Multipath Ant Colony Optimization Algorithm (MBEEACO) to Improve the Life Time of MANET

S. S. Kokila[1], Dr. C. L. Brindha Devi[2]
[1]Assistant Professor, Department of Computer Applications
Vellalar College for Women, Erode
[2]Assistant Professor, Department of Computer Science
Queen Mary's College, Chennai

Abstract:- MANET selects a path with least number of intermediate nodes to reach the destination node. As the distance between each node increases, the quantity of transmission control increases. The power level of nodes affects the simplicity with which a route is constituted between a couple of nodes. This research paper utilizes the swarm intelligence technique through the artificial bee colony (ABC) algorithm to optimize the energy consumption in a dynamic source routing (DSR) protocol in MANET. The ABC algorithm is used to identify the optimal path from the source to the destination to overcome energy problems. The performance of the proposed MBEEACO algorithm is compared with DSR and bee-inspired protocols. The comparison was conducted based on average energy consumption, average throughput, average end-to-end delay, routing overhead, and packet delivery ratio performance metrics, varying the node speed and packet size. The proposed MBEEACO algorithm is superior in performance than other protocols in terms of energy conservation and delay degradation relating to node speed and packet size.

Keywords: *ACO, ABC, AntHocNet, AODV, DSR, Energy Efficiency*

*****

I. INTRODUCTION

The Mobile Ad Hoc Network (MANET) is characterized by multihop communication between mobile nodes by wireless links. There are also no infrastructures and routing paths are established by routing algorithms (Figure 1). The traditional routing algorithms and protocols are based on routing schemes, which can find a path for a given node pair according to various metrics, and data packets are transmitted from one intermediate relay node to the next specified relay based on physical condition of wireless channels. The routing algorithm relies on the assumption that the network graph is fully connected and fails to route messages if there is no complete route from source to destination at the time of sending [3]. The key mechanism is the routing protocol that allows finding a path for a given node pair according to various metrics.

The modified ant colony optimization algorithm is used to conduct a multipath search in which the angle factor between nodes is considered. Based on the remaining energy of nodes along multiple paths, a path decision model is established to determine the optimal network routing. In the process of communication, a repair ant is sent along random paths to identify nodes whose energy level is below a certain threshold. The transmission path is then strengthened according to the remaining energy of the nodes. We conduct a series of simulations under two different scenarios, and compare the performance of the proposed method with that of existing routing algorithms. Simulation results show that the proposed algorithm can consume less energy and retain more live nodes, helping to balance the energy consumption of the network.

II. BACKGROUND AND RELATED WORK

Dynamic source routing (DSR) is efficient and ideal for routing in multihop wireless ad hoc mobile node networks. A network can independently organize and configure itself based on DSR, and such network does not require network infrastructure, preadministration, or administration. To ensure that data packets are successfully delivered despite node movements in network situations, DSR affords highly reactive services. DSR is distinct from other protocols because it is capable of source routing, implying that the transmitter knows the overall hop-by-hop route to the destination. A node maintains route caches containing the familiar source routes. The node then updates entries in the route cache as it learns about the new routes. The two major phases of the protocol are route discovery and maintenance.

Ant colony optimization [1] sources from the optimization mode of ant foraging. Ant colony system (ACS) is a distributed biological system. By collaboration, the ants can complete the arduous task that a single individual is incapable of completing, which is the manifestation of biological swarm intelligence. When ants leave the residence to find food, they release the chemicals called pheromones on the path. The pheromone is volatile. Shorter paths can be completed quicker and more frequently by the ants and will therefore be marked with higher pheromone intensity. These paths will then attract more ants, which will in turn increase the pheromone level, until there is convergence of the majority of the ants onto the shortest path. Ultimately, ants can find the optimal path through the cooperation. Routing in wireless sensor networks follows the same principle. The node which needs to send data packets releases the ant-like packets to the destination node, and the ant-like packets are returned from the destination node, forming a path to the final destination node [2-4].

