

AN ENHANCED CONNECTIVITY AWARE ROUTING PROTOCOL FOR  
VEHICULAR AD HOC NETWORKS

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To my children Aishat, Hafsat and Ibrahim

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## ABSTRACT

Vehicular Ad Hoc Network (VANET) is a self organized and self maintained communication network that is spontaneously and wirelessly formed by moving vehicles to provide safety, entertainment and information to its users. To tap these benefits, efficient and reliable routing protocols are needed. Designing routing protocol in VANET is challenging as the result of high vehicles' mobility that result in frequent network disconnections. This is why existing routing protocols include route error handling to cater for the disconnection problem. Most of these solutions are variations of keep and carry strategy with or without a feedback mechanism to the source node. These strategies are sometime unnecessarily prolong the packet delivery and worst even if they failed, a new path discovery process is re-launched and that create more control overhead that waste the useful bandwidth. Even with Preferred Group Broadcast re-initiating route request creates additional control overhead. In this research, an Enhanced Connectivity aware routing (ECAR) protocol is proposed. The protocol utilizes an *alternative backup* route anytime the primary route to destination fails. It also uses *control broadcast* to further reduce the number of broadcasts needed to find routes to destination by allowing only the furthest node that receives a route request packet to rebroadcast it further in the network. NS2 simulation experimental results show that the performance of ECAR protocol outperformed the original connectivity aware routing (CAR) protocol by reducing the average packet delay by 28%, control overheads by 27% and increased the packet delivery ratio by 22%.

## ABSTRAK

Rangkaian lalu lintas *Ad Hoc* (VANET) adalah rangkaian komunikasi yang terbentuk dan terselenggara dengan sendiri secara spontan dan tanpa wayar oleh pergerakan kenderaan untuk membekalkan keselamatan, hiburan dan maklumat kepada pengguna. Untuk meraih manfaat ini protokol penghalaan yang efisien dan boleh dipercayai diperlukan. Reka bentuk protokol penghalaan VANET sangat mencabar kerana rangkaian kerap terputus oleh sebab kenderaan sangat banyak bergerak. Oleh sebab itu protokol penghalaan yang sedia ada memasukkan pengendalian ralat laluan untuk mengatasi masalah rangkaian terputus sambungan. Strategi ini kadang kala tidak perlu dan sangat tidak berkesan serta memperlambat penghantaran bingkisan. Walaupun strategi ini gagal, proses pencarian jalan baharu dilancarkan semula dan kawalan yang lebih ketat kepada pembuangan jalur lebar yang berguna diwujudkan. Pencarian semula laluan oleh Kumpulan Penyiaran Pilihan membentuk tambahan kawalan sedia ada. Dalam kajian ini protokol penyambungan penghalaan sedar dipertingkatkan (ECAR) dicadangkan. Protokol ini menggunakan laluan sokongan alternatif sebarang masa apabila laluan utama menuju destinasi gagal. Protokol ini juga menggunakan siaran kawalan untuk mengurangkan bilangan siaran yang diperlukan untuk mencari laluan menuju destinasi dengan hanya membenarkan nod jauh yang menerima permintaan bingkisan perjalanan ke siaran semula dan terus dalam rangkaian. Keputusan uji kaji simulasi NS2 menunjukkan bahawa prestasi protokol ECAR mengatasi protokol sambungan asal penghalaan sedar (CAR) dengan secara purata mengurangkan kelewatan bingkisan sebanyak 28%, kos kawalan sebanyak 27% dan meningkatkan nisbah penghantaran bingkisan sebanyak 22%.

