Power Adjustment Algorithm for Higher Throughput in Mobile Ad hoc Networks

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Abstract

In Mobile Ad Hoc Networks (MANETs), power control is necessary in order to reduce power consumption rates, avoid collisions within packets, increase spatial throughput of the system and to reduce contention among flows. The MANET nodes which are outside the transmission range are energy constraint and they consume more power for packet transmission. In this paper, we propose to develop a power adjustment algorithm to provide higher throughput and consume less power in the Mobile Ad hoc Networks. An optimal transmission power is calculated at the receiver based upon the data payload length and the interference amount. This power is given to the transmitter which increments or decrements the power with respect to the number of neighboring nodes. The adjusted power is retransmitted to the receiver so that the power level can be adjusted between the transmitter and receiver. Since the optimal transmission power is determined based upon the interference amount the possibility of collision among the nodes is reduced effectively. From our simulation results, we show that this algorithm provides higher throughput and lower energy consumption in ad hoc networks.

Keyword:
Wireless Networking, Throughput, MANET, Transmission Power, MAC, Data Packet

1. Introduction

Mobile Ad hoc Networks (MANETs) helps in classifying the people and devices into random and transitory wireless network topologies. So a fixed communication infrastructure is not required for the faultless inter network. These multi-hop networks not only handle their own product but also helps other nodes to forward their packets. In the MAC design of such networks, power conservation is a major concern since the nodes in the MANET are battery operated. During transmission, reception or data processing more amount of energy is consumed by the nodes in the MANETs. The absence of central coordination facilities causes many issues in the Power-conservative designs for ad hoc networks [1].

1. 1. Need for MAC Power Control

The Request to send (RTS) and Clear to send (CTS) packets in the basic power control MAC protocol (BASIC) scheme transmits its maximum amount of power. The subsequent DATA and ACK packet's transmission power can be determined using the RTS-CTS handshake. Interference range is not taken into consideration in the BASIC protocol. The nodes within the interference range of a transmitting node don't decode the received signal as described by IEEE 802.11 standard. Extended Inter-Frame Space (EIFS) is the interval in which the transmissions of DATA should defer. When the sender transmits DATA with lower power, then there are chances for a node to defer their transmissions since the node move out from their interference range. A collision with the ACK packet occurs in the transmission when the nodes start to transmit at the maximum power level after expiration of EIFS. Degradation of throughput is caused and energy consumption is higher due to this.

These collisions can be reduced by modifying the BASIC scheme with a Power Control MAC Protocol (PCM). The sender transmits the DATA packet at a maximum power level periodically within a short interval so that the packets transmitted by the nodes in RTS are free of collisions. The collisions are not completely eliminated by the PCM since the packets from the nodes in the carrier sensing zone of a receiver's CTS also causes collisions. [2]

1. 2. Power Control and its Benefits

When the destination is not in the transmission range of the multi-hop wireless ad hoc networks, the nodes transmit packets for other nodes. Transmission ranges at each node can be adjusted by conserving energy since it is necessary for the nodes which are energy constraint and

consumes more power. The following are advantages of dynamic power adjustments [3]

> It can significantly reduce power consumption rates
> Total system throughput for an end-to-end flow may increase due to the spatial reuse of spectrum
> Contention among flows sharing the same channel may be minimized, since the total number of neighbor nodes involved is reduced.

Covering minimum area which minimizes number of nodes to reach can be achieved by a node which makes local resolution to adjust the transmission power.

