Optimized and Reliable AODV for MANET

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ABSTRACT
In recent years, mobile and wireless networks have witnessed a tremendous rise in technological advancement. Due to dynamic changing environment of MANET, it is desirable to design effective routing algorithms that can adapt its behavior to rapid and frequent changes in the network. In this paper, we propose an Optimized Reliable Ad hoc On-demand Distance Vector (ORAODV) scheme that offers quick adoption to dynamic link conditions, low processing and low network utilization in ad hoc network. By implementing Blocking Expanding Ring Search (Blocking-ERS) and retransmission of data packet in ORAODV, it provides satisfactory performance in term of packet delivery ratio (PDR), normalizing routing load (NRL) and delay for different network density in term of number of node, various mobility rates.

General Terms
Ad hoc Network, Algorithms.

Keywords
MANET; Optimization; Reliability; Routing;

1. INTRODUCTION
Routing is the process of discovering, selecting, and maintaining paths from source to destination and deliver data packets using this discovered path. The goal of every routing algorithm is to maximizing network performance while minimizing costs. This is a main challenge in mobile ad hoc network (MANET) and it possesses dynamic and random characteristics. Nodes move in an arbitrarily manner and at changing speed, often resulting in connectivity problems. The high mobility and the arbitrarily movement of nodes in MANET (i.e., frequently change of network topology) causes links between hosts to break frequently. So it may difficult to predict traffic conditions [1]. The ideal routing algorithm for MANET should have characteristics like Distributed Solution, Rapid Adaptability, Low Overhead, Low Delay, and Scalability among few others.

Mainly, three different types of routing protocols are available and they are table driven, on-demand and hybrid routing protocols. Routes to all possible destinations are predicted in advance in proactive routing protocols. Each node is required to store complete information about link states and topology of network. It keeps the list of all available destinations and distance to reach them. So when a source has packets to send to a destination, the route is already available and the need for discovering paths to the destination node is avoided. While this approach provides good reliability and instant transmission through frequent dissemination of routing information, they entail high overhead with increasing network size. Furthermore, maintaining all possible routes may be a wasteful exercise when some routes are never utilized. Destination Sequence Distance Vector (DSDV) is an example of proactive routing protocol.

Routes are created only when there are packets to be sent to a particular destination in reactive routing protocols. It initiates a route discovery process to find the route when a mobile node needs to deliver a data packet to a destination. The advantage of reactive routing protocols are lower computation costs and lower packet overhead since nodes do not exchange routing information periodically to maintain routing tables. However, it takes large delay at the route discovery stage. It has to wait until a route to the destination is discovered on-demand when a node desires to send a packet to an unknown destination. Examples of reactive routing are AODV and DSR.

Hybrid Routing Protocols try to have advantages of both on-demand and table driven protocol. The routing is initially established proactively with some proposed routes and then serves the on-demand requests from additional activated nodes through reactive flooding. It provides a better compromise between communication overhead and delay. CBRP, ZRP are examples of hybrid routing protocols.

The expanding ring search (ERS) method is used to avoid network wide broadcasting by searching successively larger area in the network centered on the source of the broadcast [2]. So, it can reduce the total broadcast overhead and end-to-end delay. End-to-end delay may reduce due to reduce number of the route discovery process. But, more end-to-end delay will be experienced during the route discovery if the route discovery process starts from the originating source node every time. It is especially costly when a larger area of the network needs to be searched. However the above problem is addressed by Blocking-ERS [3]. It does not restart its route search procedure from the originating or source node every time when a rebroadcast is required. The rebroadcast can be initialized by any appropriate intermediate nodes on behalf of source node. To improve the time efficiency, a 'stop instruction' is sent via time to live (TTL) scheme.

Reliability in terms of packet delivery ratio (PDR) is an important factor in routing protocol which is a measure of efficiency and effectiveness of routing protocol. It can be improved by retransmitting the packet.

In this paper, we propose a routing protocol by implementing the Blocking-ERS and retransmitting the packet only once after receiving the negative acknowledgement from receiver end.

This paper is organized as follows: section 2 discusses related works and section 3 discusses proposed protocol in detail. In section 4, we discuss different simulation parameters which are used for performance evaluation of the proposed routing protocol followed by simulation model in section 5. Section 6 contains Results and discussions followed by conclusions in section 7.

