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Comparison of performance of a position-based routing protocol for: VANET

Dr. P Phanindra Kumar Reddy[1], Dr. K Prasanna[2] , Dr. S Aleem Basha[3]

Assoc. Professor's, CSE Department,

Annamacharya Institute of Technology & Sciences, Rajampet.

ABSTRACT

VANET is an application of an ad hoc mobile network for communication between vehicles. Each vehicle knows its position information by GPS or other methods. Position-based routing is a useful approach in VANET. The position-based routing protocol can be roughly divided into a forward hop transfer method and a directed flood method. We evaluate the performance of both methods by analysis and simulation is compared..

1. Introduction

A mobile ad hoc network (MANET) has received much attention for the development of computer technology and wireless communication. MANET does not depend on a specific infrastructure, behaves autonomously and performs multi-hop communication. One of MANET's most promising applications is a vehicle-to-vehicle communication system. This system is called a Vehicle Ad Hoc Network (VANET). Much research has been carried out on VANET for driver assistance services, traffic information services, and user communication and information services [1] [2].

Routing protocols for MANET are divided into two types: topology-based routing and position-based (geographic) routing. The Internet Engineering Task Force (IETF) MANET is currently working on the standardization of the topology-based routing protocol [3] [4]. On the other hand, the proliferation of car navigation systems using GPS is remarkable, and it seems that VANET can perform efficient communication using position information. A routing protocol that uses position information is called position-based routing. Compared to topology-based routing, it can:

mitigate scalability issues or control message overload. Several position-based routing approaches have been proposed [5] - [8]. These can be broadly classified into two categories. One is called the Next-Hop Forwarding method and the other is the Directed Flooding method [9]. Each method has been previously proposed and evaluated independently, but they have not been compared at all, although they have different characteristics and we had to choose one depending on the environment.

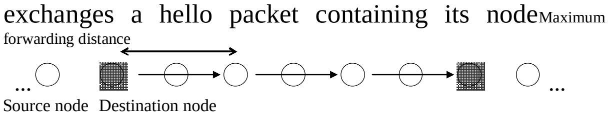
In this article, we evaluate and compare the two methods through an analytical approach and clarify the difference between them. We also run the simulation and evaluate their performance in a real situation.

The rest of the paper is organized as follows. Chapter 2 summarizes position-based routing. Chapter 3 analyzes the two position-based routing methods analytically. Numerical examples are presented in section 4. This document ends in section 5.

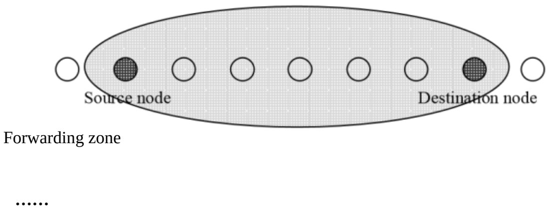
2. Related Work

The concept of position-based routing is illustrated in Figure 1. It can be classified into a next hop transfer method and a directed flood method. In both methods, a source node must know the positional information of itself and the destination node.

The next-hop transfer method is a method of transferring a packet to the selected next-hop node by unicast [5] [6]. This method determines the next hop node from the position information of the sender, its neighbor nodes, and the destination node. To know the position information of neighboring nodes, each node exchanges a hello packet containing its node



(a) Next-Hop Forwarding method.



(b) Directed Flooding method.

Figure 1: Position-Based Routing.

Identification and position information, or each node can collect neighbor information on request by sending neighbor requests to avoid the hello exchange. In addition, in this method, retransmission control is performed in the MAC layer because a packet is sent in unicast.

The directed flooding method floods a packet in a geographic area called the transfer area [7] [8]. The hello packet is not exchanged between nodes because this method does not need to know the position information of neighboring nodes. The source node defines the transfer area between itself and the destination node and floods a packet into the transfer area. To increase the packet delivery rate, the transfer area can be increased, but this leads to an increase in the flooding overhead. However, this problem can be simplified in VANET because the locations of the nodes on the route are limited. Flood overflow can be reduced by using an efficient flooding method such as the time and distance based suppression method [9]. In addition, regarding this method, the retransmission check in the MAC layer is not performed because a packet is broadcast.