AntNet [5] is developed according to the principles of ACO. It is also one of the most successful ACO-based routing protocols by far. In AntNet, the concepts of the forward ants and the backward ants are presented. The forward ants choose the next hop randomly according to the heuristic information values in the routing tables. And the ID of the node passed will be appended to the head of the ant. All the forward ants are converted to the backward ants as soon as they arrive at the final destination. The backward ant travels back to the source node through the reverse route and releases pheromones on each link passed by.

ARA [6] is the earliest on-demand multipath algorithm that applies ant colony algorithm to ad hoc wireless networks. Routing discovery relies on forward ants and backward ants. In routing discovery, ARA broadcasts forward ants which only carry a unique sequence number. If a node receives a forward ant that it has never got, it sets up a reverse path and rebroadcasts the ant to the neighbors. On the contrary, if the node has received a duplicate ant, it will drop the ant. By this way, only one path can be formed to the destination. When a forward ant reaches the destination node, it is converted to a backward ant and returns following the reverse path. If an intermediate node receives the backward ant, it creates a path to the destination node (including next hop, destination, and pheromone) and then continues transmitting along the reverse path. Intermediate nodes set up the corresponding routing tables instead of dropping same backward ants. The multipath to the destination node can be formed. The updating of the pheromone relies on data packet and time-setting volatilization. No other types of packets are required; thus overhead is reduced.

In ARAMA [7], when a node needs to establish or maintain a path to the destination node, it sends a forward ant to a neighbor node rather than flooding. Intermediate nodes' IDs are appended to the forward ant. What is more, path information of the forward ant (such as hops, remaining energy, bandwidth, and queue length) is also appended or changed. ARAMA defines the concept of the grade. The value is calculated by the backward ant and saved in nodes. The formula of the grade relies on the link information such as energy. When an intermediate node receives a backward ant, the pheromone is updated according to the path gradient of the ant. Pheromone of link which is passed by the backward ants is increased, and the other link pheromone volatilizes. The purpose of volatilization is to make nodes forget the old path quicker. The backward ants are deleted when they reach the source node. The data transmits along the best path. When the best path is destroyed, another path can be used to send data packets immediately.

Di Caro et al. proposed AntHocNet protocol [8]. AntHocNet is an ACO-based multipath hybrid routing protocol. The protocol is reactive in path discovery and proactive in route maintenance. The routing algorithm has four major phases: reactive route establishment, random data routing, proactive path maintenance and exploration, and link failure handling.

MANET Multicasting: Challenges and Issues

Issues and challenges in existing MANET multicasting include the following [9–17].

Resource Management

Mobile nodes in MANETs are limited in resources such as power and memory, so a multicast protocol minimizes the consumption of these resources and utilizes them in such a manner as to ensure competent handling of information with efficient resource consumption, such as by minimizing the use of state information packets.

Link Failure

Because of the random mobility of the nodes and the wireless nature of links, link stability is hard to preserve in mobile ad hoc networks.

Control Overhead

In multicast transmission, we need to keep track of the members involved in the multicast transmission; thus, we need control packets to be exchanged between them. Since only limited bandwidth is provided in MANETs, this may result in significant overhead requirements, so the design of MANET should take into consideration the need to keep the control packet size to a minimum.

Efficiency

In MANETs, errors and failure are more likely to happen than in ordinary networks due to their mobility and limited bandwidth. Therefore, in the multicast protocol design, efficiency is very important. Efficiency as used here is the ratio of received data to the total number of transmitted packets in the network.

Reliability

Reliability is the key issue in multicast transmissions in MANETs, and this can be difficult to deliver due to the differentiation in the members involved and the fact that any member can disconnect from the network at any time, in consideration of its environmental conditions.

Wireless Nature

The wireless nature of a MANET makes it vulnerable to the numerous types of attacks that are common to wireless links such as snooping, interference, and eavesdropping, which may also affect the network resources. Attackers can use these methods to prevent the normal communication scenario among nodes or to capture valuable information.

