GREEDY INTERSECTION-MODE ROUTING STRATEGY PROTOCOL FOR VEHICULAR NETWORKS

MAHMOUD AHMAD SALEM AL-KHASAWNEH

UNIVERSITI TEKNOLOGI MALAYSIA

GREEDY INTERSECTION-MODE ROUTING STRATEGY PROTOCOL FOR VEHICULAR NETWORKS

MAHMOUD AHMAD SALEM AL-KHASAWNEH

A dissertation submitted in partial fulfillment of the requirements for the award of the degree of Master of Science (Computer Science)

Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia

NOVEMBER 2012

This dissertation is dedicated to all of my family for their endless support and encouragement. Especially for my future wife Dita for her understanding and support.

ACKNOWLEDGEMENT

First and foremost, I would like to express heartfelt gratitude to my supervisor **Assoc. Prof. Dr. Md. Asri Ngadi** for his constant support during my study at UTM. He inspired me greatly to work in this dissertation. His willingness to motivate me contributed tremendously to our project. I have learned a lot from him and I am fortunate to have him as my mentor and supervisor

Besides, I would like to thank the authority of Universiti Teknologi Malaysia (UTM) for providing me with a good environment and facilities.

ABSTRACT

In the recent years, the development of wireless network technology has been improved and there are so many researches undergoing in Vehicular Ad hoc Network. VANET has reached the greatest attention in the world. In VANET the velocity of carriers in the vehicle is high so it is very efficient to forward data and there are so many researchers are planned to develop routing protocol. The proposed routing algorithm is used to simulate in the distributed environment. The main purposes of this routing strategy are designed and develop the sustainable routing with better efficiency and adaptability. This proposed scheme uses geographic position based routing protocol and in that position based routing we using GpsrJ+ algorithm and it is adopted by VANET technology. Due to development of countries the vehicle travel in non-ordered distribution, so we are using GPSR greedy mode to forward packets and this mode fails often and it needs recovery mode or perimeter mode. This GPSR greedy mode always fails and it is worth for forwarding packets. So the proposed enhanced GpsrJ+ mode overcomes the disadvantage of GPSR and GPCR. This proposed system gives good packet delivery ratio by simple modification of the process. This system uses greedy mode on straight roads and intersection mode on intersection and it works intelligently because it can identify the direction of node and it effectively find the shortest path of the destination to send data packets. Finally GprsJ+ does not need expensive planarization strategy and it reduces hop count effectively. The unnecessary hop count and routing overload are avoided in the enhanced proposed routing protocol.

ABSTRAK

Dalam tahun-tahun kebelakangan ini, pembangunan teknologi rangkaian wayarles telah bertambah baik dan terdapat banyak kajian yang menjalani dalam Rangkaian kenderaan ad hoc. VANET telah mencapai perhatian yang terbesar di dunia. Dalam VANET halaju pembawa di dalam kenderaan itu adalah tinggi jadi ia adalah sangat berkesan untuk mengemukakan data dan terdapat begitu banyak penyelidik merancang untuk membangunkan protokol routing. Algoritma routing yang dicadangkan digunakan untuk mensimulasikan dalam persekitaran yang diedarkan. Tujuan utama strategi routing ini direka dan membangunkan routing mampan dengan kecekapan yang lebih baik dan penyesuaian. Ini skim yang dicadangkan menggunakan kedudukan geografi berasaskan routing protokol dan dalam kedudukan itu berdasarkan laluan kami menggunakan algoritma GpsrJ + dan ia diguna pakai oleh teknologi VANET. Disebabkan pembangunan negara perjalanan kenderaan dalam pengagihan bukan supaya, jadi kita menggunakan mod GPSR tamak untuk mengemukakan paket dan mod ini gagal sering dan ia perlu mod pemulihan atau mod perimeter. Ini mod tamak GPSR sentiasa gagal dan ia adalah bernilai untuk penghantaran paket. Jadi yang dipertingkatkan yang dicadangkan GpsrJ + mod mengatasi kelemahan GPSR dan GPCR. Sistem yang dicadangkan ini memberikan nisbah penyerahan paket yang baik oleh pengubahsuaian mudah proses. Sistem ini menggunakan mod tamak di atas jalan yang lurus dan mod persimpangan di persimpangan dan ia berfungsi bijak kerana ia boleh mengenal pasti arah nod dan ia berkesan mencari laluan terpendek destinasi untuk menghantar paket data. Akhirnya GprsJ + tidak memerlukan strategi planarization mahal dan ia mengurangkan hop mengira berkesan. Kiraan hop yang tidak perlu dan beban laluan dielakkan dalam protokol routing dicadangkan dipertingkatkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AODV	-	Ad hoc On-demand Distance Vector
AODV+PGB	-	Ad hoc On-demand Vector + Preferred Group Broadcasting
CAR	-	Connectivity-Aware Routing
CBR	-	Constant Bit Rate
CBF	-	Contention-Based Forwarding
CLR	-	Cross-Link Removal
CLDP	-	Cross-Link Detection Protocol
COIN	-	Clustering for Open IVC Networks
DSR	-	Dynamic Source Routing
DTN	-	Delay Tolerant Network
GG	-	Gabriel Graph
GDSTR	-	Greedy Distributed Spanning Tree Routing
GeoDTN+Nav	-	Geographical Delay Tolerant Network + Navigation Assistant
GeOpps	-	Geographical Opportunistic Routing
GIRS	-	Greedy Intersection-mode Routing Steategy
GPCR	-	Greedy Perimeter Coordinator Routing
GPS	-	Global Positioning System
GPSR	-	Greedy Perimeter Stateless Routing
GPSR+AGF	-	Greedy Perimeter Stateless Routing + Advanced Greedy Forwarding
GRANT	-	Greedy Routing with Abstract Neighbor Table
GSR	-	Geographical Source Routing
ITS	-	Intelligent Transportation System

