EVOLUTIONARY ALGORITHM BASED NETWORK CODING FOR OPTMIZATION OF INTELLIGENT VEHICULAR AD HOC NETWORK

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Tarikh: 10 Julai 2017

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

30 September 2016

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CERTIFICATION

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ABSTRACT

This project aims to improve the throughput, energy consumption and overhead of vehicular ad hoc network (VANET) by optimising the network coding (NC) using Genetic Algorithm and Particle Swarm Optimisation (GA-PSO). VANET shows a promising technology as it could enhance the traffic efficiency and promote traffic safety on the road systems. The conventional store-and-forward transmission protocol used in the intermediate node(s) simply stores the received packet and then send at a later time to the destination. However, the rapid changing in VANET topology has made the conventional store-and-forward approach inefficient to meet the throughput and reliability demand posed by VANET. Hence, NC is proposed to perform additional functions on the packet in the source or intermediate node(s). The results showed that the NC used in wireless network outperforms the conventional store-and-forward in terms of throughput and energy consumption. However, the chances to perform NC in wireless network is highly unlikely if the packet is not transmit to the potential NC node. Therefore, GA based network routing (GANeR) is embedded into network to search for shortest path from the source to the destination, and PSO based coding aware routing (CAR) is also proposed to further converge the solutions obtained from GANeR. It showed that the developed GA-PSO in this work provides a better route with coding opportunities and reduces energy consumption in the network. The total energy consumed by GA-PSO is 7.39% fewer than the store-and-forward approach and 4.77% fewer than NC in wireless network transmission and forwarding structure (COPE).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACO	Ant Colony Optimisation
AI	Artificial Intelligence
AIFS	Arbitration Inter-Frame Space
ANCHOR	Active Network Coding High-throughput Optimising Routing
AODV	Ad Hoc on Demand Distance Vector
BE	Best Effort Traffic
BK	Background Traffic
CAR	Coding-aware Routing
CCH	Control Channel
COP	Combinatorial Optimization Problem
COPE	Wireless Network Transmission and Forwarding Structure
CORMEN	Coding-aware opportunistic Routing in Wireless Mesh Network
CRM	Coding-aware Routing Metric
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear-to-send
CW	Contention Window
DCAR	Distributed Coding-aware Routing
DDCDS	Dynamic Directional Connected Dominating Set
DiFCode	Distributed Fountain Network Coding
DSRC	Dedicated Short-Range Communication
EA	Evolutionary Algorithm
EBCD	Efficient Broadcasting using Network Coding and Directional Antennas
EC	Evolutionary Computation

ECX	Expected Number of Coded Transmissions
EDCA	Enhanced Distributed Channel Access
ETX	Expected Transmissions Count Metric
FCC	Federal Communications Commission
FIFO	First In and First Out
GA	Genetic Algorithm
GA-PSO	Genetic Algorithm and Particle Swarm Optimisation
GANeR	Genetic Algorithm based Network Routing
GPS	Global Positioning System
IEEE-SA	Institute of Electrical and Electronics Engineers Standards Association
IPv6	Internet Protocol Version 6
ITS	Intelligent Transportation System
LLC	Logical Link Control
LNC	Linear Network Coding
LPF	Linear Programming based Formulation
MAC	Medium Access Control
MANET	Mobile Ad Hoc Network
MOVE	Mobility Model Generator for Vehicular Network
MPR	Multi-Point Relay
NAV	Network Allocation Vector
NC	Network Coding
NCAR	Network Coding Aware Routing Protocol
NCP	Network Coding Problem
NeR	Network Routing
NJCAR	Network Joint Coding-aware Routing

OFDM	Orthogonal Frequency Division Modulation
OSI	Open System Interconnection
OSM	Open Street Map
PDP	Partial Dominant Pruning
PDU	Protocol Data Unit
PHY	Physical Layer
PSO	Particle Swarm Optimisation
QoS	Quality of Service
RERR	Route Error
RLNC	Random Linear Network Coding
ROCX	Routing with Opportunistically Coded Exchanges
RREP	Route Reply
RREQ	Route Request
RTS	Request-to-send
SCH	Service Channel
TIGER	Topologically Integrated Geographic Encoding and Referencing
TTL	Time to Live
VANET	Vehicular Ad Hoc Network
VI	Video Traffic
VO	Voice Traffic
V2V	Vehicle-to-vehicle
WAVE	Wireless Access in Vehicular Environment
WMN	Wireless Mesh Network
WSMP	Wireless Access in Vehicular Environment Short Message Protocol
WSM	Wireless Access in Vehicular Environment Short Message

