More Stable Ad-hoc On-Demand Distance Vector Routing Protocol

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***Abstract*—Unicast routing, which discovers a path between a source-destination pair, is a challenging problem for wireless ad-hoc networks. Mobility demands additional requirements to be fulfilled during path selections. A neighbor v of a node u, is called "stable" if v's relative movement with respect to u is very low. A path between a source-destination pair is called "stable" if it consists of most stable neighbors at each intermediate hops. Certainly it is always desirable that any routing protocol picks up more stable paths. In this paper, we propose a modified version of popular AODV routing protocol which discovers its route for sending packets based on the stability of the path. Using simulation we show that our protocol is smart enough to cope with the mobility of the network. Finally, we discuss some special scenarios in which our proposed protocol performs much better.**

***Index Terms*—Ad-hoc Network, Broadcast, Mobile Networks, Routing Protocols, ns-2.**

I. Introduction

Ad-hoc network is a computer network which uses wireless links for data transmission. This network is called Ad-hoc because other nodes or modules are used to transfer data from source to destination and the connections are built on the fly. MANet (mobile ad-hoc network), a kind of Ad-hoc network, has become a popular subject to the researchers as notebooks and 802.11/Wi-Fi networking have become widespread [1]. The main criterion of Ad-hoc network is that it is structureless and it can configure itself on the fly. So, need for structured network is eliminated. In this modern age, mobile modules (Laptop, Mobile phones, PDA, etc.) have shown great improvement in performance and memory capacity. Large volume of memory can be encapsulated into these gadgets with high processing power. Researchers around the world start trying to utilize these small, mobile and wireless modules to erect a structureless network of utmost efficiency.

In hostile and rapidly changing environment or on a distant planet, there is no preexistent network system. Then MANet appears as the only tool for communication. At the University of Michigan-Dearborn, several faculty members grouped together to form Vehicular Networking Systems Research Laboratory with the intention of performing interdisciplinary experimental research on vehicle-to-vehicle communication and roadside-to-vehicle communication based on ad-hoc network to avoid accidents. A car can get information of whether there is a traffic jam ahead or whether the road is blocked by roadworks. The driver can then choose alternative path to go. The driver can also be informed of whether a high speed vehicle is coming and thereby avoid accidents. In the roads spiraling around mountains, there is a high tendency of accidents. These phenomena can be avoided by establishing Ad-hoc network among vehicles.

Researchers around the world have been striving for a long time to devise protocols for MANet. They have tried to enhance the performance of wireless network. Reliability of the network is the main concern of their maneuvers. Because, the data packets are transmitted over radio links which are completely wireless. Due to high collision of packets and environmental obstacles, a lot of packets are dropped. This engenders retransmission of data packets, increase in overhead and reduction in throughput.

For the better performance of these metrics, researchers have endeavored different strategies. One of them is to select optimal path through which data packets can be transmitted reliably. Some protocols choose shortest paths, some choose stable paths and some choose routes based on signal quality. The main challenge of these MANet routing protocols is to provide a solid and sophisticated communication platform against the face of widely changing and highly mobile environment. During the last decade, a number of protocols have come into existence. AODV, DSDV, DSR, TORA are emerging routing protocols of IETF MANet working group [2] [3] [4]. Among the protocols, DSR and AODV show good performance in case of packet delivery fraction and routing overhead which are the most important metrics[5]. Because these metrics presage how the packet loss rate is and how the network performs in congested or low bandwidth environments respectively.

In this paper, we have proposed a modified version of AODV protocol which is based on the concept of "stability" of paths. A neighbor v of a node u, is called "stable" if v's relative movement with respect to u is very low. A path between a source-destination pair is called "stable" if it consists of most stable neighbors at each intermediate hops. Certainly it is always desirable that any routing protocol picks up more stable paths. In this work, our main goal is to mold the existing AODV so that selection of routing path would be smart enough to ensure more efficient transmission of data packets. Normal AODV protocol chooses the path of shortest delay/hops while sending packets to the destination. But our modified AODV protocol chooses path based on the stability of the path and this protocol can adapt itself dynamically to cope up with the mobility of network. Existing AODV uses "Hello" messages

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for path maintenance and we utilize these "Hello" messages to measure the stability of routing path [6]. Our proposed modified AODV performs better in highly mobile environment. By selecting more stable paths we try to minimize the number of link/path breakages and thereby alleviating the need for frequent route discovery.

