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Stable Nodes Based Routing Protocol in Heterogeneous Ad-Hoc Networks

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Abstract: Generally, homogeneous networks are assumed to have single interfaces of nodes while heterogeneous ad hoc networks may have multiple interfaces of nodes in which in each interfaces nodes can have different neighbors according to its mobility. Because of the mobile nature of nodes, they usually suffer from communication failure from the neighbor nodes. In order to improve their performance, we need to design a protocol meant for multiple interfaces so that multiple paths can be formed and the path which is most suitable can be chosen. Many routing protocols such as DSR, AODV, and AOMDV have been proposed but they do not work as required in case of multiple interfaces. HAOMDV-NS has also been proposed for obtaining the best path according to the quality of path from the multiple interfaces. In case if two same quality path exists then which one is to be chosen is a big issue because there is the possibility of two paths with the same quality and different transmission rate.

In this paper, time efficiency has been considered for the multiple paths formed due to multiple interfaces. First, we see how a number of neighbors affect the node stability and then how the transmission rate affect the decision of choosing the path. Received signal strength indicator (RSSI) is used to measure the quality of path. Quality of neighbor nodes is used to select the most stable interface. Multiple paths are formed from this protocol and the path with the highest quality is chosen if it is the only path with the highest transmission rate. In case more than one path exists for the same quality then we select the path with the highest transmission rate. If the primary path fails then alternative paths can be used as the route according to their order of stability. The comparison is done on the basis of three major factors which are the delivery rate of packets, delay in packet delivery and overall routing overhead. According to the approach used in this paper, the best suitable path, with maximum node stability and maximum transmission capability can be found for the data to be transferred with the minimum possible failure of a node in given interfaces.

Keywords: HAOMDV-TENS, multi-path protocols, time efficient protocol.

1. Introduction

Heterogeneous ad hoc wireless networks [1], [2] are generally organized in itself i.e. (self-organized wireless networks) and have no infrastructure present in it. The typical characteristics of such HETNET's networks are:

1. Channels having limited bandwidth,
2. Nodes having high mobility factor,

3. Fast transmission ability and
4. Batteries having low power.

While transmitting packets there exist some noise interferences. The above-mentioned features make poor network performance and unstable links. We will be considering the extended version of ad hoc wireless networks in which there exist nodes with multiple interfaces for dealing with these problems. Each interface of the node will be working on different channels with different power consumption and also have different communication ranges. Now to make effective packet transmission in a network, we need to analyze routing for these networks. Routing is a very important research area in any network.

Networks consist of multiple nodes and links. The networks that have nodes with the single interface are considered as homogeneous networks and networks having nodes with multiple interfaces are said to be heterogeneous networks. In these networks, the route is never fixed. The route discovery is initiated by source nodes when it needs to transmit some data to the destination node. This is called on-demand routing. Many on-demand routing protocols such as Dynamic Source Routing (DSR) [3] and Ad hoc On-Demand Distance Vector (AODV) [4] have been implemented. These protocols perform the very simple operation when a source node needs to transmit some data to destination node a path discovery process is started by broadcasting RREQ packets. The best path is chosen from source to destination after this initiation. If the current path fails then these protocols need to reinitiate the whole process again. Node mobility and node interferences are the two major reasons for the breakdown of links between nodes during the transmission. Because of this, low delivery rate and high delay in packet transmission occur. We need to minimize this in any case. Now we need to define multipath routing protocols to handle these problems. Multipath routing protocols use the route request information. Multipath routing protocols find at least one path from source to destination which is stable using the route request information. The most stable path is chosen as the primary path and the other paths are considered an alternative to the primary path by the source node. In case there is a failure in communication link of the primary path due to movement of nodes or from any other reason, the source nodes switch to the other alternative paths and that old primary path is deleted from the route table. Only a few routing protocols such as Ad-hoc On-demand Multipath Distance Vector (AOMDV) [5] and Split Multipath Routing (SMR) [6] are able to find multiple paths during the route discovery process.

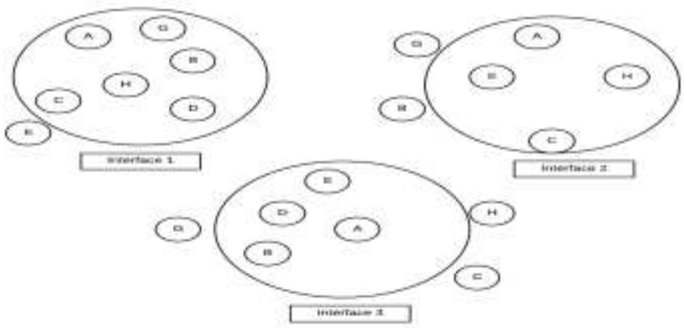

Figure:1 Different interfaces in Heterogeneous networks

On observing the scenario for multiple interfaces given in Figure-1, we can say that each node has three interfaces. In every interface, nodes have different communication ranges and links, and hence every interface has different views according to the nodes.

