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Route efficient on demand multicast routing protocol with stability link for MANETs

M. Rajendiran[1,2*] and S.K. Srivatsa[2]
[1]*Department of Master of Computer Applications, Panimalar Engineering College, Chennai -600123, India*
[2]*Department of Computer Science and Engineering, Sathyabama University, Chennai- 600119, India*
[3]*Department of Computer Science and Engineering, St. Josephs College of Engineering, Chennai- 600119, India*
muthusamyrajendiran@gmail.com*, profsks@rediff.com

Abstract
In recent years' mobile ad hoc networks (MANETs), a group oriented services has one of the primary application classes. It supports such services that use multicast routing. Therefore it is required to design stable and an efficient routing protocol for MANETs to support better packet delivery ratio, minimum delays and decreased overheads. In this paper, a multicast routing protocol based mesh networks that finds stable multicast path from source to receivers is proposed. In this model only the nodes that fulfill the delay requirements can flood the JOIN-QUERY messages. The contributing nodes are assumed to follow M/M/1 queuing systems. The queuing systems contain maximum value for queuing and contention delay which can be evaluated as the ratio of maximum queue size over the service time in a node. This model enhances link stability with contention delay and queuing system. The stable routes are found based on selection of stable forwarding nodes that have high stability of link connectivity. The link stability is calculated by using parameters link received power, distance between neighboring nodes and link quality. The performance of the proposed model is simulated over a large number of MANET nodes with wide range of mobility with two well known mesh based multicast routing protocol. It is observed that the proposed model produces better throughput and reduced overheads.

Keywords: Multicast routing, MANET, Stable forwarding node, Multicast routing, Link stability.

Introduction

In the last few years, owing to the creation of wireless devices, the use of mobile ad hoc networks is growing rapidly. Particularly, huge number of current studies focuses on mobile ad hoc networks (MANETs). The performance of a mobile ad hoc network depends on the routing method employed. Presently established routing protocols do not work capably in MANETs. In fact, MANETs are capable of dynamic topology changes (i.e. Every node can move randomly and the radio transmission conditions change quickly over the time) and have a limited bandwidth. Ad hoc wireless networks must be capable of self organization and self configuration since mobile structures changes with time.

Literature survey

They are many multicast routing protocols with unique features proposed for mobile ad hoc networks. MAODV (Royer & Perkins, 2000) is well known multicast routing protocol(Paul et al). It is the extension of AODV routing protocol where the multicast groups are identified by a unique address and group sequence number. Vasiliou and Economides (2005) proposed that if a node wants to join a group that is not communicated yet, it becomes the leader of that multicast group and is responsible for maintaining the multicast group. Vaishampayan and Gracia-Luna-Aceves (2004) propose a shared mesh multicast routing protocol called protocol for unified multicasting through announcements (PUMA). It is a receiver initiative approach where receivers join the multicast group using the address of a special core node without the need for flooding of control packets from the source of the group (Ahmad, 2005). When a node wants to join a multicast group(Perkins et al), it checks whether or not it is the first multicast receiver by checking the multicast announcement data. Multicast announcement data contains general information of the nodes such as message sequence number, core address, number of hops to the core of the group (Rodolakis et al), group ID and the address of the node from which the multicast announcement is received (Ruiz et al). If the receiver node finds the core of the group, it broadcasts the multicast announcement data and advertises the core in the group else it considers itself as the core of the group and starts transmitting multicast announcements periodically to its neighbors (Ahmad, 2005).