LOUVRE	-	Landmark Overlays for Urban Vehicular Routing Environments
LORA-CBF	-	Cluster-base Flooding
MANETs	-	Mobile Ad hoc NETworks
OLSR	-	Optimize Link State Routing
PDR	-	Packet Delivery Ratio
RNG	-	Relative Neighborhood Graph
RRP	-	Route Reply Packet
RBVT-R	-	Road-Based using Vehicular Traffic-Reactive
TORA	-	Temporally Ordered Routing Algorithm
TTL	-	Time-to-Live
UDP	-	User Datagram Protocol
VADD	-	Vehicle-Assisted Data Delivery
VANETs	-	Vehicular Ad hoc NETworks
WLAN	-	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Overview

Vehicular Ad-Hoc Networks, (VANET), are a particular kind of Mobile Ad Hoc Network, (MANET), in which vehicles act as nodes and each vehicle is equipped with transmission capabilities which are interconnected to form a network. The topology created by vehicles is usually very dynamic and significantly non-uniformly distributed. In order to transfer information about these kinds of networks, standard MANET routing algorithms are not appropriate (Lee *et al.*, 2010b).

The availability of navigation systems on each vehicle makes it aware of its geographic location as well as its neighbours. However, a particular kind of routing approach, called Geographic Routing, becomes possible where packets are forwarded to a destination simply by choosing a neighbour who is geographically closer to that destination. With the rapid growth of vehicles and roadside traffic monitors, the advancement of navigation systems, and the low cost of wireless network devices, promising peer-to-peer (P2P) applications and externally-driven services to vehicles became available. For this purpose, the Intelligent Transportation Systems (ITS) have proposed the Wireless Access in Vehicular Environments (WAVE) standards that define an architecture that collectively enables vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications (ITS, 2012).

According to architectures of network, VANET can be divided into three categories, the first of which is the Wireless Wide Area Network (WWAN) in which the access points of the cellular gateways are fixed in order to allow direct communication between the vehicles and the access points. However, these access points require costly installation, which is not feasible. The second category is the Hybrid Wireless Architecture in which WWAN access points are used at certain points while an ad hoc communication provides access and communication in between those access points. The third and final category is the Ad Hoc V2V Communication which does not require any fixed access points in order for the vehicles to communicate. Vehicles are equipped with wireless network cards, and a spontaneous setting up of an ad hoc network can be done for each vehicle (Li and Wang, 2007). This study will focus on studying ad hoc V2V communication networks, which are also known as VANETs.

