# Analysis of Mobility Models for Vehicle Adhoc Networks and a New Mobility Model—-Score Based Routing

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## Abstract

*Vehicle Ad Hoc network is a special kind of Mobile Ad Hoc Network among cars. It is equipped with wireless network communication devices and vehicle global position system. VANET is the the most extensive and promising research area of MANET.*

*This paper is based on the preliminary research results for different routing algorithms, making deep look into these algorithms and comparing them with each other. You will also find a new algorithm named Score-Based Routing. In this paper, I will first give a brief summary of the origin, characteristics and application of VANETs. In section 2,3 and 4, I will show GPSR(greedy perimeter stateless routing),MORA(movement-based routing algorithm),MAGF(movement aware greedy forwarding ) and SBR (score-based routing)in detail. In section 5, I will use JAVA to simulate these routing algorithm and find their advantage and disadvantage, focusing on the impact of density of cars and power range on delivery rate and delay. The demo will also be given.In this section,three situation will be given, city road, high way and framework.In the last section,I will give the future work.*

## 1. Introduction

This is the third and final report of the project of wireless communication course in this semester.For the three weeks from report 2 to now,I have optimized the simulation and get the final result under three situations:city road(done before report 2),high way and framework.For the three situations,the city road is of more significance because it includes the real road and vehicle density of Xu Jiahui District which I get from Professor Zhu Yanming in 973 Laboratory.However,in this final report I will give all the simulation results and the theoretical analysis of the mobility models in vehicle adhoc networks.

First of all,a brief introduction of vehicle adhoc networks.Vehicle networks have recently gained a growing interest among researchers from both academic community and the automobile industry. They provide a promising support for the future Intelligent Transportation System (ITS). Thanks to the emerging wireless technologies, vehicles are able to communicate with each other as well as with the roadside infrastructure.

Data routing through vehicle adhoc neworks(VANETs) remains a challenging task due to the high mobility of nodes which causes rapid topology changes and frequent disconnections.To address this issue, we exploit additional information about vehicles movement in order to adapt traditional position-based approach for such a dynamic environment.

As far as the information of a vehicle is concerned,three key data should be considered,that is position,speed and direction.Three mobility models are widely used in vehicle adhoc networks.Greedy perimeter stateless routing(GPSR) is based only on position.Movement-based routing algorithm(MORA)is related to positon and direction.Movement aware greedy routing(MAGF) considers all the three factors.

The class of position-based routing protocols, such as GPSR,offers an alternative approach known to be more robust in face to mobility. Indeed, no global knowledge of the network topology is required; a purely local decision is made by each node to forward data to the closest neighbor to the destination. Ideally,this process can be repeated until the packet is delivered.Unfortunately this is not always possible; a packet could not be forwarded if its current forwarder node does not have a neighbor geographically closer to the destination than itself. This problem,known as local maximum, occurs often in road intersections because position information does not always point to the right direction leading to a wrong forwarding decision. The absence of mobility prediction also prevents a node from detecting the unavailability of some neighbors. With these shortcomings, the position-based routing still needs some improvements to match the requirements of vehicular applications.

Also there is another aspect of consideration.The three factors:position,speed and direction,can be included in one scalse,that is a vehicle's possibility to function as a intermediate node.Based on this I develop my self-designed model:score-based routing(SBR).Finally I use java to compare the four models under three situations:city road,highway and framework and get the results.

The structure of this report is as follows.Section 2 will give some theoretical analysis of existing mobility models:GPSR,MORA and MAGF.Section will discuss about my self-designed mobility model–SBR.Section 4 will give the simulation demo and results.Section 5 will discuss about my future work and a conclusion of this project.

## 2. Analysis of three widely-used mobility models

There are mainly three mobility models, that is GPSR,MORA and MAGF.These three mobility models consider one,two or three factors of position,speed and direction.This section will give a brief introduction of three models.Some of this section is based on report2 because this is theoretical analysis of exsting mobility models.

### 2.1. Greedy Perimeter Stateless Routing

In VANET,Greedy Perimeter Stateless Routing(GPSR)is a common and developed mobility model.Brad Karp and H.T. Kung of Harvard U- niversity[3] give a specific discussion of GPSR and [2][12]shows a improvement model GPSR with lifetime(GPSR-LT).In this section,I mainly show the ba- sic GPSR and the simulation result is also about this one.

#### 2.1.1 Greedy forwarding

As a representative example of position-based algorithms, we describe Greedy Perimeter Stateless Routing (GPSR) as it seems to be the most popular candidate for dynamic networks. Typically,there are several requirements on the availability of position information: GPSR requires that each node is able to obtain its current location e.g., through a GPS receiver as it is becoming standard equipment in vehicles.Furthermore, it assumes that each node learns about the existence of its direct neighbors and their current positions through the exchange of periodic HELLOmessages. To make routing decisions, a sending node needs to know the position of the packet destination. This information is obtained with the help of a location service.With all these information, a node forwards incoming packets to neighboring nodes that are geographically closer to the destination. This operating mode is known as Greedy Forwarding.As shown in figure 1,x is the source node and D is the destination node.x choose y as the transmitting node in its range because y is closest to D.