ODMRP has been developed by wireless adaptive mobility (WAM) laboratory (Yi *et al.,* 2003) at UCLA. It employs a mesh structure to forward multicast data packets. Core assisted multicast routing protocol (CAMP) was proposed by Garcia *et al* (1999) which is a receiver initiated shared multicast mesh routing protocol. CAMP extends the usage of core nodes to communicate multicast mesh. Viswanath *et al.* (2006) analyzed the behavior of ODMRP under a wide range of networks. Simulation analysis reveals that ODMRP performs considerably better in terms of packet delivery ratio as a function of node mobility and multicast network traffic load. ODMRP exhibits high robustness on account of its mesh structure (Viswanath *et al.* 2006). In order to enhance the performance of ODMRP many extensions of ODMRP have been introduced, each of which tries to enhance the performance of ODMRP in terms of pack delivery ratio, packet overhead and delivery delay. Enhanced-ODMRP, proposed by Oh *et al.* (2008) suggests a mechanism that dynamically adopts the route refresh time to the environment. This mechanism

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dramatically reduces packet overhead while keeping packet delivery ratio high. R-ODMRP, introduced by Pathrina and Kwon (2007), is a subset of nodes that are not on forwarding paths, stores and retransmits the received packets to the nodes located in their minimal hop count to overcome the perceived node failures. Addition to storage and retransmission mechanisms in these nodes increases the packet delivery ratio. R-ODMRP enhances network reliability at the cost of higher delivery latency and packet overhead.

ODMRP-MPR on demand multicast routing protocol with multi-point relay proposed by Ruiz and Gomez-Skarmeta (2004) reduces the packet overhead using multipoint relay nodes. The multipoint relay nodes decrease the broadcast over head by reducing duplicated packet forwarding (Oh *et al.* 2008). Saiful Azad *et al.* (2009) proposed the technique that brings scalability and effectively solves the unidirectional link problem of wireless communication. Performance-enhanced ODMRP (PEODMRP) proposed by So *et al* (2004) reduces the packet over head by limiting the transmission area of Join-Query flooding. It shows the best simulation results in network scenarios where multicast group indicate many source nodes.

On-demand multicast routing protocol with efficient route and link stability

In this section, the proposed model that manages the flooding method of query messages in the contributing nodes based on their delay point and link stability within the network is discussed. The efficient route method in ODMRP consists of two segments. The query segment occurs when a source node desires to transmit multicast data. The query segment is performed by periodical broadcasting of member requesting message (Oh *et al.,* 2008), called Join-Query message. The reply segment supports the route found by the Join-Query message (Pathrina & Kwon, 2007).

When the source node has to send, it adds the Join-Query message in the network. Each node that receives the Join-Query message rebroadcasts the message to its neighboring nodes (Lee et al., 2000). The Join-Query messages are forwarded by relaying nodes until they are delivered by multicast receivers. The multicast receiver sends a Join-Table message carried by forwarding nodes all the way towards the source node (Tijms et al., 2003).

The key plan following this work is that the Join-Query messages are flooded only by the nodes that can satisfy the single hop delay requirements. A method is recommended that facilitates the estimation of single hop delay in each node. Another important implication is that it saves the network bandwidth in a sense that when an intermediate node satisfies the delay requirement. It keeps the upstream node address and floods the network with the Join-Query message; otherwise it drops the incoming Join-Query message. The proposed method avoids the nodes with large single hop delay values to rebroadcast the query messages. Thus, the flooding method is efficiently managed by minimizing network bandwidth wastage and high packet overhead.

Delay method

Asif *et al.,* (2008) proposed the delay requirement for high throughput applications such as voice over IP and video conferencing, the packet should be delivered by multicast receivers before the maximum threshold of 250m. The delay over a single hop consists of multiple elements. The delay over the link l_{ab} from node 'a' to 'b' is represented as

$$d_{lab} = d_{lab}^{Q} + d_{lab}^{C} + d_{lab}^{L} \quad (1)$$

where queuing delay is defined as d_{lab}^{Q}. It is the interval between the time the packet enters in the queue of node 'a' and the time the packet reaches the head of line of the queue. The average contention delay indicate by d_{lab}^{C} is the time interval between the time the packet becomes the head of line packet and the time the packet is sent by the physical medium. Link stability indicate by d_{lab}^{L} is that stores link and node related data for establishing and maintaining multicast mesh an stable path from source to multicast destinations.

