A New Energy Efficient Multicast Routing Approach in MANETs

Mehdi Nozad Bonab[1], Jalil Jabari Lotf[2], Bager Zarei[3], Mehdi Dehghan[4]

[1]Dep. of Computer Engineering, Islamic Azad University,Marand Branch, IRAN,
M.Nozad@gmail.com

[2]Dep. of Computer Engineering, Islamic Azad University, Ahar Branch, IRAN,
J-Jabbari@iau-ahar.ac.ir

[3]Dept. of Computer Engineering, Islamic Azad University, Shabestar Branch, IRAN,
Zarei_Bager@yahoo.com

[4]Dept. of Computer Engineering, Amirkabir University, Tehran, IRAN,
Dehghan@ce.aut.ac.ir

Abstract. Multicasting in mobile Ad hoc networks (MANETs) is transmission of packet to a group of nodes that identified by a single address. In ad hoc networks because of the non-existence of fixed infrastructure and also unavailability of the unlimited source of energy during operation of the system, one of the common problems is the limitation of the energy consumption in each node. Therefore, offering effective ways for better usage of energy in this type of networks seems necessary. In this article an effective way for energy efficient consumption has been proposed through the introduction of the quality of service (QOS) classes for multicasting group in ODMRP[1] protocol, which in turn it causes an increase in the networks life time which is one of the most important parameters in this type of networks. The simulation results show that life time of network, increase up to 5.45 percent in average. However, this improvement doesn't negative affect on other parameters. So that end-to-end delay remained fixed and the delivery rate increased. The only control overhead increase up to 1/10000 byte, which can be ignored because of the significant increase in the life time of the network.

Keywords: Ad Hoc Networks, Multicast Routing, Life Time, Energy Efficient

1. Introduction

Mobile ad hoc networks are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using the existing net-

---

[1] More information about ODMRP can be found in [5].

work infrastructure or centralized administration [1]. These networks include the connection of mobile nodes on a shared wireless channel, and nodes that act as the routers. Ad hoc networking is a technique which has been considered very important in resent years. These networks controlled always, they have no owner, and every body can use them. The significant advantages of ad hoc networks are: quick improvements, ability, scalability, and support of mobility which are used in a wide range of applications. In other words, the non-existence of fixed infrastructure and topology has caused these networks useable for many applications. As an example, these networks are appropriate in areas where natural disasters may cause destructions in the common infrastructures; and also there are suitable in war environments.

Multicasting is an efficient communication service for supporting multi-point applications (e.g., software distributions, audio/video conferencing) in the Internet. In MANET, the role of multicast services is potentially even more important due the bandwidth and energy savings that can be achieved through multicast packet's delivery [6]. Since MANETs exhibit severe resource constraints such as battery power, limited bandwidth, dynamic network topology and lack of centralized administration, multicasting in MANETs become complex [1].

A multicast packet is delivered to multiple receivers along a network structure such as tree or mesh, which is constructed once a multicast group is formed.[2] However, the network structure is fragile due to node mobility and thus, some members may not be able to receive the multicast packet. In order to improve the packet delivery ratio, multicast protocols for MANETs usually employ control packets to refresh the network structure periodically. It has been shown that mesh-based protocols are more robust to mobility than tree-based protocols [7], due to many redundant paths between mobile nodes in the mesh. However, a multicast mesh may perform worse in terms of energy efficiency because it uses costly broadcast-style communication involving more forwarding nodes than multicast trees [2].

In mobile ad hoc networks, energy efficiency is as important as general performance measures such as delay or packet delivery ratio since it directly affects the network life time [2]. Moreover, in these networks because of wireless communications between hosts, energy constraint has been more underlined. The existing multicast routing protocols concentrate more on quality of service parameters like end-to-end delay, jitter, and bandwidth, but they do not stress on the energy consumption factor of the multicast [3]. Thus, offering effective ways for the best usage of energy in these protocols is necessary.