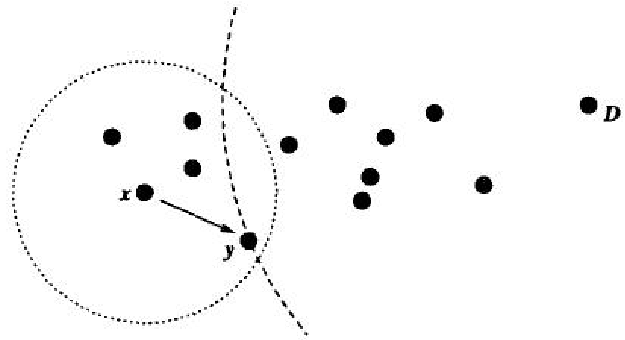


**Figure 1. Greedy forwarding**

But this mode still have some problems.For example,figure 2 shows a scenario where following the Greedy Forwarding strategy, a packet send from node S is forwarded to a node A closer to the destination D but from which a local maximum and could not be recovered. As a result, the packet is not able to progress towards D although a valid path is available from the source to the intended destination.

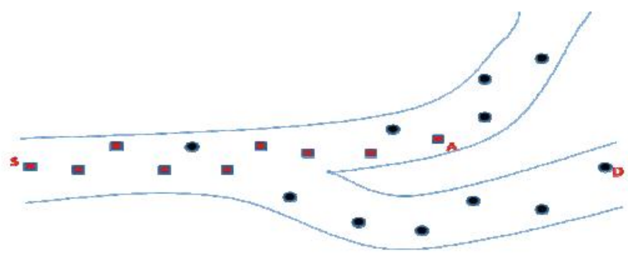


**Figure 2. Greedy forwarding failure**

In such conditions,we should take the right-hand rule.

#### 2.1.2 Right-hand rule

The long-known right-hand rule for traversing a graph is depicted in Figure 3. This rule states that when arriving at node x from node y, the next edge traversed is the next one sequentially counterclockwise about x from edge (x,y). It is known that the right-hand rule traverses the interior of a closed polygonal region (a face) in clockwise edge order–in this case, the triangle bounded by the edges between nodes x, y, and z, in the order $(y \rightarrow x \rightarrow z \rightarrow y)$. The rule traverses an exterior region, in this case, the region outside the same triangle, in counterclockwise edge order.

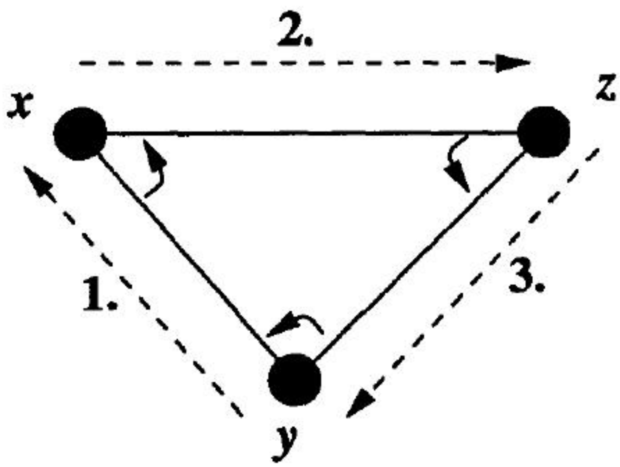


**Figure 3. Right-hand rule**

### 2.1.3 A Small Conclusion

After reading several papers with regard to GPSR. I think GPSR model in VANET can be summarized in short.It can be divided into two methods:greedy forwarding and right-hand rule.In practice,source node take the greedy forwarding method firstly.If it fails as shown in figure2,the source node changes to right-hand rule shown in figure 4.So,in short,GPSR is a alternating process between greedy forwarding and right-hand rule.This is my understanding of GPSR.

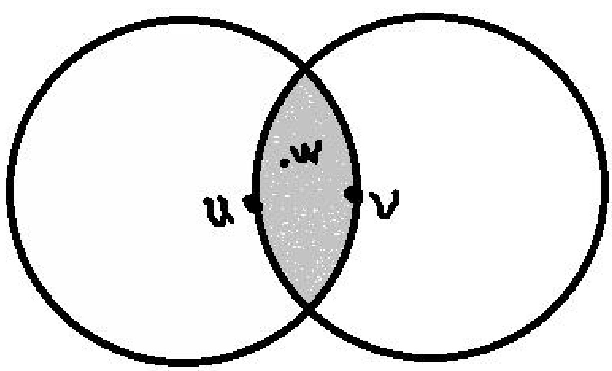


**Figure 4. Right-hand rule**

However, GPSR still have some shortcoming to improve.So Brad Karp and H.T.Kung have developed the RNG graph in [3].The RNG method is used to deal with routing circle problem in right-hand method.As shown in figure4, if a node is in the shadow region, then an edge is excluded.In this way, the probability of routing circle is reduced to minimum

## 2.2. Movement aware greedy routing

From the above section, we can easily see that greedy forwarding does not take the car's(node) state into consideration and only take the road.So another model is promoted in [2], that is Movement Aware Greedy Forwarding(MAGF).MAGF take into consideration the car's speed and direction besides the position.