Node C has three interfaces, neighbors and the communication range are shown in the Figure-1. For achieving better performance for transmission of data, nodes can switch to their different interfaces according to given instances of time and conditions in data transmission stage. In order to have better communication and maximum throughput in the transmission of data, it is a challenge to choose a stable interface. In the example in the figure, we have divided the networks into three interfaces. The different parameters such as neighbors and their stability, the power of operating are different in different interfaces. We will see how these parameters differ by first observing one plane interface. Two factors, transmission range, and node mobility are limited. Because of this neighbor of any node can change frequently. It is common thinking but also practical that a node having more number of neighbor nodes can form many numbers of links as compared to a node having lesser number of neighbor nodes. These links have an SNR ratio which may lead to frame errors and lower throughput[7]. Wireless links are disturbed by all kinds of noises while doing transmission of packets. Every parameter is to be taken into account when selecting the transmission interface.

A protocol based on node stability and time efficiency for heterogeneous ad hoc networks called Heterogeneous Ad hoc On-demand Multipath Distance Vector Routing Based on Time Efficiency and Node Stability (HAOMDV-TENS) has been introduced, which deals the path having higher node stability and working more efficiently with time.

Node stability is defined on the basis of three factors:

1. The average signal strength received.
2. The similarity in vectors representing neighbors at two given instances of time.
3. The total number of neighbors having only one hop.

Signal strength indicates the path quality. To weight these three factors we use the method of Coefficient of variation [8].

Time efficient nodes are considered to be those nodes which transmit maximum data over a given period of time.

This heterogeneous ad hoc network consists of three different interfaces, due to this each node consists of three stability values of every interface and one value for their time efficiency. At a certain interval of time periodically each node broadcasts the WELCOME packets. Accordingly, the stable node is chosen. Now if a source node needs to transmit a packet, it initiates a new route discovery process. Interface with the higher node stability is chosen to broadcast RREQ packets. The given protocol may find the same node stability paths and hence the path from where the transmission would be the fastest i.e. higher time efficient path is chosen. It can be said that the source node lists multiple paths but the path to maximum stability with high time efficiency is chosen as the primary path. In comparison with the older protocol AOMDV, new protocol HAOMDV-TENS give better performance regarding packet delivery, route discovery and delay in transmission of packets.

2. Routing

Source node needs to set up the path to the destination for transmitting the packets. The process of selecting this path is called routing. To understand how nodes establish the connection or the communication, we first need to understand the models of network and how the routes are formed in these different models. Some networks models are discussed below.

2.1 Network Model

HETNETs can be expressed using a graph $G=(V,E)$ where V represents the set of nodes/vertices and E represents the set of links/edges. A unique name or identity is given to every node in the HETNET and also the geographical position of each node is known. It is assumed that in real life example, the node's location in a HETNET is determined by Global Positioning System (GPS) [9]. Nodes are assumed to be arranged in a two-dimensional 2D graph represented by G which is a geometric graph. Every link in the graph between two neighboring nodes is represented by the edge of the graph between two nodes. Also, the weight of an edge is same for all the edges (it is to be assumed). Hence it can be said that two nodes are neighbor only if there exists an edge between two nodes. We will denote the neighbors of a node v_i by $N(v_i)$. A path of length n between a source node S and a destination node D is denoted by $(S= v_0, v_1, v_2, , , , , v_n=D)$ where $v_i \in V$ and $v_i \in N(v_{i-1})$. A path which is selected above all other paths in a network for transmitting data from the source node to the destination node is called the primary path and the other paths are alternative paths.

2.2 Routing based on the position of nodes

In a network, every node contains the information about the position of nodes in its neighbor and also the information of the destination node. In this paper, the GPSR algorithm is used to discover a route from the source node S to the destination node D. It is a greedy approach to use GPSR [10] as in this algorithm the current node, starting from the source node S, determines the next node to be communicated on the route based on:

1. It's position,
2. The position of its one-hop neighbors, and
3. The position of the destination.

During the path building procedure, the node at the given instance looks among its neighbor nodes in the interface to find the node which is closest to the next destination for transmitting the data. If no such node exists in the interface than switching occurs to perimeter forwarding using routing protocol. In perimeter forwarding using the right-hand rule the whole face of planar sub-graph is traversed until local maxima are recovered and the algorithm can continue so that it can terminate when the destination node is reached. It is a greedy approach.

2.3 The approach towards multi-path route discovery

Multi-path route discovery approach help in finding not only the primary path but also other alternative paths for routing, in case the primary path fails then alternative paths can be used as the primary path. This approach was originally presented by Yang et al [11]. The protocol presented by Yang et al is called the Greedy-based Backup Routing Protocol (GBR). In this protocol, firstly a path is discovered from the source node S to the destination node D using GPSR. This path will be considered as the primary path. Backup paths are also traced for providing link protection to the primary path. A lifetime of these links and the whole path must be known. $LET(v_i, v_{i+1})$ be the expiration time of a link $v_i v_{i+1}$, and $PET(P)$ be the path expiration time of a path P. $LET(v_{i-1}, v_i)$ is expressed as

$$LET(v_{i-1}, v_i) = \frac{-(pl+qd)+\sqrt{(p^2+q^2)R^2-(pl+qd)^2}}{p^2+q^2} \quad (1)$$

where $p = \tau_{i-1}\sin\theta_{i-1} - \tau_i \sin\theta_i$, $q = \tau_{i-1}\cos\theta_{i-1} - \tau_i \cos\theta_i$, $l = X_{i-1} - X$, $d = Y_{i-1} - Y_i$ and nodes coordinates are (X_i, Y_i), the velocity of two nodes are τ_{i-1} and τ_i, angles of the direction for the two nodes are θ_{i-1} and θ_i, and transmission range be denoted by R. A table called neighbor table is maintained by every node to store the unique id and position of each neighbor node. a primary path table, which stores primary path information for a destination node. Except for the neighbor table, three more table are maintained:

1. A primary path table to store the information of primary path.
2. A backup path table to store the local-backup path information for the links in the primary path.
3. A Route Request (RREQ) table, which stores information about all received RREQs.

