Information Collection Algorithm for Vehicular ad-hoc networks

(Application domain: Urban Traffic Wireless Vehicular Ad-Hoc Networks (VANETs))

A DISSERTATION

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In memory of my dear FAMILY

Abstract:

Vehicle to vehicle communication (V2VC) is one of the modern approaches for exchanging and generating traffic information with (yet to be realized) potential to improve road safety, driving comfort and traffic control. In this research, we present a novel algorithm which is based on V2V communication, uses in-vehicle sensor information and in collaboration with the other vehicles' sensor information can detect road conditions and determine the geographical area where this road condition exists – e.g. geographical area where there is traffic density, unusual traffic behaviour, a range of weather conditions (raining), etc. The algorithms' built-in automatic geographical restriction of the data collection, aggregation and dissemination mechanisms allows warning messages to be received by any car, not necessarily sharing the identified road condition, which may then be used to identify the optimum route taken by the vehicle e.g. avoid bottlenecks or dangerous areas including accidents or congestions on their current routes.

This research covers the middle ground between MANET [1] and collaborative data generation based on knowledge granularity (aggregation). It investigates the possibility of designing, implementing and modelling of the functionality of an algorithm (as part of the design of an intelligent node in an Intelligent Transportation System - ITS) that ensures active participation in the formation, routing and general network support of MANETs and also helps in-car traffic information and real-time control generation and distribution.

The work is natural extension of the efforts of several large EU projects like DRIVE [2], GST [3] and SAFESPOT [4]. The main difference between this research work and the research efforts outlined in these projects and related work is that they focus on V2I (Vehicle to Infrastructure) algorithms and node design, while all work related to ad-hoc wireless communication is mentioned, but not developed fully. In that respect this specific research domain is increasingly under active research consideration – utilizing ad-hoc networks algorithms for creating ad-hoc based wireless architectures and algorithms for building future intelligent information systems.

The research challenge is to design, implement and investigate novel algorithms as part of an intelligent wireless information systems node design so that the functionality of the node has all the characteristics of the network node in parallel with all the characteristics of in-car data processing device. The project redefines the base line connectivity of the device and describes to what extend the functionality of the node will depend on external factors: e.g. connectivity based on the underlying wireless technology, support of the ad-hoc networks based on the speed and the type of mobility of the mobile node etc. The big difference between MANET as described so-far in the literature and the one which will be underlined by the functionality of the intelligent node described in this project is in the functionality of the active component of the MANET described here. The MANET designed in the project will be able to more effectively generate data (not network data – but user traffic data) and also will be able to take part in the on street control of the traffic lights.

Although much research work worldwide is dedicated to the subject, the fact is that there are none implemented on the road traffic information systems based on ad-hoc networking, which shows that the principles of building such effective networks are yet to be discovered.

The achievements of this research include introducing a novel algorithm based on the “Single Ripple” algorithm approach [5], investigating and reporting in papers the parameters transmission delay and number of hops for optimum working mode of the algorithm. The work includes also developing a simulation tool and tool for analyses of the data.

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First, I would like to thank my advisor, *Dr. Evitm Peytchev*, for giving me the great chance to make a PhD under his guidance and for making it such an enriching experience. I am deeply grateful to him for his availability and help, not only in research, but also in all other aspects of the PhD. I am also very grateful to him for taking so much care of his student's personal career and promoting their results.

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List of Publications

Published papers in Conferences and presentations:

1. Emadeddin Gamati, Evtim Peytchev, Richard Germon, "*Traffic Condition Detection Algorithm for VANET Nodes in Wireless Intelligent Transportation Information Systems*", Proceeding of the 25th European Conference for Modelling and Simulation, June 2011, Krakow, Poland.

2. Emadeddin Gamati, Evtim Peytchev, Richard Germon, Yueyue Li, "*Utilization of Broadcast Methods for detection of the road conditions in VANET*", Proceeding of the 26th European Conference for Modelling and Simulation, June 2012, Koblenz, Germany.

3. Emadeddin Gamati, Evtim Peytchev, "*Sensing Traffic Conditions in VANET for Building new generation in Wireless Intelligent Transportation Information Systems*", Proceeding of the optimisation of mobile communications networks, June 2012, Southampton, United Kingdom.

