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MORA: A MOVEMENT BASED ROUTING ALGORITHM FOR AD HOC NETWORKS

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January 2004

Technical Report DIT-04-001

MORA: a movement-based routing algorithm for ad hoc networks

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Abstract

In an ad hoc environment with no wired communication infrastructure, mobile hosts necessarily operate as routers, in order to provide network connectivity. Since mobile ad hoc networks change their topology frequently and without prior notice, routing in such networks becomes a challenging task.

In this paper we present MORA, a movement-based routing algorithm for mobile ad hoc networks. The algorithm is completely distributed, since nodes need to communicate only with direct neighbors in their transmission range, and utilizes a specific metric, which exploits not only the position, but also the direction of movement of mobile hosts.

1 Introduction

Mobile ad hoc networks (MANET) consist of wireless hosts that communicate with each other in the absence of a fixed infrastructure [1]. They can be used in a wide plethors of applications, ranging from tactical operations, to establish quickly military communications during the deployment of forces in unknown and hostile terrain; to sensor networks, for communication between intelligent sensors mounted on mobile platforms. In the last application, mobile ad hoc networks are likely to achieve wide deployment in the near future because they greatly extend the ability to monitor and control the physical environment from remote locations.

In an ad hoc wireless network, mobility and bandwidth are two key elements representing research challenges. Not all hosts are within the transmission range of each other and communication is achieved by multi-hop routing, where intermediate nodes cooperate by forwarding packets between two hosts. Due to the hosts mobility, the topology of the network can change with time and no assumption can be made about the initial configuration. As a consequence, nodes have to build and update their routing tables automatically and effectively.

Traditionally, multi-hop routing for mobile ad hoc networks can be classified into proactive and reactive algorithms.

In proactive routing algorithms, each node in the mobile ad hoc network maintains a routing table that contains the paths to all possible destinations. If the network topology locally changes, all routing tables throughout the network have to be updated. This kind of routing algorithms are efficient only if the ratio ”mobility over communication” is low. If the nodes in the network are reasonably mobile, the overhead of control messages to update the routing tables becomes prohibitive. In addition, storing large routing tables in low-cost mobile nodes might be too expensive.

Reactive routing algorithms, on the other hand, find routes only on demand. Routes are designed when they are needed, in order to minimize the communication overhead. When a node needs to send a message to another node, the sender needs to flood the network in order to find the receiver and determine a path to reach it. The flooding process can still use a significant amount of the scarce available transmission resources. They are adaptive to ”sleep period” operation, since inactive nodes simply do not partecipate at the time the route is established. For additional information, a detailed review of routing algorithms in mobile ad hoc networks can be found in [2, 3].

An interesting approach is represented by position-based routing algorithms, which require information about the physical position of the participating nodes. The forwarding decision by a node is primarly based on the position of the packet’s destination and the position of the node’s immediate one-hop neighbors, typically learned through one-hop broadcasts. The distance between neighboring nodes can be estimated on the basis of incoming signal strenght or time delay in direct communications. Alternatively, the location of nodes may be available directly by communicating with a satellite, using GPS, if nodes are equipped with a small low power GPS receiver. In any case the position is affected by some level of approximation. A survey of protocols that do use geographic location in the routing decision is presented in [4, 5].

In this paper, the problem of routing in an ad hoc network is considered. An alternative movement-based routing algorithm (MORA) is presented, which exploits not only the position, but also the direction of motion of mobile hosts.

The paper is organized as follows. Section 2 introduces the new method, which is then analyzed in Section 3. In Section 4 a comparison with existing algorithms is presented. Finally, Section 5 concludes the paper.

2 The proposed method

The desirable properties of any routing protocol include simplicity, loop-free operation, convergence after topological changes, small storage, reduced computational and transmission overhead. In a position-based routing algorithm, each node makes a decision to which neighbor to forward the message based only on the location of itself, its neghboring nodes, and destination. In our approach, this decision is taken considering also which direction neighbors are moving in. Moreover, the system is made more robust by avoiding centralized information management, and easier to set up and operate.

Most routing schemes use hop count as the metric, where hop count is the number of transmissions on a route from a source to a destination. However, different metrics for choosing the best forwarding neighboring node in position-based routing protocols were recently considered. The metric used in MORA (Movement-Based Routing Algorithm) is a linear combination of the number of hops, arbitrarily weighted, and a target functional, which can be calculated independently by each node.