No Defined Physical Boundary

Due to mobility, we cannot define exactly the boundaries of our network, and the nodes can join or leave the network because of radio coverage. The scalability of MANETs is changing, so the security mechanism must be able to handle large networks as well as smaller networks, which makes for a difficult task.

Absence of Centralized Management

Detection of possible attacks is difficult due to the absence of centralized management such as an access point or base station that can monitor the traffic in a MANET, especially if the network is deployed over a large scale, which may delay the trust between involved nodes.

Infrastructure

Mobile ad hoc networks are infrastructure less, and there is no central administration that can regulate the communication between involved nodes. This means that every node can communicate with other nodes, which makes it difficult to detect faults happening in the network, and because of the highly dynamic topology of MANET, frequent network separation and route changing can result in the loss of packets.

Limitation in Power

The nodes in mobile ad hoc networks are battery powered; this restriction may cause problems such as the loss of packets, or the nodes may work in a selfish manner, meaning that they do not forward messages received.

Trust

The lack of central administration and the highly dynamic topology of MANETs may result in a lack of trust between involved nodes due to the absence of verification and the fact that some nodes may participate in a transmission even if they are not part of the network, which may result in security breaches in the network or leaks of valued information.

Security

Attacks may happen in MANETs due to their wireless nature and the lack of centralized admission of mobile ad hoc networks, which make these networks vulnerable to attacks such as eavesdropping and wormhole or black hole attacks. As such, it is essential for the multicast protocol to ensure security.

Quality of Service

The applications that currently rely on MANETs vary greatly, and these include military applications. Quality of service is an important issue in such applications, but ensuring quality of service by multicast can be difficult for reasons including throughput, delay, and reliability. The design of a multicast protocol should take into consideration the need to provide these parameters.

Energy-Efficient ACO-Based Multipath Routing Algorithm

An ACO-based multipath routing algorithm is proposed in this work. MBEEACO uses a new multipath method. MBEEACO takes into account the energy consumption rate of path, the remaining minimum energy of path, the hops from sink, and the congestion status of path. When a source node which does not have routing information to the destination node needs to send data packets, it broadcasts forward ants to the destination sink node. Sink node generates corresponding backward ants, which will travel along the forward path back to the source node. Backward ants release pheromones on the path when they move back to the source node. In traditional way of pheromone updating, pheromone is more and more accumulated on a path so that more and more data packets will be sent on this path. As a result, network cannot automatically balance load. Different from the traditional incremental pheromone update mode, however, pheromone will be thoroughly updated when a node receives a backward ant in MBEEACO. When a node has multiple paths to the destination node, it will stochastically select one of them in accordance with pheromone to the sink node. The probabilistic routing strategy leads to data load spreading according to the estimated quality of the paths. If the probabilities are kept up-to-date, this will lead to automatic routing load balancing.

Proposed MBEEACO Algorithm

In this work, the ABC algorithm is combined with ACO routing algorithm to implement the MBEEACO routing algorithm In a MANET, all nodes should work considerately and efficiently by sharing information on the quality of the node links and partial routes. This process is similar to the food searching activity behaviors of a colony of bees. The ABC algorithm is suitable for dynamic, flexible, and multi-objective problems. The MBEEACO utilizes the ABC algorithm to search for the path through on-demand nature using context-aware metrics to select the best path. The DSR routing is used by the working bees to locate possible paths.

The proposed MBEEACO algorithm can be described in the following steps:

(1)Nodes generation ()

(2)Initialize the position of nodes

(3)Randomly initialize the speed of each node

(4)Select the source and destination node

(5)Initialize the population of Pi solution Xi,

(6)Each node broadcasts hello message to its neighbors' node to check the node in free or busy state

(7)For each particle

Do

(a)While whole network is not covered

Do

(1)Select the route of (the number of solution)

(2)Find the neighbors of the route

(3)Calculate the distance between each node

(8)Calculate nodes energy probability value for the solution using MBEEACO(1)

(9)End while

(10)End for

(11)Store the best energy routes in array (ID)

(12)While the maximum number of cycles is not reached

Do

(a)Select another route of Xi

(b)Calculate the probability value for the solution step

(c)Update the contents of (ID)

(d)Increment the loop counter

(e)When the current combination of routes of the solution is better than the combination of routes contained in its memory, the particle's position is updated

(13)End while

(14)Memorize the best solution achieved so far

(15)Broadcast the data from source to destination using ACObased on the best energy route.

