Power-Aware Multiple Path Multicast Adhoc on Demand Distance Vector Routing Protocol

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ABSTRACT
Mobile ad hoc networks (MANETs) are characterized by dynamic topology, limited channel bandwidth and limited power at the nodes. Because of these characteristics, paths connecting to the source nodes with destinations may very unstable and go down at any time, making communication over ad hoc networks difficult. Energy efficiency is a limiting factor in the successful deployment of MANETs, because nodes are expected to rely on portable, limited power sources. Moreover, energy conservation is extremely challenging in multi-hop environments, where the mobile nodes should also consume energy to route packets for other nodes and to guarantee the connectivity of the network. In this paper, we propose a Power-Aware Multiple Path Multicast Adhoc On Demand Distance Vector (PAMPMAODV) for MANETs. In order to utilize the battery effectively a different strategy has been proposed for route selection. The route selection process has been designed to select multiple routes based on hop count, end-to-end delay and residual battery capacity. The PAMP-MAODV protocol has been implemented using the group learning module of VCR and compared with MAODV and MP-MAODV routing protocols for parameters such as network traffic, the node speed, the network area, throughput, control overhead, number of receivers and SD of Battery Energy Used. It better resulted in load balancing, minimal power consumption, minimal packet delays and prevents unnecessary control messages.

General Terms
Mobile Ad Hoc Networks, energy conservation, multicasting, Multiple path routing

Keywords
VCR, MAODV, MP-MAODV, PDA

1. INTRODUCTION
MANETs are infrastructure-less wireless networks where nodes are capable of moving. They are formed dynamically by a collection of arbitrarily located wireless mobile nodes without much set up time or cost and without the use of existing network infrastructure or centralized administration. Generally, some or all nodes of a MANET function as routers and communication between two hosts is done by multi-hop routing through the nodes of the network. Devices such as laptops, PDAs, mobile phones, pocket PC with wireless connectivity are commonly used.

Multicasting is intended for group-oriented computing. There are more and more applications where one-to-many dissemination is necessary. The multicast service is critical in applications characterized by the close collaboration of teams (e.g., rescue patrol, battalion, scientists, VCR) with requirements for audio and video conferencing and sharing of text and images. The use of multicasting within a network has many benefits. Multicasting reduces the communication costs for applications that send the same data to multiple recipients. Instead of sending via multiple unicast, multicasting minimizes the link bandwidth consumption, sender and router processing and delivery delay. Maintaining group membership information and building optimal multicast trees is challenging even in wired networks. Routing is needed to find a path between source and destination and to forward the packets appropriately. When it became clear that group-oriented communication is one of the key application classes in MANET environments, a number of MANET multicast routing protocols have been proposed[1-6]. These protocols can be classified according to two different criteria. The first criterion has to do with maintaining routing state and classifies routing mechanisms into two types: proactive and reactive. Proactive protocols maintain routing state, while the reactive reduce the impact of frequent topology changes by acquiring routes on demand.

Multipath routing is a technique that exploits the underlying physical network resources by utilizing source to multiple m paths. It is used for a number of purposes, including bandwidth aggregation, minimizing end-to-end delay, increasing fault-tolerance, enhancing reliability, load balancing and so on. The idea of using multiple paths has existed for some time and it has been explored in different areas of networking. Many multicast multipath routing protocols for MANETs have been Proposed [7-9].

Energy Conservation: Energy efficiency is a limiting factor in the successful deployment of MANETs, because nodes are expected to rely on portable, limited power sources. Moreover, energy conservation is extremely challenging in multi-hop environments, where the mobile nodes should also consume energy to route packets for other nodes and to guarantee the connectivity of the network. At the network layer, the route selection process should be performed by minimizing the total power needed to forward the packet [10]; if the network layer may have access to energy information; battery-level metrics can be used in the routing process. Each layer is supposed to operate in isolation in layered network architecture but, as some recent studies suggested, the cross-layer design is essential to maximize the energy performance. [11-16]; since energy conservation is not an issue of one particular layer, the cross-layer design is considered to conserve energy more effectively. In this paper we propose a Power-Aware Multiple Path Multicast AODV (PAMP-MAODV) routing protocol for ad hoc network. In order to utilize the battery effectively a different strategy has been proposed for route selection and route maintenance. The route selection process has been designed to select multiple paths based on hop count, end-to-end delay and residual battery capacity.

