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An Adaptive Transmission Power Aware Multipath Routing Protocol For Mobile Ad hoc Networks

Bhavna Arora[a], Dr.Nipur[b]
[a]Research Scholar, Dept. of Computer Science,
Gurukul Kangri Vishvavidyalya, Hardwar, India
[b2]Professor, Dept. of Computer Science, Kanya Gurukul Campus, Second Campus of Gurukul Kangri Vishvavidyalya, Hardwar.

Abstract

Selection of an optimal transmission power for forwarding packets in mobile ad hoc networks has many benefits over setting a common transmission power. These benefits are reduced congestion, reduced interference in the network, lesser number of collisions and reduced energy consumption. In this paper we have proposed a new multipath routing protocol Adaptive Transmission Power – AOMDV that is capable of dynamically changing the transmission power of control packets used for route discovery in the network. Comprehensive simulations are carried out on NS-2, the proposed protocol ATP-AOMDV is compared to AOMDV under various performance metrics like average end to end delay, packet delivery ratio, network throughput and residual battery of nodes to show ATP-AOMDV performs better than AOMDV in saving battery energy in highly mobile network with high traffic loads.

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Keywords: Multipath; Energy efficient; Variable Transmission Power; Selective Flooding

1. Introduction

The correct selection of the transmission power in mobile ad hoc networks plays a crucial role in the performance of the entire mobile ad hoc network. The transmission power which is set at the physical layer of the protocol stack affects the performance of the higher layers which in turn affects the working and connectivity of the entire network. There are various trade-offs in choosing the correct transmissionpower of the packets, like if we set a high transmission power then the transmission will cause undue interference with other nodes and also will deplete the energy of the nodes quickly. While choosing a low transmission power will lead to no or lesser number of neighbor discovery, low quality of signal strength of the transmitted packet, to name a few. Thus selecting an optimal transmission power is a crucial issue in the case of mobile ad hoc networks.

The transmission power control refers to set the transmission power for each packet in a distributed way at each node in the mobile ad hoc network. All the layers of the protocol stack right from physical layer, network layer, mac layer and the transport layer are affected by the choice of transmission power of the nodes. The physical layer in two ways firstly, the transmission power affects the traffic carrying capacity of the network also, if a too high transmission power is chosen then the number of forwarding nodes needed to reach the intended destination is reduced as a signal sent at high transmission power will reach to greater number of nodes.

* Bhavna Arora Tel.: +91-9410577500*E-mail address: shubhavna@yahoo.com*

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But a high transmission power creates excessive interference in the wireless shared. On the contrary, if a lower transmission power is chosen then it reduces the interference, but packets require more forwarding nodes to reach their destination [2]. In [3], the authors show that, if only the physical layer is considered then by reducing the transmission power the traffic carrying capacity of the network can be increased. Secondly, transmission power control also affects the connectivity of the mobile ad hoc network. Higher transmission power increases the number of direct links seen by each node thus increasing the connectivity of the network, but the capacity of the network is reduced.

The main advantage of fully connected networks is that routing protocols can find multiple paths for any source and destination pair, these paths are very useful in cases when some nodes or link fail [4]. But, in order to get a fully connected network high transmission power of nodes is required which in turn leads to reduced network capacity and reduced battery power of the nodes. As stated in [1] high transmission power leads to interference at the network layer which in turn causes congestion and thus affects the transport layer. Transmission Power also affects the contention for the medium, as well as the number of hops and, therefore, the end-to-end delay. Transmission power also affects the important metric of energy consumption at the nodes. High transmission power leads to greater energy consumption thus lowering the lifetime of the entire network. In addition, [2] transmission power also affects the signalling overhead of routing protocols used in mobile wireless ad hoc networks. Higher transmission power decreases the number of forwarding hops between source-destination pairs, therefore reducing the signalling load necessary to maintain routes when nodes are mobile. However, this signalling overhead of routing protocols consumes a significant percentage of the available resources like the bandwidth and the power availability. Transmission power control is a cross layer design problem affecting all layers of the protocol stack from physical to transport and affects many key criteria like throughput, delay, energy consumption and network lifetime.

