Power Efficient MAC Protocol for Mobile Ad Hoc Networks

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Abstract. Maximizing throughput and battery power are the key factors to design an efficient power control MAC protocol. Power management in MANET is a critical issue, since these are powered by batteries. It is also due to mobility of MANETs, the size of batteries is of great concerns. This paper presents a novel power control protocol, namely Power Efficient MAC protocol for mobile ad hoc networks. The PEMAC protocol uses minimum power level to transmit RTS instead of maximum power level. Here the minimum 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 are transmitted using 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 through simulation that the proposed protocol is energy efficient without degrading throughput.

Keywords : IEEE 802.11, MAC, MANETs, Power control.

1 Introduction

Mobile Ad Hoc Networks (MANETs) is a multi-hop in nature where, mobile nodes are operated in a distributed manner without any fixed infrastructure. MANETs are gaining popularity due to their ability to provide temporary and instant networking solution in situations i.e. military, hazardous, flood, natural calamity. In this network nodes are operated only by battery power, therefore energy saving is most important to maximize the lifetime of network. This can be implemented into two ways are: (i) allow nodes to go in sleep mode and (ii) use of power control schemes for transmission of packets. Using different transmission power level for DATA packet transmission causes the decrease of the networks capacity due to exposed terminal problem.

The Ad Hoc mode of the IEEE 802.11 standard is the most popular MAC protocol for Ad Hoc networks. 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 power level for transmitting data transmission to prevent other nodes transmission present in its carrier sensing range. Nodes that are hearing

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RTS/CTS message will defer their transmission until ongoing transmission. This scheme is useful in solving the problem of hidden and exposed terminal problem.

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, here nodes A and 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 (it is present in the carrier sensing range of node A) and therefore, it postpone its transmission to the node D [1, 3,5, 8].

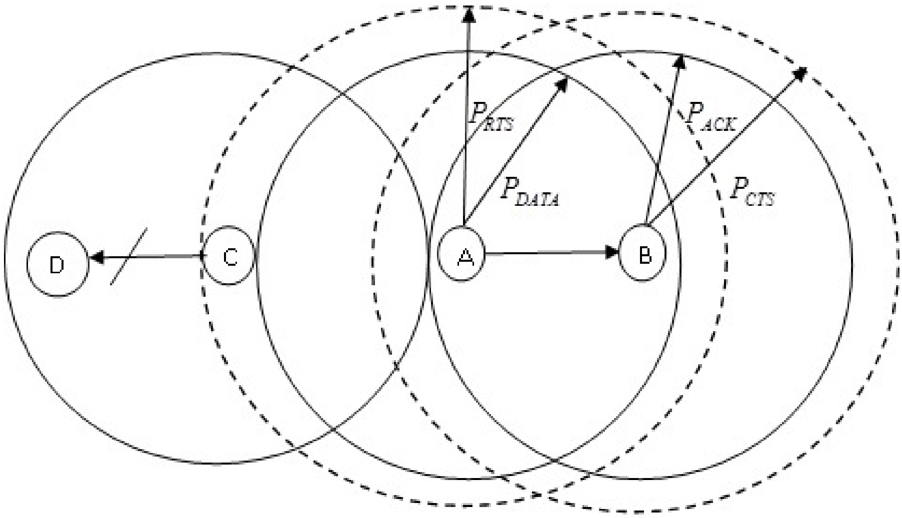

Fig. 1. Simultaneous Transmission of nodes A and C are not possible if it uses $P_{\max}$ for transmitting RTS, CTS packets

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. The rest of the paper is organized as follows. In section 2 we reviewed related work. Section 3 will present the proposed protocol. Simulation results are given in Section 4. Finally, conclusions are given in Section 5.