Packet Structure of MBEEACO

In the packet structure of MBEEACO, the forward ant needs to save all the nodes' IDs which it has visited in Visited node list. The list acts as a blacklist when selecting next hop by using probability formula in neighbor table. That is to say, only the nodes which exist in neighbor table and do not exist in the Visited node have the opportunity to become the next hop. The Visited node field increases the packet length of the forward ant but avoids a loop. The backward ant also followed the nodes in Visited node list to return to the source node.

Figure 1 is the packet structure of the forward ant. Type represents the type of packet. Src_address is the source node's address which produces the forward ant. Seqno is the sequence when the source node generates the forward ant. Every forward ant has a unique sequence number. The node which receives the forward ant can use flag ⟨Src_address, seqno⟩

to determine whether it receives a similar ant. Esum is the sum of energy consumption of the Visitednode by the ant. Esum is used for pheromone update. The Src_time field records the time when ants leave the source node. TTL reflects ants' life-span in the network. It has two main functions; first, it can limit the range of ant search; second, it prevents ants unrestricted in the network circles from wasting source of network. The Visitednode field is used to save all the nodes' IDs which the forward ant has visited.

Type	Src_address	Seqno	Visitednode	Esum	Src_time	TTL

Figure 1 Packet structure of forward ant.

Simulation Set up

Parameter	Value
Simulator	NS - 2.3.5
Channel type	Wireless channel
Protocols	AntHocNet, AOMDV, MBEEACO
Simulation duration	120 second
Packet size	512 kb

Traffic rate	128 bytes
Mobility Models	Random Waypoint
MAC Layer Protocol	802.11
Traffic Models	CBR
Network size	50 nodes
Topology	500 m x 500m

The following performance metrics are used

1.Packet Delivery Ratio

2.End to End Delay

3.Overhead Ratio

Table 1:Comparision of Proposed Routing Protocol vs Existing Routing protocol

No. of Nodes	Packet Delivery Ratio			Overhead Ratio			Average End to End Delay		
	MBEEACO	AOMDV	AntHocNet	AOMDV	MBEEACO	AntHocNet	MBEEACO	AOMDV	AntHocNet
100	3.5	3.4	3.3	2.4	2.6	2.5	1.5	2.1	2.2
200	4.3	3.9	4.8	3.3	2.9	3.2	2.2	3.1	2.9
300	5.4	4.6	5.3	4.2	3.6	4.1	2.7	3.9	3.4
400	5.9	5.1	5.7	5.0	4.3	4.9	3.2	4.5	4.1
500	7.3	6.3	7.0	5.6	4.7	5.3	3.9	5.3	4.6

Packet Delivery Ratio

The connection between the packet delivery ratio of four kinds of protocol and maximum movement velocity of nodes is shown in Figure 2. Besides AOMDV, the other three protocols for data transmission use the mechanism of multipath probabilistic routing, and the delivery ratio of the three protocols is higher than AOMDV. EEABR performs better than AOMDV, which is designed for the packet delivery ratio. As we introduce mobility in the environment, the performance of these protocols decreases substantially. AntHocNet uses the mechanism of multipath probabilistic routing, but the packets will be more likely to send to the link which has more pheromones. With data packets sent, pheromones will be increased on the link and then a "good" path will come to many load streams. Thus, it will cause local link busy and increase packet loss probability.

