitter transmits the data at P_{min}, the minimum power required to carry out successful communication, which can be decided based upon the receiver's receive threshold, transmitter-to- receiver distance, and the existing signal-to-interference-and-noise (SINR) level.

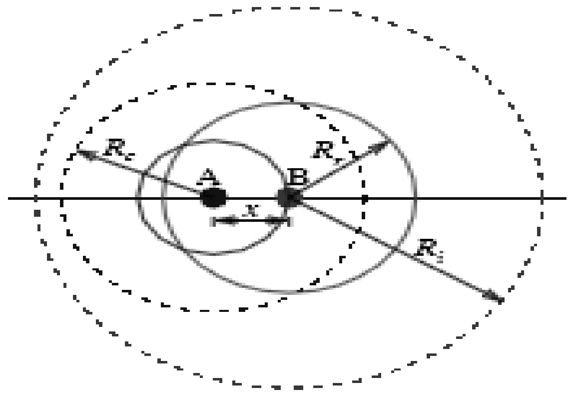

Fig 6. Elimination of hidden terminal problem in b-RIMA protocol.

Since the data frame is transmitted at Pmin, the transmitter is susceptible to interference at the time of receiver the frame acknowledgement (ACK). However, ACK frame being very short, its error probability would be low. To minimize further this error, an ACK is transmitted by the receiver at maximum power level Pmax.

Periodic busy tone from the receiver in the b-RIMA protocol eliminates the hidden terminal problem, as shown in Figure 6.

The e-RIMA protocol

In the b-RIMA protocol, if a node is within the range RC around the transmitter A or within the range Ri around the receiver B that is an exposed terminal and has to postpone its activity throughout the data frame transmission period. We observe that this unnecessary delay can be reduced, and thereby spatial channel reuse can be increased, to some extent by allowing reduced power RTS transmission. We call this enhanced approach, enhanced RIMA (e-RIMA) protocol. A key assumption in this enhanced approach is that an exposed node is able to estimate its distance from a receiving node either reading the location information from the busy tone or by periodic peak-to-average difference signal

As shown in Figure. 7, if a transmitter C within the exposed zone can decode the location of the currently active receiver B, e.g., via busy tones from B or via the signal from A during the bit stuffing duration, it determines its distance from B. C then selects its receiver D from its local neighbors' location information such that C-to-D transmission at P_{min} does not interfere B (or does not decrease the SINR level at B below an acceptable threshold). If such a node D can be found, C-to-D RTS is transmitted at P_{min}, while D-to-C CTS is transmitted at P_{max}, and the data frame transmission follows as in b-RIMA.

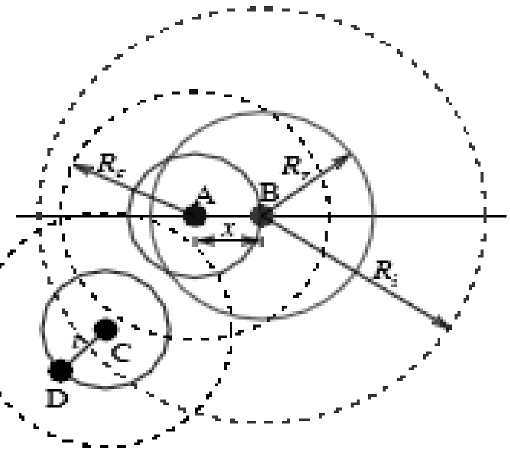

Fig7. An example of additional reduction of exposed terminal problem in e-RIMA protocol.

On the other hand, when a transmitter C is within the exposed zone but it cannot decode the location of B, only receive periodic busy signals from B, it estimates its distance from B by measuring received peak-to-average carrier sensed signal. Based on a conservative estimate of C-to-B distance, C may be able to choose its potential receiver D so that C-to-D communication is not expected to interfere A-to-B communication.

An example of reduced exposed terminals in e-RIMA protocol is also depicted in Figure.7. It may be noted that, reduced power RTS transmission allows some exposed nodes to act as transmitters; however none of the exposed nodes can be a receiver.

