Analytical Study of Broadcast in Mobile Adhoc Network

Parma Nand
Wireless Computing Research Lab
Indian Institute of Technology, Roorkee

Dr. S.C. Sharma
Wireless Computing Research Lab
Indian Institute of Technology, Roorkee

ABSTRACT
Mobile Adhoc Network (MANET) is a set of self-configuring mobile hosts, equipped with a CSMA/CA (carrier sense multiple access with collision avoidance) transceiver, that may communicate, move freely independently and any time without any base station support. The broadcasting is inevitable operation in MANET and commonly used for route discovering. The flooding technique used normally for broadcast leads to redundant rebroadcasting and causes Broadcast Storm problem. This paper analyses this problem and techniques reported to handle it briefly. These techniques control redundant messages, which in turn lessen channel contention, packet collision and other similar network related problems. In this paper broadcast overhead and link breakage due to broadcasting is analyzed comparatively over Dynamic MANET On-demand (DYMO) and Source Tree Adaptive Routing (STAR) protocols with varying mobility using Qualnet network simulator.

General Terms
Algorithms, Performance, Networking, Routing

Keywords
Adhoc networks, MANET, routing protocols, route discovery.

1. INTRODUCTION
A MANET consists of a set of self-configuring mobile hosts that may communicate with one another from time to time without any base station support. Each host is equipped with a CSMA/CA (carrier sense multiple access with collision avoidance) transceiver. The applications of MANET are very common nowadays because of its speedy, convenient, economical deployment without any base station. The applications include

- military use e.g. battlefield
- personal area network among laptops and cell phones
- intelligent transportation with vehicle to vehicle communication
- Rescue operation in area like flooded etc.

Transmitting the message from source to destination is a multihop routing process due to the short transmission range and dynamic mobility of nodes. The broadcasting is inevitable operation in mobile ad-hoc network and commonly used for route discovering.

A straight-forward approach to perform broadcast is by flooding [3,4,5]. The flooding is diffusing a message from a source node to all the nodes in the network. Broadcast is used to diffuse information and route discovery protocols in ad-hoc networks. A host, on receiving a broadcast message for the first time, has the obligation to rebroadcast the message. This causes Broadcast Storm problem [3]. In this paper redundancy caused by the simple flooding is examined and several techniques to tackle this problem are presented.

2. BROADCAST STORM CAUSED BY FLOODING
Traditionally, a straight-forward approach to perform broadcast is flooding. A host, on receiving a broadcast message for the first time, has the obligation to rebroadcast the message. This is very simple and needs only some resources in the nodes to memorize the last broadcast messages received. Clearly, this costs n transmissions in the network. In a CSMA/CA network, drawbacks of flooding include:

- **Redundant rebroadcasts:** When a mobile host decides to rebroadcast a broadcast message to its neighbors, all its neighbors already have the message.
- **Contention:** After a mobile host broadcasts a message, if many of its neighbors decide to rebroadcast the message, these transmissions (which are all from nearby hosts) may severely contend with each other.
- **Collision:** Because of the deficiency of backoff mechanism, the lack of RTS/CTS dialogue, and the absence of collision detection (CD), collisions are more likely to occur and cause more damage.

3. BROADCAST PROBLEM CHARACTERISTIC AND DRAWBACKS OF FLOODING
The broadcast is inevitable in route discovery because of the following reasons

- Route discovery in reactive routing protocols
- Proactive routing protocols
- Conflict-detection and best-effort address allocation;
- Service discovery or service advertisement;
- Unicast and some multicast communication have to resort to broadcast because of very high mobility.
- The simplest method is to receive and then forward the data packet for every node in the MANET.

With the absence of synchronizations and acknowledgement mechanism among broadcast operations causes broadcast storm problem. This problem becomes more serious with the dynamic nature, which causes collision, duplicity and lost problem of packets. This has following characteristics.

a. The broadcast is spontaneous. Any mobile host can issue a broadcast operation at any time. For reasons such as the host mobility and the lack of synchronization, preparing any kind of global topology knowledge is prohibitive (in fact this is at least as hard as the broadcast problem). Little or no local information may be collected in advance.

b. The broadcast is unreliable. No acknowledgement mechanism will be used. However, attempt should be made to distribute a broadcast message to as many hosts as possible without paying too much effort. The motivations to make such an assumption are

(i) A host may miss a broadcast message because it is off-line, it is temporarily isolated from the network, or it experiences repetitive collisions.

