Impact of Node Density and Mobility on Scalable Routing Protocols in Mobile Ad-Hoc Networks

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ABSTRACT
Mobile Ad Hoc Networks (MANETs) is a self-configurable network of mobile nodes connected by wireless links to form an arbitrary topology and communicate to each other without the use of existing infrastructure. Complexities of routing between the nodes are increasing due to the highly dynamic nature of the mobile ad hoc network results in frequent change in network topology. The routing protocols are faced with the challenge of producing multi-hop routing under host mobility and bandwidth constraint. Scalability issues are attracting attention these days due to the presence of both large node density and mobility of the nodes in ad hoc networks. Random waypoint mobility is used in this simulation. In this paper analysis and comparisons of routing protocols such as: Ad hoc On Demand Distance Vectoring Routing Protocol (AODV), Dynamic Source Routing (DSR) and Dynamic MANET On demand Routing (DYMO) is done on the basis of the packet delivery ratio, average end to end delay, average jitter and throughput.

Keywords
Mobile Ad hoc Networks (MANETs), AODV, DSR, DYMO, Node Mobility and Node Density.

1. INTRODUCTION
Mobile ad hoc networks (MANET) [1], is a self-configuring and self organizing multi hop wireless network that does not rely on a fixed infrastructure and works in a shared wireless medium. Nodes in mobile ad- hoc network sharing same random access wireless channel and each node function not only as a host but also as a router that maintains routes to and forwards data for the other nodes in the networks that may not be within wireless transmission range. Routing in mobile ad hoc networks faces challenges due to a large number of nodes, mobility of the nodes and communication resource constrained like bandwidth and energy [15]. The scalability issue for wireless multi hop routing protocols is concerned with large routing message overhead due to a large number of nodes and mobility. Routing protocols

generally use either Distance Vector (DV) or Link State (LS) routing [8]. Distance vector routing is a shortest path routing, a vector containing the cast and the path to all the destinations is kept and exchanged at each node. In a network with population N, link state updating generates routing overhead on the order of O (N2). If the networks have a large number of nodes, the transmission of routing information will consume most of the bandwidth [5]. Thus, reducing routing control overhead becomes an important to find a solution to the scalability problem of a homogeneous network using a scalable routing protocol. Scalable routing protocol may generally be categorized as: Proactive, Reactive and hybrid routing protocol. Table driven routing protocols attempt to maintain up to date routing information from each node to every other node in the network for ex. OLSR [16], LANMAR. Reactive type of routing creates routes only when desired by the source node for ex. AODV, DSR and DYMO [9]. Hybrid routing is a combination of proactive and reactive for ex. ZRP [18]. Both proactive and reactive routing protocols have their advantages and disadvantages in terms of routing table size, contrast and bandwidth consumption. If we are talking in term of routing table size, a proactive protocol has to maintain entries for all the nodes in the network, hence cannot scale well to large networks. By contrast, routing information to only active communicating nodes is maintained in an on demand routing protocol. For bandwidth consumption, reactive routing protocols are generally considered to have lower control overhead. However, when new routes have to be found frequently, the flooding of RREQ (Route Request) may cause significant overhead. In addition, a path is used as long as it is valid, hence route optimality cannot be achieved in such protocols. This means that the amount of bandwidth wasted due to the sub optimality of routes may become excessive when the call-to-mobility ratio is high. Proactive protocols can potentially be designed with the same level of control overhead as reactive protocols. In a sense, this flexibility of balancing the tradeoff between routing control overhead and path optimality is an advantage of proactive approaches over reactive ones. And if we are talking In terms of delay, proactive protocols have a route to the destination readily available whenever it is needed, while reactive protocols suffer from longer route acquisition latency due to the on-demand route discovery. Ideally, a hybrid routing protocol should have

the following properties: The protocol should choose suitable basic components and should integrate them organically to achieve better performance than any single component, the protocol should be able to dynamically adjust the contribution of each component to achieve different performance goals under different network conditions; such adaptation mechanisms generally require a clear mapping between performance metrics and hybridization parameters. Table I shows the comparison between on-demand routing protocol for different parameters. In this paper we have compared and analysis the reactive routing protocols like: AODV, DSR and DYMO on the basis of average jitter, average end to end delay, throughput, packet delivery ratio (PDR) and routing overhead. The rest of the paper is organized in following structure: Section II presents the literature survey. Section III presents a description of scalable routing protocols. Section IV presents Simulation setup and analysis of the results and section V presents the conclusion of the paper.

