QoS through Power Control in MANETs using AODV Protocol

Dr D Srinivas Rao
Principle Investigator
UGC Major Research Project

Jooby Ann Thomas
M. Tech (DSCE)

Sake Pothalaiah
project Associate
UGC Major Research Project

Dept of ECE, College of Engineering, Jawaharlal Nehru Technological University
HYDERABAD - 500 085, ANDHRA PRADESH, INDIA

ABSTRACT
In Mobile Ad hoc Networks (MANETs) QoS provisioning is very difficult than traditional networks. The MANETs is wireless network without fixed infrastructure and self organised. These networks have only limited power. This paper describes power management two schemes namely Dynamic Power Management (DPM) and Directional Local Recovery (DLR) performance evaluated and AODV used as the underlying protocol in both the schemes. Power consumed and Power variance parameters are used as metrics to evaluate the performance of power balancing. Performance of AODV is compared with the DPM and DLR. The simulation results verifies that the extended schemes which use AODV as the underlying protocol provides substantial energy savings thus prolonging the battery life of mobile nodes. Simulation is performed using NS2 simulator.

Key Words: MANETs, AODV, DPM, DLR

1. INTRODUCTION
A wireless Ad hoc network has many advantageous when compared to its wired network, such as rapid deployment without complicated configuration. It can also be used in those environments where it is difficult to set up wired networks like in military fields or emergency scenes. In wireless Ad hoc networks power consumption is a huge concern because most of the mobile nodes operate on batteries. Low power results in death of a node and in such circumstance a new path is required to be established for routing thus developing a method to reduce power consumption while maintaining network connectivity has attracted many research efforts. The classifications of Ad hoc mobile routing protocols are proactive and reactive. In this paper implemented one of the reactive protocols such as AODV protocol.

The focus of this paper is to introduce new methodologies for power management. It follows two directions to achieve this goal. The first is to balance the amount of power consumed across the network and the second reduces the overall power consumed within the network in case of a route failure. Energy management and power management are closely related. It can be defined as the process of managing the sources and consumers of energy in a node or in the network as a whole for enhancing the lifetime of the network. Both the approaches this paper describes work towards the same goal of conserving resources (energy) and extending the lifetime of the network.

2. RELATED WORK
Power management is mostly considered as a network layer problem. They are based on the observation that connectivity of the entire network is decided only at the network layer. As one of the main functions of network layer is routing, most of the work gives importance on building power efficient algorithms. Reducing the overall power consumption can be achieved by two different approaches that are correlated, to minimize the power consumption per node and to minimize the total network consumption. To minimize power consumption one approach is to select paths (such that minimum power is consumed), which can simply be considered as a shortest path problem with power consumption as the weight for each link rather than the number of hops. Some proposals for energy efficient routing protocols [1, 5, and 7] typically aim to choose a path with a large number of small range hops since they consume less power than an alternative route that has fewer hops, but with longer distance for each individual hop. They are based on the variable power scenarios in which nodes can adapt the transmission power based on the distance between the source and the destination. Variable power scheme performs much better when compared to the fixed power scheme because it can control on the amount of power spent for transmission. However a larger transmission range causes more interferences resulting in more collisions thus enabling more transmission attempts. One obvious omission in this method is that it does not pay attention to the residual power.

Another approach focused on power efficiency through topology control [3, 8, 2, 4], based on the path loss model:

$$P_r = C * \frac{P_t}{d^k} \ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

The above equation left side of the equal sign is the received power and to the right is the transmitted power, where c is a constant d is the distance between the transmitter and the receiver and k is an environment dependent coefficient between 2 and 4. They attempt to adjust the power level to control the underlying topology in order to maintain the optimal number of neighbours. This however is only applicable to pedestrian ad hoc networks. SPAN [6] selects a number of coordinators to keep an ad hoc network connected. These coordinators are responsible for forwarding and buffering packets while others sleep. Thus it saves power without significantly diminishing the capacity or connectivity of the network. However it introduces large delays and is not applicable for time critical applications. Another approach was proposed by Wu and Li [10] for approximating connected dominating sets in an ad hoc network that also appears to preserve the power capacity. In another paper Wu and Gao [9] discusses power aware routing using connected dominating sets. PAMAS [15] works by turning off a node's radio when it is overhearing a packet not addressed to it. Kim *et al*. [12] introduced a minimal drain rate into the routing process that enables the possibility to predict the lifetime of a node according to current traffic conditions. Banerjee and Misra [11] show that retransmission aware schemes outperform energy aware solutions through analysis and simulations. Feeney and Nilson [13, 14] provide a thoroughly practical view of power consumption in an ad hoc network using IEEE 802.11 technology through experiments.

