A Team Multicast Routing Protocol for Mobile Ad Hoc Networks

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Abstract

Team multicast identifies clusters of nodes with same affinity as teams and manages the multicast membership information using the unit of team rather than dealing with individual node members. The source propagates a data packet to each subscribed team's leader and each leader forwards the data to the entire team. But none of the existing work on team multicasting consider the QoS metrics of the team leader like power, bandwidth etc. In this paper, we propose a QoS-aware team multicast protocol for MANETs, which gives a better solution to the above said problems. In our proposed protocol, the team leaders are selected based on the QoS metrics like bandwidth, residual energy and stability. Thus, the problem of link breakage can be reduced proactively. In case of link breakage occurring at any place of the network, a new team leader is selected in reactive basis. This avoids the delay in route repair mechanism. By simulation results, we show that the proposed protocol achieves better packet delivery ratio with reduced delay and overhead.

1. Introduction

1.1 Mobile ad hoc networks (MANET)

The self-systemized active topology created by the set of mobile nodes via radio links is termed as ad hoc networks. The ad hoc networking design is getting reputation gradually with the latest enhancement of mobile computers such as laptops and palmtops. The characteristics such as nominal configuration and infrastructure-less environment and rapid deployment make them suitable for the crisis circumstance caused by nature such as earthquakes, cyclones or human induced disasters. The process of creating and upholding the ad hoc networks is a significant task as the movement of host can result in recurrent and topological changes in a random manner.

The ad hoc network does not utilize any router for the routing scheme. Each host in the network acts as router. Whenever a host attempts to link with other hosts in the network, host linking the source and destination creates the connection. [1]

1.2 Multicasting in MANET

The process of forwarding the similar messages from the source to a set of destinations is termed as multicasting. Essentially MANETs are equipped for multicast communication owing to their broadcast environment. The drawback such as restricted bandwidth among the mobile nodes and dynamic topology cause the accessible QoS aware multicast routing protocol to be more complex when compared to the conventional networks. [2]

The multicast protocols for mobile ad hoc networks are classified into two categories such as tree-based multicast and mesh-based multicast. In terms of energy efficiency, the performance of the multicast mesh is weak due to the extreme overhead. Whereas the tree based multicast offers good performance with the use of network resource and it can be source-tree structure or shared-tree based protocol. [3] A mesh based multicast routing protocol upholds a mesh that includes the related components of the network holding every receivers of a group. [5]

The multicast routing protocols utilized in the ad hoc networks can be proactive, reactive or hybrid type. The proactive behavior regularly maintains and updates the routing information. The reactive performance involves the construction of the routing paths depending on demand. The hybrid nature combines the advantages of both proactive and reactive nature. [4]

The existing multicast protocol does not exhibit more performance for the large scale networks. Owing to mobility criteria, it is very complicated to tackle huge multicast protocol in MANET. Adding to the above aspects, the existing routing protocols does not utilize team affinity model and members possess common mobility pattern and interest. [6]

For building a source tree, a hybrid link state and distance vector algorithms are utilized in the existing MANET multicast routing algorithms. As we discussed earlier, multicast is a relatively new topic in the field of MANETs, and only a few algorithms have been proposed. The examples of some MANET multicast algorithms are given below:

- Application Layer Multicastwith NetworkLayer Support (APPMULTICAST) [7]
- Robust Demand-driven Video Multicast Routing (RDVMR) [8]
- Overlay Multicasting for Ad-hoc Networks [9]
- Multicast AODV (MAODV) [10]
- On-Demand Multicast Routing Protocol (ODMRP) [11]
- Multicast Zone Routing (MZR) [12]
- Multicast OLSR (MOLSR) [13]
- Ad hoc Multicast Routing (AM Route) [14]
- Core-Assisted Mesh Protocol (CAMP) [15]
- Adaptive Demand Driven Multicast Routing (ADMR) [16]
- Lightweight Adaptive Multicast Algorithm (LAM) [17]
- Multicast Core Extraction Distributed Ad-Hoc Routing (MCEDAR) [18]
- Protocol for unified multicasting through announcements (PUMA) [5]

1.3 Team Multicast

The team multicast approach is utilized in large scale mobile ad hoc networks where the multicast group has teams as an alternative to individual nodes. A set of nodes possessing a movement similarity and interests distinguished by subscribed multicast groups.