In this article an effective way for energy efficient consumption has been proposed through the introduction of the quality of service (QOS) classes for multicasting group in ODMRP protocol, which in turn it causes an increase in the networks life time which is one of the most important parameters in this type of networks. The simulation results show that life time of network in proposed method increased remarkably. However, this improvement doesn't negative affect on other parameters. So that end-to-end delay remained fixed and the delivery rate increased. The only control overhead increase worthlessly, which can be ignored.

2. Energy efficient multicast routing protocols in MANETs

Two approaches have been proposed for energy efficient multicast in MANETs. The first is based on the assumption that the transmission power is controllable. Under this assumption, the problem of finding a tree with the least consumed power becomes a conventional optimization problem on a graph where the weighted link cost corresponds to the transmission power required for transmitting a packet between two nodes. The second approach for energy efficiency comes from the difference of tree-based multicast from mesh-based multicast. One general idea of the power-saving mechanism is to put a mobile node in sleep (low power) mode while it is not sending or receiving packets [2]. The two approaches are discussed in Sections 2.1 and 2.2, respectively.

2.1. Energy efficiency via adaptive transmission power control

Network performance in a MANET greatly depends on the connectivity among nodes and the resulting topology. To create a desired topology for multicast, some multicast protocols adjust the nodes' transmission power assuming that it is controllable.

2.1.1. Broadcast Incremental Power (BIP) and Multicast Incremental Power (MIP) [8, 9]

The object of BIP is the determination of the minimum-cost (in this case, minimum-power) tree, rooted at the source nod e, which reaches all other nodes in the network. The total power associated with the tree is simply the sum of the powers of all transmitting nodes. Initially, the tree consists of the source node. BIP begins by determining the node that the source node can reach with minimum power consumption, i.e., the source's nearest neighbor. BIP then determines which new node can be added to the tree at minimum additional cost (power). That is, BIP finds a new node that can be reached with minimum incremental power consumption from the current tree node. This procedure is repeated until there is no new (unconnected) node left. BIP is similar to Prim's algorithm in forming the MST (minimum spanning tree), in the sense that new nodes are added to the tree one at a time on the basis of minimum cost until all nodes are included in the tree. Unlike Prim's algorithm, however, BIP does not necessarily provide minimum-cost trees for wireless networks.

To obtain the multicast tree, the broadcast tree is pruned by eliminating all transmissions that are not needed to reach the members of the multicast group. That is, the nodes with no downstream destinations will not transmit, and some nodes will be able to reduce their transmission power (i.e., if their distant downstream neighbors have been pruned from the tree). MIP is basically sourceinitiated tree-based multicasting of session (connection-oriented) traffic in ad hoc wireless networks. In both BIP and MIP, for simplifying trade-offs and evaluation of total power consumption, only the transmission energy is addressed, and it is assumed that the nodes do not move and that a large amount of bandwidth is available. Advantages over traditional network architectures come from the fact that the performance can be improved by jointly considering physical layer issues and network layer issues (i.e., by incorporating the vertical integration of protocol layer functions). That is, the networking schemes should reflect the node-based operation of wireless communications, rather than link-based operations originally developed for wired networks.

2.1.2. Single-Phase Clustering (SPC) and Multi-Phase Clustering (MPC) [10]

The two distributed, time-limited energy conserving clustering algorithms for multicast, SPC and MPC, minimize the transmission power in two-tiered mobile ad hoc networks. In SPC, each master node pages the slave nodes at the same maximum power, and each slave node acknowledges the corresponding master node having the highest power level. The highest power at a slave node means that the paging master node is nearest to it; hence transmission power could be saved when the slave node selects the master node that provides the highest receive power. When slave nodes send acknowledgments to each master node, the master nodes set the transmission power level to support all acknowledged slave nodes.

MPC consists of the dropping-rate-down phase and the power-saving phase. In the dropping-rate-down phase, master nodes search the slave nodes that could receive the multicast packets from only one master node. The corresponding master nodes set the transmission power level to support those slave nodes, and then the searched slave nodes belong to the corresponding master node. In the subsequent power saving phase, each master node pages the information about current power level. Paged slave nodes must have two or more candidate master nodes; hence each slave node selects one master node based on the difference of the current power (P_0) and the power to support the master node (P_n). When the master node is selected, the slave node acknowledges the master node with P_n, and each master node resets the transmission power level with the maximum value between the acknowledged P_n values.

