Power Aware Virtual Node Routing Protocol for Ad hoc Networks

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ABSTRACT

A recent trend in Ad Hoc Network routing is the reactive on-demand philosophy where routes are established on demand. Most of the protocols in this category, however, use single route and do not utilize multiple alternate paths. This paper proposes a scheme to improve existing on-demand routing protocols by introducing the power aware virtual node scheme in network topology. The scheme establishes the multi paths without transmitting any extra control message. It offers quick adaptation to distributed processing, dynamic linking, low processing, memory overhead and loop freedom at all times. It also uses the concept of power aware node during route selection and concept of Virtual Nodes which insures fast selection of routes with minimal efforts and faster recovery. The scheme is incorporated with the Ad-hoc On-Demand Distance Vector protocol and its performance has been studied on simulated environment using NS-2. It is found that the scheme performs very well compared to existing schemes.

Keywords : Mobile ad hoc networks, routing, AODV, DSR

1. INTRODUCTION

A Mobile Ad Hoc Network, properly known as MANET [20] is a collection of mobile devices equipped with interfaces and networking capability. Hosts [19] can be mobile, standalone or networked. Such devices can communicate with another node within their radio range or one that is outside their range by multi hop techniques. An Ad Hoc Network is adaptive in nature and is self organizing. It is an autonomous system of mobile hosts which are free to move around randomly and organize themselves arbitrarily. In this environment network topology may change rapidly and unpredictably. The main characteristic of MANET strictly depends upon both wireless link nature and node mobility features. Basically this includes dynamic topology, bandwidth, energy constraints, security limitations and lack of infrastructure. MANET is viewed as suitable systems which can support some specific applications as virtual classrooms, military communications, emergency search and rescue operations, data acquisition in hostile environments, communications set up in Exhibitions, conferences and meetings, in battle field among soldiers to coordinate defense or attack, at airport terminals for workers to share files etc. In an Ad Hoc Network, neither the network topology nor the membership is fixed; thus the traditional wired network routing protocols cannot be deployed for this paradigm. Taking into consideration both changing topology as well as changing membership, in addition to route establishment or discovery, ad hoc routing protocols provide 'route maintenance', for the broken routes in case of member node in the route moving out of the range or leaving the network. This makes route maintenance an essential paradigm for ad hoc networks protocols. Several routing protocols for ad hoc networks have been proposed as Dynamic Source Routing (DSR) [7], Dynamic Distributed Routing (DDR) [10], Temporarily Ordered Routing Algorithm (TORA) [11], Ad Hoc On Demand Distance Vector Routing (AODV) [13] and Relative Distance Micro Discovery Ad Hoc Routing Protocol (RDMAR) [1]. Major emphasis has been on stable and shortest routes in all these protocols while ignoring major issue of delay in response whenever break occurs. Some other areas of consideration are:

1. Most of the simulation studies use fixed environment, instead of random scenes.
2. Reconstruction phase requires better approach in all protocols for fast selection of new routes.
3. Real life scenarios need to be simulated instead of predefined scenes.
4. Stable routes for better packet delivery

In the reactive protocol AODV [13], a node discovers or maintains route to a destination if and only if it is the initiator of the route to that destination or is an intermediate node on an active route to that destination. Otherwise, it does not maintain routing information to that destination. AODV maintains loop-free routes, even when the local connectivity for a node on the route changes. This is achieved by maintaining a counter for each node, called a sequence number. This sequence number of nodes increment every time as the local connectivity of the node changes. In AODV, the route discovery is initiated by the source by generating and broadcasting a route request packet

RREQ which contains sequence numbers for source as well as destination nodes, called source-sequence-num and destination-sequence-num, respectively. When a node receives a RREQ packet, if the node is itself the destination or it has a valid route to that destination, it determines the freshness of its route table entry (provided such an entry exists) for that destination by comparing the destination-sequence-num in the RREQ with that of its route table entry. The node then either responds with a route reply RREP (if it itself is the destination or has a fresh route to that destination) or rebroadcasts the RREQ to its neighbors. The node makes an entry for this route request in the route table and stores the address of the node from which it has received this request as the next hop in the route to the source of this request packet. Similarly when a node receives a response RREP for the request it stores the address of the node from which it received the response RREP as the next hop in the route to that destination. As the RREP travels back to the source, the intermediate nodes forwarding the RREP, update their routing tables with a route to the destination.

In this paper a new scheme power aware virtual node ad hoc routing protocol has been suggested which would allow mobile nodes to maintain routes to destinations with more stable route selection. This scheme responds to link breakages and changes in network topology in a timely manner and also takes care of nodes that do not have better power status. It also uses concept of virtual nodes to participate in route selection, where virtual nodes are neighboring nodes at one hop distance form participating nodes and have better power status. The distinguishing feature of power aware Ad hoc routing protocol is its use of virtual nodes and power status for each route entry. Given the choice between two routes to a destination, a requesting node is required to select one with better power status and more active virtual nodes (VNs). This makes route maintenance and recovery phase more efficient and fast. Section 2 discusses a look at the related work while section 3 analyzes new proposed scheme. Section 4 describes the simulation environment and results; Conclusion is given in the last section.

