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Performance Evaluation of Power Efficient MAC Protocol for MANETs

Sohan Kumar Yadav, D. K. Lobiyal

Abstract— Optimizing battery power and enhancing throughout are the key factors to design an efficient power control MAC protocol. Since, Mobile ad hoc networks (MANETs) are powered by batteries. Therefore power management in MANET is a critical issue. In MANETs nodes are mobile therefore the size of batteries is a big issue. This paper presents performance evaluation of a protocol, namely Power Efficient MAC protocol for mobile ad hoc networks. Here, protocol PEMAC protocol uses optimum power to transmit RTS instead of maximum power level. Here the optimum power level is predefined value, and it is noted that it is sufficient to reach the receiver. The receiver transmits CTS by using maximum power level. The data and acknowledgement packets are transmitted by using lower power level respectively which is calculated according the power level of RTS transmission. This protocol conserves energy as it uses less energy in transmitting RTS packet, and it also increases the spatial reuse in the network. It has been shown by the simulation result that the PEMAC protocol is energy efficient without degrading throughput.

Index Terms— IEEE 802.11, RTS, CTS, Media Access Control (MAC), MANET, Power control, Quality of Service (QoS).

1 INTRODUCTION

IN designing Mobile Ad Hoc Networks (MANETs) key feature is how to improve the overall performance of network i.e. how to maximize the uses of battery power and how to increase the spatial reuse. MANET is a multi-hop in nature where, mobile nodes are operated in a distributed manner without any fixed infrastructure. MANETs have the ability to provide temporary and instant wireless networking solution where deployment of cellular infrastructure is very difficult. In these situation to make fixed infrastructure is very difficult or very expensive or infeasible (i.e. military, hazardous, flood, natural calamity) [3], [4]. MANETs are gaining popularity due to this situational ability to deployment and easy to work in needy situation. In MANET nodes are operated only by battery power, therefore energy saving is most important to maximize the lifetime of network. Due to this ability MANETs have the ability to use over to the cellular network system. In cellular system single point failure may lead to the failure of the whole network and this may also uses more energy than ad hoc network.

Where as in MANETs failure of single point do not turn with the failure of the network. It can be solved by re-routing around network. In MANETs, energy consumption is also less because here communication is made by hop-to-hop.

The most popular MAC protocol for ad hoc network is IEEE 802.11. This protocol generally follows the CSMA/CA (Collision Avoidance) and the exchange of RTS/CTS between the transmitter and the receiver. In this method a transmission floor is reserved for the data packet transmission. This protocol uses maximum available power for transmitting data transmission to prevent other nodes transmission present within its carrier sensing range. Nodes that are hearing RTS/CTS message will postpone their transmission up to the ongoing transmission. This scheme is useful in solving the problem of hidden and exposed terminal problem.

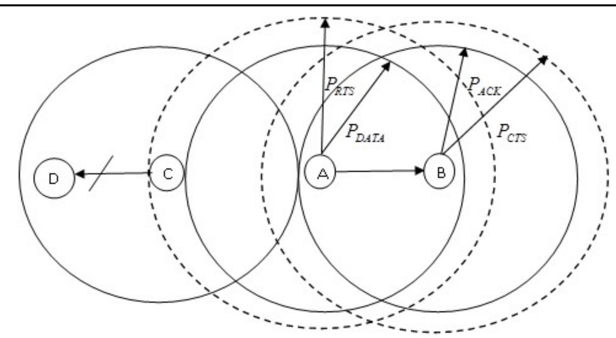

Fig. 1. Shows simultaneous transmission of nodes A and C are not possible when these nodes use maximum power to transmit RTS CTS packets [14].

This scheme does not allow concurrent transmission of nodes present in the carrier sensing range of the ongoing transmitting node. We can say that in this scheme simultaneous transmission is not possible i.e. it degrade the networks spatial reuse capacity. For example, we consider the situation as in figure 1 nodes A and node B are trying to established communication between them. Node A transmitting RTS packet with maximum power level to node B. Node C hear node A's RTS message since it present in the carrier sensing range of node A and therefore, it postpone its transmission to the node D [1],

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[5], [9], [15].