2. RELATED WORKS

We summarize the most relevant previous studies concerning ad hoc on-demand routing performance comparisons. The authors in [3] compare four ad hoc routing protocols using a maximum number of 50 nodes but their traffic load is relatively low, since the data packet size is 64 bytes, the maximum number of sources is 30 and every source node transmits 5 packets / Sec. The authors in [9] compare three routing protocols, AODV, DSR and STAR by using NS-2 simulator. Author in [22] this paper proposed mathematical framework for the evaluation of the performance of proactive and reactive routing protocols in mobile ad hoc networks (MANETs). The model in this paper covers the mandatory behavior and scalability limits of network size of both classes of routing protocols like proactive and reactive, and provides valuable direction for the performance of reactive or proactive routing protocols under various network condition and mobility model. A thorough work is presented in [11], in which the authors have performed an extensive performance evaluation between DSR and AODV, in which the basic mobility metric is the node pause times. This work however does not include large-scale networks either. This is also the case with the comparison between AODV, PAODV, CBRP, DSR, and DSDV.

3. DESCRIPTION OF SCALABLE ROUTING PROTOCOLS

Some symbols used in the table I are: N, the total number of mobile nodes in the network; S, Maximum speed of the node [2, [3] and [4].

3.1 DYMO (Dynamic manet On-demand Routing)

DYMO (Dynamic MANET on-demand) [6], [7] and [12] is a reactive type of routing protocol and inspired by AODV and uses sequence number to ensure the usage of fresh and loop free routes. Whenever a source node wishes to send information to the destination node and no path exist in the routing table. It will transmit (RREQ) Route Request Packet .Those nodes received this packet look for an entry for the source node in their routing

table, if this entry does not exist or path found invalid, the RREQ is retransmitted. If such an entry exists then the packet is forwarded only if the information is considered valid otherwise discarded DYMOM (Dynamic MANET on-demand for multipath) protocol is an enhanced version of DYMO which supports the use of the multiple node disjoint path towards the destination. DYMOM provide the lesser end to end delay and average jitter than DYMO.

3.2 DSR (Dynamic Source Routing)

Dynamic Source Routing (DSR) [13], [14] and [19] is an on-demand ad hoc network routing protocol composed of two mechanisms: Route Discovery and Route Maintenance. It uses route discovery to dynamically discover it and this route is cached and used as needed for sending further packets. If a route has been broken it will use route maintenance mechanism to detect it. The important advantage of the source routing design is that the intermediate nodes do not need to update routing information in order to route the packets that they forward, since the packet themselves already contain all the routing decisions. Optimization to route discovery is achieved non propagating route requests, replying from cache and gratuitous route replies. Optimization for route maintenance is achieved by salvaging and gratuitous route errors and optimization to caching strategies achieved by snooping and tapping.

3.3 AODV (Ad hoc on-demand Distance Routing)

Ad-Hoc On-demand Distance Vector' (AODV) Routing protocol [20], [21] is a reactive protocol that was basically designed for highly dynamic wireless mobile ad hoc networks. It is adopted as a standard routing protocol for ZigBee specification. To find a route to the destination, the source node that does not have destination route, broadcast Route request packets (RREQs) to neighboring nodes, this then forwards the request to their neighbors and so on. In order to control network-wide broadcast so RREQ packets, the source node uses an expanding ring search technique where the source node starts benefits the throughput since the number of buffered packets will be less due to a shortened inactive period. If the duty cycle is extremely small, the throughput could be reduced significantly because of insufficient bandwidth. If no reply is received within the discovery period, the TTL value incremented by a predefined increment value. This process continues until a predefined threshold is reached. When an intermediate node forwards the RREQ, it records the address of the neighbors from which first packet of the broadcast is received, thereby establishing a reverse path. When the RREQ reaches a node that is either the destination node or an intermediate node with a fresh enough route to the destination, replies by uni-casting the route reply (RREP) towards the source node. As the RREP is routed back along the reverse path, intermediate nodes along this path set up forward path entries to the destination in its route table and when the RREP reaches the source node, a route from source to the destination establish. A route established between the sources destinations pair is maintained as long as needed by the source. If the source node moves during an active session, route discovery is reinitiated to find a new route to the destination. However, if the destination

