Paper

An Improved Greedy Forwarding Scheme in MANETs

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Abstract—Position-based routing protocols are widely accepted efficient solution for routing in MANETs. The main feature of position-based routing protocols is to use greedy forwarding methods to route data. The greedy forwarding methods select a node, either having maximum progress towards destination (distance-based principle) or minimum deviation with line between source and destination (direction-based strategy). The first method minimizes the hopcount in a path and on the other hand, second method minimizes the spatial distance between source and destination. The distance-based routing has a great impact on the selection of reliable node and the direction based routing plays a major role to increase the stability of route towards destination. Therefore, in this paper authors propose a weighted forwarding method, which combines both the selection, schemes to select an optimal next forwarding node in a range. The simulation results show that the proposed scheme performs better than existing position-based routing protocols.

Keywords—MANET, distance-based routing, direction-based routing, greedy forwarding.

1. Introduction

A Mobile Ad Hoc Network (MANET) is an infrastructureless network with nodes. They change their topology dynamically and work as a host as well as routers at the same time in the network. Therefore, they perform an important role to route data. If source and destination are in transmission range of each other, they can transmit data directly. However, if source and destination are out of transmission range of each other, they have to be dependent on other intermediate nodes to forward message to the destination. Since, the mobile nodes move in any direction, which causes frequent linkages formation and breakage. In such scenarios, the traditional routing protocols [1], [2] are not an efficient choice for routing in MANETs.

To overcome these issues, position-based routing protocols are accepted a better solution for routing in MANETs. The main feature is to use location information of neighbors and destination to route data and further use greedy forwarding mechanisms to forward a message to the neighbor closest to the destination. Greedy forwarding strategies use distance or direction of nodes as a parameter for the selection of next forwarding node to route data. The first scheme selects a neighbor with the largest distance towards the destination to minimize the hop count. On the other hand, the second method favors a neighbor with the lowest angle deviation toward the destination to minimize the spatial distance between nodes.

The distance-based routing has a great impact on the selection of reliable node and the direction-based routing plays a major role to increase the stability of route towards destination. This shows that these schemes give a suboptimal solution for the selection of next forwarding node. Therefore, this paper focuses to propose a combined forwarding scheme, which considers both the methods while selecting a next forwarding node to achieve better performance in terms of routing overhead, hop count and end-to-end delay over distance-based and direction-based forwarding schemes. Further, to combine these routing schemes, a weighted factor (denoted by α) is introduced, which helps to apply both the schemes in a flexible manner.

The rest of this paper is organized as follows. Section 2 presents some geographical routing schemes proposed in the literature for mobile ad hoc networks. Section 3 outlines and discusses the key features of proposed protocol. The comparisons of simulation results are presented in Section 4. Conclusion and future researches directions are discussed in Section 5.

2. Related Work

In literature a variety of position-based schemes has been proposed as an efficient and scalable solution for routing in MANETs. The position-based routings use greedy schemes based on local forwarding decisions to construct a path dynamically from source to destination. These forwarding schemes are categorized as distance-based and direction-based routings.

The MFR is proposed by [3] as a distance-based greedy routing algorithm. MFR helps to reduce the path length by selecting the next forwarding node largest progress (closer) towards the destination. This method is loop-free and finds a short path but it does not guarantee to find a path from source to the destination. Another issue with MFR routing is high packet drop rate. An improved version of MFR scheme to achieve guarantee delivery and eliminate looping problem has been proposed named as F-MFR protocol [4]. The other latest improvements of MFR are discussed in [5] and [6].

The first direction based routing has been proposed in [7] and is called as Compass routing (DIR), which selects the neighbor having the minimum deviation from Line of Sight (LOS). This feature of protocol results to find a most direct path to route data. The protocol successfully progress around a boundary, which can help in a higher rate of path completion but the protocol is not loop free and suffers from congestion produced by frequent beaconing messages. Another variant of Compass routing, named Random Compass [4] has been proposed to select the next hop randomly between the two nodes on the closest angle to the destination.