The nodes are no longer changed when the transmission power levels are adjusted effectively. Few nodes are not capable of overhearing ongoing packet transmission due to that the RTS/CTS handshake is not successful in reserving the channel. The main problem addressed in the RTS/CTS proposal is the increase in number of the hidden stations. This is due to the dynamic power adjustments which are made even though the RTS/CTS exchanges are successful. Unproductive solutions in original RTS/CTS packets are caused due to this problem. The packets may suffer from high levels of interference from a rival flow with a higher range due to ineffective RTS/CTS exchange. Packet delivering with a small power range may be failed. Based upon the link distance and interference level at the receiver the minimum power required for transmitting DATA/ACK packet can be determined and also the nodes which transmit RTS/CTS at the same maximum power is determined. The collision between the control packets (RTS/CTS) and the data packets (DATA/ACK) is mainly due to lower spatial reuse. This is due to diverse physical carrier sensing ranges which affects the network throughput. [4]

1. 3. Challenges and Solutions of Power Control

The following changes are unavoidably encountered for designing power management protocol for a large scale MANET

❖ **Clock synchronization –**In a multi-hop MANET, since there is no central control clock synchronization is complicated. Due to erratic mobility and radio inference packet delay there is a divergence. The low power hosts are activated only for a certain period as a means of power saving mode. The active time of other hosts are not known by the other hosts without specific clock.

❖ **Neighbor Discovery-** In this case the host will transmit and receive activities from the neighboring since they are not aware of power saving host. Perhaps such incorrect neighbor information is harmful for most of the current

routing protocol. Since the route detection procedure erroneously report when there is no even route, even though the route exists in the middle with some power saving host.[5]

❖ **Beacon Contention-** In IEEE 802.11, in order to transmit its beacon at around Target Beacon Transmission Time (TBTT) each and every stations has to compete with other nodes. The beacon broadcast procedure defined by IEEE 802.11 is highly erratic therefore the deficiency of back-off mechanism, lack of acknowledgement occurs due to absence of RTS/S channels communicates. When the density of the node is higher, beacon is severely conflicted and collided. Consequently, in a small IBSS configuration the synchronization problem arises.[6]

❖ In ad hoc network, node may either a data source or sink. Router forwards the data to its neighboring nodes participates in high-level routing and control protocol. Furthermore, the roles of specific node may be changed.

❖ The centralized entity such as access point control is not present. In the network, it maintains the power management mode of each and every node; it also buffers the data and wakes up the sleeping nodes. Hence ad hoc network must be made up off a distributed and cooperative fashion for effective management of power.

❖ Energy conservation generally is at the cost of degraded performance which includes lowering the throughput and longer delay which happens to be a foremost challenge in the designing of power management framework for ad hoc network. Naïve solution only consider about the power savings at individuals nodes may result in a beneficial to the operation of the entire network.[7]

1. 4. Solutions of Power Control

Some of the solutions addressing the power control issues in MANETs can generally be categorized as follows [6]

✓ **Transmission Power Control-** For power transmission in wireless connection**,** bit error rate, transmission rate, and inter-radio interference has a strong impact. Power control is adopted so as to improve the throughput on MAC layer and to reduce the inference. Consequently, the most excellent network can be determined using the transmission power of all mobile hosts is an essence.

✓ **Power Aware Routing- W**ide range of power cost function like mobile host's battery level are the basis of power aware routing protocol. A

- hybrid environment consisting of battery powered and outlet plugged hosts, etc.
- ✓ **Low Power Mode-** The radio is activated only when needed in IEEE 802.11 in order to save the power. In order to define its individual active period, hyper LAN allows a mobile host in power saving mode. As a result of turning off active host's equalizer according to the transmission bit rate power helps in conserving power in active host.

1.5. Previous Work and Proposed Solution

In paper [8], we have proposed to develop a cross-layer based MAC protocol to completely utilize the channel bandwidth and increase the fairness of each flow without causing congestion. In this protocol, available bandwidth along each path of the source and destination pair is estimated based on a probing technique. A centralized flow scheduler is designed to overcome the overheads, achieves high throughput and fairness.

In paper [9] we have developed an Optimal Rate Adjustment Algorithm (ORAA) based on the channel state conditions. Our channel state estimation has two levels, one at the receiver end and another at each intermediate node along the path. In our ORAA the rate adjustments are done based on any of the above discussed channel states. Hence in ad hoc networks, where the channel conditions are dynamic, our proposed ORAA provides the accurate data rate most suitable for the current changes in the network.