or some intermediate node moves, the node upstream of the

A break removes the routing entry and sends route error (RERR) message to the affected active upstream neighbors. These nodes reactive routing protocol is a good choice especially for event driven or periodic data driven WSN applications. Discovery for that destination by sending out a new RREQ message. AODV is designed for highly dynamic mobile networks but the un-predictable topology change in WSN due to node failure makes them virtual mobile networks. Hence until the source node is reached. The affected source node may then choose to either stop sending data or reinitiate route a in turn propagate the RERR to their precursor nodes, and so on .

Table I: Comparison of reactive routing protocols

Attributes	AODV	DSR	DYMO
Type of Routing	Flat routing	Flat routing	Flat routing
Routing philosophy	On-demand	On-demand	On-demand
Routing metric	Newest path	Shortest path	Shortest path
Frequency of updates	As needed (Data traffic)	As needed (Data traffic)	As needed (Data traffic)
Storage complexity	O (2N)	O (2N)	O (2N)
Comm. Complexity	O (2N)	O (2N)	O (2N)
Loop freedom maintenance	Sequence Number	Source Route	Sequence Number
Communication Overhead	High	High	High
Route Recovery	New route, notify source	New route, notify source	Local repair
Route repository	Routing Table	Route Cache	Routing table

4. NETWORK SIMULATION

Network simulator QualNet, is used to analyze the impact of node mobility and node density on on-demand routing protocols in mobile ad hoc networks: AODV, DSR and DYMO. In this paper the simulations use technological specifications of IEEE802.11b wireless networks with a physical layer specification as shown in table II

4.1 Simulation Metrics

The Impact of node mobility and node density on reactive routing protocols is evaluated using the following performance metrics:

- Throughput: Average rate of successful data packets received at destination is called throughput is the. It is also called actual output. This measured in bps (bit/s)End-to-End Delay: Delays due to buffering during queuing at the interface queue, route discovery process, retransmissions at the MAC and propagation and transfer through the channel.It is generally measured in second.
- Average Jitter: It is the change in arrival time of the packets and caused due congestion, topology changes. It is different from the delay and caused due to congestion, topology change in the network. It is measured in second.
- Packet Deliver Ratio (PDR): The (PDR) is defined as Packet delivery ratio, which is the ratio of the data packets delivered to the destinations over the data packets generated by the traffic sources
- Routing overhead: It is the ratio of the number of control packets transmitted to data packet received at the destination. The total number of control packets is calculated by number of route requests forwarded, route replies forwarded, and route errors forwarded of each protocol.

Table II: Simulation parameters

QualNet 5.0.1 Simulation parameters	
Simulator	QualNet 5.0.1
Protocols	AODV, DSR,DYMO
Simulation time	180 Minutes
Simulation Area	100X100 m^2
Antenna Type	Omni-Directional
Receiving and transmitting antenna Gain	1
Transmission Power	15dBm
Number of mobile Nodes(N)	50, 75, 100, 125, and 150
Maximum Mobility of the nodes	10, 20, 30, 40, 50 (m/s)
Mobility Mode	Random Way Point
Communication	Constant Bit Rate
Data Payload	1000 bytes

4.2 Simulation methodology

In this paper simulation is performed by increasing the node density and changing the node mobility under varying node speed. The nodes are deployed randomly in the specified area and node follows the random way point mobility model. These source nodes transmit 1000 byte data packets per second at a constant bit rate (CBR) across the established route for the entire simulation time 180 minutes.

4.2.1 Simulation Results

Aim of this paper is to find out the impact of node speed and node density on the performance of three reactive routing protocols: AODV, DSR and DYMO. In this simulation

occurs: by varying the node speed and node density.