2. RELATED WORK

Destination Sequenced Distance Vector (DSDV) [4] is a proactive routing protocol. It is a hop-by-hop distance vector routing protocol requiring each node to periodically broadcast routing updates. The advantage of DSDV is that, it guarantees loop-freedom as compared with traditional distance vector routing protocol. No delay is caused by route discovery as there are no sleeping nodes, but it suffers from high overhead cost.

Dynamic Source Routing (DSR) [5] belongs to the reactive or on-demand routing protocol category. The key feature of DSR is the use of source routing and it allows nodes to dynamically discover a route across multiple network hops to any destination. It uses a route discovery process to dynamically determine the route to an unknown destination. The algorithm of DSR also makes aggressive use route caching. It stores the entire route traveled by the different route reply in its cache to enable multi-path routing. As the packet visits an intermediate node, the node caches the packet's route information for possible future use. DSR incurs extra overhead in its control and data packets because every data packet must carry in its header the entire route path it has to travel. These overhead increases exponentially for distant transmissions. This overhead may consume most of the bandwidth and lead to traffic congestion.

Ad Hoc On-Demand Distance Vector(AODV) [6] combines the use of destination sequence numbers in DSDV with the on-demand route discovery technique of DSR to formulate a loop-free, on-demand, single path, distance vector protocol. AODV shares DSR's characteristics in which it also discovers routes on an on-demand basis via a similar route discovery process.

A key feature of AODV is the use of sequence numbers. Sequence numbers determine the newness or freshness of routing information and to prevent routing loops. If the packet's sequence number is greater than its previous one in the node's routing table, it means that the packet has newer routing information and the node will update its routing table based on the updated information. It does not support multi-paths form source to destination. Each data packet only needs to know the address of the next hop node to reach its requested destination. When an active link is broken, AODV has to initiate a new route discovery process which would incur additional delay and network flooding. A study reveals that advantages in routing overhead and delay improve the network scalability [7].

The Temporally Ordered Routing Algorithm (TORA) [8][9] is a hybrid routing protocol and seems to be the worst performer in term of routing overhead. Sources initiate route requests in reactive manner and selected destinations may start route discovery in a proactive manner to build the routing table. TORA is a distributed routing protocol. Further route optimality is considered as of secondary importance, and longer routes are often used to avoid the overhead of discovering newer routes.

Reactive routing protocols in MANETs such as DSR and AODV are often supported by an Expanding Ring Search [3]. The basic route discovery structure of Blocking-ERS is extension of ERS with time to live (TTL)

In this paper, we used and implemented the Blocking-ERS [3] concept to improve the performance in terms of routing load and end-to-end delay. This also leads to reduce energy consumption at each node of network. Further, the retransmission mechanism also has been implemented to improve the reliability, efficiency and effectiveness of proposed routing protocol in large network as in [10][11][13]. This proposed scheme performs better than conventional AODV routing protocol for MANET.

3. PROPOSED PROTOCOL

The proposed protocol, Optimized Reliable Ad hoc On-demand Distance Vector (ORAODV) is designed for optimal route discovery and reliability of packet delivery. It is proposed with all other essential functionality like route request (RREQ), route reply (RREP), route error (RERR), and HELLO messages. The RREQ is broadcasted by flooding and those messages propagate from one intermediate node to another to find the route information during the route discovery stage.

Each broadcast is issued with a hop number which is a serial number indicating the sequence of the nodes in a route from the source. When a node needs to determine a route to a destination node, it floods the network with a RREQ message. The originating node broadcasts a RREQ message to its neighboring nodes, which broadcast the message to their neighbors, and so on. A RREQ message is initiated with small time to live (TTL) and a specified number of hops by the source. Intermediate nodes receive the RREQ message and check their routing table. If the route information is not available for the destination node, the intermediate nodes rebroadcast the RREQ with an incremental hop number. In this way, the nodes with the same hop number from the source node form a circle or searching ring. The diameter of the searching ring increases as the route discovery process progresses. An intermediate node is known as route node which has the requested route information towards the destination. An intermediate node searches for the requested route information in its route cache when a RREQ is received. The route node would stop rebroadcasting the RREQ, and it sends a RREP message to the source node with the complete route information consisting of the cached route in itself.