3. AD HOC ON DEMAND DISTANCE VECTOR (AODV) ROUTING PROTOCOL OVERVIEW

AODV is routing protocol for mobile Ad hoc networks and other wireless ad hoc networks. It is a reactive routing protocol. These reactive protocol is establishes a route to the destination only on demand with single or multiple hops. It employs destination sequence number to identify the most recent path. It is capable of both unicast and multicast routing. In AODV the source node and the intermediate nodes store the next hop information corresponding to each flow for data packet transmission. In an on demand routing protocol, the source node floods the Route Request packet in the network when a route is not available to the desired destination. The major difference between AODV and other on demand routing protocols is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to the destination. The node updates its path information only if the DestSeqNum of the current data packet received is greater than the last DestSeqNum stored at the node. Hello messages may be used to detect and monitor links to neighbours.

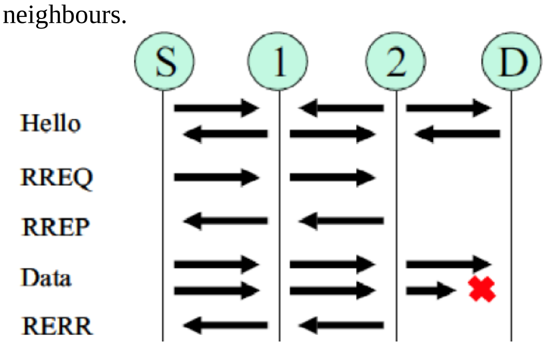

Figure 1: An idea of AODV Protocol messaging

The main advantage of AODV protocol is that routes are established on demand and the destination sequence numbers are used to find the latest route to the destination. The connection set-up delay is lower.

4. PROPOSED POWER MANAGEMENT SCHEMES

Our proposed power management schemes looks into two directions. First is to balance power consumption during data transfer and secondly to reduce the power consumed in case of a route failure. By balancing power consumption we can avoid the death of some critical nodes caused by excessive power consumption. Reducing power consumption intends to prolong the lifetime of each node which in turn extends the lifetime of the entire network. Each approach proposed in the following sections improves the network's performance either by balancing the power across the network or by reducing the power consumed by the nodes across the network. The final goal however is to determine the optimal combination of the techniques for various scenarios.

4.1 Dynamic Power Management

This section gives a possible solution for balancing the power consumed by the nodes across the network. In this way individual nodes are not overly burdened, thus avoiding the death of some critical nodes and extending the lifetime of the entire network.

Considering an ideal ad hoc network, all nodes would participate equally in the relay activity, forwarding packets for other nodes and having their packets forwarded by other nodes in return and so on. But practically this is not the case, because traffic patterns are not distributed evenly across the network thus resulting in diverse power levels at each node. Even if we consider that initially the power level is same among all nodes, depending on the communication session and the topology used the power level at some frequently used nodes would be quite different from the other nodes. The remaining power of the node diminishes so does its transmitting capability. Limiting transmission ranges can also partition the network. If each node were to contribute to the ad hoc community according to its residual power then the effects described above can be counter balanced. This is exactly what the proposed Dynamic Power Management (DPM) does, i.e., it adjusts the nodal transmission power proportionally to its remaining power. We assume all nodes can dynamically change its transmission power. It makes use of the following formula,

$$P_t = P_{tinit} * \frac{P_r}{P_f} \text{ .... (2)}$$

The terms used from left to right are the transmission power, power spent on initial transmission, residual power and full power. From the above formula we can see that a node with larger power capacity can transmit a packet with higher power level. Also nodes with limited resources would not be required to expend much energy. Without the above formula an intermediate node may be used repeatedly and before long its remaining power would be lesser when compared to others. Using the DPM scheme the power among all nodes are dynamically balanced. It dynamically adjusts the transmission power across all nodes. Compared to static power management, the total power consumed is reduced as each node transmits according to its remaining power. In DPM nodes with less residual power consume less energy than those with more residual power. Thus it helps in avoiding the early death of nodes with less residual power.