The schemes are motivated by the fact that the most hierarchical networks such as Bluetooth scatternet are two-tier networks. The amount of energy consumption in two-tier mobile ad hoc networks could be varied with cluster configuration (e.g., the master node selection). However, an optimal cluster configuration cannot be obtained within a limited time for running a heuristic multicast algorithm. It is assumed that a slave node is connected to only one master node, and direct connection between the master node and a slave node is prohibited. MPC is desirable when energy conservation is more important than computation speed. Otherwise, SPC is preferable.

2.2. Energy savings by avoiding broadcast-based multicast

Recent wireless LAN standards usually adopt sleep mode operation in order to reduce power consumption, i.e., a communication subsystem goes into energy conserving sleep mode if it has no data to send or receive. If a node sends a packet in unicast mode specifying a receiving node, other nodes except the receiver can continue to sleep. However, when a node sends a packet in broadcast mode, all neighbor nodes have to wake up and receive the packet even though they may eventually discard it. But, receiving is not that simple because a node does not know when others will send packets to it-self. Aforementioned power saving mechanisms solves the problem by providing each node with information about when to wake up and receive packets and to sleep rest of the time. Since mesh-based multicast protocols depend on broadcast-style communication, they are not suitable in an energy constraint environment. Based on this observation, the following multicast protocol employs a multicast tree but tries to improve the packet delivery ratio to the level achieved by mesh-based protocols.

2.2.1. Two-Tree Multicast (TTM) [4]

This protocol tries to reduce the total energy consumption while alleviating the energy balance problem without deteriorating the general performance. Since TTM is based on multicast trees, it inherits all the advantages of tree-based multicast protocols in terms of total energy consumption. TTM adopts shared tree multicast rather than per-source tree multicast in order to avoid the tree construction overhead. It consumes less energy than mesh-based protocols by employing multi-destined unicast-based trees. As for the energy balance problem found in conventional single shared tree-based multicast (STM), TTM uses two trees called primary and alternative tree. When the primary tree becomes unusable or overloaded, the alternative tree takes the responsibility of the primary tree, and a new alternative tree is immediately constructed. By doing this, TTM maintains only two trees at a particular time instance, but, in fact, it uses many trees per multicast group as time advances. This is in contrast with a multicast mesh, which can be regarded as a superposition of a number of trees at a time instance. TTM is similar to the relocation scheme [12], where the root node is periodically replaced with the one nearest the center location to achieve the shortest average hop distance from the root to all receiver nodes. In TTM, a group member with the largest remaining battery energy is selected to replace the root node, and the corresponding alternative tree is constructed and maintained to replace the primary tree. The selection of an alternative root is made in advance to provide a better quality of communication service. Using the example of Fig. 1, and Fig. 2 shows the two trees constructed for a multicast group of eight members (one sender and seven receiver nodes). The primary tree consists of a primary root (r_p), four forwarding nodes (p, q, s, and t), and seven receiver nodes, while the alternative tree consists of an alternative root (r_a), four forwarding nodes (p, r_p, s, and t), and seven receiver nodes.