The Blocking-ERS does not resume its route search procedure from the source node every time a rebroadcast is required. The rebroadcast can be initialized by any appropriate intermediate nodes. An intermediate node that performs a rebroadcast on behalf of the source node acts as a relay or an agent node.

We use a new control packet 'stop instruction' which is used to control the flooding, and a hop number to reduce the energy consumption during route discovery stage. The automatic flooding takes place until the 'stop instruction' message reaches all the nodes that have the same hop number as the route node that originated the RREP in the first place. If the TTL values in the RREQ have reached a certain threshold and still no RREP messages have been received, then the destination assumed to be unreachable and the messages queued for this destination are discarded. In this way, the route may be established much quicker and the total delivery time and energy consumption can be reduced.

Each destination node maintains a monotonically increasing sequence number, which serves as logical time at that time at that node. The protocol ensures that nodes only update routes with fresher/ newer ones by using sequence numbers. Doing so, we also ensure loop-freedom for all routes to a destination. Nodes along with the route path can update their routing table entries with the latest destination sequence number and RREQ and RREP messages are embedded with destination sequence number.

Each node periodically sends HELLO messages to its precursors where a precursor list is a set of nodes that route through the given nodes. Similarly, each node expects to periodically receive messages from each of its outgoing nodes. Outgoing nodes list is the set of next-hops that a node routes through. The node is presumed to be no longer reachable, if a node has received no message from some outgoing nodes for a specified period of time and it removes all affected route entries and generate a route error (RERR) message. A node only forwards a RERR message if at least one route has been removed and route repair process will start. The RERR message contains a list of all destinations that have become unreachable as a result of broken link. The node sends the RERR to each of its precursors. These precursors update their routing tables and forward the RERR to their precursor and so on.

Further it has been extended retransmission approach to improve the reliability in term of packet delivery ratio (PDR). An increased PDR value denotes more reliability. This retransmission approach is implemented as an Acknowledgement Retransmit mechanism to ensure correct delivery of the data packets at the receiver node. If the data packet could not be delivered correctly or successfully to the receiver within a predefined time quantum then the data packet is retransmitted either by the intermediate node or route node instead of originating source node.

The proposed routing protocol ORAODV is better than conventional on-demand distance vector routing protocol AODV in all respect.

4. SIMULATION PARAMETERS

The performance metrics like Packet Delivery Ratio(PDR), Normalized Routing Load (NRL), end-to-end delay are chosen to show the difference in performance among the different routing protocols which are the most crucial and common benchmark to measure the overall p erformance of the network routing protocol.

PDR is defined as a percentage of data packets delivered at receiver end compared to that of number of data packets sent for that node. It is used to measure the reliability, effectiveness and efficiency of routing protocols. Generally the reliability, effectiveness and efficiency of routing protocols can be improved by improving the PDR.

End-to-End delay is the average overall delay for a data packet to traverse from a source node to a destination node. Route discovery delay, queuing at different interfaces, queuing transmission delays at MAC, propagation and transfer times of data packets are taken into account to calculate end-to-end delay of routing protocols. It is the measure of time elapsed between data packet origination from the source and successful receipt by receiver.

NRL is the sum of all transmissions of routing packets per total delivery packets at the destination. Each hop-wise transmission of a routing packet is counted as one transmission.

In this paper, through simulation, we measure all these performance evaluation parameters for comparison of ORAODV with conventional AODV for different combinations of mobility rate, network density in term of number of nodes. Exhaustive simulation experiments are carried out with different mobility rates and number of nodes in the wireless ad hoc sensor network. Simulation results reveal that the proposed routing protocol ORAODV outperforms AODV with regard to these performance evaluation parameters.

5. SIMULATION MODEL

NS-2 simulator [14] under Linux operating system platform is used for the performance evaluation of proposed protocol and to compare with AODV. Traffic sources are chosen according to constant bit rate (CBR) generator for data packet transfer. The data traffic rate is set at 5 kbps and each source sends packets of 512 bytes at the rate of 4 packets per second. Each node maintains a queue of maximum size 50 for packets awaiting transmission by the network interface. This queue is managed in a FIFO based drop-tail mechanism.

Mobility model describes the movement pattern of the mobile nodes where each mobile node is an independent entity that is responsible for computing its own position and velocity. Nodes move around as per predefine mobility model at the beginning of the simulation. We consider random waypoint mobility model in which a mobile node begins the simulation by waiting for a specified pause-time. Apart from these basic things, the other simulation parameters are mentioned in table-1.