Q-DIR [8] – directional routing with restricted flooding protocol is proposed to restrict the broadcast area to all nodes in the same quadrant as the source and destination. To overcome the limitation of basic greedy forwarding schemes combined Greedy-Compass [9], [10] has also proposed to improve the performance of forwarding schemes to combine the basic greedy forwarding schemes, in which selects one of the two nodes, which is at the minimum distance from the destination.

Another variant of greedy routing protocol is GEDIR [11], proposed by Liao *et al*. to eliminate the loops during routing and makes it loop free. In literature, hybrid schemes are also proposed, which consider both greedy routings protocol while selecting a next forwarding node. Angular Routing Protocol (ARP) [12] is a position-based routing protocol proposed to forward data from source and destination. The protocol starts data forwarding by using greedy forwarding, if greedy forwarding fails, the protocol switches to angle-based forwarding to avoid voids in sparse networks.

A hybrid-weighted forwarding scheme named (HGR) is proposed by Chen *et al*. [13], which combines distance and direction metrics in a flexible manner. The protocol helps to tradeoff between energy usages and end-to-end delay during the routing procedure. Further, the authors proposed a dynamic variant of HGR (DHGR) mechanisms based on the basic HGR scheme. These schemes aim to define the balance between end-to-end delay and energy consumption. The protocol reduces the energy consumption during finding the path.

An Improved Progress Position Based Beacon Less Routing algorithm (I-PBBLR) [14] considers the progress metric with the direction to select the next forwarding node for improved and efficient routing between source and destination. This routing protocol guarantees loop free forwarding closer to the destination.

A few other hybrid-based combined forwarding schemes are also proposed in [15], [16].

3. Proposed Work

The used model utilizes the mobile ad hoc network as a set of nodes deployed in a two-dimensional area, where each node has unique position. The model uses the location information of nodes and makes some assumptions:

- the node can obtain the location information through the support of GPS devices;
- the source is aware of its own location and location information of destination;
- the intermediate nodes are aware of their own positions. When source S wants to send data to destination D, S utilizes the known location information of destination;
- each node has same transmission range and moving with same speed.

3.1. Description of Proposed Protocol

Generally, the position-based routing protocols select the next hop either applying the distance-based (MFR), or as direction-based strategy (Compass). The distance-based strategy tries to select a neighbor closer to the destination to minimize the hopcount and the direction-based selects a neighbor, which makes lowest angle from LOS toward the destination to minimize the spatial distance. The distance based routing has a great impact on the selection of reliable node and the direction based routing plays a major role to increase the stability of route towards destination. The selection of next forwarding node based on basic greedy principles is given in Fig. 1.

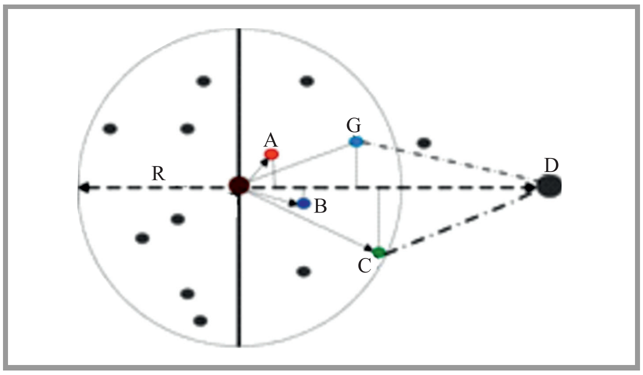

Fig. 1. Greedy forwarding methods: S and D are source and destination nodes. The S has different choices to find a next forwarding node; A = nearest with forwarding progress; C = most forwarding progress within Radius (MFR); B = Compass routing; G = greedy.