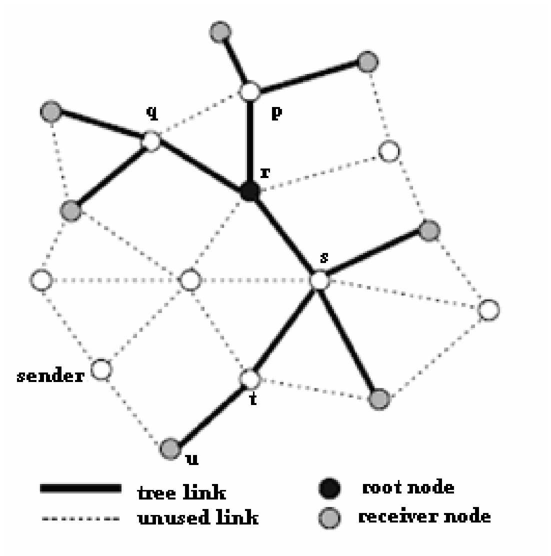

Fig. 1- An example of tree-based multicast

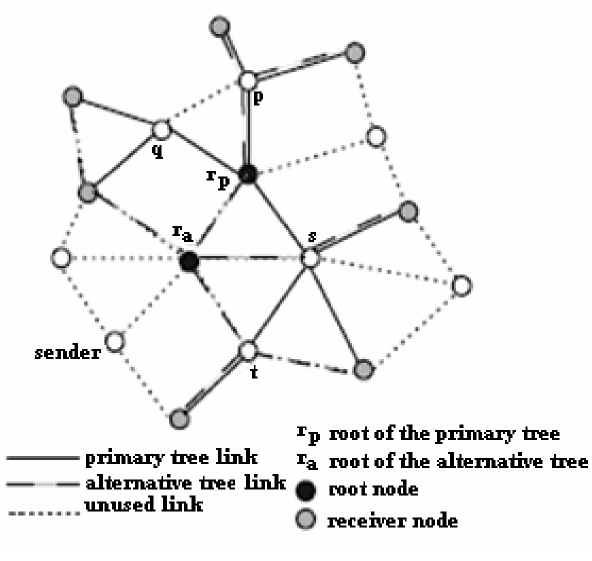

Fig. 2- An example of two trees in TTM

The TTM protocol performs as follows: Two trees are periodically reconstructed (e.g., every 3 seconds) by periodic join messages (with the information on remaining battery energy) sent by all receiver nodes to r_p and r_a. The two root nodes in dependently construct multicast trees based on the forwarding paths that the join messages traverse. When a sender node intends to send a multicast message, it forwards the multicast message to r_p to be broadcast by the root node as in most shared multicast tree protocols.

3. Suggested method

Considering the point that, MANET life time is defined as the duration of time until the first node (or some percent of nodes) in the network to fail due to battery energy exhaustion. As it mentioned earlier in introduction section, in this article a method is offered to increase network life time, which explained in this section thoroughly.

Suggested solution to increase network’s life time is the offer of the concept of service classes with three priority levels and use of it in ODMRP protocol. In this method, every multicast session is assigned a priority based on the type of application and QoS requirements such as bandwidth, delay and jitter. The multicast source assigns the priority for the session and it is assumed to be genuine. The proposed method takes the multicast requests with three different classes of priority level namely class A, class B and class C. Each packet takes its generator session class.

The class A multicast session is assigned high priority that has very stringent QoS requirements in terms of delay, bandwidth and the minimum number of receivers. High-profile multicast sessions such as real-time applications are grouped into service type class A. The class C multicast session is treated as low-priority service as that of normal best effort service. Low-profile multicast sessions such as chatting are grouped as class C. The class B multicast session is assigned medium priority that is in between class A and C services. Multicast sessions with moderate QoS requirements such as file and multimedia transfer are classified as class B.

In suggested method different amounts of threshold is considered for each node of network. Each node correspond to class of received packet to it, decides to send or not to send that packet. For example, if we assume that threshold amount for each node is 80 and 60 units for C and BC classes respectively, this node sends all packets (packet with class A, B, C) if its energy is more than 80 units; Else, if this node’s energy is between 60 and 80 units then due to the limitation of the energy, it will not transfer packets with class C and just transfers packet with class A and B, otherwise (the existing energy of node be less than 60 unit) because of the intensity limitation of the energy, doesn’t transfer packets with class B, C and only transfers packet with class A. This, in turn, causes the node energy which has reached to its threshold amount gets zero later. Consequently the rest of nodes can have more roles in the transmission of data packets and use their energy in a best way. Generally it can be said that those nodes whose energy has been limited don’t send any type of packets, thus their energy don’t end early and causes an increase in network life time.

Essential point which should be mentioned have is that ODMRP protocol operates on mesh-based protocols, therefore, unlike tree-based protocols, they don’t need having a rerouting for dropped packets; because there is different routes for transferring pockets to certain destination with more probability.