Table 1: Simulation Parameters including different mobility rate, network density in terms of number of nodes in network

S. No.	Parameters	Values
1	**Area in size**	**1000x1000 m**
2	**Transmission Range**	**250 m**
3	**Number of nodes**	**50,100,150, 200,250,300 nos.**
4	**Simulation Time**	**600 s**
5	**Mobility Rate**	**1,5,10,15,20 m/s**
6	**Pause time**	**10s**
7	**Data Rate**	**5 Kbps**
8	**No. of simulations**	**5 Times**

6. RESULT AND DISCUSSION

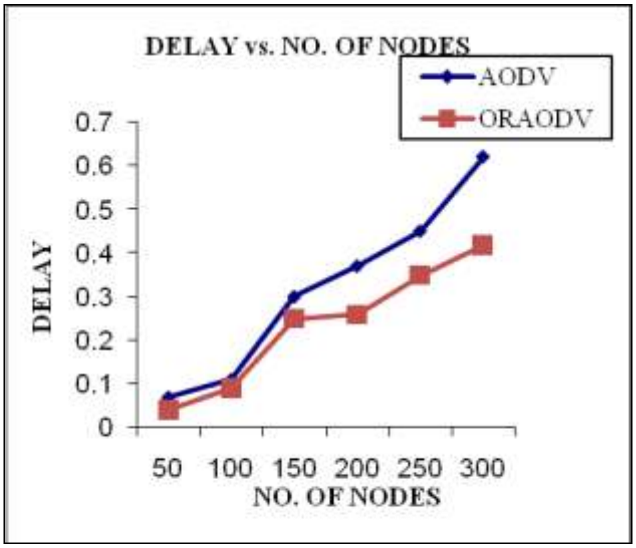

Figure 1: Delay vs. Number of Nodes at 5 m/s

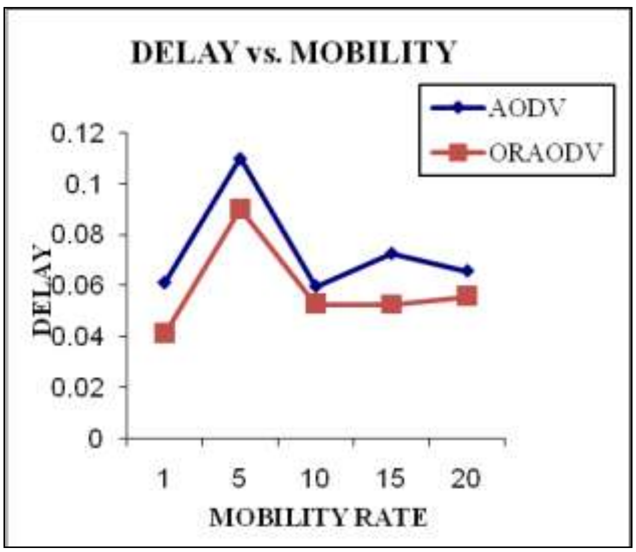

Figure 2: Delay vs. Mobility Rate at 100 nodes

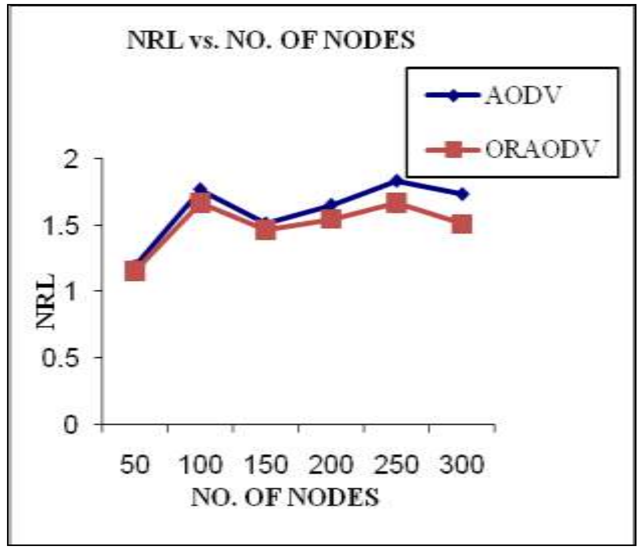

Figure 3: NRL vs. No. of Nodes at 5 m/s

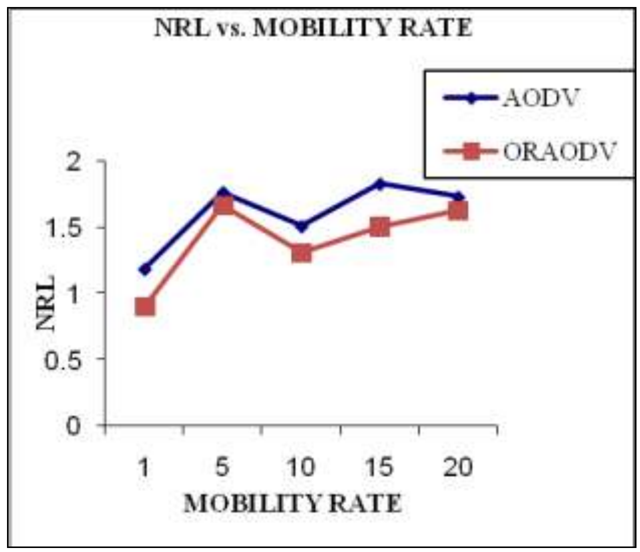

Figure 4: NRL vs. Mobility Rate at 100 nodes

With respect to end to end delay it is observed from the result that ORAODV is better than AODV as new optimized discovery approach. Figure-1 shows that, performance in term of end-to-end time delay of the proposed protocol ORAODV is better than conventional AODV. Particularly it is significantly better for higher density in terms of number of nodes. From figure-2 it is observed that performance of ORAODV is better than AODV in all respect of mobility rates. This is possible due to use of Blocking-ERS in the proposed protocol.

From the figure-3, it is observed that NRL is better for ORAODV as compared to AODV. It is also better for higher number of nodes. Further from the figure-4 it can be concluded that the performance of ORAODV is better for different mobility rates. Although retransmission of data packet expected to increase NRL of routing protocol, it is controlled as the Blocking-ERS concept is used in ORAODV.