To improve the efficiency of the IEEE 802.11 protocol, we propose a power efficient MAC protocol for mobile ad hoc networks that uses minimum power level for RTS packet and maximum power level for CTS packets transmission. The DATA/ACK packets transmission power level will be calculated after the completion of RTS/CTS handshake. And it will be according to the power level for transmitting RTS which will complete the RTS/CTS handshake. In this work we analyze the protocol with respect to energy efficiency and end-to-end delay [12], [13].

The rest of the paper is organized as follows. Section 2 gives brief review work done in this area. Section 3 will present the proposed protocol and its analysis. In section 4 we give parameter and simulation results. Finally, conclusions and future scope are given in Section 5.

2 Related Work

In MANETs power control has been studied in the literature.

MAC layer provide the base station for set of protocols. Therefore, the main target of MAC protocol for MANETs is how to maintain the channel access in the network to gain higher channel use.

2.1 MAC Protocol

In Ad hoc networks nodes share a common broadcast channel scenario, and bandwidth available for communication is limited. Therefore, access to this shared medium should be fair and controlled. Since in MANETs there are some attributes i.e. mobile node, bandwidth limitation, hidden and exposed terminal problem. To overcome these issues, a set of different protocols are required for controlled access to shared medium in ad hoc networks. Classification of MAC protocol is as follows [3]:

2.1.1. Contention-based Protocols

Contention based protocols follow a contention-based channel access policy. A node does not make any reservation in advance. Whenever it receives a packet to transmitted, it tries to access the channel to its neighbour nodes. Quality of service will not be insured in contention based protocol since nodes are not true probability to regular access to the channel. Random access protocols can be divided into two types [3]:

2.1.1.1. Sender- initiated Protocols

In sender-initiated protocols packets transmission is initiated by the sender node. It can be further divided into two types:

2.1.1.1.1. Single-channel Sender-initiated Protocols

In this protocol total available bandwidth is used. Since, in this protocol bandwidth may not be divided. A node which gets chance for the contention to the channel uses the entire available bandwidth.

2.1.1.1.2. Multichannel Sender-initiated Protocols

In this protocol the total available bandwidth can be divided into multiple channels. This may provide a platform to nodes to simultaneously transmit data using separate channel.

2.1.2. Contention-based Protocols with Reservation Mechanisms

In ad hoc networks to support real-time scenario, which requires the quality of service (QoS) guarantee to be insured. This may lead to regular access of the channel. So in order to support such real time scenario protocols have mechanism for reserving bandwidth in advance. These protocols may be further divide into two categories [3]:

2.1.2.1. Synchronous Protocols

These protocols may require time synchronization among all nodes in the networks, so that any reservation made by a node is known to all nodes in the networks. This is very difficult to maintain time synchronization in the networks.

2.1.2.2. Asynchronous Protocols

These protocols do not require any global synchronization in networks. These protocols use relative time information for effective reservations.

2.1.3. Contention-based Protocols with Scheduling Mechanisms

Scheduling mechanism done at two levels i.e. at node level and at channel access level. Node scheduling is done as all nodes are treated as fair and equal probability of getting bandwidth. Scheduling based schemes are used for priorities among flows whose packets are queued at nodes [3].

2.2 IEEE 802.11 MAC Protocol

It is a widely used MAC protocol in IEEE 802.11. It deals with both physical access and medium access control layers of network. It is responsible for the regulating the use of shared medium. It is of two types. One is distributed coordination function (DCF), and this is distributed scheme. The other MAC protocol is point coordination function (PCF), and it is fully centralized scheme.

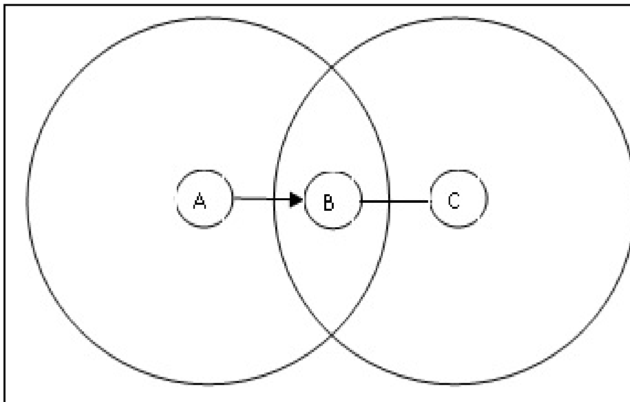

Fig. 2. Hidden terminal problem [14]