A data cache will also be required in this approach. In a fixed period of time, all nodes in the network broadcast the WELCOME messages consisting of their IDs and the position information to their neighbors.

2.4 Connection survival scheme based on node Protection

Link and node expiration in a network is a big problem. Multi-path routing protocol aims to handle both link expiration and nodes that become unresponsive in HETNETs. It deals with:

1. Mobility,
2. Break-down of links, and
3. Nodes disappearance and reappearance.

A node protection scheme for the route survival is introduced. In HETNETs it can also be considered for link protection.

2.5 Protection of links and nodes

To have a stable communication in any kind of network either heterogeneous or homogeneous, it is important to protect the link from breakage and nodes from failures. More protection of nodes and links means more efficiency of the network communication. Not only links are to be protected from breakage due to mobility but also the nodes from getting damaged and losing the connection [12]. Loss of node in any network is a loss of communicating neighbor to all nodes at that instance. It is seen, if a node of primary path fails then it will lead to a recalculation of the whole path from source node to destination node. In a heterogeneous network, due to the mobility of nodes and a different configuration of nodes, it can lead to repeated failure of communication links and recalculation of the path will lead to wastage of time. It is highly undesirable for the network. If we use multiple path protocols, we will be able to define multiple paths from the source node to the destination node for data transmission, if anyhow primary path fails then from the other list of alternative paths, another path can be chosen.

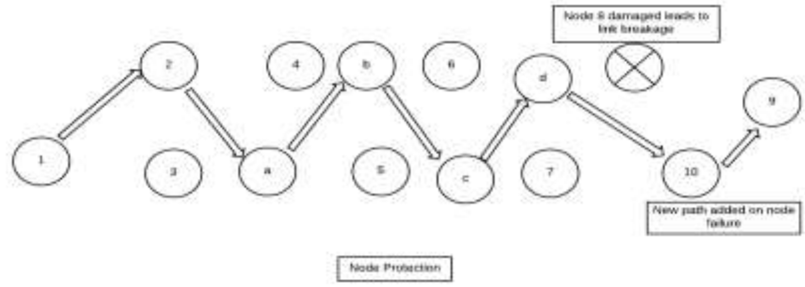

Figure:2 Node Protection

Due to the introduced factor of the backup path, routing overhead is decreased. Our focus of the paper is to find the path with the best quality and fastest transmission, multiple path approaches secure our communication by using the alternatives of the primary path, it gives maximum throughput. Each node of the primary path can be recovered and till that time the alternative path will serve as the primary path. To protect the node we can use other nodes for the path. Each node is bypassed during the failure. In case of link failure, we do not replace the whole path by backup path instead replace only that node from which communication has failed. This is heavier than node failure. In this, the whole path needs to be calculated to replace only that particular node.

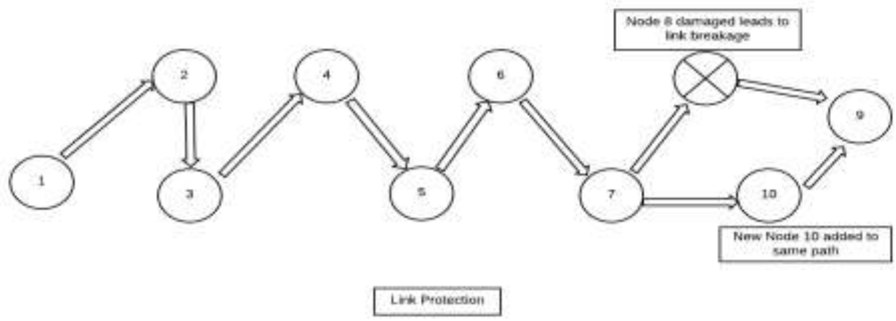

Figure:3 Link Protection

2.6 Node Protection Algorithme

To determine the backup paths for node protection, we do the following. First, the primary path is determined as described above for GBR. During the transmission of the RREP back to S, when an intermediary node v_i, or S, receives this RREP, it computes a node protection backup path P_b for v v_{i+1} from v_i to v_{i+2} using only links between nodes in P_b with LET greater than $PET(v_i, v_{i+1}, v_{i+2})$ while ignoring the node v_{i+1}. We will consider that the node v_{i+1} has no node protection backup path if we cannot find a path P_b from v_i to v_{i+2} which it satisfies the condition of $PET(P_b) > PET(v_i, v_{i+1}, v_{i+2})$. We will call this protocol based on GBR but using node protection (NP) rather than link protection as GBR-NP.