II. Related Work

Many researchers have given significant contribution to the enhancement of Ad-hoc wireless communication. They have devised several routing protocols to increase the performance of Ad-hoc network. R. Pandian, P. Seethalakshmi and V. Ramachandran have designed Enhanced AODV (EAODV) protocol for transmitting video over mobile Ad-hoc network [7]. Their protocol utilizes the stability of the path which is based on signal power received from all other neighbors. They simulated the protocol on network simulator-2 and found favorable results. They showed that EAODV outperforms existing AODV in case of average end to end delay, packet delivery ratio and normalized routing load.

As the nodes are moving and the links are easily breakable, the Ad-hoc networks succumb to several limitations like battery charge constraints, channel fading, frequency reuse, etc. Dr. Natarajan Meghanathan has done a quantitative analysis on energy consumption of the stable path and minimum hop path routing strategies [8].

Vinay Rishiwal, Ashwani Kush and Shekhar Verma have fabricated a stable and energy efficient routing protocol for Mobile Ad-hoc networks. They have tried to enhance QoS of wireless network [9]. Different simulation results show that their scheme functions very well for different network scenarios.

Garbriel Ioan Ivascu, Samuel Pierre and Alejandro Quintero have presented an approach for QoS support in Ad-hoc wireless network [10]. The routing mechanism they have used transmits data through network regions which consist of resourceful nodes and stable links. Sanjay Kumar Dhurandher and G. V. Singh have proposed a Weight Based Adaptive Clustering Algorithm (WBACA) that ensures high degree of stability in the network [11]. They have also compared the performance of WBACA with that of the Lowest-ID algorithm and the Weighted Clustering Algorithm (WCA) against different metrics.

Perumal Sambasivam, Ashwin Murthy and Elizabeth M. Belding-Royer have designed dynamically adaptive multipath routing based on AODV [12]. Their adaptive multipath solution overcomes the problem of frequent route discoveries. Their protocol makes prediction for best path according to the overall stability of the routing paths based on the relative signal strength of the links along those paths.

Srinath Perur, Abhilash P. and Sridhar Iyer have presented a strategy called Router Handoff in which a node detecting that one of its links is becoming weak, hands off routing information to a suitable node [13]. The strategy minimizes link breakage and thereby increases throughput. Their protocol makes decision of hand-off by observing the signal strengths of neighbors.

Rohit Dube, Cynthia D.Rais, Kuang-Yeh Wang and Sathish K.Tripathi have devised a distributed adaptive routing protocol called Signal Stability Adaptive Routing (SSA) protocol [14]. This protocol finds and maintains stable routes based on signal strength and location stability in Ad-hoc network.

III. Main Idea

To find out a stable path between a source-destination pair for sending and receiving data packets is the main purpose of this research. When environment is highly mobile many data packets get lost because of collision. Our main target is to implement a stable AODV in order to achieve high performance in the highly mobile environment. With this end in view, we tried to measure nodes movement in a periodic manner so that we can trace out the most stable neighbor. If every node can store the information about the stable neighbor(s), the stable path from a source node to the destination node can be easily detected. AODV sends periodic "HELLO PACKETS" for detecting the neighbor. We utilize this existing feature of original AODV to find out the stable neighbor of each node. Every node periodically observes its neighborhood for some predefined time say δ amount of time and counts number of hello messages received from its neighbors. Based on this statistics a node decides about the most stable neighbor. When a source initiates a route request packet it simply broadcasts the route request to all its neighbors. A node receiving this broadcast packet rebroadcast to its neighborhood after appending the stability measure (i.e. the hello count) between itself and the source of broadcast. This process continues and stability count gets accumulated hop by hop. In this manner when the packet reaches to the destination, the destination gets a measure of stability of a paths and can easily determine the most stable path. It just sends out the reply packet through this most stable path (in the reverse order).

IV. Definition of Stability

Stability is the quality which asserts the network environment's consistency. In mobile ad hoc network, nodes are continuously moving from one place to another with a certain pause-time. Stability is an important parameter in such an environment. Here comes two types of stabilities – Neighbor stability and Path stability. *Neighbor Stability* gives an idea of the neighbor's consistency in the network while *Path stability* gives an idea of the path's consistency from a source node to destination. Neighbor stability helps us to find out the stable neighbor being used as a next hop node. Path stability helps us to use always an stable path for sending packets.