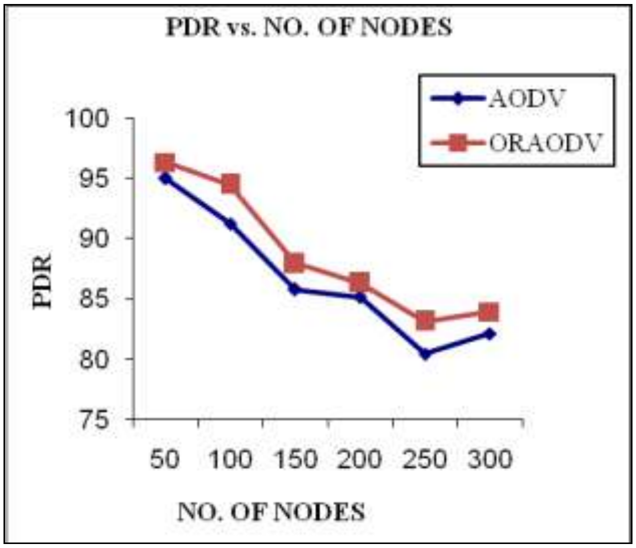

Figure 5: PDR vs. No. of Nodes at 5 m/s

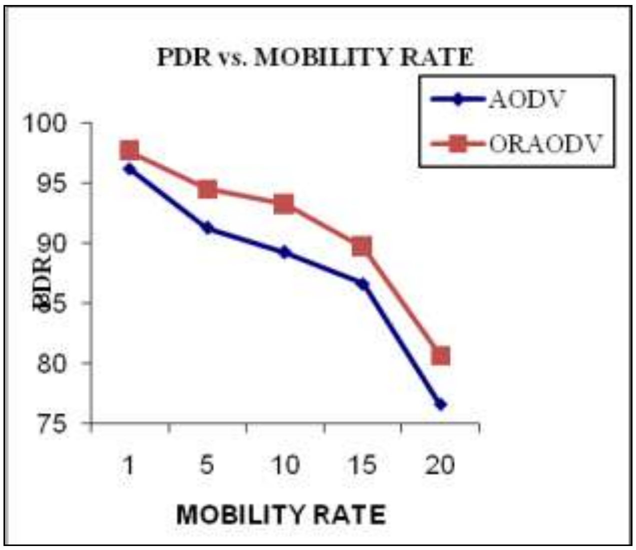

Figure 6: PDR vs. Mobility Rate at 100 nodes

PDR is also an important performance evaluation parameter for routing protocols to measure reliability. So, data packets which can not be delivered successfully are retransmitted to improve the reliability in terms of PDR. It is observed that the performance of ORAODV in terms of PDR is better than conventional AODV. Form figure-5, it is evident that PDR is better for different number of nodes with a fixed mobility rate 5m/sec. Similarly figure-6 shows that the performance of proposed routing protocol ORADOV is better than AODV in mobility rates. It is observed that the proposed routing protocol ORAODV performs better than traditional AODV in all simulated cases.

7. CONCLUSION

The use of retransmission mechanism of undelivered data packets together with Blocking-ERS of search model in ORAODV enables optimal path routing and fast route discovery with an improvement of PDR. Exhaustive simulation studies show that proposed ORAODV outperforms the AODV for different number of nodes and mobility rates. It is able to scale up to a large network and performs well for high network density and for high node mobility which may be suitable for real time communication in a dynamic network such as MANET.

8. REFERENCES

[1] Corson, S. & Macker, J., "Mobile Ad Hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation considerations.", Internet Engineering Task Force (IETF), Network Working Group (RFC 2501), 1999, http://www.ietf.org/rfc/rfc2501.txt

[2] I. Park and I. Pu, "Energy Efficient Expanding Ring Search", Proceedings The First Asia International Conference On Modeling & Simulation, pp: 198-199, 2007.

[3] Incheon Park, Jinguk Kim, Ida Pu London, "Blocking Expanding Ring Search Algorithm for Efficient energy Consumption in Mobile Ad Hoc Networks", Proceedings of the WONS, Les Menuires, France, pp: 185-190, 2006.