Team multicast recognizes the team of nodes as per similarity characteristics and tackles the multicast information with the help of team rather than dealing with individual nodes. [19]

The source broadcasts the data packet to every subscribed head of the team and every head forwards the data to the whole team. The nodes within the same team travel possess the synchronized motion. Hence the multicast turns out to be important research area in the current years.

An example illustrating the team multicast technique is as follows.

- Depending on the assignments in the battlefield, several units in a section is structured into companies and then divided into task forces.
- As the platoons of cars in a highway possess the motion similarity the cars are treated as teams.

Search and rescue operations, disaster monitoring, and mobile sensor platforms also exhibits multicasting technique.

1.4 Problem Identification and Solution

In Hypercube based Team Multicast Routing Protocol (HTMRP) [6] tree maintenance phase, eachteam leader maintains a table called Neighbor's-Neighbor Team Leader Table (NNTT) which has theinformation about the neighbor's neighbor.

Since NNTT maintains two-hop neighbor team leader information, only a maximum of two consecutive link breakages can be locally repaired. Longer link breakages have to follow the conventional route repair mechanism, which leads to additional overhead.

None of the existing work on team multicasting consider the QoS metrics of the team leader like power, bandwidth etc.

In this paper, we are going to propose a new team multicast protocol for MANETs, which gives a better solution to the above said problems. The features of our new team multicast protocol are

1. The team leaders are selected based on the QoS metrics like power, bandwidth etc. Thus, the problem of link breakage can be reduced, proactively.

2. In case of link breakage occurring at any place of the network, a new team leader is selected in reactive basis. This avoids the delay in route repair mechanism.

2. Related Work

Emy E. Egbogah et al [2] proposed the scalable team oriented reliable multicast (STORM) routing protocol intended to offer consistency in a tactical mobile ad hoc network. The individual nodes with same mobility model and speeds are systematized into teams and a hierarchy based multicast mesh structure is constructed among the elected team nodes. A unicast acknowledgement Scheme (UAS) is introduced to model the routing structure efficiently. A modified version of Reliable Adaptive Congestion controlled multicast (ReACT) is utilized as a reliable transport protocol to enhance the reliability of STORM.

Yunjung Yi et al [19] proposed a multicast protocol called team oriented multicast (TOM). TOM constructs a motion aware hierarchy to maintain efficient scalable team multicast protocol. It utilizes a two-tier dissemination scheme in which the source broadcasts a data packet to every team leaders and every leader forwards the data to the entire team.

Yunjung Yi et al [20] proposed a multicast-enabled landmark ad hoc routing that utilizes tunneling from multicast sources to each landmark of the subscribed team and limited flooding within the motion group. A multicast source sends multiple copies of the packet to the landmarks in the multicast group. Further, each landmark forwards the multicast packet to its

associated team through flooding. The features of the proposed approach includes enhancement of the scalability, reliability and congestion control properties of multicasts protocols.

R. Manoharan and P. Thambidurai [6] proposed the hypercube based team multicast routing protocol (HTMRP) for mobile ad hoc networks. HTMRP provides a three-tier multicast routing paradigm consisting of Landmark tier, Hypercube tier and Mesh tier. Mesh Layer on top of the Hypercube tier helps for effective fault tolerance. HTMRP addresses the issues of link failures owing to mobility by adding in a logical hypercube model. Besides scalability, HTMRP assures the QoS needs such as high availability and load balancing by adding team, hypercube and mesh tiers.

3. Proposed Work

3.1 Algorithm Description

Team multicasting builds an essential hierarchy by organizing nodes to a few teams. In the team multicasting the source delivers the packet to each member in two steps:
(1) inter-team data forwarding: data forwarding to each team leader (TL).
(2) intra-team forwarding data distribution within a team initiated by the TL.

The network which is considered by the team multicasting consists of many teams (T) and individual nodes which do not belongs to any team due to the shortage of the similarity. A team T is a connected un-directed graph with the maximum distance D from a node i to j (i and j 2 T). A link (i, j) gives a direct connection between i and j. A team T is defined as a set of nodes having the same mobility pattern and common interests i.e., motion affinity group. Based on the idea in the section 3.2, each node discovers a team and selects a leader in a distributed manner. In this paper, we assume:

- a node does not join a multicast group if it does not belong to a team
- all nodes in the same team subscribe the same multicast groups for simplicity.