These features motivate to combine both distance and direction metrics while choosing next hop to forward message from source to destination. In this work, a joint forwarding scheme is proposed, which is blessed with both the metrics. To combine these metrics, a weighted scheme is defined and calculated. The node having the highest score is selected as the next forwarding node within the transmission range of the source node towards the destination. The formula to calculate the weights is given below:

$$w = (1-\alpha)\left(1-\frac{x}{\mathrm{R}}\right) + \alpha\left(1-\frac{\theta}{90^\circ}\right), \qquad (1)$$

where w is the weighted score of a node to become a next forwarding node, α is the adjustment factor to combine these metrics, x is the distance from node i to destination D, R is the transmission range, and $\frac{x}{\mathrm{R}}$ is the closeness of next candidate hop. Angle θ is the deviation of node i from the straight line between source S to destination D. In Fig. 2, x and θ denote the projected progress and the deviation angle of node i respectively. When source S wants to send data to destination D, it utilizes the location information and tries to find next forwarding node to forward the data to destination. As an intermediate node receives a data packet, it calculates the distances and deviations of nodes by using its angle formula. The distance between the source S and destination D is denoted by h, l and x are the distances between node i and destination D and node S and node i respectively. These calculations are given in Eqs. (2)–(4). The deviation angle θ is calculated in Eq. (5).

$$h = \sqrt{(X_S - X_D)^2 + (Y_S - Y_D)^2}\,, \tag{2}$$

$$x = \sqrt{(X_S - X_i)^2 + (Y_S - Y_i)^2}\,, \tag{3}$$

$$l = \sqrt{(X_i - X_D)^2 + (Y_i - Y_D)^2}\,, \tag{4}$$

$$\theta = \frac{h}{2x\cos(x^2 + h^2 - l^2)}\,. \tag{5}$$

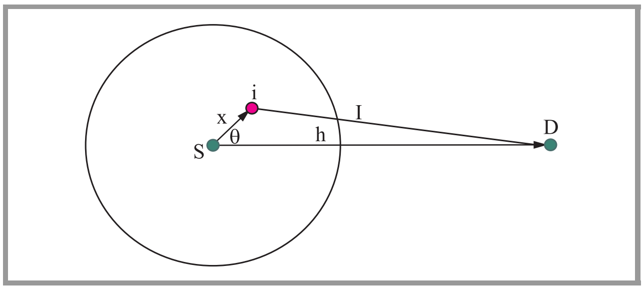

Fig. 2. Calculation of distance and direction of node.

To enhance the capability of traditional greedy forwarding, presented approach considers nodes in any potential regions defined below to perform forwarding decision. In general, whenever a source S attempts to forward a message, it will first search the potential region and pick the node in that region that is the closest to the destination. There might be several nodes within these defined regions, therefore, to select the best forwarding node, protocol calculates the progress and deviation of each node within the region. These values are further used to determine the value of weight score (w) for selecting a next hop to forward data. The node with highest weighted score among all the nodes will be chosen as next hop. Secondly, by adjusting α, distance- and direction-based forwarding schemes could be balanced. There are two scenarios:

1. If $\alpha = 0$, protocol behaves like a pure distance-based forwarding when nodes are reside in region A.

2. Distance-based routing fails, if there is no node in region A, in this situation the value of α lies at $0 \leq \alpha \leq 1$. The node switches to hybrid mode and the distance and angular deviation of each node are calculated. These values are combined by using the weighted factor.

In simulation, we set the weights according to the distance and direction of node. If value $\frac{x}{R} < \frac{\theta}{90°}$, the value of α goes to upper side that is 1 means more weightage to direction metric than distance metric. Else, hybrid forwarding approach with more priority to distance based forwarding.

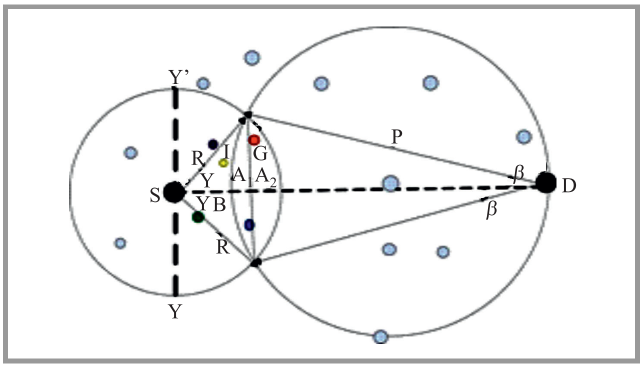

Fig. 3. Next node selection method.