Most of the routing protocols designed for mobile ad hoc networks use common transmission power for the network. As stated earlier a common transmission power has many drawbacks, so in this paper we present an adaptive and distributed transmission power control multipath routing protocol that calculates the required and sufficient transmission power at each node before forwarding a packet. The proposed routing protocol Adaptive Transmission Power – AOMDV (ATP-AOMDV) is a modification of Ad hoc On-demand Multipath Distance Vector (AOMDV) Routing Protocol.

Power-Aware Routing Optimization (PARO) [5] is a dynamic power controlled routing scheme that helps to minimize the transmission power needed to forward packets between wireless devices in ad hoc networks. PARO uses, one or more intermediate nodes called "redirectors" to forward packets on behalf of source–destination pairs thus reducing the aggregate transmission power consumed by wireless devices. It utilizes power consumption as the route metric its sole focus is on minimizing the transmission power consumed in the network.

PCM [6], a Power Control MAC protocol, periodically increases the transmit power during DATA transmission. The main scheme of these power control schemes of this protocol is to use different power levels for RTS-CTS and DATA-ACK. Specifically, maximum transmit power is used for RTS-CTS, and the minimum required transmit power is used for DATA-ACK transmissions in order to save energy.

1. AD-HOC ON-DEMAND MULTIPATH DISTANCE VECTOR ROUTING

Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV) [7] protocol is an extension to the AODV protocol for computing multiple loop-free and link disjoint paths. In AOMDV, as the RREQ propagates from the source towards the destination multiple reverse paths are established both at intermediate nodes as well as the destination. Multiple RREPs traverse the reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. Intermediate nodes also keep track of alternate paths to the destination node. Duplicate RREQs are not forwarded by the intermediate nodes, so any two RREQs arriving at an intermediate node via a different neighbor of the source could not have traversed the same node.

To find multiple link-disjoint routes, the destination only replies to duplicate RREQs, to RREQs arriving from unique neighbors. The routing entries for each destination contain a list of the next-hops along with the corresponding hop counts. All the next hops have the same sequence number which helps in keeping track of a route. For each destination, a node also maintains the advertised hop count, which is defined as the maximum hop count for all the paths, used for sending route advertisements of the destination. Each duplicate route advertisement received by a node defines an alternate path to the destination. Loop freedom is assured for a node by accepting alternate paths to destination if it has a less hop count than the advertised hop count for that destination. Because the maximum hop count is used, the advertised hop count therefore does not change for the same sequence number. When a route advertisement is received for a destination with a greater sequence number, the next hop list and the advertised hop count are reinitialized.

AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQs arriving via a different neighbor of the source defines a node-disjoint path. This is because nodes cannot be broadcast duplicate RREQs, so any two RREQs arriving at an intermediate node via a different neighbor of the source could not have traversed the same node. In an attempt to get multiple link disjoint routes, the destination replies to duplicate RREQs, the destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow the reverse paths, which are node disjoint and thus link-disjoint.

2. ADAPTIVE TRANSMISSION POWER-AD HOC ON DEMAND MULTIPATH DISTANCE VECTOR

The basic working of ATP-AOMDV routing protocol is similar to that of AOMDV but we have set the transmission power adaptively based on the distance and the propagation model at each node for each packet before forwarding it. When a node has a data packet to send to a particular node, it first looks up for a valid route in its routing table if no valid route is available then the source node initiates a RREQ packet and broadcasts it in the network intended for the destination. This broadcast is done at common transmission power that is all RREQ packets originating from the source node are broadcasted at common transmission power. Also the hello packets are broadcasted at common transmission power so as to discover maximum number of neighbouring nodes. Each node maintains its list of neighbours which will be later utilized by the intermediate node for forwarding the RREQ packet. An intermediate node is a one that is neither the source nor the destination for a particular RREQ packet.