[4] C.E. Perkins and T.J. Watson, "Highly Dynamic Destination Sequenced Distance Vector Routing (DSDV) for Mobile Computers", Proceeding of ACM SIGCOMM Conference on Communications Architectures, London, pp: 234-244, 1994.

[5] D.B. Johnson,D.A. Maltz, and Y.-C. Hu., "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)", Internet draft, draft-ietf-manet-dsr-09.txt, Apr. 2003. http://tools.ietf.org/html/draft-ietf-manet-dsr-09

[6] Perkins, C.E., "Ad Hoc On-Demand Distance Vector Routing (AODV)." IETF, Internet draft., 2003. http://www.ietf.org/internet-drafts/draft-ietf-manet-aodv13.txt

[7] S.J. Lee, E.M Royer. & C.E Perkins, "Scalability study of the Ad Hoc On-Demand Distance Vector Routing Protocol", ACM Wiley International Journal of Network Management, Volume-13 Issue-2,, 97-114, March/April 2003.

[8] Park V. D. and Corson M. S., "A highly adaptive distributed routing algorithm for mobile wireless network." Sixteen joint annual conference of the IEEE computer and communication society, pp: 1405-1413, 1997.

[9] V. D. Park and M. S. Corson., "Temporally-Ordered Routing Algorithms(TORA) Version-1 Functional Specification", Internet Draft: draft-ietf-manet-tora-spec-01.txt, April 2002. http://tools.ietf.org/html/draft-ietf-manet-tora-spec-01

[10] Srinivas Sethi, Siba K. Udgata, "IMAODV: A Reliable and Multicast AODV Protocol for MANET", IEEE proceeding of WCSN 2009, Dec. 2009.

[11] Sun Baolin, Li Layuan,"On the reliability of MAODV in Ad Hoc Networks", Proceedings Of IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications, Vol. 2, pp: 1514-1517, 2005.

[12] G. Jayakumar, G. Gopinath, "Performance Comparision of MANET Protocols Based on Manhattan Grid Mobility Model", Journal of Mobile Communication, 2(1), 2008.

[13] Yufang Zhu and Thomas Kunz, "MAODV Implementation for NS-2.26", Systems and Computer Engineering Carleton University Technical Report SCE-04-01, January 2004.

[14] Ns-2 Manual, internet draft, 2009. http://www.isi.edu/nsnam/ns/nsdocumentation.htm