Case 1: Performance with node maximum speed

- Average End to End delay: AODV has less average end to end delay compared to DSR and DYMO under all variations of speed. Delay increases as speed increases as indicated in figure1. The some abnormality of graphs may be due to occurrence of higher congestion
- Average Jitter: AODV have less jitter compared to DSR and DYMO. Average jitter for AODV and DYMO decreases as node speed increases as shown in figure 2. But as the speed of the node increases the value in case of DSR increases.
- PDR: The reasons for packet loss in wireless ad hoc routing protocols are congestion, characteristics of wireless channels and mobility. The packet delivery ratio decreases as speed increases; it means that the links are relatively stable and more reliable at lower speed. AODV routing protocol provides more PDR than DYMO & DSR as shown in Figure 3.

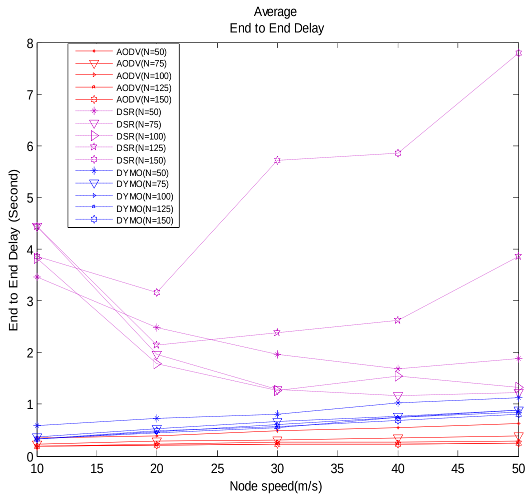


Figure1: Average end to end delay versus node maximum speed

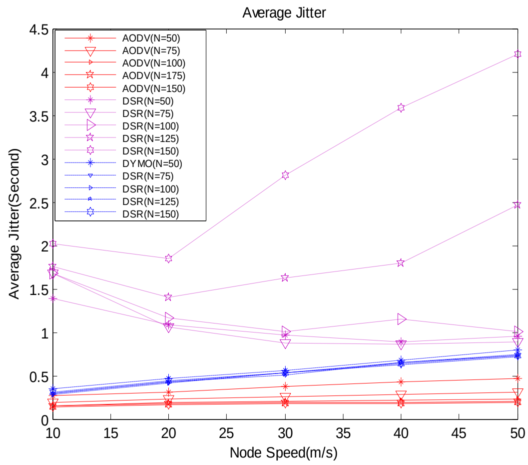


Figure 2: Average Jitter versus node maximum speed

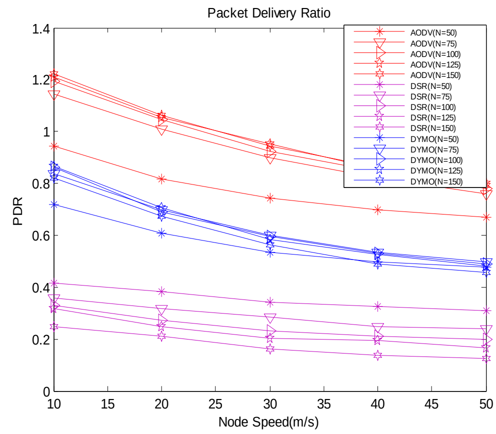


Figure 3: PDR versus node maximum speed

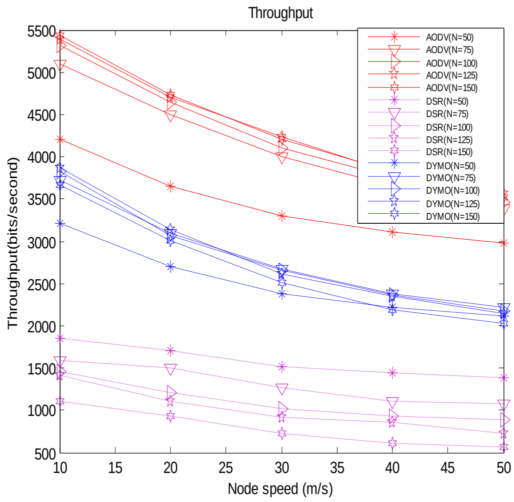


Figure 4: Throughput versus node maximum speed

- Throughput: Throughput of AODV is higher to DSR and DYMO as shown in figure 4. As the speed of the nodes increases the throughput, of routing protocols AODV, DSR and DYMO decreases because of more congestion

- Routing Overhead: DYMO shows an increase in the routing overhead to AODV and DSR. Routing overhead increases as speed of nodes increases as shown in figure 5. An increase in the routing overhead is due to hello packets through local connectivity.

