Performance Analysis on Mobility of Ad-hoc Network for Inter-vehicle Communication

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Abstract

This paper presents the feasibility of using an ad-hoc network as an infrastructure for a small group of inter-vehicle communication network. Mobile ad-hoc networking with wireless LAN infrastructure can be employed to build inter-vehicle communication based network. The irregular driving environment pose a challenge to the performance of a wireless LAN. We have measured transmission characteristics for sending and receiving high data volumes using TCP and UDP in vehicles moving on IEEE 802.11b. Our framework aims to evaluate the effect of our proposed mobility models on the performance of Dynamic Source Routing (DSR) based on measured data. Proposed mobility models are varied by conducting the experiments under different driving environment, driving conditions, and vehicular patterns. Our result shows that the routing protocol mechanism, such as route discovery and route maintenance, does not interrupt the data transmission seriously.

I. INTRODUCTION

Inter-vehicle communication can be used to facilitate applications [1] improving driving safety and convenience. Potential uses of such applications are dynamic traffic routing, driver assistance and navigation, entertainment, co-operative driving, etc. The existing ad-hoc networking infrastructure can be leveraged and performance enhancement measures can be innovated for provisioning seamless inter-vehicle communication. As opposed to centralized service, and ad-hoc network is much better suited for vehicle-related applications that exchange data having local relevance. The existing 802.11 compliant devices can be used for providing wireless connectivity between moving vehicles. With the advent of 802.11a hardware, bandwidths of up to 54 Mbps have become realizable. However, Vehicular traffic scenarios pose greater challenges than the indoor WLAN applications, due to associated driving speeds, varying vehicular traffic patterns and driving environments. Performance measurements for 802.11 based wireless LANs have been done in indoor office and industrial environment [2]. These results do not provide performance indication for the more challenging vehicular scenarios. Through the test we conduct, we investigate the performance achievable by an 802.11b-based WLAN in vehicular scenarios.

There are two types of inter-vehicle communication network using Ad-hoc. One is Inter-vehicle communication supported by AP(Access Point), which has been discussed [3]. However, this approach is not cost-effective. It requires development of exclusive infrastructure. Access points may be provided at each street corner, co-located with traffic lights, or emergency phones, be placed in parking lots or in rest areas or may be co-located with gas stations or other shops in service areas. The other is inter-vehicle communication supported by ad-hoc routing algorithm [4]. In this approach, it is important that each mobile node can detect other's position and routing path continuously.

In this paper, we focus on plain WLAN connectivity and transport protocol behavior-and only briefly address implications on applications in the end. Our goal is to prove that WLAN technology is capable of enabling the vehicle network using ad-hoc in the first place and to document the communication characteristics we have observed with different measurement configurations using UDP and TCP as standard transport protocols. After simulation and measurement of transport protocol in ad-hoc mode, we also investigate the ad-hoc routing algorithm with our proposed mobility models.

The rest of this paper is organized as follows. Section 2 gives a brief description of the related work and elaborates our contribution. Section 3 discusses some ad-hoc routing protocols and some limitations of previous works. In section 4, we present the measurement configurations that we have chosen. We also document the measurement results and simulation results. In section 5, we present the simulation configurations for analyzing the efficiency of ad-hoc routing protocols which are applied to suggested mobility models. Finally, section 6 concludes this paper confirming the suitability of WLAN-based access technologies for the vehicle network using Ad-hoc and pointing out next steps in our research.

II. RELATED WORK

As the ad-hoc network itself is a technology mainly on the IP layer, various radio devices can be used with it. For inter-vehicle communication or vehicle-to-internet

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communication, there may be several candidates for the radio device. The research about inter-vehicle communication are just started, which are not using any base stations(AP-Access Point). However, in general, some researches have been investigated about vehicle-to-internet communication. This kind of researches expect that by using an ad-hoc network, spatial service range, connection time to the access point while driving, and amount of data transferred from the access point would be better than in existing public wireless LAN services.

