Associativity Tick Averaged Associativity based Routing (ATAABR) for Real Time Mobile Networks

Barbaros Preveze

Cankaya University,
Department of Electronical and Communications Engineering,
Ankara, Turkey
b.preveze@cankaya.edu.tr

Aysel Şafak

Başkent University,
Department of Electrical and Electronics Engineering,
Ankara, Turkey
asafak@baskent.edu.tr

Abstract

This study proposes a long lived routing method which is also based on Associativity such as ABR (Associativity Based Routing) for real time applications. The main purpose of our work is improving the ABR algorithm in order to reduce the outage of the nodes and decreasing the number of reconstructions required to keep the nodes in communication. The performance of ABR is compared with other long-lived relay selection algorithms for real-time applications.

Key words - ABR, wireless communications, mobile networks, ad-hoc networks, routing, real time applications

1 Introduction

In this study, an ad-hoc mobile network is considered in which there are many randomly located nodes moving randomly from one point to another with random velocity. In such a condition, a route construction that reliably keeps nodes in communication for a long time may be difficult. It is important in real time applications to keep the number of reconstructions in low levels.

In this study, the performances of some relay selection algorithms (RSA), ABR and an improved version of ABR ATAABR (Accessitivity Tick Averaged Accessitivity Based Routing)) algorithm is compared in terms of outage counts and number of Route Reconstructions (RCC) [1]. In ATAABR, the associativity ticks are used in calculation of the paths along the network as in ABR but with the difference that their weighted averages are also calculated and used.

2 Methods

In the simulated ad-hoc network there are six nodes: a transmitter (Tx), a receiver (Rx), and four relay nodes. When a node reaches to the boundary, it reflects back and stays in the region. In this study, performance is evaluated in terms of number of RRC, and in terms of number of outages according to path selected from Rx to Tx by each algorithm for real time applications.

3 Relay Selection Algorithms

When the node Tx tries to sent packets to Rx , a relay through which the packets can traverse will be selected. Note that Tx always uses the direct path from Tx to Rx additionally provided that such a path is available, This way the signals forwarded by different nodes using AAF (Amplify and Forward) or DAF (Decode and Forward) can be combined at the Rx [2].

During the implementation of the algorithms below, the distance information from each node to Rx and Tx will be needed. If GPS technology were available, the required distances could easily be taken from there as in [3] , but since it is assumed in this study that GPS is not available, the estimations of these distances are done by using the received power formula derived from Free space path loss (FSPL) formula given in eq. (1) [4]

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi f d}{c}\right)^2 = \frac{P_t}{P_r} \qquad (1)$$

where λ: signal wavelength (in meters), P_t : transmitted power (in watts), P_r : Received power (in watts), c=speed of light (3x 108 meters / second), d=distance from Tx to Relay or Rx (in meters), f : frequency of the signal (in hertz).

By retrieving "d" from eq (1) ; distance can be found as in eq (2)

$$d(T_x, R_n) = \left(\frac{c}{4\pi f \sqrt{\left(\frac{\mathrm{P_r}(R_n)}{P_t}\right)}} \right) \qquad (2)$$

$d(T_x, R_n)$: Distance from Tx to Rn (meters), Rn : nth relay numbered from 1 to 4 in our simulation.

P_r(Rn) : Power level (in watts) received by Rn

Note that P_t has almost same value in the simulation program from 0.75 watt to 1 watt for all nodes in the predefined range and it can also be written and sent from one node to another node to inform each other using the discovery packets which are already being sent through the network.

A. Minimum Distance Path

This algorithm uses eq. (2) in eq.(5) and selects the relay through which our packets travel through the minimum distance [5] shown in figure 1.For each possible route S from Tx to Rx

$$Path_{\min} = \min\left[(d(T_x, R_s^1) + d(R_s^{hc_s-1}, R_x) + \sum_{n=1}^{hc_s-2} d(R_s^n, R_s^{n+1})) \right] \quad (3)$$

where;

R_s^n : nth node on the sth route,

hc_s : Hop count of the sth route

Note that the tiles at the back of each node in the figures 1, 2 and 3 illustrate the velocity and directions of the nodes.