4. Performance evaluation of suggested method

4.1. Simulation environment

The simulator is implemented within the Global Mobile Simulation (GloMoSim) library. The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation capability provided by PARSEC [11]. Our simulation models a network of 50 mobile hosts placed randomly within a 1000m × 1000m area. Radio propagation range for each node is 250 meters and channel capacity is 2 Mbits/sec. Each simulation executes for 300 seconds of simulation time. Multiple runs with different seed numbers are conducted for each scenario and collected data is averaged over those runs.

One multicast group with a single source is simulated. The source sends data at the rate of 20 packets/second. The size of data payload is 512 bytes. Multicast member nodes are randomly chosen with uniform probabilities. Members join the multicast group at the start of the simulation and remain as members throughout the simulation. Random waypoint is used as the mobility model. A node randomly selects a destination and moves towards that destination at a predefined speed. Once the node arrives at the destination, it stays in its current position for a pause time between 0 and 10 seconds. After being stationary for the pause time, it selects another destination and repeats the same process.

In simulations, mobility speed is varied from 1 km/s to 70 km/s, and the number of nodes is considered from 2 to 30. In additional, quantities of 20-30, 40-50, and 60-80 used as BC and C threshold limits respectively for nodes; and the quantities of 600-1200, 800-1500, 1000-1800, 1400-2500, and 8000-4000 were considered as primary energy of normal nodes and traffic generator nodes respectively.

In simulation of the suggested method, the following parameters were evaluated:

Life Time: Life time is defined as the duration of time until the first node (or some percent of nodes) in the network to fail due to battery energy exhaustion.

Packet Delivery Ratio: The number of data packet delivered to multicast receivers over the number of data packets supposed to be delivered to multicast receivers.

Control Overhead: Number of control bytes transmitted per data byte delivered. In addition to bytes of control packets (e.g., JOIN REQUESTS, JOIN TABLES), bytes of data packet headers are included in calculating control bytes transmitted. Accordingly, only bytes of the data payload contribute to the data bytes delivered.

End-to-End delay: The time taken for a packet to be transmitted across a network from source to destination.

4.2. Simulation results

The results of simulation regarding the setting of section 4.1 are as follows:
In simulations, we considered three cases NON_Restrict, C_Restrict, and BC_Restrict for comparing proposed method with primary ODMRP protocol. In NON_Restrict case, the nodes don't have any restriction for packets transferring; in other words the nodes transfer all packets (packets with class A, B, and C). In C_Restrict case, the packets with class C dropped if nodes energy reaches to C threshold. The BC_Restrict is similar to C_Restrict with this difference that packets with class B also dropped if nodes energy reaches to BC threshold.

Fig. 3 show the average network life time for different thresholds. As such it can be observed, by increasing the threshold values and also by increasing the intensity of constraints, the network life time is increased; because the nodes are reached to their energy thresholds, only transfer packets with higher classes, thus their energy finished later, consequently the network life time is increased.

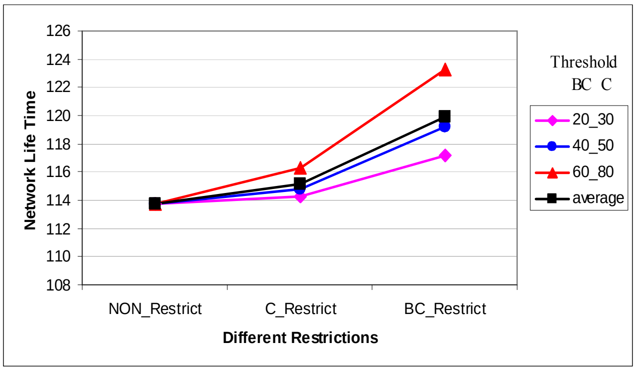

Fig. 3- Average network life time for different thresholds

As there was not any energy parameter in primary ODMRP protocol, it is equivalent to NON_Restrict case with infinite energy values for nodes, which in this case network life time was equal to the end time of simulation (300 second).