The purpose of VANET is to allow wireless communication between vehicles on the road including the roadside wireless sensors, enabling the transfer of information to ensure driving safety and planning for dynamic routing, allowing mobile sensing as well as providing in-car entertainment. As VANETs have unique characteristics which include dynamic topology, frequent disconnection of the networks, and varying environments for communication, the routing protocols for traditional MANET such as Ad hoc On-demand Distance Vector (AODV) (Perkins and Royer, 1999) are not directly usable for VANETs.

Researchers have developed a variety of efficient routing protocols for VANETs including Greedy Perimeter Stateless Routing (GPSR) (Karp and Kung, 2000); Greedy Perimeter Coordinator Routing (GPCR) (Lochert *et al.*, 2005); and GpsrJ+ (Lee *et al.*, 2007). The current issue, however, is that the range of the wireless sensors on vehicles is limited to a few hundred meters at most and the traffic conditions in a vehicular urban environment often change dynamically. Other than that, VANET routing protocols also face other problems including the issue of unstructured roads, the difference in the sizes of the intersections in a certain area, the sharp curves of the roads, uneven slopes, and other obstacles such as large buildings, traffic lights, trees, and sign boards. As it is impractical to spend excessively on rebuilding or restructuring the existing roads in urban environments, a routing protocol for the purpose of a larger distance of data communication in one-to-one and one-to-many transfers specifically for VANETs need to be developed. This study will focus on the current challenges in the research of geographical routing protocols for real-time vehicular networks in urban environments.

1.2 **Problem Background**

Although it is considered not feasible to use the known end-to-end wireless communication which uses multi-hop to represent the highly mobile nodes available in VANETs, there are various mobile communications capable of supporting networks for vehicular purposes, fulfilling the needs to dynamically route file transfer and sharing, a system to disseminate real-life traffic alerts as well as context-free advertisements (Dashtinezhad *et al.*, 2004; Nandan *et al.*, 2005; Riva *et al.*, 2007; Zhou *et al.*, 2005). Therefore, a VANET routing protocol which is capable of handling any number of nodes in an urban environment needs to be developed to allow a higher delivery ratio for packet transfers while lowering the end-to-end delay. This study focuses on addressing a known challenge in providing better services in vehicular networks for urban environments: the problem of decision-making at intersections and how to forward messages when an intersection is reached. This problem often occurs in any vehicular network in real urban environments and can directly affect the performance of the network.

VANETs require geographical routing protocols that utilize the Global Positioning System (GPS) to locate the next available node on the network (Bose *et al.*, 2001; Karp and Kung, 2000; Kuhn *et al.*, 2003; Lee *et al.*, 2010a; Lochert *et al.*, 2005). The use of GPS allows a more dynamic form of communication in which routes do not need to be established between the source nodes and the destination nodes before the data can be forwarded. GPS obtains the neighbour nodes by selecting the next best hop. The Greedy Perimeter Stateless Routing (GPSR) by Karp and Kung, (2000) is an example of a popular and widely used geographical routing protocol in which a route is established between the source node and the destination node through the utilization of the greedy and the perimeter modes within the network. Greedy forwarding is first used for the data forwarding in which the packet is forwarded to the node closest to the destination node. Due to the limitations of the radio range within the network, the local maximum of the network may be reached through the use of this mode and data may not be successfully transferred. The GPSR then uses the perimeter mode to forward the packet to a neighbour node closest to the destination node according to the right hand rule, to recover from the encounter with the local maximum. A planar graph is needed in this mode in order to avoid routing loops. Cross-edges can be removed from the graph with the use of two algorithms: Relative Neighborhood Graph (RNG) and Gabriel Graph (GG). These planarization algorithms assume that the links between any two nodes exist if and only if the nodes are within a certain threshold distance. The application of GPSR is proven to provide better performance within a typical urban environment, where a high ratio average delivery and low average delay can be achieved. However, other than neglecting to consider problems such as intersections, network partitioning and cross-links, the main problem in the use of the GPSR is that a direct link cannot be established between two nodes at an intersection as GPSR does not take into account large obstacles in an urban environment (Kim *et al.*, 2005b; Lee *et al.*, 2010a; Li and Wang, 2007). Figure 1.1 shows the failure of GPSRs: Figure 1.1(a) the relative neighborhood graph (RNG) is a planar topology used by GPSR, which consists of a link *N1 N2* if the intersection of two circles centered at *N1* and *N2* with radius *N1 N2* (shaded area) does not contain any other nodes. In Figure 1.1(b) the link *N1 N2* is removed by RNG since nodes *X* and *Y* are inside the intersection of two circles centered at *N1* and *N2*. Similarly, Figure 1.1(c) GG is used to remove link *N1 N2*. However, due to obstacles (such as buildings), there is no direct link *N1 X* or *N2 Y*. Thus the network is disconnected between *N1* and *N2*, resulting in GPSR's failure.

