Smart Collision Avoidance and Hazard Routing Mechanism for Intelligent Transport Network

Gurpreet Singh¹, Pooja Gupta¹, Mohd Helmy Abd Wahab²

¹Faculty of Computer Science and Engineering, Lovely Professional University, Punjab, India.
²Embedded Computing System Research Group, Faculty of Electrical and Electronic Engineering, UniversitiTun Hussein Onn Malaysia, P.O. Box 101, Pt. Raja, Batu Pahat, Johor, Malaysia

Corresponding author: gurpreet.17671@lpu.co.in, pooja.19580@lpu.co.in, helmy@uthm.edu.my

Abstract—The smart vehicular ad-hoc network is the network that consists of vehicles for smooth movement and better management of the vehicular connectivity across the given network. This research paper aims to propose a set of solution for the VANETs consisting of the automatic driven vehicles, also called as the autonomous car. Such vehicular networks are always prone to collision due to the natural or un-natural reasons which must be solved before the large-scale deployment of the autonomous transport systems. The newly designed intelligent transport movement control mechanism is based upon the intelligent data propagation along with the vehicle collision and traffic jam prevention schema [8], which may help the future designs of smart cities to become more robust and less error-prone. In the proposed model, the focus is on designing a new dynamic and robust hazard routing protocol for intelligent vehicular networks for improvement of the overall performance in various aspects. It is expected to improve the overall transmission delay as well as the number of collisions or adversaries across the vehicular network zone.

1. Introduction

The vehicular ad-hoc networks (VANETs) are evolved as a smart technology in order to exchange the data between the vehicular nodes across the urban roads. The vehicular networks are usually known for communication via Wi-Fi, Wi-Max or cellular networks which have the communication range between 100 metres to few kilometres for the establishment of the intelligent transportation networks [10]. The moving vehicles are meant to join or leave the network cells (controlled by the road side units or RSUs, denoted hexagonal) during their journey under the intelligent vehicular networks. The vehicle integration in the intelligent transportation networks facilitates the smart management of the traffic, collision detection, prediction and prevention policies, malicious or anomaly detection in the given vehicular network and security establishment like authentication.
The smart management of the vehicular networks (known as the intelligent transportation networks) has become very important for the convergence of the networks with changing position of the nodes. The vehicles are connected using the RSU (Roadside Units) centred cells, where they need to leave and join the new cells in order to stay connected during their journey, which is an automated process. The primary advantage of the vehicular networks relies on their efficient management. The Google Maps utility is capable of telling us the current situation of the traffic on the roads across the globe, which is helpful for the drivers to select the low congestion paths in order to reach their destination [12].

The intelligent vehicular networks can give major control over the moving vehicles, which can help the policy makers to prevent traffic jams and collisions across the smart cities.

1. Smart City

Smart cities are the cities that are capable of smart information management and exchange across the buildings, people, vehicles and others in order to manage various types of communication.[13] The information exchange is very important in order to update the public about any disaster, transportation or other issues. The concept of smart cities is realized with the efficient implementation of the internet of things (IoT), which can be utilized for the smart home management, smart transportation, disaster management, sustainability (power consumption), etc. The Internet of things consists of various small nodes for the inter-connectivity of different kinds of devices. It creates a network of system where data is propagated and collected through various domains. The concept of smart cities can be further broken down into small segments on the basis of the differentiation and demarcation of the smart applications. In order to simplify the process of the implementation and establishment of the infrastructure the following steps give the segmental reference to the various modules of the smart cities:

- Smart Disaster Management Service (SDMS)
- Smart Transportation Systems (STS)
- Smart Healthcare Networks (SMN)
- Smart Environment Control (SEC)

1.1. Smart Disaster Management Service (SDMS) is the module of the smart city implementation, which is associated with the exchange of the data among the residents during the occurrence of any disaster like Hurricane, Tsunami, Storm, Flood, Earthquake, etc. The exchange of effective and accurate information can save the lives of the millions residents across the world in the case of disasters [5].

1.1. Smart Transportation Systems (STS) is the module of the smart city networks, which is associated with the intelligent management of traffic of the city. The traffic management requires number of computations and variety of information for the realization of the intelligent transport networks [7][9].

1.1. Smart Healthcare Networks (SMN) is the module in the smart city environments, which is primarily associated with the exchange of the healthcare data among the residents in order to manage the emergency service. The healthcare sensors are deployed by the patients for regular monitoring of diabetes, heart, brain and other activities, which make it easy to monitor and predict the health of the residents.[11][15].