A. Neighbor Stability

We have used the concept of "moving average" to calculate the neighbor stability. In this case each node calculates the stability of its neighbors considering both old stability and current stability values. By old stability, we mean the stability

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a node has encountered in the previous stability calculation. Stability calculation occurs periodically after a constant time period (i.e. 5 seconds). This event is triggered by a timer which expires after a constant interval periodically. Our moving average equation looks like the following:

$$Stability_{new} = (Stability_{old} \times (1-c)) + (Stability_{current} \times c)$$

Here $Stability_{new}$ is newly calculated stability of the neighbor of a node, $Stability_{old}$ is old stability of the neighbor of a node which is already written in the neighbor management table, $Stability_{current}$ is the number of "Hello" messages the node has received from its neighbor within the last 5 sec. period and "c" is moving average constant which determines the weight imposed on the current stability. The value of "c" spans from 0 to 1. As the value of "c" increases, the routing protocol will put more importance on the current stability measurement. For lower value of "c", the protocol will impose more importance on the old average value calculated. Thus different network works well for different value of "c" and it is a matter of experiment to choose the appropriate value of "c". In our experiment we kept this value to 0.65. Now all the nodes update their stability value in the neighbor management table with the newly calculated $Stability_{new}$ after every 5 sec. Whenever a source needs data transmission, it broadcasts RREQ packets which add up all the $Stability_{new}$ of all links along the path to the destination. The destination calculates the best path[1] by using arithmetic average of stabilities and sends back REPLY through that path.

B. Path Stability

Here, we used "Arithmetic Average" to find out path stability. Path stability can be defined as the summation of neighbor stabilities of all the links on the path from source to destination. As the request packet traverses hop by hop, it collects the neighbor stabilities of all the links on the path it has traveled. When the destination has got the request packet, it retrieves the cumulative stability from the packet and then divides the value by total number of hops in that path.

For example, suppose there are n+1 nodes $x_0, x_1, \ldots, x_n$ on a routing path p_j from source to destination. Now as RREQ packet traverses this path it picks up stability from each node on the path and finally it reaches the destination carrying the $CumStability_{p_j}$. The destination calculates average stability of this path denoted as AS_{p_j} by dividing cumulative value by $HopCount_{p_j}$. If there exists multiple paths between source-destination pair then the destination chooses the path with the highest average stability value.

$$CumStability_{p_j} = \sum_{i=0}^{n-1} Stability(x_i, x_{i+1})$$

$$AS_{p_j} = \frac{CumStability_{p_j}}{HopCount_{p_j}}$$

$$ChosenPath = arg \max_{p_j} \{AS_{p_j}\}$$

[1]most stable path

V. MODIFIED AODV

We have applied modification on the existing AODV protocol by changing selection criterion of routing path. MS-AODV (More Stable AODV) acts according to existing AODV in case of sending RREQ and REPLY packets. Even packet formats are almost same. But for the convenience of measuring stability we have added some extra fields in the neighbor management table of the node and in the packets. Forward path and reverse path setup are almost same as existing AODV with a difference that Forward path setup is delayed.

A. Reverse Path Setup

Before sending data packets, AODV protocol discovers the routing path from source to destination. Source broadcasts RREQ packets to its neighbors and these packets are forwarded from node to node until the desired destination receives this packet. As the node forwards packets it updates its routing table as well as its stability table which is used for comparing stability of adjacent links. Thus several reverse paths are created from source to destination. As the RREQ traverses it carries the cumulative value of the stabilities seen so far. So every node adds its stability to the RREQ packet as it forwards the packet [15] [16].

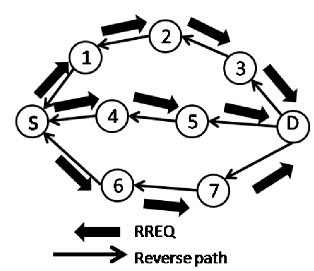

Fig. 1. Reverse path setup

B. Forward Path Setup

This part is different from existing AODV protocol. In existing AODV, the destination sends REPLY packet as soon as it receives first RREQ packet. But in modified AODV, as the destination needs to determine the most stable path, it needs to wait for a short while so that it can receive RREQ packet within this period as much as possible. RREQ packets arrive through multiple paths between source and destination. In each RREQ packet, the destination gets the cumulative stability of the path from the source to the destination. Comparing those values, the destination decides which path to be used for data communication and hence sends a REPLY packet to that path in reverse direction. As the REPLY packet traverses, it sets up Forward path by updating routing tables. Other reverse paths remains untouched which will expire after some time interval.