For example, wireless LAN, and DSRC(Dedicated Short Range Communication) [5] would be considered as strong candidates for ad-hoc network radio devices. In Japan, DSRC needs approval for its use because of its frequency range, whereas WLAN(802.11b) can be freely used even outside. The ongoing FleetNet [6] project aims at developing an ad-hoc network for inter-vehicle communications and for data exchange between running vehicles and fixed gateways at the road side. And Hitachi evaluates the performance of and ad-hoc network in a mobile environment in order to access its feasibility as an infrastructure for vehicle-to-internet communication services [7].

However, these approaches are at the proposal and demonstration stage and requires development of exclusive infrastructure. In the worst case, if geographic environment is hard to construct infrastructure, it is out of the question that we can not communicate with other mobile node(vehicle).

We assume that it is useful and cost-effective that vehicles are related wireless network without using base station. In this paper, we investigate ad-hoc routing algorithm in laptop's ad-hoc mode. In the experiment, we used 802.11b WLAN cards.

1) Analyze the ad-hoc mode measurement and the ad-hoc mode simulation. the TCP/UDP throughput in Inter-vehicle communication is measured
2) Focus on realistic mobility characteristics such as overtaking other vehicles. stop at cross road with measured data. Previous work did not consider these situations and measured database into their simulation.

III. MODEL BACKGROUND

A. Ad-hoc routing protocol

A Mobile Ad-hoc NETwork (MANET) is the cooperative engagement of a collection of mobile nodes without the required intervention of any centralized access point. Such mobile nodes detect the direct link with neighbor nodes and automatically constitute a network utilizing these links. Each node calculates the route to discover the most suitable route to other nodes. That is, all nodes can serve as routers for each other, and data packets are forwarded from node to node in a multi-hop fashion. So, it can be applied in situations where no fixed infrastructure is available, such as military activities in enemy territory, disaster recovery operations, and Inter-vehicle communication.

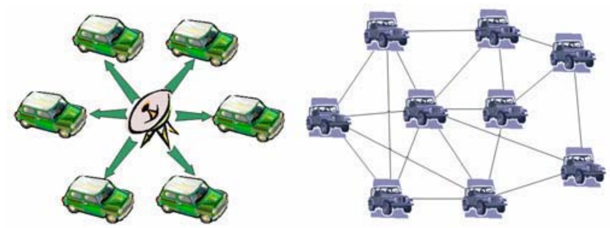

Figure. 1. The current network using access point vs. ad-hoc network without access point

MANET is a technology which is being discussed in IETF manet working group(WG) [8]. The purpose of the WG is to standarize IP routing protocol functionalities suitable for wireless routing applications on both static and dynamic topologies. The routing protocols for the ad-hoc network mostly fall into two categories [9]. One is proactive protocols such as DSDV [10] and OLSR [11], and the other is reactive protocols such as AODV [12] and DSR [13]. In a proactive protocol, a routing table for the entire network is always kept up to date, while in reactive protocol, the entries of the routing table are created on demand. This means that every node in reactive protocol can notice the new node has joined as soon as it comes in. Additionally, there are some protocols that are placed between reactive and proactive protocols. In such hybrid protocols, each node always maintains the topology information about its zone, but gets, on demand, search route information for outside the zone. That is, it has proactive property within its zone and reactive property outside its zone [14], [15]. For our simulation, we chose to use the reactive protocol. Because we assume that it is more efficient than proactive protocol in case that mobility of nodes are free to move such as Inter-vehicle communication network.

B. Mobility Models

Mobility pattern, in many previous works was assumed to be Random Waypoint. In the current network simulator(ns-2) distribution, the implementation of this mobility model is as follows: at every moment, a node randomly chooses a destination and moves towards it with a velocity chosen uniformly randomly from [0,], where is the maximum allowable velocity for every mobile node [16]. Most of the simulations using the Random Waypoint model are based on this standard implementation.