In Fig. 3, the selection criterion for next node is presented. In this example, forwarding area is divided into sub regions border region (A) and reminder region (B). These areas are potential regions for distance and combined routings respectively. To define the border area, we first draw tangent from the point D (center of destination) to the circle with radius R around the source S. Draw a circle having radius P and they are shown by blue shaded area in Figs. 2 and 3. This area (A1+A2) [17] can also be called as area of interaction of the two circles and calculated by Eqs. (6)–(7).

$$\mathrm{A1} = \mathrm{R}^2\gamma - \frac{\mathrm{R}^2 \sin 2\gamma}{2}\,, \tag{6}$$

$$\mathrm{A2} = \mathrm{P}^2\gamma - \frac{\mathrm{P}^2 \sin 2\gamma}{2}\,. \tag{7}$$

The distance-based principle chooses a next node in area A, because area A lies closest to borderline of the sender's transmission range. Greedy routing is the appropriate method to selects a next-hop node for the given region, it has been analytically proved in [18]. Further, the protocol defines the potential regions (reminder region) for combined forwarding scheme. This reminder region is represented by B and Eq. (8).

$$\mathrm{B} = \mathrm{area}(\mathrm{SD} - \mathrm{A1} + \mathrm{A2}) \tag{8}$$

where

$$\mathrm{B} = \frac{\pi r^2}{2} - \mathrm{R}^2\gamma - \frac{\mathrm{R}^2 \sin 2\gamma}{2} + \mathrm{P}^2\beta - \frac{\mathrm{P}^2 \sin 2\beta}{2}\,.$$

In this region, both the progress (distance) and deviation of nodes are compared by applying the weighted methods and adjustment criterion given in scenario 2.

4. Simulation and Performance Analysis

To evaluate the performance of the proposed protocol, implementation is carried out in Matlab 7.0. The simulation results are compared with distance-based routing (MFR), and direction-based routing (Compass). The simulation setup is given with parameters is shown in Table 1.

Table 1
Simulation parameters

Simulation parameter	Value
Topology size	1000 · 1000 m
Number of nodes	20–100
Speeds	5–25 m/s
Mobility model	Random way-point
Simulation time	200 s
Channel rate	2 Mb/s
MAC layer protocol	IEEE 802.11b
Radio propagation model	Two ray-ground
Transmission range	200 m
Traffic type	CBR

To analyze the performance of proposed protocol is compared by using below discussed metrics. Node density and mobility are the important factors that affect the performance of routing protocols.

Routing overhead. Routing overhead is an important measure for the scalability of routing protocols. It is a metric to determine the efficiency of the routing protocol and calculated as number/size of routing control packets sent by the protocol.

Hop count. The number of nodes encounter to the path from source to destination. The path length is directly related to number of hops in the path.

End-to-end delay. The ratio of the packets that successfully reach destination to the original sent ones.

4.1. The Impact of Varying Number of Nodes

This section presents the simulation results of proposed protocol at varying number of nodes from 20 to 100 while the speed is fixed at 10 m/s.

The simulation results in Fig. 4 show that the routing overhead increases linearly for all the protocols on increasing the nodes in network. The proposed scheme produces less routing overhead in comparison to basic distance-based greedy forwarding schemes and higher routing overhead than direction-based routing. The reason behind these results is that the distance-based routing select the node closer to the destination but it may fail, if it has no neighbors closer to the destination. Then they do re-routing to find the path and on contrast, direction based routing algorithms has lowest routing overhead because it chose the node, which is less deviated from LOS without considering the progress. The proposed protocol has lesser routing overhead than distance-based routing and higher than direction-based routing protocol.