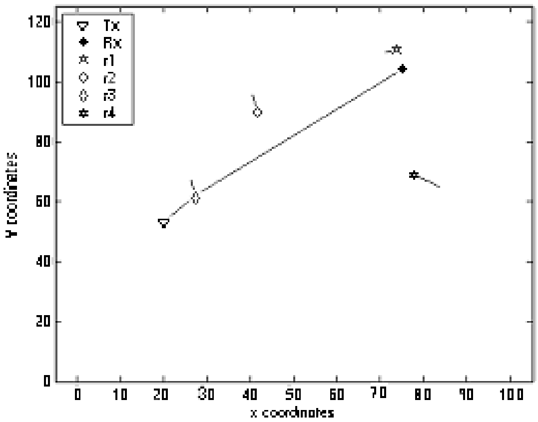

Fig 1. Minimum distance path is the shortest path for which the packets will travel from source to destination via the shortest path

B. Minmax Distance Path

This algorithm selects the path from a set of paths for which the maximum distance between any 2 linked nodes of the path, is lower than all other path's corresponding values, by this way enough signal power level received by any node,is tried to be provided [5] (See figure 2). The max partial link distance of each route numbered from 1 to S is found by eq. (4) and among these S routes, the route which returns with the lowest result from eq. (4) is selected by this algorithm.

$$Path_s = \max\left[(d(T_x, R_s^1), d(R_s^1, R_s^2), ..., d(R_s^{hc_s-1}, R_x)) \right]$$

$$Path_{\min\max} = \min\left[Path_1, Path_2, Path_3, ..., Path_s \right] \quad (4)$$

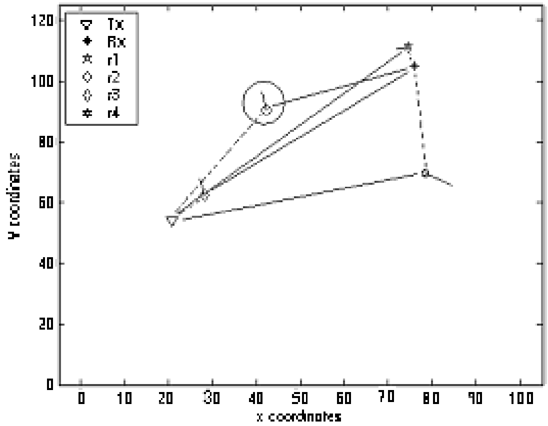

Fig2. MinMax distance path choses the path for which the packets will travel from source to destination via the path whose longest link is lower than the corresponding distance values of all other possible paths

C. Relay Selection Using Power Threshold (PT)

In wireless mobile Ad-Hoc networks there are some algorithms such as LLRP (Longest life routing protocol) that use discovery packets in order to discover which node it has access to, [6] and ABR in which the destination sends "here I am packets" to its neighbours [7] In this algorithm all nodes signatures a discovery packet and sends it to it's neighbours who will also forward these discovery packets to it's own neighbors, then it returns back to it's sender, Thus the relay from which Tx can receive Rx's discovery packet, can forward Tx's packets to Rx, so we select one of the relays according to eq.(5) (retrieved from eq.(1)) for which the Tx receives the signal from Rx with the power level greater than Power threshold and other relays power levels.

$$\left(P_r(R_n)\right) = P_t \cdot \left(\frac{c}{d(T_x, R_n)(4\pi f)} \right)^2 \geq Power_{Thrs} \quad (5)$$

D. Relay Selection According to Path Loss

In order to be able to compare the results of other long-lived algorithms with the one made according to path loss, the path loss values are calculated by eq. (6) [4] for the connections among Rx, Tx and each relay. Since the path loss algorithm selects the strongest and reliable path from the possible path combination in figure 3, the algorithm, with selections that match the selection of path loss algorithm the most will be the best for this performance criteria, even if it has no effect on having long life routing. Evaluating eq.(6) from eq.(1) [4] ; where units are as in eq (1)

$$\mathrm{FSPL}(\mathrm{dB}) = 20.\log_{10}\left(\left(\frac{4\pi fd}{c}\right)\right)20.\log_{10} d +$$

$$20.\log_{10} f + 20.\log_{10}\left(\frac{4\pi}{c}\right)$$

$$\mathrm{FSPL}(\mathrm{dB}) = 20.\log_{10} d + 20.\log_{10} f - 147.56 \qquad (6)$$

The most important performance evaluation criteria for this study, is of course the life time of the selected relays or paths which is inversely proportional to the number of RRC. Figure 9 shows the number of RRC graphs for each Relay selection algorithm.

