ROXY: A VEHICULAR AD-HOC NETWORKS ROUTING PROTOCOL IN VEHICULAR CROWDED URBAN ENVIRONMENT

By

Mohamed Abubaker Ibrahim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

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Title of Thesis:

ROXY Ad-Hoc Network Routing Protocol in Vehicular urban Environment

Key Words:

VANET; Ad-Hoc; Routing protocol; Position base routing protocol; collision avoidance

Summary:

Vehicular Ad-hoc Network (VANET) is a wireless network between vehicles equipped with on-board units. VANET can be used in safety applications, where low latency is of high importance, or for entertainment and Internet access. VANET is a part of the overall vision of Intelligent Transportation Systems (ITS). The nature of the VANET network is dynamic due to the different speeds of vehicles on the roads, and their sudden change of directions/lanes. Therefore, packet routing algorithms in VANETs should take into consideration the fast topology changes. This is usually done by sending beacon packets by the vehicles to all other vehicles, and updating the routing table frequently. This is considered as a high overhead in VANET networks that tremendously decreases the effective throughput.

In this work, we introduce Receiver as prOXY (ROXY) VANET routing protocol to overcome the limitations of other protocols. ROXY employs the geographic routing scheme with opportunistic next hop selection to increase the overall network throughput in VANET networks. ROXY main objective is to solve the increasing congestion and collisions in heavy loaded network traffic. The improvement in VANET network is caused by tackling three issues. Firstly, we utilize the spatial resources by using two directed antennas on each vehicle, one on the front side, and one on the back side. The directed antennas are used to send and receive packets from two different directions simultaneously, which efficiently use the transmission medium and increase the overall throughput. Secondly, ROXY is a distributed routing algorithm, where the decision of next relay selection does not need communication with a central entity. Lastly, we reduce the transmission time delay through proposing a new collision avoidance algorithm that takes advantage of the directed antennas and the street topology in urban areas. Simulation results show the superiority of our algorithm in terms of overall network throughput compared to other algorithms.

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List of Nomenclature

ACK	Acknowledge
CCH	Control Channel
CSIA	Current sender IP Address
CSMA/CA	Carrier sense multiple access with collision avoidance
CSMA/CD	Carrier sense multiple access with collision detection
CSP	Current sender position
CSU	Channel sender using
DHCP	Dynamic Host Configuration Protocol
DIA	Destination node IP Address
DOT/CP	Denial Of Transmission with Collision Prevention
DP	Destination node position
DSRC	Dedicated Short Range Communication
FNIA	FROM Node IP Address
In	Index
ITS	Intelligent transportation system
MANET	Mobile Ad hoc Network
NAS	Not Allowed to Send
NIA	New IP Address
Nix	New Index
PI	Packet Index
PTAIF	Packet Type the ACK Issued For
QoS	Quality of Service
RNIA	Receiver Node IP Address
ROXY	Receiver as Proxy
RREP	Route Reply
RREQ	Route Request
RSU	Road Side Unit
SCH	Service Channel
SIA	Source node IP Address
SP	Source node position
TA	Time to create and send

TRS	Time to Retransmit
TS	Time to fully send
UTC	Coordinated Universal Time
V2I	vehicle to infrastructure
V2V	vehicle to vehicle
VANET	Vehicle Ad-hoc Network

Abstract

Vehicular Ad-hoc Networks (VANET) is a wireless network between vehicles equipped with on-board units. VANET applications vary from safety applications, where low latency is of high importance, to entertainment and Internet access. VANET is a part of the overall vision of Intelligent Transportation Systems (ITS). Vehicles in VANET network have dynamic nature due to the fast speed variation of the vehicles on the roads, and their sudden change in directions/lanes. Therefore, packet routing algorithms in VANETs should take into consideration the fast topology changes. Usually this is achieved through sending beacon packets by the vehicles to all their neighbors, and updating the routing table frequently. This is considered as a high overhead in VANET networks that tremendously decreases the effective throughput.

In this work, we introduce Receiver as prOXY (ROXY) VANET routing protocol to overcome the limitations of other protocols. ROXY employs the geographic routing scheme with opportunistic next hop selection to increase the overall network throughput in VANET networks. ROXY main objective is to solve the increasing congestion and collisions in heavy load network traffic. ROXY improves the system by tackling three issues. Firstly, it utilizes the spatial resources by using two directed antennas on each vehicle, one on the front side, and one on the backside. The directed antennas are used to send and receive packets from two different directions simultaneously, which efficiently use the transmission medium and increases the overall throughput. Secondly, ROXY is a distributed routing algorithm, where the decision of next relay selection does not need communication with a central entity. Lastly, it reduces the transmission time delay through proposing a new collision avoidance algorithm that takes advantage of the directed antennas and the street topology in urban areas. Simulation results show the superiority of our algorithm in terms of overall network throughput compared to other algorithms.