So AntHocNet is not as good as the MBEEACO in the slowly moving scene. MBEEACO uses a better multipath mechanism; pheromone will adjust with current energy and load condition of the path in time, and the data will be more balanced injected into each path of the network. It leads to automatic load balance in network at last. It will be more reasonable for MBEEACO when the data flow is busy and node movement speed is fast. In addition, the mechanism of link failure recovery of the MBEEACO is more reasonable. As a result, MBEEACO outperforms the other three protocols when the routing problems arise. In the moving scene, MBEEACO protocol shows a better performance in packet delivery than the other three protocols.

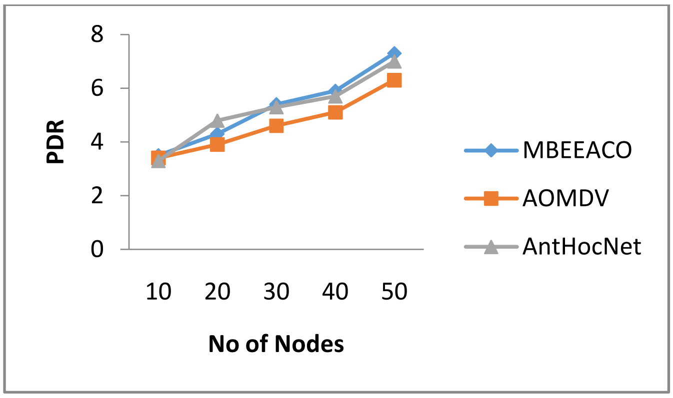

Figure 2: PDR vs Number of Nodes

End to End Delay

Figure 3 shows the relationship between the average delays on end-to-end with nodes' maximum moving speed in four protocols. Obviously, in the aspect of average delay, EEABR, AntHocNet, and MBEEACO are much better than AOMDV. AntHocNet is more likely to send data packets to delay link of the minimum. AntHocNet has better final results compared to the other two protocols when packet sending rate is slow. When the node moves faster, MBEEACO presents the better results.

On the one hand, the multipath mechanism of MBEEACO has completed more paths to the destination node than the other two protocols. Pheromone in each link will adjust with current energy and load condition in time, resulting in load balancing. On the other hand, the MBEEACO will use a mechanism of link failure recovery. When the routing problems arise, it can quickly resume routing and reduce the packet sending blindly and reduce the time delay correspondingly. When a node moves faster, unreachable possibilities of the next hop will increase, and the data packets dropout and routing reconstructs will be increased. In this case, the delay of all the four protocols has tendency to increase.

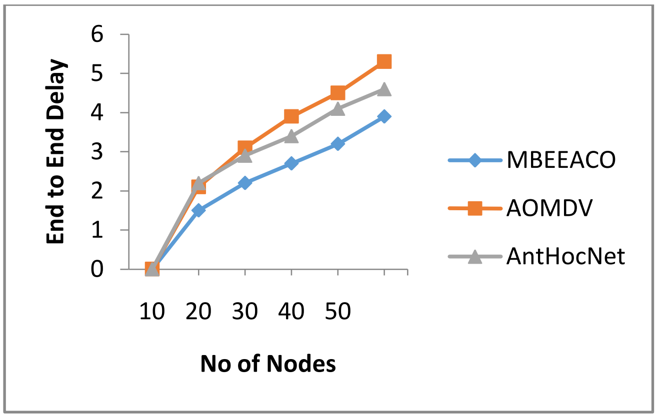

Figure 3: End to End Delay vs Number of Nodes

III. OVERHEAD ANALYSIS

MBEEACO sends the forward ant regularly in route maintenance, through the backward ant update pheromone on paths. What can be seen from the earlier simulation results is that MBEEACO improves data delivery ratio and reduces the transmission delay, but the regular ant transmission also increases routing overhead. Both AntHocNet and AOMDV also regularly send ant package in route maintenance. In many aspects, the routing overhead of MBEEACO is less than AntHocNet. These aspects include the method of forward ant send in route maintenance, multipath mechanism, pheromone update mechanism based on energy, and improved link maintenance mechanism. As Figure 4 shows, the routing overhead of AOMDV outperforms other protocols.