Inter-team membership maintenance and data forwarding become simple with those assumptions. Thus this paper mainly concentrates on the inter-team membership management and data forwarding. In this paper, the team leaders are selected based on a combined weight of QoS metrics like residual energy, bandwidth and link stability.

3.2 Team Leader Selection

Team Leaders are selected based on the following weighted sum

$$w = (v_1 + v_2 + v_3) * k \qquad (1)$$

Where v_1 is the nodes residual energy, v_2 is the bandwidth and v_3 is the stability index and k is the weighting constant.

Team leader is selected through the node which has the maximum w. When a node becomes the team head then either that node or its members will be considered as "elected". Then for the "unelected" nodes the election process takes place. At first, all the nodes are "unelected". When all the nodes have been elected then the election algorithm will come to an end. The sections given below discusses about the estimation of v_1, v_2 and v_3.

Team Leader Election Algorithm

1) Each Node N_i calculates its weight W_i using (1), where i=1,2,….
2) N_i exchanges W_i with each other through a packet WT_MESSAGE
3) N_i calculates Max (W_i)
4) Then the node N_k, with W_k=Max (W_i) sends a TLB (Team Leader Beacon) to other nodes.
5) The nodes N_i (i $\neq$ k) elects N_k as the TL.

4. Estimation of weight Factors

4.1 Estimating Residual Energy

Let the nodes have the location information about their neighbors and destination and also a uniform energy distribution among the homogeneous nodes.

The information about the residual energy of the neighbors is stored by every node by requesting the other nodes about their residual energies. The residual energies at a node i can be calculated as

$$E_{R(i)} = E_{I(i)} - E_{C(i)} \qquad (2)$$

Where E_R - Residual Energy, E_I - Initial Energy, E_C – Consumed Energy

By exchanging this information with all nodes in the network, the total residual energy is attained. From this, the energy index of the node i is calculated as

$$EI_i = (E_{R(i)} / E_{Rmax}) * \alpha \qquad (3)$$

Where $E_{R(i)}$ – residual energy of node i, E_{Rmax} – maximum value of residual energy in the entire network, α (0<α<1) – system defined experimental parameter.[22][23].

Hence we can replace v_1 with the value of EI_i in (1).

4.2 Estimating Bandwidth

The available bandwidth is computed depending on the channel status for finding the busy and idle states of the shared wireless media. [21] The channel utility of the node is investigated to acquire the bandwidth used. The fraction of

time within which a node is sensing the channel as being utilized is termed as channel utilization ratio (CUR). All nodes continuously a monitor the changes in the channel state either busy to idle state or idle to busy state and updates the ratio in each state.

The channel utilization ratio (CUR) for each time period t is computed as follows.

$$CUR = CBP / t$$

Where CBP – channel busy period.

A smoothing constant $\lambda \in [0, 1]$ is introduced to smooth the evaluation of channel utilization.

Let CUR_{t-1} represent the final channel utilization ratio

Then the current channel utilization ratio is given as

$$CUR_c = \lambda CUR_{t-1} + (1 - \lambda) CUR \qquad (1)$$

Here $CUR_c = [0,1]$.

Following the suitable estimation of the channel utilization at time t, the available bandwidth of a node at time t is calculated using the following formula.

$$ABW_t = b. (1 - CUR_t) \qquad (2)$$

Here, b is the raw channel bandwidth.

4.3 Estimating Stability

4.3.1 Link Quality Estimation

The link quality demonstrates the link stability of a wireless networks. The electronic signals are important factor for communication and through this, route condition can be monitored and signal quality can be estimated. By utilizing the received signal strength from the physical layer, the link quality can be estimated and further the links with the minimum signal strength is discarded while selecting the routes.

The received signal strength indicator (RSSI) is superior estimator of the link quality which represents the received RF signal. It estimates the link quality rapidly as it is more reliable over time.

During the propagation of the RTS packets the sender embeds it with transmission power P_{tx}. The node on receiving the RTS packet measures the received signal strength. The free-space propagation model possesses the following relationship.

$$P_r = P_{tx}.(\lambda/4\pi d)^2.G_{tx}.G_r \qquad (3)$$

Where λ = wavelength carrier
d = distance between sender and receiver
G_{tx} = unity gain of transmitting omni directional antennas
G_r = unity gain of receiving omni directional antennas, respectively.
The noise and fading effects are not considered.
Hence the link quality is given as

$$L_q = P_r \qquad (4)$$

Hence in our equation (1), replace v3 with L_q.