This paper gives more emphasis on the IEEE 802.11 MAC protocol and its power optimization. In this protocol RTS/CTS handshake will be done using maximum transmission power level [2], [10]. And DATA/ACK will be transmitting by using maximum transmission power level. Headers of RTS, CTS, and DATA include the time duration to inform the nodes which are in carrier sensing range of the ongoing transmitting when ACK will be sending. In this scheme, nodes present in carrier sensing range of the sender and receiver are capable of decoding RTS, CTS, and DATA, knowing about that the ongoing transmission. In figure 1, node B in carrier sensing range of node A and node C. When node A transmit packet to node B, node C which is present in transmission range of node B, does not know about ongoing transmission of node A and B because it out of carrier sensing range of node A. Therefore, if node C also starts sending some data to node B it may cause collision at node B. This problem is named as hidden terminal problem. This problem in MAC of ad hoc networks can be solved by medium access collision avoidance scheme. It also avoids the very first stage collision.

The IEEE 802.11 will use CSMA scheme by adding RTS/CTS handshake to solve the hidden terminal problem. This is illustrated by the following example. Let us take there are several node in a MANET, which is shown as in figure 3. In figure 3, if node A has data to transmit to node B, it send RTS packet. Node B will respond with CTS packet whenever it receives RTS packet, CTS packet has the information about the ongoing transmission. Since node C which is in carrier sensing range of node B, clearly it decodes and extracts information about the neighbour ongoing transmission. Therefore, if node C wants to transmit to node D, it has to wait until ongoing transmission of nodes A and node B. It is clear that hidden terminal problem is solved using RTS/CTS mechanism [8], [9].

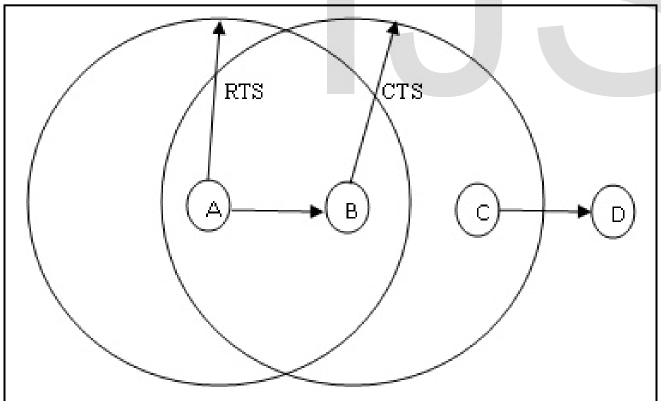

Fig. 3. RTS-CTS handshaking in IEEE 802.11 [14]

Clearly, IEEE 802.11 MAC protocol solved most common problem such as hidden terminal problem in MANETs. However, in this protocol there is no power saving attempt has been made to save battery power. It uses maximum and same transmitting power level for all type of packet transmissions, which leads to more battery consumption.

2.3 Basic Power Control MAC Protocol

The basic power control protocol (BPCMP) uses different power for handshake of RTS and CTS packets and for DAT/ACK packets [4]. In this scheme RTS/CTS will be sends with maximum power, therefore, all nodes presents in neighbor of the transmitting node, know about ongoing transmission. And DATA/ACK packets sent by using minimum required power level. Let $P_{DESIRED}$ be the minimum required power for transmitting DATA and ACK, and is given by