2 Related Work

Power Control for MANETs has been studied in the literature. Therefore, the goal for MAC protocol for MANETs is to coordinate the channel access among the number of nodes to achieve high channel use. The IEEE 802.11 deals with the both physical and medium access control layers of network. Most widely used MAC protocol is IEEE 802.11, and MAC layer is the host for set of protocols. It is responsible for the regulating the use of shared medium. In this paper the study will focus on the IEEE 802.11 MAC protocol and its power control schemes. We will give detailed discussions about the scheme in the following text.

2.1 IEEE 802.11 MAC Protocol

It is a widely used protocol, in which RTS/CTS handshake will be done using maximum transmission power level [2, 10]. In this protocol DATA/ACK will also transmitted, 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. This scheme avoids the very first stage collision. It prevents the hidden terminal problem. For example, in figure 2, if node A wants to transmit to node B, it first send RTS packet. After receiving RTS node B will reply with CTS packet which include the total time period for ongoing transmission. Since node C within the carrier sensing range of node B, clearly it decodes and extracts information about the neighbor ongoing transmission.

Therefore, even if node C wants to transmit to node D, it will keep silent till ongoing transmission of nodes A and B. It is clear that hidden terminal problem is solved using RTS/CTS mechanism.

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

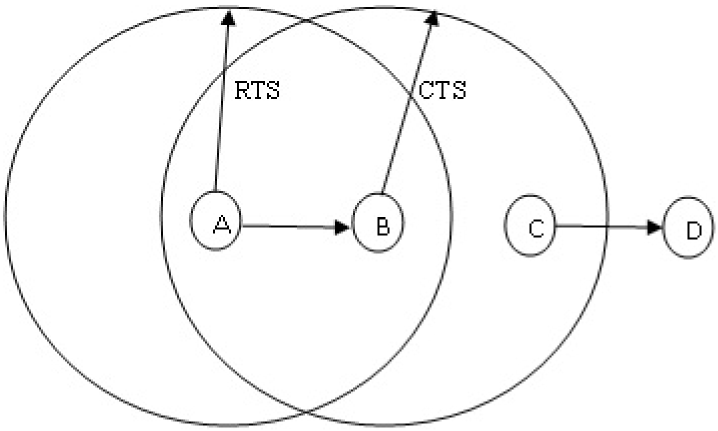

Fig. 2. RTS/CTS handshaking (prevent hidden terminal problem in IEEE 802.11) [5]

2.2 BASIC Power Control MAC Protocol

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

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

Where $R_{XTHRESH}$ is the minimum signal strength necessary to receive the signal, which is determined by the physical characteristics of the node, β 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. From the figure 3, it is clear that the basic power control MAC protocol sends RTS/CTS using maximum power level (P_{MAX}), and DATA/ACK using lowest possible power level ($P_{DESIRED}$).

This 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

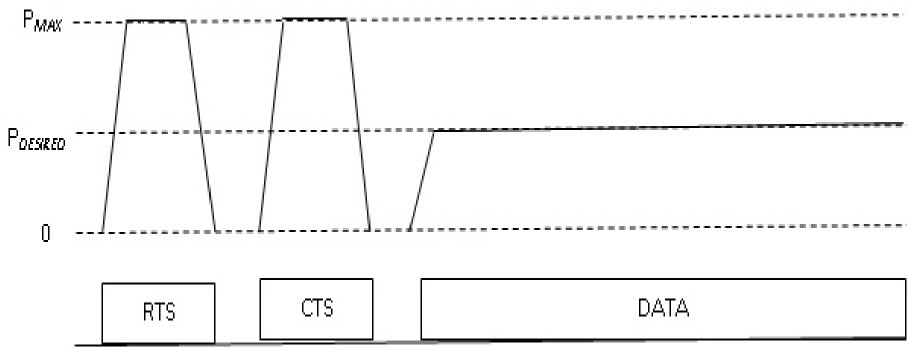

Fig. 3. BPCMP uses different power level for RTS/CTS and DATA

2.3 The PCM Protocol

As we discussed earlier, BASIC scheme consumes more energy and also degrade the networks throughput. Authors [1], proposes an improved power control MAC protocol for MANETs. It is similar to the BASIC power control protocol. This PCM protocol can avoid the collision by using maximum power level for transmitting DATA periodically. The time for periodically transmission should be less than the EIFS (extended inter-frame space) duration to let other nodes to know ongoing transmission of its neighboring node.