5. Inter-team Group Membership Management

The team multicasting approach constructs m-ary linked multicast mesh model between the subscribed team leaders. Each leader contains maximum q wandering links with other leaders. The node permits the reception of q redundant packets from connected leaders. By this way each node sends a data packet to all connected leaders excluding the incoming direction. The mesh model offers a consistent transmission framework over tree structure. The team multicasting constructed an algorithm for upholding the mesh.

The main objectives of this algorithm are as follows.

1. The necessity of the minimum dynamic mesh re construction
2. Functioning in a distributed manner
3. Minimum overhead demand.

The team multicasting utilizes a distance vector routing protocol (DSDV) for upholding a path among two leaders linked in the multicast mesh model. Every node takes the initiative to tackle the paths to leaders inclusive of mobility of each team in a random manner. Hence every node in the network retains a leader's table (TL) that holds the details of the leaders who are subscribed to any group and the node swaps and updates the table with the neighbor node from time to time.

5.1 Group Membership Join

The team multicasting scheme can broadcast the part of membership information with minimum overhead to the entire network due to the TL update mechanism. The root vertex of multicast groups publicizes the address of the group and the size of the multicast mesh graph to the whole network. This is performed by linking the exchanged information in the TL table. Through this action, the new team can discover a point to forward a join query by gazing at the TL table.

Let TM_i represent the team
Let T_{Hi} represent the leader of TM_i

Let F represent the multicast mesh graph.
Let G_j represents the group.
Let RV represent root vertex
Let N_g be sequence number
Let ML represent the member list
Let sq represent the sequence value.
It is assumed that every node has two connection catalog namely parent catalog CC_p and children catalog (CC_c).

It is assumed that vertex should have at least one link say I= (a, b) where $sq_b < sq_a$ in order to assure a connected graph.

The process of linking T_{Hi} and edges with F represents the linkage of new TM_i to the G_j. This process is described in following steps

Step 1

If new TM_i wants to link with G_j

Then

T_{Hi} initially gazes at local TL table to recover the RV of F and forwards a query.

Else

TM_i declares itself as a root vertex in a graph F = {TM_i} Advertise the membership information with TL table exchange.

Step 2

When the root vertex findsanother graph for the similar group, it attempts to combine two graphs (Graph MergeProcedure).
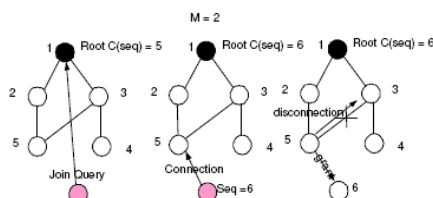

Fig. 1. Join Procedure

Step 3

Upon reception of the query packet at RV, the current value of n_g gets incremented and gets allocated to TM_i. (i.e. sq (TM_i) = N_g).

Step 4

RV sends back the ML and new N_g to TM_i.

Step 5

TM_i categorizes the ML in ascending order as per the distance from TM_i depending on TL.

Step 6

TM_i keeps sending a connection request (C_{req}) to a node a_j (i.e. j^{th} element in ML) till its finds the parent node for connection.

Step 7

a_j executes the connection establish process on reception of C_{req}.

Step 8

As soon as TM_i is linked to F, it updates RV. RV then includes TM_i to ML and broadcast to F with the current value of n_g.

When a node gets connected to a group, it may add connections till G links in a flexible manner.

5.2 Membership Leave

At the time of departure of a team from a group, the leader forwards membership depart request (MD_{req}).

1) If leader $\neq$ RV

Then

The leader detaches all connections and notifies RV

End if

2) If RV wants to depart

Then

It selects the vertex with smallest N_g and transfers the responsibility of the root.

End if

Following the above process, the new root publicizes the modification in the root address to the entire nodes in the graph. The root devoid of the edge just halts the publicizing process which causes every node in the network to take away the entry from TL following the time expiry.

5.3 Inter/Intra-team Data Forwarding

The process of data forwarding in inter and intra team is shown in the Fig. 2.

