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Performance Evaluation of Position-based and Non-position-based Routing Protocols in a Vehicular Ad-Hoc Network

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VANET에 있어서 위치기반과 비위치기반 라우팅프로토콜의 성능 평가

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Abstract In this paper, we evaluate and compare performance between position-based and non-position-based routing protocols in a vehicular ad-hoc network. The protocols evaluated in this paper for many performance evaluation aspects are a position-based routing protocol, GPSR (Greedy Perimeter Stateless Routing), and the non-position-based such as AODV (Ad-hoc On-Demand Distance Vector) and DSR (Dynamic Source Routing) protocols. The three protocol characteristics such as Packet Delivery Ratio, Latency of first packet per connection, and Average number of hops depending on distance are compared and evaluated. As the result of simulation, the AODV performed better than the DSR. However, due to the high mobility characteristic of a vehicular ad-hoc network, GPSR, the position-based routing performs better than the non-position-based routing protocols such as AODV and DSR in a vehicular ad-hoc network environment.

요 약 본 논문에서는 자동차 에드혹망에서의 위치기반 라우팅 프로토콜과 비위치기반 라우팅 프로토콜의 성능을 비교하고 분석하였다. 여러 가지 성능평가 요소로 분석되어진 프로토콜들은 위치기반 라우팅 프로토콜의 GPSR (Greedy Perimeter Stateless Routing)과 비위치기반 라우팅 프로토콜의 AODV (Ad-hoc On-Demand Distance Vector)과 DSR (Dynamic Source Routing) 프로토콜들이다. 패킷 전송율, 접속시 첫 번째 패킷의 지연, 그리고 거리에 따른 평균 홉수의 3가지 프로토콜 특성들을 비교하였다. 시뮬레이션의 결과로 AODV는 DSR 보다 우수한 성능을 보였다. 그러나, 자동차 에드혹망의 높은 이동성 때문에 위치기반 라우팅 프로토콜인 GPSR이 AODV와 DSR과 같은 비위치기반 라우팅 프로토콜들보다 우수한 성능을 보여주었다.

Key Words : VANET, Ad-Hoc Routing Protocols, GPSR, AODV, DSR

1. Introduction

Vehicular Ad-Hoc Networks (VANETs) are an important technology for developments of vehicular communication systems. Vehicles are able to exchange information within these networks without the need of installing any infrastructure along the roadside. VANETs can be used to improve the road safety by e.g. warning drivers about accidents in front of the road or to provide Internet access to the passengers via gateways along the road. However, Intelligent Transportation System (ITS) relies heavily on Inter Vehicle Communication (IVC) [1].

Projects like FleetNet propose the establishment of multi-hop Ad-hoc networks between vehicles based on Dedicated Short Range Communication (DSRC) for future vehicular communication systems [2]. For IVC, ad-hoc networks were considered the most suitable method [3]. This is because vehicles moving on the road equipped with wireless communication devices are themselves the mobile nodes, which inter-link to form a vehicular ad-hoc network.

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Hence, one of the main challenges of IVC is the implementation of routing protocols, which are effective in vehicular ad-hoc network environments. Many simulations such as in [4] and [5] were performed to compare the performance of routing protocols in Mobile Ad-hoc Networks (MANET) using random mobility models. A few recent studies have evaluated the routing protocols for the vehicular Ad-hoc environment just for either non-position-based or position-based protocols. Hence, in this paper, we evaluate and compare the performance on a position-based routing protocol, GPSR (Greedy Perimeter Stateless Routing), and the non-position-based such as AODV (Ad-hoc On-Demand Distance Vector) and DSR (Dynamic Source Routing).

2. Routing Protocols

Various ad-hoc routing protocols have been proposed in recent years, whereas two main classes of unicast protocols can be distinguished: location-based and non-location-based (or topology-based) protocols. These protocols enable the exchange of data between distinct pairs of nodes, using intermediate network participants for forwarding packets on their way to the destination.