3. Related work

There have been three major factors in any routing protocol. These are:

1. Bandwidth utilization,
2. Lowering the overheads, and
3. Improving the delivery system of networks.

Multipath routing protocol has been introduced to enhance these factors up to an extent [13] [14]. It can be seen that protocols based on signal-to-interface and noise are used for multipath routing protocols. A similar case in a protocol called cross-layered multipath AODV (CM-AODV) [15] introduced by, J. Park. SINR helps in determining the quality of the route. Minimum SINR of the link in path defines the quality of the route. Each node while forwarding the RREQ packet updates the quality of the route. Primary paths and alternative paths are determined by the destination node in CM-AODV protocol. Due to this, the overhead occurred at the intermediatory nodes is reduced and route discovery becomes more simple.

Another work related to multipath formation has been discussed in [16]. Mobility Prediction Ad hoc On-Demand Multipath Distance Vector (MPAOMDV) routing protocol has been introduced by Puts. In this, it can be seen that source node plays the major role in selecting the best route having the best (strongest) signal strength for transmission of data. Source node unicasts the update packet in a certain period of time repeatedly for every single path for measuring the signal strength of path hop by hop. Multiple paths are formed in this case also.

Work on multiple paths formation is also seen in HAOMDV-NS [17], where the focus is made on the formation of multiple paths and then selecting the most stable path for the transmission of data to the destination node. In this paper, there is selection based on path quality and then HAOMDV-NS is extended such that if there exists more than one path with same quality value then the path which is more likely to transmit data fast, can be chosen i.e. transmission capability of different paths is taken into account. Name of this new algorithm, based on time efficiency and node stability, is HAOMDV-TENS.

4. Stability model

For selecting the most efficient node from the most stable interface for transmitting packets, an efficient node stability model for routing is proposed in this section. Higher stable nodes will be having a neighborhood with more stability and will also be capable of strong transmission ability. Nodes random movement and their limited battery power can lead to weak links between different nodes that can break easily during transmission of data. Communication occurs between nodes and its neighbors only. Hence node’s ability of transmission mostly relies on its neighbors. In an ad hoc network, neighbor nodes have an important role in calculating the node stability. More information based on neighbor nodes is discussed in the rest of the sections. To understand how an interface works we discuss network parameter for only one interface.

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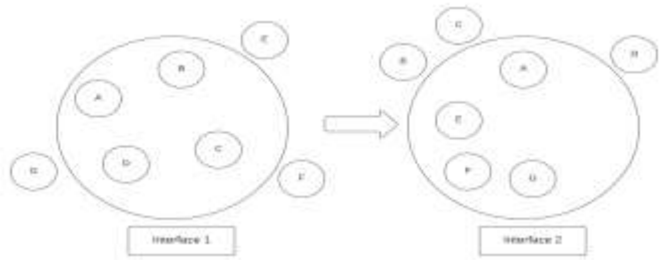

Figure:4 Neighbor of center nodes

4.1 Neighbor nodes affecting the stability

RREQ packet is broadcasted by a node to its neighbors for constructing a connection in order to discover routing path. Due to more neighbors nodes around a single node more reverse paths are constructed and also multiple paths may form to the destination node. So, it can be said that neighbors of nodes are a key factor in the construction of multiple paths. In case the primary path fails, then there is another routing path for the source node to transmit packets to the destination node. In judging node stability, a number of neighbors plays an important role.

If we consider only neighbor nodes in judging stability then it will not be fair. As it is possible that neighbor changes and links breaks. Clearly in Figure 2, at time T_i node A has a communication range, and in this communication range node B, C and D lie. Nodes E, F and G are not in the range of node A. Total number of neighbors around node A is three. Now due to the movement of node A from one instance to another instance, its neighbors get changed. At the time T_{i+1} node A again consists of three neighbors but now these neighbors are E, F, and G. Because of this difference the communication links for node A at the time T_i were broken at the time T_{i+1}. It is not appropriate to consider only the neighbor count as the factor of building the stability, as there are some other factors which have changed in the neighborhood and require attention. Hence a parameter called neighborhood similarity has to be taken into account.

Let the neighbor nodes be denoted by some vector. Then neighboring similarity can be expressed by the angle between the two vectors of nodes. If the neighbors of nodes are same at Ti and Ti+1 then the vectors of neighbor nodes would make no difference in relative angles, and hence both the vectors will posses equality and the difference in their angle remain 0. In case the node does not possess any common neighbor at any two instances of time, then the angle made by the vector will be a right angle i.e. the angle will be 90. The neighbor similarity with higher values can be indicated with higher cosine values, it means larger the cosine value larger will be the neighbor similarity factor. Mathematically it can be defined as, the cosine value of the angle between the two neighbor vectors. Let the first vector be $< x_0, x_1,,,, x_n >$ and the second vector is $< y_0, y_1,,,, y_n >$, then the neighbor similarity can be expressed as the cosine value of the angle between these two vectors :

$$f = \frac{x_0 y_0 + x_1 y_1 + \ldots + x_n y_n}{\sqrt{x_0^2 + x_1^2 + \ldots + x_n^2} \sqrt{y_0^2 + y_1^2 + \ldots + y_n^2}}$$

(2)

in this f denotes the cosine value and its magnitude can be used to judge neighbor similarity.