3. Characteristic Analysis

In this section, we analyze the characteristics of position-based routing. We assume an ideal CSMA, in which a packet collision does not occur. Then we can model the one-hop forwarding as an M / D / 1 queue [10]. Of course, these assumptions are too simple, but it will suffice to examine the principle behavior of the two position-based routing protocols.

In general, the distance between vehicles is distributed exponentially when a vehicle is moving freely in live traffic. When a vehicle moves while being affected by neighboring vehicles, the distance to the head of the vehicle becomes an Erlang distribution [11]. We consider vehicles traveling on a road as a linear network and the distance between nodes is determined according to the Erlang distribution. Let R be the average distance between the nodes, R0 the maximum communication range, R_{sd} be the distance between the source and the destination, and R_0/R be the node density maximum communication range, Rsd is the distance between source and destination, and R0 / R is the node density..

3.1. Next-Hop Forwarding Method

Up to now, various selection schemes of the nexthop node for the Next-Hop Forwarding method were proposed [5][6]. In this paper, we define the maximum forwarding distance R_{max}, and the nearest node to the destination among nodes within a distance R_{max} from the sender is selected as the next-hop node.

The maximum transmission count of the unicast including retransmission is denoted by M_{max}, and $P_b(r)$ is the bit error rate at the transmission distance r. The packet reception success probability of L bits, $P_d(r,L)$, is given by

$$P_d(r,L) = \sum_{m=1}^{M_{\max}} (1-P_b(r))^L (1-(1-P_b(r))^L)^{m-1}. \quad (1)$$

Average distance S_{av} advancing by one-hop transmission is given by

$$S_{av} = \int_{r=0}^{R_{\max}} r \cdot f(r) dr, \quad (2)$$

where f (r) is the probability density function of the distance r between the sender and the node of the selected next hop. This probability density function can be calculated from the Erlang distribution. Since each one-hop transmission is independent of other one-hop transmissions, the PT (L) packet delivery ratio between source and destination is given by

$$P_T(r) = \left\{\int_{r=0}^{R_{\max}} P_d(r,L) f(r) dr\right\}^{\frac{R_{sd}}{S_{av}}}. \quad (3)$$

The average number of transmissions, which include retransmissions, in one hop may be expressed as

$$M_{av}(r,L) = \sum_{m=1}^{M_{\max}} \left\{ m(1-P_b(r))^L (1-(1-P_b(r))^L)^{m-1} \right\} + M_{\max}(1-P_d(r,L)). \quad (4)$$

Therefore, the delay d_{sd} that is the packet transmission time from the source to the destination normalized by a packet transmission time is given by

$$d_{sd} = \frac{R_{sd}}{S_{av}(1-G_n)} \cdot \int_{r=0}^{R_{\max}} M_{av}(r,L) f(r) dr, \quad (5)$$

where G_n is total traffic density of hello and data packets of all nodes that exist within the maximum communication range.

In addition, if the distance between nodes is constant, (3) and (5) can be simplified as the followings.

$$P_T(L) = P_d(R_{\max}, L)^{\frac{R_{sd}}{R_{\max}}}, \quad (6)$$

$$d_{sd} = \frac{R_{sd}}{R_{\max}(1-G_n)} \cdot M_{av}(R_{\max}, L). \quad (7)$$

3.2. Directed Flooding Method

This paper assumes ideal flow suppression, that is, if some nodes in the transfer area manage to receive the packet, only the node closest to the destination forwards the packet. When the number of nodes in the transfer area is indicated as n, the probability of successfully receiving the Pd (n, L) packet in one hop is given by

$$P_d\,(n,L) = \sum_{m=1}^{n} \square\square(1-P_b\,(r_m\,))^L \prod_{i=m+1}^{n} (1-\ (1-P_b\,(r_i\,))^L\,)^{\square}\square,(8)$$

where ri (i = 1,…, n) is the distance to the ith node of a sender node among the nodes existing in the routing area. The average distance Sav while moving forward is given by