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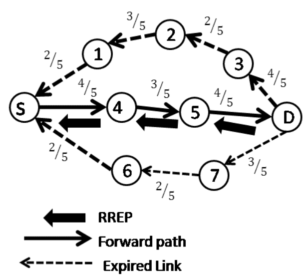

Fig. 2. Forward path setup

C. Stability Measurement Example

For the measurement of stability, we used different metrics. We analyzed the performance of the protocol based on these metrics and investigated which one performs better. These metrics are selected so that the protocol behaves in accordance with the mobility of the network. All these metrics are characterized by number of "Hello" messages. Our protocol measures the stability of the neighbors of each node after every 5 sec. As all the nodes broadcast "hello" messages every 1 second, the stability of the neighbor is defined by the number of "Hello" messages a node has received from that neighbor within the last 5 sec. We can also call it the stability of the link from neighbor to a node. Suppose, in Fig.2, the source "S" has obtained two, four and two "Hello" messages from the nodes "1", "4" and "6" respectively during last 5 second. Now the current stabilities of the neighbors "1", "4" and "6" with respect to the source "S" i.e. the stabilities of the links from the neighbors "1", "4" and "6" to the source "S" are 2/5, 4/5 and 2/5 respectively.

As the RREQ packets traverse, they sum up the stabilities of the links along the paths to the destination. Thus the destination "D" has got three cumulative stabilities $(2/5 + 3/5 + 2/5 + 4/5 = 11/5)$, $(4/5 + 3/5 + 4/5 = 11/5)$ and $(2/5 + 2/5 + 3/5 = 7/5)$. In this example, the destination chooses the middle path according to arithmetic average metric. Other metrics are introduced in order to help our protocol taking smarter decision.

VI. Simulation Results

To compare the performance of MS-AODV and that of AODV, we have used a detailed simulation based on ns-2 (network simulator - 2.26) [17]. All the default settings of the ns-2 are applied. That is, node behavior of the simulation environment is set to the default settings. All packets (both data and routing) sent by the routing layer are stored at the interface queue until the MAC layer can transmit them. The interface queue is FIFO, with a maximum size of 50.

We have utilized different sets of traffic and mobility scenarios to evaluate the performance of the protocols. Traffic sources are CBR (constant bit-rate). The source destination pairs are spread randomly over the network. Only 512 bytes of data packets are considered. Field configuration is set to 670m x 670m field with 50 nodes. Here each node starts its journey from a random source to a random destination with a randomly chosen speed. The speeds of the nodes are varied in the range from 15m/sec to 40m/sec. That is, minimum speed of the mobile nodes is 15m/s and maximum speed of the nodes is 40m/sec. We have varied the pause time which affects the relative speeds of the mobile nodes. Simulations are run for 1000 simulated seconds for 50 mobile nodes. Each data point represents an average of five runs with identical traffic models, but different randomly generated mobility scenarios.

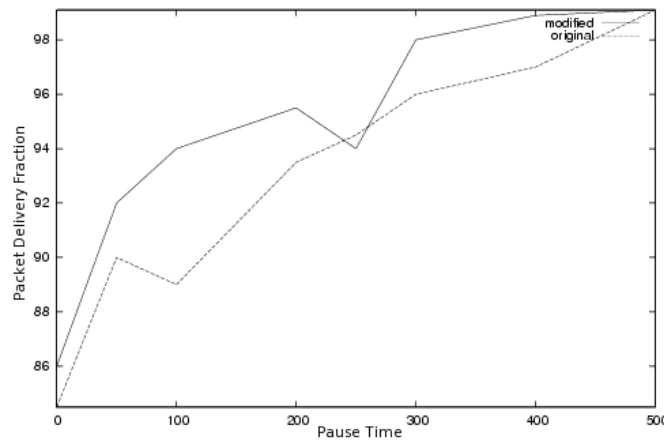

Fig. 3. Impact of Mobility: Packet Delivery Fraction vs. Pause Time

A. Performance Metrics

We evaluate four performance metrics: a) *Normalized Packet Delivery Fraction*– ratio of the data packets delivered to the destination to those generated by the CBR sources; b) *Average End-to-End Delay of Data Packets*– this includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times; c) *Normalized Routing Overhead*– the number of routing packets "transmitted" per data packet "delivered" to the destination; d) *Normalized Route Discovery*– the number of RREQ packets generated per data packets after link breakage.