After selecting the stable nodes for choosing a path, the node with maximum time efficiency is chosen so that maximum data can be transferred in a minimum amount of time. Time efficient system is very important for processing a large amount of data.

Received signal strength indicator (RSSI) [18] reflects the nodes transmission ability to some extent. If the power of the node is low, then the link may get damaged and break, it may lead to packet loss. So we need to consider those nodes with maximum stability including time efficiency factor and power factor.

4.2 Judging the node stability

Factors affecting the node stability according to the discussion done above are:

1. Number of neighbors,
2. Neighbor similarity,
3. Average RSSI, and
4. Time Efficiency.

These factors can be used to define the node stability as follows:

$$f = \alpha N + \beta S + \chi R + \delta T$$

(3)

In above mathematical expression N represents the total number of neighbors, S denotes the neighbor similarity, R represents the average received signal strength indicator and T denotes the transmission time of the node. α , β , χ and δ represents the fours factor's weight coefficient. The coefficient of variation (CoV) method is used to weight these factors. The ration between the standard deviation and the mean of values is called CoV. A mathematical expression is:

$$C_i = \frac{\delta_i}{\overline{x_i}}$$

(4)

in which C_i represents the CoV, δ_i represents the standard deviation and $\overline{x_i}$ represents the total mean. The first task is to collect the historical data. Then for every factor, we have to calculate the CoV. This can be mathematically expressed as:

$$W_i = \frac{C_i}{\sum_{k=0}^{n} C_k} \tag{5}$$

This weight factor can be used to determine node stability. More neighbors around a node mean a number of available links for transmitting data from source to destination. Considering the neighbor similarity, it can be said that if it is higher, then the possibility of losing the node or more clearly losing the connection to the link is lower. This will lead to the path having more stable nodes and the best path for data transmission. Considering the higher value of RSSI we get the stronger transmission ability in nodes in networks. And the last one, if more time efficient nodes, it fastens the transmission ability of nodes in the network. After measuring all these factors node stability is determined and it can be said that a node having stability is confirmed to be more stable. Values of these factors are updated by different nodes periodically. The most recently updated information is used to calculate the stability of a node and these calculated stability values are then further broadcasted to neighbors nodes by WELCOME packets. Like this, every node will have recently calculated neighbor's stability value. In the calculation of interface, at first, the node calculates the average neighbor node stability for each interface and then select the interface with the largest mean value.

5. Multiple Paths Based on Stability and Faster Transmission Rate

The protocol for multiple paths considering node stability called Heterogeneous Adhoc On-demand Multipath Routing Based on Time Efficiency and Node Stability (HAOMDV-TENS) is presented. Path quality of the multiple paths is determined using the received signal strength indicator (RSSI). After calculating the quality of paths, if the same quality path exists then the path with faster transmission rate is chosen. Route discovery process with the stable interface selection according to the stability of node and faster transmission is described. After the selection of path data transmission using the chosen path occurs and if it fails then alternative paths are used to select the primary path from them.

5.1 Path Quality and Route Table Modification

A general routing protocol in a heterogeneous ad hoc network chooses a path consisting only hops. Paths having fragile links are also selected. This result in a low delivery. It is considered that any route with a lesser number of hops is not necessarily the best route of all. Neighbors ability to transmit the data can be determined by RSSI. And so RSSI can be used to represent the path quality and points to the calculation method like paper [19]. When a route is set, it consists of links and nodes, the quality of this path depends on the links between the nodes. The route is broken if any link fails. By considering this situation, we define the path quality as follows.

Let there be a path from source to the destination named as P consisting of some nodes $\{n_0, n_1, \ldots, n_n\}$, then the mathematical expression for the quality of path can be represented as

$$P_q = \min_{0 \le k \le n-1} RSSI(n_k, n_{k+1}) \tag{6}$$

where n_k and n_{k+1} are nodes having same links in P and $RSSI(n_k, n_{k+1})$ is RSSI of a link $< n_k, n_{k+1} >$ for $0 \le k \le n-1$.

Route table and packet format must be modified to understand and determine the better path quality. Two new fields are added at the end of the header, first one for determining the path quality using RREQ and RREP and a second field for determining the time efficiency of the path. The value of quality is the smallest RSSI of links along the path and highest time efficiency along the path. This path quality factor will be used to find the best route in the network for transferring the data, then best time-efficient root will be chosen if there exists more than one path with same quality.

5.2 Route Discovery Process

HAOMDV-TENS provides a very simple path discovery process and is same as compared to AOMDV, the only difference is the path quality and time efficiency. These two factors are added during the RREQ and mechanism of selecting an interface occurs before forwarding RREQ. The process of route discovery includes the Route Request process and Route Reply process. Now in starting of the process, we can have a source node with a packet to be transmitted and no route available initially. The source node generates an RREQ. The interface is selected using the mechanism discussed above so that the most stable interface is selected for broadcasting RREQ packets. Nodes coming in between the source and destination may receive many instances of RREQ with the exact same source address and same broadcast id. Path quality and time efficiency of different paths are updated by the nodes after collecting the set of RREQ packets. There is a certain period of a timeout after that intermediate node chooses the path with the highest quality, and in case more than one path exists having same path quality then time efficiency factor is given the preference to set up a reverse path. The most stable interface is selected to forward the RREQ packets if there is no path to the destination. If there are others packets of RREQ with same address of the source and same broadcast id then these RREQ packets are dropped immediately. Destination node acts a bit different from the source node, after receiving first RREQ packet, it waits for two periods of RREQ WAIT TIME. Then after this timeout, the destination sorts the received RREQ packets by the two factors, path quality and time efficiency and handles the Packets.

