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Position and Velocity Aided Routing Protocol in Mobile Ad Hoc Networks

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Abstract

Routing protocol is a pivotal issue in Mobile Ad Hoc Networks (MANETs). Several routing protocols have been proposed to deal with the routing issue in MANETs. However, routing turns to be a tough and complex task if all nodes in the network are at a relatively high speed. In this paper, we propose Position and Velocity Aided Routing protocol (PVAR) to resolve the problem. PVAR is designed for MANETs within which all nodes are at a relatively high velocity and aware of position and velocity information of all other nodes as well as itself. By using the information, we change the criterion of selecting a node's neighborhoods and route request procedure. The result shows that with a middle level of traffic flow, our proposed PVAR has a good performance on packets delivery ratio. Routing packets overhead also reduced.

Keywords: *MANET, routing, position, velocity, route discovery*

1. Introduction

Unlike wireless network with predefined infrastructures such as mobile cellular networks, mobile ad hoc networks (MANETs) are infrastructure-free networks with no administrative node. Any nodes within the networks may come and go, turn on and off unpredictably, move continuously leading to a volatile network topology with communications between nodes that are also modified time to time [1]. These features of MANET give rise to its great flexibility and cost efficiency. Several routing protocols have been proposed to solve data transmission problem. Among them, DSR [2], AODV [3] are the most frequently referred. However, these protocols are just designed for common wireless networks. They use basic route discovery and route recovery mechanism to complete the routing task. LAR [4] and GPSR [5] are the protocols with the consideration of location as an important metric to evaluate their performances. However, scenarios within which nodes are with relatively high speed make positional information unpredictable and hence prone to fallible.

In this paper, we suggest an approach to improve the reliability of the process of route discovery as well as to decrease overhead of route packets by utilizing position and velocity information for the mobile nodes. The information may be obtained by using the global positioning system (GPS). We investigate how position and velocity information can be used to achieve our goal.

The rest of the paper is organized as follows: Section 2 discusses some related works. In section 3, we describe our proposed PVAR in details. Simulation sets are described in section 4. The performance evaluation of PVAR is shown in section 5 and at last section 6 presents conclusion.

2. Related Work

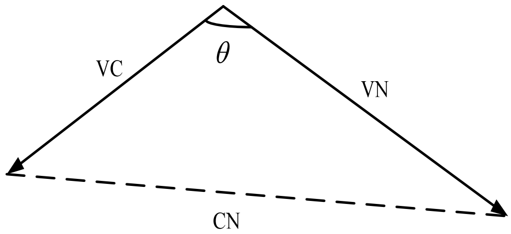
In MANETs, design of routing protocol is always a crucial issue. Several routing protocols have been established (e.g., [2][3][4][5]). DSR (Dynamic Source Routing) [2] uses route discovery and route maintain mechanism to ensure the routing process. A distinct feature of DSR is that it uses route cache strategy to reduce routing messages in the whole network. Every host holds a route cache table which updates periodically to get the latest information about the network. Perkins and Royer raise another prominent algorithm AODV (Ad Hoc On-demand Distance Vector routing) [3]. It uses unique sequence number of every route discovery packet to avoid loop route. DSR and AODV are both reactive protocols. A performance analysis of these protocols is shown in [7]. There are also some protocols use location information to optimize their algorithms. LAR (Location Aided Routing) [4] uses the concept of request zone to minimize the route discovery scope. GPSR (Greedy Perimeter Stateless Routing) uses GG (Gabriel Graph) or RNG (Relative Neighborhood Graph) [5] to select a path which can be used to send route discovery. [8] improved GPSR by using position update and geographic forwarding. But it does not consider the velocity information. [9] also mainly uses position information to ensure reliable routing. Guo Lei and Yu Y have proposed new routing protocols based on reputation [10].