4. Emadeddin Gamati, Evtim Peytchev, Richard Germon, "*Collaborative Data Dissemination Methods in VANET for Identifying Road Conditions Zone boundaries*", Proceeding of the 27th European Conference for Modelling and Simulation, June 2013, Alesund, Norway.

Published posters and presentations:

- Nottingham Trent University, School Research Conference (11th and 12th May 2010), Clifton Campus, Nottingham, United Kingdom.
- University of Nottingham, School Research Conference (May 2011), Electronic School, Main Campus, Nottingham, United Kingdom.
- The Second Saudi International Electronics, Communications and Photonics Conference, 27-30 April 2013, King Abdulaziz City for Science and Technology (KACST), The National Electronics, Communications and Photonics Research Centre, Riyadh, Saudi Arabia. (www.kacst.edu.sa). (formal presentation and poster).

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GLOSSARY

ABS	Anti-lock Braking System
Ad-Hoc	Latin; "for this purpose", decentralized wireless network.
CALM	Continuous Air interface for Long and Medium distance
CVIS	Cooperative Vehicle- Infrastructure Systems
GPS	Global Positioning System
HSPA	High Speed Packet Access
Intelligent flooding	Algorithm for discovering areas by as few messages as possible.
MAC	Media Access Control address uniquely identifies most network equipment.
NS2	Network Simulator, based on C++, through Otcl.
DSDV	Destination Sequence Distance Vector Routing Protocol
OLSR	Optimized Link State Routing protocol
AODV	Ad-Hoc On-Demand Distance Vector
Otcl	Object-oriented Tool Command Language
DSR	Dynamic Source Routing protocol
DTN	Delay Tolerant Network protocol
HCBS	Hop Counter Based Scheme (Data Dissemination).
DBS	Distance Based Scheme (Data Dissemination).
LBS	Location Based Scheme (Data Dissemination).
POI	Point of Interest.
Pure flooding	Algorithm that sends any new message to any receiver within reach.
TCP	Transmission Control Protocol.
UDP	User Datagram Protocol.
UMTS	Universal Mobile Telecommunications System.
VANET	Vehicular Ad-Hoc Network.
VIN	Vehicle Identification Number uniquely identifies any vehicle.
WiMAX	WiMAX, meaning Worldwide Interoperability for Microwave Access
WLAN	Wireless local area network

CHAPTER 1

INTRODUCTION

Chapter outline:

- Vehicular Networks.
- Motivation.
- Objectives.
- Methodology.
- Main Contributions.
- Thesis Organization.

Chapter 1

1 Introduction

1.1 Introduction to Vehicular Networks

The research community and the automotive industry is investing its efforts in the inter-vehicular communication (IVC), where it plays an important role in the provision of the intelligent transportation system (ITS) [6]. A novel class of wireless networks is emerging in the form of vehicular ad hoc networks (VANETs), which are spontaneously created between the moving vehicles equipped with the wireless interfaces. A short-to-medium range communication systems could be employed by various radio interface technologies to implement such networks. Communication is provided between the nearby vehicles and between the vehicles and the fixed roadside equipment through VANET, which acts as a form of mobile ad hoc network.

1.1.1 What Are Vehicular Networks?

The advancements in the wireless technologies and the automotive industry have led to the development of the vehicular networks that have emerged as a new type of a wireless network. Moving vehicles have these vehicular networks created between them spontaneously. Homogeneous or heterogeneous technologies may be found among the wireless networks in these vehicles. Communication with the nearby vehicles and with the roadside equipment is available through the ad hoc network real life application of VANET. These vehicles could be privately or publicly owned or owned by companies. Private network operators or service providers can be the owners of the fixed equipment.

Diverse communication services to drivers and passengers are possible through these vehicular networks thus the great interest of the research community and automotive industry in conducting research in such networks. Governmental authorities and standardization organizations are also showing a keen interest. The U.S FCC has approved a 75 MHz spectrum for the short-range communication DSCR system [7] in North America in 2003. This was specifically approved for vehicular networks. Car manufacturers and automotive OEMs have completed the car-to-car communication consortium (C2C-CC) [8] in Europe, with the main objective of enhancing the efficiency of IVC and road safety. The IEEE 1609 family of standards has been completed by the IEEE for the wireless access in the vehicular environments (WAVE) [9].