This scheme maintains the carrier sensing area periodically and also using less power level as in BASIC protocol. However, if nodes are mobile, the low power level causes more retransmission. Thus it consumes higher energy consumption [1, 6,9,11]. Therefore, this scheme is not acceptable when nodes are mobile, and network is dense.

3 Proposed Protocol

In this section, we proposed the power efficient MAC protocol for mobile ad hoc networks. This protocol can be considered as an improved version of BASIC protocol. In the proposed protocol different power level are used to transmit RTS and CTS packets. Let us take situation as in figure 4. From figure 4 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, this increases the spatial reuse, and the network capacity. Therefore to increase the spatial use of network and also to increase the life of battery we propose a power control MAC protocol for mobile ad hoc networks. This protocol will able to solve above discussed problem.

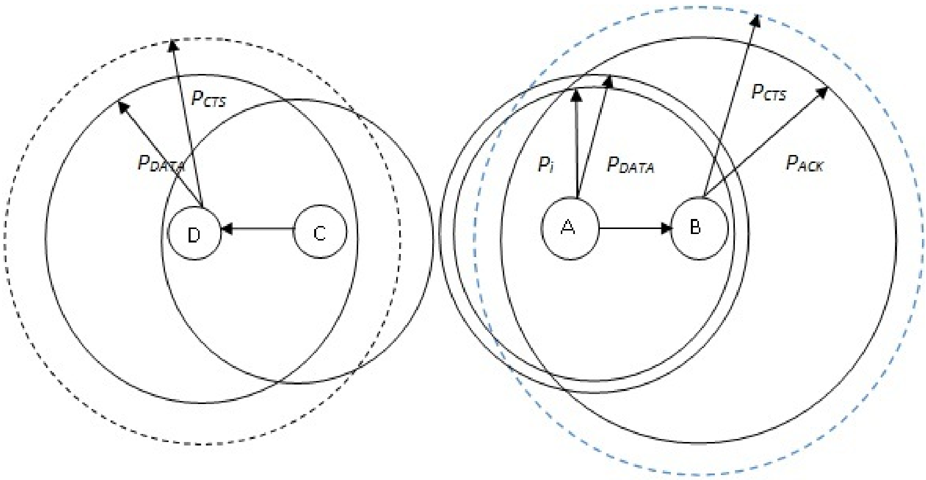

Fig. 4. Spatial reuse in PEMAC (Here nodes A and C can communicate simultaneously)

The proposed protocol uses the following steps to transmit the data to the intended receiver.

I. 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 the receiver node. If receiver node receives RTS, it replies with CTS to the 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 as follows

$$P_{RTS}^{i+1} = P_{RTS}^{i} + \frac{P_{MAX} - P_{RTS}^{i}}{k \times i} \tag{2}$$

Where k is system parameter and is set to be 3 for better network performance.

II. CTS frame is sent by using maximum power level i.e. P_{MAX}. Nodes in carrier sensing range of receiver are sensing it and defer their transmission for period of ongoing transmission.

III. After RTS/CTS handshake is over, the DATA/ACK will be sent by using power level defined as follows

$$P_{DATA/ACK} = P_{RTS}^{i} \times \varepsilon \tag{3}$$

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

IV. When the retransmission occur, transmission power level is increased as P_{MAX} instead of P_{RTS}^{i}.

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. The possibility of network failure will increase when nodes are mobile. Therefore, it will increase the number of retransmission of the packets. Most of the retransmissions are due to insufficiency of power (nodes are mobile). Therefore,