The power consumption can be reduced if unnecessary traffic can be reduced or eliminated. The method proposed below is based on the fact that much energy can be saved if localized route recovery is deployed rather than global flooding during the process of route recovery. Before moving into a route failure case let us first understand the general transmission of a data packet between the source and the receiver and the various terms associated with it. In an on demand routing protocol the source node floods the network with RREQ messages when it doesn't find a suitable route to the destination. A RREQ carries the source identifier (SrcID), destination identifier (DestID), source sequence number (SrcSeqNum), destination sequence number (DestSeqNum), broadcast identifier (BcastID) and time to live (TTL). When an intermediate node receives a RREQ it either forwards or prepares a RREP if there is a path to the destination. Every intermediate node while forwarding the RREQ enters the previous node address as its Bcast ID. If a RREQ is received multiple times which is indicated by the BcastID-SrcID pair, the duplicate copies are discarded. As shown in Figure 3

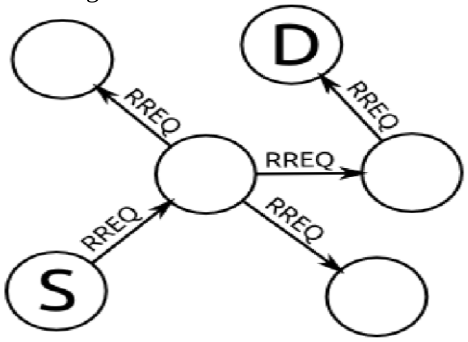

Figure 2: Transmission of RREQ from source to the destination

When the RREQ reaches the destined node a RREP packet is sent back to the source node. The link between two nodes may be unidirectional; hence a flag is set in the RREP to indicate that the connection has been acknowledged. As shown in below Figure 6

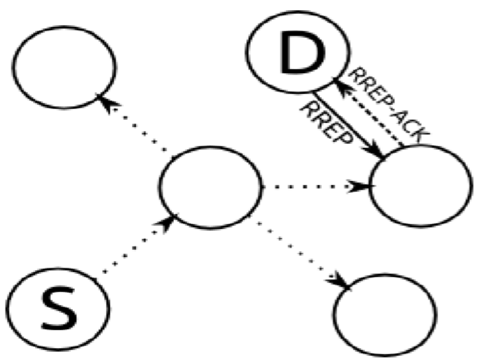

Figure 3: RREP to connection has been acknowledged

Before we discuss the proposed method, let us see how a route is repaired using the simple AODV protocol. The existing ad hoc network routing protocols use a recovery scheme to repair a broken link rather than going through the entire procedure of discovering a new route. One advantage of this is that it limits the amount of flooding of request message and thus reduces the amount of power consumed while repairing the broken link.

4.2 AODV

AODV may use Expanding Ring Search (ERS) or Query Localization (QL) for link recovery. In ERS and QL, the range of flooding is restricted by using a TTL parameter. Because TTL value cannot restrict a particular direction of search there exists some unnecessary flooding in one direction.

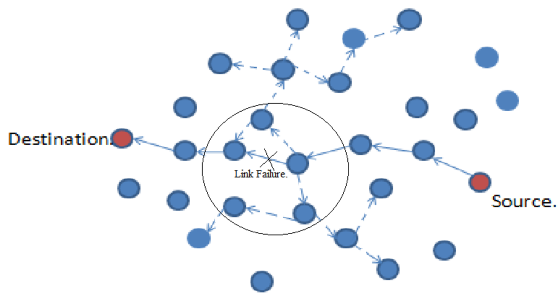

Figure 4: Original routing request and nodes repairs

In Figure 4 the set of nodes in blue colour are the nodes that will be traversed by the original routing request issued by the node detecting a broken link using ERS or QL. On the other hand the nodes depicted in the smaller circle in the above figure are the required nodes needed to repair the broken link. Hence we can conclude that the search using ERS or QL utilizes unnecessary nodes. This study led to the motivation of our proposed method.

4.3 Directional Local Recovery

In DLR the flooding issued by the node detecting the broken link has a directional property. Note that the ability of directional transmission is not assumed at each node. The directional concept is embedded in the route recovery by using the number of hops the candidate nodes share with the primary path. This method can be broadly classified into the following steps,

Step 1: Form the set of candidate nodes.