On the basis of the obtained results, network life time in average for NON-Restrict case is 113.7 and for BC-Restrict is 119.9, which it shows that the network life time of proposed method rather than primary ODMRP protocol increases about 5.54%.

As the increase in the network life time may cause decrease of the quality of the other parameters in network, we evaluated some of theses parameters.

In fig. 4, the average delivery rate is shown for different thresholds. As such it can be observed, by increasing the intensity of constraints, the network life time is increased, thus the number of received packets and consequently delivery rate increases. It should be noted that the obtained results for the primary ODMRP protocol is constant due to there was no restrict on it.

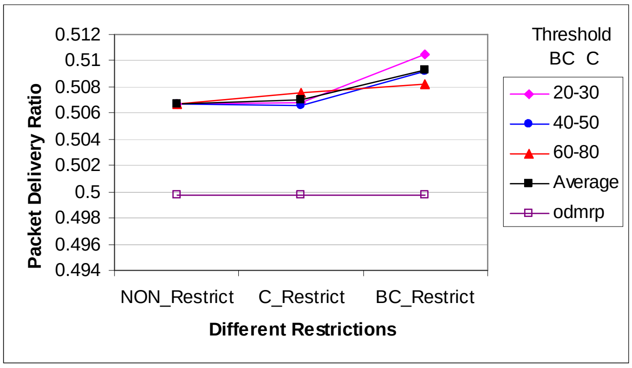

Fig. 4- Average delivery rate for different thresholds

In fig. 5, the average control overhead is shown for different thresholds. Regarding that in the implementation of the proposed method, one field is added to the data packets structure for maintain of class of class (A=00, B=01, C=10) two bits are also added to the total size of each packet. Consequently, in the comparison of the suggested method with the primary ODMRP protocol, these two added bites are considered in the size of the data packets.

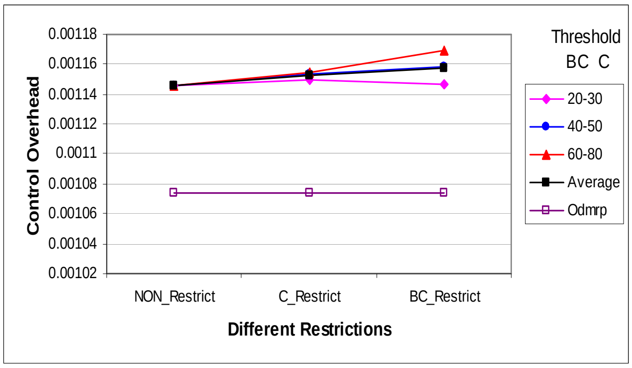

Fig. 5- Average control overhead for different thresholds

Regarding fig. 5, by increasing the intensity of constraints, the number of the control packets and consequently the control overhead increased. Also by increasing the threshold values, because of the act of dropping packets start early then the number of received packets decreases, and consequently control over head increases.

As it can be considered, control overhead of the proposed method in comparison to primary ODMRP protocol has increased up to 1/10000 bits, which it is ignorable in practice.

In fig. 6, the average end-to-end delay is shown. In simulations initial energy, threshold values, and intensity of constraints had no effects for this parameter, only the number of participated nodes in simulation and also the speed of mobility of these nodes had some effects on this parameter. As it can be seeing in fig. 6, by increasing the number of nodes, the end-to-end delay decreases and increasing the network life time had no effect on this parameter.

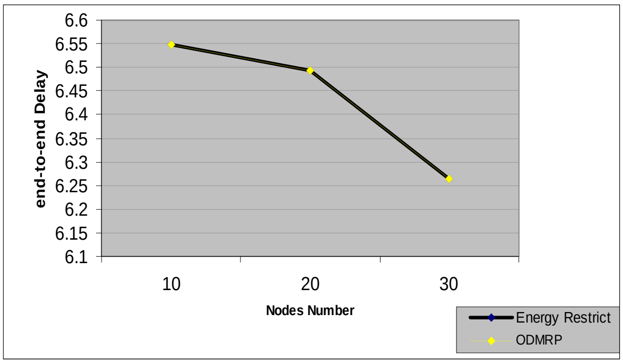

Fig. 6- Average end-to-end delay for different number of nodes

On the basis of the obtained results from fig. 3 to 6 we can conclude that the proposed method increases the network life time considerably; also this increase does not have any negative effect on the other parameters. Of course it is possible to increase the network life time by increasing threshold values as much as it has no negative effect on other parameters.