WSN Wireless Sensor Network

XOR Exclusive Or

LIST OF SYMBOLS

α	Weighting factor of crossover
β	Free space path-loss exponent
CRM_l	Expected number of transmissions for successfully transmitting of existing and incoming packet for each new flow
CW_{max}	Maximum size of the contention window
CW_{min}	Minimum size of the contention window
c_1	Acceleration constant for cognitive learning factor
c_2	Acceleration constant for social learning factor
D_{sd}	Distance between the source and the destination node
ϵ_e	Energy consumed on radio circuitry
Ed	Euclidean distance to determine the distance between nodes
E_{Rx}	Energy used to receive n bits data from transmitter
E_{Tx}	Energy used to transmit n bits packet over a distance of d
Ev	Euclidean vector to calculate the angle between relay node and its destination node
g	Total bit of the segment node i
G_n	Number of gene
i	Number of nodes that are potential to become network coding node
j	Incoming flow of node i
k	Outgoing flow / current attempt to transmit the packet
l	Link
L	Path
m	Maximum size of the window
$MIQ_d(l)$	Dynamic queue length of a transmitter on l

n	Total number of received packets in destination or packet size
n_{max}	Total number of all the possible coding nodes in the network
n_{node}	Total number coding nodes present in chromosome
P_i	Previous best position
P_G	Global best position
P_l	Packet loss probability on l
R	Transmission range of a node
r_1, r_2	Random number distributed in the range of 0 to 1
$r_{i,j}$	probability of a successful two-way delivery between node i and node j
T	Total simulation time
T_d	Total time of a packet to travel from source to its destination
T_R	Throughput
v_i	Velocity of the ith particle
v_{max}	Maximum velocity
x_i	Position of the ith particle

CHAPTER 1

INTRODUCTION

1.1 Vehicular Ad Hoc Network

Over the last few years, an increasing trend in number of on-road vehicles has been observed. This trend has led to the increase of interest towards the use of computer and communication technologies in transportation system, especially when the roads are becoming saturated and driving has become not only challenging, but also dangerous. Thus, Intelligent Transportation System (ITS) has been introduced by the researchers as an effort to advance car technology towards a sustainable transportation system aimed at reducing the traffic congestion and accidents happened on the road.

ITS plays a vital role in providing different means of traffic management and enables users to be better informed of traffic condition, promoting safer, coordinated and efficient use of transport network. ITS can be beneficial to many as it could help to improve the transportation operating environment by expanding the capabilities of transport infrastructure and traffic information sharing services. Many countries and automobile manufacturers are actively developing ITS-related technologies such as autonomous cruise control, electronic toll collection, intelligent parking system and many more. These features are no longer limited to laboratories study and testing. One of the many examples of such services has been envisaged into vehicles like Mercedes Benz Class–S (Benzshops, 2016): It can detect if the car is straying from the lane and alerting the driver by vibrating the steering wheel, and if necessary, it can apply the brakes to bring the car safely back into its lane. Meanwhile, the Audi A8 is capable of responding autonomously to help avoid collisions with other vehicles and pedestrians (Autocar, 2016); park assist pilot that is featured in the Volvo XC90 offers automatic parking by using multiple sensors to make sure the car is properly positioned for parking (Volvo Car Group, 2014). Other than that, ITS can provide traveller and weather information to the driver, displaying local signage such as stop sign and school zone on the display unit in the car, providing other traffic management such as pothole management, ramp metering and signal timing optimization. Electronic payment system for parking, toll and gas collection is also another ease of access feature highlighted in ITS.

Successful deployment of ITS strongly depends on the wireless communication technology. ITS projects often target short-to-medium range wireless technology to establish communication between wireless infrastructures and mobile nodes. These establishments are important to disseminate the collected real-time traffic information in order to recuperate the efficiency and road safety in transportation system (Faye and Chaudet, 2016; Sommer and Dressler, 2015).