2.1 The functional F

Since mobile ad hoc networks change their topology frequently and without prior notice, the life time of connections between hosts vary appreciably.

The goal is to exploit the knowledge about the directions neighboring nodes are moving in to optimize data path. Generally speaking, there are different strategies a node can use to decide to which neighbor a given packet should be forwarded (MFR, NFP,...) [4]. None of these takes into consideration that hosts in ad hoc network are moving in directions that can introduce unpredictable changes in the network topology. Moreover, changes in the network configuration hamper the stability of the links and routes (see Sec.1). For the purpose of the paper, the impact of errors in the estimation of the position of the nodes will be neglected, and they are currently under study by the authors.

The idea is to create a functional that each node can independently calculate, which depends on how far the node is from the line connecting source and destination, sd, and on the direction the node is moving in. The target functional should reach its absolute maxima in the case the node is moving on sd and it should decrease as the distance from sd increases. Moreover, the more a node moves towards sd, the higher should be its value, i.e. for a fixed distance from sd the functional should have a maximum if the node is moving perpendicularly to sd.

Let d_0 be a reference distance metric, chosen on the basis of the application context (e.g. 1 meter, or 10 cm). Let $x = \frac{d}{d_0}$ be the adimensional distance of the current node from sd and $y = \frac{l}{d_0}$ the adimensional distance from destination of the point of intersection between sd and its perpendicular starting from the node current position (see Figure1). The functional F is a function of $x \in [0, \infty]$ and $\alpha \in [-\pi, \pi]$, where α represents the angle between the line of direction and the perpendicular line to sd (see Figure1) .

For the purpose of the paper, the functional F is defined as follows

$$F_{\delta,\gamma}(x, \alpha) = sin\frac{|\alpha|}{3}\, e^{-|x|} + cos\frac{\alpha}{3}\, e^{-\frac{(x-\delta)^2}{\gamma}}$$

where δ and γ are two parameters set on the basis of the application. The functional F is not a function of y. With such definition of F, more weight is given to nodes moving on sd, and also to nodes moving towards it (see Figure 2) as required above. In fact

- for $x = 0$ there are 2 absolute maximums, for $\alpha = \pm\frac{\pi}{2}$ respectively;
- for $0 < x < \epsilon$ (ϵ arbitrarily small) the trend is the same as above;
- for $x \to \infty$ the function decreases;
- for $x = \delta$ there is a relative maximum corresponding to $\alpha = 0$;
- for $x \in [\delta - a_{\delta,\gamma}, \delta + b_{\delta,\gamma}]$ ($a_{\delta,\gamma}$ and $b_{\delta,\gamma}$ constants defined with the choice of δ and γ) there is a maximum corresponding to $\alpha = 0$.