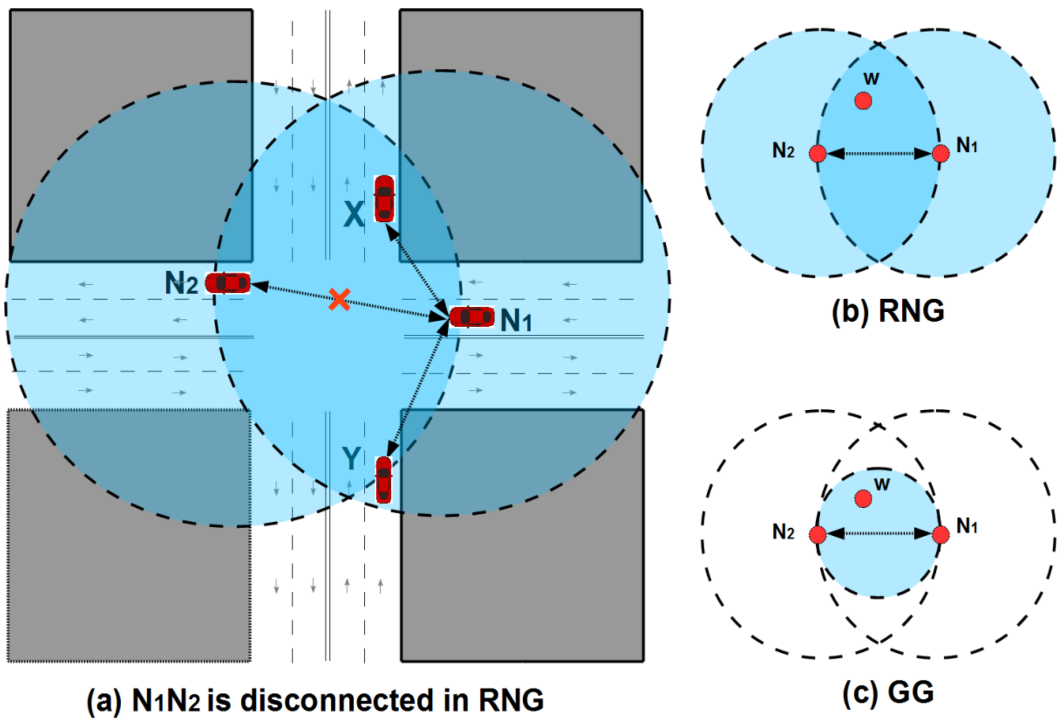

Figure 1.1: GPSR Failure at Street Intersection

The problem of cross-links caused by the use of the GPSR is resolved by the Cross-Link Detection Protocol (CLDP) proposed by Kim et al.,(2005) in which a distributed graph planarization technique allows proactive search and removal of the cross-links while the complexity of the message has a high overhead. Another protocol aimed at removing cross-links is the Lazy Cross-Link Removal (LCR) Protocol by Govindan et al.,(2006) which reduces the complexity of the message through the removal of cross-links that cause loops. A planar graph is generated based approximately on the underlying topology whereas LCR removes the cross-links through the use of a mutual witness algorithm. (Lee *et al.*, 2010a) proposed

GeoCross, an event-driven geographical routing protocol which can dynamically remove cross-links to avoid the problem of loops. Instead of the usual use of planar graphs, GeoCross uses urban maps with natural planar features. Compared to GPSR and GPCR, GeoCross offers a higher ratio of packet delivery and lower average delay. However, none of the previous protocols attempt to solve the problem of how to forward messages when the intersection is reached.