By the way, Random Waypoint does not seem to capture the mobility characteristics of scenarios in which MANETs may be deployed. "IMPROTANT" [17] suggested various protocol independent metrics to capture interesting mobility characteristics, including spatial and temporal dependence and geographic restrictions. In addition, a various set of parameterized mobility model is introduced including Random Waypoint, Group Mobility, Freeway and Manhattan models. In Freeway Mobility model, Each mobile node is restricted to its lane on the freeway, and the velocity of mobile node is temporally dependent on its previous velocity. If two mobile

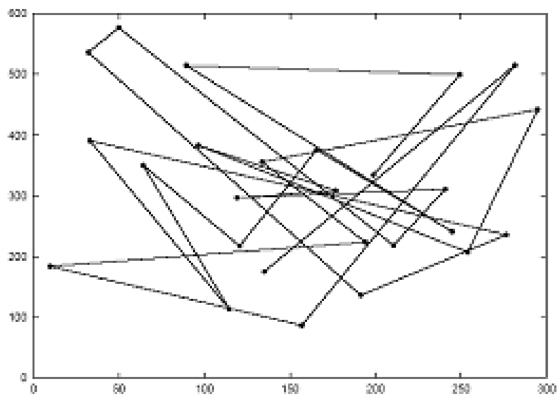

Figure. 2. Node Movement of Random waypoint mobility

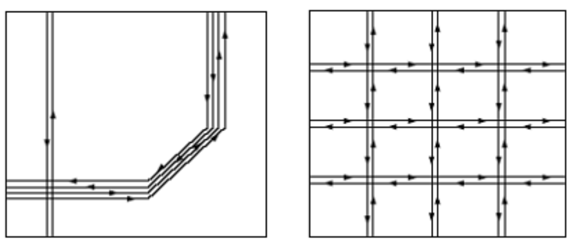

Figure. 3. Highway Mobility Model and Manhattan Mobility Model

nodes on the same freeway lane are within the Safety Distance(SD), the velocity of the following node cannot exceed the velocity of preceding node. The freeway map used in our simulation is shown in Figure 3. In Manhattan Mobility model, the mobile node is allowed to move along the grid of horizontal and vertical streets on the map. At an intersection of a horizontal and a vertical street, the mobile node can turn left, right or go straight. The Manhattan map used in our simulation is shown in Figure 3.

However, these mobility models did not consider some situations such as overtaking other vehicles and a halt at crossroad. In this paper, we analyze the efficiency of reactive ad-hoc routing algorithms(DSR) with our proposed mobility models and measured data.

IV. Measurements

A. Measurement tools

We have used the cars with notebook as depicted in Figure 4. For the moving vehicles, we have equipped the PCMCIA card with an external antenna that has been placed at the right hand side of the vehicle. The PCMCIA card supports IEEE 802.11b, and the external antenna is outdoor omni-directional antenna. The PCMCIA card was configured to use ad-hoc mode, so all the notebook has communicated with each other. We use the same ESSID, and WEP encryption has been deactivated, and

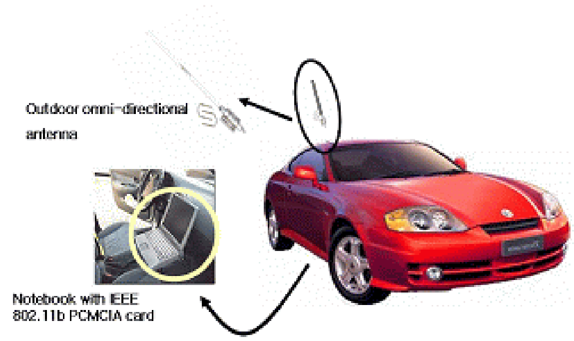

Figure. 4. Vehicle configuration

Figure. 5. Map used by the scenario

we have used a beacon interval of one second which is the default settings for most access points. The mobile device had a statically assigned IP address.

We have measured both UDP and TCP performance in the same scenarios. For all UDP and TCP measurements, we have used two tools, one for configurable packet transmission and a receiving tool sinking the received packets. We have transmitted packet size of 2500 bytes and used sending intervals of 2ms, i.e., 500 packets per second. So nominal sending rate is 3Mbps and 5Mbps.

B. Measurement Scenario

This measurements are performed in the area of Figure 5. The starting point of the measurements are 1. via 2, 3, ..., 7 and finally arrived at 1. The length which the measurements is performed is about 2.7km. As we performed the measurements in the downtown, the maximum speed of the vehicle was 40km. We stopped the vehicle frequently because of the red light and another vehicle. The vehicles that are used in measurement moves in a line and the distance between the vehicles are within 10m.

