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Adaptive Power Control Technique for Improving Throughput in MANETs

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Abstract: In Mobile Ad hoc Networks (MANETs), battery power is a limited resource and it is expected that battery technology is not likely to progress as fast as computing and communication technologies do. Hence, in order to lengthen the lifetime of batteries is an important issue which is supported by batteries only. But the existing power control techniques rarely consider the delay incurred in power estimation and connectivity of the network. Overhead problems are also caused by sending RTS packets. In order to solve the above problems, researchers propose to develop a power control MAC protocol for minimizing the power consumption and increasing the throughput in MANET. Initially, researchers assume that each node contains a neighbor set (NSET). Based upon the critical transmission range for connectivity, the nodes within the transmission range can be identified. Within the transmission range, the source node chooses the nodes with optimal initial transmission power value. These are stored in NSET to which the source can directly transmit the data with the selected optimal transmission power values. For the nodes beyond the transmission range, the power values of the intermediate nodes are also calculated and the source node sends data to the destination through nodes that has minimum transmission power value.

Key words: Mobile Ad hoc Network (MANET), Neighbor Set (NSET), MAC protocol, power, nodes

INTRODUCTION

MANET: A Mobile Ad hoc Network (MANET) is a form of dynamically changing network which includes collection of wireless mobile nodes such as portable computers, personal digital assistances or nodes for brevity. No centralized administration or existing network infrastructure is used in MANETs (Chen *et al*., 2006).

Characteristics of MANET: The mobile hosts connected by wireless links act as routers and are their movement is free since, MANET is an autonomous system. Here some of the characteristics of MANET are explained (Sun, 2001).

Autonomous terminal: The purpose of both host and a router can be satisfied in MANET since the mobile terminal is an autonomous node.

Distributed operation: The central control of the network operations lacks the presence of background network which leads to distribution of control and management of the network within the terminals.

Multihop routing: When delivering data packets from a source to its destination out of the direct wireless transmission range, the packets should be forwarded via one or more intermediate nodes. More than one intermediate node is required by the source node for delivering the packets to its destination which is outside the direct wireless transmission range.

Dynamic network topology: According to time, the connectivity among the terminals changes quickly and impulsively due to the mobile nature of the nodes. The routing among the mobile nodes are dynamically created among the nodes.

Fluctuating link capacity: MANETs can have bandwidth lesser than the wired network, due to the noise, fading and interference in the channels used for communication. Multiple wireless links which can also be a heterogeneous link navigates in a path between any two users.

Lightweight terminals: Mobile devices having lesser CPU processing capability, smaller memory size and lower power storage can be identified in most of the MANET

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nodes. The computing and communicating functions for these devices require optimized algorithms and mechanisms.

Applications of MANET: Large scale, mobile, highly dynamic networks applications can be diversely provided using the MANETs and to the other extreme the small, static networks which are constrained by power sources are also provided by the MANETs. Military battlefield, commercial sector including disaster relief efforts in fire, flood and earthquake which are included in the typical applications can also be provided by MANETs. Local applications can also be provided such as taxicab, sports stadium, boat, small aircraft and conference hall in which the wireless connections are replaced in place of tedious wired cables. Wireless LAN (WLAN), GPRS and UMTS networks can also be accessed by ad hoc network.

Issues of MANET: Though many typical applications can be handled by MANETs some issues are faced which are discussed (Sun, 2001).

Routing: It is a critical task for routing the packets between any pair of nodes due to continuous change in network topology. Multiple hops which are more complex compared to single hop are present in the routes between nodes.

Security and reliability: Various schemes of authentication and key management are needed for distributed operation. Due to limited wireless transmission range and broadcast nature of wireless medium reliability problems may arise in the wireless link.

Quality of Service (QoS): It is quite critical for MANETs to provide quality of service in different levels due to its continuous changing environment. Fixed guarantees on the device services offered is quite difficult in MANETs due to the inbuilt stochastic feature of communications quality. In order to support multimedia services, the traditional resource reservation requires adaptive QoS.

Power consumption: For minimum power consumption, the communication related tasks needs to be optimized for lightweight mobile terminals. In addition to the power conservation, it is necessary to consider the power aware routing.

Power control in MANET: The signal transmission by a node uses an amount of power which is known as transmission power (Gautam *et al*., 2011). It is quite critical for estimating the performance of the network including throughput, delay and energy consumption because the transmission power estimates the range over which the signal is coherently received (Krunz *et al*., 2004).