$$P_{DESIRED} = \frac{P_{MAX}}{P_r} \times R_{XTHRESH} \times \beta \quad (1)$$

Here $R_{XTHRESH}$ is the minimum signal strength which is necessary to receive the signal, and it is calculated by the characteristics of the node. B is a constant, P_r the amount of power level received at the receiver side, when it will be sends by maximum power level by the sender. Since we know that basic power control MAC protocol sends RTS and CTS using maximum power available, and DATA and ACK by the lowest possible power available ($P_{DESIRED}$). There are some problems with the Basic power control MAC protocol. As it uses maximum transmitting power level P_{MAX} for RTS and CTS is not energy efficient as the position of nodes may change from time to time. Using maximum transmitting power also cause interference to the ongoing transmission. Use of different power for transmitting DATA and ACK will results in asymmetric topologies and this may lead more energy consumption. Thus protocol may introduce more collisions. Therefore, using this protocol increases the number of retransmission to achieve better throughput as compare to IEEE 802.11. This scheme gives better network performance at the cost of more energy consumption. Therefore, this scheme is not suitable for us because we are interested in finding higher throughput with minimum energy consumption. Due to mobility for nodes the low power level transmission also causes more retransmission. This leads to higher energy consumption.

2.4 Power Control MAC Protocol

As we discussed in section 2.3, BASIC scheme consumes more energy and also degrade the networks throughput. Authors [1], proposes an improved MAC protocol for MANETs. It is similar to the BASIC power control protocol. This PCM protocol can avoid the collision with ACK by using maximum power level for transmitting DATA periodically with using maximum transmitting power level P_{MAX}. The time for periodically transmission should be less than the EIFS (extended interframe space) duration to know about the other nodes of ongoing transmission of its neighbouring node. This scheme maintains the carrier sensing area periodically and also using less power level as in BASIC protocol. However, when nodes are mobile, lower power level causes more retransmission. This scheme may not useful when nodes are mobile, since it uses less transmitting power level for DTA and ACK this may cause link failure. Thus this scheme increases energy consumption [6], [9], [11]. Therefore, this scheme is not acceptable when nodes are mobile, and network is dense.

3 Performance Evaluation Of PEMAC Protocol

Power management is necessary in MANETs as it is powered by batteries. So, here we proposed the power efficient MAC protocol for mobile ad hoc networks. This PEMAC protocol is an improved version of BASIC MAC protocol. The proposed protocol different power level is used to transmit RTS and CTS packets. Let us take a scenario as presented in figure 4. From the scenario it is clear that node A and node C cannot communicate simultaneously. It is clear that if we use minimum power level for transmitting RTS packet instead of maximum power level, simultaneous transmission of node group A & B and C & D can be possible. Thus, we can say that using this protocol network spatial reuse capacity will enhance. This increases the network capacity and performance. Therefore to increase the spatial use of network and to increase the life of battery we propose MAC protocol for MANETs.

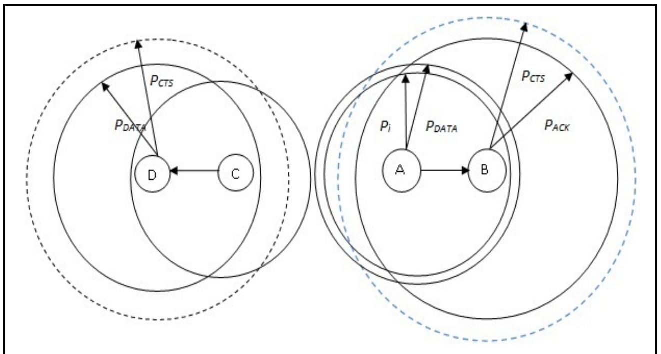

Fig. 4. Spatial reuse in Power Efficient MAC Protocol [14]

The proposed power efficient MAC protocol uses different required power to transmit RTS/CTS packet and DATA/ACK packets [6], [14]. To calculate these required power levels for transmit data it takes the following steps.

1) Initially, sender node sends RTS frame with minimum power level i.e. P_{RTS}^{i} . It is predefined value and is sufficient enough to reach to receiving node. If receiving node receives RTS, and it replies with CTS to sender node. Otherwise the value of P_{RTS}^{i} will be increased, since it not enough to reach the receiver. The value of this will be increased by the formula given by equation 2.

$$P_{RTS}^{i+1} = P_{RTS}^{i} \times \frac{P_{MAX} - P_{RTS}^{i}}{\kappa \times i} \qquad (2)$$

Where *K* is system parameter and is set to be 4 for better network performance.

2) Receiver node sends CTS frame by using maximum power level i.e. P_{MAX} . Nodes present in the carrier sensing range of receiver are sensing it and defer their transmission for the period of ongoing transmission.