1.1.2 Possible Deployment Scenarios for Vehicular Networks

Two main types of communication environments are possible for the vehicular networks, keeping in mind the developments in the heterogeneous communication technologies combined with the C2C-CC reference architecture. The car-to-car communication scenario and car-to-infrastructure communication scenario are the two types.

Various deployment options are provided by these types of communication environments [12]. Alongside the roads, the vehicular network deployment can be integrated into the wireless hot spot. A wireless or an integrated service provider can operate these hotspots individually at home or at offices. Two existing cellular networks can also use the vehicular network deployment. There is no need for a communication network for the vehicles to communicate with other vehicles directly, as the vehicles can coordinate with each other and forwards data on behalf of each other. A possibility to combine these deployments was also realized.

Vehicles are considered as active nodes by the future architecture for an intelligent transportation system (ITS), which can collect and forward critical information. Intelligent sensors can be used by the vehicles to collect and process data, as the vehicular network will coexist with the sensor networks [13] . This will allow a creation of a global communication system that will allow the vehicles to exchange data with other nodes as well.

1.1.3 Vehicular Network Potential Applications and Services:

A wide range of the cooperating technologies are utilized by the various vehicular network applications [16] that range from road safety applications oriented to the vehicle or to the driver, to the entertainment and commercial applications for passengers.

Real time and safety applications for the drivers and passengers are the primary objective of the vehicular networks. Traffic conditions can be improved and accidents can be minimized by these applications as useful data is provided to the drivers and the passengers such as, roadside alarms, in-place traffic view and collision warnings.

There are various benefits offered by the vehicular networks in the driver and passenger related services [17][18]. The various services may include; electronic tolling system, on demand fashion, multimedia services, etc. New services can be designed for the passengers in addition to the safety applications by exploiting other communication networks [19], such as, 2-3G, WLANs IEEE 802.11a/b/g/p, and WiMAX. Services can include entertainment applications, infomobility, etc. These can conveniently rely on the vehicular network also.

Car manufacturers, automotive OEMs, network operators, service providers, and integrated operators are presented with new opportunities with respect to the potential of application of the vehicular networks. Commercialization, provision of infrastructure and provision of various services can be done. The network operator can act as the trustworthy third party by assuring the authentication of each participant related to the safety related applications. The network operator will authenticate the participating nodes and issue a certificate to each participant that will further aid the authentication process. In the case of non-safety related applications, the network providers can help in providing authorized access to the services and charge the users for the services they have used. A high vehicle density is required to provide a more reliable communication to penetrate the ad hoc systems. Cellular communication systems are providing a wider coverage along the roads and are equipped with a reliable process of security and authentication, which means that the vehicular network needs to be developed to help in its wide scale application. This will help lower the investment costs for a new communication infrastructure for vehicular networks. Some of the problems faced by the vehicular network are discussed ahead in this section.

To summarize this section, Inter vehicular communication (IVC) is gaining recognition as car manufacturers and public transport authorities are investing in this sector and navigation safety requirements are given due consideration. To conclude the section of technical challenges, we can safely say that this particular field is continuously developing and is providing various opportunities in terms of services [33]. Network evolution, event detection and dissemination are some of the issues under debate that need to be solved. Research in this field is turning out to be an attractive venture. The research community and the automotive industry are giving its attention to IVC in the hope of gaining a benefit in the form of an intelligent transportation system with assistant services for the driver and the passenger. The vehicular ad hoc networks are emerging as a promising concept in this context, in the form of a new class of wireless networks. These are being increasingly used between the moving vehicles as they are able to provide a variety of applications. These applications range from entertainment to road safety applications. When opening a new business, these networks can provide an attractive opportunity for the network operators, service providers and industrial and telecom companies.

1.2 Motivation

In one of the new types of ad hoc network architectures, the recently emerging VANET achitectures, which build on the vehicles as nodes in a wireless network. broadcasting in ad hoc network is an elementary operation to support many applications in VANET [16]. This encouraged vehicle manufacturers and researchers to invest more in the techniques of dissemination of VANET. Nowadays, so many vehicles are running on the roads, that serious traffic problems including traffic accidents and traffic jams are raised. In the US, about six millions of injuries occurred every year [34]. In 2007, more than 325k traffic accidents occurred in China, which caused more than 80k deaths and more than 380k injuries. Investigations show that most traffic accidents are collisions, however, 60% of crashes would be avoided by 0.5 sec earlier warning [35]. An attempt should be made to distribute the safety messages to the vehicles with possibility of accidents. On the other hand, the traffic conditions of big cities become terrible, which result in time wasting, gasoline exhausting and serious air pollution. Something should be done to make drivers aware of alternative routes to avoid traffic jams. So, at present, two main research objects on urban traffic are enhancing safety and increasing efficiency. Broadcasting in VANETs can disseminate assistant traffic condition messages to all vehicles within a certain geographical area to make drivers of vehicle control models pre-act to avoid accidents and pre-select ways to avoid traffic jams. In this condition, VANETs rely heavily on broadcast to transmit emergency message efficiently in modern road traffic environment [36].