In different packets of MANETs, the selection of accurate transmits power levels are based on the power control for the MAC protocols. The radio range, battery lifetime and network capacity of MANETs are affected by transmit power levels (Chen *et al*., 2006).

Using power control: Spatial reuse and energy efficiency can be provided effectively (Alawieh *et al*., 2007). Spatial channel reuse can be increased which in turn increases overall channel utilization (Muqattash and Krunz, 2004). Network lifetime can be extended due to improvement in the overall energy consumption in a MANET (Muqattash and Krunz, 2004).

Need for power control in MANET: The mobile device becomes worthless when there is no power in it. Like computing and communication technologies, the battery technology progression is not much effective due to its limited battery power. For the MANETs supported by batteries, the major issue is to determine how the lifetime of batteries is lengthen (Tseng *et al*., 2002).

Classification of power aware MAC protocols in MANET: The following specifies different categories of power aware MAC protocols:

Reservation-based power-aware MAC protocols: In the MAC layer, collisions related retransmissions and additional power consumption can be avoided using this protocol.

The local base station is a kind of coordinator selected from the group of nodes in this reservation schemes. The nodes in the network share the coordinator's role in most of the schemes since, the node resources are consumed at the coordinator.

Switching off power-aware MAC protocols: In these protocols, the inactive node which does not involve in sending or receiving any packets are forced and put into a sleep state in order to minimize the energy consumption. When a pending traffic is noticed then these nodes are powered up.

Transmission power control MAC protocols: The channel's spatial reuse can be increased in this protocol in order to reduce the power control. For varying packet destination the power control MAC protocol reserves different types of floors. Similar to the slow start mechanism, transmission power control contention-based MAC protocol utilizes the control packets and carrier sensing.

Impact of power problem in MANET: The channel bandwidth in wireless environments considers the power control as a major issue. There are two ways in which the physical layer performance can be affected by power control. Traffic carrying capacity of the network is affected by the power control and also the connectivity of the resulting network is affected (Gomez and Campbell, 2007).

The connectivity of the network can be affected when the transmission power determines which node can notice the signal. The network is partitioned and the number of active nodes is reduced in order to determine the node. The network topology needs to be considered in power control operations so that the connectivity can be maintained (Krunz *et al*., 2004). The survivability of portable devices can be affected by energy saving mechanisms since, the batteries have limited weight and lifetime (Muqattash and Krunz, 2004). Due to the absence of central control and varying packet delays clock synchronization is critical in multi-hop MANETs. Erratic mobility and radio interference are the reason for varying packet delay (Chen *et al*., 2006). It is critical for MAC protocols, to obtain efficient power control since, MANETs are dynamic in nature (Chen *et al*., 2006).

Problem identification and proposed solution: Power control is a critical issue in MANET. Designing an efficient power control mechanism for MANET is a challenging task. Existing power control techniques rarely considers the delay incurred in power estimation and connectivity of the network. The slow start power controlled MAC protocol for mobile ad-hoc network has been proposed by Varrarigos *et al*. (2009). In this protocol, RTS control packet has to wait T_{RTS} time for getting acknowledgement and further process. This waiting tine leads to delay. In addition to this sending RTS packet is increased with P^{i}_{RTS} which leads to overhead problems. To solve the above-mentioned problems, researchers propose to develop a power control MAC protocol for minimizing the power consumption and increasing the throughput in MANET.

In this MAC protocol, each node contains neighbor set denoted as N_{SET}. The N_{SET} contains the set of neighbors with their optimal transmission power values. Each node has a set of three values as initial transmission power denoted as P_{ini-1}, P_{ini} and P_{ini+1}. These initial values can be different for different nodes. The protocol has two phases:

- Power estimation within the transmission range
- Power estimation beyond the transmission range

Power estimation within the transmission range: When the source node has to transmit some data packets to the destination, it send 3 RTS packets with different transmission power levels P_{ini-1} and P_{ini}, P_{ini+1} to all nodes within its transmission range (one-hop neighbors). Depending on the correctly received CTS packet from the nodes, the source node chooses the optimal initial transmission power value P_{data} for these nodes. It then adds these nodes in N_{SET} along with the optimal transmission power values. Now, N_{SET} has a set of nodes to which the source can directly transmit the data with the selected optimal transmission power values.