3) After RTS/CTS handshake between sender and receiver, DATA and ACK will be transmitted by using power level defined as follows

$$P_{DATA/ACK} = P_{RTS}^{i} \times \varepsilon \qquad (3)$$

Where P_{RTS}^{i} is the power level of RTS transmission at which receiver responds with CTS packet, and ε is a constant and set to be greater than 1.

4) Whenever first collision occur in packet transmission, transmission power level to transmit DATA/ACK is increased to the P_{MAX} instead of P_{RTS}^{i} .

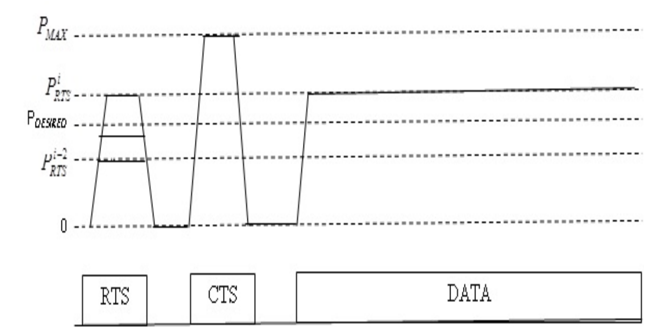

Fig. 5. Different power level used in Power Efficient MAC protocol for sending RTS/CTS and DATA [14]

In BASIC and PCM protocol, the power level for transmitting data packets is not changed whenever retransmission occurs. This may create a problem of network failure. This may occur more frequently if nodes are mobile. Therefore, it will increase the number of retransmission of the packets. This will decrease the battery power of the networks. Therefore, proposed PEMAC protocol solves this problem by using the maximum power level for retransmission. This will also solve somehow the problem of mobility. The different level of power which is used to send RTS and CTS packets are shown in the figure 5. Figure 5 clearly shows that proposed protocol uses different level of power to send DATA and ACK packets.

4. Performance Analysis

This section deals with the analysis the performance of the PEMAC protocol with network simulator GloMoSim [7] and compared it with IEEE 802.11 MAC protocol.

4.1 Simulation Environment

For simulation we use network simulator GloMoSim. We have considered that every node may send packets in density i.e. 60, 160, 260, 360, 460, and 560. Network model is taken as mess topology of 800x800 meter square, and transmission range is considered as 250 meter. The career sensing range is 550 meter, just double as transmission range, and the highest power level at 24.5 dBm. Bandwidth is taken as 2Mbps. Further the other parameters used in simulation are listed in table 1.

4.2Simulation Results

To validate the proposed protocol we use metrics as throughput, average energy consumption, and delay. So, here we perform experiments for throughput, average energy consumed, and delay in term of number of packet sent per second. This can be done for both protocol PEMAC and IEEE 802.11, where PEMAC protocol will use adjustable power level to transmit packets and IEEE 802.11 protocol takes maximum power level for all type of transmission. Delay is defind as average time that elapses between the begining of transmission and the time a packet reached to the destination.

TABLE 1
SIMULATOR PARAMETERS

Parameters	Values
Simulation Time	1500 seconds
Radio Transmission Range	250 m
Network Area	$800m \times 800m$
Propagation Model	Two –Ray Path Loss
Bandwidth	2 Mbps
Node Placement	Random
Mobility-Wp-pause	0.1 Millisecond
Mobility-Wp-Min-Speed	0 m/s
Mobility-Wp-Max-Speed	10 m/s
Noise	4
Radio-Tx-Power	24.5 dBm
Radio-Antenna-Gain	0.0 dBm
Radio-Rx-Sensitivity	-71.42 dBm
Mobility Model	Random Way Point
Routing	LAR1
Promiscuous-Mode	No