(ii) Acknowledgements may cause serious medium contention (and thus another "storm") surrounding the sender.

In addition, it is assumed that a host can detect duplicate broadcast messages. This is essential and is used to prevent endless flooding of a message. The source ID and sequence number is being attached with each broadcast message to prevent endless flooding.

4. REDUNDANCY OF REBROADCASTS

Redundancy due to the rebroadcasting is a severe problem which consumes limited bandwidth and cause packet collision etc. The severety of this problem is demonstrated with help of two examples in figure 1 and figure 2. Subsequently, the additional region covered by the rebrodcasting is also discussed in next section. It is observed that 50% rebroadcasting can be saved if endless flooding is controlled. In Figure 1 the optimal broadcast messages are just two whereas four transmissions will be carried out if no attempts are made to reduce redundancy.

These controlled endless rebroadcasting techniques can even save more rebroadcasting in network scenario having more number of nodes as it can be saved to the extent of 70 % in figure 2. In figure 2 it is observed that just two transmissions are sufficient to complete a broadcast in comparison to seven transmissions caused by simple flooding.

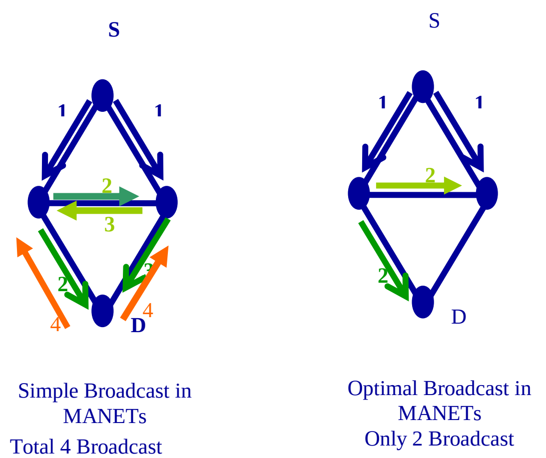

Figure 1. Simple Broadcast and Optimal Broadcast for 4 nodes Network topology

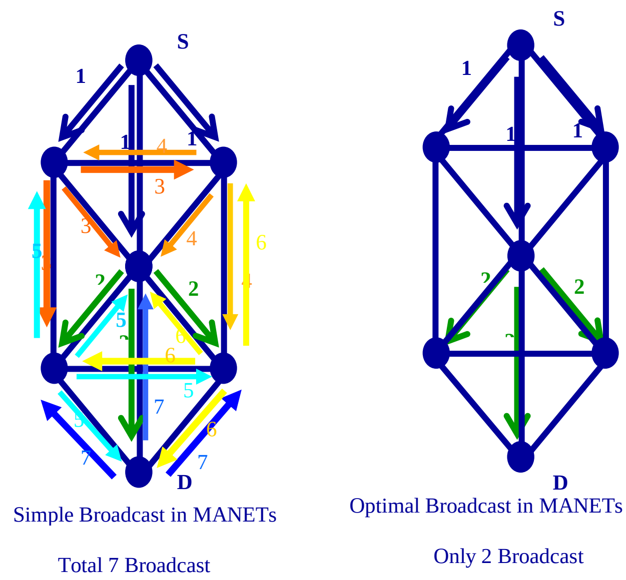

Figure 2. Simple Broadcast and Optimal Broadcast for 7 nodes Network topology

5. THE ADDITIONAL AREA COVERED BY REBROADCAST

In figure 3, two nodes A and B with there transmission range are shown by the respective circle S_A and S_B centered at A and B with radius r. These nodes are separated by distance d.