Intersections in a vehicular network are the other main problem in the routing protocols as in VANET. Since traffic is always changing, the intersections in vehicular networks are ineffective. The greedy forwarding technique can be used, since it transfers to the next node. Thus intersection problem can safe. This causes unnecessary routing. In Figure 1.2 where the change in Sackets from source end *S* to the destination *D*. the shortest distance in Sackets *N2*. where the intersection of nodes is *A* at the road intersection. Thus the intersection between the source and the destination end is most considered. The shortest distance on the parallel streets does consider the distance between the node *S* and the destination is farther. The intersection is not considered in these parallel streets. The best route is as shown by the dotted arrows in Figure 1.2; $S \Rightarrow N1 \Rightarrow A \Rightarrow B \Rightarrow C \Rightarrow D$.

Through the enhancement of GPSR, the Greedy Perimeter Coordinator Routing (GPCR) protocol was proposed by Lochert et al (2005) in which the nodes at an intersection (coordinator) are according to a natural planar graph. The right hand rule of the GPCR is that a restricted greedy algorithm is to be followed if the neighbour nodes are located in the same street while a repair strategy is applied should the nodes be located at an intersection. When there are obstacles, the GPCR will broadcast a continuous beacon message to all the neighbours within radio range. In reality, however, obstacles such as trees, sign boards, and advertisements may cause interruption to the radio signals. The GPCR also faces the problem of cross-links should there be a large obstacle or when the nodes have high mobility. Although the GPCR is well-suited for an ideal urban environment, the planar graph is not usable if there are no nodes, such as in the case of node *A* in Figure 1.2. GpsrJ+ Lee *et al.*, (2007) improves the ratio of packet delivery of the current GPCR protocol through the prediction of road segments.