Queuing and contention delay

$$P_{i-1}\lambda = P_i\mu$$

$$P_i = \left(\frac{\lambda}{\mu}\right) P_{i-1}$$

$$\frac{\lambda}{\mu} = \rho \Rightarrow \left(\frac{\lambda}{\mu}\right)^k P_0 = \rho^k P_0$$

Where ρ denotes the utilization factor. We know that

$$\sum_{i=0}^{K} P_i = 1 \Rightarrow \sum_{i=0}^{K} \rho^i P_0 = 1$$

$$P_0 = \frac{1}{\sum_{i=0}^{K} \rho^i} = \frac{\rho - 1}{\rho^{K+1} - 1}$$

for $\rho \neq 1$

$$P_i = \frac{\rho^i(\rho - 1)}{\rho^{i+1} - 1} \quad (2)$$

for $\rho = 1$

$$\sum_{i=0}^{K} \rho^i = K + 1 \Rightarrow P_i = \frac{1}{K+1} \quad (3)$$

If $\rho \neq 1$ then the expected number of packets in the node's queue is given by

$$\mathrm{N} = \sum_{i=0}^{K} nP_i = \sum_{i=0}^{K} n\rho^i P_0$$

$$\Rightarrow \frac{\rho-1}{\rho^{k+1}-1}\rho \sum_{i=0}^{K} n\rho^{n-1} N = \frac{\rho-1}{\rho^{k+1}-1}\rho \frac{\partial}{\partial\rho}\sum_{i=0}^{K}\rho^k$$

$$N = \left(\frac{(K+1)\rho^{k+1}}{\rho^{k-1}} + \frac{\rho}{1-\rho}\right) \quad (4)$$

and if $\rho = 1$ and $\mathrm{P}_i = \frac{1}{K+1}$ then

$$N = \sum_{i=0}^{K}\frac{1}{K+1} i = \frac{K}{2} \quad (5)$$

and the mean waiting time from the time a packet arrives at the relaying node to the time the packet reaches the head of line of the queue in node 'i' is

$$d_{Q+c} = \frac{N}{\lambda}$$

For $\rho \neq 1$, we have

$$d_{Q+c} = \left(\frac{(K+1)\rho^{K+1}}{\rho^K - 1} + \frac{\rho}{1-\rho}\right)\frac{1}{\lambda} \quad (6)$$

and for $\rho = 1$, we have

$$d_{Q+c} = \sum_{i=0}^{K}\frac{1}{K+1} i = \frac{K}{2\lambda} \quad (7)$$

Due to the fact that a node's queue size is upper bounded by a maximum queue size, say K the maximum queuing and contention delay can be estimated. The maximum value of d_{Q+c} denoted by $d_{upbound.}$ can be calculated as

$d_{upbound} = \lim_{\rho\to\infty} d_{Q+c}$

$$d_{upbound} \approx \frac{K\rho^{K+1}}{\rho^{K\lambda}}$$

Therefore, $d_{upbound}$ is approximately defined as

$$d_{upbound} \approx \frac{K}{\lambda} \quad (8)$$

This equation reveals that the maximum value for queuing and contention delay can be estimated as the ratio of maximum queue size over the service time in a node.

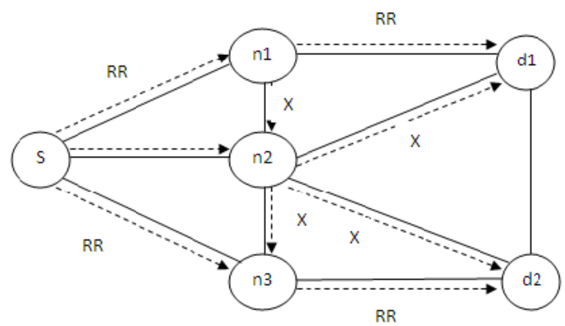
Link stability based multicast routing

A link stability based multicast routing scheme in MANET is proposed. It is a process of creating a mesh of multicast routes with the help of Route Request and Route Reply packets.