4 Long Life Path Selection Algorithms

A. ABR (Accociativity Based Routing) :

ABR algorithm is an algorithm based on associativity of the nodes. All moving nodes in the network broadcast "here I'm" messages to all available nodes, during this period they also receive "here I'm" messages which is also called associativity tick (AT), from all other nodes. These AT messages can only be received if the received power is greater than a predefined threshold power value. By separately counting the number of AT messages received from each node and calculating an AT threshold value each node, creates and keeps its own table (see Tables 1- 6) which will be used to inform all other nodes about the state. The tables are updated by broadcasting discovery messages to all nodes as in LLRP (Longest life routing Protocol) [6] , hence all the nodes are aware of all other nodes tables and all available paths from Tx to Rx in the network. If one of the nodes stops sending AT ticks the corresponding field that keeps the associativity tick of that node, is reset to zero in the table, thus if the AT field is not zero, it is understood from the table that corresponding node is in the range, but having AT value greater than AT Threshold value will also be important. Since all the nodes in the network keeps the tables in the same structure, the nodes can have the individual neighbor availability information's of it's neighbors from their tables.

Once a connection is tried to be established, one of the available neighbor node is selected from the table, and during this selection an other row of the table which includes AT threshold value calculated by AT / (number of nodes) is used, this AT threshold value is continuously calculated for each node according to current state of the network and the connection through this node will be provided if and only if AT > AT Threshold for this node.

On the other hand the tables will also be used to discover if the node that Tx has access to, has a path to Rx or not. The tables for a moment for which Tx has no direct access to Rx, are given in tables 1 to 6.

TABLE 1: ABR TABLE OF RELAY 1

R1	R1	R2	R3	R4	Rx	Tx
Availability	-	1	1	1	0	0
number of AT	-	3	2	4	7	0
AT Threshold	-	16/6	12/6	14/6	15/6	5/6

TABLE 2: ABR TABLE OF RELAY 2

R2	R1	R2	R3	R4	Rx	Tx
Availability	1	-	1	1	1	1
number of AT	**3**	**-**	**3**	**5**	**4**	**1**
AT Threshold	16/6	-	12/6	14/6	15/6	5/6

TABLE 3: ABR TABLE OF RELAY 3

R3	R1	R2	R3	R4	Rx	Tx
Availability	1	1	-	1	1	1
number of AT	2	3	-	2	4	1
AT Threshold	16/6	16/6	-	14/6	15/6	5/6

TABLE 4: ABR TABLE OF RELAY 4

R4	R1	R2	R3	R4	Rx	Tx
Availability	1	1	1	-	0	1
number of AT	4	5	2	-	0	3
AT Threshold	16/6	16/6	12/6	-	15/6	5/6

TABLE 5: ABR TABLE OF RECEIVER

R4	R1	R2	R3	R4	Rx	Tx
Availability	0	1	1	0	-	0
number of AT	7	4	4	0	-	0
AT THRESHOLD	16/6	16/6	12/6	14/6	-	5/6

TABLE 6: ABR TABLE OF TRANSMITTER

R4	R1	R2	R3	R4	Rx	Tx
Availability	0	1	1	1	0	-
number of AT	1	1	3	0	0	-
AT Threshold	16/6	16/6	12/6	14/6	15/6	-

where AT Threshold values for nodes are calculated by adding number of AT values in corresponding table and dividing the result to total number of hops in the net, e.g AT Threshold value for R1 is calculated from Table 1 as in eq (7) ;

$$R_{1_{THRS}}\left(\frac{3+2+4+7+0}{\text{number of nodes}}\right)=16/6 \qquad (7)$$

This calculated value is highlighted in the tables from 1 to 6.According to these tables for a path selection from Tx to Rx , the ABR algorithm in [1] is used .

This algorithm selects a set of possible routes and a new group is constructed by selecting the ones with minimum number of hops from this group in the next stage the one with maximum of the average of node counts in the routes for which number of AT is greater than the AT Threshold of corresponding node is selected. The difference in ATAABR comes in to consideration at this point.

B. ATAABR :

Main working principle of new proposed ATAABR looks like an extension of ABR, the proposed algorithm differs exactly when selecting a route by using the tables generated by the nodes according to the network conditions.