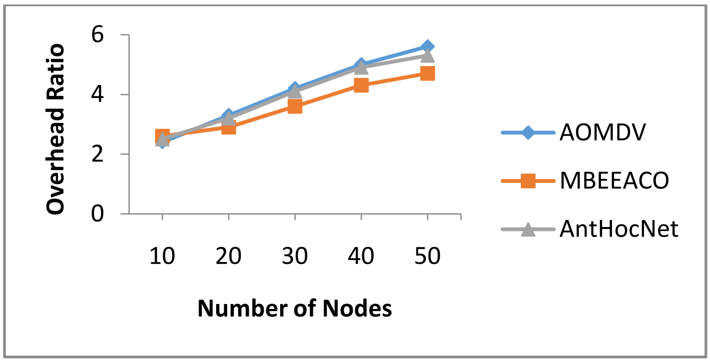

Figure 4 :Overhead Ratio vs Number of Nodes

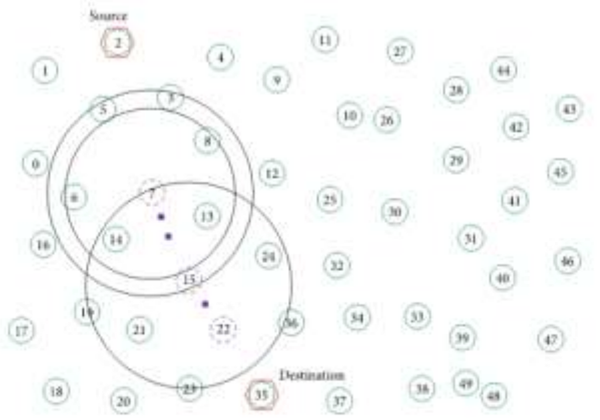

Figure 5: Search for the best available node and nearest path in MBEEACO algorithm.

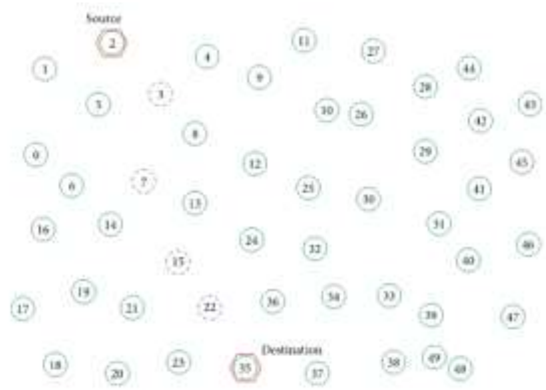

Figure 6: Path selection among the source to the destination in MBEEACO algorithm.

IV. CONCLUSION

In this paper, the existing ACO-based routing protocols AOMDV, AntHocNet and proposed MBEEACO are evaluated. In the MBEEACO, the ant packet structure, pheromone update formulas, pheromone update mode, and the mechanism of multipath established are all enhanced. In the pheromone update formulas, MBEEACO takes into account the energy consumption rate of path, the remaining minimum energy path, the hops to the sink, and the congestion of path. Different from traditional incremental pheromone update mode, the pheromone will be thoroughly updated when the node receives a backward ant. With a new multipath mechanism, MBEEACO can be more reasonable to establish multiple paths between the source node and the final destination node. Probabilistic routing mechanism is designed to make data flow into network more balanced.In particular, we can make conclusions from the performance of MBEEACO, EEABR, AOMDV, and AntHocNet. From the simulation results, it is clear that MBEEACO achieves an improvement in packets delivery ratio, and end-to-end delay.