The mentioned routing algorithms seldom take into account that what the performance of the routing protocol be like if velocity of the nodes in MANETs are at relatively high. Obviously, high velocity would lead more route failure because one node would move out of another node's broadcasting range more easily, which will in turn break any route of the other nodes which includes the node as a relay. The aim of our proposed PVAR is to use both position and velocity information to increase the possibility of holding a valid route for long time and to reduce routing overhead in the network as a whole.

3. Position and Velocity Aided Routing (PVAR) Protocol

3.1 Neighborhood Selection

In this paper, we assume that nodes/hosts in MANETs at a relatively high speed (at least 10m/s) when traveling through the network. We also assume that nodes move along a line toward their destination. That means nodes make a unidirectional move toward their finals. In MANET, a central/source2 node's neighbors are the nodes within the central node's one-hop broadcasting scope. The central node can only communicate with its neighborhoods using broadcasting. If a central node wants to communicate with another node which is not one of its neighbors, the source node can reach the intended node hop-by-hop. So it is indispensable for a node to maintain and update its neighbors' information. The problem is that every node in the network may move constantly while a node's broadcasting range is limited. So if all nodes in the networks have a relatively high speed, neighbors of every node may change quickly and the topology as a whole may change fast. Quickly changed neighborhood can cause the failure of a valid route because a neighbor of one node may be an intermediate node to some destinations. Lost of it can lead the destinations unreachable, which will further affect normal communication in the network. Because our route discovery mechanism, key issue of PVAR, is based on broadcasting hop-by-hop, the selection of neighborhood is crucial to PVAR algorithm. If a node's neighbor move parallel with it and has the similar speed of the node, the neighbor may be the node's neighbor constantly before it changes the direction and the rate of velocity. This kind of neighbors can be called "good candidates". While a node's neighbor move to the opposite direction of the node, the distance of the two nodes will be longer and longer and leave each other's one-hop communicate range. They will be no longer each other's neighbor eventually. If the neighbor itself is an intermediate node of a valid route that is used by central node to communicate with other nodes, the route will be an invalid route. This would cause the failure of communication and hence increase overhead of routing messages because the source node has to initiate another route discovery procedure. The more easily broken a valid route, the more routing message generates. This kind of neighbors can be called "bad candidates". There should be some criterion to cut all neighbors of a node into two distinct parts--"good candidates" and "bad candidates". Because in our implementation every node in the networks are at the similar speed (relatively high), its position and a unit vector that specifies the direction of the node's movement are the only two metrics that we decide to use to judge which neighbors should be the good ones in order to set as relies. Assume the central node's unit vector of its speed is VC; the unit vector of speed of one of its neighbors is VN. If we know clearly about VC and VN, by using low of cosine, we can calculate the angle between VC and VN. By calculating a node's neighbors one by one with a threshold angle, we can decide whether a neighbor is "good" or "bad". Figure 1 shows how to calculate angle between VC and VN.



$$\theta = \arccos \frac{\left|\vec{VC}\right|^2 + \left|\vec{VN}\right|^2 - \left|\vec{CN}\right|^2}{2 \bullet \left|\vec{VC}\right| \bullet \left|\vec{VN}\right|}$$

Figure 1. Calculate the Angle Between VC and VN

However, only using unit vector of speed is not enough to decide whether a neighbor can be selected as a "real neighbor". We should take the position into account as well. A central node calculates the distance between its neighbor and itself. If one of its neighbors is further than a predefined threshold, the neighbor is judged as a "bad candidate"; otherwise it is a "good candidate". A neighbor is seemed as a "real neighbor" only if it is "good candidate" under both vector of speed and positional criterion. As implement now, we simply deny "bad candidates" as neighborhoods while "good candidates" seemed as neighbors. "Bad candidates" do not take part in the route discovery procedure because central node will not send route request packet to them. In other words, we do not want "bad candidate" acts as a relay. In our implementation, the threshold between VC and VN is 135°. The threshold of distance between neighbors and central node is 220m (default broadcasting range is 250m). Figure 2 shows some "good candidates" and bad ones.