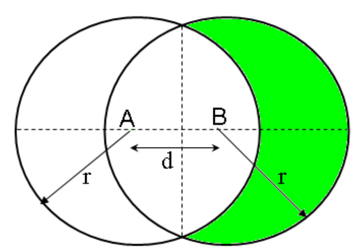

Figure 3. Shaded region is additional area that can benefit from B's Broadcast

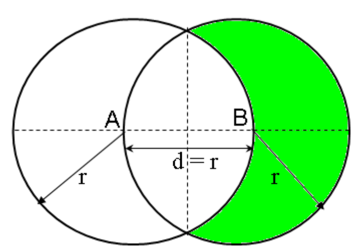

Figure 4. Shaded region is maximum additional area that can benefit from B's Broadcast when distance d between nodes is equal to radius of their transmission range r

The host node A broadcast the message first. The node B after receiving this message is bound to rebroadcast it as per broadcasting policy. The additional area that can benefit from B's rebroadcast is green shaded region in figure 3 and 4, denoted as

S_{B-A}. It can be derived that $|S_{B-A}| = |S_B| - |S_{A\cap B}| = \pi r^2$ - INTC(d), where INTC(d) is the intersection area of the two circles centered at two points distanced by d,

$$\text{INTC(d)} = 4\int_{d/2}^{r}\sqrt{r^2 - x^2}\,dx.$$

When d = r, the coverage area $|S_{B-A}|$ is the largest, and is equal to

$$\pi r^2 - \text{INTC(r)} = r^2\left(\frac{\Pi}{3} + \frac{\sqrt{3}}{2}\right) \approx 0.617\,\pi r^2$$

This shows a surprising fact that a rebroadcast can provide only 0 ~ 61% additional coverage over the region which had already been covered by the previous transmission. This coverage is will be varying with the mobility of the nodes. The additional coverage will be minimum i.e. 0% when the centers of both nodes coincides with each other. The maximum additional coverage will be maximum i.e. 61% when they are d = r distant apart as shown in figure 4. Therefore, the another surprising fact is that the average additional coverage of rebroadcasting is only 41% as shown by the formula

$$= \int_0^r \frac{2\pi x.[\pi r^2 - INTC(x)]}{\pi r^2}dx \approx 0.41\pi r^2$$

6. CLASSIFICATION OF BROADCASTING TECHNIQUES

Many probabilistic and deterministic approaches are proposed in literature to reduce redundant rebroadcasts and hence to ease routing time complexity, channel overheads and other related problems.

These broadcasting techniques are broadly classified and described briefly as follows.

6.1 Simple Flooding [3,7]

A source node initiates flooding by broadcasting a packet to all its neighbors. The neighbor nodes in turn rebroadcast the packet exactly once and the process continues until each node in the network has retransmitted the packet. As a result, all nodes reachable from the source receive the packet. Flooding causes the broadcast storm problem [3] which is characterized by redundant rebroadcasts, channel contention and collision of messages.

6.2 Probability-based Methods

6.2.1 Probabilistic Scheme [7,8,9]

When a node receives a broadcast message for the first time, the node rebroadcasts the message with a probability P. If the message received is already seen, then the node drops the message irrespective of whether or not the node retransmitted the message when received for the first time. For sparse networks, the value of P has to be high enough to facilitate a higher packet delivery ratio. When P = 1, the scheme resorts to simple flooding.

6.2.2 Counter-based Scheme [10, 11,17]

A broadcast message received for the first time is not immediately retransmitted to the neighborhood. The message is queued up for a time called the Random Assessment Delay (RAD) during which the node may receive the same message (redundant broadcasts) from some of its other neighbors. After the RAD timer expires, if the number of times the same message is received exceeds a counter threshold, the message is not retransmitted and is simply dropped.

6.3 Area-based Methods

6.3.1 Distance-based Scheme [12,13]

When a node receives a previously unseen broadcast message, the node computes the distance between itself and the sender. If the sender is closer than a threshold distance, the message is dropped and all future receptions of the same message are also dropped. Otherwise, the received message is cached and the node initiates a RAD timer. Redundant broadcast messages received before the expiry of the RAD timer are also cached. When the RAD timer expires, the node computes the distance between itself and the neighbor nodes that previously broadcast the particular message. If any such neighbor node is closer than a threshold distance value, the message is dropped. Otherwise, the message is transmitted.