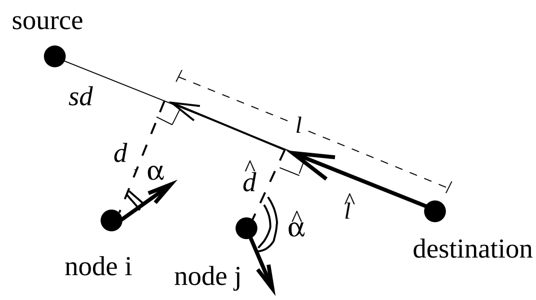

Figure 1: Definition of d, l and α

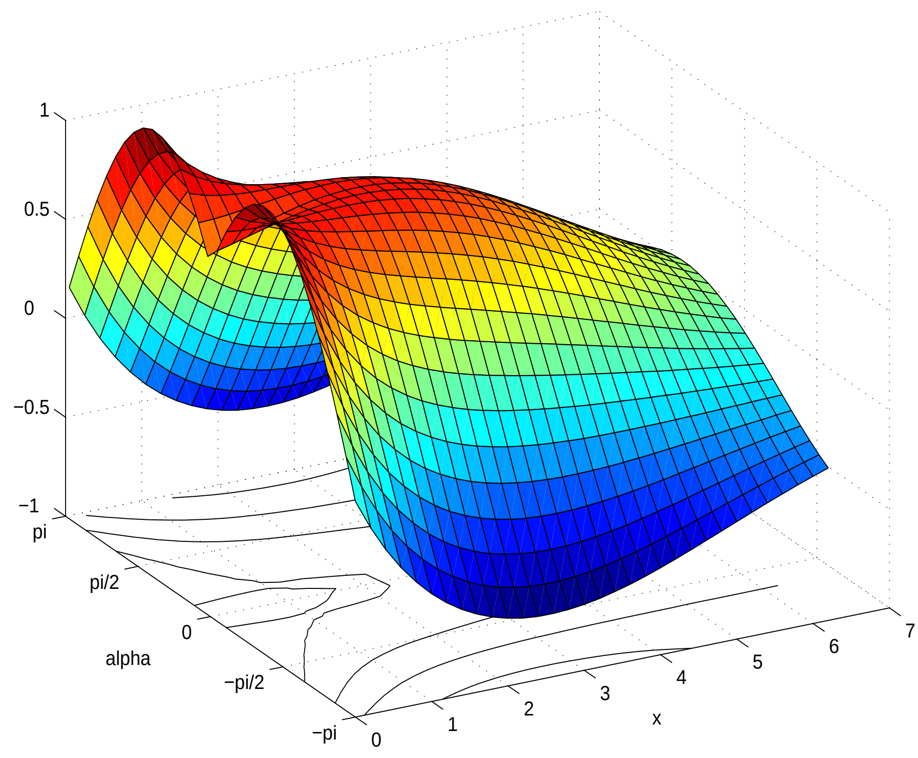

Figure 2: $F_{\delta,\gamma}\left(x,\alpha\right) = sin\frac{|\alpha|}{3}\, e^{-|x|} + cos\frac{\alpha}{3}\, e^{-\frac{(x-\delta)^2}{\gamma}}$ con $\delta = 2, \gamma = 15$

The idea is to favor relatively stable paths and not necessarly those with smaller number of hops. Moreover, by carefully setting δ and γ, it is possible to modify the influence of node's direction of movement and therefore the curvature of functional F.

The functional F will be sampled and put into a look up table. In this way, each node does not need to calculate F for any computation, but it can easily obtain the value corresponding to a given combination of x and α with a table lookup.

2.2 The metric m

Another degree of freedom of the metric employed in MORA is the weight assigned to each node, which can be used to represent traffic conditions, application constraints, etc. The goal of the weighting function is to obtain a fair distribution of the available resources through the overall network.

For the purpose of the paper, the function W, defined for $y \in [0, y_{source}]$, is given by

$$W(x,y) = \begin{cases} 1 & \text{for } 0 \leq w(x,y) < 0.1 \\ -log_{10}\, w(x,y) & \text{for } 0.1 \leq w(x,y) \leq 10 \end{cases}$$

where $w(x,y) \in [0,10]$ is the weight of node i with coordinates x, y.

Now the following metric can be defined, for $y \in [0, y_{source}]$

$$m_{\delta,\gamma}(x,y,\alpha) = \frac{1}{2}\left(W(x,y) + F_{\delta,\gamma}(x,\alpha)\right)$$

where both $W(x,y)$ and $F_{\delta,\gamma}(x,\alpha) \in [-1,1]$ and therefore $m_{\delta,\gamma}(x,y,\alpha) \in [-1,1]$. Due to the fact that x and y are the coordinates of node i and α depends on the node i, in following sections we refer to $m_{\delta,\gamma}(x,y,\alpha)$ and m_i without distinction.

The reader should note that, by choosing such metric, the higher the value of m_i the higher the probability node i is selected for the path from source to destination. Moreover, if node i is congested and therefore $w(x,y) \rightarrow 10$, then $W(x,y) \rightarrow -1$.

3 The MORA routing protocols

U-MORA

The first version of the routing protocol is called Unabridged-MORA, because the core idea is similar to source routing on IP networks and it does not support scalability. In position-based routing algorithms, usually a short probe message is used for destination search, that collects routing information from destination to sender, and finally data are send from source to destination. Our approach exploits this small packet, not only to localize the destination, but also to get information about the best path between source and destination at that moment and for the near future (see Figure 4).