References

[1] Dorigo, M., Stutzle, T.Ant Colony Optimization2007Beijing, ChinaTsinghua University Press

[2] Saleem, M., Di Caro, G. A., Farooq, M.Swarm intelligence based routing protocol for wireless sensor networks: survey and future directions Information Sciences 20111812045974624l0.1016 /j.ins.2010.07.0052-s2.0-79960558299

[3] Wang, H., Luo, N.An improved ant-based algorithm for data aggregation in wireless sensor networks3Proceedings of the International Conference on Communications and Mobile ComputingApril 2010Shenzhen, China23924310.1109/cmc.2010.1832-s2.0-77953982795

[4] Ullah, I.Bee-sensor: a step towards meta-routing strategies in hybrid Ad hoc networksSwarm Intelligence: Proceedings of the 7th International Conference, ANTS 2010, Brussels, Belgium, September 8–10, 201020106234Berlin, GermanySpringer392399Lecture Notes in Computer Science10.1007/978-3-642-15461-4_36

[5] Di Caro, G., Dorigo, M.AntNet: distributed stigmergetic control for communications networksJournal of Artificial Intelligence Research1998913173652-s2.0-0000873984

[6] Gunes, M., Sorges, U., Bouazizi, I.ARA: the ant-colony based routing algorithm for MANETsProceedings of the International Conference on Parallel Processing Workshop2002Aachen, Germany798510.1109/icppw.2002.1039715

[7] Hussein, O., Saadawi, T.Ant routing algorithm for mobile ad-hoc networks (ARAMA)Proceedings of the 22nd IEEE International Performance, Computing, and Communications Conference (IPCCC '03)April 20032812902-s2.0-0038782825

[8] Di Caro, G., Ducatelle, F., Gambardella, L. M.AntHocNet: an adaptive nature-inspired algorithm for routing in mobile ad hoc networksEuropean Transactions on Telecommunications200516544345510.1002/ett.10622-s2.0-26844541249

[9] Arvind and G. Prasad, “Enhancement of network life time using binary tree based multicast routing protocol for mobile Ad Hoc network,” Global Journal of Computer Science and Technology Network, vol. 13, no. 10, 2013. View at Google Scholar

[10] S. Kim and Y.-J. Cho, “Efficient multicast scheme based on hybrid ARQ and busy tone for multimedia traffic in wireless LANs,” Applied Mathematics and Information Sciences, vol. 8, no. 1, pp. 171–180, 2014. View at Publisher

[11] M. Manjul, R. Mishra, Joytsna, and K. Singh, “Link utilization based multicast congestion control,” Communications and Network, vol. 5, pp. 649–653, 2013.

[12] G. Li and Y. Xu, “A TCP-friendly congestion control scheme for multicast with network coding,” Journal of Computational Information Systems, vol. 9, no. 21, pp. 8541–8548, 2013. View at Publisher · Vie

[13] R. Halloush, “HopCaster: a network coding-based hop-by-hop reliable multicast protocol,” in Proceedings of the Global Communications Conference (GLOBECOM '12), Anaheim, Calif, USA, 2013.

[14] L. Chen, T. Ho, M. Chiang, S. H. Low, and J. C. Doyle, “Congestion control for multicast flows with network coding,” IEEE Transactions on Information Theory, vol. 58, no. 9, pp. 5908–5921, 2012. View at Publisher

[15] M. K. Marina and S. R. Das, “Ad hoc on-demand multipath distance vector routing,” ACM SIGMOBILE Mobile Computing and Communications Review, vol. 6, no. 3, pp. 92–93, 2002.

[16] T. Lathies Bhasker, “A scope for MANET routing and security threats,” ICTACT Journal on Communication Technology, vol. 4, no. 4, p. 840, 2013.

[17] T. Sasanth, S. Umar, and D. Bellam, “A study on data security in MANETS,” International Journal of Computer Science Engineering & Technology, vol. 3, no. 11, pp. 408–415, 2013.

[18] R.Rajeshkanna and Dr.A.Saradha “ Multipath Load Balanced Congestion Control Routing Techniques in Mobile Adhoc Network”, International Journal of Scientific Research and Development,Vol.2015 Issues 5, ISSN:2321-0613