2. RELATED WORK

A routing protocol is needed whenever a packet needs to be handed over via several nodes to arrive at its destination. A routing protocol finds a route for packet delivery and delivers the packet to the correct destination. Routing Protocols have been an active area of research for many years; many protocols have been suggested keeping applications and type of network in view. Routing protocols can broadly classify into two types:

i) Table Driven Protocols or Proactive Protocols
ii) On-Demand Protocols or Reactive Protocols

2.1 Table Driven or Proactive Protocols

In Table Driven routing protocols each node maintains one or more tables containing routing information to every other node in the network. All nodes keep on updating these tables to maintain latest view of the network. Some of the existing table driven or proactive protocols are: DSDV [12], DBF [2], GSR [4], WRP [8], ZRP [6] and STAR [5].

2.2 On Demand or Reactive Protocols

In On Demand routing or reactive protocols, routes are created as and when required. When a transmission occurs from source to destination, it invokes the route discovery procedure. The route remains valid till destination is achieved or until the route is no longer needed. Some of the existing on demand routing protocols are: DSR [7], DDR [10], TORA [11], AODV [13] and RDMAR [1]

Study has been concentrated for reactive protocols because they work well in dynamic topology. Surveys of routing protocols for ad hoc networks have been discussed in [3, 15, 16]. A brief review of DSR and AODV is presented here as new scheme has been compared with these protocols.

2.2.1 Dynamic Source Routing (DSR)

DSR uses dynamic source routing [7] and it adapts quickly to routing changes when host movement is frequent, however it requires little or no overhead during periods in which host moves less frequently. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which to forward the packets, the sender explicitly lists this route in the packet's header, identifying each forwarding hop by the address of the next node to which to transmit the packet on its way to the destination host. The protocol is designed for use in the wireless environment of an ad hoc network. There are no periodic router advertisements in the protocol. Instead, when a host needs a route to another host, it dynamically determines one based on cached information and on the results of a route discovery protocol. It is on demand routing based on Flat architecture. DSR is based on two mechanisms as Route discovery and Route maintenance. To perform Route discovery a ROUTE_REQUEST is sent and answered by ROUTE_REPLY from either the destination or from another node that knows route to destination. Route cache is maintained to reduce cost of route discovery. Route Maintenance is used when sender detects change in topology or source code has got some error. In case of errors sender can use another route or invoke Route Discovery again. Performance of this algorithm as follows:

(a) It works well when host movement is frequent.
(b) It works well over conditions such as host density and movement rates.
(c) For highest rate of host movement the overhead is quite low.
(d) In all cases, the difference in length between the routes used and optimal route lengths is negligible.
(e) It makes full use of the route cache.
(f) It improves handling of errors.

The DSR is single path routing. It suffers from scalability problem due to the nature of source routing. As network becomes larger, control packets and message packets also become larger. It does not guarantee shortest path route.

2.2.2 Ad hoc On Demand Distance Vector Routing

The Ad hoc On-Demand Distance Vector (AODV) routing protocol is intended for use by mobile nodes in an ad hoc network. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. It uses destination sequence numbers to ensure loop freedom at all times (even in the face of anomalous delivery of routing control messages), avoiding problems (such as “counting to infinity") associated with classical distance vector protocols. One distinguishing feature of AODV is its use of a destination sequence number for each route entry. The destination sequence number is created by the destination to be included along with any route information it sends to requesting nodes. Using destination sequence numbers ensures loop freedom and is simple to program. Given the choice between two routes to a destination, a requesting node is required to select the one with the greatest sequence number. AODV has been termed as a pure on-demand route acquisition system, since nodes not on a selected path do not maintain routing information or participate in routing table exchanges. Route Requests (RREQ), Route Replies (RREP), and Route Errors (RERR) are the phases defined by AODV. A node disseminates a RREQ when it determines that it needs a route to a destination and does not have one available. A node generates a RREP if either (i)it is itself the destination, or (ii) it has an active route to the destination, A node initiates processing for a RERR message in three situations : (i) if it detects a link break for the next hop of an active route in its routing table while transmitting data (and route repair, if attempted, was unsuccessful), or (ii) if it gets a data packet destined to a node for which it does not have an active route and is not repairing (if using local repair), or (iii) if it receives a RERR from a neighbor for one or more active routes.
AODV satisfies the following properties:
(a) It is loop free routing protocol
(b) It is quick in adaptation to dynamic link conditions
(c) In AODV nodes that are not on a selected path do not maintain routing information or participate in routing table thus reducing
(d) It establishes new routes quickly
(e) In this Hello messages are used as periodic broadcasts for beaconing.
(f) In this concept of sequence number is used for selection of fresh routes.
(g) It erases all invalid routes within a finite time.
(h) It has reduces control overhead.