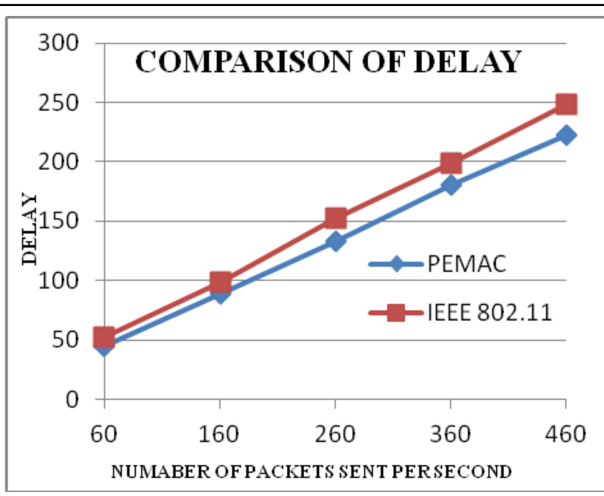

Fig. 6. Comparison of delay for PEMAC and IEEE 802

From the figure 6 it is clear that for PEMAC and IEEE 802.11 average dealy time increases as number of packets incraeses. It shows that proposed protocol perfrom well over IEEE 802.11 because it uses maximum power to transmit RTS/CTS and DATA/ACK. PEMAC uses adjustable power to transmit data, so it allows more simultaneous transmission. Simultaneously transmission is upto the limit that will not cause interference with hte ongoing transmission.

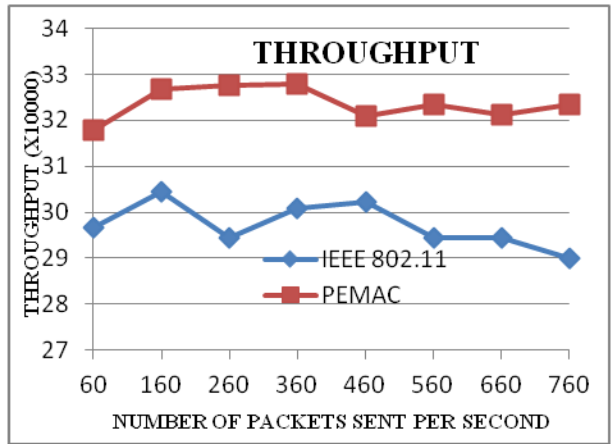

Fig. 7. Comparison of throughput for PEMAC and IEEE 802.11

Figure 7, shows network throghput i.e. number of packets sent in per second when a communication had been made between sender and receiver. This shows that PEMAC performance will in comparision to IEEE 802.11. As the number of packets sent by a node increases the proposed protocol performances increases. IEEE 802.11 uses maximum power level for transmission, large number of nodes present in sender neighbour have defer thier transmission. This will lead to decrease network throughput. And proposed protocol uses adjustable power level, this will increases network throughput and also increases simultaneous transmission.

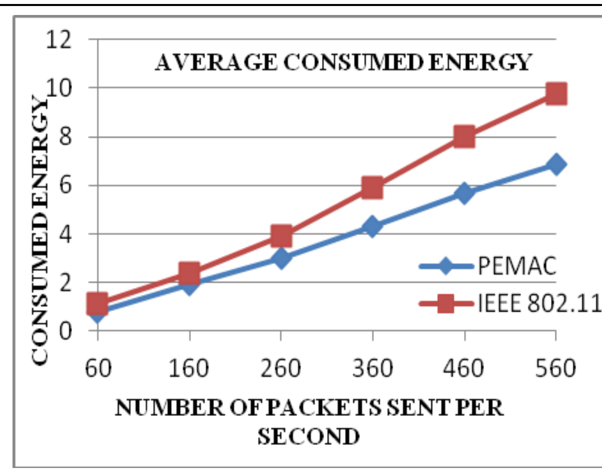

Fig. 8. Comparison of Average Energy consumed in PEMAC and IEEE 802.11

Here we present analysis of energy related. From the figure 8, average consumed energy by per node in joule when all packets have been sent from sender to receiver node for PEMAC and IEEE 802.11. Since proposed protocol uses adjustable power, it will result in smaller energy consumption in comparison to IEEE 802.11. Energy saving will increases in proposed protocol as the number of packets increase. This is because proposed protocol adjusted power level according to the formula give in equation (2). Whereas IEEE 802.11 use maximum power level even when receiver is very smaller distance from sender maximum transmission range. Therefore a node may expend unnecessary energy, and also causing interference.