But, in multi-hop wireless ad hoc networks, nodes relay packets for other nodes if the destination is out of the transmission range of the source. Since each node is energy constrained and packet transmission consumes a certain amount of power, energy conservation may be achieved by dynamically adjusting transmission ranges on the fly at each node. Thus for the same MAC protocol, we require a power adjustment algorithm in order to reduce power consumption rates, increase spatial reuse of spectrum and to minimize the contention among the flows sharing the same channel. In this paper, we propose to develop a power adjustment algorithm to provide higher throughput and consume energy in the Mobile Ad hoc Networks.

2. Related Work

Emmanouel A. Varvarigos et al. [1] have evaluated the performance of a new MAC layer protocol for mobile ad hoc networks called the Slow Start Power Controlled (SSPC) protocol. Their SSPC have improved IEEE 802.11 by using power control for the RTS/CTS and DATA frame transmissions, so as to reduce energy consumption and increased the network throughput and lifetime. The

transmission power used in their scheme for the RTS frames was not constant, but has followed a slow start principle. At the same time in their scheme DATA frames were sent using the minimum transmission power that guaranteed the connectivity between the nodes plus some margin that allowed for future interference.

Javier Gomez et al. [10] have presented a Power Controlled Quality of Service (PCQoS) scheme for wireless ad hoc networks which have built QoS mechanisms for specific applications that wished to tradeoff better QoS performance for sub optimal paths. Their PCQoS have allowed only the selected flows to modify their transmit power as a way to add and remove relay nodes from their paths. Their PCQoS have integrated control algorithms to realize the Power/QoS trade-off in wireless ad hoc networks. Also, their PCQoS could also be used to establish a set of differentiated service classes in wireless ad hoc networks.

Resul Kara [11] has proposed on-demand and position based algorithms that minimized end-to-end packet delays which had used their node energies most effectively. Also his algorithm had helped to transport packets to their destinations by keeping the data transfer power of nodes in the lowest level. His main idea was to transmit along the node in the possible nearest distance to transport the packet to its destination. In addition, he also had noted that the time it took to reach the destination did not exceed some certain value.

Dinesh Ratan Gautam et al. [12] have developed a mechanism called Enhanced Transmission Power Control Mechanism (ETPCM) which minimized the required transmission power consumption of radio during packet transmission. They have also dynamically set the transmission power according to the distance and the distance could be calculated by using a parameter Receiving Signal Strength Indicator (RSSI) between these nodes. On the whole their ETPCM have saved power consumption and increased the life time of nodes as well as network and was mainly designed for transmission power control of radio PHY802.11b.

Kuei-Ping Shih et al. [13] have analyzed the relationships when power control was adopted among the transmission range, carrier sensing range and interference range. They have also proposed an adaptive range based power control (ARPC) MAC protocol for wireless ad hoc networks to avoid collisions. They have also proposed four mechanisms such as Sender's Transmission Range Cover (STRC), Receiver's Transmission Range Cover (RTRC), Sender's Carrier-sensing Range Cover (SCRC) and Receiver's Carrier-sensing Range Cover (RCRC). They have further analyzed the superiority of each mechanism under certain situations and have proposed their ARPC MAC protocol to make use of the advantages of the four mechanisms to avoid collisions.

Mahasweta Sarkar and Sahitya Borra [14] have proposed a reservation based asynchronous MAC protocol called Multi-rate Multi-hop MAC Protocol (MMMP) with power control for multi-hop ad hoc networks. Their protocol has conserved power and provided QoS guarantees for multimedia traffic. Also their MMMP with power control have achieved QoS guarantee, by having every node maintained two reservation tables to keep track of ongoing transmissions. Their MMMP also have calculated the appropriate transmission power specifically the power level high enough to reach the destination node rather than transmitting at maximum power. Their calculations were based on node distances, which resulted in energy savings without causing throughput degradation.