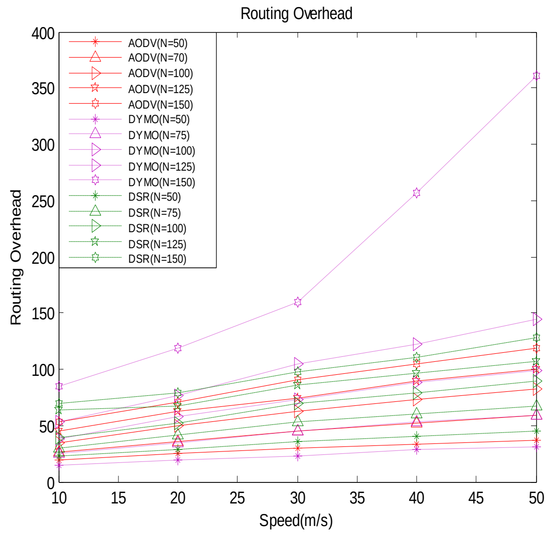


Figure 5: Routing Overhead versus node maximum speed

Case 2: Performance with nodes Density

- **Average End to end delay**: AODV has less average end to end delay to DSR and DYMO under all variations of node density. Delay decreases as node density increases in case of AODV and DYMO but DSR shows decrement in end to end delay and lower node density but increases with node density increases as indicated in figure 6.

- **Average Jitter**: AODV has less jitter to DSR and DYMO. AODV and DYMO shows decrement in average jitter as node density increases as shown in figure 7. DSR shows an increment in average jitter as node density increases.

- **PDR:** AODV and DYMO routing protocols show an increase in PDR value as node density increases but DSR shows decrement in PDR value as node density increases as shown in figure 8.

- **Throughput:** Throughput of AODV is higher than DSR and DYMO as shown in figure 9. As node density increases the throughput, of routing protocols AODV and DYMO increases but the value of throughput for DSR decreases.