AODV does not specify any special security measures. It does not make any assumption about the method by which addresses are assigned to the mobile nodes, except that they are presumed to have unique IP addresses. Consideration for other better routes is absent in AODV. Also it does not exploit the fast and localized partial route discovery method. HELLO messages causes carry overhead. Links are always considered as bidirectional, RREP messages are bounced back where they are originated. Bidirectional assumption might cause improper execution of the protocol.

3. Proposed Scheme

The proposed scheme takes care of on demand routing and also power features along with a new concept of virtual nodes. Virtual nodes (VN) are nodes at the one hop distance from its neighbor. These virtual nodes help in reconstruction phase in fast selection of new routes. Selection of virtual nodes is made upon availability of nodes and their power status. Each route table has an entry for its power status (which is measured in terms of Critical, Danger and Active state) and number of virtual nodes attached to it. Whenever need for a new route arises, check for virtual nodes are made, their power status is checked and a route is established. Same process is repeated in route repair phase. Route tables are updated at each Hello interval as in AODV with added entries for power status and virtual nodes. The proposed scheme is explained with the help of an example shown in Figure 1. It is assumed that there are 12 nodes and nodes are numbered 1 through 12. Assume further that the node with index 1 is the source while destination is the node with index 4. Note that the route discovered using power aware virtual node ad hoc routing protocol may not necessarily be the shortest route between a source destination pair.

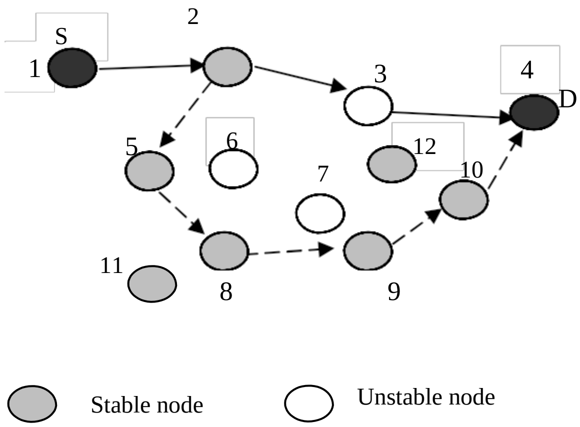


Figure 1: An Example of stable routing

If the node with index 3 is having power status in critical or danger zone, then though the shortest path is 1—2—3—4 but the more stable path 1—2—5—8—9—10—4 in terms of active power status is chosen. This may lead to slight delay but improves overall efficiency of the protocol by sending more packets without link break than the state when some node is unable to process route due to inadequate battery power. The process also helps when some intermediate node moves out of the range and link break occurs in that case virtual nodes take care of the process and the route is established again without much overhead. In Figure 1 if the node with index 8 moves out, the new established route will be 1—2—5—11—9—10—4. Here the node with index 11 is acting as virtual node (VN) for the node with index 5 and the node with index 8. Similarly the node with index 12 can be VN for the nodes with indices 7, 10 and 4.

Some work already have been done on using multiple routes approach in ad hoc network protocols; the scheme by Nasipuri and Das [9], Temporally-Ordered Routing Algorithm (TORA) [11], Dynamic Source Routing [7] and Routing On-demand Acyclic Multi path (ROAM) [14], but these algorithms require additional control message to construct and maintain alternate routes. The proposed routing scheme is designed for mobile ad hoc networks with large number of nodes. It can handle low, moderate, and relatively high mobility rates. It can handle a variety of data traffic levels. This scheme has been designed for use in networks in which all the nodes can trust each other, and there are no malicious intruder nodes. There are three main phases in this protocol: REQ (Route Request) phase, REP (Route Reply) phase and ERR (Route Errors) phase. The message types are also defined by the protocol scheme. The messages are received via UDP, and normal IP header processing applies.

3.1 Route Construction (REQ) Phase

This scheme can be incorporated with reactive routing protocols that build routes on demand via a query and reply procedure. The scheme does not require any modification to the AODV's RREQ (route request) propagation process. In this scheme when a source needs to initiate a data session to a destination but does not have any route information, it searches a route by flooding a ROUTE REQUEST (REQ) packet. Each REQ packet has a unique identifier so that nodes can detect and drop duplicate packets. An Intermediate node with an active route (in terms of power and Virtual Nodes), upon receiving a no duplicate REQ, records the previous hop and the source node information in its route table i.e. backward learning. It then broadcasts the packet or sends back a ROUTE REPLY (REP) packet to the source if it has an active route to the destination. The destination node sends a REP via the selected route when it receives the first REQ or subsequent REQs that traversed a better active route. Nodes monitor the link status of next hops in active routes. When a link break in an active route is detected, an ERR message is used to notify that the loss of link has occurred to its one hop neighbor. Here ERR message indicates those destinations which are no longer reachable. Taking advantage of the broadcast nature of wireless communications, a node promiscuously overhears packets that are transmitted by their neighboring nodes. When a node that is not part of the route overhears a REP packet not directed to itself transmit by a neighbor (on the primary route), it records that neighbor as the next hop to the destination in its alternate route table. From these packets, a node obtains alternate path information and makes entries of these virtual nodes (VN) in its route table. If route breaks occurs it just starts route construction phase from that node. The protocol updates list of VNs and their power status periodically in the route table.