3. Proposed Power Adjustment Algorithm

3.1 Overview

In this paper, we propose to develop a power control mechanism by adjusting the power level based upon the neighboring nodes. Initially, each node creates two tables Recent data table (RT) and Inspection table (IT). The transmitter checks the record of the receiver initially in the RT and if it not present it checks in the IT for transmitting RTS packet to the receiver. Once the receiver obtains the RTS packet, it calculates the data payload length and the interference amount based upon the SIR. The optimal transmission power is determined using these and the receiver sends this optimal transmission power to the transmitter through the CTS packet. After receiving the optimal power, transmitter checks the number of neighbors. When the number of neighbors is more than the desired number of neighbors, then the power level is decremented for the neighboring nodes. If the number of neighbors is lesser than the desired number of neighbors then the power level is incremented. The new transmission power is retransmitted to the receiver via the RTS packet. Since equal optimal transmission power is maintained both at the receiver and the transmitter the throughput can be improved and the energy can be conserved effectively. This also reduces power consumption rates, increases spatial reuse of spectrum and minimizes the contention among the flows sharing the same channel.

3.2 Transmission Power Adjustment Algorithm

In this section, optimal transmit power can be determined by a Transmission power control protocol in ad hoc network. Using RTS/CTS handshake the nodes can exchange TX power levels in order to determine the optimal power level. The interference from the entire network can be determined by the RTS transmit power. The receiver determines the optimal TX power based on the interference and data payload. CTS, DATA, and ACK are then transmitted with this optimal TX power.

Initially, at the transmitter two tables are created to maintain the transmission power for each communicating node. Based upon this, the optimal transmission power can be determined.

3.2.1 Creating Tables

Each transmitting node maintains two tables. The first table, called Recent data Table (RT), keeps the most recent TX power for each communicating node. If the transmitter can find the receiver's record from the RT, then the transmitter transmits to the receiver using the power level in that record. Else the Inspection Table (IT) is checked for the receiver's record in it. IT is used to find the minimum required TX power for the current transmission. The distance to the receiving node or the interference amount in the network can be determined by the transmitting node by selecting the power level from the IT. IT is used when the transmitter can not find the current receiver's record in the RT, or, the RTS transmission with the TX power recorded in RT fails. When RT doesn't contain receiver record, then TX transmits RTS which is given in the IT. The TX power is incremented to the next level in IT when there is no response.

Initially, in IT a minimum TX power and a maximum transmission power are considered. The first entry in the IT will have minimum TX power level. Here, we use that TX power as the maximum TX power in IT. For worst conditions, the farthest required distance can be determined from the chosen value. Equal interval additions can be produced to the maximum transmission radius when sequential entries are chosen from IT. Maximum transmission radius can be found in the Last row. Thus, IT can be used to find the minimum required TX power for RTS transmission. If the frame cannot be transmitted after the last try, the frame will be discarded.

In this figure 1, the blue line from RT to TX indicates that the receiver's record is found in the RT. So, the RTS packet is transmitted from the TX to the RX. The blue dashed line from the RT to TX indicates that the RT doesn't contain the receiver's record and thus the TX checks the receiver's record in the IT which is indicated by the green line. After receiving the record from the IT, TX transmits the RTS packet to the RX. Accordingly CTS is received.
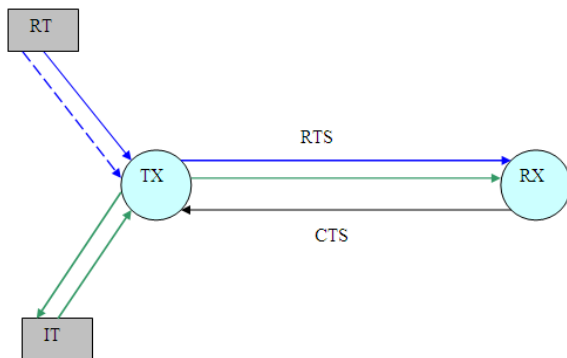
Figure 1: Recent data Table and Inspection table

3.2.2 Determining Optimal Transmit Power (η)

In this section, the transmitter and the receiver collaborate to find the optimal TX power level (η). The receiver uses both the required SIR and the required BER to calculate the optimal TX power for the transmission.
In the transmitter two cases are identified.