Power estimation beyond the transmission range: A node that is beyond the transmission range of the source node overhears a control packet (RTS and CTS packets) in its neighborhood. Immediately it transmits CTS packet using its transmission power values and send to the source node. On receiving this message, the source node checks its power values with the condition:

$$Pij \leq Piu+Puj \tag{1}$$

Where:

Pij = The minimum transmission power required for transmitting the data from i to j

Piu = The minimum transmission power required for transmitting the data from i intermediate node u

Pui = The minimum transmission power required for transmitting the data from intermediate node u to the j

Among the three transmission power values, a value which satisfies the condition can be elected as an optimal power value for that node and the node is added to N_{SET}. If none of the power value satisfies the condition then that intermediate node is rejected by the source node.

Now, the source node sends data to the destination through nodes that has minimum transmission power value. Thus, the proposed research provides optimal power control in MANET.

LITERATURE REVIEW

Gautam *et al*. (2011) have developed a mechanism, Enhanced Transmission Power Control Mechanism (ETPCM). During packet transmission the required transmission power consumption of radio can be minimized. In this research, the transmission power is dynamically set according to the distance. Using

Receiving Signal Strength Indicator (RSSI) between these nodes, they calculate the distance. Alawieh *et al.* (2007) have proposed a distributed correlative Transmission Power Control (TPC) scheme for mobile ad hoc networks using prediction filters. The interference of nodes can be predicted using Prediction filters. The power values are assigned to the related ensued packets which assures IEEE 802.11 (RTS/CTS/DATA/ACK) communication accomplishment. The transmitter and receiver use the predicted interference in MANETs.

Gomez and Campbell (2007) have proposed a new variable-range transmission-based routing protocol. They derived an asymptotic expression for the computation of the average variable-range transmission and traffic capacity in wireless ad hoc networks. They showed that the use of a variable-range transmission-based routing protocol uses lower transmission power and increases capacity. They also derived expressions for the route discovery and maintenance phases of an ideal on-demand routing protocol.

Varvarigos *et al.* (2009) have proposed and evaluated a new MAC protocol for Adhoc networks, called the Slow Start Power Controlled (SSPC) protocol. In SSPC, RTS frame transmission power follows a slow start principle while DATA frames are sent using the minimum transmission power that guarantees the connectivity between the nodes plus some margin that allows for future interference. CTS frames are sent at the maximum transmission power and include information that is used by the recipients to compute the maximum power they can use for their DATA frame transmissions. Rate adaptation mechanisms can also be combined with the SSPC protocol.

Giovanidis and Stanczak (2011) have investigated the effects of hop by hop packet loss and retransmissions via ARQ protocols within a Mobile Ad hoc Network (MANET). They first derive the expression for the network's capacity region where the success function plays a critical role. Properties of the latter as well as the related maximum good put function are presented and proved. In this model, each node decides independently over its transmitting power through a chosen link.

ADAPTIVE POWER CONTROL TECHNIQUE

Overview: In this study, researchers propose to design a power control MAC protocol for minimizing the power consumption and increasing the throughput in MANET. Initially, researchers assume that each node contains Neighbor set (N_{SET}). The critical transmission range for connectivity of randomly placed nodes is calculated and they are classified into the nodes within transmission level and nodes outside the transmission level.

Depending upon the minimum transmission range between two nodes the neighbor set is created. The source node transmits RTS packets with three transmission power levels P_{ini-1}, P_{ini} and P_{ini+1} to the destination node when the node is within the transmission range. Based upon the timer value and network allocation vector, the transmission power level between two nodes can be estimated. The destination node transmits back the CTS packet with one of the power levels.

When the node outside the transmission range overhears the RTS and CTS packets in its neighborhood, it transmits CTS packet using its transmission power values and send to the source node. On receiving this message, the source node checks its power values with the condition that the minimum transmission power required for transmitting the data from source to destination is lesser than or equal to the sum of the minimum transmission power required for transmitting the data from source to intermediate node and the minimum transmission power required for transmitting the data from intermediate node to the destination. Now, the source node sends data to the destination through nodes that has minimum transmission power value. Thus, the proposed research provides optimal power control.

Variable range transmission: Initially, researchers assume a Mobile Ad hoc Network (MANETs) with n number of nodes. In this network, researchers determine the minimum transmission range between two nodes. Now, let us assume that each node can dynamically control the transmission power it uses independently of other nodes.