From the node detecting the broken link the nodes that have to be traversed by RREQ can be referred as the candidate nodes cluster. Candidate nodes are used to recover the disconnected path using the reconnected routing information. This scheme produces better results with less control packets and with faster path recovery time. The cluster can be formed by overhearing the RREP messages from the destination. The neighbour of a node in the primary path from source to destination also overhears the RREP from the destination. A flag (candidate flag) is set by each neighbour to indicate if a node is a candidate node for a future alternative path. A candidate node in addition shares the same number of hops to the destination as the associated member node in the primary path. An example is illustrated below show in figure 5

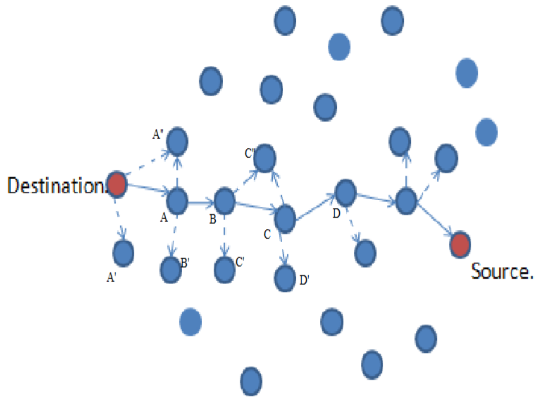

Figure 5: A candidate node in addition shares the same number of hops to the destination

The dashed lines depict overhearing and the solid lines RREP message. From the above figure we observe that when the destination sends the RREP to node A, nodes A' and A" overhear the RREP and the number of hops from the destination. Next when node A relays the RREP to node B, node B' overhear the number of hops and RREP of node A. Node A" also overhears the RREP of node A, but since A" already has the number of hops of previous node in the primary path it discards this 2nd RREP. In the similar way we can say nodes A' and A" are associated with the destination node, node B' associated with node A, C' and C" associated with node B and so on. Consequently as the primary path is set the cluster of candidate nodes are as shown the figure below,

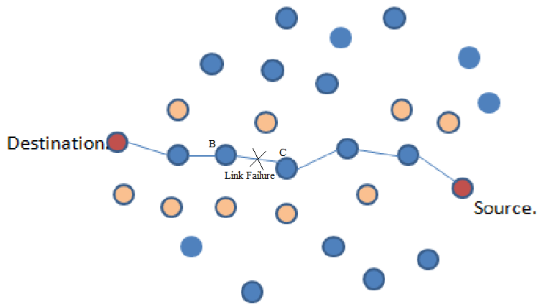

Figure 6: The route connecting the source to the destination

The route connecting the source to the destination is the primary path and the number of hops here are six. The nodes in orange are the cluster of candidate nodes.

Step 2: Repairing a broken link.

Assume that as shown in figure 6 a broken link has been detected between two nodes B and C. Node C detects the broken link and tries to repair by broadcasting RREQ message to its neighbours. Only if the following conditions are fulfilled will the neighbouring nodes receive the RREQ.

1) The candidate flag of the neighbour node must be set.

2) The number of hops of the node receiving RREQ must not be less than the number of hops of the node sending RREQ.

Having these conditions fulfilled the neighbour nodes rebroadcast the RREQ to other neighbours or discard otherwise. This ends up in a local flooding in search for a new primary path from the location of link failure to the candidate nodes further on the path, which consists of nodes whose hop count is larger than or equal to the hop count where the flooding began, not considering the backward candidate nodes.

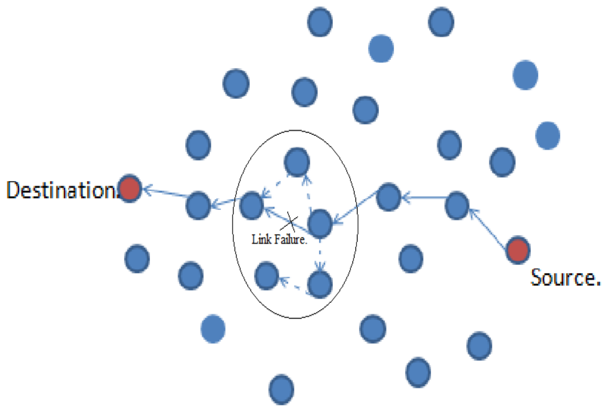

Figure 7: Final Route Source to Destination

Hence compared to ERS or QL unnecessary flooding can be expected to be reduced by using DLR. The fact that overhearing itself requires additional power is acknowledged. With further investigation we can determine accurately how much beneficial the approach is in achieving the desired goal.

