Chapter 1

Introduction

Exponential growth of vehicles on highways during recent years in India, and the immense number of fatal accidents have allowed the researchers for the development of new generation technologies to help the drivers travel more safely on highways. One major cause of traffic accidents is that drivers cannot consistently and appropriately respond to the changing Mumbai-Pune Express Highway Road conditions. In fact, most of the accidents can be avoided if drivers could obtain relevant information of traffic that which is beyond their vision, using vehicular communication technology.

Rapid increase and advancement of wireless technologies create new avenues to utilize these technologies in support of vehicular safety applications. The new Dedicated Short Range Communication (DSRC) or IEEE 802.11p protocol, enables a newer class of vehicular safety applications which will increase the overall safety on Mumbai-Pune Express Highway Road, reliability, and efficiency of current transportation system. Vehicular Ad-hoc Networks (VANET), which is a part of Intelligent Transportation Systems (ITS), will provide a wide spectrum of applications to avoid highway accident.

1.1 Overview

Vehicular Ad-hoc Networks (VANET), a part of Intelligent Transportation Systems (ITS) is referred to as the integrated applications of the advanced technologies in Information Technology, communications logic controls and sensor networks provide travelers and authorities important information they need to make the transportation system more safe, efficient, effective and reliable. Since the advent of Vehicular Ad-
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Vehicular Ad-hoc Networks, lots of research work for real-time transportation system management, has been conducted. Recent advances in wireless and sensor technologies rapidly promote the seamless integration of various types of information from transportation networks, to benefit drivers and provide a wide array of transportation-oriented services. Vehicle-to-Vehicle and Vehicle-to-Infrastructure communications will be important practically in the near future resulting in an operational Internet on the highways called vehicular ad-hoc networks (VANET) that will revolutionize our concept of travelling.

As reported in Times of India (TOI) (Times) (WHO) Jan-2014 newspaper, more than 81.5% people died on Mumbai-Pune expressway accidents accounted due to human error. In a highway scenario due to speed, drivers slow reaction time can often lead to catastrophic multi-vehicle pile ups. Most of the traffic accidents can be preventable if an vehicular ad-hoc networks (VANET) system is installed to inform the driver instantly about the obstacles ahead.

Accidents, delays and traffic congestion causes significant loss of lives, waste of energy, increased carbon dioxide gas emissions and loss in productivity. Solving these issues by building wider highway and flyovers is costly, time consuming and impossible in some congested areas. Therefore, applying the latest wireless technologies to the current infrastructure will help in improving its safety, reliability, efficiency and security.

The Vehicular Ad-hoc Networks System is composed of the following major parts:

a. Vehicles: Automobile industry is giving more attention to the safety of their vehicles by equipping them with complex sensor arrays to continuously gather information. They, pay attention to many aspects as air bags, tyre pressure, mechanical and electronic parts, speed, breaking condition, steering condition, distance detection and collision events. This gathered information will help the driver and the vehicle to avoid serious accidents by taking the appropriate action or by initiating built in control system to bring the vehicle to a safe mode. It is crucial to forward this information to neighboring vehicles to quickly respond in time.

b. Infrastructure: Many highway in India are equipped with signs, with messages
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to alert the drivers on road conditions. Based on the advertised messages, the drivers may take actions like slowing the speed or changing lanes. Sensors or cameras installed on roads, measure the traffic movement and the number of vehicles passing from one point. Thus, help in making plans for better traffic flow.

c. Control Systems: Systems are deployed to take appropriate action automatically, when an error, such as forgetting to turn on the headlight at night, that is potentially dangerous on highway. The actions taken by the system may ranging from turning on the headlight, to activating the braking system.

d. Communication System: This is the most important aspect of VANET system, since without communicating essential information with proper recipients, the VANET system will not achieve its goal, of providing safety and comfort to passengers. Highway safety has attracted more attention, such as active accident warning, icy patch alarm, and others. Whether a successive collision can be effectively avoided mainly depends on transmitting warning information reliably and efficiently on multi-paths. Vehicles can form a mobile ad-hoc network on the highway to pass this essential information to each other. If the driver becomes aware of the emergency braking of the preceding vehicle, in time, he can slow down enough to avoid an accident.