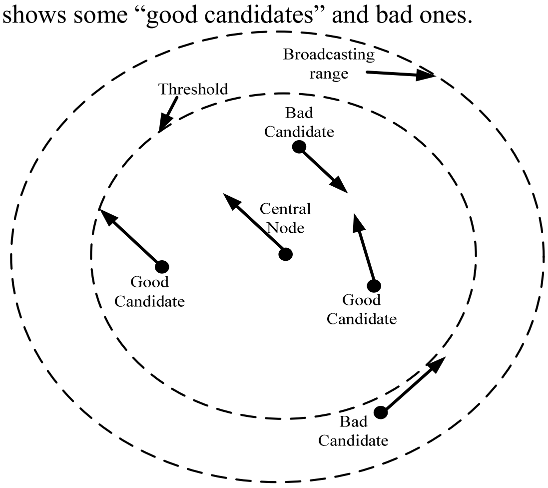


Figure 2. Example of Good and Bad Candidates

3.2 Route Discovery

In PVAR, we focus mainly on efficient route discovery mechanism. Our aim is to make the process of route discovery more reliable and less overhead.

3.2.1. Route discovery use flooding

The route discovery mechanism of PVAR protocol is based on flooding (this is very similar with DSR and AODV). When a node S wants to communicate with node D which is not one of its neighbors, route discovery procedure starts to work. Based on previous discussion, S broadcasts a route request packet with a sequence number (SN) to its one-hop neighbors. Actually, we do not have the same implementation when a node receives a route request packet. But now, we only discuss some basic mechanism. The neighbors that receive the route request packet first check if it has a fresh enough route to the destination D. A fresh enough route means that the SN of a route cached by the node is bigger or at least the same as that in the received route request packet. If it has such route, it sends a route reply to S, S drops other reply packets that have the same or smaller SN. Then S can send its data flows and the route discovery procedure concludes. If the neighbor does not have a route to D, then it broadcasts the route request packet to its own neighbors. Every node does the same procedure until D receives the packet. Then D itself sends back a route reply to S along the way the route request packet forwards. Whenever S receives a route reply, it updates its route table to maintain the latest information of the network. In PVAR, every node holds a sequence number (SN). Whenever it sends a routing packet, it adds the SN to the packet. When receives a packet, it only handle with the packet whose SN is the same as or bigger than its own. Otherwise it drops the packet immediately and silently.