The VANETs are considered as a specific case of MANETs, therefore they have MANETs characteristics, such as multi-hopping, decentralization, self-organization etc. By VANETs, vehicles running on the road can constitute decentralized, burst and temporary networks. The shape of network can be determined. For example, the vehicle infrastructure Integration (VII) initiative in US proposes that the information about an accident should be communicated through VANET within half a second to all equipped vehicles in a 500m range [37]. Because of the shared wireless medium, a simple broadcast scheme, which is called flooding, may lead to frequent contention and collisions in transmission among neighbours [38]. The inherent problem of the blend flooding technique is the huge amount of superfluous retransmissions that consume the limited network resources [39]. These may lead to lower reliability and more latency [40]. At an extreme condition, the channels may be blocked and broadcasts may fail, this phenomenon is called broadcast storm.

Inter-Vehicle- Communications Based on VANET

City Scenario (Situations Examples - Parameters)

Discoverable Road Conditions

By Single Node

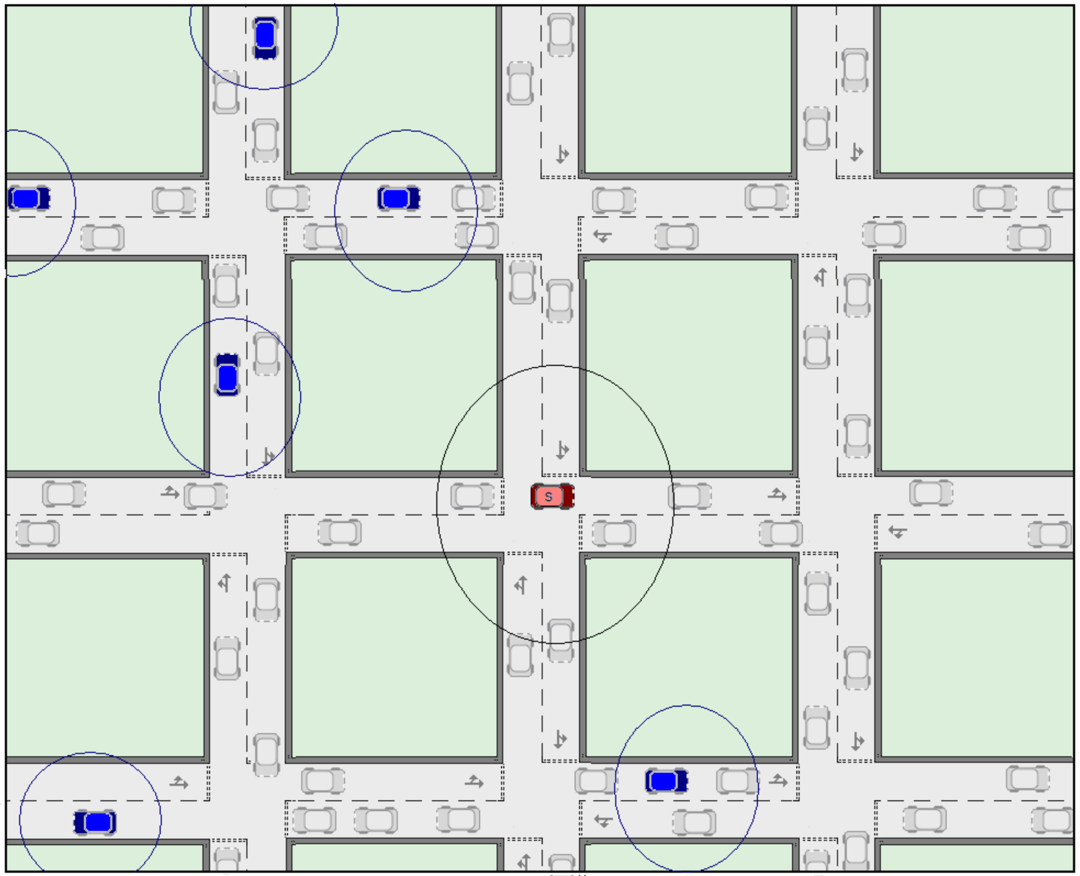
1. Temperature of engine.
2. Out side Temperature.
3. Headlights (On/Off).
4. Stop movement.
5. Hazard Lights (On/Off).
6. Breakdown.
7. Loading truck.
8. Roadwork.
9. Infotainment.
10. Accident.
11. Emergency vehicle.
12. Point-of-interest.
13. E-payment.
14. e-call.