3.2 Route Error and Maintenance (REP) Phase

Data packets are delivered through the primary route unless there is a route disconnection. When a node detects a link break (e.g. Figure 2, receives a link layer feedback signal from the MAC protocol, the node with index 1 does not receive passive acknowledgments, the node with index 2 does not receive hello packets for a certain period of time, etc.), it performs a one hop data broadcast to its immediate neighbors. The node specifies in the data header that the link is disconnected and thus the packet is candidate for alternate routing. Upon receiving this packet, previous one hop neighbor starts route maintenance phase and constructs an alternate route through virtual nodes by checking their stability and power status. Route Recovery involves Finding VN, their Power status, Invalidate route erasures, Listing affected DEST, Valid route update, New route (in worst cases).

(1) Nothing is done if Mobile Host that has moved is not the part of any active route , or power status of that node is below danger level which is not part of active route.

(2) If current host is SRC (Source) and host moved is next_hop then REQ is sent to search VN and Power status is checked.

(3) Local Repair scheme is used if host moved is an active route.

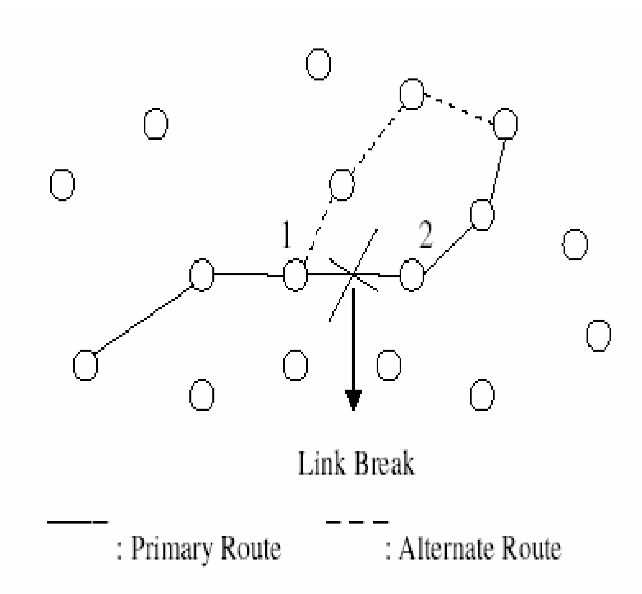


Figure 2: Route Error and Maintenance Phase

Nodes which have an entry for the destination in their alternate route table transmit the packet to their next hop node. Data packets, therefore, can be delivered through one or more alternate routes and are not dropped when route breaks occur. To prevent packets from tracing a loop, these mesh nodes forward the data packet only if the packet is not received from their next hop to the destination and is not a duplicate. When a node of the primary route receives the data packet from alternate routes, it operates normally and forwards the packet to its next hop as the packet is not a duplicate. The node that detected the link break also sends a ROUTE ERROR (ERR) packet to its previous neighbor to initiate a route rediscovery. The reason for reconstructing a new route instead of continuously using the alternate paths is to build a fresh and optimal route that reflects the current network topology. Figure 2 shows the alternate path mechanisms at the time of route error ERR. In this phase when route error message sent to previous neighbor of any intermediate node it just reinitiate route construction phase by considering power status of all its virtual nodes.

All this route maintenance occurs under local repair scheme.

3.2.1 Local Repair

When a link break in an active route occurs, the node upstream of that break may choose to repair the link locally if the destination was no farther and there exists VNs that are active. To repair the link break, the node increments the sequence number for the destination and then broadcasts a REQ for that destination. The Time to live (TTL) of the REQ should initially be set to the following value

TTL = max (VN attached, 0.5 * #hops) + POWER status

where #hops is the number of hops to the sender (originator) of the currently undeliverable packet. Power status is checked from route table VN attached is the number of virtual nodes attached.

This factor is transmitted to all nodes to select best available path with maximum power. Thus, local repair attempts will often be invisible to the originating node .The node initiating the repair then waits for the discovery period to receive reply message in response to that request REQ. During local repair data packets will be buffered at local originator. If, at the end of the discovery period, the repairing node has not received a reply message REP it proceeds in by transmitting a route error ERR to the originating node. On the other hand, if the node receives one or more route reply REPs during the discovery period, it first compares the hop count of the new route with the value in the hop count field of the invalid route table entry for that destination. If the hop count of the newly determined route to the destination is greater than the hop count of the previously known route the node should issue a route error ERR message for the destination, with the 'N' bit set. Then it updates its Route table entry for that Destination. A node that receives a ERR bit set. Then it updates its Route table entry for that Destination. A node that receives a ERR message with the 'N' flag set must not delete the route to that destination. The only action taken should be the retransmission of the message. Local repair of link breaks in routes sometimes results in increased path lengths to those destinations. Repairing the link locally is likely to increase the number of data packets that are able to be delivered to the destinations, since data packets will not be dropped as the ERR travels to the originating node. Sending a ERR to the originating node after locally repairing the link break may allow the originator to find a fresh route to the destination that is better, based on current node positions. However, it does not require the originating node to rebuild the route, as the originator may be done, or nearly done, with the data session. When a link breaks along an active route, there are often multiple destinations that become unreachable. The node that is upstream of the lost link tries an immediate local repair for only the one destination towards which the data packet was traveling. Other routes using the same link must be marked as invalid, but the node handling the local repair may flag each newly lost route as locally repairable; this local repair flag in the route table must be reset when the route times out. In AODV, a route is timed out when it is not used and updated for certain duration of time. The proposed scheme uses the same technique for timing out alternate routes. Nodes that provide alternate paths overhear data packets and if the packet was transmitted by the next hop to the destination as indicated in their alternate route table, they update the path. If an alternate route is not updated during the timeout interval, the node removes the path from the table.