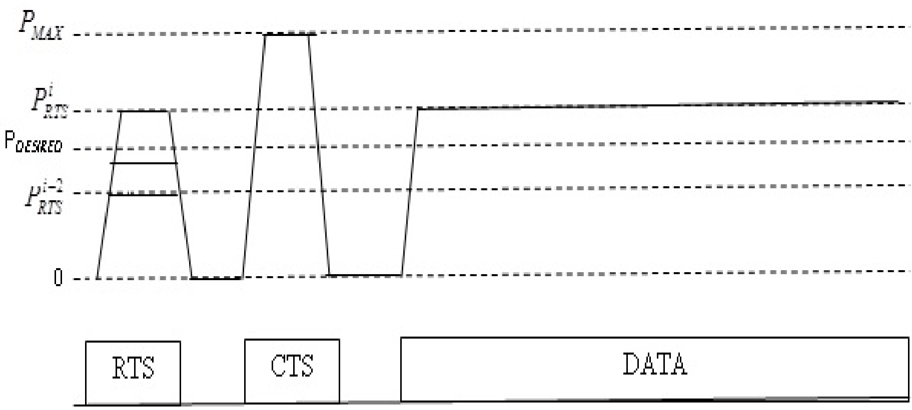

Fig. 5. Different power level will be used in PEMAC protocol for RTS, CTS, and DATA

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 power level used in sending RTS and CTS packets are shown in the figure 5. This also uses different power level for DATA packets.

4 Performance Evaluation

In this section, we evaluate the performance of the proposed PEMAC protocol using the computer simulator GloMoSim [7]. Here we also compared the performance of the PEMAC protocol with the other power control MAC protocol i.e. PCM, BASIC, and IEEE 802.11.

4.1 Simulation Environment

We have considered varying node density i.e. 3, 6, 9, 12, and 15 with and without mobility. Further the other parameters used in simulation are listed in table 1. The carrier sensing range is twice the transmission range (approx.).

Table 1. Parameters used in simulation

Simulation Time	15 second
Network Area	500×500
Radio Transmission Range	250m
Radio Carrier Sensing Range	500m(approx)
Propagation Model	Two-ray path loss
Bandwidth	2Mbps
Node Placement	Random
Mobility-Wp-pause	0.1 Millisecond
Mobility-Wp-Min-Speed	0 m/s
Mobility-Wp-Max-Speed	10 m/s
Noise Figure	4
Radio-Tx-Power	24.5 dBm
Radio-Antenna-Gain	0.0 dBm
Radio-Rx-Sensitivity	-71.42 dBm
Routing	LAR1
Promiscuous-Mode	No
Mobility Model	Random way point

4.2 Simulation Results

We used following metrics to evaluate the performance of the PEMAC, PCM, BASIC, and IEEE 802.11 protocols under both the mobile and static environment. In mobile condition the maximum speed is considered 15 m/s.

Throughput: It is the total number of data bits transferred from source to destination in per unit time i.e. per second. This shows the performance in terms of network capacity.

Rate of Energy Efficiency: It is the number of data bits delivered per joule energy consumed. Higher the rate of energy efficiency means protocol more efficient. It is measured in bits/joules.

Rate of Energy Efficiency = total number of data bits / total energy consumed in joule

Figure 6 shows, throughput in bits per second when nodes are not mobile. In this we have taken 3, 6, 9, 12, and 15 nodes for evaluation of the scenario. From the figure 6 it is clear that our protocol performs better than the other.

In Figure 7, we compared network throughput when nodes are mobile with maximum moving speed 10 m/s. Here, we are using same parameters as used in the above case. Figure 7, shows that proposed protocol is performing better as compared to PCM, BASIC, IEEE 802.11.