Route request

To create mesh network and stable route in mesh from source to destination many types of control packets such as Route Request, Route Reply and Route error packets are used. The Route Request packet containing source address, multicast group address, sequence number, route reply flag, previous node address, power, antenna gain and route reply.

Fig.1. Route request paths from s to d1 and d2



Stable link quality

A major part decides the link stability to form multicast routes. BER (bit error ratio) is defined as the ratio of bits in error to the total number of bits received. It is calculated by determining how many bits transmitted are sufficient for the desired estimate quality. This can be obtained by using the concept of statistical assurance level (AL) and can be defined as the probability that the true bit error ratio (TBER) is less than a specified bit error ratio. The assurance level can be determined by the equation

$$AL = \Pr ob[TBER \leq BERS] \quad (9)$$

The true bit error ratio (TBER) between nodes i and j within AL is given by following equation. The specified error can be calculated if S is the average of standard deviation of many bit errors and a is the accuracy of the bits received,

$$BER_{ij} = \frac{S^2}{a^2} \quad (10)$$

The link quality q_{ij} between two neighboring nodes i and j is inversely proportional to bit error ratio (BER), an improved estimation of link quality with proportionality constant K is given by equation

$$q_{ij} = KX\frac{1}{BER_{ij}} \quad (11)$$

Where q_{ij} is quality depending on parameters such as the interference effect of the wireless channel, Additive White Gaussian Noise and signal transmission range.

Stable link table (SLT)

Every node maintains SLT (Gt=1,Gr=1,L=1,power level 400mW,dij=174, BER=10^{-4}) that stores link and node related messages for establishing and maintaining multicast mesh and stable routes between source and multicast destinations(Qing Dai & Jie wu,2005; Rajashekhar Biradar *et al.,* 2010) . The Stable link table contains the following parameters:

- Node ID (It contains the neighbor node id) Antenna related information (G_t, G_r, L)

- Power level (Pw_{ij}): Whenever a packet is received from its neighbor, this field stores the ratio of power. Pw_{ij} is measured value of the power received (P_r) at the node to the power transmitted (P_r) by neighbour node.

- Distance (d_{ij}): It stores the distance between the neighboring nodes. The distance is calculated by using the free space propagation model given in the equation.

$$P_r(d) = \frac{P_t G_r \lambda}{(4\pi) d^2 L} \quad (12)$$

where G_t and G_r denotes the antenna gains of the transmitter and the receiver respectively. L is the system loss, λ (lambda) is the wavelength, and d is the distance between two MANET nodes.

(e) Stability link(S_{ij}): The value is calculated for a link to a neighbor based on the power level, distance and link quality. Link stability S_{ij} of a link between nodes I and j is defined by following equation.

$$S_{ij} = \frac{Pw_{ij} x q_{ij}}{d_{ij}} \quad (13)$$

Where, Pw_{ij} and d_{ij} denotes the signal strength and the distance between nodes I and j respectively. q is the stable link quality. Substituting the q_{ij} values with BER_{ij} between nodes I and j, we get S_{ij} as given below.

$$S_{ij} = \frac{Pw_{ij} x K x \frac{1}{BER_{ij}}}{d_{ij}} \quad (14)$$

Now the single hop delay to transmit a packet from node i to its neighboring nodes can be represented as

$$d_i = d_{upbound} + S_{ij} = \frac{k}{\lambda} + \frac{Pw_{ij} X k X \frac{1}{BER_{ij}}}{d_{ij}} \quad (15)$$

By applying the above equation in contributing nodes, each node can estimate the delay interval from the time a packet arrives at the node to the time the packet is completely inserted into the network. The delay evaluation in a node can be representative of a certain characteristic of a node. The nodes that are situated in a traffic congested area generally show higher delay due to higher packet arrival rate at a node. In addition, higher latency can also represent longer waiting time that the nodes should use to access the channel due to neighboring interference. Therefore, the nodes with high single hop latency may be located in congested areas where bit error rate is considerably high due to shared wireless bandwidth.