Chapter 1. Introduction

Vehicular Ad-hoc Networks (VANETs) are wireless networks between vehicles moving or parking in the streets. Vehicles are equipped with onboard units and computerized control units in VANET. The onboard units can transmit to 300m range and they do not require mobile or stationary infrastructure to create the network for some applications. However, to have a much better services for the VANET customers, a good designed infrastructure is needed and spread through the streets in the shape of road side units (RSUs) to help leveling up the services and to serve as an Internet gateway. Packets going out of source transmission range need to be sent through multiple nodes in the network to reach the final destination.

VANETs are considered as a subclass of mobile ad hoc networks (MANETs) with some differences. The similarity between MANET and VANET are that in both networks the nodes are mobile, except for VANET, the vehicles are not moving randomly but they move in a controlled mobility manner, which makes their mobility pattern more predictable. The difference between the two networks is that VANET's vehicles move in various speeds from 20km/h to 60km/h in urban road and can exceed 130km/h on highways. Also the difference in nodes directions according in which side of the road they are moving on. All that leads to unstable connections and rapid changes in the network topology. Therefore, developing routing protocol, which is topology independent or at least can be adapted to the rapid changes in the network topology, is needed to achieve a decent VANET system

People spend 10 to 15% of their travel time in traffic jams [1]. VANET with a good designed infrastructure can leverage the Intelligent Transportation Systems (ITS) through the real time information gathered from the vehicles to achieve a better driving experience by advising drivers to change their travel path to a better one with no or less congestions. In addition, it can enhance the safety application to avoid accidents, which will save human lives and improve productivity. VANETs can be used to support different applications. For example:

- Accidents and hazards situation in the area can be reported to other users of VANET before reaching it, and the authority can be informed automatically e.g. the police, ambulance, or fire department to solve the situation as soon as possible,
- Sudden breaks in highways with the presence of fog or any sudden break downs for the vehicles will be reported fast to prevent accidents from happening,
- Traffic state information in the vehicles' traveling path (e.g. traffic congestion, blocked road for maintenance, or any sudden reason) can be gathered in real time and the system automatically update the path and inform the driver that a sudden issue occurred in the path chosen and a detour is advised,
- Empty parking spaces. Vehicles can reserve empty space even before they can reach their destination which is very helpful to the user to lower the congestion in the crowded zones,
- Reservation for restaurants, hotels, theater houses etc. While on the move, last minute change of plans, or if the person is new to the area, the reservation can be handled on the run through a simple application. It can reserve, lead the way to the best route, and reserve the place to park automatically without the need to waste time and effort,
- Internet access for streaming, communication, gaming, or any other service the Internet can offer.

To accomplish that, communication is needed between moving vehicles with each other's (V2V) and vehicles with the infrastructure (V2I) to be done as efficiently as possible with low time delay. Furthermore, RSUs deployment is expensive, and because of that, not all the vehicles will be in the RSUs transmission range. However, the vehicles should be connected to the RSUs, and this is accomplished through multi-hop transmission using a routing protocol designed for the heavy loaded VANET environment, to transmit the data from vehicles to the RSU and vice versa with low collisions and reduced time overhead.

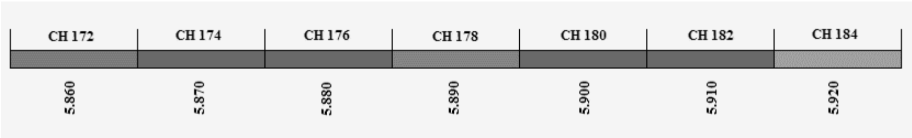

Figure 1.1: VANET channels frequencies available

The IEEE 802.11p/WAVE Wireless Access in Vehicular Environments [2] standard allocates seven channels (10MHz bandwidth per-channel centered around the frequency 5.89GHz) in the Dedicated Short Range Communication (DSRC) frequency band 5.85-5.925 (CH 172-CH 184) as shown in Figure 1.1. The seven channels are distributed as follows: one channel is called Control Channel (CCH) for sending emergency and beacons and the other six are Service Channels (SCH) [3] [4] [2] [5]. Some papers use channels in a different way: CH 172 and CH 184 are reserved for special purposes. CH 178 for CCH and the remaining four channels for SCH [6]. Others use CH 172 for safety transmission and CH 178 as CCH while CH 184 for long range high power transmission and the remaining four channels for SCH as in [7] and [8]. Vehicles equipped with single network devices must alternate between the CCH and SCH. The method used is to divide time into integer number of sync intervals with fixed length of 100ms. A sync interval is the sum of a CCH interval and a SCH interval. 50ms is used for each channel. To coordinate the access to these channels, vehicles must have time synchronization by using coordinated universal time (UTC). In addition to that, there is 2ms guard interval at the beginning of each interval for devices switching [9]. The network devices channels can be classified to four modes [6], as shown in Figure 1.2:

1. **Continuous access:** in this mode, the network devices access only the CCH to send and receive the emergency and control messages.
2. **Alternating access:** the network device alternates between the CCH and SCH in fixed interval.
3. **Immediate access:** In this mode, the devices must switch to the CCH every new sync interval and when the transmission on the CCH ends then the devices can switch back to the SCH.
4. **Extended access:** the network devices work in the SCH as long as there is no transmission on the CCH.