5. RESULTS AND DISCUSSIONS

In this paper performance evaluation has been carry out using NS 2. The performance of Dynamic Power Management and Directional Local Recovery compare with original AODV. The variation of power at different nodes reflects the degree of power balancing; hence we narrow our study to the total power consumption and the power variance.

Table 1: Simulation Scenario

1.	Protocol Used	AODV
2.	Simulation Time	200 sec
3.	Traffic Model	Constant Bit Rate
4.	No of Connections	10,20,30,40,50
5.	Mobility Model	Random Way Point
6.	No of Nodes	100
7.	Speed	20m/s
8.	Area	1000x1000

Figure 8 shows the total power consumed for the three methods using the simulation scenario tabulated above.

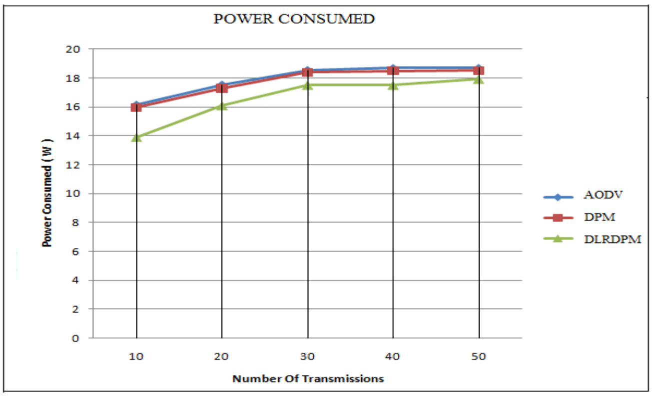

Figure 8: Plot of the power consumed Vs No of transmitting sources

The total power consumed using the DPM scheme is better when compared to the power consumed with the original AODV. The total power saving increases as the number of nodes increases because more number of mobile nodes are engaged in the routing process. However the total power consumed when DLR and DPM together is applied is better when compared to the other two. The reason is that DPM scheme can be used to save more power and DLR scheme helps reduce the amount of traffic in the network. Hence both when used together gives substantial power saving. Figure 12 shows the total power remaining of the proposed methods in comparison to the original AODV.

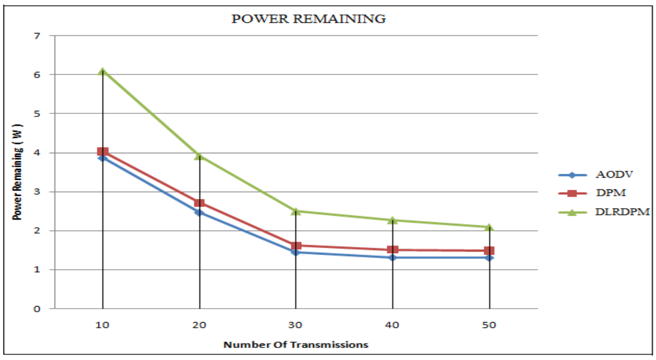

Figure 9: Residual Power Vs No of Transmissions

We observe that power remaining is highest in the case of AODV with DLR and DPM, followed by AODV with DPM and finally AODV as shown in figure 8. As AODV with DLR and DPM consume the least amount of power, the remaining power is also higher. The comparison of the power variance is shown in figure 10.