When these nodes receive a join query message, they verify single hop delay requirement within the join query message. Based on their one hop delay estimation, if the node can satisfy the delay requirement, it floods the network with join query message. This method shows the stable link process only to the nodes that can assure one hop delay required. The stable link avoids the nodes located in congested areas or where nodes are occurrence high delays.

Performance evaluation

In this part, the performance of our proposed technique and the original ODMRP under different simulation scenarios are compared.

Simulation setup

The simulation setting used is based on NS2. The simulated setting consists of wireless nodes placed randomly in a 1200 x 800 m2 area with a maximum node speed of 10 m/s. The simulation time is 900s. The radio propagation range is 250m and the channel capacity is 2Mbps. Two Ray propagation model is assumed. The source generates constant bit rate (CBR) traffic. Each node is drop-tail queue. The packet size is 512 bytes. The packets send at the rate of 4 packets/ second. The single hop delay threshold is defined as 10 m and interval of 3s. Each scenario consists of 1 multicast group with 1 multicast source and 20 multicast receivers. The simulation parameters are summarized within Table 1.

Throughput: The network throughput is the average rate of successful data delivery over a communication channel. Throughput is usually measured in data packets per second. The throughput can be evaluate mathematically by means of queuing theory, where the load in packet per time unit is denoted arrival rate λ and the throughput in packets per time unit is denoted departure rate μ .

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The following is a detailed summary of the proposed routing protocol. A wide range of scenarios was applied to investigate the behavior of the SLODMPR. The performance behavior of the LSODMRP, RODMRP and ODMRP was investigated in terms of mobility and number of nodes. The following parameters are used to evaluate the performance of the protocols.

Table 1. Simulation parameters

Network size	1200 x 800 m area
Number of nodes	150
Node speed	1-20 m/s
Radio propagation rate	250 m
Channel capacity	2 Mbps
Packet size	512 bytes
Queue	50 kb
Queuing policy	Drop-tail queue
Duration of experiments	900 s
Routing protocols	ODMRP, RODMRP, LSODMRP
Multicast group size	10-50
Number of sources	1-6

Average-end-to-end delay: The delay of a data packet delivery contains queuing, propagation, and data transfer delays.

Effect of node speed

It means that an efficiency of a network as represented by the data transfer rate of effective and unnecessary data. It is based on various features such as bandwidth, network traffic, error correction etc. The throughput is calculated by the file size divided by the time and higher is the output performance better is the performance. Fig. 2 and Fig. 3 shows the throughput of each model under varying mobility and number of nodes. It can be observed from Fig. 2 that when the number of nodes increases the throughput for LSODMRP is better than the RODMRP and ODMRP. This can be attributed to the reason that LSODMRP maintains link stability between a pair of nodes and establishes a stable route. Similarly it can be observed from Fig. 3 that when the mobility speeds increase, the throughput of LSODMRP is better than RODMRP and basic ODMRP. This is because in LSODMRP, the link stability between source and destination showing good output resulting in the reduced path breakage and improved throughput.

Analysis of control overhead

Figs. 4 and 5 shows the number of control packets increased to establish a mesh with the increase in number of nodes in the network for proposed work. When network size increases the number of control packets decrease at higher multicast group sizes. It is due to the possibility of selecting the link stable path between two nodes. Since this 'LS' happens to be nearest neighbor for all those receivers as per the LS selection rule and it reduces the number of control packets to construct a