Location-based routing protocols use additional information on the node's geographical positions to find suitable routes. For example, these positions may be the node's GPS coordinates. However, when using location-based protocols, there is always a need for location services and servers. We chose three well-known routing protocols to be evaluated for our vehicular traffic scenario: a position-based routing protocol, GPSR [6], and the non-position-based such as AODV [7] and DSR [8].

2.1 Position-Based Routing Protocol

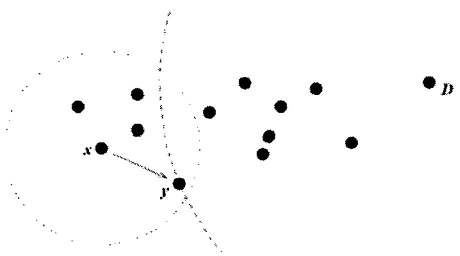

Fig. 1 GPSR: Greedy Forwarding

Greedy Perimeter Stateless Routing (GPSR): GPSR is a responsive and efficient routing protocol for mobile networks. Unlike established routing algorithms before it, which use graph-theoretic notions of shortest paths and transitive reachability to find routes, GPSR exploits the correspondence between geographic position and connectivity in a wireless network, by using the positions of nodes to make the packet forwarding decisions. Nodes learn immediate neighbors' positions through beacons/piggybacking on data packets. GPSR uses greedy forwarding to forward packets to nodes that are always progressively closer to the destination. In regions of the network where such a greedy path does not exist (i.e., the only path requires that one move temporarily farther awayfrom the destination), GPSR recovers by forwarding in perimeter mode, in which a packet traverses successively closer faces of a planar subgraph of the full radio network connectivity graph, until reaching a node closer to the destination, where greedy forwarding resumes.

2.2 Non-Position-Based Routing Protocols

Ad hoc on-demand distance vector (AODV): AODV is essentially a combination of DSR and DSDV. It borrows the basic on-demand mechanism of route Discovery and Route maintenance from DSR, plus the use of hop-by-hop routing, sequence number and periodic beacon from DSDV. When a source S needs a path to some destination D, it broadcasts a route request message enclosing the last known sequence number to that destination. The route request is broadcasted across the network until it reaches a node that has a route to the destination with the destination sequence number higher than that enclosed in the request. Each node that forwards the route request creates a reverse route for itself back to node S. when the route request reaches a node with a route to D, that node generates a route reply that contains the number of hops necessary to reach D and the sequence number for D most recently seen by the node generating the reply. Each node that participates in forwarding this reply back forward the originator of the route request creates a forward route to D. The state created in each node along the path from S to D is hop-by-hop state that is, each node remembers only the next hop and not the entire route as would be done in source routing.

In order to maintain routes, AODV normally requires that each node periodically transmit a HELLO message, with a default rate of once per second. Failure to receive three consecutive HELLO message from a neighbor is taken as an indication that the link to the neighbor in question is down.

When a link goes down, any upstream node that has recently forward packets to destination using that link is notified via an unsolicited route reply containing an infinite metric for that destination. Upon receipt of such a route reply, a node must acquire a new route to the destination using route discovery.

Dynamic source routing (DSR): DSR is an on-demand routing protocol where the source determines the ordered list of nodes through which a packet must pass while traveling to its destination. The key advantage of source routing is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward, since the packets themselves already contain all the routing decisions. This fact, coupled with the on-demand nature of the protocol, eliminates the need for the periodic route advertisement and neighbor detection packets present in other protocols.

Whenever a source has a packet to transmit, it checks its route cache for a route to the destination. In case a route is not found then a route request is broadcast across the network. On receiving this request, an intermediate node without a cache route to the destination appends its address to the request packet and rebroadcast it until the request packet reaches the destination.

If any intermediate node has a cache route to the destination then it will discard the request and will send route reply back to the source. Otherwise, the destination will send a route reply to the source containing the route from the source to the destination. When the reply packet reaches the source a connection is established and all subsequent packets contain the complete route in the packet header.

If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using the link from its cache and initiates a new route discovery if this route is still needed.