5.3 Transmission of data and maintaining the route

Source node discovers the multiple paths from source to destination for the transfer of data. The source node chooses the path with the highest quality and highest time efficiency. This path will be considered as the primary path and other paths will be considered as alternatives to the primary path.

Let there be three paths with same path quality named. We check for the time efficiency of this path as how much time each path takes to send the same data in a heterogeneous network. Then the optimal path is chosen. Let the time efficiency factors for three paths be τ_1, τ_2, τ_3, now path with maximum quality is chosen as :

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$$O_P = \max(P_1 + \tau_1, P_2 + \tau_2, P_3 + \tau_3) \quad (7)$$

Where, O_P represents the optimal path.

The primary path is used unless some link breakage occurs and path fails. If primary path fails then source node deletes the path data from route table and switches to the other path having the best quality and fastest route possibility.

5.4 Selection of stable path

When stable nodes are collected together to make the most stable path in the communication network, a best quality path with maximum delivery ration is configured with these nodes. A table of different paths is observed according to node stability and time efficient nodes. The path having maximum quality is ordered first according to time efficiency. If the primary path chosen for data transfer fails, the alternative path from this table can be used as a primary path for the instance while the primary path is being repaired or reconfigured.

6. Simulation and analysis

The proposed algorithm is to be validated from different aspects such as packet delivery ratio, delay in packet delivery and route discovery overhead. To have a comparison between this new protocol and the older protocols, we will be considering another multipath routing protocol named AOMDV supporting a number of different interfaces [20]. In order to investigate the effectiveness of multiple interfaces, scenarios of a single interface will also be simulated.

6.1 Environment

Nodes are assumed to have a random motion and are free to move. They can move in any direction at any instance of time. Parameters required for simulation are listed in the table given below. These parameters include the time taken in simulation, size of the message, node mobility, the rate of message, transmission bandwidth, etc. For validating interference scenarios, four additional interference sources are set and every source is capable of making side effects on at least one interface of nodes either in communicating or forwarding data packets.

Parameter	Value
Time for simulation	1000s
Size of message	512 bytes
Routing Protocol	HAOMDV-TENS,AOMDV
The speed of movement of the node	1-10 (m/s)
Message Rate	10 packet/s
Transmission Bandwidth	2 Mbps

Number of Connections	2-20
Number of Nodes	20
Number of Interfaces	3

Table:1 Simulation Parameters

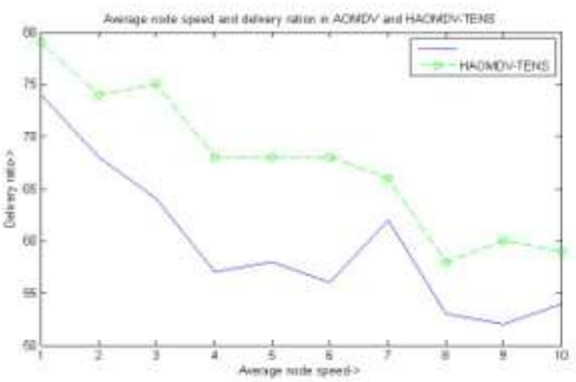
7. Simulation Result

This section represents the result of the simulation. The results are analyzed and compared. We use two algorithms HAOMDV-TENS and AOMDV. We will be observing results from three aspects:

1. Delivery ratio,
2. Delay in packet delivery,
3. Routing overhead.

7.1 The rate of packet delivery

Due to movements node in a network, there are chances of the disturbance in root of data transfer. Because of this, there can be loss in path due to node loss. More movements indicate more loss in path. When we make the path by the most stable nodes then there are fewer chances of loss of node due to node movement as compared to the path made by the unstable node. When we use node stability algorithm, we use most stable nodes. Clearly in AOMDV ratio of packet delivery is always less as compared to HAOMDV-TENS for any node speed. This node speed is due to the factor of mobility of a node in a heterogeneous network. Here mobility problem to an extent is solved by using the new protocol.



Graph: 1 Average node speed vs delivery ratio

On plotting the graph of delivery ratio on average node speed for AOMDV and HAOMDV-TENS, we obtain the graph-1, which can be manipulated to table given below.

Average Node speed (m/s)	Delivery ratio of AOMDV	Delivery ratio of HAOMDV-TENS
1	74	79
2	68	74
3	64	75
4	57	68
5	58	68
6	56	68
7	62	66
8	53	58
9	52	60
10	54	59

Table:2 Average node speed and delivery ration in AOMDV and HAOMDV-TENS

Now for any instance of HAOMDV-TENS. We see if there exist two paths of the same quality. If there exist such paths like given in figure 4, there are two paths for the same source node and destination to transmit data, then we use the path where the overall timing of transmitting data is less.