$$S_{av} = \int_{rr_1=\square 0} \int_{rr=_n 0} P_d(1n, L) \sum_{mn=1} \square\square\square r_m(1-P_b(r_m))_{L\,i} \prod_{=mn+1}(1-(1-P_b(r_i))_L)\square\square\square$$

$$\cdot\ f_n(r_1,\square, r_n)dr_1\square dr_n,(9)$$

where $f_n(r_1,\ldots,r_n)$ is the probability density function that the distance from the sender to the *i*th node is r_i. Therefore, packet delivery ratio $P_T(L)$ from the source to the destination is given by

$$P_T(L) = \int_{r=0}^{1}\cdots\int_{r=0}^{n} P_d(n,L) f_n \Big\{ \;r\;\; r\;\; (r_1,\square,r_n)dr_1\square dr_n \Big\}_{S_{avsd}}.(10)$$

The normalized delay d_{sd} is given by $d_{sd} = S_{av}\,(1 \overset{R}{-}{}_{sd}G_d)$,   (11)

where G_d is total of traffic density of data packet of all nodes that exists within the maximum communication range.

If distance between nodes is constant, $n = R_0/R$, and (8)-(10) can be simplified as follows:

$$P_d\,(L) = \sum_{m=1}^{n} \square\square(1-\ P_b\,(mR))^L \prod_{i=m+1}^{n} (1-\ (1-\ P_b\,(iR))^L\,)^{\square}\square,$$
(12)

$$S_{av} = {}_d\,1 \sum_{mn=1} \square\square m\cdot R(1-\ P_b(mR))_{L\,i} \prod_{=mn+1}(1-\ (1-\ P_b(iR))_L)\square\square\square, (13)$$

$$\overline{P\,(n,L)}\;\square \quad \underline{R_{sd}}$$

$$P_T\,(L) = P_d\ \,(n,L)^{S_{av}}.\qquad(14)$$

4. Numerical Examples

Some numerical examples of both analytical and simulation results are shown in this section.

Table 1: Parameter for the ideal situation.

Path loss exponent	4.5
Fading	Rayleigh
Average SNR at the distance R_0	24 dB
Maximum forwarding distance R_{max}	R_0
Maximum transmission count in unicast	3
Packet size	1002 bits
Traffic density of data packet	0.02 erl
Traffic density of hello packet	0.011 erl
Distance between source and destination	$4R_0$

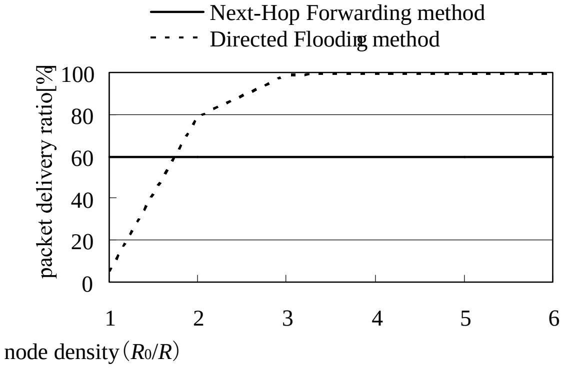
4.1. An Ideal Situation

The analytical results derived in 3 are presented in this section. Table 1 lists the parameters of these results.

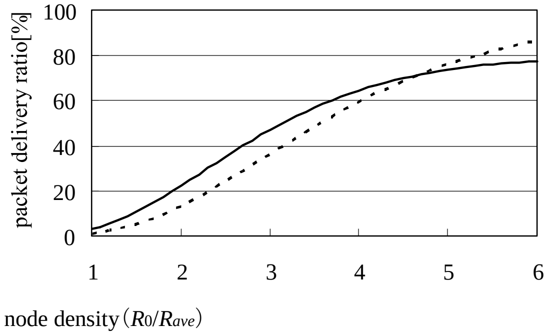
Figure 2 shows the packet delivery rate as a parameter of the node density. The distance between nodes is (a) a constant, (b) an exponential distribution, and (c) an Erlang distribution. The Erlang distribution phase is fixed at 2 in the congestion situation [11]. In Fig. 2 (a), the packet delivery rate of the directed flooding method is low when the node density is low, but the packet delivery rate suddenly increases as the node density increases. In Directed Flooding, the candidates of nodes that can receive the packet increase as the density of the node increases because the packet is sent in broadcast mode. On the other hand, the packet delivery speed does not change even if the node density increases in the next hop forwarding method. This is because the node closest to the destination is selected from among the nodes in the maximum transfer range of the sender, even if the density of the node increases.