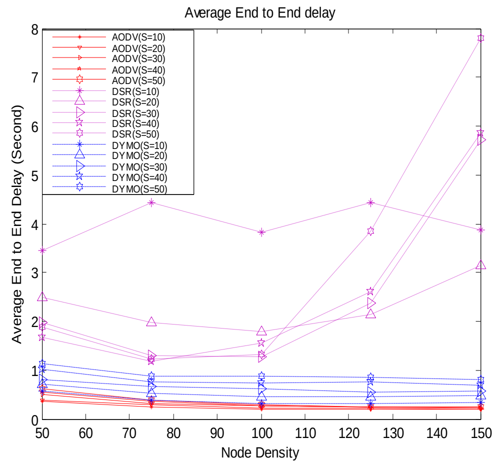


Figure 6: Average end to end delay versus nodes Density

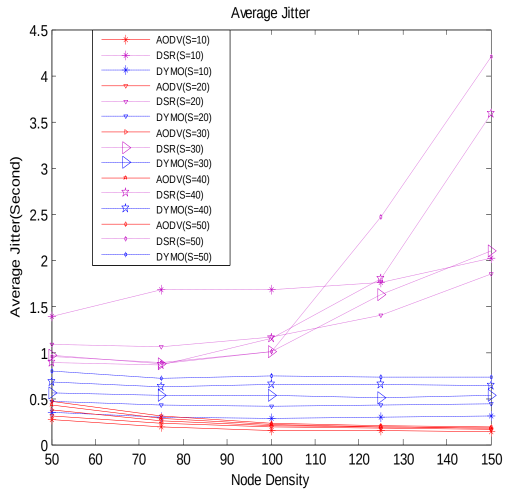


Figure 7: Average Jitter versus nodes Density

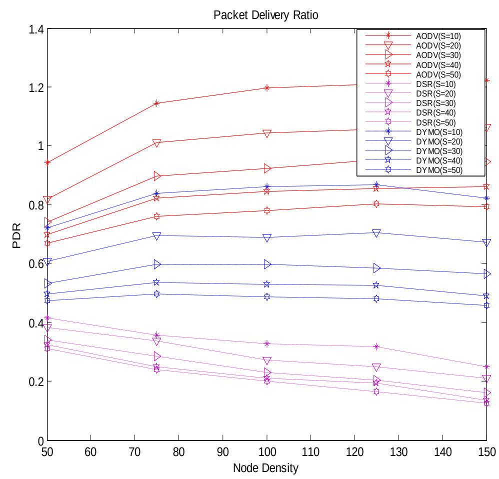


Figure 8: PDR versus nodes Density

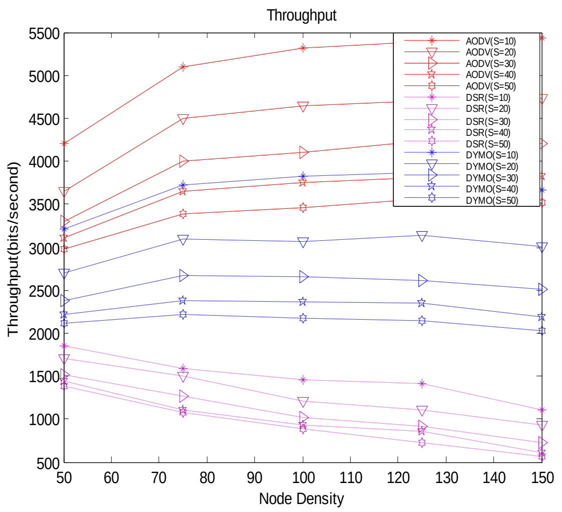
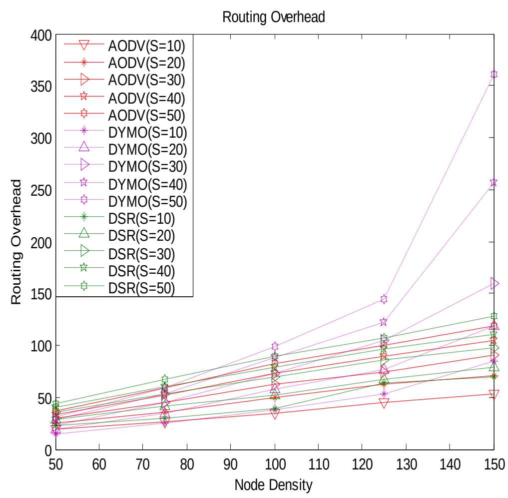


Figure 9: Throughput versus nodes Density



- **Routing Overhead**: DYMO shows an increase in the routing overhead when compared with AODV and DSR. Routing overhead increases as node density increases as shown in figure 10.

5. CONCLUSIONS & FUTURE WORKS

In this paper, we have analyzed the effect of node mobility and node density on reactive routing protocols (AODV, DSR and DYMO) in mobile ad hoc networks. These reactive routing protocols performed quite differently and this provides an idea to the fact that results for mobile ad hoc networks have to be analyzed in order to conclude accurate results particularly when

the qualities of service (QoS) of routing protocols are considered. We have found that routing protocols (AODV, DSR and DYMO) have both cons and pros in different evaluating parameters with varying node density and node mobility. In case of performance with various maximum node speed AODV has less average end to end delay, less average jitter, more PDR and high throughput compared to DSR and DYMO routing protocols under all variations of speed. But DYMO show increases in routing overhead to AODV and DSR. In case of performance with different node density, AODV has less average end to end delay, less jitter, high throughput compared to DSR and DYMO routing protocols under all node density variations. But DYMO show increases in routing overhead to AODV and DSR. In future we would like to evaluate these routing protocols for heterogeneous nodes.

6. REFERENCES

[1] Corson, S. and Macke, J.1999. Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations. RFC 2501.

[2] Royer, E., and Toh, C.1999. A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks. IEEE Personal Comm. , 46-55.