By Multiple Nodes (Conclusion)

1. Windscreen Wipers (On/Off). (Rainy).
2. ABS device (On/Off). (Slippy).
3. Slippery spots (Snow/rain/…)
4. Fog light (On/Off). (Fogy).
5. Traffic flow control. (Traffic Jam)
6. Reduce speed. (Hazard Ahead).

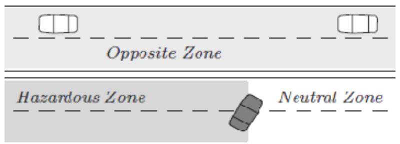
FAQ:

1. **Broadcasting?**
   - How each node ensures that at least one node has received its message?
   - How far should each message travel (distance/number of hops)?
2. **Redundancy?**
   - Avoiding sending the same message from two or more nodes.
   - Who will stop forwarding the massage?
3. **Granulation?** Situation criteria
   - Optimal number (# of Yes's - # of No's)/ Total #?
   - Who will decide the situation?
   - What is the next step after confirming the situation?



Situation dynamic parameters:

1. Position.
2. Shape / dimensions.
3. Intensity.



Routing Context:

1. Maximum number of forwarding.
2. Medium Hops ID.
3. Maximum travelling distance.

Context / Variables / Parameters

Message Context:

1. Message Age.
2. Time since last Broadcast.
3. Time since last reception.
4. Number of sent message.
5. Time to wait until forwarding.
6. Time to wait until repeating.
7. Time to wait if "channel not free".

Vehicle Context:

1. Driving direction.
2. Distance to last forwarder.
3. Current number of neighbour nodes.
4. Distance to/direction of adjacent nodes.
5. Route flexibility.
6. Vehicle speed.
7. Initial speed.
8. Max Speed.
9. Current road type.

Information Context:

1. The time of day.
2. Purpose of travelling.
3. Distance to the source.
4. Information accuracy.
5. Information category.
6. News value.
7. Change information.

Communication Context:

1. Bandwidth.
2. Latency.
3. Average packet size.
4. Security and privacy.
5. Communication range.
6. Guaranteed receiving rage.
7. Distribution logic implementation (Application / network level).
8. Intermittent connectivity (Store-and-forward mechanisms).

Road Context:

1. Number of vehicles
2. Number of Lanes.
3. Road Length (Hazardous Zone / Neutral Zone / opposite Zone).
4. Penetration rate.
5. Position of accident.

Figure 1-1: City Scenario (Discoverable Conditions)

In reality, traffic jams often occur in big cities at the traffic peaks, more than 1 Km long saturated traffic jams are common. The investigation shows that the traffic becomes saturated when the density reaches 133 vehicles/Km/lane [36].The flooding scheme is infeasible in dense VANETs, because it brings us serious contentions, redundancies and collisions. To reduce these problems, an effective VANET broadcast protocol/scheme is necessary in dense traffic schemes.

Let us start by classifying the discoverable road conditions (Figure 1-1) based on ❶ how many cars needed to discover certain road condition? And also, ❷what kind of parameters and variables are needed to put it in its context (determine the road condition)?. In Table 1-1, we tried to present these conditions and their parameters and variables, as well as the associated research challenges, which may arise questions in terms of:

Table 1-1:associated research Challenges with conditions and their parameters and variables.

1	Broadcasting:	How does each node ensure that at least one node has received its message? How far should each message travel form the generated node (distance / number of hops / time)?
2	Redundant:	Can we avoid sending the same message from two or more nodes? Who will stop forwarding the message?
3	Collecting data: (Granulation)	In case of multiple cars needed to determine certain situation, what is the optimal number for each condition? (Percentage: number of cars with specific condition vs. total number of nearby cars). Which car will announce the warning message of the discovered road condition?