All the performance metrics are equally important. As MS-AODV waits a while (i.e. 2 seconds) before making its decision about the route, *Average End-to-End Delay of Data Packets* in MS-AODV becomes a little bit higher than that in AODV. But, this delay is small enough to discard. MS-AODV shows extremely better performance in all other cases. Main performance metrics are *Normalized Packet Delivery Fraction*, *Normalized Routing Overhead* and *Normalized Route Discovery*.

B. Organization of Simulation

We simulate the MS-AODV on the basis of two important criteria of the mobile nodes. First one can be titled as Impact of Mobility on the network and the second one is Impact of Traffic Load on the network. Impact of Mobility shows the effect of mobility of the nodes on the performance of the

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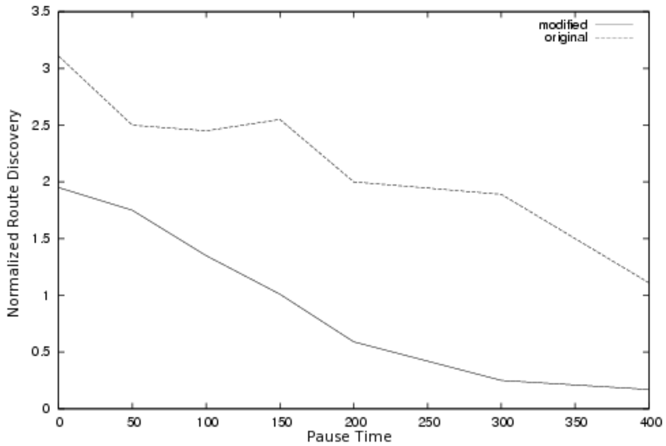

Fig. 4. Impact of Mobility: Normalized Route Discovery vs. Pause Time

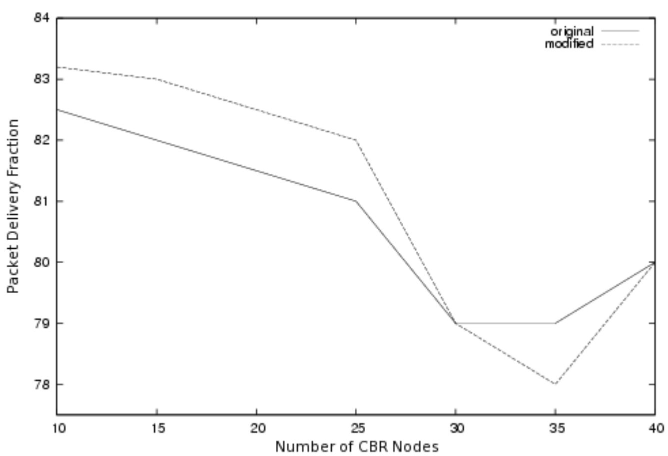

Fig. 5. Impact of Traffic Load: Packet Delivery Fraction vs. Number of CBR Nodes

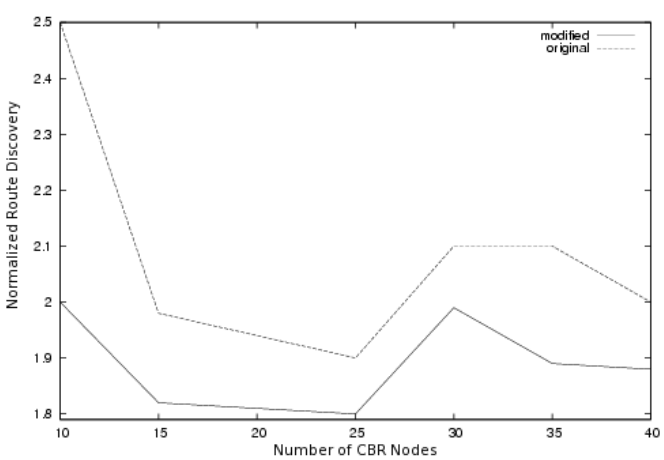

Fig. 6. Impact of Traffic Load: Normalized Route Discovery vs. Number of CBR Nodes (Variation in the number of CBR sources)

network and Impact of Traffic Load shows how the variation of CBR sources affects the performance of the network.