Case 1: The transmitter finds the receiver's record in the RT and sends RTS using the recorded TX power;
Case 2: The transmitter does not find the receiver's record in the RT and starts to send RTS using the minimum level TX power in IT.

RTS packet combines the TX power along with it to reach the transmitter. The next higher TX power level can be taken for both cases when the RTS is timed out. The TX power level is retransmitted through the RTS. Once the CTS packet is received the process is stopped.
The reasons for the time out could be:
1) When a node inside the sender's transmission range transmits simultaneously;
2) The TX power is not high enough for the path loss;
3) A conflict occurs at the RTS because of too much interference.
Once the transmitter receives the CTS from the receiver, it transmits the data frame using the TX power requested by the receiver (as included in the CTS) and writes it down in RT.
At the receiver the acceptable BER (Bit Error Rate) is determined. The receiver determines the data payload length and the Interference amount in order to determine the optimal transmission power. The interference amount can be reduced by increasing the SIR value to a certain level.

3.2.2.1 Data Payload Length Calculation

In order to meet the BER requirement the TX power level should be determined. This can be determined from the data payload length in the duration field of RTS when the data frame is longer than the RTS. Higher BER is achieved when the data frame is received with the same SIR as the RTS. The transmission may fail due to this. When data frame is larger, longer burst errors occur and thus SIR value needs to be incremented to 0.5 dB.

3.2.2.2 Interference Amount Calculation

Furthermore, the interference also will increase BER. Since the data frame is transmitted with the higher TX power, it will cause more interference to other nodes. Check whether the SIR value satisfies the data payload length. When the condition is not satisfied then the SIR value is incremented by one more 0.5. After finding the required SIR, the receiver calculates the required TX power. This is known as the optimal TX power.
Finally, the maximum TX power will be limited by the initial maximum TX power. Throughput cannot be improved nor is the energy consumption not reduced when a control frame with a higher TX power than the frame is transmitted. CTS are sent to the transmitter at the optimal TX power and the CTS frame also includes the expected TX power. The receiver can adjust the optimal TX power when RTS transmission power is higher than the original. After receiving the CTS, the transmitter will record the TX power for the receiver in RT and send the data frame using the expected TX power. [15]
Now the network topology may change due to mobile nodes and thus it causes variation in the number of neighboring nodes of transmitter. So in the next section, we provide that the optimal transmission power calculated is also given to the neighboring nodes so that power level can be adjusted.

3.3 Neighboring Nodes Power Adjustment

The Receiver calculates the optimal transmission power (η) in the previous section. This η is sent via CTS packet to the transmitter. Once the transmitter receives η, it will adjust the power of the neighboring nodes accordingly.
If the number of neighbors increases we decrease our power and if the number of neighbors decreases we increase our power. Thus, the algorithm is executed every time when the number of neighbors changes.
Let total number of neighbors be K, transmission power be Tp, maximum transmission power be Tpmax , current number of neighbors be NC and desired number of neighbors be ND. The increase or decrease in ND is Pd and transmission power history is Ht.
We compare the number of neighbors currently with the desired number of neighbors. When current number of

neighbors is lesser, then than the desired the transmission power is maximum else the transmission is decremented or incremented using the equation

$$Pd = \varepsilon * \log_{10}(L) * H_t$$

where $L = \dfrac{N_c}{N_D}$

When the total number of neighbors reduces or increases, the transmission power are modified based on the Pd.