The organization of the paper is as follows: Section 2 describes the review of existing Power-Aware routing algorithms. Next we have introduced the base protocol and MAODV based multicast multipath routing protocol in section 3. Section 4 describes the implementation details of PAMP-MAODV routing algorithm. The experiment results and discussions are presented in Section 4. Finally, the conclusion of this paper is given in Section 5.

2. REVIEW OF EXISTING POWER AWARE LAYER ROUTING ALGORITHMS

ECMRP[11] has a better delay than MAODV and a more balance in energy consumption. it has a longer network lifetime than MAODV and successfully solves the inconsistent question of energy and delay. EA-MAODV [12] protocol based on the classifying energy level, considers the remaining battery level of nodes and chooses the route with maximal remaining power in order to increase the operational lifetime of the whole network. An energy-aware routing scheme[13] is proposed that uses sub-optimal paths to provide substantial gains. The scheme does not find a single optimal path and use it for communication. Rather, it keeps a set of paths and chooses one based on a probabilistic algorithm. In addition, a node-based energy metric[14] that minimizes the overhearing cost of energy consumption on the multicast tree. The metric uses self-stabilizing shortest path spanning tree protocol to obtain energy-aware SS-SPST and the energy-latency tradeoff. The improved MAODV has a better packet delivery ratio even in a large multicast group. The Power-Efficient Preferred Energy Forecast Multicast Protocol [15] called PPEF that uses both hops and energy consumption level of each node together for multicast routing. A Cross-layer design of Energy-aware Multicast Ad hoc On-Demand Distance Vector (CEMAODV)[16] routing protocol adopts cross-layer mechanism and energy-aware metric to modify AODV routing protocol to reduce the energy consumption of the route to construct a source-based tree.

3. ROUTING PROTOCOLS FOR MANET

3.1 Multicast Ad hoc On-demand Distance Vector protocol (MAODV)

MAODV [4] is a multicast extension of AODV. In MAODV, all members of a multicast group are formed into a tree (which includes non-member nodes required for the connection of the tree) and the root of the tree is the group leader. Multicast data packets are propagated among the tree. The core of the MAODV protocol is about how to form the tree, repair the tree when a link is broken and how to merge two previously disconnected trees into a new tree. There are four types of packets in MAODV: Route Request (RREQ), Route Reply (RREP), Multicast Activation (MACT) and Group Hello (GRPH). RREQ and RREP are also packets in AODV. A node broadcasts a RREQ, when it is a member node and wants to join the tree, or it is a non-member node and has a data packet targeted to the group.

When, a node in the tree receives a RREQ and it response with a RREP using unicast. Since RREQ is broadcast, there may be multiple RREP's received by the originating node. The originating node should select one RREP that has the shortest distance to the tree and unicast a MACT along the path to set up a new branch to the tree.

GRPH is the group hello packet, it is periodically broadcasted by group leader to let the nodes in the tree to update its distance to the group leader.

3.2 Multiple Path - Multicast Ad hoc On-demand Vector (MP-MAODV)

MP-MAODV[11] is a multipath routing protocol extension based on MAODV [4]. In this extension MAODV is based on three aspects: multipath selection and establishment, multipath route maintenance and load distribution for distributing traffic among node-disjoint paths. They add two control messages and one backup routing table for the MP-MAODV, and extend it from three aspects: multipath selection and establishment, multipath routing maintenance and load distribution. The flag S with value 1 is added to control message MACT-S and RREP-S for selecting and establishing disjoint paths.