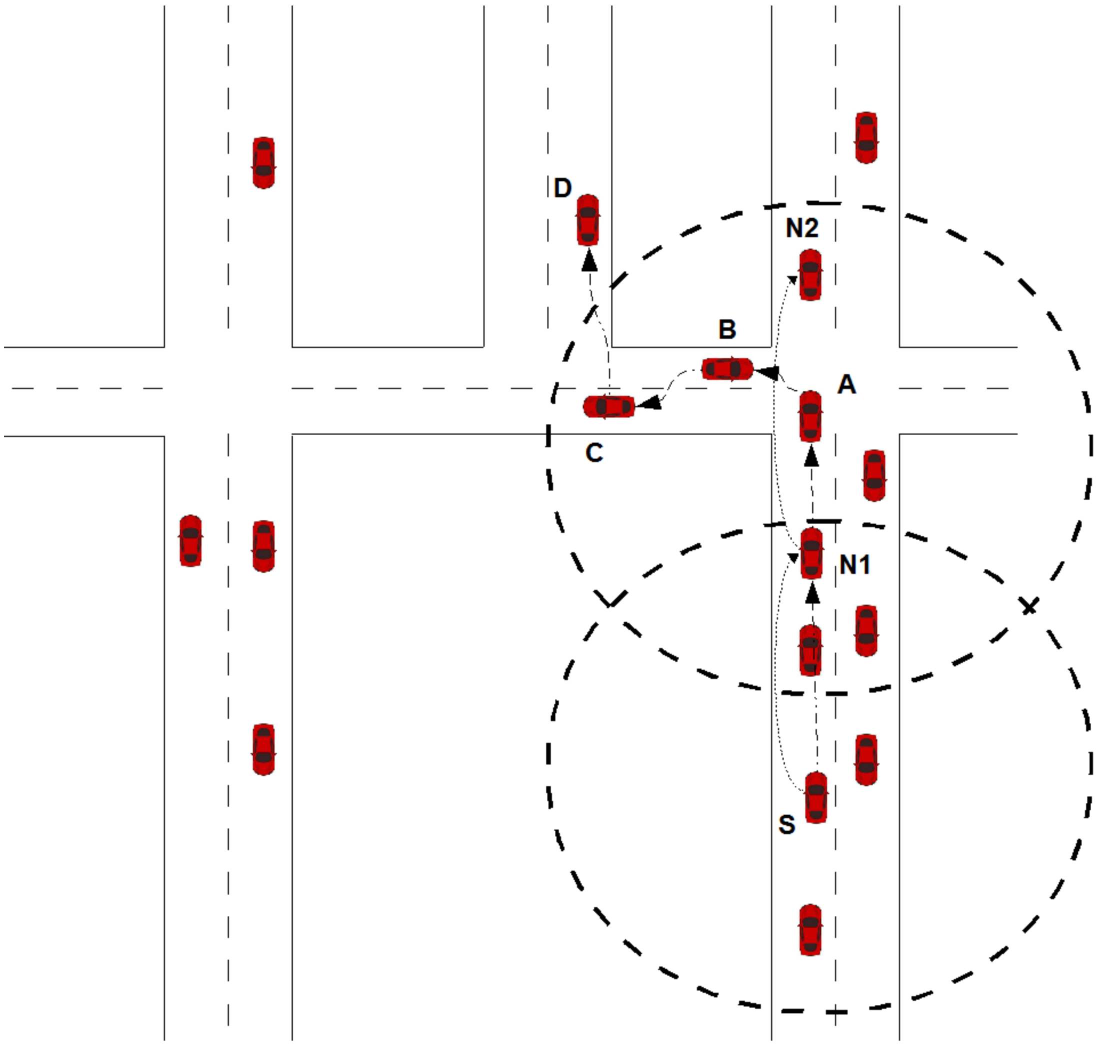

Figure 1.2: Important Intersection Ignored in Most Widely used VANET Routing Protocols

The prediction is done to decide which neighbours at the intersections the packet should be forwarded to next. GpsrJ+ also uses natural planar features of maps in an urban environment and the hop count in the perimeter is reduced, allowing quicker return to the greedy mode. Observation by Jarupan and Ekici (2010) stated that this protocol is not efficient for use in the vehicular networks of a typical urban environment as the neighbour management around an intersection is considered intensive.

RBVT-R is the name of Road-Based Used Vehicular Traffic information, as Nzouonta *et al.*, (2009) proposed and which contains road intersections. It features high probability and network connectivity. Instead of sending frequent messages, RBVT-R introduces a new method to reduce the path sensitivity. It has several parameter values. RBVT-R works in its own environment and does not implement in real VANET where there is always a change in network and traffic conditions.

In a geo-proactive overlay routing called Landmark Overlays for Urban Vehicular Routing Environments (LOUVRE) proposed by Lee *et al* (2008) creates overlay links on top of an urban topology. In LOUVRE, the nodes at intersections are defined as landmarks and the overlay links are only possible if there is enough traffic density between intersections. LOUVRE's guaranteed multi-hop routing is a suitable method for avoiding dead-end roads. Jerbi et al.,(2009) also proposed an intersection-based geographically greedy traffic-aware routing (GyTAR) protocol to find the best routes in urban environments. GyTAR creates routes from source to destination based on a sequence of connected intersections. Two parameters, including change in vehicular traffic information and the remaining distance from the destination, are used to define a best route. GyTAR also uses an improved greedy forwarding mechanism to forward data packets on the road segments. However, if there is no node at an intersection, the packet can not be forwarded and the performance of LOUVRE and GyTAR are affected as data packets are dropped and there is higher end-to-end delay.

1.3 Problem Statement

In order to achieve better performance in vehicular communication, the problems regarding intersections need to be handled to improve the transfer of real-time vehicle-to-vehicle data. Although VANETs have proven to be promising for communication in urban environments, VANETs need to be able to provide higher delivery ratios while minimizing delay of all the applications in the networks.

"How to improve the decision for next node selection at intersections in Vehicular Networks"

Therefore, this study needs to answer the following research question:

How to develop a geographical routing protocol that is capable of making better routing decisions at intersections to significantly improve the performance of VANET?

1.4 Research Aim

This study aims to develop a geographical routing protocol capable of efficiently handling the problems regarding intersections in real-time vehicular urban environments

.

1.5 Research Objectives

The objectives of this research are:

i To enhance a geographical routing protocol which is capable of making better decisions at intersections.

ii To develop an enhancement of a geographical routing protocol that reduces average delay.

iii To evaluate the performance of the proposed routing protocol as compared to widely-used VANET routing protocols (GPSR, GPCR, GpsrJ+) regarding average delivery ratios and end-to-end delay.

1.6 Scope of the study

The scope of the study covers the following

i The assumed scenario is that vehicles are able to move in a two-way urban environment where no network infrastructure or centralized traffic control is considered.

ii Forwarding of the data packets can be done freely if the next node within the vehicles communication range is available.