Fig.2. Throughput Vs Mobility

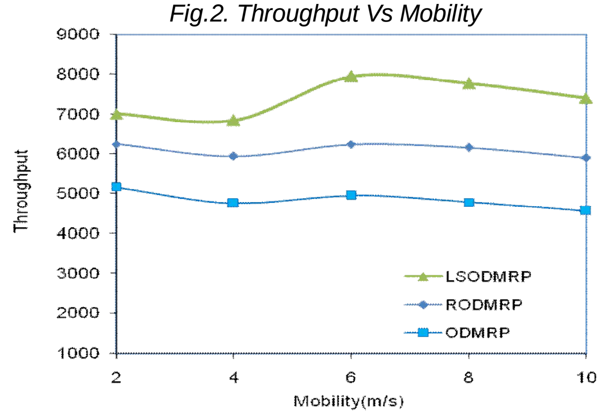


Fig.3. Throughput Vs number of nodes

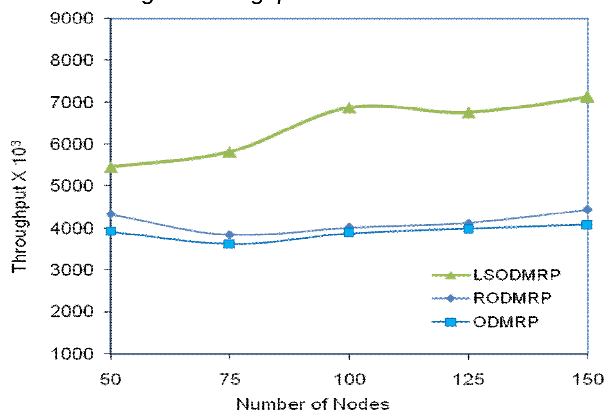


Fig.4 Control Overhead Vs Mobility

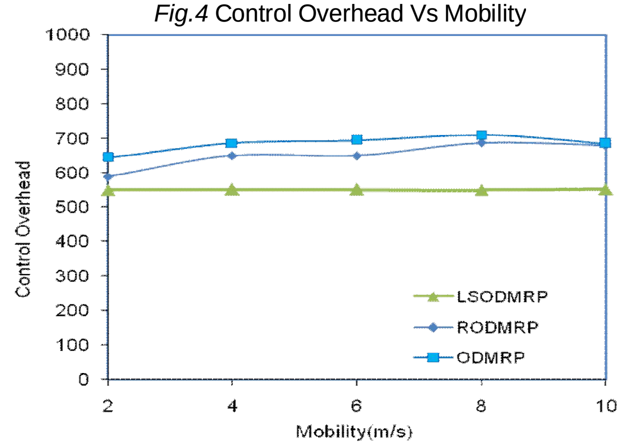
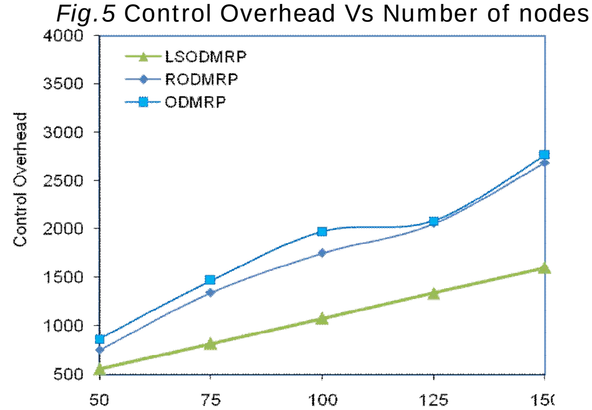


Fig.5 Control Overhead Vs Number of nodes



mesh network. LSODMRP uses less number of control packets compared to the overheads required by RODMRP and basic ODMRP.

Conclusions

In this paper, a link stability based on demand multicast routing protocol in MANET is proposed. The protocol finds multicast paths to receivers by using route request and route reply packets with the help of routing message and link stability parameters maintained in LST on every node in a MANET. Multicast mesh of alternate routes between every source-destination pair is established in mesh creation segment. Link stability within a mesh network is established by choosing link quality among its neighbors. This shows better quality of link stability and decreases the possibility of link failures and the overhead needed to construct the routes.

Link failure conditions are notified to the source with bit error ratio so as to enable the source to start route detection for new path establishments. In addition, simulation is performed to assess the network with control overhead and throughput.

The performance metrics are compared with RODMRP and basic ODMRP. The proposed algorithm showed significant improvements in terms of throughput and control overhead compared with to ODMRP and RODMRP.

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