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## LIST OF ABBREVIATIONS

ACAR	-	Adaptive Connectivity Aware Routing
AGP	-	Anchor Geographical based routing Protocol
AODV	-	Ad hoc On Demand Distance Vector
AP	-	Anchor Point
A-STAR	-	Anchor Street and Traffic Aware Routing
CAR	-	Connectivity Aware Routing
CBR	-	Continous Bit Rate
DSR	-	Dynamic Source Routing
ECAR	-	Enhanced Connectivity Aware Routing
GIS	-	Geographic Information System
GPSR	-	Greedy Perimeter Stateless Routing
GSR	-	Geographic Source Routing
MANET	-	Movile Ad hoc Network
PEV	-	Persistent Vector
PGB	-	Preferred Group Broadcast
PRS	-	Present Vector
RBVT-R	-	Road Based using Vehicular Traffic-Reactive
RERR	-	Route Error
RREP	-	Route Response
RREQ	-	Route Request
STAR	-	Spatial and Traffic Aware Routing
VANET	-	Vehicular Ad hoc Network

## CHAPTER 1

### INTRODUCTION

#### 1.1 Overview

Vehicular Ad Hoc Network (VANET) is a self organized and self maintained communication network that is spontaneously and wirelessly formed by moving vehicles to provide safety, entertainment and information to its users. To tap these benefits, efficient and reliable routing protocols are needed. Designing routing protocol in VANET is challenging as the result of high vehicles' mobility that result in frequent network disconnections. In order to tackle this challenge, numerous routing protocols have been proposed in the literature. The most promising among these protocols are real time connectivity aware protocols. These protocols have the ability to reactively discover connected paths to destination by flooding the networks with a route request message and computing dynamically vehicles' density from on the fly data collected to enable paths selection. Once an optimal path is selected, the communication between source and destination is carried out by *unicast* transmission using the selected path. The major drawback is that new path discovery process will constantly be needed any time the selected path becomes disconnected. Therefore, this research enhances a Connectivity Aware Routing, CAR (Naumov and Gross, 2007) protocol to provide better performance. The resulting new protocol called *an Enhanced Connectivity Aware (ECAR)* protocol reduces the network control overhead by using a *control broadcast* and also reduces the need for relaunching new path discovery process whenever a connected path breaks by utilizing an *alternative backup route*. The new protocol *ECAR* was evaluated using NS-2.3.

## 1.2 Problem Background

Connectivity aware protocols have the advantage of discovering the best connected path to destination. Even though flooding will introduce bandwidth wastage, it is necessary since location service is not assumed. Once a path is selected, it is used for subsequent message transfer between source and destination nodes. The selected path can probably be disconnected as the result of change in vehicle density over time. Since network disconnection is frequent in VANET, remedial measures are necessary. One remedy suggested by ACAR (Yang et al, 2009) and AGP (Yan et al, 2011) protocols is simply to keep and carry the packet until there exists available next hop. This strategy will work fine if the path disconnection is for a short time. If the disconnection is long or even permanent, this remedy strategy will either prolong the packet delivery time or at worst cause the packet to be lost. Furthermore, since there is no feedback mechanism to the source, the source will continue sending packets through the broken path which will result in losing all the packets hence decreasing the packet delivery ratio.

Another alternative solution suggested by CAR (Naumov and Gross, 2007) and RBVT-R (Nzounta et al, 2009) protocols is to keep and carry the packet for a threshold time. The RBVT-R (Nzounta et al, 2009) protocol requires that when the time elapsed, the node that detects the problem drops the packet and send route error message to the source (sender). On receiving of the error message, the source stops sending packets through the failed route path and launch a new path discovery process. In the other hand, the CAR protocol requires that the node that detected the problem to sends an error message to the source node and at the same time begins a search of a new connected path to destination. If the search is successful, the found path is concatenated with the part of the old path to make a new path. This new path is communicated to the source node. The source node analyzes the new path and if it found the path okay it utilize it in subsequent transmission otherwise it launch a new path discovery process. This solution provided by the CAR (Naumov and Gross, 2007) protocol may introduce more control overhead as a consequence of starting new path discovery by the node that detected the route failure or introduces even more control overhead by re-launching a new path discovery by the source node.

Analyzing this CAR recovery strategy, it can be seen that any new path discovery has high potential of wasting the network bandwidth in addition to prolonging the delivery time.