1.1. Smart Environment Control (SEC) is the module of the smart city environments for the control and prevention of the high level pollution by regularly monitoring and predicting the increasing level of pollutants in the environment. The smart environment control networks are deployed by using the air quality evaluation sensors all over the smart city for the realization of the pollution monitoring and control module in the smart cities.[14].

2. Related Work
Stefansson, Gunnar et. al.[1] has worked towards the evaluation of the performance issues related to the intelligent vehicular networks. In this paper, the authors have studied the fact of the concept of STM (known as smart transportation management systems), where they have primarily focused on the study of the various factors of the realization and efficient management of the vehicular networks in the smart city environments. The authors have included all types of data in the study of the STM system in the given environment, where the primary focuses of the study remained at the data acquisition and analysis from the carriers, software manufacturers, truck manufacturers, etc.

Sen, Rijurekha et. al.[2] has studied the primary problems in the vehicular networks in the Indian vehicular environment. In this paper the author has discussed about the intelligent transportation systems (ITS), where they have mentioned various aspects of the implementation and realization of the intelligent transportation network in the smart cities. The authors have discussed various problems and issues related to the ITS applications and have presented meaningful interpretation of the problems in real-time. The major focus of the authors has been remained at the scenarios of traffic across various Indian cities, where they have given efficient and effective study of the Indian traffic scenarios.

Borgia, Eleonora et. al.[3] has worked on the study of the unique issues of the IoT (or internet of things) for the purpose of the research and development in the specific area of intelligent transportation systems. In this paper, the authors have discussed various aspects of the internet of things in different environments. The authors have primarily worked on the study of data monitoring and sensing cloud using the IoT, mobile to mobile communications and their applications, process management such as request processing, problem ticket resolution, etc. Furthermore, the authors have focused on the applications of the internet of things (IoT) in environments with the changing requirements. In addition to that, the authors have also discussed the programming models and their detailed evolution in the form of easily understandable preamble of the historical events for IoT environments.

Conti, Marco et. al.[4] has presented the study of the MANETs for the public-centric application, their current standards, progress and related challenges in the research on the specific research domains related to the intelligent network systems. The author has focused on the MANET as the primary objective of their study, where work has been done on a variety of applications. The authors have studied the wireless mesh networks, vehicular ad-hoc networks, wireless sensor networks and/or sensor clouds, personal networks, etc under their study to understand the in-depth topics related to the latter MANET formations. They have represented the new and innovative directions for the new research on the MANETs for the progress in various applications in the routine life.

Borgia, Eleonora et. al.[5] has enlisted important issues related to the internet of things in the recent years. The author has studied smart objects and networks for the implementation of the intelligent applications in the various domains across the smart cities. The smart IoT networks are deployed to gather information, process information and to extract the important aspects in order to use these networks for various applications in real-time for the facility of the residents.

Zhou, MengChuet. al.[6] has worked towards the advanced level applications of the IoT in the industrial zones in order to understand the versatility and primary issues of the applications. The author has studied about the inter-connectible abilities of the people, things and networks altogether in order to realize the smart data applications in real-time environments. The author further stated about information sensing(using sensors) is being used to gain the valuable information from the data to understand the regular patterns and adversaries.

3. Problem Formulation

The existing techniques are designed for the prevention of natural hazards, such as tree falling, water breakout, avalanche and other natural adversaries on the roads, which may cause massive jams and put the public life in danger. The proposed model was designed to handle over the maximum issues altogether that are related to the smart and intelligent transport networks using a thoroughly designed mechanism. The proposed model was equipped with the robust road side unit (RSU) networks and smart transport system centre (where data analysis was done) connected in the network. The advanced hazard routing concepts were utilized for the realization of the smart vehicular network zone to handle the traffic complexities using some of the intelligent algorithms, which might have computed all of the effective and
accurate preventions or avoidance possibilities in minimum possible time in order to control the situations in the earliest possible stages. Hence, there was a strong requirement of the hazard prediction method, which predicted the adversaries such as accidents or traffic jams by continuously calculating the vehicular activities across the roads in the given zone. Overall, the proposed model would offer a complete solution to the cumulative traffic problems in the given vehicular zone.