The consecutive numbers of neighbors and corresponding transmission powers are maintained in the LIST. The corresponding power can be taken from the LIST when there is variation in the number of neighbors. [16]

Changing the powers according to neighboring nodes are illustrated in Figure2, 3, and 4. Consider ND =4 for TX in figure 2. The RX sends it optimal transmission power to TX along with CTS. Once the TX receives η, it checks ND. If ND =4, no changes occur. The same power is distributed to the four neighboring nodes.

In figure 3, when ND =5, (i.e) the number of neighbors increases, then transmit power is decremented given ηd. When the CTS packet is transmitted to the TX, it adjusts the power level of its neighboring nodes to ηd which is lesser than η.

In figure 4, when ND =3, (i.e) the number of neighbors decreases, then the transmit power is incremented given as ηi. When the TX receives the optimal transmit power, it adjusts the power according to the neighbors and incremented power is given to the neighbors.

After the transmit power is adjusted, the RTS packet is transmitted along with the new transmit power to the receiver. Due to mobile nodes, the position of the nodes may change; the transmission power is also adjusted in this case.
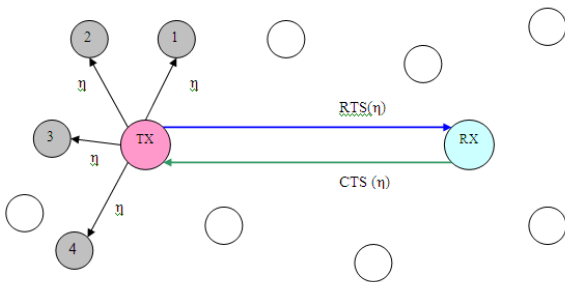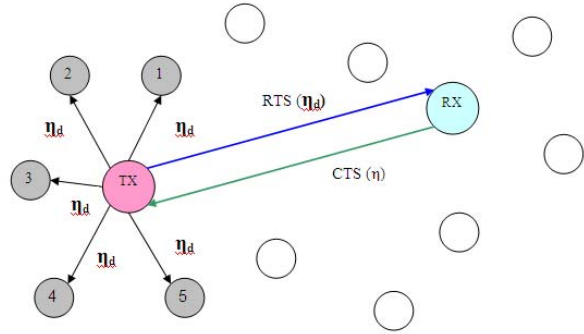
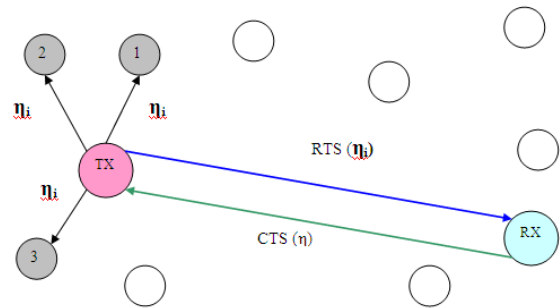Figure 3: Distributing Decremented Transmit power to Neighbors.

Figure 4: Distributing Incremented Transmit power to Neighbors.

3.4 Overall Algorithm

Here we present an overall algorithm for calculating the optimal transmission power and adjusting power level according to the number of neighbors. Let TXt be the number of transmissions, SIRn be the incremented SIR value, and minimum number of neighbors of transmitter be K.

1. Initially create RT and IT tables for each node as described in section 3.2.1
2. If TX finds RX's record in the RT,
      2.1 TX sends RTS packet to the RX.
  Else
      2.2 TX checks RX's record in the IT.
      2.3 TX sends the corresponding RTS packet to RX.
   End if
3. Sends RTS with TX power according to the TXt entry in IT, and include the TX power in RTS
4. If RTS is timed out
    4.1 If TXt = 0,
        4.1.1 Find next higher transmission power in IT.

Figure 2: Distributing Optimal Transmit power to Neighbors.