3.2.2. Specified Route Discovery in PVAR

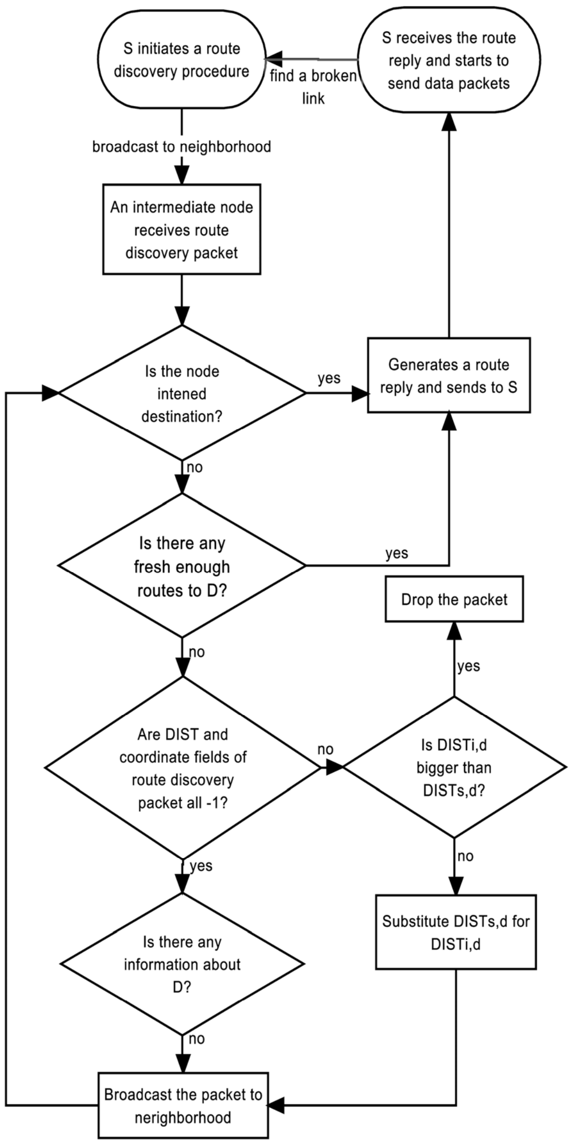


Figure 3. PVAR Mechanism

Basically, our algorithm is based on flooding in order to complete the route discovery procedure. However, with the help of position and velocity information, we modified the flooding based route discovery strategy to increase reliability and reduce routing overhead. Our scheme is like the following: When a node S wants to communicate with another node D which is not already in S's route table, S initializes a route discovery by generating a route request packet. Besides source address, destination address and sequence number fields, S adds its own position and velocity information into the packet. If S knows about the position and velocity information of D, it calculates the distance between D and itself then put the distance (DIST) and the coordinates and the velocity of D into the packet. If S do not knows about the position and velocity information of D, it fills the DIST, coordinates and the velocity of D with recognizable flags (in our implementation -1.0). When an intermediate node M receives the route request packet, it first checks if it is the destination. If it is the destination (M is D), it generates a route reply packet to S and put its position and velocity information into the route reply packet. Then it updates the sequence number of the SN field of the packet as well as itself and broadcasts the route reply until it reaches S. Here we use flooding to send the route reply back to S instead of sending it follow the route that route request forwards. Our consideration is that this modification can make as many nodes as possible be informed the velocity and information about D which will make the selection of neighbors more precisely. At the same time, there are as many nodes as possible know about a valid route to D without sending a route request packet. This will in turn reduce routing overhead a lot. Any node receives the route reply packet immediately updates its route table destined to D. When S receives the route reply packet, the route discovery concludes. S now can send data packet from upper layer according to the route table. If M itself is not the destination, it first check if it has a fresh enough route to D (it means the sequence number of route it holds for D is the same or bigger than that in the route request packet). If M, according to our previous discussion, is the selected neighborhood of its predecessor node, it generates a route reply packet and fills the position and velocity information of D into the packet. Then it sends the route reply packet to S using flooding. If M is neither the destination nor has a fresh route to D (In PVAR, we use HELLO message to establish the neighbors. The route discovery packet also contains a field of good neighbors. Only good neighbors do the following procedures.), it plays the role of relay station. It first checks the DIST and the position field of the route request packet. If these fields are all with the value of -1.0, that means S do not know any information about D yet. M checks if it has the position and velocity information about D. If M does not know, it keeps these fields with -1.0 and simply broadcasts the route request packet. Otherwise, it calculates the distance between D and itself. If the distance between D and M is shorter than the DIST field in the packet, that means DISTD, M is shorter than DISTS, D, and then it replaces the DIST field of the route request packet with DISTD, M and broadcasts the packet until it arrives D. The situation is less likely to happen but in route recovery procedure. In route recovery procedure, a part of link of the path S to D fails. So S has to initializes another route discovery procedure to find another valid route to D. Every node with the route to D may be invalid, so the information about D in route table also may be invalid. But if there is not the movement of D causes the failure of linkage, the information about D is available. Figure 3 shows route request packet header of our implementation. Figure 4 is the flow chart of PVAR mechanism.