In order to prevent collisions in the smart VANETs, the location aware fixed nodes were used in our proposed method. Location aware fixed nodes would be aware of their coverage areas in the perspective of the GPS coordinates. The direction of the movement of the vehicles with their velocity and location was evaluated with the positions of the other nodes and the movement emulation was performed at the fixed node. The movement emulation predicted the future position of the nodes and compare it with the future location of the other nodes. If any of the collision or congestion occurrences are predicted in the future, the other nodes will be informed regarding this and new path can be decided. See Figure 1.

Figure 1. Working Diagram of smart traffic system

4. Methodology
Aggregation decision made by the Roadside unit depends on the data classification. Normal data, also referred to as non-urgent data is aggregated as it donot not require quick response from the one traffic zone, so it could be offloaded with a minimum delay in the intelligent transport network. Advanced hazard routing model allow the RSUs to club the normal data into a single packet, whereas the critical or super critical updates containing the node failure or other such things, also referred to as urgent data required on the spot prevention to avoid any serious consequences. So the urgent data must be broadcasted after the quick response prediction as soon as it is received without a minimum queuing delay. The proposed advanced hazard routing model presented two scenarios for offloading intelligent transport data to the vehicular mainframe for the further computations. See Figure 2.

5. Mathematical Model
The use of the trigonometric equations becomes mandatory in order to understand the vehicular movement across the given cluster that requires the inclusion of important equations. The $X_p$ and $Y_p$ are the coordinates of RSU and $X_c$ and $Y_c$ are the coordinates of nodes that are moving and Dist is the distance.
Vehicular node joined the highway traffic

It searched for nearest RSU neighbour

If RSU neighbour found

Yes

No

Joined the RSU cluster

If RSU had the node information from its neighbour RSU nodes

Yes

No

Node became member and RSU sent the periodic updates to the vehicle nodes

If a member node failed

RSU sent periodic updates about the hazards on the way

RSU sent unicast queries to the failure node

If node replied

Yes

No

Node rejoined the RSU cluster

RSU sent hazard update on the last location of the failed node

When vehicle nodes came in range of an RSU

RSU propagated all the Unicast messages in the update trigger

If vehicle node was connected with RSU

Yes

No

Forwarded a query to the vehicular node to get its RSU cluster

If RSU neighbour vehicle node found

Yes

No

Figure 2. Workflow diagram
Based on that, the following sets of equations are utilized to draw the transmission distance for the assessment of the neighbouring nodes in the given cluster.

\[
\text{Dist} = (X_p - X_c)^2 + (Y_p - Y_c)^2 \quad (1)
\]

a. \(\text{Dist} < r^2\)  \quad (2)

If the given equation (2) is satisfied, then the vehicular node is considered in the transmission reach.

b. \(\text{Dist} == r^2\) \quad (3)

If the given equation (3) is satisfied, then the vehicular node is not considered in the transmission reach.

c. \(\text{Dist} > r^2\)  \quad (4)

If the given equation (4) is satisfied, then the vehicular node is considered on the edge or boundary of the transmission reach.

The data table for the neighbouring nodes is handled using the following set of the equation in the given vehicular cell:

\[
d. N_s = \int_{n=1}^{N} (d') \leq 250 \quad (5)
\]

In (5), all of the vehicular nodes\((N_s)\) within the transmission range are added to the neighbouring table, which is updated with the occurrence of each convergence event in the given vehicular network segment.

e. If \(N_i(1,2,3\ldots,N)\) is RSU
   Then, connect \(N_i\) nodes to \(N_s\) nodes. \quad (6) (7)

In (6), the nodes\((N_i)\) are assigned the membership with the zonal RSU node, which is also considered as the base station of the particular zone. The RSU would register all of the nodes within its channel capacity in order to provide the communication across the given vehicular cluster.

All of the nodes within the RSU zone or cell are connected with each other in order to create the full mesh network, where each vehicular node was inter-connected with all other nodes within the vehicular cluster, which was either defined in its transmission range or out of transmission range but within the similar RSU cell. The nodes in the direct transmission reach are connected in the vehicle to vehicle and vehicle to RSU infrastructure, whereas the nodes out of the transmission reach were inter-connected using the vehicle to RSU infrastructure option only.

6. Conclusion

In this paper, a new model is primarily designed for the realization of the smart and intelligent transport networks with collision detection & avoidance along with the hazard routing for the robust path planning across the given region. The efficient data management among the intelligent vehicular networks also requires the inclusion of the vehicular data prioritization in order to efficiently transmit & exchange the data among the vehicular nodes in the given cluster. The proposed model is also projected to provide damage avoidance using the smart vehicular movement tracking model for the detection and avoidance of the collision, which might be caused by the computational error.

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