In this algorithm a similar short probe message, used to localize the destination, once it is received, it is sent back from the destination node through several routes, imposing strictly increasing values of y to avoid loops and values of F bigger than a certain threshold η to avoid flooding. Each node j, except the source node, receiving the packet through the link (i, j), updates the value of the function

$$M_j = M_i + m_j$$

by calculating the functional (see Section 2.1) and increasing the number of hops (with relative weight). The packet is updated with the node identifier and the updated value M_j In such a way each M_i received by the source identifies a single path to destination. The state diagram for node j is presented in Figure 3.

Supposing that different probe packets, following different routes, pass through the same node j, in order to avoid computational and traffic overheads, node j has to make a decision depending on functions M_i of packets arriving simultaneously (in a predefined time-window). After the decision, node j updates the function to get M_j and forwards only one probe message. All other packets getting to node j after the decision will be discarded.

When a fixed timeout T expires, the source has a set of different reliable paths to the selected destination and the corresponding functions M_i. The source node has to take a decision to which path to use. Such decision obviously depends on the weight of each node, its position and direction of movement.

Figure 4 presents a simple example, where only two paths are available between source and destination. The destination node 1 computes $M_1 = m_1$, while

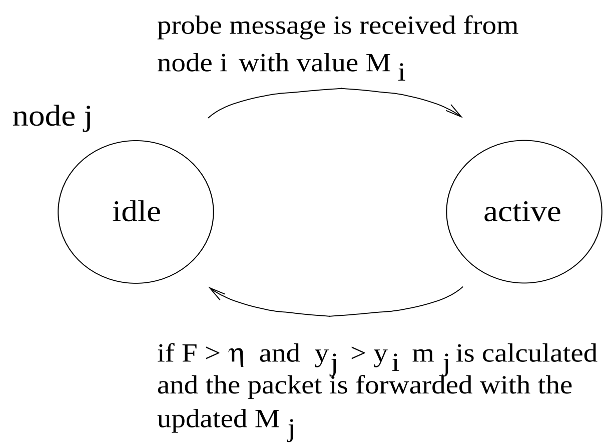

Figure 3: U-MORA flow chart

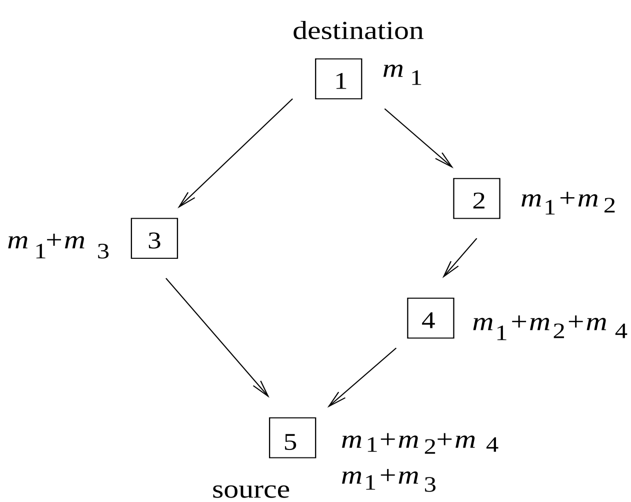

Figure 4: Example

the intermediate nodes update the received function, i.e. $M_2 = M_1 + m_2$, $M_3 = M_1 + m_3$, $M_4 = M_2 + m_4$. The source node 5 get two packets, in which an available path and M_3, M_4 are respectively recorded: if $m_1 + m_3 > m_1 + m_2 + m_4$ data are then sent through the path $5 \to 3 \to 1$, rather than through $5 \to 4 \to 2 \to 1$.

U-MORA requires a relevant amount of traffic, due to the several possible paths and therefore to the several packets trasmitted. The following routing algorithm, D-MORA, presents another use of the metric m, defined in such a way to reduce control traffic overhead.

D-MORA

The second version of MORA is scalable and it is called Distribuited-MORA. D-MORA yields a single path from source to destination.

Let $k \in \mathbf{N}^+$. Again the short probe message is sent from destination back to source. Every k hops the current node receiving it polls for information its neighboring nodes, considering only those with bigger value of y in order to avoid loops (y is related to the distance from the destination as in Section 2.1). The probe message is then forwarded to the neighbor with the higher value of m, attaching path information as in U-MORA.