Figures 2 (b), (c) show the rate of packet delivery in the case where the distance between nodes is not constant. In these cases, nodes can be set at locations greater than the maximum transfer distance. The packet cannot reach the destination node if at least one gap between the sending node and the receiving node is greater than the maximum transmission distance. This is one of the reasons why the parcel delivery rate of the

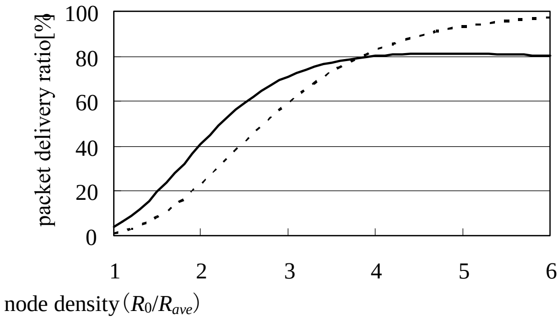
The Next-Hop Forwarding method is degraded when the node density is low. The range where the package delivery rate of the directed flood method is higher than that of the Next-Hop transfer method becomes large for case 2 (c) compared to 2 (b). Note that the exponential distribution corresponds to the Erlang distribution of phase k = 1, and the constant distribution corresponds to that of



(a) Distance between nodes is constant.

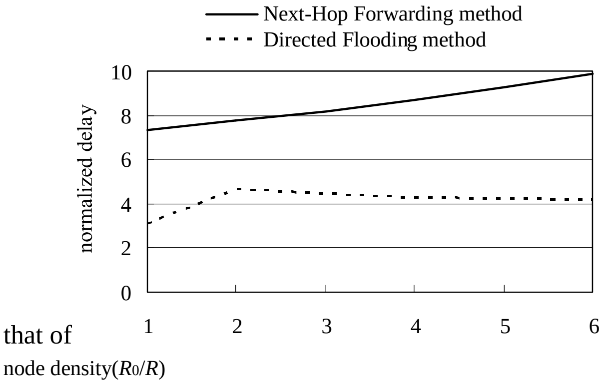


(b) Distance between nodes is an exponential distribution.

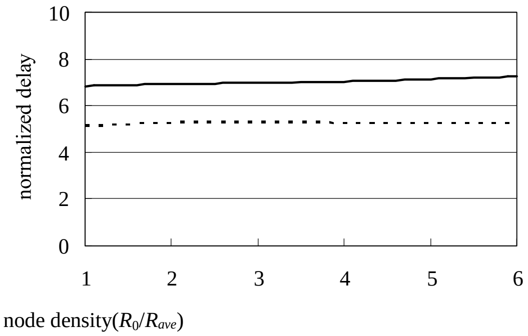


(c) Distance between nodes is an Erlang distribution of phase $k = 2$.

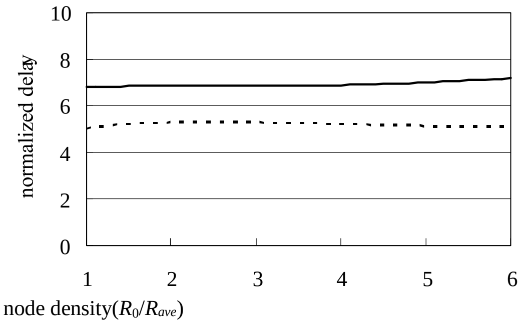
Figure 2: Packet delivery ratio in an ideal situation.



(a) Distance between nodes is constant.



(b) Distance between nodes is an exponential distribution.



(c) Distance between nodes is an Erlang distribution of phase k = 2.