6.3.2 Location-based Scheme [7,14]

Whenever a node originates or rebroadcasts a message, the node puts its location information in the message header. The receiver node calculates the additional coverage area that would be obtainable if it were to rebroadcast. If the additional coverage is less than a threshold value, all future receptions of the same message will be dropped. Otherwise, the RAD timer is started. Redundant broadcast messages received before the expiry of the RAD timer are also cached. After the RAD timer expires, the node considers all the cached messages and recalculates the additional obtainable coverage area if it were to rebroadcast the particular message. If the additional obtainable coverage area is less than a threshold value, the cached messages are dropped. Otherwise the message is rebroadcast.

6.4 Neighbor Knowledge based Methods

6.4.1 Multi-point Relaying [7,15]

Under this scheme, each node is assumed to have a list of its 1-hop and 2-hop neighbors, obtained via periodic “Hello” beacons. The “Hello” messages include the identifier of the sending node, the list of the node’s known neighbors and the Multi-Point Relays (MPRs). After receiving “Hello” messages from all its neighbors, a node has the 2-hop topology information centered at itself. Using this list of 1-hop and 2-hop neighbors, a node selects the MPRs – the 1-hop neighbors that most efficiently reach all nodes within its 2-hop neighborhood. Each node selects the set of MPRs using a greedy approach of iteratively including the 1-hop neighbors that would cover the largest number of uncovered 2-hop neighbors.

6.4.2 *Minimum Connected Dominating Set [7,19]*

A Connected Dominating Set (CDS) is a set of nodes in the network such that all nodes in the network are either in the CDS or directly attached to a node in the CDS. A Minimum Connected Dominating Set (MCDS) is the smallest CDS, in terms of the number of nodes in the CDS, for the entire network. The size of the MCDS is the minimum number of retransmissions required in a broadcasting process so that all nodes in the network receive the broadcast message. Determining the MCDS for a given network graph is an NP-complete problem and hence several heuristics have been proposed to approximate MCDS for a given network graph.

6.5 Adjusted rebroadcast probability [5,16,18,21]

This adjusts the rebroadcasting probability as per the node distribution and node movement. This is done based on locally available information and without requiring any assistance of distance measurements or exact location determination devices.

6.6 Dynamic probabilistic rebroadcasting [11,20]

The dynamic probabilistic broadcasting scheme is used for mobile ad hoc networks where nodes are static and mobile according to some mobility model. It combines the fixed-value probabilistic approach with some other basic criteria to calculate probability counter-based approach. The proposed approach dynamically sets the value of the rebroadcast probability for every host node according the host density in its neighborhood. This approach generates less rebroadcasts and has lower broadcast latency and high reachability.

7 BROADCASTING ANLYSIS OF DYMO [1] AND STAR [2] ROUTING PROTOCOL

Dynamic MANET On-demand (DYMO) [1] and Source Tree Adaptive Routing (STAR) [2] protocols are used to analyze broadcasting of packets in a network scenario as described in next section. DYMO is a reactive, multihop, unicast routing protocol. The DYMO is a memory concerned routing protocol and stores minimal routing information and so the Control Packets is generated when a node receives the data packet and it doesn't have any valid route information. The basic operations of DYMO are Route Discovery and Route Maintenance.

Source Tree Adaptive Routing (STAR) [2] Protocol for adhoc network, is a proactive table driven routing protocol. The STAR routing protocol operates in two different mechanisms but chooses one at a time. It may work either in the Least Overhead Routing Approach (LORA) mode or Optimum Routing Approach (ORA) mode. With ORA, the routing protocol attempts to update routing tables as quickly as possible to provide paths that are optimum with respect to a defined metric whereas in LORA mode it tries to provide shortest route as per performance and delay metrics