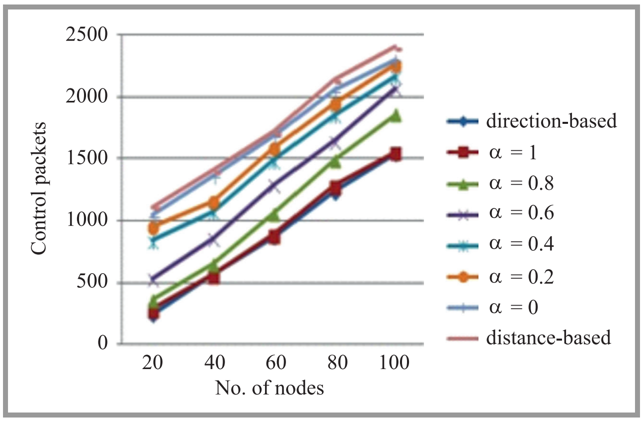

Fig. 4. Routing overhead at speed 10 m/s. (See color pictures online at www.nit.eu/publications/ journal-jtit)

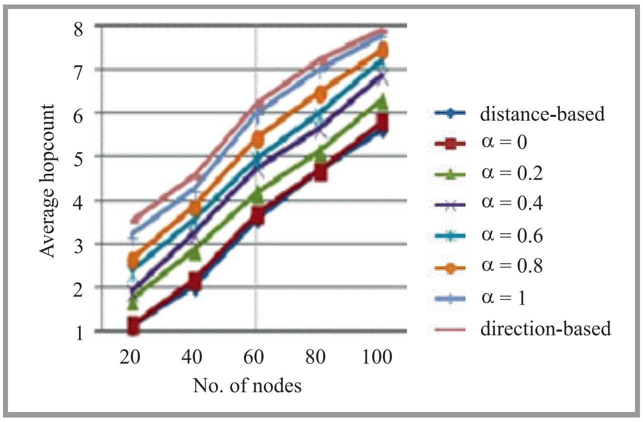

Fig. 5. Average hopcount at speed 10 m/s.

Figure 5 illustrates the number of hops vs. the varying number of nodes and the hopcount of all the protocols increases with the number of nodes. The results show that the hopcount of the proposed protocol is lower than direction-aware routing and higher than distance-aware routing protocol.

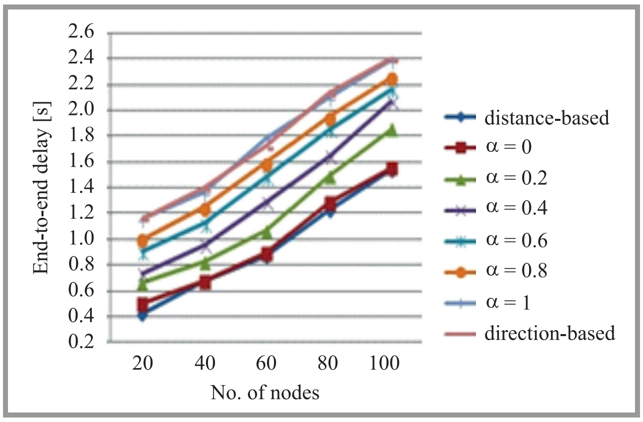

Fig. 6. End-to end delay at speed 10 m/s.

In Fig. 6 the simulation results of end-to-end delay vs. speeds are presented. The result reveals that the delays of all the schemes are inversely related to speed values. The angular scheme shows the highest delays in comparison to other protocols. The reason behind is that it only focuses the directions (deviation from the LOS) while ignoring progress towards destination and selects a path with larger numbers of hops and, thus, longer delays. On the other hand, distance-based routing has the smallest delay and proposed protocol has larger delay than distance-based routing and smaller delays in comparison with direction-based routing protocols. The delay of all the protocols increases on increasing the number of nodes.

The performance of proposed protocol also depends on weight factor α. If α is larger, proposed protocol behaves more like distance-based routing and on the other hand if value is small, protocol behaves like direction-based routing. The weight factor used in proposed protocol also affects the performance of proposed protocol.

4.2. The Impact of Node Speeds

In this simulation the speed is varied from 5 to 25 m/s while the number of nodes are fixed at 40.