3.3 Route Erasure (RE) phase

When a discovered route is no longer desired, a route erasure broadcast will be initiated by Source, so that all nodes will update their routing table entries. A full broadcast is needed because some nodes may have changed during route reconstruction. RE phase can only be invoked by SRC (source).

The ERR message is sent whenever a link break causes one or more destinations to become unreachable from some of the node's neighbors.

4. SIMULATION AND RESULTS

Simulation study has been carried out to study the Performance study of existing different protocols. Simulation Environment used for this study is NS [21]. Earlier versions of ns have no support for multi-hop wireless networks or MAC sub layer, but its latest version (NS-2.28) provides support for MAC sub layer and a lot of support for wireless environments. Wireless environments are taken from next release with embedded features ported from CMU/Monarch's code [19].

4.1 Parameters used for Testing

Many parameters have been used for evaluating performance of new scheme. Degree of connectivity among nodes, speed , number of duration and data flow, type of packets, size of packets are some of the parameters that influence the performance of routing schemes.

A. Degree of Connectivity among Nodes

In many scenarios simulated in previous simulation studies of ad hoc networks, nodes were usually densely connected. In a highly dense network, almost every node has at least a path to any other node, usually just a few hops away. Meanwhile due to the high volume of routing control messages, congestion happens frequently in such networks. A sparsely connected ad hoc network bears different characteristics. In such a network, paths between two nodes do not always exist, and routing choices are more obviously affected by the mobility of the network. In the simulation study, simulations have been carried out in both sparse and dense networks. Area of simulation for dense medium selected has been taken as 1 km* 1 km, and the number of nodes to be 20 and 50. The transmission range of each node in the dense network is 300 m. In case of sparse medium the nodes have been taken as 10 and network area as 700*700 meters whereas the range of transmission is 200 m.

B. Degree of Mobility

Varying the degree of mobility, or the moving speed of each node in the network, is a useful way to test how adjustable a routing protocol is to the dynamic environment. There are several mobility models used in the past. The proposed scheme uses the random waypoint because this has been used more widely than other mobility models. In this model, each node begins the simulation by remaining stationary for a fixed "pause time" seconds. It then selects a random destination in the simulation space and moves to that destination at a speed distributed uniformly between a minimum and a maximum speed. Upon reaching the destination, the node pauses again for "pause time" seconds, selects another destination, and proceeds there as previously described, repeating this behavior for the duration of the simulation. In the simulation scenes , the minimum moving speed has been taken as 0 and maximum speed as 30m/sec. Different speeds as 1, 2, 5, 10, 15, 20 and 30 meters per second have been used for checking effect of mobility. The pause time has been varied between 0 and 500 seconds. A pause time of 0 second corresponds to continuous motion, and a pause time of 500 corresponds to no motion. The simulation time has been taken as 500 seconds.

C. Number and Duration of Data Flows

Because on-demand protocols query routes only when data flows exist for them, the number of data flows would influence the number of paths found and the control overhead for on demand protocols, such as AODV, TORA and DSR. How well a protocol adjusts to the change of data flows is another important criterion for evaluating a routing protocol. In the simulations environment, the number of data flows has been varied between 5 and 50. Many connections have been established among nodes. Distant connections have been set even if connection fails after some time. Random scenarios has been created, where many connecting paths are initially far away and also some initially connected paths move too far away till the end of simulation In most previous simulation studies, each data flow started at an early time of the simulation period, and continued until almost the end of the period. In present simulations, besides this long lasting flow pattern, protocols have been tested under data flows that last shorter time periods. Packet size used is 64 bytes and 512 bytes.

D. Other Factors

There have been other factors also for which the scheme has not changed the values and studied the effects. The effect of having a static node or a few static nodes as points of attachments to the Internet, such that most of the traffic in the ad hoc network is to and from such point(s) has not been taken into account. In the simulation environment of the study and several previous simulations, traffic type chosen has been the constant bit rate source (CBR). In a real case, there are all kinds of popular applications with different traffic patterns from CBR. Simulations have been carried out for TCP and UDP both. The behavior of DSR protocol has been quite different for UDP and TCP Packets. DSR handles UDP much nicely compared to TCP packets at fast speeds. To observe the protocols more objectively, it would be worth trying different applications in the future.