The Impact of Mobility feature consists of traffic files with moderate packet rate and pause time is varied from zero (0) to 500 seconds where total simulation time is 1000 seconds. Two different types of traffic files are considered. First one starts transmitting packets immediately after the simulation begins. Second one waits for a few seconds (250-300 seconds) after the simulation begins in order to gather information about the network's stability and then starts transmitting packets. In both cases all performance metrics for MS-AODV are better than those for AODV. But graphs with delayed traffic files are shown in Fig.3 and Fig.4. In Fig.3 we show the *Normalized Packet Delivery Fraction* and in Fig.4 we show the *Normalized Route Discovery* with respect to Pause time.

Impact of Traffic Load considers the case where number of packets generated is changed by the variation in number of sources and the variation in number of traffic generation rate. Our network consists of 50 nodes where 10 to 40 sources are considered. Fig.5 and Fig.6 show the performance of the network under traffic load with variation in CBR sources. The most mobile environment (environment with zero pause time) is considered to make the situation more challenging for the routing protocol. In all other cases, performance improvement is obvious. The variation of traffic generation rate shows the same performance as variation in number of sources. That case is not shown here.

C. Performance Comparison

Throughout the simulation our main target was to observe the performance of the network in highly mobile environment. As pause time is increased the environment becomes more and more static and MS-AODV performs remarkably well in this environment. So we consider only the average mobile environment, that is, when we evaluate the performance metrics we consider 400s as the maximum pause time where total simulation time is 1000s. MS-AODV outperforms AODV in the most mobile environment and it is the most important thing to consider, because we are trying to establish a stable path from the source to the destination in the mobile environment. From Fig.3, it is obvious that our MS-AODV performs much better than the original one for *Normalized Packet Delivery Fraction*. Fig.5 shows the same performance metric of the network with respect to number of CBR nodes.

Normalized Route Discovery is one of the main criteria to consider here. As the number of route discoveries is reduced, we will get more stable paths. Fig.4 shows the *Normalized Route Discovery* with respect to the pause time and Fig.6 shows the *Normalized Route Discovery* with respect to the number of CBR sources. In both cases, *Normalized Route Discovery* of our modified protocol is much lower than that of the original one. This indicates that MS-AODV selects the stable path in most of the cases and thus it has to initiate route discovery procedure fewer times.

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VII. Conclusion

We have presented a modification of Adhoc On-Demand Distance Vector(AODV) Routing Protocol with the assumption that all nodes will cooperate and no deception is made among neighboring nodes. The modification is solely based on the path stability. We also investigate other mechanisms for measuring stability but path stability seems good to us among all the mechanisms. We can summarize the features of our proposed improved model of AODV:

- Every node stores its all neighbor's stability in Neighbor Management Table.
- Stability measurement is based on path stability which outperforms over all other parameters of stability measurement.
- Use of stable path minimizes overhead for path switching and thus improves packet delivery ratio and also minimizes excessive packet drop.
- No overhead for the maintainig stability information of the neighbors. Original AODV's Neighbor Management Table is used for the purpose.
- Environment is co-operative. It is assumed that every node shares its information. Hostility and deceptive environment is not considered.
- Need for broadcast is minimized.
- Quick response to link breakage as path stability is the selection criteria for next possible path .

We plan to further investigate the proposed model of AODV for multimedia application(Audio and Video data transmission). Quality of Service in MANET field is an attractive issue to the researchers. We envision to make further improvement of our proposed model by considering QoS.

Another possible modification of the proposed algorithm can be considering realistic environment. Any round or square environment for simulation can be considered with high restriction. A square environment with no perimeter coverage or circular environment with no diagonal coverage can be possible proposal for further investigation.

Again we have omitted hostility issue. This can be a great issue for measuring the performance of the Stable AODV. Using cryptic information or deceptive behavior is another issue for measuring the performance. It can easily be viewed considering different types of node behavior. A selfish node can hide information. Lack of information misleads its neighbor and in this way wrong information can be carried through the network. Node can be a bit intelligent and thus it tracks information in the data packet and alters some information and broadcasts the altered packet throughout the network. This raises another issue of MANET named security. In the hostile environment we have to consider secured transmission so that important and advantegeous information can be passed to the destination in a secured way.

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