6. Simulation and Results

6.1 Simulation environment

We have conducted preliminary evaluation of the proposed RIMA protocol performance via network simulations using MATLAB. The network consists of 800 nodes, each with unit disc coverage range Rr = 40 meter, uniformly random distributed in a location space of size 500 meter square. Frame arrival process in the network is considered Poisson distributed, and the per node arrival rate is varied between 3 frames/s and 7 frames/s to achieve different network traffic load. Frames are of constant size 2kb, and transmission speed of a node is considered 2 Mbps. This environment effectively simulates CSMA (carrier sensing multiple access) Aloha system with an appropriate power control mechanism (PCM, b-RIMA, or e-RIMA). The effect of power control is simulated by considering carrier sensing range R c that is

IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 1, Issue 5, Oct-Nov, 2013
ISSN: 2320 - 8791
www.ijreat.org

twice the transmitter-receiver distance. The effect of full power transmission is simulated by considering interference range Ri = 2Rr.

When a frame arrives at a transmitter node, it determines if there are ongoing communications in its neighborhood by physical carrier sensing (CS). If the physical CS finds the surrounding idle, depending on the power control protocol, the transmitter exchanges suitable power RTS and CTS messages, i.e., determines its receiver's surrounding. If successful, the appropriate carrier sensing range R c around the transmitter and the interference range R i around the receiver is considered busy. In e-RIMA simulation, a potential transmitter in the exposed zone is assumed to know the exact location of the active receiver, based on which it tries find its suitable receiver. In PCM protocol simulation, if a new frame transmission is initiated from the hidden terminals zone, the ongoing as well as new frames collide, and both are considered lost. If at any time a frame is collided or if the channel is found busy during a transmission attempt (i.e., the transmitter is an exposed terminal, and cannot initiate transmission immediately), the frame is backlogged following binary exponential backoff with initial backoff period twice the frame transmission time, i.e., 2 ms. After 4 tries on a frame transmission, it is declared lost. In RIMA, frame delay and loss can happen if the channel is found occasionally busy, and some additional delay can happen due to the added bit stuffing period in a frame. On the other hand, in PCM, frame loss and delay can happen due to hidden terminals as well as if the channel is found occasionally busy. For a transmitter, a receiver is selected randomly from among its local neighbors. One-hop frame loss rate and aver- age delay per successful frame are considered as performance parameters, where average delay includes the waiting time in queue plus the frame transmission time. Since in e-RIMA an exposed transmitter node attempts to find a suitable close by receiver to achieve a higher spatial reuse, we anticipate a little shorter distance between a transmitter-receiver pair on average. So, this is considered as a performance tradeoff measure of e-RIMA protocol.

6.2 Results and discussion

In Fig.8 the average frame loss rate is plotted against different network traffic load. The RIMA protocol has clearly lower frame loss rate, which is attributed by the existing hidden terminals in PCM, and this problem is aggregated at higher network load. The effect of reduced exposed terminals is also observed in e-RIMA performance, which is more prominent at higher network traffic. This is because at higher traffic load, probability of finding a potential transmitter within an exposed zone of an ongoing transmission is higher. In b-RIMA (as well as in PCM), such a transmitter has to wait and eventually the frame may be lost after a repeated such waits. On the other hand, in e-RIMA, an exposed terminal transmitter may be able to find a suitable receiver, thus the frame success rate is low.

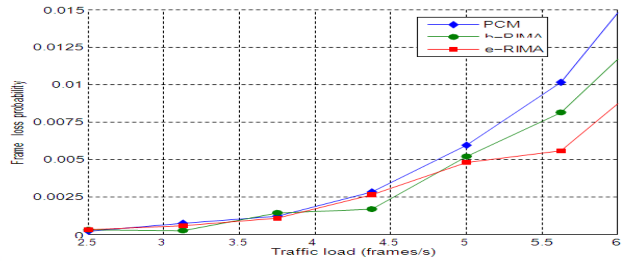

Fig 8 Frame loss rate performance versus network load.

The PCM performance is the poorest, which is again attributed to the fact that due to hidden terminals frame collisions may happen, and they are backlogged for longer time before some of them are successfully transmitted. The e-RIMA performance improvement over b-RIMA is also clearer as the network load increases.

Overall, although the RIMA protocol needs to stretch the data frame length approximately by 10%, the total average waiting delay of RIMA is quite small and compensates a little longer frame transmission delay.