8 SIMULATION SETUP

The Qualnet 5.0 network simulator is used for the analysis. The IEEE 802.11[6,22] for wireless LANs is used as the MAC layer protocol. In the scenario UDP (User Datagram Protocol) connection is used and over it data traffic of Constant bit rate (CBR) is applied between source and destination. The 100 nodes are placed uniformly initially over the region of 1500mx1500m. The multiple CBR application are applied over 13 different source nodes– 4,53,57,98,100,7,5,49,10,93,1,92,99 and destinations nodes - 51,91,94,59,60,96,58,97,100,54,45,44,38 respectively. The mobility of nodes is varied as 10, 20, 30, 20, 50 meter per sec to analyze the packet broadcasting performance of DYMO and STAR-LORA (with LORA method) routing protocols. The simulations parameters are shown in Table I.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Area	1500mX1500m
Simulation Time	90,120, 200 sec
Channel Frequency	2.4 Ghz
Data rate	2.Mbps
Path Loss Model	Two Ray Model
Mobility Model	Random-Way Point
Max Node Speed	50
Packet size	512 bytes
Physical Layer Radio type	IEEE 802.11b
MAC Protocol	IEEE 802.11
Antenna Model	Omni-directional

9 RESULTS & DISCUSSION

The performance of STAR with LORA and DYMO routing protocol is analyzed with varying traffic load and mobility. In this analysis thirteen different CBR traffic as described in simulation setup is applied on separate source to destination nodes. The results are shown in figures from 5 to 8.

Broadcast packets sent

Adhoc network performance is analyzed on this parameter and it is observed that DYMO routing protocol sent broadcast packets more than STAR-LORA because it tries for quick route discovery. STAR-LORA sent fewer packets than DYMO because of its LORA technique in greed to find shortest path. It is shown in figure 5.

Broadcast packets received

It is observed that in DYMO protocol nodes receive more broadcasting packets for route discovery than STAR-LORA as more rebroadcasting messages are sent by this protocol. It is shown in figure 6.

Broadcast packets overhead

The broadcast packets overhead is high in STAR-LORA than DYMO protocols overall and is attributed to mobility. This also reflected in figure 8 as the route breakages are high. The DYMO is showing better performance with the mobility of nodes as packets carry source route in packet header and thus routes easily available. The performance is shown in shown in figure. 7.

No. of times Link failures

The link failure occurs when node moves far and beyond the reach of it's neighbor transmission range. The link failures are very high because of mobility nodes in case of STAR-LORA. In case of DYMO the link failures are very low as it stores only the route for the next hop. Overall the performance of DYMO is very good even with high mobility. The performance is shown in figure 8.