Else
        4.1.2 Increment TXt
        4.1.3 Go to step 3.
        End if
    Else
Send the data frame using the TX power indicated by the receiver in CTS and record in IT.
    End if
5. Increase SIR to (SIRn= SIR+0.5)
6. If SIRn satisfies data payload
        6.1 SIR = (SIR + (SIRn × 0.5))
    Else
        6.2 SIR = (SIR + ((SIRn+1) × 0.5))
    End if
7. At RX, data payload length and Interference amount is calculated to determine the optimal transmission power.
8. RX sends the calculated power to the TX along with the CTS.
9. When TX receives the transmission power it checks its number of neighbors.
10. If number of neighbors = K,
        Same transmission power η is distributed among the neighbors.
    Else
        If Number of neighbors = < K
            Transmission power is increased to ηi among the neighbors.
        Else
            If Number of neighbors > K
                Transmission power is decreased to ηd among the neighbors.
                End if
            End if
    End if.
11. Then, the new transmission power is retransmitted to the RX along with RTS.

4. Simulation Results

4. 1. Simulation Model and Parameters

We use NS2 [17] to simulate our proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. In our simulation, 100 mobile nodes move in a 1500 meter x 300 meter rectangular region for 50 seconds simulation time. Initial locations and movements of the nodes are obtained using the random waypoint (RWP) model of NS2. We assume each node moves independently with the same average speed. In this mobility model, a node randomly selects a destination from the physical terrain. In our simulation, the speed is 5 m/s. and pause time is 5 seconds. The simulated traffics are Constant Bit Rate (CBR) and Variable Bit Rate (VBR) traffic. For each scenario, ten

runs with different random seeds were conducted and the results were averaged.

Our simulation settings and parameters are summarized in table 1.

No. of Nodes	100
Area Size	1500 X 300
Mac	PAA
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR and Video
No. of Connections	6
Packet Size	512
Mobility Model	Random Way Point
Speed	5m/s
Pause time	5 sec
Rate	100kb,200kb,…..500Kb

Table 1: Simulation Settings

4. 2. Performance Metrics

We compare the performance of our proposed Power Adjustment Algorithm (PAA) with the Adaptive Range-Based Power Control scheme in [13]. We evaluate mainly the performance according to the following metrics.

Average End-to-End Delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations

Average Packet Delivery Ratio: It is the ratio of the number .of packets received successfully and the total number of packets transmitted.

Bandwidth: It is the measure of received bandwidth for all traffic flows.

Fairness: For each flow, we measure the fairness index as the ratio of throughput of each flow and total no. of flows.

Energy: It is the total amount of energy consumed the nodes during the transmission process.

The performance results are presented graphically in the next section.

4. 3. Results

A. Based On Rate
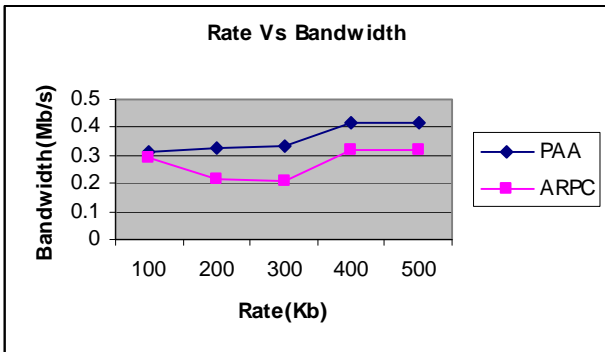In our initial experiment, we vary the traffic rate set as 100,200,300,400 and 500Kb.
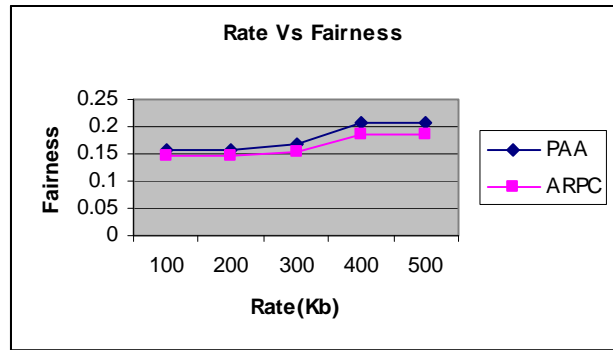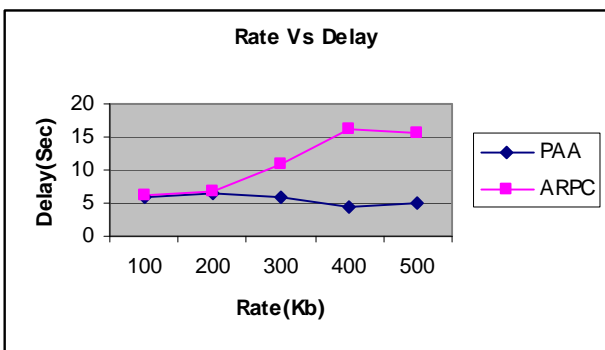
Fig 5: Rate Vs Bandwidth