MAODV[4] and MP-MAODV[11] are creates bi-directional shared multicast trees connecting multicast sources and receivers. MAODV is a shortest routing, that is, the least hops routing and MP-MAODV is creating multiple routes from a source to a destination is used to provide a backup route. When the primary route fails to deliver the packets in some way, the backup is used. This provides a better fault tolerance in the sense of faster and efficient recovery from route failures. Multiple paths can also provide load balancing and route failure protection by distributing traffic among a set of disjoint paths, which do not consider the energy aware problem. However, the portable communication devices in Ad Hoc networks are untethered, batteries operated and have limited energy, so the network is an energy constrained system. How to preserve the nodes energy and prolong the lifetime of the system gradually plays an important role on evaluating the performance of Ad Hoc network routing protocols. The energy conservation of the network system is a key problem especially in the situations such as military areas, disaster relief, classrooms and conferences, where the time and the devices are constrained.

4. POWER-AWARE MULTIPLE PATH MULTICAST AODV (PAMP-MAODV)

In this section, we propose a Power-Aware Multiple Path Multicast AODV (PAMP-MAODV). In PAMP-MAODV, to utilize the battery effectively a different strategy has been proposed for route selection and route maintenance. The route selection process has been designed to select multiple routes based on hop count, end-to-end delay and residual battery capacity.

4.1 Determination of Threshold

The threshold for the residual battery capacity Rth has been calculated based upon the number of total packets to be transferred and the maximum transmit power used for each packet Tr [17]

$$Rth=N*Tr \quad (4.1)$$

where N = Number of packets to be transferred by each route and Tr = 32 mW,

$$N \text{ is calculated as } N = nd + nc \quad (4.2)$$

where nd = number of data packets to be transferred by each route, nc = number of control packets to be transferred by each route

$$nd = X/ \text{Number of assumed routes} \quad (4.3)$$

where X = Total number of pending packets to be transferred by the source

$$\text{Number of assumed routes} = 2 \quad (4.4)$$

$$nc = 0.10 \times nd \quad (4.5)$$

By using equations (4.3), (4.4) and (4.5), equation (4.2) can be written as

$$N = X/2 + 0.1 * (X/2) \quad (4.2)$$

In a free-space environment, like our atmosphere, the signal strength is calculated by measuring the distance 'd' between the two nodes using Frii's equation [18], and is inversely proportional to the square of the distance between the nodes.

$$SignalStrength = 1/ d2 \quad (4.6)$$

The distance 'd' between neighbouring nodes has been calculated by using received signal strength, which can be read by using low level API. The safe_threshold for the distance Dth (which is set to 25m) has been calculated by using (4.6).

4.2 Multipath Selection and Establishment

MAODV relies on broadcast based on-demand route discovery. When a source node wants to send a packet or join a multicast group, it broadcasts a route request (RREQ) Packet, it is often likely to receive more than one response packet since any node in the multicast tree can responds to the packet. Each intermediate node, which receives RREQ, calculates 'N' using equation (4.2) and battery capacity Rth needed to transfer 'N' packets. When the residual battery (RB) capacity is greater than Rth , then each neighbour node calculates the distance between itself and the previous node which has sent RREQ, using equation (4.6). If the calculated distance is less than Dth , then the intermediate node forwards RREQ further. When an RREQ packet arrives at its any member, the received RREQs are stored in RREQ table.

All the member nodes are wait for a particular time RREQ_TIMER (which is set to 3 seconds), receives all the incoming RREQ packets and maintains them in a RREQ TABLE. Upon RREQ_TIMER expiry, Member node assigns rank for each path based on the hop count and link quality and sends corresponding reply, which travel back to the source retracing the path. The member generates a RREP packet that contains the node list of the whole route and unicast it back towards the source that originated the RREQ packet along the reverse route. When an intermediate node receives a RREP, it updates its mcast routing table to add an entry towards member node by using the nodes list of the whole route contained in the RREP. If the source node receives one or more RREP messages in this time, it queries the multicast table and check if the route is activated to confirm which one is the first arrival. The source node unicasts a MACT to the node which RREP is the first arrival for activating the route and sends packets through the path due to the first path has the shortest latency. The intermediate nodes, which received MACT, activate the related entry in mcast routing table, and set mpath field as 1, then forward the MACT to next hop until one group member receives MACT. If the RREP received by the source node is not the first arrival, the source node replies MACT-S to the next hop. The intermediate nodes, which received MACT-S, query the multicast table and check if the route is activated. If the route is activated, the intermediate nodes discard this MACT-S, if not , it will add an entry to the backup route table to establish reverse route in backup route table and send MACT-S to the next hop until this MACT-S forward to a group member. The multicast group node received the MACT-S then unicasts a RREP-S to the source node. The intermediate node that received MACT-S adds an entry to the mcast routing table to establish forwarding route and set mpath field as 2, then forwards it to the source node. So this mechanism can guarantee two node disjoint paths and avoided loops. Source node is likely to receive one or more RREP-S messages during this time, but it selects the route with largest sequence number and smallest hops by checking the RREP-S messages as the second path, and adds an entry to the mcast route table with mpath field as 2. Maintaining more than two backup paths cannot evidently improve route performance. So we select only two paths in order to reduce resource consumption and improve calculation efficiency. If the source node does not receive a RREP-S message before timeout, it uses the one path to send data packets.