### 2.2.1 Early assumptions

The MAGF model has some early assumptions.MAGF assumes that every vehicle easily obtains its accurate position as well as its velocity and direction through the navigation system. Typically, in a self-organizing ad hoc network like VANET, each vehicle learns about the existence of its neighboring nodes through the exchange of the periodic beaconing messages known as HELLO messages. A Hello message, in addition to the vehicles position, includes the speed and the direction of the vehicle.

### 2.2.2 MAGF explanation

Our routing approach MAGF is based on the Greedy Forwarding strategy with consideration of nodes movement. It is designed to match the high mobility requirements and to perform even in cases of pure Greedy Forwarding failure. The core idea of this approach is to define a function to assign priority between neighbors while selecting a next hop forwarder. The function is a weighted score which depends on three factors: the position, the speed and the direction of mobile nodes. This score Wi is computed by current packet forwarder for a neighbor i as follows:

$W_i = \alpha P_m + \beta D_m + \gamma S_m$

Here $\alpha$ $\beta$ and $\gamma$ are weighted metrics for position,speed and direction,and $\alpha+\beta+\gamma = 1$.Then I will give three formulas to calculate $P_m, D_m, S_m$ as shown in figure 5

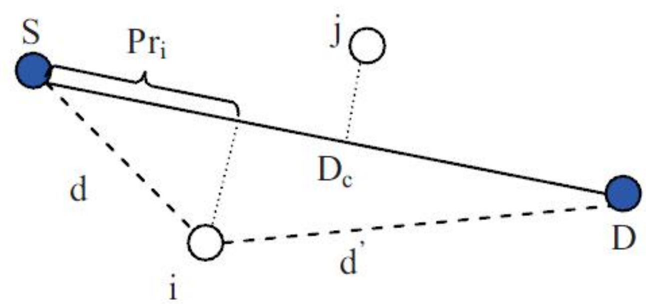


**Figure 5. Relations of position,speed and direction**

$P_r = \frac{{D_c}^2 + d^2 - d'^2}{2D_c}$

where Dc is the closest distance from source to destination, d and d are distances separating intermediate node i from source and destination respectively. Hence, the target position metric is defined by comparing the progress value to the distance between the source and the destination. Such a definition of the position metric assures that priority is given for nodes closer to the destination. The direction factor is defined to select the optimal direction of forwarding by choosing nodes moving towards the destination: where $\theta$ is the angle between the movement direction of the intermediate node and the straight line connecting it to the destination.The speed factor is chosen to favor among all neighbors, the node moving with the highest speed. For a node moving with a speed $V_i$ it can be computed as:

$$S_m = Norm(diff(V_i)) = \frac{diff(v_i)-Min}{Max-Min}$$

where Max and Min represent respectively the maximal and minimal values among all the speed factors computed for all the neighbors of node i. diff represents the difference of speeds between the node i and the source S:

$$diff(v_i) = v_i - vs$$

### 2.2.3 A small conclusion

From the above two sub-sections, we can see that MAGF calculates the weighted $W_i$ of each node based on the position,speed and direction. The source node choose the node with the biggest $W_i$ in its transmitting range as a intermediate node.

## 2.3. Movement-based routing algorithm

As what I have presented in the above section,we need to consider the vehicle's state.Besides MAGF, there is also another model,Movement-based Routing Algorithm(MORA).

A specific definition and explanation of MORA is given in[1]and[7] . The author develop a function F,which is a key in judging the intermediate node in the range as shown in figure 6

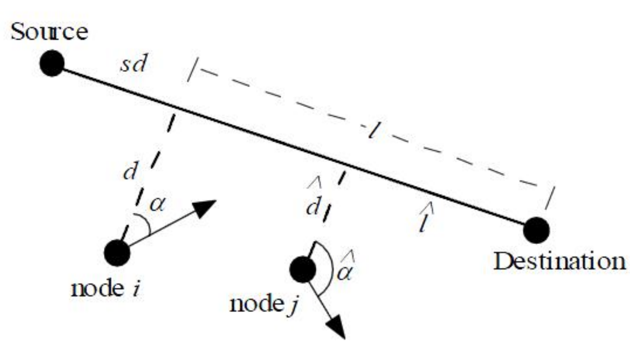


**Figure 6. Function F**

Let 0 d be a reference distance metric, chosen on the basis of the application context. Let x = d d0 be the adimensional distance of the current node from sd and 0 y = l d the adimensional distance from the destination of the intersection point between sd and its perpendicular starting from the nodes current position (see Fig. 1). The functional F is a function of $x \in [0, \infty]$ and $\alpha \in [-\pi, \pi]$, where $\alpha$ represents an angle between the line of the movement direction and the perpendicular line to sd. Function 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 $\delta$ and $\gamma$ are two parameters set on the basis of the application, which simply vary the curvature of F, adjusting the weight associated with nodes movement direction, $\delta$ defines the value of x corresponding to the relative maximum along the x axis and $\gamma$ leads to a smoother or steeper behavior down to zero.