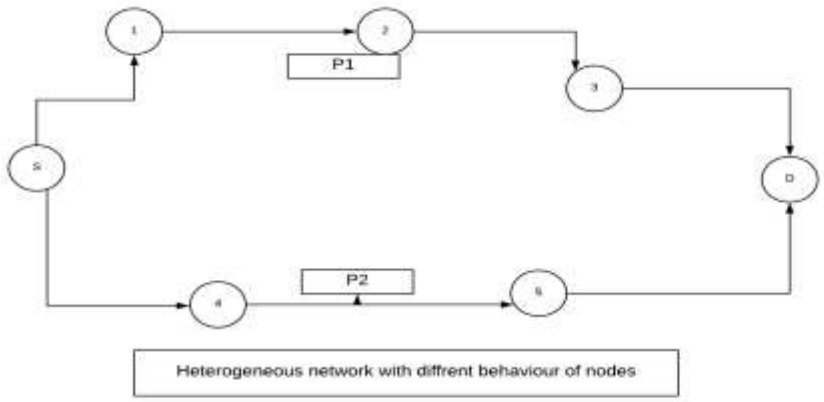


Figure:4 Different transmission behavior of nodes

For the average node speed of 5 (m/s), there exist two different paths which are obtained by the multipath protocol. Now a source has the information of time efficiency. Hence source node S chooses path P1 to transfer the data instead of path P2, although there are a lesser number of nodes in path P2. Hence the delivery mechanism is improved in this way. Most reliable path and fastest path can be found for the source node to transmit data.

7.2 Delay in packet delivery

Packet delivery is an important aspect of the communication network. On using the multipath protocol, we achieve the maximum quality path and using time efficiency we achieve the maximum quality and time efficient path for the transmission of data from the source node to destination node. High transmission of data from the source node to the destination node reduces the overall delay in transmission of data. As seen above if at average node speed 5 (m/s), we have heterogeneous nodes with a different transmission speed of data in two different paths from source to destination. Then we can choose the path with the highest transmission rate and reduce the delay.

Table: 3 same quality path with different time efficiency

Path	Quality (Grade)	Time Efficiency (%)	Delay (ms)
1	A	0.6	60
2	A	0.4	80

Using HAOMDV-TENS, we achieve the minimal delay in transmission. We choose path P1 for the transmission. This is a normal problem faced in the heterogeneous network because every node in a heterogeneous network can behave in different ways.

7.3 Routing Overhead

In HAOMDV-TENS, a record of an alternative path is kept so that if primary path fails then alternative paths can be used. These alternative paths are arranged in descending order of their overall performance i.e. in descending order of quality of path with their time efficiency.

Table:4 Table for a different path according which primary path is chosen

Path	Quality	Time Efficiency	Considered as
Path 1	A	0.6	Primary Path
Path 2	A	0.4	Alternative Path
Path 3	B	0.7	Alternative Path
Path 4	B	0.4	Alternative Path
Path 5	B	0.2	Alternative Path
Path 6	C	0.5	Alternative Path
Path 7	C	0.3	Alternative Path

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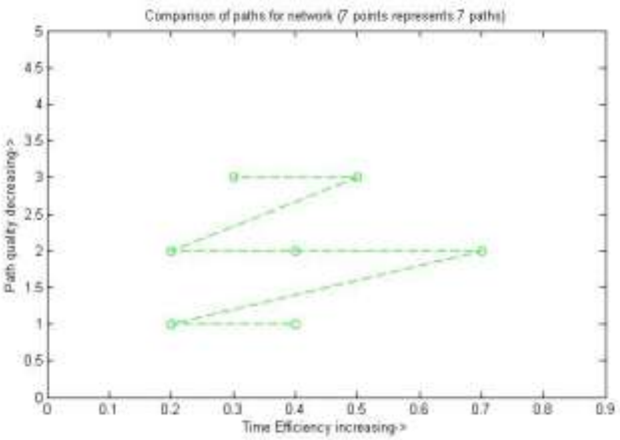
In the given table, after one initiation of protocol, multiple paths are formed from which we can choose primary and alternatives. Quality A is better than quality B, like grade system. If anyhow primary Path 1 breaks, then Path 2 will be used and considered as primary, in the table they are shown according to their priorities. After a path fails, it is deleted from this table. The extra overhead of routing and re-routing is decreased to an extent from HAOMDV-TENS.

This can be pictorially represented as below graph in which we chose a path from the right side and down most point and then continue in its direction for alternative paths.



Here the first primary path will be a point with efficiency 0.4, and quality 1, then point with efficiency 0.2, and quality 1, like this we will follow the graph and choose the path.

8. Conclusion

This paper introduces a new heterogeneous ad hoc routing protocol based on the formation of multi-paths during the transmission of data. A new observation-based multipath protocol on maximum node stability with highest time efficient nodes have been introduced. Every node in the networks defined in the paper consists of multiple interfaces, the important thing is how we select the stable interface. Importance of neighbors have been discussed in the paper and using the neighbor similarity methods in a heterogeneous ad hoc network during the transmission of packets, we measure the three things:

1. Node stability,
2. The neighbor similarity between adjacent time, and
3. The average received signal strength indicator from neighbors.