Different names have been adopted for wireless network according to their specific application, such as wireless sensor network (WSN), wireless mesh network (WMN) and mobile ad hoc network (MANET). These wireless networks are used as a part of the novel approach for ITS technology (Anaya *et al.*, 2015; Anisi and Abdullah, 2016; You *et al.*, 2016; Zelikman and Segal, 2015). Among these wireless networks, vehicular ad hoc network (VANET) has been gaining popularity and attention from both research and industry communities in recent years due to its inexpensive, flexibility, fault tolerance and ability to function in high mobility pattern and rapid changing topology. An ad hoc network can be defined as a representation of a network with minimal infrastructure or no infrastructure, which is formed by two nodes or more, with the capabilities to relay information and function as a network router, data source or data destination. VANET is a subclass of MANET and it uses vehicles as mobile nodes. It is a crucial fragment of ITS, which uses short-to-medium range wireless technology such as the Global Positioning System (GPS) and Dedicated Short-Range Communication (DSRC) or IEEE 802.11p radio for information interchange.

In VANET applications, vehicles on the road exchange their information with one another, either through fixed infrastructure units along the roadsides or with the roadside sensors as shown in Figure 1.1. The infrastructure plays as a coordination role in VANET by gathering relevant traffic information from the sensors planted on the roadside before distributing it to all the related nodes or vehicles, but it is infeasible considering the infrastructure cost involved.

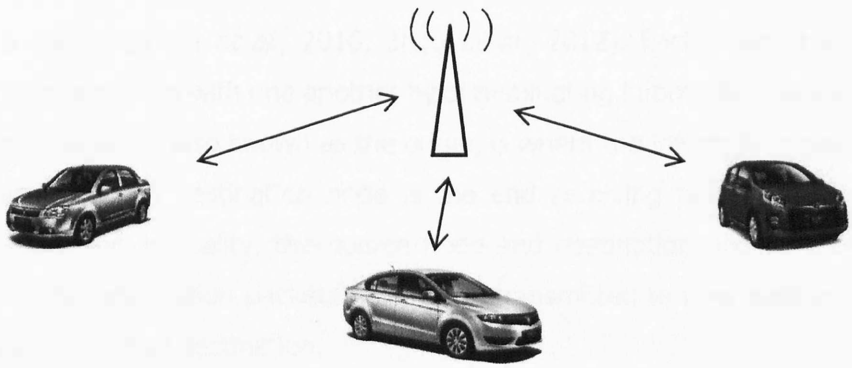

Figure 1.1: Single Hop Vehicular Network with Fixed Infrastructure.

Another architecture that is commonly used in VANET is the car-to-car communication. This approach allows the moving cars to participate or engage in communicating with one another, creating a wide range network. The advantage of this approach is that when any car falls out of the transmission range or drop out of the network, another car can come in and reform the connection in the network. The communication and distribution of information can also be either broadcasted or pick-up by any vehicle within the transmission range. However, a wireless link is required to provide a sufficient throughput, energy and reliability for each vehicle.

These vehicle-to-vehicle (V2V) communications network allows data transfer operations without the need of any network infrastructure as illustrated in Figure 1.2. It is based on the multihop ad hoc paradigm, where it could self-organizing and adapt dynamically to any atypical features of the vehicular field, without the need of pre-deployed infrastructure (Han *et al.*, 2008; Jiang *et al.*, 2015). A hybrid of these architectures enhances all the vehicles and roadside wireless devices capabilities to communicate with one another, either through single-hop or multi hop links and enable them to always remain connected to the world.

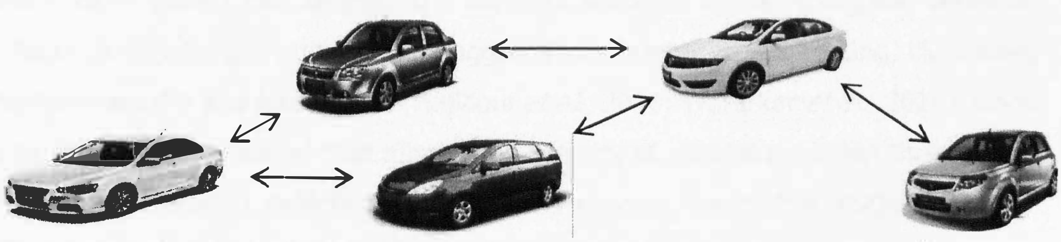

Figure 1.2: Baseless Station Vehicular Ad Hoc Network.