The functional F can be sampled and put into a look up table. In this way, each node does not need to calculate F at any iteration, but it can easily obtain the value corresponding to a given combination of x and $\alpha$ with a simple and fast table lookup.

Besides function F,another function m is also analyzed in[1].Considering I choose function F in my simulation,this section just talk about function F.

## 2.4. Theoretical comparison of GPSR,MAGF and MORA

The theoretical part is almost the same with the preview report,but I also do some new analysis about the three existing mobility models for the past three weeks.

### 2.4.1 GPSR optimization—additional judge

For GPSR,as mentioned above, there is a problem for city road simulation.If GPSR is the only used judgement,it is possible for the source node to forward the the package to the intermediate node in the wrong path resulting in the longer delay and lower package delivery ratio.So an additional judge should be given.I set a additional judgement range which is defined as A.If the selected intermediate node according to GPSR is in the A range of the destination node, then I apply to an additional judge which check whether the intermediate node is in the right path.Beacuse I set A equal to the transmitting range of nodes,this additional judge only takes place in the last transitting.

### 2.4.2 Plot of Functional F(MORA)

MORA use functional F to choose the intermediate node.In fact,F functional has some speciality which influence the choose of intermediate nodes.

for x=0 there are 2 absolute maximums, for $\alpha = \pm\pi/2$respectively;

for 0¡x¡$\varepsilon$($\varepsilon$ arbitrarily small)the trend is the same as above;

for x$\rightarrow \infty$ the function decreases;

for $x = \delta$ there is a relative maximum corresponding to $\alpha = 0$;

for $x \in [\delta - a_{\delta,\gamma}](a_{\delta,\gamma}\ and\ b_{\delta,\gamma}$ constants defined with the choice of $\delta\ and\ \gamma$) there is a maximum corresponding to $\alpha = 0$.

#### 2.4.3 Lifetime for MAGF

MAGF is a mobility model considering all the three factors: position,speed and direction.However,these three factors can only tell the best intermediate node at a certain time unit.At the next time unit,the intermediate node may be out of the transmitting range.So the lifetime of a node should be considered.Lifetime is related to the position,speed,direction and transmitting range of a vehicle.

## 3. A new mobility model—Score based routing

### 3.1. Score based routing algorism

This is enlightened by MORA and MAGF,both using a function to choose intermediate node.This function gives a weighted factor to each node and the node with the biggest weighted factor is the choice.So I think I can give a weighted factor to each node.This weighted factor is based on the node's past performance.If a node successfully functioned as a intermediate,then we add 1 to it.A source node searches for all the intermediate node in its transmitting range and compare their factors.The node with the biggest factors is chosen.However,I think there must be a complementary explanation.When all the nodes in the transmitting range have small factor or they have the same factors,it is not proper to judge with weighted factor.I think in this condition,we should choose the node with GPSR model

