**URBAN ROAD NETWORK MACROSCOPIC FUNDAMENTAL DIAGRAM ANALYSIS UNDER VEHICULAR AD-HOC NETWORKS (VANETs) ENVIRONMENT**

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**ABSTRACT**

This research aims to analyze the urban road network macroscopic fundamental diagram under vehicular ad-hoc networks (VANETs) environment. The Macroscopic (Network) Fundamental Diagram (MFD or NFD), which relates network space-mean density and flow, has been shown to be existed in urban network with homogeneous traffic conditions. Although MFD represents the network performance and is an important indicator for traffic management, the practical application of the MFD is limited to the fact that the homogenous traffic condition is generally not observed in the real network. However, with wireless communication technology, vehicular ad-hoc networks (VANETs) provide such environment and therefore could be evaluated by MFD. VANETs are networks in which each node is a vehicle. The adjacent vehicles in VANETs are equipped with wireless communication devices. Under VANETs environment, the road network system provides communications not only between individual vehicles, but also between vehicles and nearby fixed equipment and roadside facilities. Therefore, the vehicles in VANETs environment receive real-time road information and thus, improve traveling safety and efficiency.

The primary object of this study is to explore whether a well-defined macroscopic fundamental diagram exists in urban road network under VANETs environment. To analysis the MFD under VANETs environment, a simulation test is conducted with gird road network in NS-3 simulation platform. The macroscopic fundamental diagram of the simulated network is presented in the study. The simulation results are compared between different wireless communication scenarios. The results show that the urban road network performs a MFD under VANETs environment. Meanwhile, wireless communications under VANETs environment has an impact on the shape of the MFD for the simulated road network.

Key Words: macroscopic fundamental diagram, VANETs environment, wireless communications.

INTORDUCATION
(Ongoing work)

The Macroscopic (Network) Fundamental Diagram (MFD or NFD), which relates network space-mean density and flow, has been shown to be existed in urban network with homogeneous traffic conditions. Although MFD represents the network performance and is an important indicator for traffic management, the practical application of the MFD is limited to the fact that the homogenous traffic condition is generally not observed in the real network. However, with wireless communication technology, vehicular ad-hoc networks (VANETs) provide such environment and therefore could be evaluated by MFD.

VANETs are networks in which each node is a vehicle. The adjacent vehicles in VANETs are equipped with wireless communication devices. Under VANETs environment, the road network system provides communications not only between individual vehicles, but also between vehicles and nearby fixed equipment and roadside facilities. Therefore, the vehicles in VANETs environment receive real-time road information and thus, improve traveling safety and efficiency. Due to the advantages of VANETs, it has received much attention from the automotive industry, government agencies and researchers.

The primary object of this study is to explore whether a well-defined macroscopic fundamental diagram exists in urban road network under VANETs environment. To analysis the MFD under VANETs environment, a simulation test is conducted with gird road network in NS-3 simulation platform. The macroscopic fundamental diagram of the simulated network is presented in the study. The simulation results are compared between different wireless communication scenarios.

## LITERATURE REVIEW
**(Ongoing work)**

## VANETs NETWORK AND VEHICLE WIRELESS COMMUNICAITONS
### Introduction to VANETs Network

Vehicular ad-hoc networks (VANETs) are networks in which each node is a vehicle. The adjacent vehicles in VANETs environment are equipped with wireless communication devices and therefore they are no longer isolated systems. Such systems aim to provide communications between (1) individual vehicles and between (2) vehicles and nearby fixed equipment, or roadside units. The goal of VANETs is to improve traffic safety and by traffic efficiency by providing timely information to drivers and concerned authorities.

### Wireless Communication Standards and Data in VANETs

The automotive industry is working to develop the dedicated short-range communication (DSRC) technology, for use in vehicle-to-vehicle and vehicle-to-roadside communication in VANETs. There are several standards which defines the wireless communication standards in VANETs environment. *The IEEE 802.11p amendment for wireless access in vehicular environments (WAVE)* defines the wireless communication band of DSRC in VANTEs. *The IEEE 1609.2, 1609.3, and 1609.4 standards* define the security, network services and multichannel operation standard in VANETs. *The SAE J2735 Message Set Dictionary* supports interoperability among DSRC applications through the use of standardized message sets, data frames and data elements.

## MACROSCOPIC FUNDAMENTAL DIAGRAM ANALYSIS UNDER VANETs ENVIRONMENT

### Simulation Study in NS-3 Simulation Platform

(Ongoing work): Proposed simulation test is conducted with the NS-3 network simulator platform. Vehicle mobility and network communication are integrated through events under NS-3 simulator. User-created event handlers can send network messages or alter vehicle mobility each time a network message is received and every time vehicle mobility  updated by the model.

*Test Network*

(Ongoing work): Propose simulation network is a grid network which consists of grids and links with same properties. This study employs NS-3 network simulator as a simulation platform.

*Simulation Setting*

(Ongoing work): Simulation will be conducted with the NS-3 network simulator. Different simulation scenarios will be tested during simulation. (1) Grid network simulation with communications between vehicles to vehicles (V2V) and vehicles to Infrastructure (V2I). (2) Grid network simulation with only communications between vehicles to vehicles (V2V).

### Macroscopic Fundamental Diagram Analysis in VANETs

*The Macroscopic Fundamental Diagram in Simulation Network*

(Ongoing work): The macroscopic fundamental diagram of the simulation network, which relates network flow and space-mean density, will be presented under VANETs environment according to the simulation results. The MFDs for different simulation scenarios will be compared and analyzed.

*Impacts of Wireless Communication in VANETs to MFD*

(Ongoing work): By comparing the MFDs for different simulation scenarios, the impacts of wireless communication in VANETs to MFD will be discussed.

## CONCULSION AND FUTURE WORK

(Ongoing work) The research investigates the urban road network macroscopic fundamental diagram under vehicular ad-hoc networks (VANETs) environment. The major contribution of this study is to show the existence of macroscopic fundamental diagram in urban road network under VANETs environment. To analysis the MFD under VANETs environment, a simulation test is conducted with gird road network in NS-3 simulation platform. The macroscopic fundamental diagram of the simulated network is presented in the study. By comparing simulation results between different wireless communication scenarios, research shows that wireless communications under VANETs environment has an impact on the shape of the MFD for the simulated road network.

Future research will investigate the macroscopic fundamental diagrams under VANTEs environment with field data and real urban network rather than grid network in simulation.

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(Ongoing work)

**REFERENCES**
(Ongoing work)