C. Measurement

The nominal sending rate is the sending rate which the sender's application attempts to send data. It is derived from the

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	TCP		UDP	
Sending Rate	3.80	4.80	3.80	4.80
Simulation	2.51	2.55	3.31	3.41
Indoor Measurement	3.60	2.91	3.72	3.38
Outdoor Measurement	1.76	1.43	1.45	1.07

Table 1. The effective throughput of TCP and UDP

parameters packet size and interval - it is not the effective sending rate, which is the sending rate sender sends data actually. The effective throughput is the throughput as observed by the receiver. The loss rate is derived from the parameters effective sending rate and effective throughput.

Table 1 depicts the effective throughput of TCP and UDP as we drove around sogang university. In case of the TCP, the effective throughput of outdoor was 1.76Mbps when the nominal sending rate was 3.8Mbps, while the effective throughput of outdoor was 1.43Mbps when the nominal sending rate was 4.8Mbps. In case of the UDP, the effective throughput was 1.45Mbps and 1.07Mbps respectively. In comparison with the effective throughput of indoor, the effective throughput was lower. The wireless PCMCIA cards lower the sending rate. This is caused by the IEEE 802.11b media access mechanism [2] - the Distributed Coordination Function (DCF). DCF relies on a CSMA/CA approach and defines an algorithm by which a sender tries to allocate sending slots in order to avoid collisions. The allocation of sending slots can be delayed. Furthermore the effective throughput of TCP is higher than that of UDP, because of TCP's congestion control that results in a more efficient use of the available bandwidth compared to UDP. [3]

The throughput using UDP in simulation is better than that of TCP. Moreover, the effective throughput of indoor and outdoor when the nominal sending rate is 3.8Mbps reached the maximum value, but that of simulation increased continually.

If we perform the simulation using ad-hoc routing algorithm, it is the same effective throughput in ad-hoc mode simulation. Likewise we estimates the effective throughput of indoor of about 1.7Mbps. The effective throughput of the two node may be the same value above, but as the nodes are increased, it is obvious that we experience the lower effective throughput.

V. AD-HOC ROUTING SIMULATION

In the following, we define the vehicle mobility scenarios, and perform ad-hoc routing simulation with Opnet [18] using proposed scenarios. After that, the results obtained from the experimentation are presented herewith. Wireless LAN performance for the ad-hoc communications in mobile nodes is noted by observing the throughput.

A. Mobility models

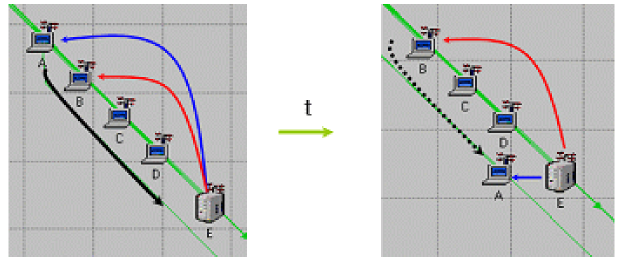

Figure 6. Highway Mobility Model

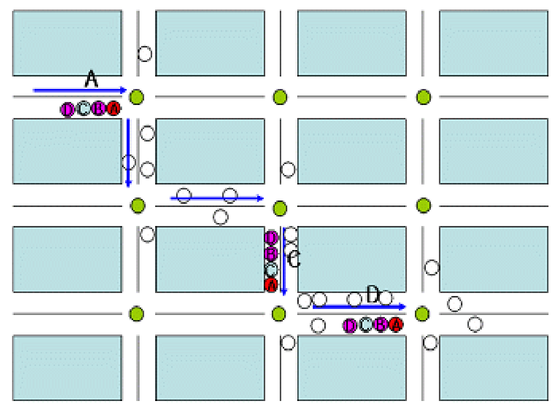

Figure 7. City Mobility Model

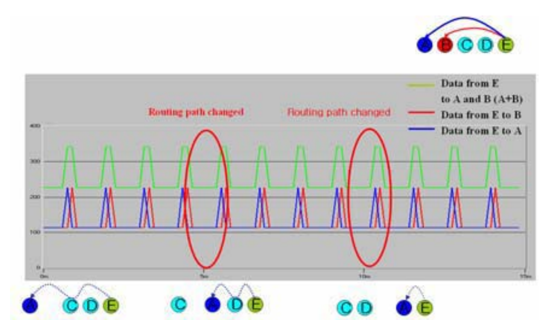

Figure 8. TCP data transmission

Highway Mobility Model: We propose this model to emulate the motion behavior of mobile nodes on a highway. The topology of this model in our study is shown in Figure 6.