Till here the working of ATP-AOMDV is similar to that of AOMDV, also ATP-AOMDV handles route errors in the same way as AOMDV does.

2.1 Modifications

On receiving a RREQ packet, an intermediate node checks whether it is a copy of previously received RREQ. If it is a copy, then the node simply discards the duplicate RREQ packet otherwise it looks for any valid route to the desired destination in its routing table. If it does not have any valid route to the destination then instead of broadcasting the RREQ packet at common transmission power, the intermediate node only forwards it to its neighbors at variable transmission power which is sufficient for reaching to its neighbors.

2.1.1Calculation of Transmission Power

An intermediate node first calculates its distance from each of its neighbors and then adjusts the transmission power for each RREQ (one for each neighbor) before forwarding. Here we calculate the node's distance from each of its neighbors by the following Equation (1).

Distance = sqrt(Xpos + Ypos + Zpos).... Equation (1)

Where Xpos = (x1-x2)2, Ypos = (y1-y2)2, Zpos = (z1-z2)2, (x1, y1, z1) are the coordinates of the intermediate node and (x2, y2, z2) are the coordinates of its neighbor nodes.

For calculating the transmission power not only the distance between the nodes but many factors has to be considered like the underlying propagation model, the antenna parameters, the threshold value of the receiving signal at the receiving node called the Rxthreshold or Rxthresh – below which the signal is not received by the receiving end. The distance calculated from the above equation (1) at the routing layer is passed onto the physical layer so that the transmission power (Pt) can be set adaptively. Other information which is required for the calculation of Pt_ like the antenna characteristics, rxthreshold, wavelength of the medium are already available with the physical layer.

As we know that the value of Pt depends on the radio propagation model, its correct and accurate calculation is done with respect to the implemented radio propagation model. A radio propagation model, also known as the Radio Wave Propagation Model or the Radio Frequency Propagation Model, it is an observed mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions. The received signal strength of each packet is predicted by these radio propagation models. A receiving threshold is maintained for each packet at each node. On receiving a packet, if its signal power is below the receiving threshold, it is marked as error and dropped by the MAC layer. Three propagation models are implemented in the network simulator, which are the free space model, two-ray ground reflection model and the shadowing model. We have implemented the two-ray ground radio model for calculation of the transmission power

The two ray ground reflection model considers both the direct path and a ground reflection path. This model gives more accurate prediction at a long distance than the free space model. The free space propagation model assumes the ideal propagation condition that there is only one clear line of-sight path between the transmitter and receiver. The received power is only dependent on the transmitted power Pt, the antenna's gains (Gs and Gr) and on the distance between the sender and the receiver. It accounts mainly for the fact that a radio wave which moves away from the sender has to cover a larger area. So the received power decreases with the square of the distance. The shadowing model realizes the log-normal shadowing model. It is assumed that the average received signal power decreases logarithmically with distance. A Gaussian random variable is added to this path loss to account for environmental influences at the sender and the receiver [8].

We have implemented the two ray ground radio propagation model for our proposed protocol. The transmission power is calculated at the intermediate node based on the distance between itself and its neighbors, if the distance between the nodes is less than the cross over distance that is the minimum threshold distance between the sender and the receiver then the value of Pt is calculated by equation (2). Where Pr is the received signal power, lambda is wavelength, Gt is transmission gain, Gr is the receiver gain, and L is the system loss. In case when the distance between the nodes is greater than the cross over distance then equation (3) is used to evaluate the transmission power Pt

$$Pt = \frac{(4 * pi * distance)^2 * Pr * L}{Gt * Gr * lambda^2} \text{......equation (2)}$$

$$Pt = \frac{Pr * distance^4 * L}{Gt * Gr * ht^2 * hr^2} \text{........equation (3)}$$

Where Pr is the received signal power, Gt is transmission gain, Gr is the receiver gain, L is the system loss, ht and hr is the height of xmit and receiver antenna respectively. The steps followed at the intermediate node before forwarding the RREQ packet is given in figure 1.