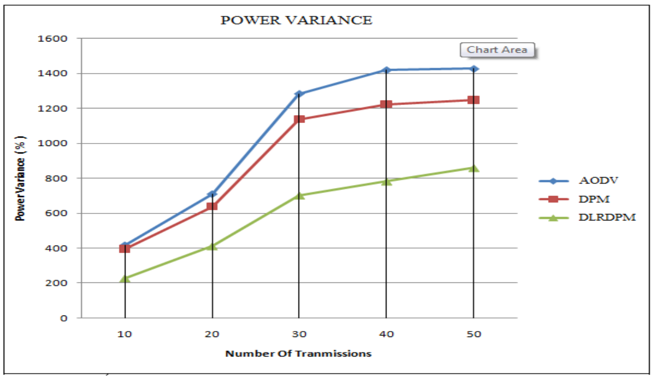

Figure 10: Plot of Power variance Vs No of Transmissions

We observe that AODV with DPM and DLR gives the best result followed by AODV with DPM and finally AODV. The number of dead nodes over time is an important metric to measure the power management scheme. Live nodes are able to acquire new link whereas dead nodes are static. The death of a node must be delayed at each monitoring time in a good and fair power management. Figure 11 shows the number of dead nodes vs. time.

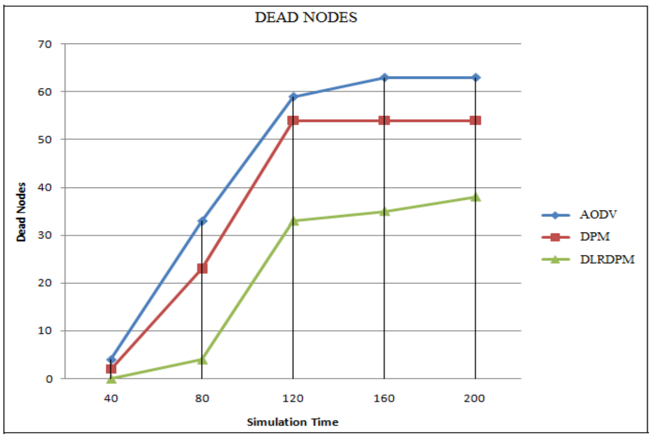

Figure 11: No of Dead nodes Vs Simulation Time (sec)

Initially mobile nodes are in full power hence the number of dead nodes in the beginning is very less. With time we observe that the gap is widened between the original AODV and with the extensions of AODV. However in all three cases the number of dead nodes shoots up with time. The reason being the surviving nodes have a greater responsibility and the additional burden of the network as the dead nodes increases, which results in more power consumption as well as accelerates the speed of nodes halting. From the Figure 12 shows the end to end delay with different number of connections.

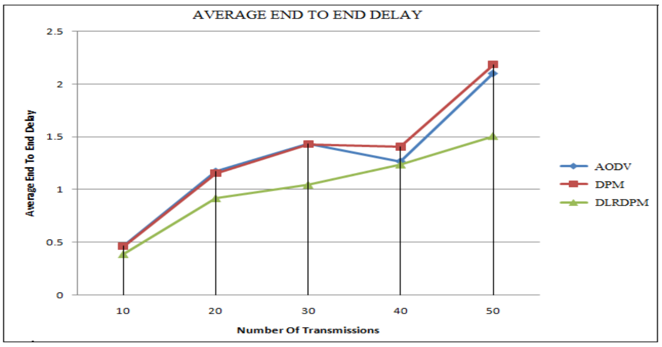

Figure 12: Average end to end delay (sec) Vs No of Transmissions

The delay occurs in transmission of CBR packet from client to the server can be termed as the end to end delay. For CBR packet the delay can occur due to number of reasons such as network layer queue, MAC layer delay, transmission delay and propagation delay. In the above figure we observe that AODV with DPM is larger than the original AODV because DPM is employed at MAC layer. The underlying AODV protocol tends to select longer paths, hence AODV with DLR and DPM is very close to that of the original AODV.Figure 16 plots the number of packets sent in each of the methods.

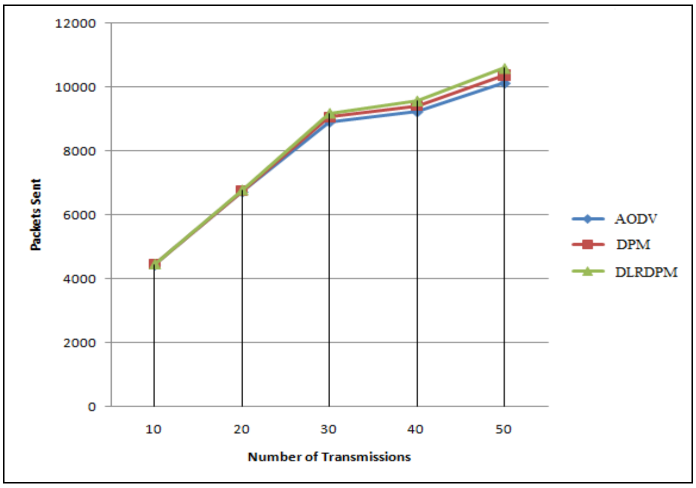

Figure 13: Plot of Packets sent Vs No of Transmissions

The plot shows that more number of packets sent, as the number of transmitting sources varies, in the case of DLRDPM when compared to DPM and AODV. Figure 17 gives the plot of the number of packets received in each of the three methods.