CoV method is used to weight the factors in order to calculate node stability. According to the result of node stability, the transmission interface is selected during the routing process. During the forwarding of RREQ packets and selection of the primary path, path quality is a major factor to be involved. Those nodes which are receiving the packets of RREQ do not handle them at that time only, there is a wait time for collecting the whole set of RREQ packets from neighbor nodes. An intermediate node only forwards packets with the highest quality. And at last the destination node receives the list of paths having best qualities. Now the destination node sorts the paths according to the best quality and then according to the time efficiency. At the end of the whole process, there exist multiple paths among which a primary path is chosen and others are considered as alternative paths. Now we need to choose an optimal path from the multipath for transmission, and it can be easily done on the basis of time efficiency. The path having more time efficiency factor is to be chosen for routing purpose. In the three parts of observation, we see how effectively the new proposed protocol HAOMDV-TENS defeats the other algorithm in case of packet delivery, delay in packet delivery and decreasing the routing overhead. The advantage of this approach can be seen in case we lose the primary path, the alternative best path can be used by the paths list stored in the cache.

Refrences

[1]. C. E. Perkins, Ad hoc networking. Addison-Wesley Professional, 2008.

[2]. Qiu, Tie & Chen, Ning & Li, Keqiu & Qiao, Daji & Fu, Zhangjie. (2017). Heterogeneous ad hoc networks: Architectures, advances and challenges. Ad Hoc Networks. 55. 143-152. 10.1016/j.adhoc.2016.11.001.

[3]. O. Abu Salem, Amer & Samara, Ghassan & Alhmiedat, Tareq. (2017). Performance Analysis of Dynamic Source Routing Protocol.

[4]. Uddin, Md Ashraf & Akther, Arnisha & Parvez, Shamima & Stranieri, Andrew. (2017). Efficient route selection in ad hoc on-demand distance vector routing. 1-6. 10.1109/ICCITECHN.2017.8281807.

[5]. Jayanthi, N & K R, Valluvan. (2018). Hybrid routing algorithm for improving path selection in sustainable network. Cluster Computing. 10.1007/s10586-018-1903-y.

[6]. Kato, Yukiya & Ono, Fumie. (2011). Node Centrality on Disjoint Multipath Routing. Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd. IEEE. 1-5. 10.1109/VETECS.2011.5956728.

[7]. Wahiba, Mohguen & Bekka, Raïs El'hadi. (2017). An Empirical Mode Decomposition Signal Denoising Method Based on Novel Thresholding.

[8]. Salkind, N. J. (2010). Publications Ltd doi: 10.4135/9781412961288.

[9]. Sharanya Shashidhar, Sourabha K R, Santhosh S, Virani Nafeez, Sunil M P, "Design and fabrication of a low-cost single board portable GPS data logger", Electrical Computer and Communication Technologies (ICECCT) 2015 IEEE International Conference on, pp. 1-6, 2015.

[10]. Mahsa Tavasoli, Mohammad Hossein Yaghmaee, Amir Hossein Mohajerzadeh, "Optimal placement of data aggregators in smart grid on hybrid wireless and wired communication", Smart Energy Grid Engineering (SEGE) 2016 IEEE, pp. 332-336, 2016.

[11]. Yang, W., Yang, X., Yang, S. and Yang, D. (2011) A Greedy-Based Stable Multi-Path Routing Protocol in Mobile Ad Hoc Networks. Ad Hoc Networks, 9, 662-674.

[12]. A. Jarray, Yihong Song and A. Karmouch, "p-Cycle-based node failure protection for survivable virtual network embedding," 2013 IFIP Networking Conference, Brooklyn, NY, 2013, pp. 1-9.

[13]. M. Tarique, K. E. Tepe, S. Adibi, and S. Erfani, "Survey of multipath routing protocols for mobile ad hoc networks," Journal of Network and Computer Applications, vol. 32, no. 6, pp. 1125–1143, 2009.

[14]. E. Alotaibi and B. Mukherjee, "A survey on routing algorithms for wireless ad-hoc and mesh networks," Computer networks, vol. 56, no. 2, pp. 940–965, 2012.

[15]. J. Park, S. Moh, and I. Chung, "A multipath aodv routing protocol in mobile ad hoc networks with sinr-based route selection," in Wireless Communication Systems. 2008. ISWCS'08. IEEE International Symposium on. IEEE, 2008, pp. 682–686.

[16]. P. Sambasivam, A. Murthy, and E. M. Belding-Royer, "Dynamically adaptive multipath routing based on aodv," in Proc. 3rd Annual Mediterranean Ad Hoc Networking Workshop. Citeseer, 2004.

[17]. W. Liu et al.,"A Node Stability-Based Multipath Routing Protocol in Heterogeneous Ad Hoc Networks," 2016 IEEE 18th International Conference, Sydney, NSW, 2016, pp. 70-77.

[18]. M.Sauter,"3.7.1mobilitymanagementinthecell-dchstate,," From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband, p. 160, 2010.

[19].J. Park, S. Moh, and I. Chung, "A multipath aodv routing protocol in mobile ad hoc networks with sinr-based route selection," in Wireless Communication Systems. 2008. ISWCS'08. IEEE International Symposium on. IEEE, 2008, pp. 682–686.

[20]. R. A. Calvo and J. P. Campo, "Adding multiple interface support in ns-2," University of Cantabria, 2007.