Researchers calculate β min as the weight or cost of each individual link e in graph L. This is taken as transmission range between two nodes connected by link e. The end to end weight of a route from node i to node j is the summation of the weight of the individual links representing a continuous traversal from node i to node j. Then, the critical transmission range for connectivity of n randomly placed nodes in A square meters is shown to be:

$$TR_C > (1+\gamma)\sqrt{\frac{\lambda \ln n}{\pi n}}; \ \gamma > 0 \tag{2}$$

where, λ is the total area of the network. The end to end weight and average transmission range in the network can be minimized by assuming unique route between source-destination pair. The TR_C value is calculated as the above equation and node is located. Once the locations of the nodes are estimated then the transmission power of the nodes can be determined effectively. When the above equation is satisfied, the node is considered to be inside the transmission range else the node is considered to be outside the transmission range.

Selecting optimal transmission value: When the connection between the nodes doesn't exceed the TR_c value then they are considered to be inside the transmission range and are added to the N_{SET} to which the source can directly transmit the data with the selected optimal transmission power values. If the nodes are beyond the transmission level then an intermediate node is chosen which needs to satisfy the following condition:

$$Pij \le Piu + Puj \tag{3}$$

Where:

Pij = The minimum transmission power required for transmitting the data from i to j

Piu = The minimum transmission power required for transmitting the data from i intermediate node u

Puj = The minimum transmission power required for transmitting the data from intermediate node u to the j

The power level Piu and Puj which is for the intermediate nodes is calculated in study. After the power level are checked then the nodes which satisfy the condition are included in the N_{SET} (Gomez and Campbell, 2007). In Fig. 1, researchers consider a source node Sn, Destination node Dn and 9 nodes. Initially the critical transmission range for connectivity between two nodes TR_C is calculated. From the Sn each node calculates its TR_C. The TR_C value of node 2 and Sn is not upto the critical level and thus it is considered to be inside the transmission range (indicated by black arrows). Then, the TR_C between the node 8 and Sn is calculated and it is seem to be above the critical value (indicated by blue arrows).

So, the node 8 is considered to be outside the transmission level. Similarly, researchers calculate the TR_C value for all the nodes and in this network, node 1-4 lie inside the transmission range and node 5-8 lie outside the transmission level.

Power estimation within the transmission range: Initially, researchers consider that each node contains neighbor set N_{SET}. The N_{SET} contains the set of neighbors with their optimal transmission power values. Each node has a set of three values as initial transmission power denoted as P_{ini-1}, P_{ini} and P_{ini+1}.

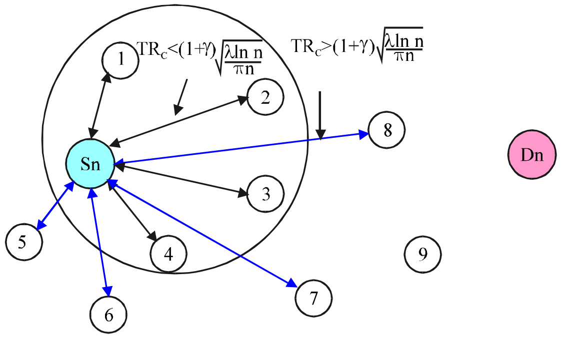

Fig. 1: Estimation of TRc value

These initial values can be different for different nodes. Researchers consider a Source node (Sn) which has three power levels P_{ini-1}, P_{ini} and P_{ini+1}. The node sends RTS frame with all the three power levels and also sets a timer which is equal to RTS transmission duration (Rd). The value of the timer is set to:

$$Rd = 2D_p R + W_{SIFS} + Cd \tag{4}$$

Where:

D_pR = The propagation delay it takes for the RTS frame to reach the sender

W_{SIFS} = Time the receiver must wait before sending back the CTS frame

Cd = CTS duration

η_d = Time taken by DATA frame to reach the destination

Ad = Time it takes the ACK frame to reach the transmitter of the DATA frame

Equation 4 is the sum of the propagation delay required for the RTS frame to reach the destination. When Destination node (Dn) correctly decodes the RTS frame, it replies with a CTS frame that includes the transmission power P_{DATA} that Sn must use to transmit DATA frames to Dn. This power is given by the equation:

$$Pij = P_{DATA} = Pr + K \tag{5}$$

Where:

Pr = The transmission power of the current (ith) RTS transmission attempt

K = A safety margin to allow for any future interfering transmission

The location of all the nodes in the network or the channel conditions is not required for computing DATA frames transmission power. Pr derives the DATA frame transmission power. K is the safety margin used for future interference at Dn. In other words, to allow for a number