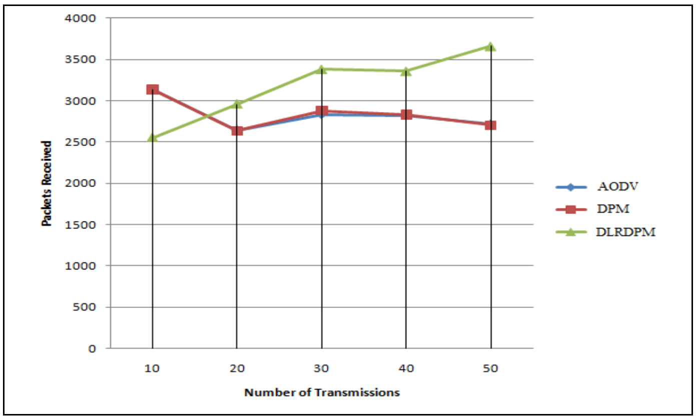

Figure 14: Plot of Received packets Vs No of Transmissions

From the plot we observe that initially the reception of packets is better in AODV when compared to DLRDPM, but as the number of transmitting sources varies DLRDPM gives better performance when compared to other two methods. Figure 15 shows the packet delivery fraction of each of the three methods. The plot is found out by considering the packet delivery fraction on the Y axis and the Number of transmissions on the X axis.

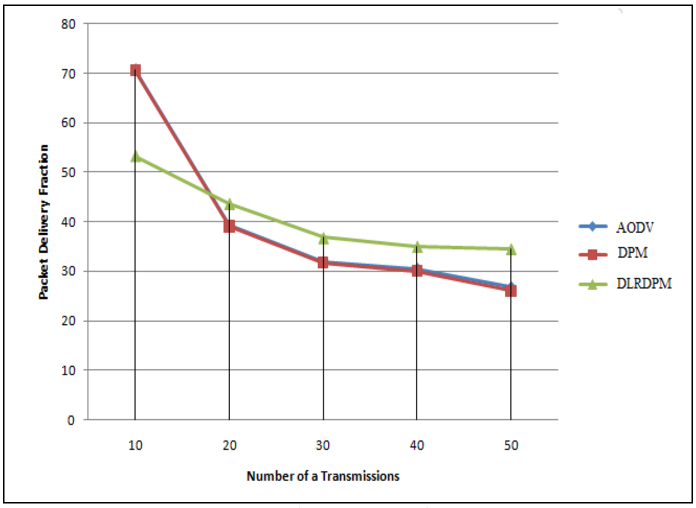

Figure 15: Plot of PDF Vs No of Transmissions

Packet delivery fraction is nothing but the number of packets received to the number of packets sent. We observe that initially the performance of AODV and DPM is better when compared to that of DLRDPM, however as the number of transmitting sources varies, DLRDPM exhibits better performance when compared to the other two.

6. CONCLUSION

The proposed methods Dynamic Power management and Directional Local Recovery are implemented in this paper. AODV is used as the underlying protocol in each of these methods. The performance evaluation has been carried out using the ns-2 simulator .Performance analysis shows that the extended methods of AODV when compared with the original AODV reduced power consumption. A DLRDPM and DPM method not only help in reducing the power consumed but also reduces the number of dead nodes which plays a crucial role in network balancing. The end to end delay has also been measured. The simulation results clearly show how power can be managed and balanced using the DLRDPM and DPM methods. DPM scheme effectively helps in power balancing. The performance of DLR alone is not as impressive as DPM, because in order to repair a potential network failure all mobile nodes have to turn their radio on and overhear the traffic. However when DPM and DLR schemes are employed together the performance has been better in all cases, as shown in the analysis.

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