1.7 Significance of the Study

In order to achieve further advancement in the technology of mobile communication, research in the vehicular industry has been done with special emphasis in the areas of routing and routing management, information security, and enabling communication between vehicle-to-vehicle and vehicle-to-infrastructure, as well as technological deployments. In the area of routing, however, real-life urban environments cannot be properly reflected by the currently implemented routing protocols for VANETs. Therefore, this study is done in order to solve the problems regarding roads with intersections by addressing the issues which arise from packet transfers on the road and at intersections. The study focuses on improving VANETs in terms of routing and data forwarding where the characteristics of VANETs are incorporated into the design of a protocol for urban environments.

1.8 Structure of the Thesis

The remainder of the thesis is structured as follows: Chapter 2, Literature Review, provides extensive review of highly related literature regarding geographical routing protocols of urban environments. Chapter 3 presents and describes the research methodology used for the study, including the operational framework of the design and the development of vehicular networks. Chapter 4 provides the formal introduction of the proposed routing protocol through the design, and examples of routing protocols as well as analysis of the performance. Finally, Chapter 5 provide the conclusion and suggestions for future work.

REFERENCES

Bernsen, J. and Manivannan, D. (2009). Unicast routing protocols for vehicular adhocnetworks: Acriticalcomparisonandclassifcation. Pervasive and Mobile Computing. 5(1), 1 –18. ISSN 1574-1192.

Blum, J., Eskandarian, A. and Hoffman, L. (2003). Mobility management in IVC networks. In Intelligent Vehicles Symposium, 2003. Proceedings. IEEE. 150 – 155.

Bose, P., Morin, P., Stojmenovic, I. and Urrutia, J. (2001). Routing with Guaranteed DeliveryinAd Hoc WirelessNetworks. Wireless Networks. 7(6),609–616.

Dashtinezhad, S., Nadeem, T., Dorohonceanu, B. and Borcea, C. (2004). TraffcView: ADriverAssistantDeviceforTraffcMonitoringBased onCar-to-Car Communication. In In IEEE Semiannual Vehicular Technology. May. 17–19.

Fubler, H., Mauve, M., Hartenstein, H., Vollmer, D. and Kasemann, M. (2002). A comparison of routing strategies in vehicular ad-hoc networks. Technical report. UniversittMannheimMarch.

ITS(2012). ITS Standards. Retrievableat http://www.standards.its.dot. gov/about.asp.

Jacquet, P., Muhlethaler, P., Clausen, T., Laouiti, A., Qayyum, A. and Viennot, L. (2001). Optimized link state routing protocol for ad hoc networks. In Multi Topic Conference, 2001. IEEE INMIC 2001. Technology for the 21st Century. Proceedings. IEEE International.62 –68.

Jerbi, M., Senouci, S.-M., Rasheed, T. and Ghamri-Doudane, Y. (2009). Towards Effcient Geographic Routing in Urban Vehicular Networks. Vehicular Technology, IEEE Transactions on. 58(9),5048 –5059.

Johnson,D. B. and Maltz, D. A. (1996). Dynamic Source Routing in Ad Hoc Wireless Networks. KluwerAcademic Publishers.

Karp,B.andKung,H.T.(2000). GPSR:greedyperimeterstatelessroutingforwireless networks. InMobiCom ’00: Proceedings of the 6th annual international conference on Mobile computing and networking.New York,NY, USA: ACM, 243–254.

Kim, Y.-J., Govindan, R., Karp, B. and Shenker, S. (2005a). Geographic routing made practical. In Proceedings of the 2nd conference on Symposium on Networked Systems Design & Implementation -Volume 2. NSDI’05. Berkeley, CA, USA: USENIX Association,217–230.

Kim, Y.-J., Govindan, R., Karp, B. and Shenker, S. (2005b). On the pitfalls of geographicfacerouting. In Proceedings of the 2005 joint workshop on Foundations of mobile computing. DIALM-POMC ’05. NewYork, NY, USA: ACM,34–43.

Kuhn, F., Wattenhofer, R., Zhang, Y. and Zollinger, A. (2003). Geometric ad-hoc routing: of theory and practice. In PODC ’03: Proceedings of the twenty-second annual symposium on Principles of distributed computing. New York, NY, USA: ACM, 63–72.

Lee, K., Haerri, J., Lee, U. and Gerla, M. (2007). Enhanced Perimeter Routing for Geographic Forwarding Protocols in Urban Vehicular Scenarios. In Globecom Workshops, 2007 IEEE. nov. 1 –10. doi:10.1109/GLOCOMW.2007.4437832.