3. Traffic Simulations

The traffic simulation modeled in this paper compares performance of the position-based GPSR and the non-position-based DSR and AODV routing protocols in the vehicular ad-hoc network. Simulations were done with the network simulator NS-2 [9] in its version ns-2.1b8a (with some bug fixes from ns-2.1b9a) with the CMU-extensions [10] as well as the GPSR in ns-2 [11]. The simulator was extended with a basic form of obstacle modeling: spaces between streets are assumed to be buildings and, therefore, radio waves cannot propagate through them. Thus, two nodes can only communicate directly with each other when they are in their respective transmission ranges and also obey the 'line-of-sight' criterion.

The varied input parameters were the speed of the mobile nodes, the pairs of nodes communicating and the initial distances of the communicating pairs of nodes. During the simulations, the speed of the mobile nodes changed frequently even in short distances to better represent the wide range of velocity changes. The initial distances were varied in order to compare the performances of the routing protocols in different distances. Different pairs of nodes in similar group of distances were then used in order to obtain an average result from the simulations.

4. Simulation Results and Evaluation

4.1 Simulation Environment

We assume that nodes transmit according to the IEEE 802.11 wireless LAN standard (2 Mbps). The transmission range was originally set to 250 m but an analysis of the connectivity graph of the network shows that with this range too often there is no connectivity along the street between two junctions. Real-world tests with vehicles equipped with IEEE 802.11b cards also have shown that transmission ranges in the order of 500 to 800 meters are feasible with external antennas. We thus have set the transmission range in our simulations to 500 m. However, the blocking of transmission caused by buildings or other obstacles is not considered in this paper.

The constant input parameters are such as the connection type that is Constant Bit Rate (CBR), connection rate of 0.25/sec, packet size of 512bytes, 10,000 maximum numbers of packets exchanged and 1000 total numbers of nodes in an area of a size (2.5 km × 1.5 km), to acquire the same node density.

Numerous simulations were performed to obtain average values. For example, the number of Hops which refers to the number of intermediate mobile nodes taken by the First Packet Arrived is simulated. The average results were then compared over a range of initial communication distances, between 200 and 2600 meters.

4.2 Simulation Results

We measured three performance values such as the achieved packet delivery ratio (Fig. 2) versus the distance between the two communication partners, latency for the first packet (Fig. 3) and number of hops (Fig. 4). Each point in the graphs is based on at least 10,000 packets exchanged.

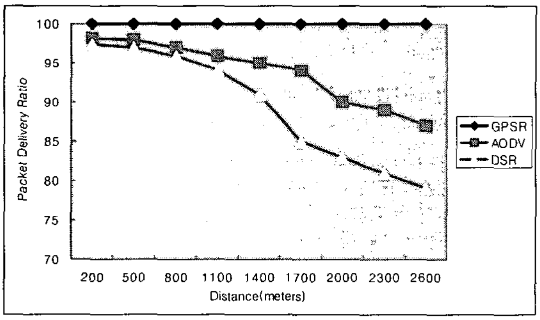

Fig. 2 Packet Delivery Ratio

The study on achievable packet delivery ratio (Fig. 2) shows good results for the position-based approach compared to DSR that shows some performance problems. In comparison to AODV there is still some advantage for the position-based approach. A detailed analysis of the causes for undelivered packets indicates that the position-based routing approach fails when the connectivity on a street selected by the path-finding algorithm is broken. Thus, with improved and more adaptive path selection procedures one can expect to improve the obtained results for the position-based approach.

