An Instantiation of Way Point Routing for Mobile Ad Hoc Networks

Waseem M. Arain and Sayeed Ghani

Abstract--Mobile ad hoc networks are increasingly finding their existence in the marketplace heading to a new paradigm of pervasive computing. However there are many areas open to research in the field. Due to node mobility resulting in an ever-changing network topology, conventional routing methods cannot be applied in MANETS. Therefore, this is one of the core areas of research. Researchers are challenged to design protocols that can potentially scale to anything from thousand to tens of thousands of nodes and to reduce the route discovery latency. In this paper a different instantiation of Way Point Routing (WPR) model is proposed, where a route is divided into sub-routes to decrease route-latency in frequently occurring subsequent-route-discoveries and to adapt varying topologies in MANET, and future simulations are suggested to evaluate the performance of the proposed routing protocol.

1.0. Introduction and Review of Routing Protocols

Mobile Ad hoc NETworks (MANETS), consist of dynamically self-configurable, un-administered, wireless, low-powered, autonomous multi hops **[1]** attracting the concept of pervasive communications – an idea intrinsically attached to heterogeneous networks and 4G architecture. They are also referred as *multihop wireless networks* as nodes not only serve as end-systems but also function as routers acting as intermediate nodes **[2]**. Any such network is expected to have a dynamic and variable topology to offer the flexibility of MANETS. Applications of MANETS include but are not limited to: emergency services, hospitals, conferencing, community networking, home networking, embedded computing applications (ubiquitous computing) and digital battlefield operations **[1][3]**.

Due to the potential node and link mobility, routing is a highly challenging area of research in MANETS. Many ad hoc routing protocol projects are underway worldwide, **[1]** mainly, to achieve the aims of reliability, efficiency and scalability.

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The key challenge for mobile ad hoc routing protocols is to tackle the inherent limitations of MANETS such as high power consumption, low bandwidth and high error rate **[4]**. Some of the key ad-hoc routing protocols are as follows.

Dynamic Source Routing (DSR) proposed by D. B. Johnson et al. **[5]**, uses two key processes namely: Route Discovery and Route Maintenance. Routes are stored in caches. RREQ broadcasts leads to RREP, which contains complete routes to be used by the source and all other intermediate nodes. RERR messages are used to notify the source about any broken links on the route, which on its subsequent RREQ piggybacks the error notification to avoid staleness in caches.

C.E. Perkins et al. **[6]** proposed **Destination-Sequenced Distance-Vector (DSDV)** routing based on modifications to bellman-Ford routing scheme. In DSDV packets are sent using routing tables stored at each node. Any change in the route is updated, periodically, throughout the network and as soon as new critical information is available. Central to the concept is the sequence number in the routing table, against each entry, generated by the destination. This helps prevent looping.

Advance On-demand Distance-Vector (AODV) routing protocol is a modified DSDV with on-demand behavior. It involves steps of path discovery similar to DSR but here RREQ includes two additional parameters i.e. source sequence number and destination sequence number. Source sequence number is used to maintain freshness of the reverse route and destination sequence number is used to seek freshest route (in RREP) from the node. Link with neighboring nodes stay active as long as the packets are delivered to them or in case there's nothing to send then a HELLO message – a special RREQ with TTL set to 1 is sent **[7].**

Clustered-gateway Switch Routing (CGSR) is a hierarchical and proactive protocol based on DSDV. It divides the network into clusters and elects a cluster-head such that each node is one hop from its cluster-head. Nodes that belong to more than one cluster would act as gateways. Thus it maintains route in a hierarchy of *clusterhead-gateway-clusterhead* fashion **[8].**

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In the following section we would compare the DSR and AODV, because, first these are the two protocols which have been earlier used in DOA as an instantiation of way point routing **[19].** We consider efficiency and scalability as two most important characteristics which make them strong candidates for way point routing. Lately, in [26] also these are the two most important and key characteristics for such comparison.

In section three we would propose our protocol which is an instantiation of way point routing and then in the end in section four we would set directions of our future work before concluding.