Type(8)	Dst(32)	Src(32)	XD(32)	YD(32)	VD(32)	DIST(32)	SN(32)

Type: Packet Type Dst: Destination Address Src: Source Address
XD: X coordinate of destination YD: Y coordinate of destination
VD: Velocity of destination DIST: Distance between Dst and Src
SN: Sequence Number

Figure 4. Route Request Packet Header

4. Simulation Model

We simulate PVAR in ns-2[6]. By measuring the result of the internal code and PVAR, we could ensure our results are reliable and comparable to previous routing protocols.

In our implementation, number of nodes in the network was chosen to be 50 and 100 for several times run. The nodes in the MANET are confined to a 670m X 670m square region. The actual speed follows Gaussian distribution in the range between 1-10m/s, 10-20m/s and 20-30m/s respectively. At the start of the simulation, all nodes are distributed randomly among the plane. Upon moving to the destination, the node pauses for a predefined period before it can move forward again. In our model, the pause time was chosen to be 0s (no pause), 10s, 20s and 30s. The total simulation time is 100s.

In the simulations, we compare PVAR with AODV. We simulate 20 CBR traffic flows, originated by 20 nodes. Each CBR flow sends with 128-byte packets, 10packets/second. When CBR flow starts, its source and destination are chosen randomly. Any node can only communicate with its neighborhood directly. Any data packets that can not delivered to the destination due to the invalid route are simply dropped.

Other perimeters are as follows:

MAC protocol: 802.11

Length of Link layer queue: 100 packets

Propagation model: Two Ray Ground

Antenna pattern: Omni-direction

5. Simulation Results

To display the performance of PVAR, we choose two metrics for comparisons: delivery ratio and routing packet costs. Packet delivery ratio is the ratio of successfully delivered packets and the total transmitted packets of CBR traffic flows. While routing costs is the ratio of the number of routing packets and the number of CBR packets.

3.3 Packet delivery ratio

In figure 5, the x axis stands for pause time, say 0s, 10s, 20s and 30s respectively, the y axis signals the delivery ratio.

In figure 5, the number of nodes in the network is 50. Their speeds are all follow Gaussian distribution in the range between 1-10m/s, 10-20m/s and 20-30m/s respectively. However, we annotate them with simply 10m/s, 20m/s and 30m/s. The figure shows that the packet delivery ratio of PVAR is at least more than 0.988 and more stable when pause time alters when speed of nodes is chosen to be 10m/s. But the performance of both PVAR and AODV is desirable. When speed is between 10m/s and 20m/s, the performance of PVAR and AODV is poorer concurrently than that when speed is 10m/s. This is reasonable; consider there should be more broken route when nodes in the network move toward their destinations. But when pause time is 30s, the packet delivery ratio of AODV decrease sharply. This shows that AODV is not as stable as PVAR. When speed is between 20m/s and 30m/s, the figure demonstrates that the jitter of packet delivery ratio of AODV is very high. The instability of AODV appears again. On the other hand, the performance of PVAR shows its stability.

It can be seen clearly from figure 5 that PVAR has a higher packet delivery ratio than AODV with different speed choice. The jitter of delivery ratio of PVAR between different pause times is also smaller than that of AODV. So PVAR has a better performance over AODV.

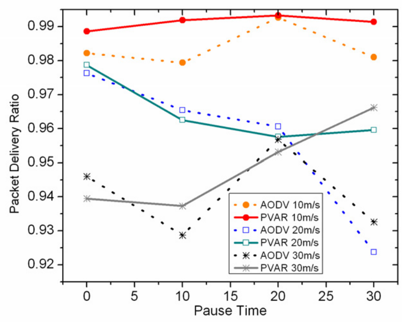


Figure 5. 50 Nodes with Different Speeds

In figure 6, the x axis and y axis have the same meaning as that in figure 5. The number of nodes increases to 100. The speed of nodes is also between 1m/s and 10m/s, 10m/s and 20m/s, 20m/s and 30m/s respectively. From the figure, we can see the jitter of packet delivery ratio between different pause times is larger than that of 50 nodes for both PVAR and AODV. The packet delivery ratio decreases compared with 50 nodes on average as well. But this time, PVAR wins over AODV under all situations (different speeds). With different speeds, packet delivery ratio of PVAR is at least above 90%; while the performance of AODV with max speed 20m/s and 30m/s is below 90%. We can say that AODV is unqualified under this situation. We can conclude from the figure that when the topology of the network is more complex and more prone to change (the nodes in the network have a relatively high speed), the performance of PVAR on packet delivery ratio is better than AODV.