In this model, there are five mobile nodes in highway. Data is transmitted from node E to node A and node B. As time goes by, node A overtakes node B, C, D one by one, then approaches node E. Consequently, routing path has changed by ad-hoc routing protocol because of the node mobility.

City Mobility Model: We suggest this model to emulate the motion behavior of mobile nodes on a highway. The topology of this model in our study is shown in Figure 7.

In this model, there are twenty five nodes are located in this map(10Km10Km). Among them, four nodes are fixed in one group which are communicate with each other. Data is transmitted from node A to node B and node D. Node B

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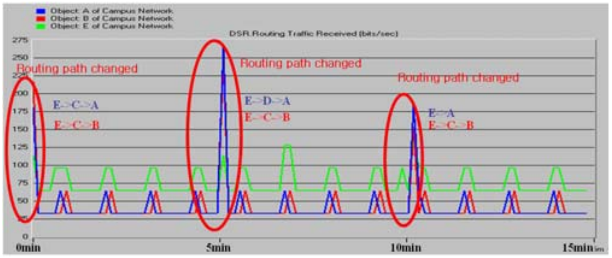

Figure 9. Routing message

receives data from node A directly, and Node D receives data from node A via node C. Routing path is changed after twelve minutes. Every nodes halts for thirty seconds at crossroad. And we determine that nodes are moving around with random velocity for realistic vehicular movement.

B. Simulation Results

Figure 8 shows the result in case of adapting Highway Mobility Model. Simulation time is 900 seconds, and selected ad-hoc routing algorithm is DSR, which are used to investigate data transmission according to the change of the routing path. We use TCP as transport protocol and transmission result is achieved by FTP data transmission. We also assume that nominal sending rate is 400Kbps. When data is transmitted from node E to node A, B, the change of routing path also appears, effective throughput and routing overhead is measured.

Routing path is changed when node A moves at five minutes and at ten minutes one by one, but data transmission is not disrupted. It means that rapid change of routing path does not interrupt data transmission, and there are no packet loss.

Figure 9 shows routing message overhead when routing path is changed. At the beginning, the amount of routing message increases because of the initialization of routing path, but as time goes by, it decreases and draw regular curve. We notice that routing message rapidly increases when routing path is changed at 5, 10 minute. In addition, there is an incensement in E-C-B path which is not changed. Because node A broadcast changed routing path to other nodes in which are transmit range of node A. The DSR protocol is composed of two mechanisms that work together to allow the discovery and maintenance of source routes in the ad-hoc network. Route discovery is used only sender attemps to send a packet to destination and does not already know a route to destination. Route maintenance indicates a source route is broken, sender can attempt to use any other route it happens to know to destination, or can invoke Route Discovery again to find a new route. However, data is transmitted in the group which are engaged in small number of nodes heading same direction, relative velocity is zero. Overtaking nodes in the only one which is faster than other nodes , but relative velocity is small. The mean value of the route discovery time in our simulation is 5ms. It means that route discovery does not interrupt the data transmission seriously.

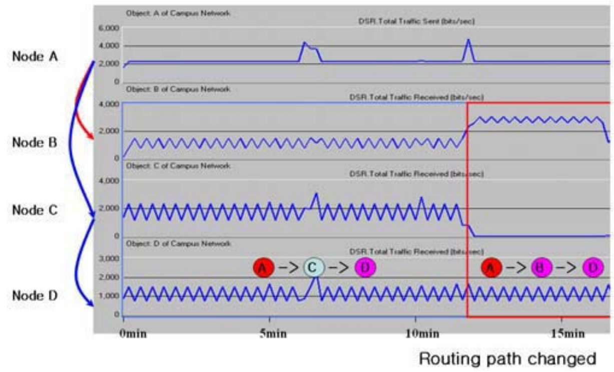

Figure 10. TCP data transmission

Figure 10 shows the result in case of adapting Highway Mobility Model.