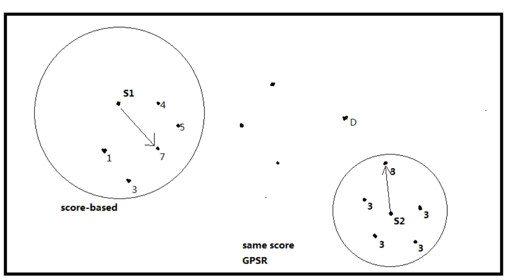


**Figure 7. Score based routing**

The routing algorism can be shown in the following figure

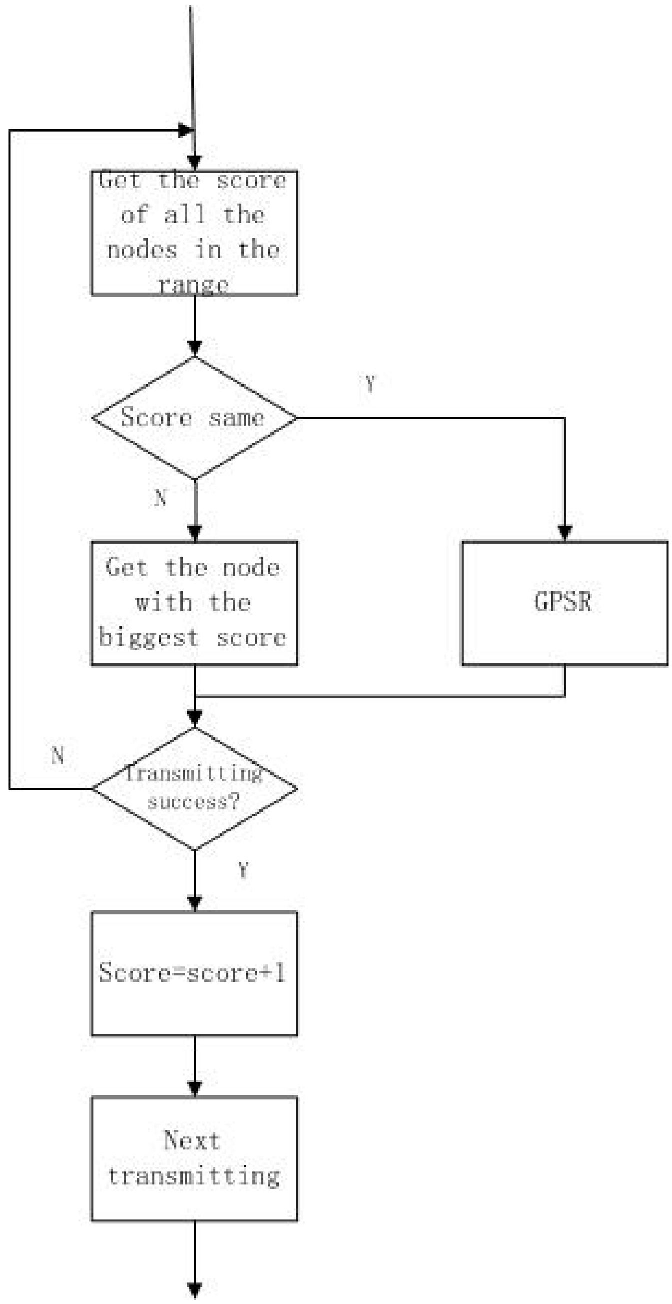


**Figure 8. Flow chart of score based routing**

### 3.2. SBR optimization

Score based routing is a simple mobility model because it only takes into consideration of the vehicles' past performance.It takes a node because it perform better in the past.But we have to consider the current situation of a vehicle.If it is in the bad situation, for example, in the wrong path, we have to kick it out.So the optimization is to add a judge.This judge takes into consideration the path of a city road situation, the direction in the framework and highway situation. If the selected node is in the wrong path or the wrong direction,we have to select another node according to SBR.From the flow chart,it is clear the optimized SBR will have two on-off judges for each transmitting, and for each judge,GPSR is a substitute for SBR when it failed.

## 4. Simulation and Demo

### 4.1. Simulation Situation

I use JAVA to do the simulation.First, I simulate the vehicle adhoc networks in a simple framework with no road.Then I use the data from Professor Zhu Yanming to simulate the road situation in Xu Jiahui District.Finally,I design a highway situation.

The city road situation is a macro situation with a broad perspective. In this situation, the road restrict the trick of vehicles.The demo and data analysis is shown in figure 9.The framework is a simplified one with no roads and all the vehicles are restricted in a enclosed rectangular area.This situation is only for initial simulation and is greatly different from real life.The highway situation has both positive and negative direction of the lane.There is a long straight road with vehicles run on it.

The purpose of my design and development of this demo is that users can set the speed,range and vehicle density according to their need and also,select the situation.The users can observe and monitor the running of the networks.After the setting time is over,users can get the data and the final results.

Users can set the parameters of the simulation as described below:

1.Area size.This parameter is used to set the size of the simulation area.

2.Vehicle density.(per square km).This parameter is used to set the number of the vehicles.Because the vehicle density is more intuitive,users can set the vehicle density.The demo will calculate the number of vehicles.

3.Simulation time(s).This parameter is used to set the system simulation time.If the area size is larger,the simulation time should be longer.

4.Transmission power(m).Transmission power is actually a one-hop transmission distance. The users can set the transmission range and this range is defined as a system property. Once set,all vehicles have the same transmitting range.

5.Speed range(m/s).Vehicle speed has significant impact on the network performance.

6.City road simulation.Thanks to Professor Zhu Yanming's data, I get the road and vehicle data of Xu Jiadistrict.This parameter is only used in the city road situation.The data is in the form of "vehicle identification,latitude,longitude,altitude,speed,direction and delivery time"

7.Road length(km).In the highway situation,users have to set the length of the highway road.

The demo is shown in the following figures.