4.3 Load Distribution

Once the source node activates the first path, it sends all packets through the path in order to reduce latency caused by route discovery. When two paths has been selected, the source node starts to send packets through two paths in turn, that is, send a packet through the first path, then send the next packet through the second path. This simple method can balance the network load and relieve the network congestion.

4.4 Multipath Route Maintenance

The wireless link is easy to break because of nodes mobility or other reasons. When a node doesn't receive any message from the adjacent node or can't send any packet to the next hop, it thinks the link is broken. If the broken node on the tree, it will be treated according to the MAODV. If not, the upstream node unicasts a route error message (RERR) to the source node which notifies the source node that link is broken. When the intermediate nodes in this path receive RERR, they delete the entry in the route table, and continue to forwarding RERR until the source node receives RERR message. When the source node receives the RERR, it deletes the related entry in the route table, searches backup route table and checks whether both paths are invalid. If the two paths are broken at the same time, the source node broadcasts RREQ to initiate a new route discovery.

5. RESULTS AND DISCUSSION

The above mentioned protocols are implemented to form a Virtual Class Room (VCR) [9, 20]. A VCR is one that can be immediately established, and whose members can be dynamically added or removed; the group structure of the members can be reorganized dynamically. Figure 1 illustrates such an idea. The ad hoc classroom can support urgent and timely learning activities, thus improving learning effectiveness. For example [6], a teacher may establish a virtual classroom from his residence, students located around can take the opportunity to form an ad hoc group to improve the teaching learning process at any time using IEEE802.11g WLAN. VCR based on ad hoc network has been constructed [19] as shown in Figure1. The network has been formed with 30 PDA nodes. Each node in the network is assigned with static IP address. The software components used for development are Microsoft Visual Studio C#.Net 2005, Windows Mobile 5.0 Pocket PC SDK, Microsoft ActiveSync Version 4.2 and Microsoft.Net Compact Framework 2005 and XML technology. The XML technology was used for providing description and representation of data and control packets.

Different traffic: In VCR Application, we have compared the performance of MAODV, MP-MAODV and PAMP-MAODV for different traffic: 1, 5, 10, 20 and 50 KBytes sec1. We measured the Packet Delivery Ratio (PDR) and the Latency for the three protocols. PDR is the ratio of the number of packets sent to the number of packets received and shows the reliability of the protocol. Latency is the average end-to-end packet delay (Table 1).

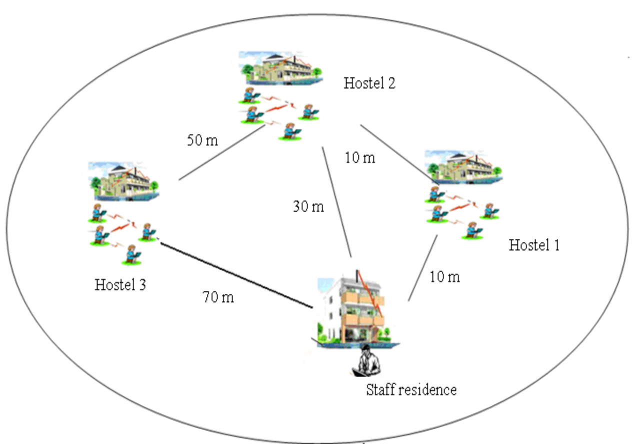

Figure 1: A scenario of VCR using MANET

Table 1: Implementation parameters for the different traffic scenarios

Number of members (students and teacher)	29+1
Number of teacher (sender)	1
Number of receivers	15
Speed	1 m sec^{-1}
CBR	1, 5, 10, 20 and 50 KBytes sec^{-1}
Area	500×500 m