[3] Broch, J., Maltz, D.A., Johnson D.B., Hu, Y.-C., and Jetcheva , J.1998. A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols. Proceeding of MobiCom, pp. 85-97

[4] Hu, Y.-C., and Perrig, A. 2004. A Survey of Secure Wireless Ad-Hoc Routing. IEEE Security and Privacy, 2, 3, 28-39.

[5] Lee, S.-J., Belding-Royer, E.M., and Perkins, C.E.2003.Scalability Study of the Ad Hoc On-Demand Distance Vector Routing Protocol. Int'l J. Network Management, 13, 2, 97-114.

[6] Perkins, C.E. and Bhagwat, P.1994. Highly Dynamic Destination- Sequenced Distance Vector Routing (DSDV) for Mobile Computers. Proc. ACM SIGCOMM, 234-244.

[7] Chiang, C.-C., Wu, H.-K., Liu, W. and Gerla, M. 1997. Routing in Clustered Multi-hop Mobile Wireless Networks with Fading Channel. Proc. Singapore Int'l Conf. Networks (SICON'97), 197-211.

[8] S. Keshav.1999. An Engineering Approach to Computer Networking: ATM networks, the Internet, and the Telephone Network. Ch. 11, Addison Wesley

[9] Jiang, H. and Garcia-Luna-Aceves, J. J. 2001. Performance Comparison of Three Routing Protocols for Ad Hoc Network. International Conference on Computer Communications and Networks, 547-554

[10] Broch, J., Maltaz, D.A., Johnson, D.B. and Hu, Y.C. 1998. A Performance Comparison of Multi-hop Wireless Ad Hoc Network Routing Protocol. Proc. IEEE/ACM MOBICOM, 85–97.

[11] Das, S. R., Perkins, Royer, C. E., and Marina M. K.2001.Performance Comparison of Two On-demand Routing Protocols for Ad hoc Networks. IEEE Personal Communication's Magazine special issue on Ad hoc Networking, 16-28.

[12] Chakeres, C. and Perkins.2006.Dynamic MANET On-demand (DYMO) Routing Protocol. IETF Internet Draft.

[13] Johnson, B. D. and Maltz D.1999.The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks. http://www.ietf.org/internet-drafts/draft ietfmanet.

[14] Broch, J., Maltz, D.A., Johnson, D.B., Hu. F.-C., Jetcheva, J. 1998. A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocol. Proceedings of ACWIEEE MOBICOM, 85-97.

[15] Hong, X., Geria, M., Pei, G. and Chiang, C.-C. .1999. A Group Mobility Model for Ad Hoc Wireless Networks. Proceedings of ACM/IEEEMS, 53-60.

[16] Dhurandher, S.K., Obaidat, M.S. and Gupta M.2007.OPHMR: An Optimized Polymorphic Hybrid Multicast Routing Protocol for MANET. IEEE Transactions on Mobile Computing, l6, 5, 551 - 562.

[17] Misra, R. and Mandal, C. R. 2004. Performance Comparison of AODV/DSR on Demand Routing Protocols for Ad hoc Networks in Constrained situation. IEEE International Conference on personal wireless communication, 86-89.

[18] Haas, Z.J. and Pearlman M.R. 2001. The Performance of Query Control Schemes for the Zone Routing Protocol. ACM/IEEE Trans. Networking, 9, 4, 427-438.

[19] Johnson, D. B., Maltz, D. A.and Broch, J.2001. DSR: The Dynamic Source Routing Protocol for Multihop Wireless Ad Hoc Networks. Ad Hoc Networking, C. E. Perkins (Ed.), 139–172.

[20] Charles, E., Perkins, and Royer, M. E.1999. Ad-Hoc on Demand Distance Vector Routing. Proc. 2nd IEEE Workshop on Mobile Computing 147 Systems and Applications, 90–100.

[21] Perkins, E., and Royer, E. M. 2001.The Ad Hoc on-Demand Distance-Vector Protocol (AODV). In Ad Hoc Networking, C. E. Perkins (Ed.), 173–219, Addison-Wesley.

[22] Hui, X., Xianren, W., Sadjadpour, H.R. and Garcia-Luna-Aceve, J.J.2010.A unified analysis of routing protocols in MANETs. IEEE transaction on communication, 58, 3, 911 – 922.