2.0. Comparison Of The Two On-Demand Routing Protocols

In simulations DSR has fared better in less stressful conditions, i.e., fewer nodes and less node mobility; however in more stressful conditions AODV has surpassed DSR **[9].** Simulation results in **[10]** indicate DSR and AODV have delivered 95% of data packets regardless of mobility rate. However, DSR consistently generates less routing overhead than AODV **[9], [10]**. The poor performance and delay of DSR can be attributed to its aggressive and inefficient caching mechanics **[9].** Yih-Shun Hu et al. have stated that source routing is favorable for security provisions in a routing protocol as compared to distance-vector routing protocols. **[11]**.

2.1. Efficiency Issues

Route caching is used aggressively by DSR to reduce (i) routing overheads and (ii) route discovery latency **[12]**. However it results in polluted caches over time as many entries become stale. There are two types of cache organization schemes currently used in DSR, one is path cache and the other is link cache. Path cache keeps the full path from source to destination, whereas link cache proposed by Weinging Lou et al. **[13]** decomposes the path received in RREP to links, using the concepts of link lists in graph theory and stores a graphical view of the topology. Simulation results have shown improved performance under stressful network conditions when link cache was used.

Three modifications to the DSR have been proposed by Mahesh K. Marina et al. namely wider-error notification, route expiry mechanism with adaptive timeout selection and use of negative caches. The simulation results showed that combination of these techniques brings 15% improvement in packet delivery **[12].**

Hu and Johnson **[14]** studied the cache design choices in terms of cache structure, cache capacity and cache timeout. They found that link caches yield more routing information than path caches and were able to reduce routing overheads more effectively. However it was also noted that path caches are simple to implement whereas link caches are complex, as nodes will have to use graph search algorithms hence taking more CPU time to execute **[14].** In a similar work **[13]** also found that link caches without appropriate timeout mechanisms can potentially increase the route errors resulting in performance degradation. Marti et al. **[15]** use two extensions on top of DSR to outline processes for efficiency such that nodes with high mobility are not chosen in a path.

Yu **[16]** has proposed a distributed cache-updating algorithm for DSR and has shown that it reduces the discovery latency for path caches by up to 29% and 49% for Link-MaxLife – an adaptive timeout mechanism for link caches. When a node detects a broken link it is proactively updated on the network. Thus the failure detection retains its on-demand behavior and yet the nodes are updated proactively.

2.2. Scalability Issues

Erikson et al. **[17]** propose a new dynamic addressing scheme where address and identifier of the node are two separate entities. IP address is an identifier and routing address is a dynamically changing tree. Use of dynamic addressing scheme is tipped for building a scalable routing protocol.

Lee et al. **[18]** have proposed five versions of a modified AODV for scalability test with 10,000 nodes. The simulations show that it's quite difficult to scale to that level. Certain schemes have worked well in certain ways thus leading to the intuition that similar improvements can be brought about in other on-demand routing protocols too.

Recently Bai et al. **[19]** have proposed the Way Point Routing model, a route is divided into segments. Each node on a route is either a waypoint node or a forwarding node within a segment. Waypoint nodes delimit each segment and two different protocols are run: one within segment and the other between segments. Other than source and destination all other waypoint nodes act as Start node for the downstream segment and end-node for the upstream segment. The source node is only a start node likewise the destination node is always an end node. Since waypoint nodes are designated for the route only therefore they may be only forwarding nodes for other routes.

DOA (DSR over AODV) protocol proposed in **[19]** is an instantiation of the WPR model. DSR is used as a high-level routing protocol for inter-segment and AODV is used as low-level routing protocol running within segments. Each node maintains route cache and route table for DSR and AODV respectively.

3.0. PROPOSED INSTANTIATION OF WPR

Several routing protocols have been proposed to date, having strengths and applications in different areas. However our motivation comes from the study of hybrid and hierarchical reactive protocols. WPR as a model has a distinct advantage over two key hierarchical protocols; namely, CGSR and ZRP (zone routing protocol). We have discussed only one of them i.e. CGSR to explain the underlying idea used in such protocols. It fairly distributes the work by splitting the route into segments rather than the entire network into clusters where additional work is placed on certain nodes in the network, thereby depriving them of their energy resources [19].

We propose here a new protocol, as an instantiation of the Way Point Routing approach for reasons of achieving better scalability and efficiency of M-TORA and ABR protocols. After studying the set of protocols we selected M-TORA and ABR as inter-segment and intra-segment protocols respectively. In a similar work earlier [19], DSR is used as a high-level routing protocol for inter-segment and AODV is used as low-level routing protocol running within segments.