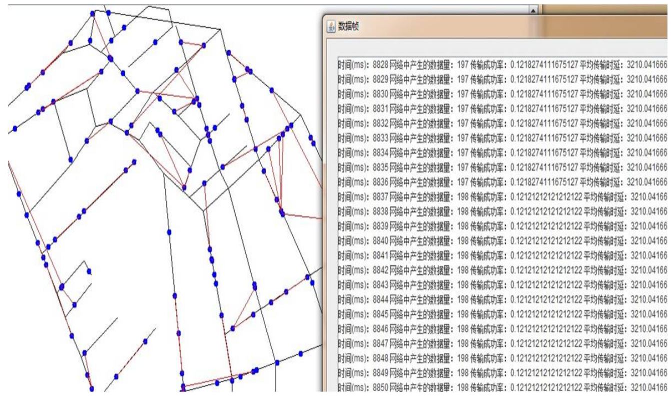

**Figure 9. City road demo**

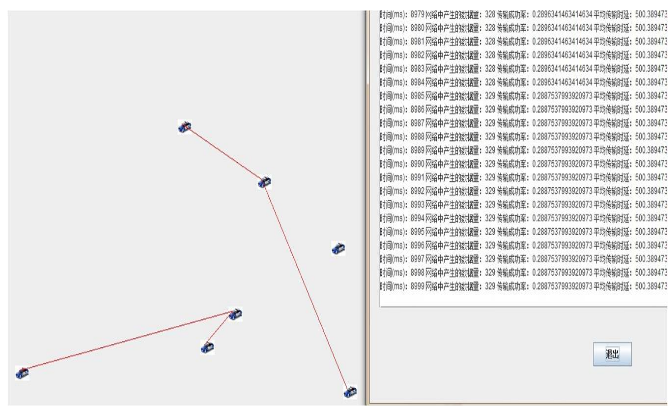

**Figure 10. Framework demo**

**Figure 11. Highway demo**

### 4.2. Simulation Setup

With regard to the simulation of VANET, ns2 and Glomosim are the most usually used software. As a new starter in this field, I choose JAVA to do the simulation.The simulation setting is shown in the following table.

| Simulation Setting | |
|---|---|
| time unit | 1ms |
| simulation time | 1800s |
| speed | 10m/s-30m/s |
| packet size | 1-10 |
| vehicle density | 1 per km,2 per km,3 per km |
| transmission range | 100m,300m,500m,800m |

There are several points to explain before I give my simulation results.

1).My simulation researches into the impact of vehicle density and range on end-to-end delay.As shown in the above table,the simulation time is 1800s and the time unit is 1ms.So I have done 1.8 million test during my simulation.I have confidence in my simulation result.

2).Because the region is 400km,there is a huge number of cars in this simulation.The vehicle density above is of statistic average.

3).The simulation has concentrated only on transmission range and vehicle density. Other factors are considered same or ignored in order to simplify the simulation and get better results with regard to the two key factors.

### 4.3. Simulation results and analysis

1.The following four figures show the impact of vehicle density on delay.

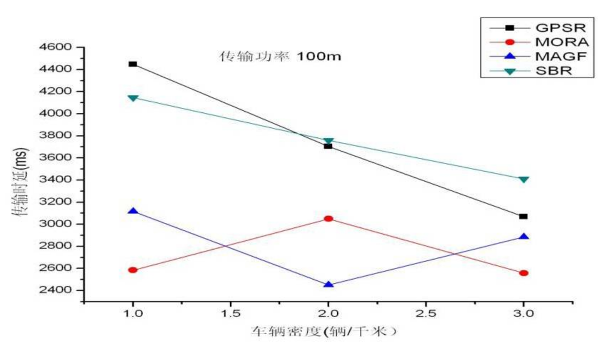


**Figure 12. Delay-vehicle density of range 100m**

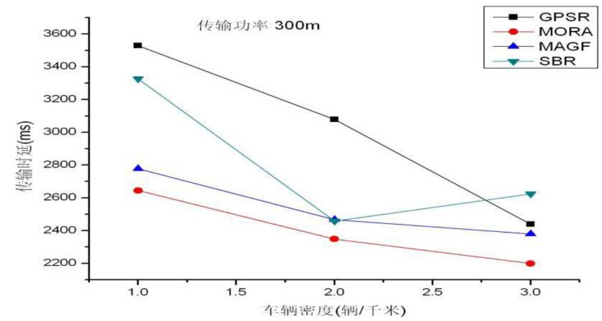


**Figure 13. Delay-vehicle density of range 300m**

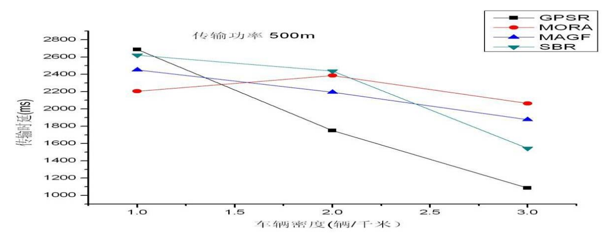


**Figure 14. Delay-vehicle density of range 500m**

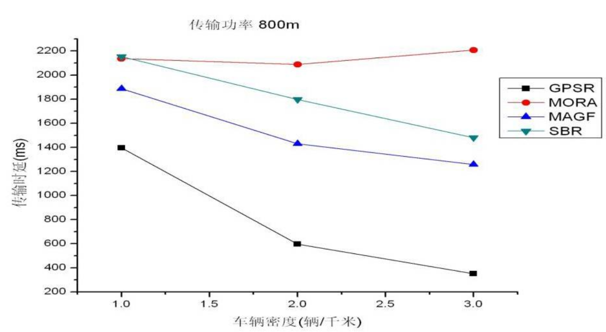


**Figure 15. Delay-vehicle density of range 800m**

We can see clearly from the four figures:

1). With the increase of vehicle density, the delay decreases.