Note that data is transmitted from node A to node D via node B without packet loss when they are moving around the map. And twelve minutes have passed after starting simulation, routing path is changed from A->C->D to A->B->D. Consequently, there is no received data in node C which just plays a role in transmitter, and a sum of data from node A and data in node B is measured in node B.

In City Mobility Model, in case that routing path is selected by DSR, each node is not sensitively affected. And it is probable that replaced routing path is located in a group, we expect that route discovery process is more faster than ordinary DSR fashion.

The amount of routing traffic is increased when routing path is changed. In general, it degrades the effective throughput in case that routing path is changed frequently. However, we think that it is not a serious problem. Because small number of vehicles are engaged in a group, routing algorithm can be done easily.

VI. Conclusion

In this paper, we analysis the ad-hoc network where the several vehicles communicate with each other. It is advantage not to use the base station. But intermediate nodes are used to transfer the data, so the traffic pattern influences the intermediate nodes. We analysis the throughput and routing discovery time as the intermediate nodes moves using highway and city mobility model for adaptation of ad-hoc network in inter-vehicle.

We measured and analysis the effective throughput between two vehicles by simulating the ad-hoc mode simulation and deploying the test bed network using ad-hoc mode. In this measurement, the effective throughput of TCP and UDP is 2.55Mbps and 3.41Mbps respectively in case of TCP, and 1.76Mbps and 1.45Mbps respectively in case of UDP. We can observe that the effective throughput of TCP is better than that of UDP in the test bed network. This is caused by the congestion control of TCP.

First, we simulated the ad-hoc routing algorithm of vehicle. In case of highway mobility model, we simulated the scenario where the route was changed in receiving the data while a vehicle pass another. If the route was changed, the interval time when we change the route of data route is very short, so this didn't have an effect on the data transfer. Therefore this can be deployed where the data is transferred in highway. When the route is changed, the amount of routing messages is increased, but the increased messages are small so that it doesn't have an effect on the overall performance.

Second, when we simulated the ad-hoc routing algorithm of vehicle with city mobility model, the result was similar with that of highway. That is, it didn't have an effect on the overall performance even if the nodes stopped or moved.

When the intermediate node was changed, the average routing reconfiguration time was within 0.005s in highway and city mobility model. Like highway and city mobility model, when a small number of the vehicles moved in the same speed and the same direction, the routing discovery time is very short. But we expected that routing discovery time was affected by the relative delay of the packets in the test bed network unlike simulation. Therefore we need how to minimize the relative delay of the packets in inter-vehicle communication.

Third, we measured the effective throughput of the amount of data and the effective throughput of the distance among the vehicles in the simulation. We measure the similar effective throughput while the vehicle got the data from server directly or got the data via intermediate node. Also, we observed that all the data was successfully delivered within the distance where the signals could reach. But as the distance where the signals could reach got longer, the effective throughput is sharply decreased.

Forth, we observed that if we sent the excess data the overall performance was decreased. Therefore we need how not to excess the available bandwidth.

Finally, we simulated the effective throughput of varied speed and the distance between vehicles. We observed that this didn't affect the throughput, but when the nominal sending rate is high, the relative delay of the packets also increased.

We proposed the possibility deploying the ad-hoc network of vehicle, which can be adopt the telematics based on GPS or wireless multimedia service. Based on our measurements of simulation and test bed network, the effective throughput of 1.5Mbps can be used in streaming multimedia service or massive data transmission.

In case that ad-hoc routing algorithm is applied to vehicle, distance between two nodes increases. However, if the relative velocity increases, then link connection time will be reduced. It means that routing overhead will be heavy, and effective throughput will fall off. In other words, when relative velocity is uniform, link connection time increases. And effective throughput grows in proportion to the reduction of routing overhead.

In the future, we plan to measure ad-hoc routing protocol based on IEEE 802.11b wireless LAN under different velocity and different distance. We are interested in how the measurement of this experiment will be different from our ad-hoc routing simulation.

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