3.1. Discussion on opting for M-TORA and ABR

Among a plethora of protocol properties we believe that the ability of a routing protocol to keep multiple paths and load-balancing should be the key requirements of the inter-segment routing protocol. This is because multiple routes ensure that there are alternatives available when a link goes down and load balancing prevents congestion, consequently resulting in fewer subsequent route discoveries, low latency, congestion control leading to better packet delivery ratio (PDR) and energy management. Similarly for a protocol to be fit for intra-segment routing, high degree of stability and reliability apart from greater throughput will be the most desirable features.

	M-TORA	TORA	DSR	AODV	ABR
Route Metric	Shortest Path, Congestion free Path	Shortest Path	Shortest path	Freshest and Shortest path	Associativity, load delay etc
Periodic Message	IMEP Control	IMEP Control	None	Hello	Beacons
Multicast	Yes	Yes	No	Yes	No
Multiple route possibilities	Yes	Yes	Yes	Yes	No
Route Reconfiguration Methodology	Link Reversal, Route Repair	Link Reversal, Route Repair	Erase Route, Notify Source	Erase Route, Notify Source	Localized Broadcast Query
Source Routing	No	No	Yes	No	Yes

TABLE: Showing protocol characteristics gathered from literature review.

Lately M-TORA has been propose, where some of the bottlenecks such as congestion, believed to be responsible for low throughput of TORA have been eliminated by load balancing [22]. It is likely to have lower overhead in comparison to DSR and TORA. Though in some simulation studies it has been shown that TORA has serious performance bottlenecks [23, 24] however, studies are not available to compare if M-TORA has not significantly altered the situation. Thus M-TORA meets our criterion i.e. it is the only protocol after DSR and TORA to have the ability to record multiple paths and it is the only protocol that uses load balancing capability.

Associativity-Based Routing (ABR) protocol is selected for intra-segment routing because it has been found stable and reliable, with lower overhead and plausibly better throughput when compared to AODV. This observation stems form the fact that ABR has fared well on overhead, delay and throughput parameters when compared with DSR [25].

3.2. Proposed Method

We propose to conduct broad-ranging simulations using NS2. Our simulations will compare the DOA and our proposed instantiation of the WPR for performance and scalability factors. We will study the scalability in networks with 100 to 2500 nodes with a minimum pause time of 0 indicating constant mobility. Five simulation parameters will be used, i.e., control overhead, packet delivery ratio (PDR), end-to-end delay, average route length and route repair ratio. However upon finalization of our protocol design, additional parameters and simulation conditions may be included.

Though in **[20]** QualNet was evaluated to be the best among other alternatives for simulating Mobile Ad-hoc Networks. The preference to work with QualNet or GloMoSim is there, because Bai et. al has implemented DOA while using GloMoSim **[19]** and QualNet is simply an industrial version of GloMoSim but there is also a good justification to use NS2 for our simulation. First, it has been cited as most widely used simulation tool for studies on Mobile Ad-hoc Networks, second it's an open source with many researchers contributing to it and third it has been extensively used in credible research projects like Monarch, establishing its validity. Also, it has the potential to be used as an emulator, though this function still needs lots of improvements.

4.0. FUTURE WORK AND CONCLUSION

First simulations need to be conducted to compare the MOA – proposed protocol – with DOA then a special case of improving the DOA (DSR Over AODV) by implementing it with modified DSR with distributed cache updating as discussed in [16] can also being considered. A decision regarding changing both or one of the protocols would also have to be taken after a thorough study of these protocols. The design choice for our protocol will depend on multiple factors including the convenience to work with the selected protocols among *candidate protocols*.

There were many other works suggesting improvements but we have chosen only those that bring forth some significant improvement of our interest that is scalability and efficiency of a routing protocol for mobile ad hoc networks. It is clear from the above discussion that a growing body of research is indicating two factors of critical importance for MANETs maturity i.e., the routing protocols should be able to scale well and should handle communication efficiently i.e. with lesser route discovery latency. The DOA protocol was designed in order to meet these goals, however, it can further be improved if the underlying idea behind the DOA protocol i.e., waypoint routing approach, is utilized to design further improved protocols. Hence our paper has suggested another instantiation of the WPR model and we have proposed that simulation be carried out to evaluate and compare its performance with DOA.

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