4.2 Metrics

Simulation results have been compared with other existing protocols like AODV, DSR and TORA. Simulations have been conducted on P-IV processor at 2.8 GHZ, 512 MB of RAM in Linux Environment with ns-2.26 with facilities for wireless simulations. The following metrics have been used in the simulation study.

1. Packet Delivery Ratio: The fraction of successfully received packets, which survive while finding their destination. This performance measure also determines the completeness and correctness of the routing protocol. If F is fraction of successfully delivered packets, C is total number of flows, f is id, R is packets received from f and T is transmitted from f, then F can be determined by

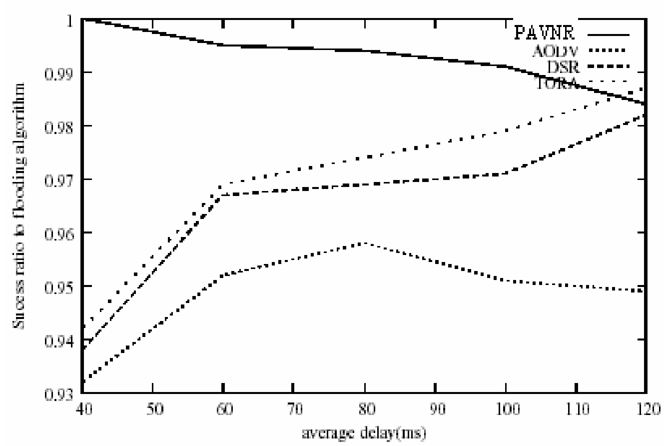
$$F = \frac{1}{C}\sum_{f=1}^{C}\frac{R_f}{T_f}$$

2. End-to-End Delay: Average end-to-end delay is the delay experienced by the successfully delivered packets in reaching their destinations. This is a good metric for comparing protocols and denotes how efficient the underlying routing algorithm is, because delay primarily depends on optimality of path chosen. This metric can be defined by

$$\text{Average end-to-end Delay} = \frac{1}{S}\sum_{i=1}^{S}(r_i - s_i)$$

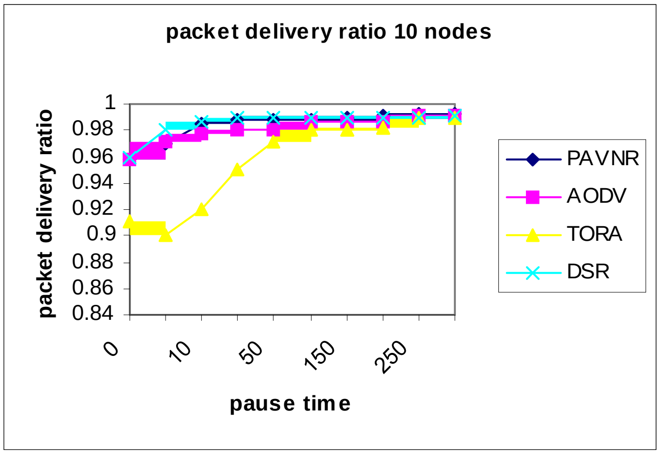
where S is number of packets received successfully, r_i is time at which packet is received and s_i is time at which it is sent, i is unique packet identifier.

3. Routing Overhead: The number of routing packets sent by the routing protocol to deliver the data packets to destination.

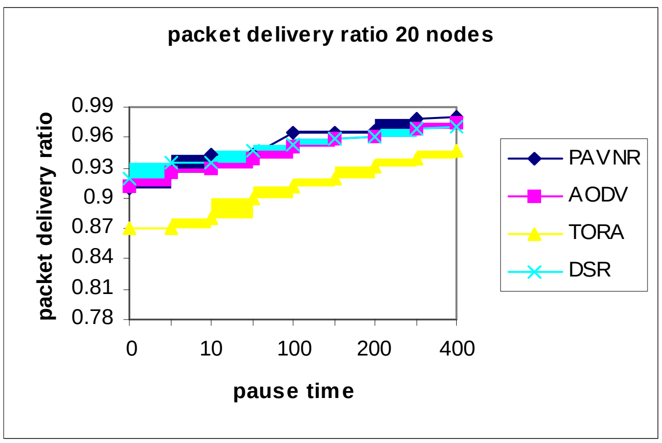


Graph 1: Average delay in packet delivery

Since PAVNR and AODV both have the same amount of control message overhead, we used a different metric for efficiency evaluation. It has been clearly visible in Graph 1, that the average path cost of PAVNR is higher than that of AODV and others when link break is relatively low. That can be explained as follows: PAVNR has a much higher success ratio than AODV when the link break rate is 50%. Those connections, which PAVNR is able to establish but AODV is not, tend to have relatively long routing paths, as observed in the simulation. They also tend to have higher cost, which brings the average path cost up. There are two reasons for this result. First, when route breaks PAVNR uses longer alternate paths to deliver packets that are dropped in AODV, Second when there are multiple paths, redundancy is created and hence increases the number of data transmission. It has been observed that efficiency has slightly been sacrificed in order to improve throughput and protocol effectiveness. Next graphs are comparison among PAVNR, AODV, DSR and TORA in terms of packet delivery ratio.