Figure 3: Normalized delay in an ideal situation.

phase k = infinity. The Directed Flooding method package delivery rate increases sharply when the Erlang distribution stage is high. The variance of the Erlang distribution becomes low when the phase is high. The low variance of the Erlang distribution ensures a stable existence of nodes in the communication range.

Figure 3 (a) shows the normalized delay when the distance between nodes is constant. The normalized delay decreases as the node density increases in the case of the next hop transfer method, but the normalized delay increases in the case of the directed flooding method. This is because transmitting the Hello packet wastes the wireless resource, increasing latency when a node transmits a packet. Figures 3 (b), (c) show the normalized delay when the distance between nodes is not constant. They have the same function, but the delay of the directed flooding method is slightly less than that of Figure 3(a).

4.2. A Realistic Situation

We have analytically evaluated the functionality of the position-based routing protocol in the previous section, but saturation overhead and packet collision are not taken into account. In this section, we perform a simulation to evaluate the position-based routing protocol in a more real environment.

The Next-Hop Forwarding method determines the following-hop node by exchanging Hello packets. However, this method can send the packet to the node with poor receiving environment when the node closest to the destination is selected. This is because the selected next hop node is too far away from the sending node. Then, the maximum transfer distance is set to an appropriate value to avoid such situation.

The directed flooding method uses distance timer based suppression [9] in the navigation area to reduce flooding overhead. In this method, each node that receives a packet in the transfer area does not immediately rebroadcast the packet, but sets the timer, which is determined by its distance from the sender. The longer the distance to the transmitter, the shorter the jitter. When the timer expires and the node does not receive the same packet transmitted by other nodes, it forwards the packet.

We consider the linear network where the distance between nodes is defined according to an Erlang distribution. Table 2 shows the parameters of this simulation. We also set the transmit power so that the distance at which it can receive 1 kbyte packets is 250m with a probability of 90%. The maximum transfer distance for the Next-Hop transfer method is set at 250m.

Figure 4 shows the parcel delivery rate. The packet delivery rate of the Next-Hop Forwarding method with Rmax = infinity shows a very low value compared to the other cases. Hello packet with small packet size can be received, but data packet with big packet size could not be received. In this case, the nearest neighbor node to the destination is selected as the next hop node. This degradation can be avoided by reducing the maximum transfer distance. As the average distance between nodes becomes small and the density of nodes increases, hello packets collide with data packets and the packet delivery rate decreases. Therefore, the packet delivery rate of the Directed Flooding method displays a higher value than that of the Next-Hop Forwarding method when the node density is high. The average distance between nodes corresponds to the maximum communication range R0 divided by the density of nodes R0 / R. Compared to fig. 2 (c) the simulation results of the Next-Hop Forwarding method with Rmax = 250 and of the Directed Flooding method have the same characteristics as the analytical results. Therefore, our analysis can show the main behavior of the two position-based routing protocols.

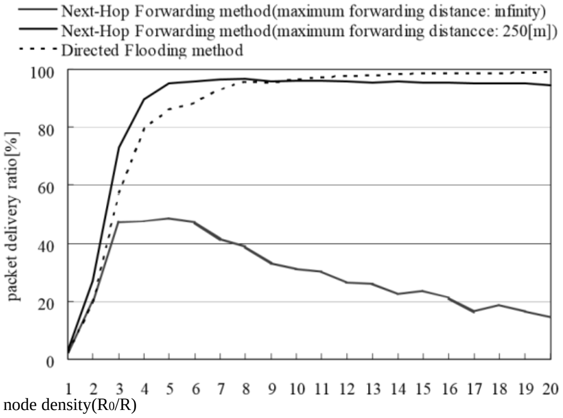


Figure 4: Packet delivery ratio in realistic environment.

5. Conclusions

In this paper, we compared and evaluated the Next-Hop Forwarding method and the Directed Flooding method by an analytical approach in an ideal situation, and also evaluated their performances by simulation in real situation. The Next-Hop Forwarding method can achieve a higher packet delivery rate than the Directed Flooding method when the node density is low. This relationship also depends on the distribution of car locations. Therefore, we conclude that it is efficient for position-based routing to choose either the next hop forwarding method or the directed flooding method based on the density and distribution of nodes.

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