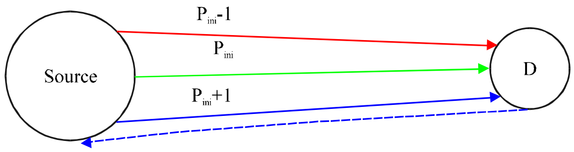

Fig. 2: Selection of transmission power level

of future interfering transmissions to take place in the vicinity of Dn then Dn requests Sn to increase by K the transmission power of the DATA frames. The nodes in the vicinity of DATA frame receiver which is allowed to transmit depends upon a larger K. The interference caused by the transmitting node to nodes other nodes is larger than the intended receiver. Maximum transmission power is used by Dn to send the CTS frame (Varvarigos *et al*., 2009).

In Fig. 2, researchers show the Sn transmitting RTS packet with three transmission power levels is sent to the Dn. Based upon the timer, the Dn transmits the CTS packet. Here, researchers consider that the Dn selects the power level P_{ini+1} data transmission.

Power estimation beyond the transmission range: In this study, researchers provide the estimation of power level for the nodes which are outside the transmission range. For this type of transmission, an intermediate node is required and the interference power of the intermediate node is computed here.

The intermediate node is used by the source node to send their RTS packet with three transmission power levels to the destination node. To ensure Dn that its CTS frame was received successfully by Sn, Dn sets a timer to a timeout value:

$$Cd = 2(Dp) + W_{SIFS} \tag{6}$$

The DATA frame must be received before this time Dn, if not it is considered that the CTS frame is failed for the transmission. NAV_{CS} = EIFS value is set for the nodes in the carrier sensing zone of Sn. For a particular duration, the transmission levels may defer. The nodes in the carrier sensing zone cannot decode the received frame, so they do not know the duration of the frame and also they cannot compute the maximum power they can use. These nodes set their NAV's for the EIFS duration, to prevent a collision with the DATA frame at the receiver. The interference power Ip needs to be computed and it is the major concern which is to be addressed. The total interference margin K at the receiver is not suitable for contribution of each neighbor node. The future interference K that is allowed must be equitably distributed among the future potentially interfering users in the vicinity of Dn. Let Ht be the number of nodes in the vicinity of Dn at time t that are to share the interference K at a time t, the instantaneous umber of simultaneously active transmissions in the neighborhood is followed by Dn.

This is denoted as $H_{sim}(t)$. This can be easily computed by monitoring the RTS/CTS exchange. When RTS packet is received at the receiver, $H_{sim}(t)$ value is denoted by the H_{RTS}. In addition, Dn keeps track of a moving average of $H_{sim}(t)$, denoted by H_{avg} (t). Then, Ht is calculated as follows:

$$H_t = \max\{H_{avg}(t),\ H_{sim}(t)\} - H_{RTS} \tag{7}$$

H_{RTS} active transmissions in the neighborhood of Dn can be obtained when CTS message is sent. The future interference margin K is to be shared by future interferers, other than the H_{RTS} interferers already accounted for. The interference power that each neighbor can add to Dn is finally given by the equation:

$$P_{iu} = P_{uj} \max\{K \mid H_t, P^{min}\} \tag{8}$$

where, P^{min} is a lower bound researchers pose on P_{iu} or P_{uj}. The interference power that every node will be allowed to cause to D_n value maybe small or unusable if the margin K is distributed among a large number of neighboring nodes.

The lower bound nodes P_{iu} or P_{uj} which do not correctly decode the CTS frame does not determine the accurate value of Ip. This is not safe for power level and so it is prevented from transmission. The nodes can transmit up to a given power level when they are at a greater distance from Dn.

Therefore, P_{iu} or P_{uj} is the additional interference power that each future interferer can add to a receiver and is chosen to be the same for all the neighboring nodes while K is the aggregate future interference that the receiver can tolerate which is equitably distributed to its neighboring nodes (Varvarigos *et al*., 2009). The power level P_{iu} or P_{uj} is sent to the D_n with their three transmission power values P_{iu-1}, P_{iu}, P_{iu+1} or P_{ui-1}, P_{ui}, P_{ui+1}. Among the three transmission power values, a value which satisfies the condition can be elected as an optimal power value for that node and the node is added to N_{SET}. If none of the power value satisfies the condition then that intermediate node is rejected by Sn. Finally, the source node sends data to the destination through nodes that has minimum transmission power value which achieves optimal power level.