We propose a method with ATAABR that it at first selects the paths for which all nodes are linked to each other such that number of AT's are greater than AT Threshold, and among the set of selected paths, the ones that have min hop counts are selected from this set ,the one is selected for which average of the AT values in each route has the maximum value. The route selection will be made by using eq. (8) noting that all paths are consist of linked nodes that have AT's greater than AT Threshold. For each route S from T_x to R_x

$$Path_{ATAVE} = \left(\frac{(AT(T_x, R_s^1) + AT(R_s^{hc_s-1}, R_x) + \sum_{n=1}^{hc_s-2} AT(R_s^n, R_s^{n+1}))}{hc_s} \right) \quad (8)$$

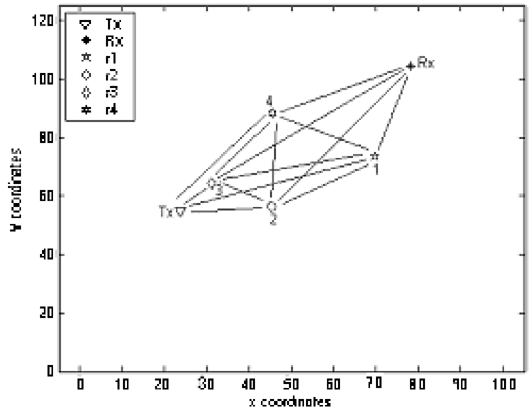

Fig 3. All possible path combinations from Tx to Rx are illustrated

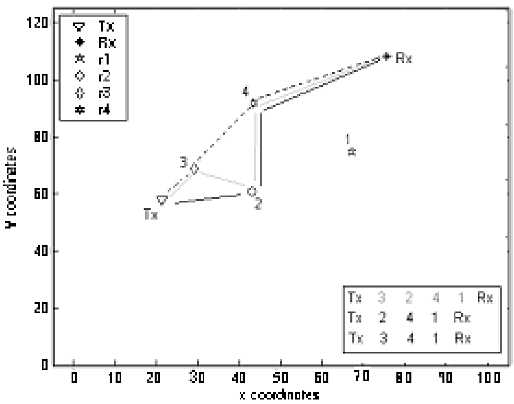

Fig 4. Example of Selected paths from fig. 4 , as a result of EABR algorithm

The possible path combination that can be constructed from Tx to Rx is shown in Figure 3, assume that as a result of ATAABR , 3 paths shown in Figure 4 are selected noting that all partial links in these paths has AT values greater than AT Threshold values , at this point, the path Tx -3 -2 -4 -1 Rx will be eliminated since it has more hop counts than available minimum hop counts in other paths, and randomly selecting one of the paths from the selected ones which has three hops. For the state shown in figure 4, selection will be done according to eq (8).

5 *Results and Discussion*

A. *Results for Relay Selection Algorithms:*

For RSA's mentioned above, in order to be able to compare the results of other algorithms with the one made according to path loss values , we calculated the pathloss values using eq. (6) for the connections between Rx , Tx via each of the relays. And relay selection is made according to path loss RSA. So in one of our performance evaluations; the algorithm, with most selections matching the selection of path loss algorithm, will be the best for this performance criteria. In figure 5 , it's seen that, since it's selections match most with the path loss algorithm's selections the best selections with minimum pathloss are made by "minimum distance" algorithm in terms of path loss.

Another performance evaluation criterion is the the life time of the selected relays or paths which is inversely proportional to number of RRC. Figure 6 shows the number of RRC graphs of each RSA. Since PT and path loss RSA's have minimum number of RRC's in figure 6 it's clearly seen that the PT is the best algorithm.

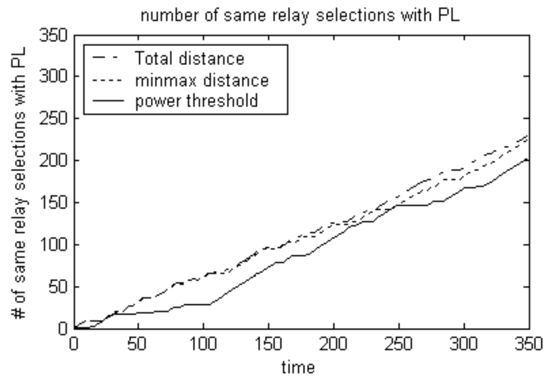

Fig5. Number of relay selections that matches the selection done according to path loss