7. Conclusions

In IEEE 802.11, carrier sensing range for RTS-CTS is the same as that of DATA-ACK since transmit power does not change. However, in BASIC, carrier sensing range for RTS-CTS and DATA-ACK may vary because the transmit power can be different for those packets. Thus, when using BASIC, nodes in the carrier sensing zone of RTS-CTS can cause collisions with on-going DATA-ACK

We propose PCM, a Power Control MAC protocol, which periodically increases the transmit power during DATA transmission.

Although PCM provides energy saving it does not yield improved spatial reuse as

A new receiver initiated distributed power control multi-access (RIMA) protocol has been proposed that works based on conventional single-channel single-transceiver design of ad hoc network nodes. The basic protocol eliminates the exposed terminal problem by stretching a data frame transmission period approximately by 10% and incorporating periodic in-band busy tones from the receiver. An enhanced version of the protocol (e-RIMA) works by reduced power RTS transmission thereby increasing spatial reuse of the wireless channel, and hence reducing the exposed terminal problem. The proposed protocol performance has been compared with a competitive transmitter initiated power control MAC (PCM) protocol. Simulation based performance evaluation has shown that although the RIMA protocol requires a little extra frame transmission time, overall frame loss ratio and average delay per successful frame transmission is significantly better with respect to the PCM protocol.

References

[1] S. Agarwal, S. Krishnamurthy, R. H. Katz, and S.K.Dao. Distributed Power Control in Ad-hocWirelessNetworks. In PIMRC01, 2001.

[2] B. Chen, K. Jamieson, H. Balakrishnan, and R. Morris. Span: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad HocWireless Networks. In MOBICOM 2, July 2001.

[3] Kuei-ping shih . A Collision avoidance power control MAC protocol for wireless Ad Hoc networks. A paper in Communication letters, IEEE, volume-9, 2005 .

[4] J.-P. Ebert, B. Stremmel, E. Wiederhold, and A. Wolisz. An Energy-efficient Power Control Approach for WLANs. Journal of Communications and Networks (JCN), 2(3):197–206, September 2000.

[5] J.-P. Ebert and A. Wolisz. Combined Tuning of RF Power and Medium Access Control for WLANs. In IEEE International Workshop on Mobile Multimedia Communications (MoMuC'99), November 1999.

[6] J. Gomez, A. T. Campbell, M. Naghshineh, and C. Bisdikian. Conserving Transmission Power in Wireless Ad Hoc Networks. In ICNP'01, November2001.

[7] Miser: An optimal low-energy transmission strategy for ieee 802.11a/h - Qiao, Choi, et al. – 2003

[8] E.-S. Jung and N. H. Vaidya. An Energy EfficientMAC Protocol for Wireless LANs. In INFOCOM 2002, June 2002.

[9] A. Kamerman and L. Monteban. WaveLAN-II: AHigh-Performance Wireless LAN for the UnilicensedBand. Bell Labs Technical Journal, 2(3), summer 1997

[10] S. Singh, M. Woo, and C. S. Raghavendra.Power-aware Routing in Mobile Ad Hoc Networks. In MOBICOM '98, October 1998.

[11] De, S, Egoh, K,; Dos:, G- A receiver initiated power control multi-access protocol in wireless ad hoc networks Conference Publications, IEEE- April 30 2007-May 2 2007.

[12] Dongyu Yang, Ying Qiu; Shining Li - An asynchronous receiver-initiated ultra low power MAC protocol for Wireless Sensor Networks - Wireless Sensor Network, 2010. IET-WSN. IET International Conference on 15-17 Nov. 2010.

[13] "Wireless medium access control (MAC) and physical layer (PHY) specifications for low-rate wireless personal area networks (LR-WPANs),IEEE Std 802.15.4," 2003.

[14] A. Muqattash and M. Krunz, "Power control dual channel (pcdc) medium access protocol for wireless ad hoc networks," in *Proc. IEEE INFOCOM*, San Fransisco, CA, April 2003.

[15] M.B.Pursley, H. B. Russell, and J. S. Wysocarski.Energy-Efficient Transmission and Routing Protocols for Wireless Multiple-hop Networks and Spread-Spectrum Radios. In EUROCOMM 2000, pages 1–5, 2000.