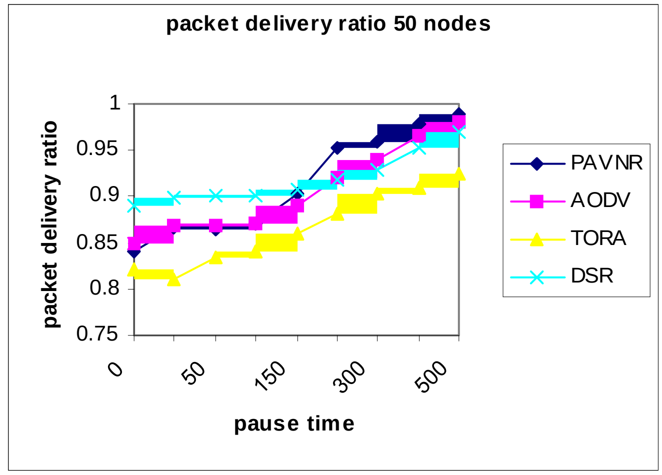


Graph 2: Packet delivery ration for 10 nodes



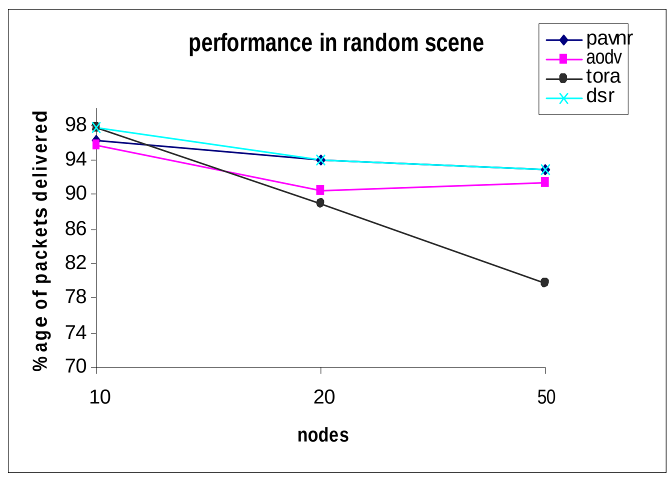
Graph 3: Packet delivery ratio for 20 nodes

In the scene the speed has been changed form 1 meter per second to 25 meters per second. It was observed as in Graph 2 and Graph 3, that Packet delivery ratio was very good for TORA as it is good in sparse mediums, performance of PAVNR was below ADOV and DSR, reason being less virtual nodes available and more time spent in calculating power status, but the performance of PAVNR was overall best for 20 and 50 nodes proving the point that it was better to take care of power and virtual nodes factors. It was much better than its counter parts for 50 nodes (Graph 4) i.e. in dense mediums. The reason is easy availability of virtual nodes and more nodes available for recovery phase.



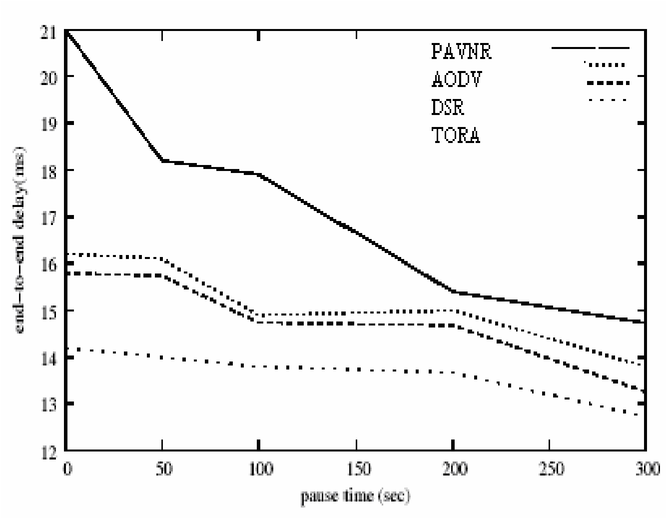
Graph 4: Packet delivery ratio for 50 nodes

The performances of all four protocols have also been tested in a random scene environment also where different nodes have different speeds and movement pattern are different for connecting nodes. The scenario has been simulated for 10, 20 and 50 nodes. PAVNR performed better than others and came out to be more close to DSR in higher number of nodes, TORA packet delivery ratio dropped at higher nodes but it was good for less number of nodes.



Graph 5: %age of Packets delivered in random scenario

In Graph 5 random scene layouts is taken with 10, 20 and 50 nodes with varying pause times and varying speeds. TORA performance gets poorer with increasing speeds. AODV and DSR performance has been relatively constant throughout the process.