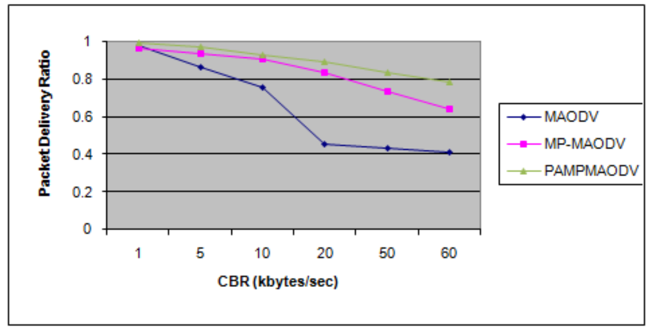

Figure 2: Packet delivery ratio versus traffic

Figure 2 shows the packet delivery ratio of MAODV, MP-MAODV and PAMP- MAODV for different traffic. When, we increase the traffic, all the MAODV and the MP-MAODV and PAMP-MAODV's packet delivery ratio have decreased. However, the MAODV decreased more quickly compare to MP-MAODV and PAMP-MAODV. Suppose the source node sends out 10 KB per second, the packet delivery ratio of PAMP-MAODV is 88 percent higher than MAODV, also 9.5 percent higher than MP-MAODV.

Different areas: In VCR Application, we have compared the performance of PAMP-MAODV, MP-MAODV and MAODV for different areas. The nodes may move in areas of: 100×100, 500×500, 1000×1000, 1500×1500 and 2000×200 m. We have measured the PDR and the Latency for the three protocols and is shown in Table 2.

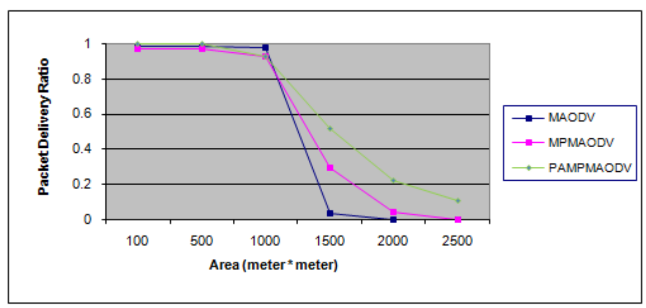

Figure 3: Packet delivery ratio versus area

Figure 3 shows that the PDR of PAMP-MAODV, MP-MAODV and MAODV are better for small areas up to 1000×1000 m because of tree link breakage and reconstruction is easy. For larger areas PAMPMAODV and MPMAODV performs better because of multiple path available in the routing. Suppose the node may move in area of 1500*1500m, the packet delivery ratio of PAMP-MAODV is 24 percent higher than MAODV, also 11 percent higher than MP-MAODV.

Table 2: Implementation parameters for the different area scenarios

Number of members (students and teacher)	29+1

Number of teacher (sender)	1
Number of receivers	15
Speed	1 m sec^{-1}
CBR	1 KBytes sec^{-1}
Area	100×100,500×500, 1000×1000,1500×1500 and 2000×2000 m

Different speeds: In VCR Application, we have compared the performance of PAMP-MAODV, MPMAODV and MAODV for different node speeds: 1, 5, 10, 15 and 20 m sec^{-1}. We have measured the PDR and the Latency for the two protocols and is shown in Table 3.

Figure 4 shows that the PDR of PAMPMAODV is better for node speed up to 15 m sec^{-1}. MAODV and MPMAODV are not influenced by the node speed and perform better than PAMP-MPMAODV for speed larger than 5 m sec^{-1} and 5 m sec^{-1}.This resulted in more multicast tree partitions for PAMP-MAODV, MPMAODV and MAODV. Notice that the number of packet deliveries was high when the nodes had low mobility. Note also that the multicast tree structure was mostly static and, therefore, the packet delivery ratio was high. At high speeds, the tree links broke down quite often, leading to constant branch reconstructions and larger packet losses.