5. Conclusion and future works

The energy efficient consumption in MANETs is a necessity for each node and as a whole for the total network. The performed researches show that the on demand tree-based protocols in which the topology of network changes frequently can not be the best choice in a dynamic environment. Considering this point that usability of alternative routes allow information to be delivered to all or most of the multicast receivers even though a link is broken seems that mesh-based protocols is effective than tree-based protocols. In mesh-based protocol, one of the important problems is energy efficient consumption in these types of networks. The reason for this is unavailability to infinite sources of energy during the operation of network in directly.

Our proposed method is based on energy efficient consumption in order to increase network life time by classifying multicast sessions. Using GloMoSim software the performance of the proposed method and other parameters which were probability affected by the proposed method were evaluated. The result showed that proposed method increases network life time remarkably, and do not negative effect on other parameters. Future attempts should be focused on the scalability of multicast routing by increasing the number of multicast sessions and number of multicast sources.

6. References

1. Chlamtac I, Conti M, Liu J J (July 2002) "Mobile ad hoc networking: imperatives and challenges", Elsevier, Amsterdam, 1000 AE, Netherlands, PP. 13-64
2.Ilyas M (2002) "The Handbook of Ad hoc Wireless Networks", Florida Atlantic University Boca Raton, CRC Press, FL, U.S.A.
3.Manoharan R, Thambidurai P, Ramesh R (December 2006)"Power aware scalable multicast routing protocol for MANETs", International Journal of Communication Systems, John Wiley and Sons Ltd, Chichester, West Sussex, PO19 8SQ, United Kingdom, PP. 1089 - 1101, vol. 9, No. 10
4.Moh S, Yu C, Lee B (2001) "Energy Efficient Two-Tree Multicast for Mobile AdHoc Networks", IEEE INFOCOM
5.Lee S J, Su W, Gerla M (December 2002) "On-Demand Multicast Routing Protocol in Multihop Wireless Mobile Networks", Kluwer Academic Publishers, Dordrecht, 3311 GZ, Netherlands, PP. 441-453, VOL. 7, NO. 6
6.Chlamtac I, Weinstein O (April 1987) " The wave expansion approach to broadcasting in multi-hop radio networks, in: Proceedings", IEEE INFOCOM, San Francisco, CA
7.Lee S, S u W, Hsu J, Gerla M, Bagrodia R (March 2000) " A Performance Comparison Study of Ad Hoc Wireless Multicast Protocols", IEEE Infocom 2000, Tel Aviv, vol. 2, PP. 565–574
8.Wieselthier J, Nguyen G, Ephremides A (November 1999) "Algorithms for Energy-Efficient Multicasting in Ad Hoc Wireless Networks", Military Communication Conference (MILCOM 1999), Atlantic City, NJ, VOL. 2, PP. 1414–1418
9.Wieselthier J, Nguyen G, Ephremides A (May 2001) "Energy Efficiency in Energy-Limited Wireless Networks fo r Session-Based Multicasting", IEEE Vehicular Technology Conference (VTC 2001), VOL. 4, PP. 2838–2842
10.Ryu J, Song S, Cho D (September 2000)"A Power-Saving Multicast Scheme in Two-Tier Hierarchical Mobile Ad-Hoc Ne tworks", IEEE Vehicular Technology Conference (VTC 2000), VOL. 4, PP. 1974–1978
11.UCLA Parallel Computing Laboratory and Wireless Adaptive MobilityLaboratory, GloMoSim: A Scalable Simulation Environment for Wireless and Wired Network Systems.
12.Gerla M, Chiang C, Zhang L (1999) "Tree multicast strategies in mobile, multihop wireless networks", Baltzer/ACM Journal of Mobile Networks and Applications (MONET), VOL 3, PP. 193–207