SIMULATION RESULTS

Simulation parameters: Researchers evaluate the Adaptive Power Control Technique (APCT) through Network simulator (NS-2) Network Simulator, http://www.isi.edu/nsnam/ns. Researchers use a square region of 500×500 m^2 in which nodes are placed using a uniform distribution. The number of nodes is varied as 50, 100, 150 and 200. We assign the power levels of the nodes such that the transmission range of the nodes varies from 250-400 m. We have modified the standard 802.11 CSMA MAC protocol to include the adaptive power control technique. The simulated traffic is Constant Bit Rate (CBR). Researchers assumed that nodes have global knowledge of the network topology for adjusting their transmission power and no control packets and related overhead were included. Table 1 summarizes the simulation parameters used.

Performance metrics: Researchers compare the performance of the proposed APCT method with the Power Controlled Dual Channel (PCDC) MAC protocol (Muqattash and Krunz, 2004). To compare the two approaches, the same paths were selected for the packets delivery from the source to the destination nodes. Researchers evaluate mainly the performance according to the following metrics:

Packet delivery ratio: It is the total number of packets received by the receiver during the transmission.

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

Table 1: Simulation parameters

Parameters	Values
No. of nodes	50,100,150 and 200
Area size	500×500
Mac	Modified 802.11
Simulation time	25 sec
Traffic ource	CBR
Packet size	500
Transmit power	0.660 W
Receiving power	0.395 W
Idle power	0.035 W
Initial energy	10.3 J
Transmission range	250, 300, 350 and 400 m
Routing protocol	AODV

Table 2: Results for varying nodes

	Delay		Delivery ratio		Energy	
Nodes	PCDC	APCT	PCDC	APCT	PCDC	APCT
50	0.117020	0.095017	0.992925	0.995844	11.11027	10.45838
100	0.177450	0.199663	0.977923	0.993766	10.20559	9.880098
150	0.826488	0.078671	0.943461	0.996164	10.61285	10.20350
200	1.635976	0.922472	0.915663	0.951233	10.13982	9.662517

Average energy consumption: The average energy consumed by the nodes in receiving and sending the packets.

Based on nodes: In the initial experiment we vary the number of nodes as 50, 100, 150 and 200 with transmission range 250 m (Table 2). Figure 3 shows the average end to end delay occurred for both APCT and PCDC approaches. For both approaches, the average packet delay increases as the number of nodes increases. It can be seen that APCT outperforms the PCDC approach. Figure 4 depicts the packet delivery ratio achieved for both APCT and PCDC approaches. As shown in Fig. 4, APCT results in higher delivery ratio than PCDC. When nodes use PCDC, a larger number of neighboring nodes defer their transmissions, upon hearing a RTS or CTS frame, resulting in lower delivery ratio. But in the APCT case, more simultaneous transmissions can take place. The average energy consumed by each node is shown in Fig. 5. The variance of the consumed energy indicates how the power consumption in the network is distributed among the various network's nodes. From Fig. 5, it can be seen that APCT approach results in smaller energy consumed per node than the PCDC approach. This indicates that APCT tends to spread energy consumption more uniformly among the nodes.

Based on transmission range: In the third experiment researchers vary the transmission range as 250, 300, 350 and 400 m (Table 3).