Algorithm 1 : forwardRREQ

Pre conditions: Intermediate have not received this RREQ before, also it does not have a valid route to the desired destination in its routing table.

Post conditions: The RREQ is forwarded only to the neighbors at variable Pt for each copy of RREQ and for each neighbor

Step 1 : The intermediate node look up its neighbor cache.

Step 2 : For each neighbor (1 to n)

Distance is calculated from itself

Based on the distance the required Pt (Transmission Power) is calculated for each neighbor.

Each RREQ packet is marked with the Pt at the physical layer before actually forwarding it.

Figure 1

Once the RREQ packet reaches the desired destination the destination node generates a RREP packet and sends it along the reverse path traversed by the RREQ packet. Here also the transmission power is adjusted dynamically for each hop of the RREP packet. Rather than sending the RREP packet at a common transmission power to the source node via intermediate nodes over multiple hops, we adjust the Pt for RREP packet at each hop. Starting at the destination node the transmission power Pt is adjusted as per its distance from the next hop node which is recorded in the reverse path set by the RREQ packet. This process of adjusting the Pt is done at each hop till the RREP packet reaches the source node. The finding of suitable transmission power for transmission is done in the same manner as done for RREQ packet.

Thus a considerable amount of battery power of the nodes and interference that in turn increases the congestion in the network is reduced by setting variable transmission power for each packet before forwarding it. We have carried out comprehensive simulation in order to support our findings. Once multiple paths are set between a particular source and destination pair of nodes, these routes are used for data transfer. In case of any route failure due link breakage, route maintenance is performed by generating REER packet as done in AOMDV protocol.

3. PERFORMANCE EVALUATION

3.1 Simulation Environment:

Comparative simulation for both the protocols AOMDV and ATP-AOMDV are carried out on Network Simulator-2. Constant bit rate (cbr) traffic at a rate of 4p/s each of size 512 bytes is generated for all the scenarios. The dimension of the topography is 500 x500 and the simulation is carried out for 500 s. The radio propagation model used is Two Ray Ground and the Mac is specified as IEEE802.11. The results are computed after at least 5 runs of the simulation for each scenario. To study the impact of mobility on ATP-AOMDV we have varied the pause time of the nodes from 0s to 400s. Where, 0s specifies highly mobile network and 400s specifies a quasi static network. The maximum number of connections is constant which is 50. The speed of the nodes is also constant at 20m/s. The energy model used is the Ns-Energy model. The initial energy of the nodes is 1000 Joules and the energy consumption in transmission, reception, idle and sleep is 2.0, 1.0, 0.1 and 0.001 in watts respectively.

3.2 Simulation Results

In order to analyze the simulation results of ATP-AOMDV in MANET, we compare its performance with AOMDV in terms of packet delivery ratio, end-to-end delay, normalised routing load, network throughput and average energy of nodes at the end of simulation.

A. Packet delivery fraction: The fraction of the data packets delivered to the destinations to those generated by the sources. The higher the value of this metric the better the performance of the protocol.

B. Average end-to-end delay of data packets: It is defined as the mean time taken in seconds by the data packets to reach their respective destinations. The lower the value of this metric the better the performance of the routing protocol.

C. Network Throughput: Throughput or network throughput is the average rate of successful message delivery over a communication channel. The higher the throughput the better is the performance of the routing protocol. The unit is Kbps.

D. Average Energy of nodes at the end of simulation: It is the average residual energy left in the nodes after the simulation is carried out for 500 s that is at end of the simulation. The higher is the value the more is the network lifetime.

Figure 2 below demostrates the performance of ATP-AOMDV in terms of packet delivery ratio and it give upto 26% higher packet delivery ratio as compared to AOMDV. The average end to end delay is reduced remarkably by up to 69% in ATP-AOMDV than that of AOMDV as in Figure 3. The network throughput is also as in figure 4 about 23 % higher in the proposed protocol; this is due to lesser congestion in the network which is in turn the result of choosing variable Transmission power. As AOMDV works on common transmission power it causes undue traffic and interference in the network lowering the network throughput.