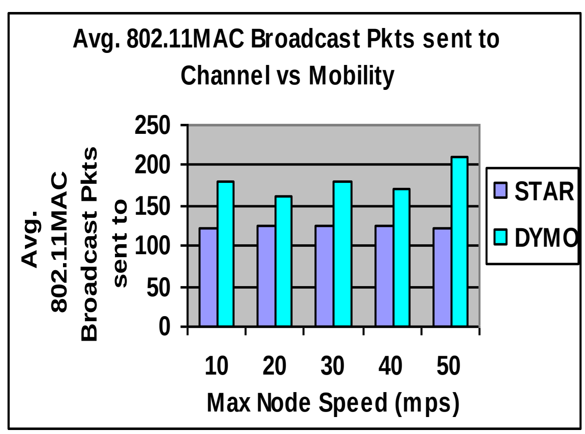

Figure 5. Avg. 802.11 MAC Broadcast Pkts sent vs Node Mobility

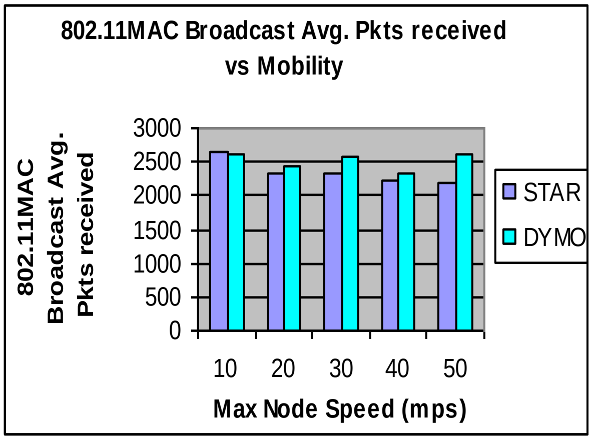

Figure 6. Avg. 802.11 MAC Broadcast Pkts recieved vs Node Mobility

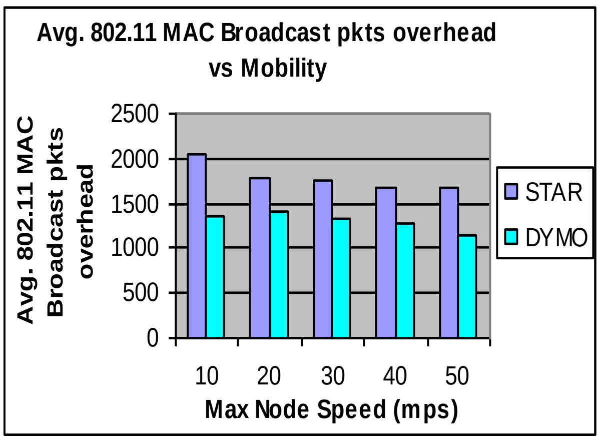

Figure 7. Avg. 802.11 MAC Broadcast Pkts overhead vs Node Mobility

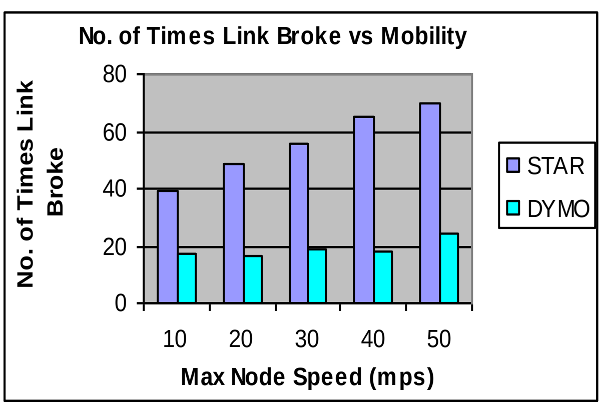

Figure 8. Avg. No. of times Link Broke vs Node Mobility

10 CONCLUSION

With the review of literature it is observed that simple flooding leads to heavy redundancy and this can be reduced with controlled flooding. The different techniques are used to reduce it but the suitability of one can not be fixed for all types of network topologies. The features of dynamic probabilistic rebroadcasting are found to be more suitable among all. It is also observed that DYMO has more broadcast packet transmission than STAR-LORA routing protocols for the route discovery. The STAR-LORA performs poor and has large route failure and thus more flooded broadcast packets. The DYMO performs better in scenario having high mobility nodes as the packet sender knows the complete hop-by-hop route to the destination

11. REFERENCES

[1] Ian D. Chakeres and Charles E. Perkins, "Dynamic MANET on demand (DYMO) routing protocol". Internet- Draft Version 06, IETF, October 2006.

[2] J.J. Garcia-Luna-Aceves, M. Spohn, "Source-Tree Adaptive Routing in Wireless Networks", Proceedings of the 7th Annual IEEE international conference on Network Protocols, Toronto, Canada. Oct 31- Nov 3, 1999. http://www.ieee-icnp.org/1999/ papers/1999-29.pdf.

[3] S.Y. Ni, Y.C. Tseng, Y.S. Chen, J.P. Sheu, "The broadcast storm problem in a mobile ad hoc network", Proceedings of the 1999 Fifth Annual ACM/IEEE International Conference on Mobile Computing and Networking, IEEE Computer Society, New York, Aug 1999, pp. 151–162.

[4] W. Peng, X. Lu, Poster, "On the reduction of broadcast redundancy in mobile ad hoc networks", Proceedings of the First ACM International Symposium on Mobile Ad hoc Networking and Computing, MOBIHOC, Boston, MA, 2000, pp 129–130.

[5] Y. Tseng, S. Ni, E. Shih, "Adaptive approaches to relieving broadcast storms in a wireless multihop mobile adhoc network", IEEE Trans. Computers, v 52 (5), May 2003, pp 545–557.