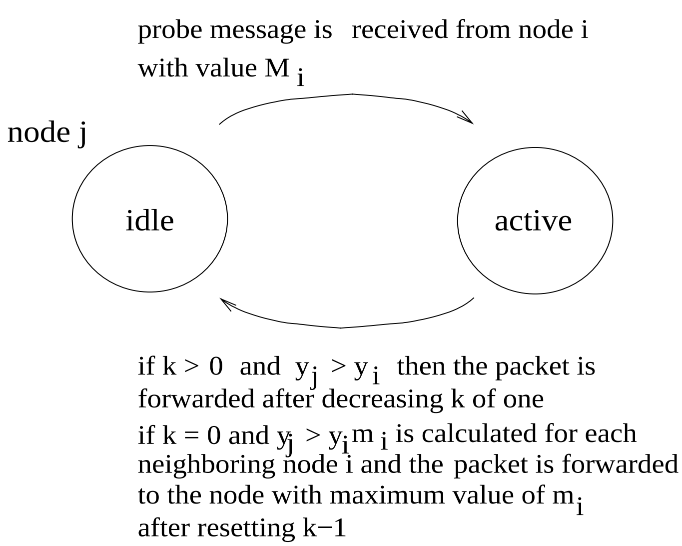

Figure 5: D-MORA flow chart

If a node has no possibilities to forward the packet, it removes its identifier from the packet, increases the value of k by one and returns the packet to the node from which it originally received it.

4 Comparison with existing routing schemes

This section outlines potential advantages and disadvantages of the MORA approach with respect to other existing routing algorithms taking as a starting point the taxonomy of position-based routing protocols proposed in [5]. The following Table 1 reports the selected features of some routing algorithms. It is clear that none of the existing localized routing algorithms takes into account the movement of the hosts.

Table 1: Comparison among caracteristics of existing routing protocols

Method	Position information	Path strategy	Metric	Scalability
shortest path	no	single-path	hop count	no
MFR, greedy	only position	single-path	hop count	yes
DIR	only position	single-path	hop count	yes
LAR, DREAM	only position	flooding	hop count	no
DFS	only position	single-path	hop count	yes
power aware	only position	single-path	power	yes
GFG	only position	single-path	hop count	yes
U-MORA	pos + movement	multiple-path	combined	no
D-MORA	pos + movement	single-path	combined	yes

Exploiting the knowledge of the hosts position could be not enough in a configuration with frequent topological changes. In such a situation it is important to try to garantee links stability and therefore robustness of the routing protocol. The idea behind MORA is to take also into consideration also the direction of movement of the nodes in order to try to find a solution to this critical problem. In ad hoc networks, for communication between fixed terminals such considerations will not improve the communication, but if the terminals are mounted on mobile platforms exploiting the knowledge of direction of movement could have some advantages.

If only position information is used, it is possible to lose some good candidates to forward the packet. For example, considering LAR (Location Aided Routing) and DREAM (Distance Routing Effect Algorithm for Mobility) if one host, moving in direction of sd, is out of the ”request zone” it will be never considered. Similarly, MFR (Most Forward within Radius) doesn't care if the selected next hop is moving in the wrong direction (exactly in direction of the source node for example). Similar comments can be done for DIR (Compass Routing).

Another advantage of MORA over LAR and DREAM concerns flooding: U-MORA significantly reduces flooding in comparison to such algorithms, while D-MORA quite completely eliminates it.

DFS (Depth First Search) could appear similar to D-MORA, since the decision among direct neighbors is taken by minimizig a distance function. However, with this method links are unstable if the topology is highly dynamic.

Shortest-path-based solution are also very sensitive to small changes in local topology and activity status. On the contrary, MORA is adaptive to ”sleep period” operation, since power consumption is extremely reduced for inactive nodes (not participating in route establishment), and only a few nodes are involved in packet routing.

5 Conclusions

In this paper, a motion-based routing algorithm for ad hoc networks (MORA) is proposed. The algorithm is completely distributed, since nodes need to communicate only with direct neighbors in their transmission range, and utilizes a specific metric, which exploits not only the position, but also the direction of movement of mobile hosts. Considerations outline that MORA represents a good solution in cases of high-mobility of the terminals.

Future work will provide a numerical and statistical evaluation of the MORA routing protocol and extensive comparison with other existing approaches. In addition, the problem of accuracy in the knowledge of the position of the nodes will be studied.

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