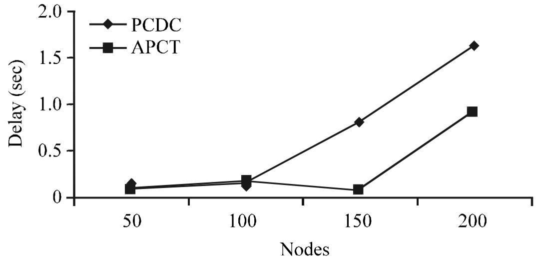

Fig. 3: Nodes vs. delay

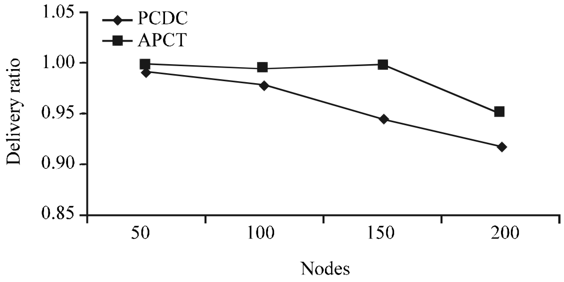

Fig. 4: Nodes vs. delivery ratio

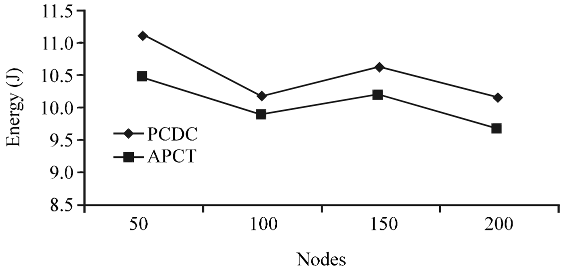

Fig. 5: Nodes vs. energy

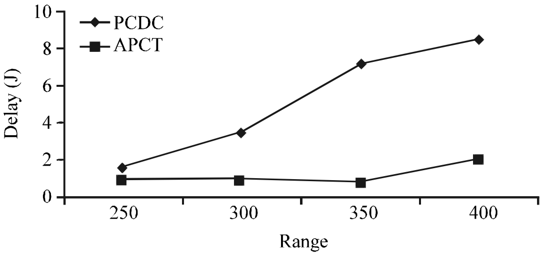

Fig. 6: Range vs. delay

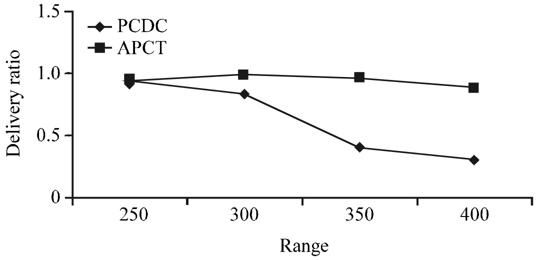

Fig. 7: Range vs. delivery ratio

Table 3: Results for varying range

	Delay		Delivery ratio		Energy	
Range	PCDC	APCT	PCDC	APCT	PCDC	APCT
250	1.635976	0.922472	0.915663	0.951233	10.13982	9.662517
300	3.433489	0.870898	0.831325	0.991233	10.08355	9.399612
350	7.105501	0.723745	0.416210	0.960548	10.44934	9.663720
400	8.356210	2.030977	0.301095	0.870685	10.83573	9.866638

Figure 6 shows the average end to end delay occurred for both APCT and PCDC approaches when the transmission range is increased. As researchers can see from the Fig. 6, the delay is less for APCT when compared to PCDC. Figure 7 shows the packet delivery ratio occurred for both APCT and PCDC approaches when the transmission range is increased. As researchers can see from the Fig. 7, the delivery ratio is high for APCT when compared to PCDC. Figure 8 shows the energy consumption for both APCT and PCDC approaches when the transmission range is increased. As researchers can see from the Fig. 8, the energy consumption is low for APCT when compared to PCDC.

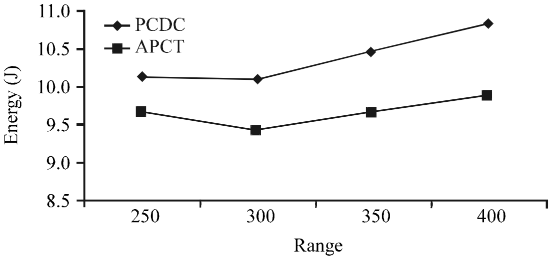

Fig. 8: Range vs. energy

CONCLUSION

In this study, researchers have proposed to develop a power control MAC protocol for minimizing the power consumption and increasing the throughput in MANET. Based upon the critical transmission range for connectivity, the nodes within the transmission range can be identified.

The source node transmits RTS packets with three transmission power levels P_{ini-1}, P_{ini} and P_{ini+1} to the destination node when the node is within the transmission range.

Based upon the timer value and network allocation vector, the source node chooses the nodes with optimal initial transmission power value. For the nodes beyond the transmission range, the power values of the intermediate nodes are also calculated and the source node checks its power values with the condition that the minimum transmission power required for transmitting the data from source to destination is lesser than or equal to the sum of the minimum transmission power required for transmitting the data from source to intermediate node and the minimum transmission power required for transmitting the data from intermediate node to the destination. Thus from the simulation results, researchers show that the proposed MAC protocol provides improved packet delivery ratio with reduced power and delay for MANET.

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