Fig 6: Rate Vs Delay

Fig 7: Rate Vs Delivery Ratio
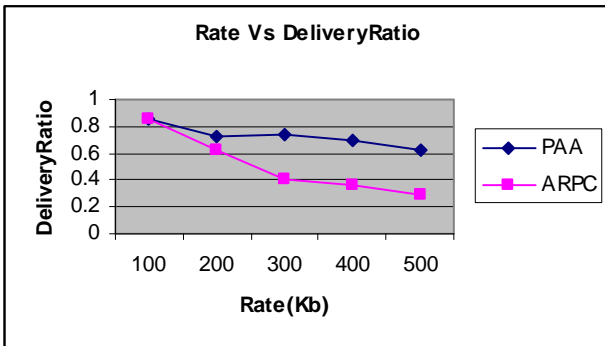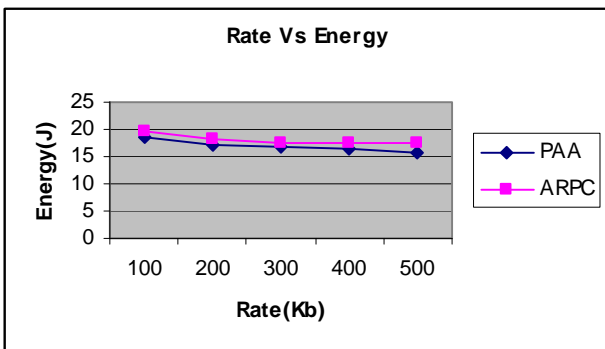

Fig 8: Rate Vs Energy

Fig 9: Rate Vs Fairness

From figure 5, we can see that the received bandwidth of our proposed PAA is higher than the existing ARPC scheme.

From figure 6, we can see that the delay of our proposed PAA is less than the existing ARPC scheme.

From figure 7, we can see that the delivery ratio of our proposed PAA is higher than the existing ARPC scheme.

From figure 8, we can see that the energy consumption of our proposed is less than the existing ARPC scheme.

From figure 9, we can see that the fairness of our proposed PAA is higher than the existing ARPC scheme.

5. Conclusion

In this paper, we have proposed to develop a power adjustment algorithm to provide higher throughput and consume less energy in the Mobile Ad hoc Networks. Initially, each node creates two tables Recent data table (RT) and Inspection table (IT). The transmitter checks the record of the receiver initially in the RT and if it not present it checks in the IT for transmitting RTS packet to the receiver. Optimal transmission power is calculated at the receiver based upon the data payload length and the interference amount. The interference amount is calculated based upon the SIR value. This power is given to the transmitter adjusts the power level with respect to the number of neighboring nodes. When the number of neighbors is more than the desired number of neighbors, then the power level is decremented for the neighboring nodes. If the number of neighbors is lesser than the desired number of neighbors then the power level is incremented. The adjusted power is retransmitted to the receiver so that the power level can be adjusted between the transmitter and receiver. Since the optimal transmission power is determined based upon the interference amount the possibility of collision among the nodes is reduced effectively. From our simulation results, we show that this algorithm provides higher throughput and lower energy consumption in ad hic networks.

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