During Intra-team data forwarding, we assume that a team member of team 1 needs to obtain the data from the multicast source. This is done by multicasting the data packets to the team leader of team 1. Upon reception of data from source, team leader of team 1 sends the data to its team members.

--- Source (S)

● -- Team Leader

● -- Team Member

→ -- Intra-Team Forwarding

→ -- Inter-Team Forwarding

Fig: 2. Inter/Intra Team Data Forwarding
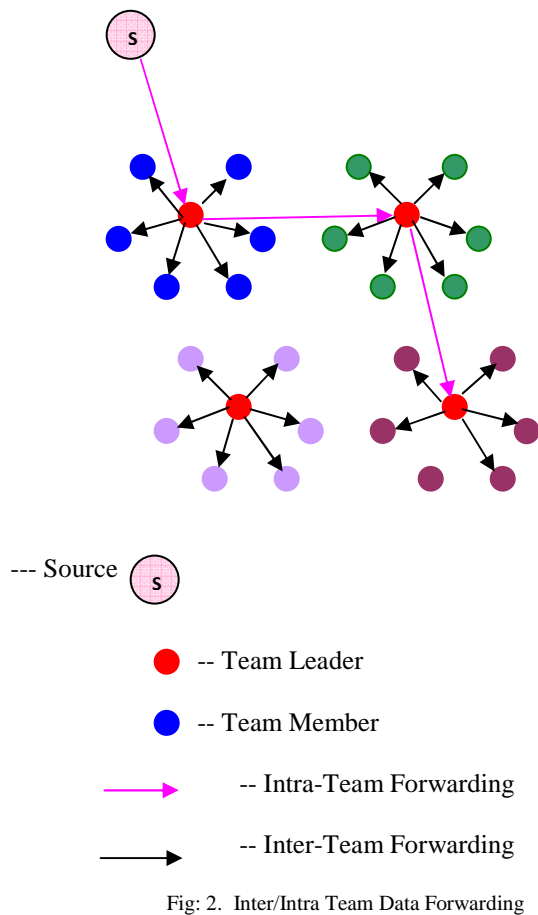
In the Inter-team data forwarding, we assume that a team member of team 3 needs to obtain the data from multicast source. This is accomplished by forwarding the data through team leaders of team 1 and team 2. Further the subsequent team leader of team 3 sends the data to its members with the help of intra-team data forwarding.

6. Simulation Results

NS2 is used to simulate the proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. The distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol is used. It has the functionality to notify the network layer about link breakage.

In the simulation, mobile nodes move in a 500 meter x 500 meter rectangular region for 50 seconds simulation time. Initial locations and movements of the nodes are obtained using the Reference Point Group Mobility (RPGM) model of

NS2. All nodes have the same transmission range of 250 meters.

In the simulation, the mean speed is 5 m/s. and the mean pause time is 5sec. The network consists of 5 teams with 4 members in each team. The simulated traffic is Constant Bit Rate (CBR). For each scenario, ten runs with different random seeds were conducted and the results were averaged.

The QATMR protocol is compared with M-LANMAR [1] and MAODV [7]. The evaluation is mainly based on performance according to the following metrics:

Control Overhead: The control overhead is defined as the total number of routing control packets received.

End to End Delay: It is average end-to-end-delay of the transmission.

Packet Delivery Ratio: It is the ratio of the fraction of packets received successfully and the total no. of packets sent.

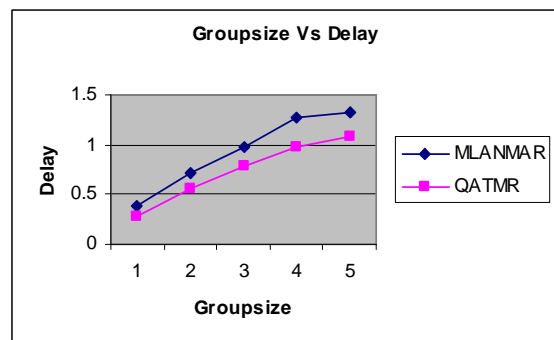For measuring the above metrics, we vary the group size as 1,2,3,4 and 5.