The routing overheads of all the protocols and comparison study is given in Fig. 7. The results show that the routing overhead of proposed protocol depends on α. When α is high, protocol produces less overhead as direction-based. As the value of α decrease, the protocol produces more routing overhead and behaves as a distance-based.

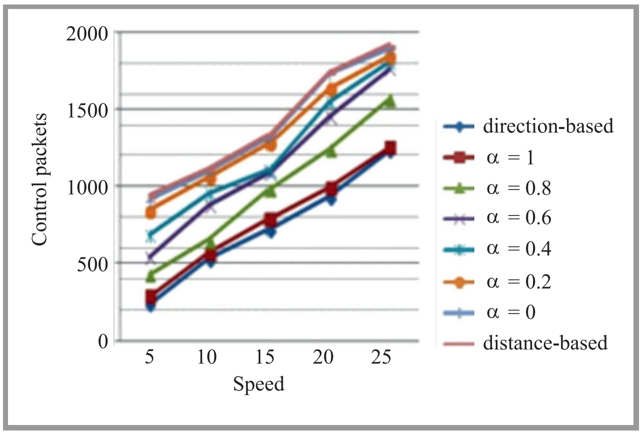

Fig. 7. Routing overhead with 40 nodes.

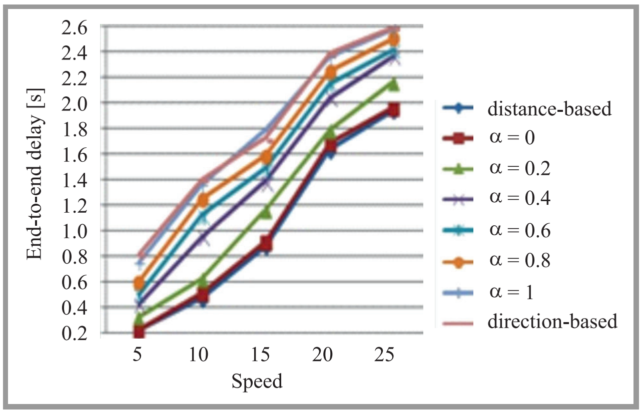

Fig. 8. End-to-end delay for 40 nodes.

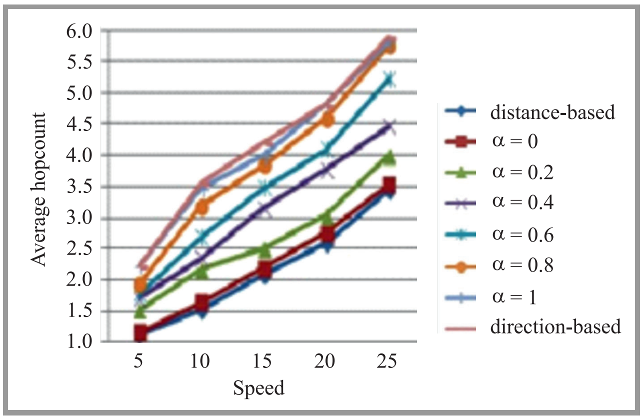

Fig. 9. Average hopcount for 40 nodes network.

In Fig. 8 the simulation results of end-to-end delay vs. speeds are given and result reveals that the delays of all the schemes decrease as higher speeds. The direction-based scheme has the highest delays because it only focuses the directions (deviation from the LOS) while ignoring progress towards destination and selects a path with larger numbers of hops and, thus, longer delays. On the other hand, distance-based routing has the smallest delay in comparison with the proposed protocol. In simulation, the end-to-end delay of proposed protocol will depend on α. If α is closer to 1 then end-to-end delay of proposed protocol is more like distance-based routing. Figure 9 illustrates the number of hops vs. the varying node's speeds and the results show that the hopcount of the proposed protocol is lower than direction-based routing and higher than distance-based routing protocol.

5. Conclusion

The simulation results show the proposed protocol outperforms than distance-based and direction-based routing significantly in the terms of average hopcount, end-to-end delay and routing overhead. The protocol increases the quality of route in terms of both stability and reliability over conventional distance and direction-based algorithms if they are used separately.

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