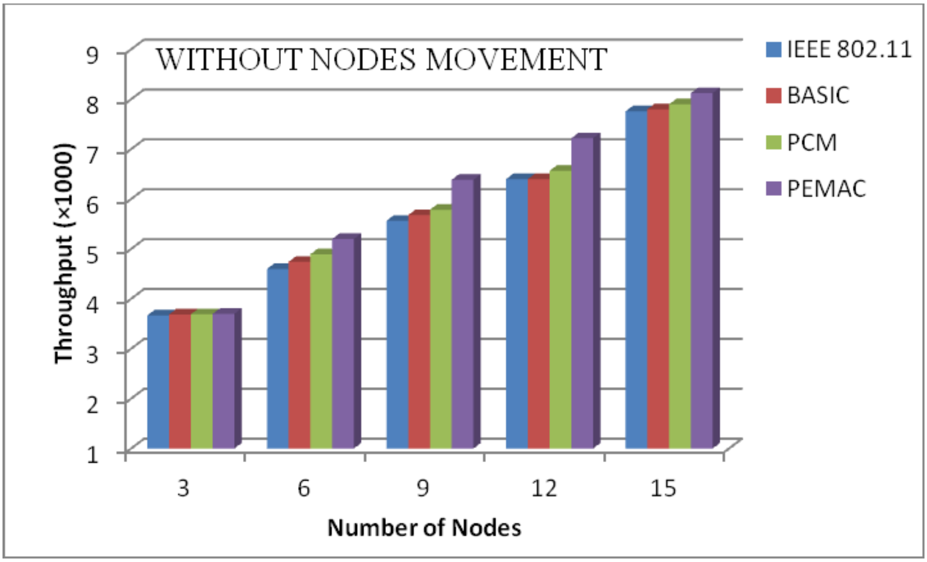

Fig. 6. Comparison of Throughput (moving speed = 0)

Figure 8, shows that ratio of energy efficiency as nodes are static. In this situation we take 3, 6, 9, 12, and 15 nodes. It shows that PEMAC performs better in comparison of PCM, BASIC, and IEEE 802.11.

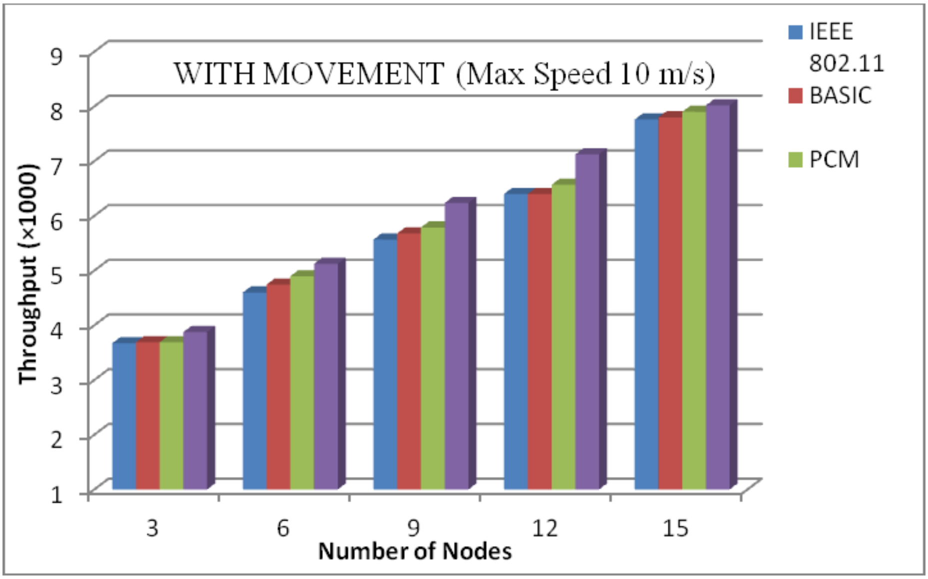

Fig. 7. Comparison of Throughput (moving speed = 10)