Fig. 3. Group SizeVs End-to-End Delay

Fig. 3 shows that the end-to-end delay of the proposed QATMR protocol is significantly less when compared with M-LANMAR, since the multicast tree formation involves less overhead when compared with M-LANMAR algorithm. In the figure we can see that, as the group size increases, the corresponding delay also increases.
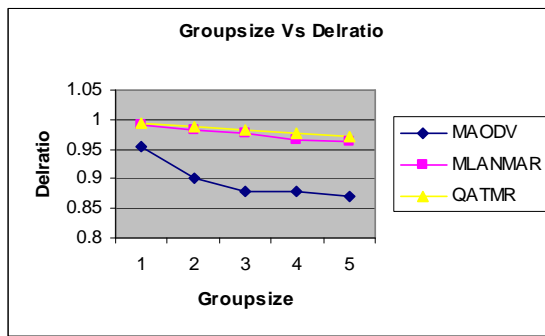
Fig. 4. Group SizeVs Delratio

Fig. 4 shows the packet delivery ratio of all the protocols. From the figure, we can see that the packet delivery ratio of QATMR is slightly more than M-LANAMR and significantly more thanMAODV, since the mobility induced errors are minimized in QATMR.
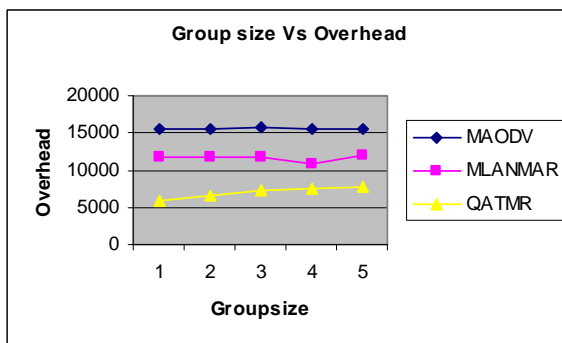

Fig. 5. Group SizeVs Overhead

Fig. 5 shows the control overhead occurred in all the protocols. From the figure, we can observe that the control overhead increases when group size grows. Since less control messages are exchanged in QATMR, its overhead is less than that of MAODV and M-LANMAR.

7. Conclusion

Extending the availability of today's radio spectrum is a In this paper, Team multicast identifies the teams of nodes with the same similarity as teams and manages the multicast membership information using the unit of team instead of dealing with the individual node members. A data packet is broadcasted to each subscribed team's leader from the source and each leader forwards the data to the entire team. But none of the existing work on team multicasting consider the QoS metrics of the team leader like power, bandwidth etc. In this paper, we have proposed a QoS-aware team multicast protocol for MANETs, which gives a better solution to the above said problems. In our proposed protocol, the team leaders are selected based on the QoS metrics like bandwidth, residual energy and stability. Each team member estimates a combined weight value of these QoS metrics. Then team leader is selected through the node which has the maximum weight value. Thus, the problem of link breakage can be reduced proactively. In case of link breakage occurring at any place of the network, a new team leader is selected in reactive basis. This avoids the delay in route repair mechanism. By simulation results, we have shown that the proposed protocol achieves better packet delivery ratio with reduced delay and overhead.

References

[1] Al-SakibPathan, Muhammad Monowar, Md. Rabbi, Muhammad Alam, and Choong Hong, "NAMP: Neighbor Aware Multicast Routing Protocol for Mobile Ad Hoc Networks", The International Arab Journal of Information Technology, Vol. 5, No. 1, January 2008.

[2] Emy E. Egbogah, Abraham O. Fapojuwo, and Norbert Chan, "Scalable team oriented reliable multicast routing protocol for tactical mobile ad hoc networks", IEEE military communication conference (MILCOM), pp 1-7, 2008.

[3] ParizaKamboj and Ashok.K.Sharma, "Energy Efficient Multicast Routing Protocol for MANET with Minimum Control Overhead (EEMPMO)", International Journal of Computer Applications, Volume 8– No.7, October 2010.

[4] Adel Ben Mnaouer, Lei Chen, ChuanHengFoh and Juki WirawanTantra, "A New Polymorphic Multicast Routing Protocol for MANET", IEEE International Conference onCommunications (ICC), pp 233 - 238 Vol. 1, 2005.

[5] RavindraVaishampayan and J.J. Garcia-Luna-Aceves, "Efficient and Robust Multicast Routing in Mobile Ad Hoc Networks", IEEE International Conference on Mobile Ad-hoc and Sensor Systems,pp304 – 313, 2004.