Lee, K., Le, M., Harri, J. and Gerla, M. (2008). LOUVRE: Landmark Overlays for UrbanVehicularRoutingEnvironments. InVehicular Technology Conference, 2008. VTC 2008-Fall. IEEE 68th.1–5.

Lee, K. C., Cheng, P.-C. and Gerla, M. (2010a). GeoCross: A geographic routing protocol in the presence of loops in urban scenarios. Ad Hoc Networks. 8(5), 474 –

488. ISSN 1570-8705. Vehicular Networks.

Lee, K. C., Lee, U. and Gerla, M. (2010b). Survey of Routing Protocols in Vehicular Ad Hoc Networks. IGI Global.

Lee, U., Zhou, B., Gerla, M., Magistretti, E., Bellavista, P. and Corradi, A. (2006). Mobeyes: smart mobs for urban monitoring with a vehicular sensor network. Wireless Communications, IEEE. 13(5), 52 –57.

Leong,B.,Liskov,B.andMorris,R.(2006). Geographicroutingwithoutplanarization. In NSDI'06: Proceedings of the 3rd conference on Networked Systems Design & Implementation.Berkeley,CA, USA: USENIX Association,25–25.

Li,F. andWang,Y. (2007). Routinginvehicularadhocnetworks: Asurvey.Vehicular Technology Magazine, IEEE. 2(2), 12 –22.

Liu,C. G.,Liu,G.,sungLee,B.,chongSeet,B.,hengFoh,C. andkeeLee,K. (2004). ARoutingStrategyforMetropolisVehicular. In In Proc. International Conference on Information Networking. 533–542.

Lochert, C., Mauve,M., Fubler, H. and Hartenstein,H. (2005). Geographicroutingin city scenarios. SIGMOBILE Mob. Comput. Commun. Rev. 9, 69–72. ISSN 15591662.

Namboodiri,V.,Agarwal,M. andGao,L. (2004). Astudyonthefeasibilityofmobile gateways for vehicular ad-hoc networks. In VANET '04: Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks.66–75.

Nandan, A., Das, S., Pau, G., Gerla, M. and Sanadidi, M. (2005). Co-operative downloading in vehicular ad-hoc wireless networks. In Wireless On-demand Network Systems and Services. jan. 32 – 41.

Naumov,V., Baumann,R. and Gross,T. (2006). Anevaluationofinter-vehiclead hoc networks based on realistic vehicular traces. In MobiHoc '06: Proceedings of the 7th ACM international symposium on Mobile ad hoc networking and computing. New York, NY,USA: ACM, 108–119.

Nzouonta, J., Rajgure, N., Wang, G. and Borcea, C. (2009). VANET Routing on City Roads UsingReal-Time Vehicular Traffc Information. Vehicular Technology, IEEE Transactions on. 58(7), 3609 –3626.

Perkins, C. and Royer, E. (1999). Ad-hoc on-demand distance vector routing. In Mobile Computing Systems and Applications.90 –100.

Perkins, C. E. and Bhagwat, P. (1994). Highly dynamic Destination-Sequenced Distance-Vector routing (DSDV) for mobile computers. SIGCOMM Comput. Commun. Rev. 24(4), 234–244.

Riva, O., Nadeem, T., Borcea, C. and Iftode, L. (2007). Context-Aware Migratory Services in Ad Hoc Networks. Mobile Computing, IEEE Transactions on. 6(12), 1313 –1328.

Santos, R. A., Edwards, A., Edwards, R. M. and Seed, N. L. (2005). Performance evaluation of routing protocols in vehicular ad hoc networks. Int. J. Ad Hoc Ubiquitous Comput. 1(1/2), 80–91.

Schnaufer, S. and Effelsberg, W. (2008). Position-based unicast routing for city scenarios. InWorld of Wireless, Mobile and Multimedia Networks, 2008. WoWMoM 2008. 2008 International Symposium on a.1 –8.

WAVE(2010). Wireless Acess for Vehicular Environment (WAVE).

Zhou, P., Nadeem, T., Kang, P., Borcea, C. and Iftode, L. (2005). EZCab: A Cab Booking Application Using Short-Range Wireless Communication. In Pervasive Computing and Communications. mar. 27 –38.