5. Conclusions

MANETs are powered by batteries and there is no centralized administration. Therefore, to enhance network quality we have to reduce energy consumption, and this is vital for providing quality of service in mobile ad hoc networks. Thus, to enhance network performance, improved version of autonomous power control MAC protocol for MANETs can adjust transmitting power level automatically as well as periodically according to the network situation. It reduces collision except first one. Therefore, this protocol saves energy without degrading data delivery ratio. It also increases rate of energy efficiency. From the simulation results obtained, it is clear that IAPCMP has better results than BPCMP, APCMP, and IEEE 802.11in terms of metrics energy efficiency and end-to-end delay. It also serves the purpose of energy conservation through power control, and decreases collision rate. IAPCMP does not degrade the network quality as generally other protocols do while conserving energy. Therefore, from the simulation results it is shown that IAPCMP yields significant improvement in power saving and delivery ratio of the network.

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Reference

[1] E-S. Jung, and N. H. Vaidya., "A Power Control MAC Protocol for Ad Hoc Networks," Proceeding of the International Conference on Mobile Computing and Networking (MOBICOM'02), pp 36—47, 2002.

[2] A. Muqattash and M. M. Krunz, "A Distributed Transmission Power Control Protocol for Mobile Ad Hoc Networks," IEEE transactions on Mobile Computing, Vol.3, NO.2, pp 113-128, 2004.

[3] C. S. R. Murthy and B. S. Manoj, "Ad Hoc Networks: Architectures and Protocols," Second Edition, Pearson Education, 2005.

[4] H. H. Chen, Z. Fan, and J. Li, "Autonomous Power Control for MAC Protocol for Mobile Ad Hoc Networks," Hindwani Publishing Corporation, EURUSIP Journals on Wireless Communication and Networking, Vol. 2006, Article ID 36040, pp 01-10, 2006.

[5] H. Yan, J. Li, G. Sun, and H. H. Chen, "An Optimistic Power Control MAC Protocol for Mobile Ad Hoc Networks," IEE ICC Proceedings, pp.3615–3620, 2006.

[6] E. M. Varvariyos, G. Vasileios, and K. Nikolaos, "The Slow Start Power Control MAC Protocol for Mobile Ad Hoc Networks and its Performance Analysis," Ad Hoc Networks 7, pp.1136--1149, 2009.

[7] J. Nuevo, "A Comprehensible GloMoSim Tutorial," INRS-Universite du Quebec, Nuevo@inrs-telecom.uquebec.ca, pp.01–34, March 26, 2004.

[8] C. Yuan and C H. Lin, "Distributed MAC Protocol to Improve Energy and Channel Efficiency in MANET," Wired/Wireless Internet Communications, Lecture Notes in Computer ScienceVolume 2957, pp.01–12, 2004.

[9] C. Y. Chang and H. R. Chang, "Power Control and fairness MAC mechanisms for 802.11 WLWNs," Computer Communications 30, pp.1527–1537, 2007.

[10] M. Krunz and A. Muqattash, "Transmission Power Control in Wireless Ad Hoc Networks," Challenges, Solutions, and Open Issues. Network IEEE, Volume 18, Issue 5, pp.08–14, 2004.

[11] P. Gupta and P. R. Kumar, "The Capacity of Wireless Networks," IEEE Transaction on information theory, volume 46, No.2, pp.388–404, 2000.

[12] Sohan Kumar Yadav and D. K. Lobiyal, "Improved Autonomous Power Control MAC Protocol for MANETs," In proceedings of Second International Conference on Advance in Computing and information Technology (ACITY), Springer, Vol. 178, pp. 503-562, 2012.

[13] Sohan Kumar Yadav and D. K. Lobiyal, "Performance Analysis of Improved Autonomous Power Control MAC Protocol (IAPCMP) for MANETs," International Journal on AdHoc Networking Systems (IJANS), Vol. 2, No. 4, pp. 17-27, 2012.

[14] Sohan Kumar Yadav and D. K. Lobiyal, "Power Efficient MAC Protocol for Mobile Ad Hoc Networks," In proceeding of Quality, Reliability, Security and Robustness in Heterogeneous Networks - 9th International Conference, Qshine, Springer, Vol. 115, pp. 207-217, 2013.