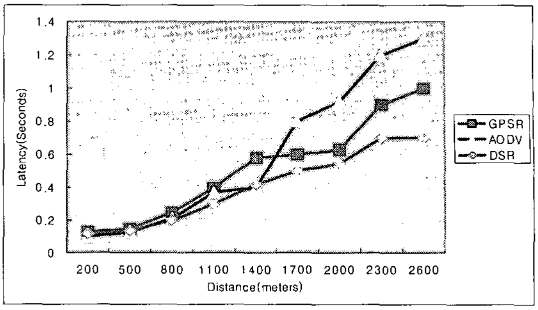

Fig. 3 Latency of first packet per connection

The observed latency shown in (Fig. 3) for the first packet of a 'connection' is similar for DSR and GPSR approaches with a small advantage for DSR. This was to be expected since the route establishment in DSR and the location discovery in position-based routing are very similar. However, AODV seemed to increase faster than others do as distance increases. The usage of expanding ring search technique of AODV is responsible for the higher. One possible explanation for this is as follows. DSR uses source routing method that is aggressive in gathering routing information. Hence, many different routes are stored for a single source and destination. In an event when a link breaks, alternative routes could immediately be used that would then reduce the average latency of first packet arrived. Route discovery only occurs when all the cached routes are stale. AODV on the other hand only maintains a single route to a destination. Therefore, whenever a link breaks, AODV would rely on flooding to establish a new route. As the distance increases it would then take more time for AODV to establish a valid route to a certain destination.

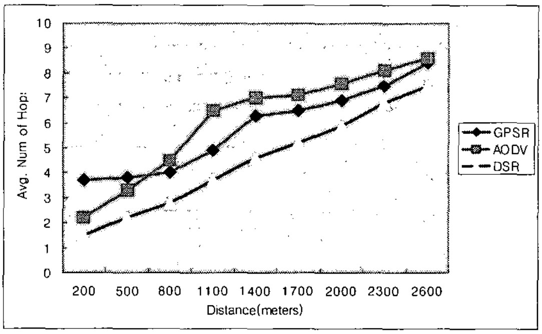

Fig. 4 Average number of hops depending on distance

In contrast to DSR where a node drops a packet when route breaks occur GPSR uses some recovery strategies such as the fall back on greedy mode to by-pass this particular node. As can be seen in Fig. 4 this strategy implies a slightly longer route to the destination node. AODV using routing tables instead of source routes shows similar results with GPSR. One can assume that DSR is much more aggressive in routing to a destination. And this would lead to more route breaks involving more packet drops. In general, the fluctuation of the curves has their reason in the restricted scenario and is not due to an insufficient number of packet transmissions.

Additionally, the poor performance of DSR in terms of packet delivery ratio is also caused by the high mobility nature of a vehicular ad-hoc network. In high mobility, routes tend to break often. In DSR, this would mean a frequent change of routes to those cached. However, due to high mobility, those routes stored in the cache tend to become stale most of the time, which means that the packets sent using the routes would eventually drop. This would then also increase the time for packets to reach its destination.

Due to the high mobility characteristic of a vehicular ad-hoc network, GPSR, the position-based routing performs better than the non-position-based routing protocols in a vehicular ad-hoc network environment. Moreover, we have shown that the AODV routing protocol performs better than DSR in a vehicular ad-hoc network environment in terms of packet delivery, with slight disadvantage in terms of length of routes chosen.

V. Conclusions

In this paper, we evaluate and compare performance not only between position-based and non-position-based routing protocols but also between protocols of non-position-based ones in a vehicular ad-hoc network. We have found that there are distinct characteristics among them with simulation of performance results. The latency of first packet per connection and the average number of hops depending on the distance shows similar results among the three protocols, however, in the packet delivery ratio, the GPSR outperforms both AODV and DSR. Due to the high mobility characteristic of a vehicular ad-hoc network, GPSR, the position-based routing performs better than the non-position-based routing protocols in a vehicular ad-hoc network environment. Moreover, we have shown that the AODV routing protocol performs better than DSR in a vehicular ad-hoc network environment in terms of packet delivery, with slight disadvantage in terms of length of routes chosen. The key high mobility characteristic of a vehicular ad-hoc network seemed to have the most affect on the outcome of the simulations. Finally it will be interesting to investigate and compare the behavior of the routing strategies when used in scenario involving city traffic.

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<Area of Interest>
Ad-Hoc (Sensor) Network, VANET, ITS(Intelligent Transportation System)

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<Area of Interest>
TCP/IP, Internet Protocol, Sensor Network, Bluetooth, RFID etc.