Graph 6: End to end delay in delivery of packets

Graph 6 shows that PAVNR has longer delays than AODV and others. One can only measure delays for data packets that survived to reach their destination. PAVNR delivers more data packets and those packets that are delivered in PAVNR but not in AODV take alternate and possibly longer hop routes. PAVNR with longer delays does not represent its ineffectiveness since these protocols use the same primary route.

5. CONCLUSION

In this paper a new scheme has been presented that utilizes a mesh structure and alternate paths. The scheme can be incorporated into any ad hoc on-demand unicast routing protocol to improve reliable packet delivery in the face of node movements and route breaks. Alternate routes are utilized only when data packets cannot be delivered through the primary route. As a case study, the proposed scheme has been applied to AODV and it was observed that the performance improved. Simulation results indicated that the technique provides robustness to mobility and enhances protocol performance. Study is going on currently investigating ways to make this new protocol scheme robust to traffic load. The Power aware virtual node Routing protocol gives a better approach for on demand routing protocols for route selection and maintenance. It also takes care of Power factor which improves the performance of protocol. It was found that overhead in this protocol was slightly higher than others, which is due to the reason that it requires more calculation initially for checking Virtual nodes and power checks. This also caused a bit more end to end delay. The process of checking the protocol scheme is on for more sparse mediums and real life scenarios and also for other metrics like Path optimality, Link layer overhead. The proposal is also to check this protocol for multicast routing. Additionally, the plan is to further evaluate the proposed scheme by using more detailed and realistic channel models with fading and obstacles in the simulation.

6. References

1. G. Aggelou and R. Tafazoli, “Bandwidth efficient routing protocol for mobile ad hoc networks (RDMAR)”, CCSR, UK 1997.
2. D. Bertsekas and R. Gallager, “Data Networks” Prentice Hall Publ., New Jersey, 2002
3. J. Broch, D. A. Maltz and J. Jetcheva, “A performance Comparison of Multi hop Wireless Adhoc Network Routing Protocols”, Proceedings of Mobicomm’98, Texas, 1998.
4. Tsu-Wei Chen and M. Gerla, "Global State Routing: A New Routing Scheme for Ad-hoc Wireless Networks" Proceedings of international computing conference IEEE ICC 1998.
5. J. J. Garcia, M. Spohn and D. Bayer, “Source Tree Adaptive Routing protocol”, available at IETF draft, www.ietf.org .
6. Z. J. Hass and M. R. Pearlman, “Zone routing protocol (ZRP)”, Internet draft. available at www.ietf.org .
7. D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad Hoc Networks", Mobile Computing, T. Imielinski and H. Korth, Eds., Kulwer Publ., pp. 152-81, 1996.
8. S. Murthy and J. J. Garcia-Luna-Aceves, "An Efficient Routing Protocol for Wireless Networks", ACM Mobile Networks and App. Journal, Special Issue on Routing in Mobile Communication Networks, pp.183-97, 1996.
9. A. Nasipuri, R. Castaneda, and S. R. Das, “Performance of Multi path Routing for On Demand Protocols in Mobile Ad Hoc Networks”, ACM/Baltzer Journal of Mobile Networks(MONET).
10. N. Nikaein and C. Bonnet, “Dynamic Routing algorithm”, available at Instiut Eurecom, Navid.Nikaein@eurocom.fr.
11. V. D. Park and M. S. Corson, “A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks”, Proceedings of the IEEE International Conference on Computer Communications (INFOCOM), Kobe, Japan, pp. 1405-1413, 1997.
12. C. E. Perkins and P. Bhagwat, “Highly dynamic destination-sequenced distance vector routing (DSDV) for mobile computers”, Proceedings of ACM SIGCOMM 94, pp. 234–244, 1994.
13. C. E. Perkins and E. M. Royer, “Ad-Hoc On Demand Distance Vector Routing”, Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (WMCSA), New Orleans, LA, pp. 90-100, 1999.
14. J. Raju and J. J. Garcia-Luna-Aceves, “A New Approach to On-demand Loop-Free Multi path Routing”, Proceedings of the 8th Annual IEEE International Conference on Computer

Communications and Networks (ICCCN), Boston, MA, pp. 522-527, 1999.
15. S. Ramanathan and M. Steenstrup, “A survey of routing techniques for mobile communications networks”, Mobile Networks and Applications, pp. 89–104, 1996.
16. E. M. Royer and C. K. Toh, “A review of current routing protocols for ad hoc mobile wireless networks”. IEEE Communications, pp. 46–55, 1999.
17. A. Tanenbaum, “Computer Networks”, Prentice Hall, New Jersey, 2002.
18. C. K. Toh, “Ad hoc mobile wireless Networks”, Prentice Hall, New Jersey, 2002.
19. CMU/Monarch's Code, available at www.monarch.cs.edu
20. National Science Foundation, “Research priorities in Wireless and mobile networking”, available at www.cise.nsf.gov.
21. NS Notes and Documentation, available at www.isi.edu/vint.