[6] C.-K. Toh. Ad hoc Mobile Wireless Networks: Protocols and Systems[M]. Prentice Hall 2005.

[7] B. Williams, T. Camp, "Comparison of broadcasting techniques for mobile ad hoc networks", Proceedings of the ACM International Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC 2002), pp. 194–205.

[8] Y. Sasson, D. Cavin, A. Schiper, "Probabilistic broadcast for flooding in wireless mobile ad hoc networks", EPFL Technical Report IC/2002/54, Swiss Federal Institute of Technology(EPFL), 2002.

[9] J. Spencer, Ten Lectures on the Probabilistic Method, Conference Board of the Mathematical Sciences, Regional Conference Series, AMS and MAA, 1987.

[10] Dariusz Kowalski, Andrzej Pelc, "Broadcasting in undirected ad hoc radio networks", Proceedings of the 22nd ACM Symposium on Principles of Distributed Computing, (PODC 2003), Boston, MA, USA, July13–16, 2003, pp. 73–82.

[11] Qi Zhang, Dharma P. Agrawal, "Dynamic probabilistic broadcasting in MANETs", Journal of Parallel and Distributed Computing v 65(2), Feb 2005, pp 220-233.

[12] Qing Huang, Yong Bai, Lan Chen, "Efficient lightweight broadcasting protocols for multihop adhoc network"s, The 17th Annual IEEE International Symposium on Personal,

Indoor and Mobile Radio Communications (PIMRC'06), Sept 2006, pp 1-5.

[13] Stefan Pleisch, Mahesh Balakrishnan,Ken Birman, Robbert van Renesse, “MISTRAL: Efficient flooding in mobile ad-hoc networks”, 7th ACM International Symposium on Mobile Ad Hoc Networking & Computing, Florence Italy, 2006, pp 1-12.

[14] Benoit Garbinato, Adrian Holzer, François Vessaz, “Context-aware broadcasting approaches in mobile adhoc networks”, Computer Networks: The International Journal of Computer and Telecommunications Networking v54 (7), May 2010, pp 1210-1228.

[15] Rendong Bai, Mukesh Singhal, “Salvaging route reply for on-demand routing protocols in mobile adhoc networks”, International Workshop on Modeling Analysis and Simulation of Wireless and Mobile Systems Proceedings of the 8th ACM international symposium on Modeling, analysis and simulation of wireless and mobile systems, 2005, pp 53-62.

[16] Jie Wu , Fei Dai, Efficient “Broadcasting with Guaranteed Coverage in Mobile Ad Hoc Networks”, IEEE Transactions on Mobile Computing, 2005, pp 1-35.

[17] Z. Haas, J. Halpern, L. Li, “Gossip-based adhoc routing”, Proceedings of the IEEE INFOCOM, IEEE Computer Society, New York, 2002.

[18] H. Lim, C. Kim, “Multicast tree construction and flooding in wireless ad hoc networks” Proceedings of the ACM International Workshop on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM 2000), Boston, MA, 2000, pp. 61–68.

[19] J. Wu, H. Li, “A dominating-set-based routing scheme in ad hoc wireless networks”, Wireless Networks Telecomm. Systems Journal (special issue) 3, 2001, pp. 63–84.

[20] Yassein, M.B., Khaoua, M.O., et al.: “Improving route discovery in on-demand routing protocols using local topology information in MANETs”, Proceedings of the ACM international workshop on Performance monitoring, measurement, and evaluation of heterogeneous wireless and wired networks, Terromolinos, Spain, ACM Press, New York 2006, pp. 95–99.

[21] Abdalla M. Hanashi, Aamir Siddique, Irfan Awan, Mike Woodward, “Performance evaluation of dynamic probabilistic broadcasting for flooding in mobile ad hoc networks”, Journal: Simulation Modelling Practice and Theory Simulation Modelling Practice and Theory 17 2009, pp 364–375.

[22] IEEE, 1997, Wireless LAN Medium Access Control (MAC) and Physical layer (PHY) Specifications, IEEE Std. 802.11.