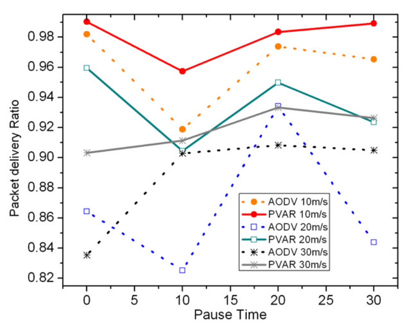


Figure 6. 100 Nodes with Different Speeds

3.4 Routing Costs

In figure 7, the x axis of the figure stands for pause time 0s, 10s, 20s, 30s we use for different runs. The y axis stands for the average number of routing packets per data packet.

Figure 7 shows that when number of nodes in the network is 50, the performance of routing costs for both PVAR and AODV. We can see that when the speed of nodes increases, the routing costs increase as well as a result. This probably because the higher of speed of nodes, the more possible a route will be invalid. We can also conclude that although there are some jitters, but the overall performance of PVAR is clearly better than AODV.

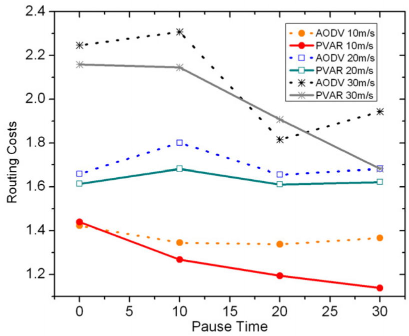


Figure 7. 50 Nodes with Different Speeds

Figure 8 shows when the number of nodes is altered to 100, the performance of both PVAR and AODV. When the speed of nodes is 10m/s, we can see the routing packet cost of PVAR is better than AODV and keep a low value of it. But when the speed of nodes increases to 20m/s and 30m/s, the routing cost of both PVAR and AODV increase significantly. The jitter of routing cost is also higher. This may because the higher of speed of nodes, the more possible the CBR source nodes need to recovery from broken route. From the figure, we can see the route costs of PVAR are lower than AODV, this is because: 1. "neighborhoods" are selected; they are more reliable to make themselves relays. 2. When nodes receive route request, it first check whether it is closer to destination of route request. If it is farer than the generator of route request, it just drops the route request packet silently. So the total route costs can reduce considerably but with no reduce of performance.

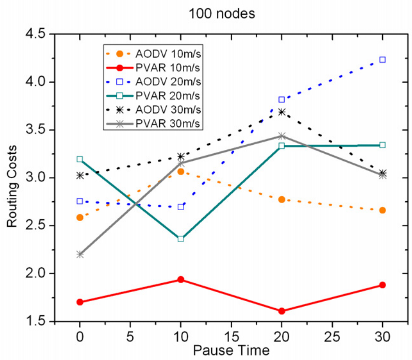


Figure 8. 100 Nodes with Max Speed 30m/s

6. Conclusion

We present Location and Velocity Aided Routing protocol, PVAR, a routing algorithm that uses location and velocity information of nodes in the network to achieve better performance of packet delivery ratio and routing packet cost. Our research limits to the neighborhood selection and the route discovery process. We do several runs of simulation compared with AODV, another prominent routing protocol for MANET.

Simulation results indicate that using neighborhood selection mechanism and specified route discovery result in higher packet delivery ratio and lower routing packet costs when nodes in the network are at a relatively high speed.

7. Acknowledgment

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