The vehicular communication system is classified as follows:

(1) Intra-Vehicle Communication System: This system is adapted inside the vehicle itself. It can be a wired or wireless communication system like Bluetooth (IEEE 802.15.1)[Gla], Ultra Wide-band (UWB) (IEEE 802.15.3)[Three] or ZigBee (IEEE 802.15.4)[Four]. To reduce the amount of wiring complexity usually used in vehicles and to offer more mobility.

(2) Vehicle-to-Vehicle Communication System (V2V): It is a major part of the VANET architecture, since it enables the drivers to communicate with other drivers or vehicles even if they are out of range of Line Of Sight (LOS). Ad-hoc mode is the most appropriate model that suits (V2V) (where vehicles communicate with each other without a centralized ser-
vice), due to high mobility of vehicles and the changing relative speeds between vehicles. This will add more challenges to the wireless communication system compared to the indoor Wireless Local Area Networks (WLAN) or Mobile Ad-hoc Networks (MANETs).

(3) Vehicle-to-Infrastructure Communication System (V2I) : This type of communication is between roadside unit and vehicles to provide services to drivers and passengers, like high-speed Internet or traffic information. These units are placed along the highway road to maintain the high data rates and facilitate the hand-off from one zone to another.

The VANET system will enable new mobile services and applications for the traveling public. The integration of sensor networks and computers inside the vehicle itself with the Global Positioning Systems (GPS), digital road maps and the wireless communication technologies will open the door widely to many safety and non safety applications. The Vehicle Safety Communication (VSC) project (Transportation) determined 34 possible safety applications for VANET.

These applications can be categorized as follows:

- Safety applications: Protect lives and properties by warning drivers of related traffic hazards, as shown in Figure 1.1, traffic jams, halted vehicle, lane closure and rail crossings. These applications can also include left-turn and stop sign movement assistance, blind spot warning, traffic signal violation warning, curve speed warning, emergency break light warning and lane change warning.

- Traffic management applications: Authorities help in managing the traffic such as control signals to reduce traffic jam, fleet management and cargo tracking systems.

- Infotainment applications: Enhance the drivers by providing Internet connection and instant messaging system between vehicles. They also include vehicle rental help, drive through and petrol/LPG payment, toll collection and enhance route guidance.

Several projects were initiated to address VANET’s challenges around the world. Fleet-Net is one of the pioneer European projects (B) to standardize VANET so-
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Network on Wheels (NoW) and CarTALK2000 are other European projects for the development of vehicular communication and co-operative driver assistance systems. Car-to-Car Communication Consortium (C2C-CC) is an organizational umbrella for VANET research activities in Europe. It includes many automobile industry members like Daimler, BMW, Audi, Fiat, Renault and some German Universities. The overall objective of C2C-CC is to initiate, develop and oversee vehicle-to-vehicle communication standards, business models and regulatory matters in the European Union.

In US, the Vehicle Infrastructure Integration (VII) Initiative is a cooperative effort between US government and automobile manufacturers. Its goal is to let vehicles communicate between them and with road side units, in order to increase the safety, efficiency, and convenience of the transportation system. Their solutions based on the IEEE 802.11p, rely on a business model to satisfy the interest of all participating parties. Its safety solutions rely on radar, vision systems to reduce rear-end collisions by tracking obstructions in front or behind the vehicle and apply brakes automatically when needed.