2). GPSR performs the worst in case of small range and low vehicle density.However,GPSR becomes the first choice in case of big range and high vehicle density.This is easy to explain according section 3.Greedy forwarding is less likely to fail in case of high density and big range.

3).SBR performs better in high range and high vehicle density,but it performs bad in low range.Compared with other mobility models,SBR's advantage and disadvantages are clear.

2.The following three figures show the impact of range on delay

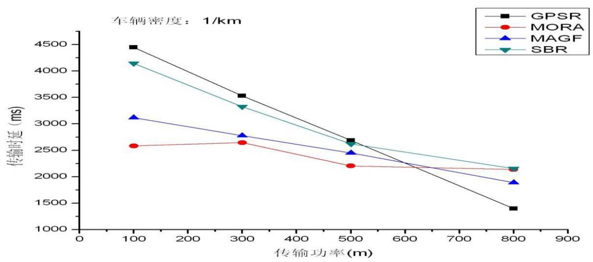


**Figure 16. Delay-range of vehicle density 1/km**

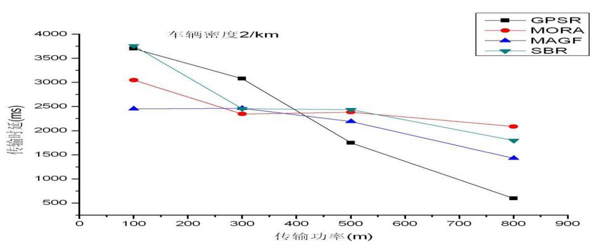


**Figure 17. Delay-range of vehicle density 2/km**

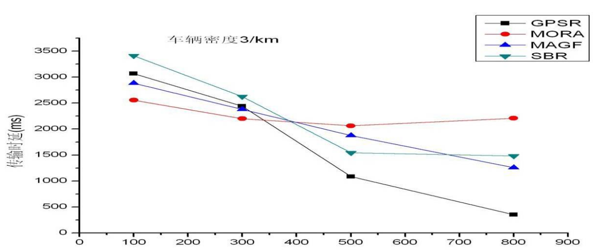


**Figure 18. Delay-range of vehicle density 3/km**

We can see clearly from the three figures:
1).With the increase of range, the delay decreases.

2).The increase of range has more impact on GPSR than on MORA and MAGF.This is easy to explain because GPSR is only position related,MORA is position and direction related,and MAGF is position,speed and direction related.

3).SBR has similar curve with GPSR.This is easy to explain because I apply to GPSR in the same score situation of SBR.

3.The following four figures show the impact of vehicle density on package delivery ratio

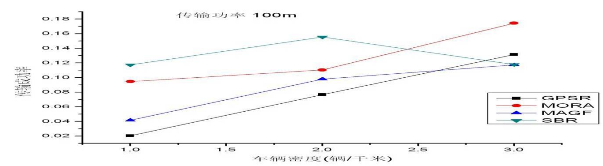


**Figure 19. Package delivery ratio-vehicle density of range 100m**

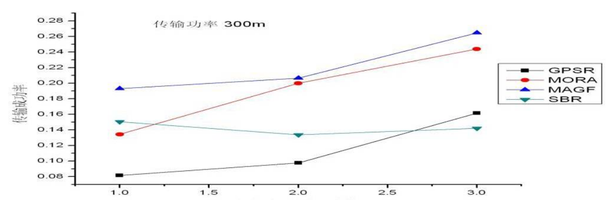


**Figure 20. Package delivery ratio-vehicle density of range 300m**

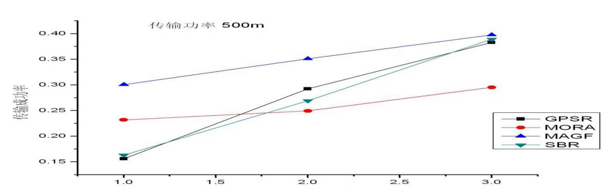


**Figure 21. Package delivery ratio-vehicle density of range 500m**

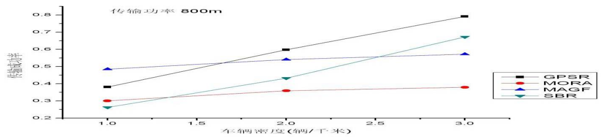


**Figure 22. Package delivery ratio-vehicle density of range 800m**

We can see clearly from the four figures above:

1)With the increase of vehicle density, the package delivery ratio of all the four mobility models increases.

2)With the increase of range,the package delivery ratio of GPSR increases faster than other mobility models.