### 1.3 Research Questions

Below are some of the important questions this study will try to provide answers to them:

- i. How to reduce the broadcast problem inherent in the route discovery process?
- ii. How to enhance route error maintenance processes to overcome or reduce excessive need of route discovery process due disconnection problem?
  - a. Will incorporating alternative path to destination, in addition to the primary path, assists in overcoming the problem?
  - b. How do you decide the primary path and the alternative path?
- iii. How to evaluate the performance of the resulting new protocol *ECAR* relative to the original CAR protocol?
  - a. What are the evaluation metrics to be considered in evaluating the new protocol?
  - b. What are the appropriate scaling models to be used?
  - c. Is the performance of a new protocol better than the original CAR?

### 1.4 Problem Statement

Path disconnection is highly probable in VANET. Existing solution by various connectivity aware protocols is not sufficient. Most of the solution suggested are variations of traditional keep and carry packet strategy that enqueued incoming packets until the next available hop to forward the packets or keep and carry the

packets for a threshold time. When the time elapsed, packets are dropped and an error message is sent to the source, which will in turn launch a new path discovery process. Each path discovery process causes a large increase in the control overheads as a result of flooding the network with broadcast request that waste useful bandwidth. In addition, the process increases the packet delivery delay as there will be no meaningful data transmission during a route request process. In the case of launching route discovery by intermediate nodes, some data packets are lost when the route path request is unsuccessful and that negatively increases the packet lost ratio. Thus, there is a need to alleviate or reduce this problem associated with these remedial measures.

## 1.5 Research Aim

This research work is aimed at proposing an Enhanced Connectivity aware routing protocol based on a Connectivity Aware Routing (CAR) protocol. The new protocol incurred less control overhead in a route discovery process and is equipped with alternative backup path in the route error maintenance that reduced the need for re-initiating of a new path discovery process.

## 1.6 Research Objectives

The following are the objectives of this research:

- i. To reduce the number of control overhead from a route path discovery process using *control broadcast* mechanism.
- ii. To enhance route error maintenance process by incorporating alternative path to destination in addition to the primary path. The alternative path is utilized whenever the primary path fails.

- iii. To evaluate the performance of the new protocol relative to the original CAR protocol based on control overhead , packet delivery ratio, end-to-end delay, and packet lost ratio.

### **1.7 Scope of the Study**

This research study is concerned with developing an efficient CAR protocol that will be useful for VANET routing. The scope of this research covers the following:

- i. Only the CAR protocol is enhanced and implemented. Other connectivity aware protocols are not enhanced and implemented because CAR protocol was chosen to be a representative of them.
- ii. The enhancement is focused on route discovery and routing error recovery.
- iii. The source node will use a Constant Bit Rate (CBR) traffic to generate data packets during the simulation experiment.
- iv. Security issues in vehicular communication are not considered.
- v. The performance of the ECAR protocol relative to the original CAR protocol will be evaluated by using an NS-2.33 simulator.

### **1.8 Dissertation Report Organization**

The rest of this report is organized as follows:

Chapter 2 reviewed related literature in the area of study. It explained what VANET is all about and highlighted its significance. The chapter also compares and contrast the relationship between MANET and VANET and explained why MANET protocols are not suitable for VANET. Furthermore, various VANET protocols were

reviewed highlighting weaknesses and lastly proposes a solution for the enhancement. A relative detail description of Connectivity Aware Routing, which is the base protocol of this research, is described towards the end the chapter.

Chapter 3 describes the research methodology used in this research. It discusses the approach used in conducting literature and how the research problem was formulated. It also describes how the research design and procedure was conducted. Towards the end, it explains the experimental simulation setup as well as the evaluation metrics used.

Chapter 4 provides details design description of the proposed ECAR protocol. It also presents the results obtained from simulating the original CAR protocol and the new ECAR protocol and provides comparison analysis of the two protocols in terms of the packet delivery ratio, packet lost ratio, average packet delay and the routing overhead.

Lastly, chapter 5 describes the achievement of this research and provides recommendations for future research.

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