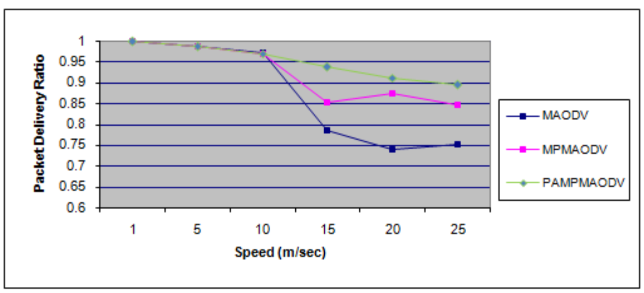

Figure 4: Packet delivery ratio versus node speed

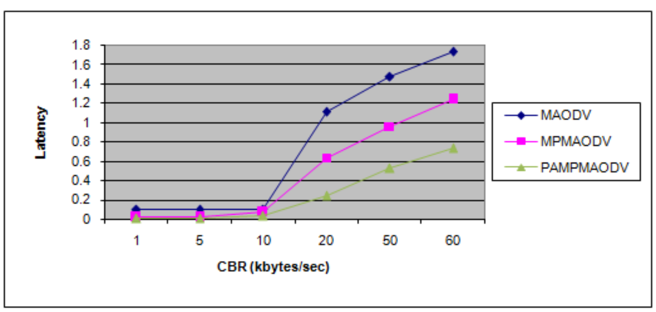

Figure 5: Latency versus traffic

Figure 5 illustrates the variation of the average end-to-end delay as a function of data rate for MAODV, MP-MAODV and PAMP-MAODV. The performance of PAMP-MAODV is 35% to 45% better than that of MAODV and 4% to 20% than MP-MAODV.

Figure 6 shows that the latency of PAMP-MAODV, MPMAODV and MAODV are low for small areas up to 1000×1000 m because of tree link breakage and reconstruction is easy. For larger areas PAMPMAODV and MPMAODV performs better because of multiple path available in the routing. Suppose the node may move in area of 2000*2000m, the packet delivery ratio of PAMP-MAODV is 34 percent higher than MAODV, also 9 percent higher than MP-MAODV.

The PAMP-MAODV's latency has been found to be the smallest for any node speed as shown in Figure 7.

Figure. 8 depicts the SD of battery energy used for various data rates. The SD of the battery energy used in PAMP-MAODV has been found to be 4% to 8.5% better than that of MAODV and 1.8% to 3.5% better than that of MPMAODV for different data rates.

Table 3: Implementation parameters for the different speed scenarios

Number of members (students and teacher)	29+1
Number of teacher (sender)	1
Number of receivers	15
Speed	1, 5, 10, 15, 20 m sec^{-1}
CBR	1 KBytes sec^{-1}
Area	500×500 m