The results we had from figure 7 and figure 8 show us the way, that; using average AT count on acceptable linked paths is a better way than using the average count on acceptable linked paths in Route selection algorithms. This may give us an idea of that received power level can be used in acceptance of received AT's and making the decision according to these power levels for all links in each

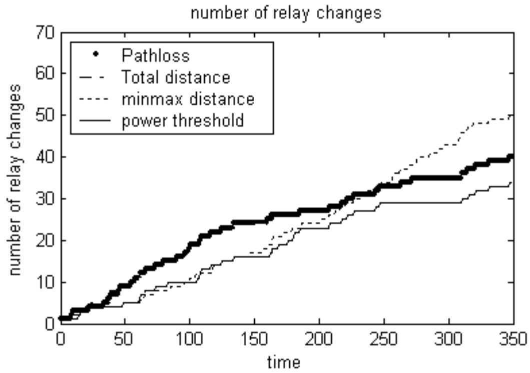

Fig.6. Number of RRC for each RSA

B. Results for Long Life Path Selection Algorithms ABR and ATAABR

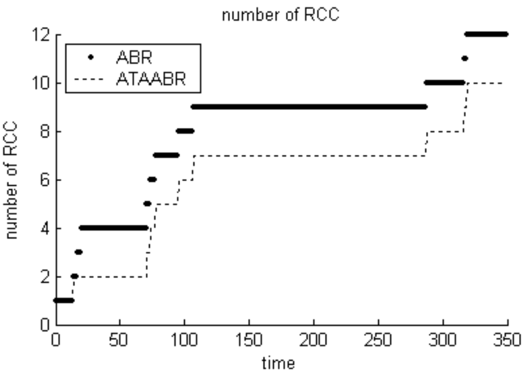

Fig7. Number of RRC for path loss, power threshold, ABR and ATAABR

As a result, we see in figure 7 that the developed algorithm namely ATAABR always provides better results than performance of ABR which also has much more better performance than path loss relay selection algorithm. Since the path loss relay selection algorithm is one of the best of other RSA's according to figure 6,and since all decisions are taken by each algorithms itself, in the same conditions and in the same time period (350 seconds), ABR and ATAABR has been indirectly compared with all other RSA's in terms of number of RRC's, and it's seen in figure 7 that ATAABR always has lower number of RCC and it gives better results than ABR. Note that more than multi-nodes can be used in path constructions where neccessary.

On the other hand, number of moments that Tx and Rx couldn't get connected (number of TRCC) to each other while reconstructing a new route or when a relay that can connect them couldn't be found, is also a very important performance criteria especially in real time applications for routing. By ATAABR, while reducing the number of RRC's, the number of TRCC should also increase. Because processing time and staying connected are both very important parameters for routing in Real time applications, It can seen from the figure 8 that , this condition is also satisfied by ATTAABR, because the line of ATAABR always lies below the line of ABR in Time vs. TRCC graph.

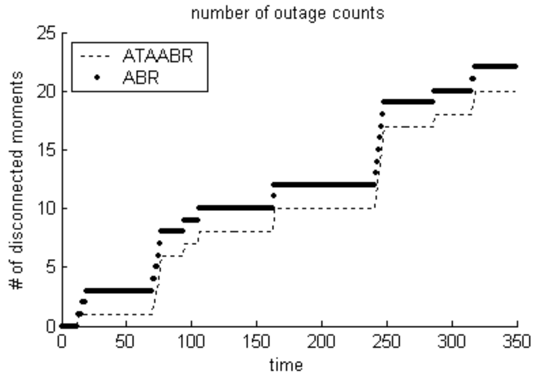

Fig.8. Number of moments that Tx and Rx couldn't get connected (TRCC)

6 CONCLUSION

An extension of the ABR algorithm is developed and compared to ABR [1] in terms of number of RRC's and number of disconnected nodes. ATAABR has approximately 17 % higher performance for a fixed number of RCC's and about 13 % higher performance for a fixed number of outage counts than ABR. that Since ABR has higher performance than all other well known single hop relay selection algorithms such as minimum distance path, minmax path, path according to power threshold and path according to path loss, the improvement of these factors will provide advantages in real time applications such as video or voice conversations for which calculation time for RRC and having a reliable connection is crucial.

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