1.2.1 Problem definition:

Most of the existing systems in use today work through establishing direct connection between mobile nodes in MANET and pre-existing infrastructure node, which immediately raises questions about the compatibility, required services, updating devices …etc. when we move to collaborative ad-hoc networking, the systems already in place have relatively high cost [26][41] [42]. The proposed algorithm does not depend on the network topology, but the connectivity between the cars can influence the region definitions while identifying traffic conditions. It is clear that the more cars we have on the road, the more effective the algorithm will be, since the algorithm works on the basis of collaborative data generation. And the more cars we have linked in one ad-hoc network, the more entities will take part in the collaborative process.

1.2.2 Example

Here is a small scenario, which illustrates the idea:

1) Here is (Figure 1-2) snapshot of certain area (the lines are roads; the black small points are nodes or vehicles). In urban areas, density of cars in streets is high which allows us to formulate network between cars if we put a small wireless device to enable the communication between the cars. This will establish direct communication channel between each two cars in the range of each other (Ad-Hoc network). This makes sharing individually sensed data among cars more effective, useful and less expensive than any infrastructure communication for generating new knowledge.

Figure 1-2: Street map with vehicles in move (Black dots)

2) The network has been established, the nodes start talking, they exchange messages –called discovery messages- to share all the data they have (their own sensed data or data they already received about nearby cars). Each node is able to calculate the percentage of cars - within certain area – that got the same situation. If this percentage is big enough to consider this area has that situation (Figure 1-3), warning message will be

generated and broadcasted it by that node to inform as much and far cars as possible with the routing feature in each node.

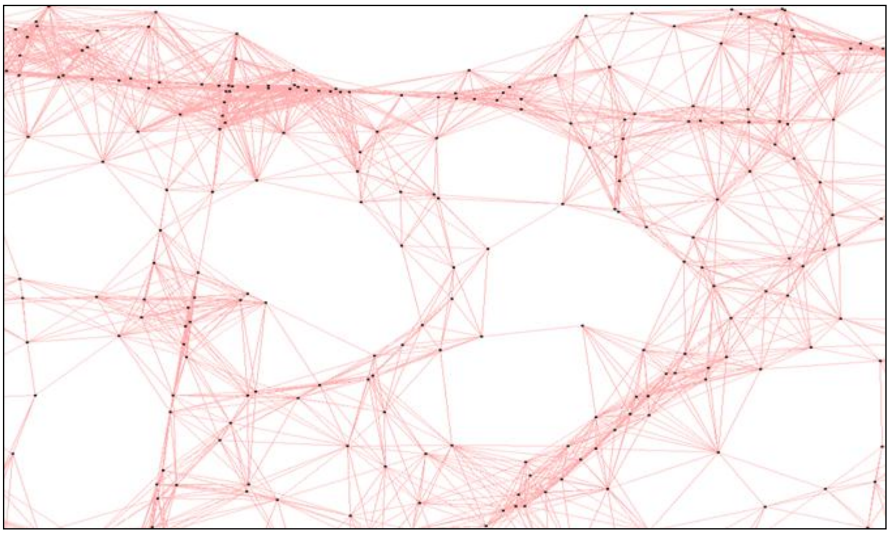


Figure 1-3: Establishing direct link between Vehicles

3) Certain areas will be declared as situation zones (Figure 1-4) for a while, each node or vehicle can know about them by receiving the warning message. This declaration will last for a period of time, if this information is not confirmed again– by receiving new message each car will consider the situation is finished and the normal condition is back on the roads in that area.