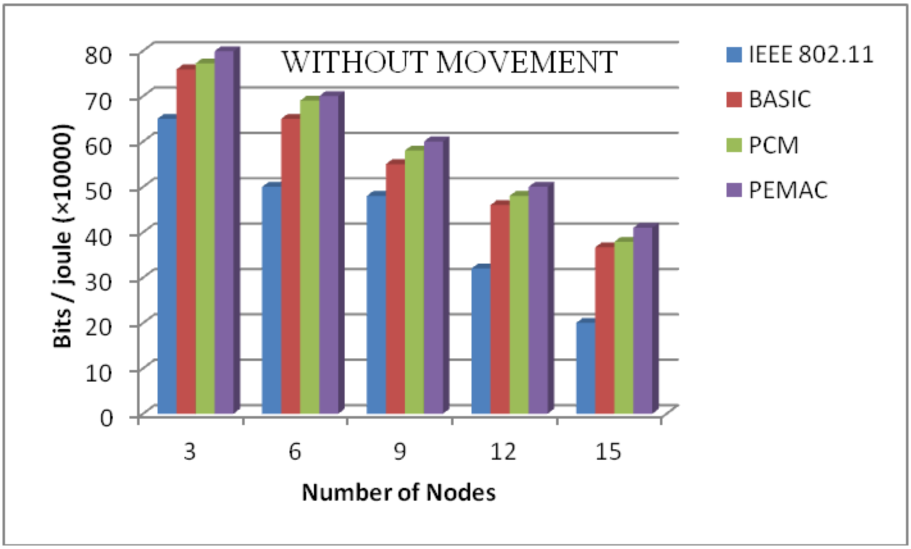

Fig. 8. Compariosn of energy efficiency (moving speed = 0)

Figure 9 shows that the comparison of energy of network in mobile state (moving speed = 10 m/s). And other parameters are same as static situation. Form the figure 9 it is clear that proposed protocol works better with the existing protocol.

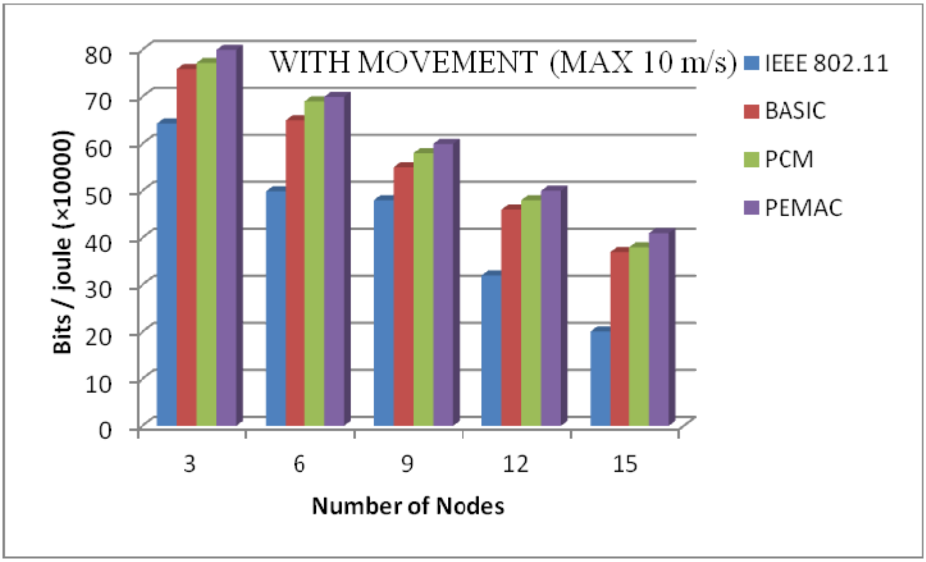

Fig. 9. Compariosn of energy efficiency (moving speed = 10)

5 Conclusion

We presented a new power control MAC protocol (named, PEMAC) for MANETs. Introduction of IEEE 802.11 and BASIC protocol forms the basis to propose this protocol, which gives better performance in terms of battery life and data delivery. The proposed PEMAC protocol uses minimum power level to transmit RTS packet and uses maximum power level for CTS. Hence it calculates the power level for DATA/ACK according to the RTS transmitting power level. It has been observed from the simulation results that PEMAC protocol conserved energy without degrading network throughput as generally other protocol degrading network performance while going for power control.

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