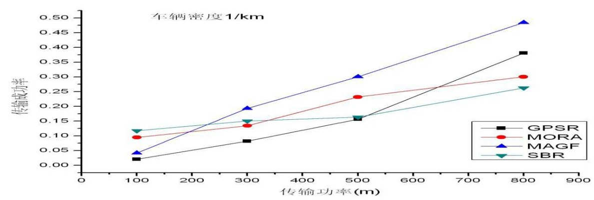


**Figure 23. Package delivery ratio-range of vehicle density 1/km**

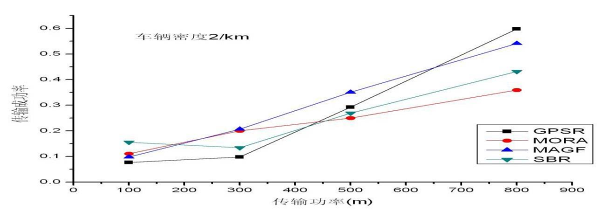


**Figure 24. Package delivery ratio-range of vehicle density 2/km**

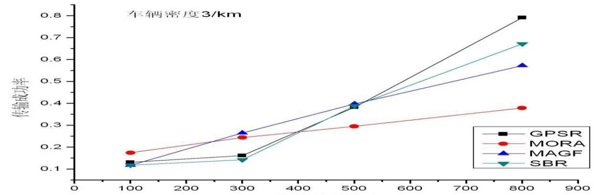


**Figure 25. Package delivery ratio-range of vehicle density 3/km**

We can see clearly from the three figures above:

1)With the increase of range,the package delivery ratio increases.

2)With the increase of vehicle density,SBR and GPSR performs better than other mobility models.

### 4.4. A small conclusion

From the above simulation,we can see that MORA and MAGF are more stable than GPSR with the change of range and vehicle density.GPSR performs worst in case of low density and small range.However GPSR becomes the top choice in case of high vehicle density and big range.There are also two principles.The high vehicle density, the smaller delay.The bigger transmitting range, the smaller delay.

As far as SBR is concerned,I find it similar with GPSR in low vehicle density and range.This is clear because GPSR is the substitute for SBR in our design in these situation.However, with the increase of vehicle density and range,SBR performs better but not as good as other mobility models.I think some additional measures can be used to improve the performance of SBR,for example,the judge of current lifetime as mentioned above.

## 5. Conclusion and future work

In this paper,I proposed a new mobility model for vehicle ad-hoc networks(VANETs)—score-based routing. In this model,I consider the past performance of the nodes in the transmitting range and choose the node with the best past performance.Besides the above work, I studied and researched into three widely used mobility models:GPSR,MORA and MAGF. I use JAVA to do the simulation and compare the three existing models with my self-designed model–SBR.I make full use of JAVA and develop a demo which can apply to all the parameter needs of users.From the simulation,we can see clearly that with the increase of range and vehicle density, the delay decreases and the package delivery ratio increases.SBR performs better in high density and long range.

However,there still remains some work to do.It is clear that SBR has some drawbacks in low density and small range situation.In these situation,according to my design,SBR is often substituted with GPSR because of same score or low score.I think this is an interesting problem to study.

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## 6. Reference


[1]Fabrizio Granelli, Giulia Boato,and Dzmitry Kliazovich,"MORA: a Movement-Based Routing Algorithm for Vehicle Ad Hoc Networks".

[2]N.Brahmi, M.Boussedjra, J.Mouzna and M.Bayart,"Adaptative Movement Aware Routing for Vehicular Ad Hoc Networks".

[3]Brad Karp and H. T. Kung,"GPSR: Greedy Perimeter Stateless Routing for Wireless Networks".

[4]Hamid Menouar and Massimiliano Lenardi and Fethi Filali,"Movement Prediction-based Routing (MOPR) Concept for Position-based Routing in Vehicular Networks".

[5]HUO Meimei,ZHENG Zengwei and ZHOU Xiaowei,"Research overview of simulation of vehicular Ad hoc networks".

[6]Hao Jianjun,Luo Tao and Yue Guangxin,"Vehicle Ad HOC Network".

[7]E. M. Royer and C.-K. Toh, A review of current routing protocols for ad hoc mobile wireless networks.

[8]W. Su, S. J. Lee, and M. Gerla, Mobility prediction and routing in ad hoc wireless networks.

[9]J.Gong, C. Xu, J. Holle, Predictive Directional Greedy Routing in Vehicular Ad hoc Networks.

[10]I.Stojmenovic. Position-Based Routing in Ad Hoc Networks. IEEE Communications Magazine.

[11]L. Tonghong, S. K. Hazra and W. Seah A Position-Based Routing Protocol for Metropolitan Bus Networks.

[12]E.Royer and C.Toh. A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks.

[13]R.S. Aditya, M. Pai, M. Boussedjra, J. Mouzna, GPSR-L: Greedy perimeter stateless routing with lifetime for VANETS.

[14]D. B. Johnson and D. A. Maltz, Dynamic source routing in ad hoc wireless networks