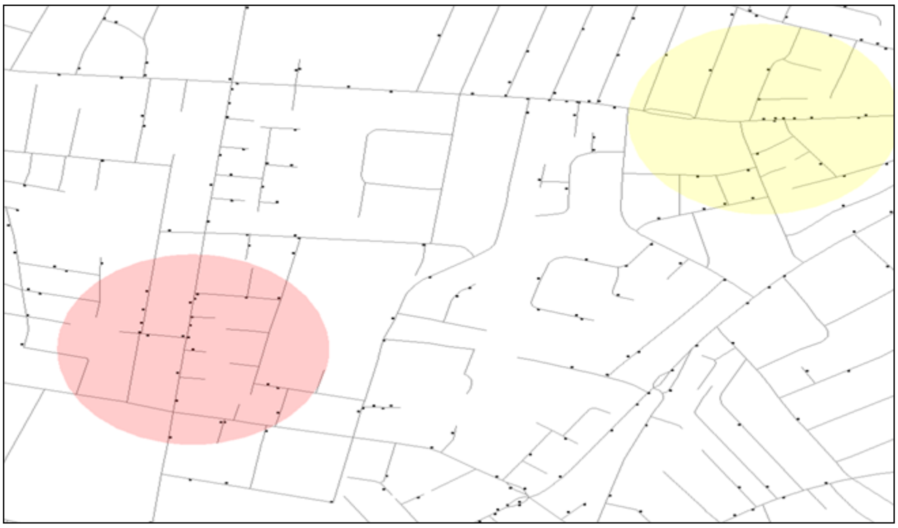


Figure 1-4: Situation Zones have been identified

4) This will cause each GPS or driver itself to avoid these zones if he/she was planning to pass through them (Figure 1-5) to avoid any risk or delay (The red lines in the figure show the pre-planned routes for certain cars).

Figure 1-5: Pre-planned Traveling paths

All designs and suggestions regarding the questions mentioned above subject of rigorous evaluation and scrutiny process and this process should follow iterative steps (design feature – simulate – evaluations) in order to achieve its maximum potential. Each iteration was aimed at focusing on the most promising feature, at developing new ones, and finally at refining and enhancing the different evaluations.

1.3 Objectives

The main objective of this thesis is to come up with a new traffic data discovery and dissemination algorithms, which are appropriate for the challenging environment of mobile ad-hoc and vehicular networks. Given the intrinsic characteristics of these networks, our solutions must be adaptive to changing topologies, efficient in terms of bandwidth usage, and scalable with respect to various network parameters.

One of the main advantages of the ad-hoc networks is the opportunity to use collaborative effort in connecting and delivering network messages as necessary [43]. This opportunity is under-utilised so far in the area of traffic control and traffic information systems where every car can be considered to be a node in an ad-hoc network [44].

Our aim is to investigate the possibility of bringing into the development of such systems ad-hoc collaborative information generation and control and to investigate how the functionality of the ad-hoc node (within the vehicle) affects the quality of the traffic wireless information systems in ITS. The project covers the middle ground between VANET and collaborative data generation based on knowledge granularity (aggregation)

[45]. It will investigate the designing, implementing and modelling the functionality of a condition identification algorithm for an intelligent node in ITS wireless information system that will be - at the same time - an active participant in the formation, routing and general network support of such systems and also act as in-car traffic information and real-time control generator and distributor [46].

As yet there is no consensus on the functionality of the nodes forming part of a traffic based ad-hoc network, one of the main research objectives will be to define the node's functionality based on the identified algoritm's features. This will form the basis of a computer model of the network with the required node features which in turn will be implemented as a real-life case study and programmed. The results have been reported in research papers and journal papers.

Furthermore, we focus on realistic approaches with applicability in real-life deployments. This means that our algorithms must not be designed on the basis of simplistic assumptions, which could lead to erroneous conclusions. Realistic models and experimentation are the tools we will employ to ascertain that the developed algorithms are implementable and efficient.

Fulfilment of these objectives involves providing understanding of the realities of ad-hoc networking. In addition, our proposals must be compared against other solutions found in the literature. Our proposal algorithms must provide better performance than the others so that they can contribute something to the research community.

The following metrics will be used to evaluate the project:

- Optimum number of hops needed for each message journey to scan the whole area.
- Best delay time we can use to rebroadcast message in each node to reduce the network noise.

To summarize, this thesis is focused on advancing the general knowledge in ad-hoc networking by providing solutions, which can help develop new services for VANET. The next section details the methodology we employ to achieve our goals.

1.4 Methodology

The methodology for this project will be based on designing a model, optimising the model through.

The first task will be to design the functionality of the mobile node, then obtaining optimisation results from simulation run for the best features of the Wireless Traffic Information Systems' Intelligent Node. Thus through simulation, the most valuable features in the design of the Node will be identified. Next these results will be validated – several typical real-life use case scenarios will be created and simulation. The overall achievement will be the design, implementation and validation of all core issues in the functionality of the intelligent node for MANET for wireless urban traffic information systems, their comparison with the already existing designs and subsequently building real-life test models for field testing and using them for field testing in the future developments. [47] [48] [49].