As we have adopted variable transmission power for route discovery mechanism, it provides a benefit over the overall energy consumption of the nodes in the mobile ad hoc network. The average initial energy of the network at the start of the simulation was 1000 watts and after running the simulation for 500 s, we have seen that there is more than 15% increase in the average residual energy of the nodes in the network (figure 5). This increased energy levels of the network leads to higher network lifetime, which is a crucial requirement for mobile ad hoc networks as energy is one of the scant resources.

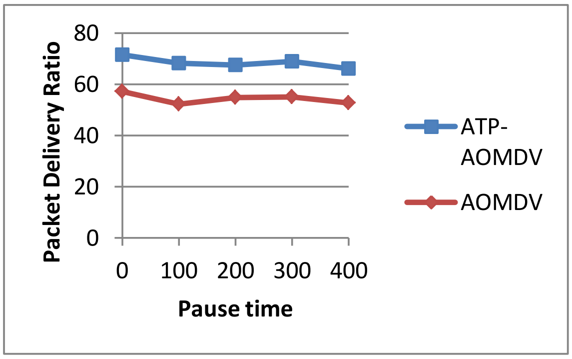

Figure 2

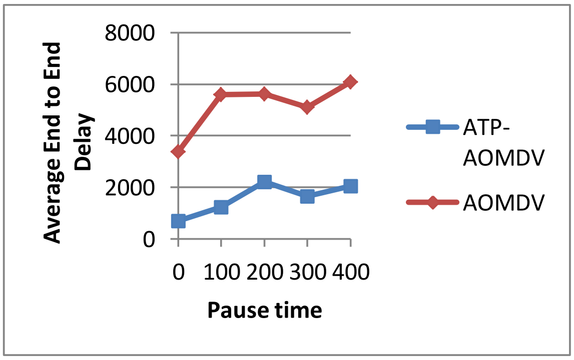

Figure 3

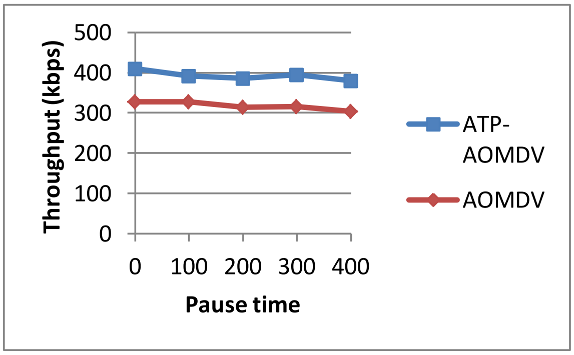

Figure 4

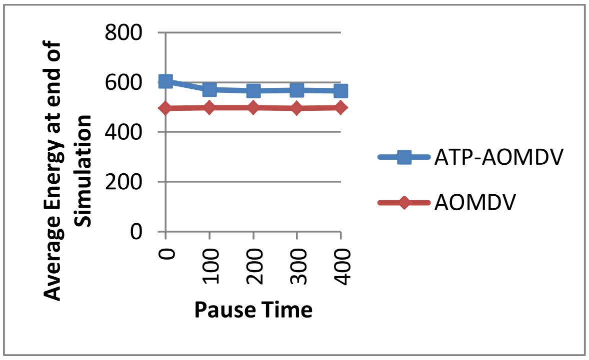

Figure 5

4. Conclusion & Future Work

In this paper we have proposed an energy efficient multipath routing protocol for mobile ad hoc networks. ATP-AOMDV is an extension of the existing multipath AOMDV routing protocol. ATP-AOMDV uses adaptive selection of sufficient transmission power for individual packet thus does not cause high interference and undue traffic generated by control packets. Also ATP-AOMDV is capable of energy conservation as proved by comprehensive simulation and comparison. In the future work, we will try to incorporate varying the Transmission power not only for control packets as RREQ and RREP but also for data forwarding.

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