The development of Vehicle-to-Vehicle and Vehicle-to-Infrastructure mobile mesh and ad-hoc networks, is one of the most challenging and critical issues for the VANET research and automobile industry. The characteristics of VANET are different from those of Mobile Ad-hoc Networks (MANETs). Vehicles move with high speed, highly
changing topology. This results in shorter communication links between vehicles and unpredictable node density. Since VANET’s effective network diameter is small, their redundancy is limited. So, it is unrealistic for a node to maintain a complete global network topology. This adds more challenge to apply the existing routing and MAC algorithms in MANETs, to VANET. Due to high mobility of vehicles, it is difficult to maintain any form of group membership or establish an accurate list of neighboring vehicles. Hence, it is difficult to implement protocols that rely on group membership such as clustering or flat routing. Another challenge in VANET is its security. Driver’s anonymity and privacy must be preserved; hence vehicle movement is not recorded and VANET messages are not tampered. Tampering of safety messages could result in traffic accidents, which VANET are designed to prevent. Contrary to MANETs, VANET do not move in random directions and have no constraints on storage capacity, battery and processing power. A good characteristic of VANET that help in building a new stable protocol, is the future movement of a vehicle is predictable, since it is constrained by the highway road.

1.2 Problem Statement

The main objective of this research work is to design a new Broadcasting protocol for Vehicular Ad-hoc Networks (VANET). The challenges and limitations of the existing protocols in vehicular environments must be explored first in order to achieve this objective. Secondly, issues towards the design of the new broadcasting protocol must be identified by using theoretical foundations and algorithmic methodologies.

The key contributions of this dissertation are summarized as follows:

- To develop a simulation and analysis setup for IEEE 802.11p protocol using test bench development is a difficult and costly proposition. Therefore, simulations are used to study and analyze VANET.
  - Study of different mobility and network simulators is performed to select an appropriate simulator, in order to solve the real-time vehicle-to-vehicle communication on highway road.
  - Wireless channel in VANET and its different radio propagation models are analysed to find the most appropriate model that best characterises in
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vehicular environment.

- Analysis of physical wireless channel and the best propagation model will derive a formula for the probability density function (pdf) of the communication range that will be used in our subsequent analysis.

- The different routing protocols in VANET are studied and their performance on highway is analysed.

- A new mobility model is developed that takes into account the vehicles that follow the safety rules. This will accurately capture the relationship between the vehicle’s speed and network density.

- A new Broadcast Protocol for vehicular ad-hoc networks is developed for the vehicle-to-vehicle communication on highways.

- A new broadcast algorithm to alleviate the impact of broadcast storm problem in VANET is introduced, taking into consideration the network topology and traffic parameters. This will also reduce the effect of the hidden terminal problem.

- An analytical model is developed to evaluate the performance of the IEEE 802.11p PHY and MAC protocol in single-hop (broadcast mode) and multi-hop scenarios.

  - An analytical framework is proposed that models the reliability of the Dedicated Short Range Communication (DSRC) control channel to handle VANET safety applications.

  - Using analytical model, an adaptive algorithm is presented in order to increase the DSRC systems reliability in terms of the probability of packets for successful reception and time delay of emergency messages, in a harsh vehicular environment.

The performance of the proposed protocol is evaluated through extensive simulations using the SUMO and Network Simulator (NS2 version 2.34) (DNS). Some of the existing MAC protocols are developed for the sake of comparison. Hence, the evaluation result shows that the proposed protocol and algorithms can support traffic safety and increase VANET efficiency and reliability.
1.3 Dissertation Outline

Dissertation is organized as follows:

- Chapter 2, presents the literature study.
- Chapter 3, investigates the physical wireless channel of the DSRC.
- Chapter 4, the performance of different routing protocols on highways/roads is analysed.
- Chapter 5, a new mobility model is proposed.
- Chapter 6, a new broadcast protocol is proposed to alleviate the broadcast storm problem and hidden terminal problem in VANET.
- Chapter 7, performance of V2V Communication is evaluated using IEEE 802.11p and STDMA.
- Chapter 8, performance of IEEE 802.11p is analysed.
- Chapter 9, Conclusion and future scope of research work.