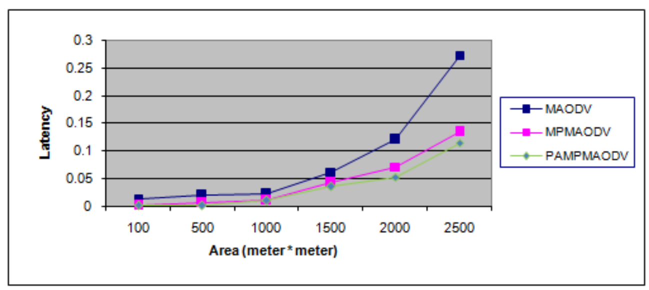

Figure 6: Latency versus area

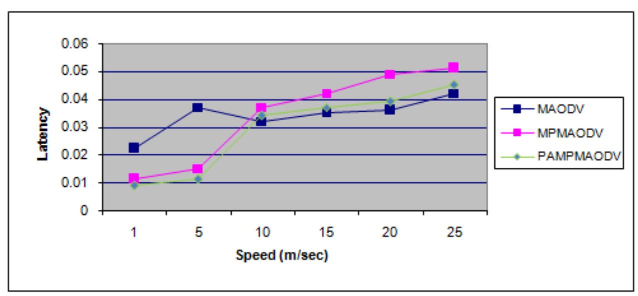

Figure 7: Latency versus node speed

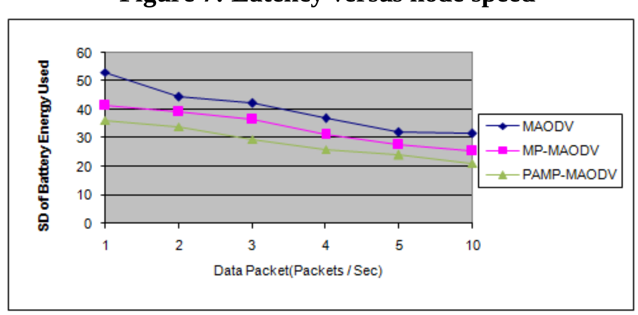

Figure 8: SD of Battery Energy Used in MAODV, MP-MAODV and PAMP-MAODV for varying Data Rates

Figure 9 compares the packet delivery ratio of the protocol PAMP-MAODV, MPMAODV and MAODV. As the number of receivers is increased the packet delivery ratio remains constant due to the selection of the minimum energy paths in routing packets in PAMPMAODV. Packet delivery ratio in MPMAODV and MAODV decreases as the number of receivers is increased.

Although the PAMP-MAODV, MP-MAODV has an additional control message, its control overhead is still lower than the MAODV protocol along with the increase of network load. When source node sends out 50 packets per second, the control overhead of PAMP-MAODV is about 20 percent lower than MAODV and 3 percents lower than MP-MAODV protocol, as is shown in Figure10.

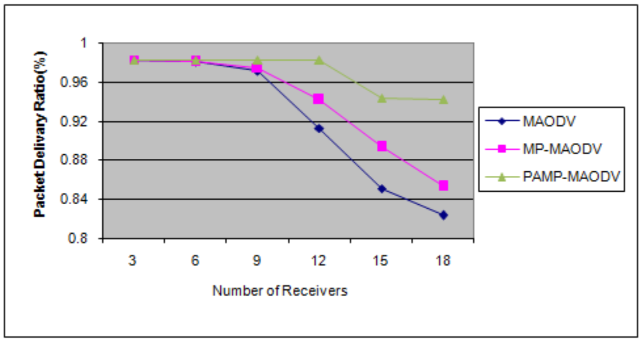

Figure 9: PDR versus Number of Receivers

Because the power aware backup path provides a better fault-tolerant capability and it can efficiently reduce the control overhead used for frequently route discovery due to link breakage caused by network topology change. The additional control packets can be ignored compared to the increased network load.

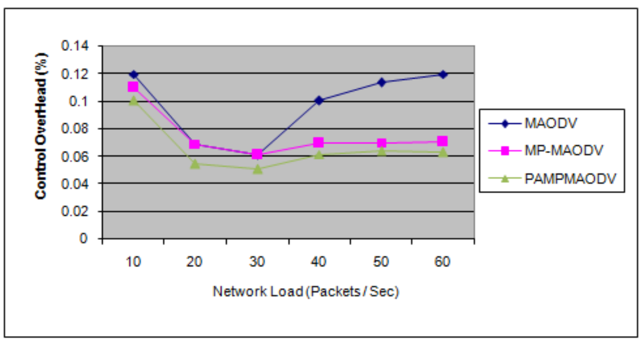

Figure 10: Control Overhead versus Network Load

6. CONCLUSION

In this analysis, we have presented a performance comparison of PAMP-MAODV, MP-MAODV, and MAODV using VCR with different implementation scenarios. Our results shows that number of receivers is increased the packet delivery ratio remains constant due to the selection of the minimum energy paths in routing packets in PAMP-MAODV. For larger areas PAMPMAODV and MPMAODV performs better because of multiple paths and energy aware available in the routing. The presented approach considered residual battery capacity; it resulted in load balancing, minimal power consumption, minimal packet loss, minimal packet delays and prevents unnecessary control messages.

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