[6] R. Manoharan and P. Thambidurai, "Hypercube based Team Multicast Routing Protocol for Mobile Ad hoc Networks", 9th International Conference onInformation Technology (ICIT), pp 60 – 63, 2006.

[7] JayantaBiswas and S. K. Nandy, " Application Layer Multicasting for Mobile Ad-Hoc Networks with Network Layer Support", In Proceedings of 29th Annual IEEE International Conference on Local Computer Networks,pp.24-31,2004.

[8] Agrawal, D. Reddy, T.B. Murthy, C.S.R.,"Robust Demand-Driven Video Multicast over Ad hoc Wireless Networks", In proceedings of 3rd International Conference on Broadband Communications, Networks and Systems, pp.1-10,San Jose,CA, Oct.2006.

[9] M. Ge, S. V. Krishnamurthy, and M. Faloutsos, "Overlay multicasting for ad hoc networks",In proceedings of Third Annual Mediterranean Ad Hoc Networking Workshop, Turkey, 2004.

[10] Elizabeth M. Royer and Charles E. Perkins, "Multicast operation of the ad-hoc on-demand distance vector routing protocol", In proceedings of 5th annual

ACM/IEEE international conference on Mobile computing and networking,pp.207-218, Seattle, Washington, United States,1999.

[11] S.-J. Lee, M. Gerla, and C.-C. Chiang, "On-Demand Multicast Routing Protocol", In Proceedings of IEEE WCNC '99,pp. 1298–1302. New Orleans, LA, September 1999.

[12] V. Devarapalli and D. Sidhu, "MZR: A Multicast Protocol for Mobile Ad Hoc Networks", in proceedings of IEEE International Conference on Communications, Vol. 3, pp. 886-891, June 2001.

[13] P. Jacquet, P. Minet, A. Laouiti, L. Viennot, T. Clausen, and C. Adjih, "Multicast Optimized Link State Routing," IETF manet,2002.

[14] Mingyan Liu and Rajesh R. Talpade and Anthony Mcauley and EthendranathBommaiah, "AMRoute: Adhoc Multicast Routing Protocol", Technical Report, 1999.

[15] Garcia-Luna-Aceves, J.J.; Madruga, E.L,"The core-assisted mesh protocol", IEEE Journal on Selected Areas in Communications, Vol. 17, No. 8, pp.1380 - 1394, Aug 1999.

[16] Jorjeta G. Jetcheva and David B. Johnson,"Adaptive demand-driven multicast routing in multi-hop wireless ad hoc networks", in Proceedings of the 2nd ACM international symposium on Mobile ad hoc networking & computing, pp.33-44,Long Beach, CA, USA, 2001

[17] L. Ji and M. S. Corson,"A Lightweight Adaptive Multicast Algorithm",In Proceedings of IEEE GLOBECOM '98, pp.1036- 1042, December 1998.

[18] PrasunSinha and RaghupathySivakumar and VaduvurBharghavan,"MCEDAR: Multicast Core-Extraction Distributed Ad hoc Routing", In Proc. of the Wireless Communications and Networking Conference, pp.1313-1317, 1999.

[19] Yunjung Yi, Mario Gerla , J.-S. Park, D. Maggiorini, "Team Oriented Multicast: A Scalable Routing Protocol for Large Mobile Networks", Lecture Notes in Computer Science, Vol. 2816, 2003.

[20] Yunjung Yi, Mario Gerla and Katia Obraczka"Scalable Team Multicast in Wireless Ad hoc Networks Exploiting Coordinated Motion", Ad Hoc Networks,Vol.2,No.2, pp.171-184, April 2004.

[21] Xu, K.; Tang, K.; RajiveBagrodia; Gerla, M.; Bereschinsky, M, "Adaptive bandwidth management and QoS provisioning in large scale ad hoc networks", IEEE Military Communications Conference (MILCOM), pp 1018 - 1023 Vol.2, 2003.

[22] VinayRishiwal, S. Verma and S. K. Bajpai, " QoS Based Power Aware Routing in MANETs", International Journal of Computer Theory and Engineering, Vol. 1, No. 1, April 2009.

[23] Anuradha Banerjee and Dr. ParamarthaDutta, " Fuzzy-controlled Power-aware Routing Protocol (FPRP) for Mobile Ad Hoc Networks", International Journal of Computer Applications, Volume 11– No.7, December 2010.