It is envisaged that the research will include the following two stages:

First stage:

- Literature Review in the field of MANET – identifying core functionality of the Intelligent Node and building in new features.
- Identifying single node and collaborative nodes data that the node can generate.
- Identifying the format of the message exchange.
- Design of the collaborative model for new data and control generation.
- Design of the simulation model.
- Report on the design process (paper).

For the second stage

- Simulation model programming implementation.
- Project simulation runs – identifying and optimising the model on a limited scale – test data.
- Preparation of the simulation model with real-life data – traffic network topology in Nottingham embedded in the simulation model.

- Real-life use-case scenarios identification.
- Obtaining results through simulation for the real-life use-case scenarios.
- Choosing the real-life trials setup – hardware, connectivity technology etc. of the device.
- Staging real-life data runs and validation of the results for the traffic network in Nottingham.
- Report of the results (paper).

A significant effort has been made to analyse the related state of the art and precisely define the problem at hand. Once the problem is detailed, we employ models, which capture the essence of the scenario we have decided to address. For the data dissemination problem in VANET (Chapter 3), we employ the designed algorithm to model a dynamic ad-hoc network. This algorithm is very convenient to address the different network topologies that are formed in the network as time passes by. We define the concept of ***minimum broadcasting structure*** and demonstrate that it represents an optimum solution for the data dissemination problem. Therefore, heuristic approaches must be used in real networks.

Analytical techniques are very useful to provide understanding about a given problem and extract performance tendencies among the approach. However, in order to be tractable, analytical models often need to make simplistic assumptions and are not very representative of the behaviour of a system under real operation. Thus, we also employ simulations to add much more detail to the scenarios under evaluation.

We make extensive use of simulation along this thesis. In fact, many scenarios we have designed have been implemented in a network simulator, along with competing approaches, and their performance has been carefully examined (Chapters 4, 5). In this way, we can check that our algorithm makes a real gain with respect to the solutions available in the literature. Simulation is a very convenient tool to analyse networks that otherwise would be very difficult to set up in a testbed. For instance, we can study the scalability of our algorithm as the network size increases to hundreds of nodes.

Among the various network simulators, which are widespread, we employ ***The Network Simulator ns-2*** [50]. We choose this software because it is freely available, counts on active user and developer communities, and it is widely used for ad-hoc networking research. Our work puts emphasis on protocols, which are suitable for real networks. Therefore, we try to use the most recent and accurate simulation NS2 version 2.3.3. Thus, data link and physical protocols are simulated by means of realistic ns-2 models which are known to correctly mimic the IEEE 802.11 standard [51]. Modelling of wireless signals is especially cumbersome given the high number of factors that affect signal propagation. In the specific case of vehicular networks, wireless communication is challenged by an extremely multi-path environment. Vehicles, pedestrians, traffic signals and surrounding trees scatter the wireless signal. In addition, bigger obstacles such as buildings can shadow the signal. Besides, even in free space, wireless signal loses energy as it travels away from the source. These phenomena make the decoding of the signal at the receiver difficult.

Since we focus on mobile networks, nodes' motion must also be accurately incorporated into the simulation. In the case of a generic VANET we employ random mobility models, in accordance with related literature [12,52]. Given that nodes in a VANET could follow arbitrary mobility patterns, we assume random movements according to a synthetic mobility model. The simulation of real-life use-case is quite different in this regard, since vehicles follow well-defined trajectories. Therefore, realistic movements are derived from vehicular mobility models. We have used to test our algorithm scenarios that were extracted from a real data monitoring system in Nottingham traffic control agency. This supports and increases the reality of our scenarios in all aspects (real road map, cars movement, road density, cars speed, … etc.). It allows us to simulate common vehicular situations such as overtaking and stoping at intersections. This leads to intermittent connectivity and uneven distribution of vehicles, as it actually happens in urban streets.

In order to convey statistically significant results from simulations, we follow best current practices in network analysis [52][53]. Hence, our simulation set-up allows for the establishment of a transient period until the network reaches the steady state. In that moment, we start to gather measurements about the performance of the simulated algorithm. We also avoid extracting conclusions from a single experiment and each test is executed several times with different random seeds (section 5.2.2). Thus, we provide average results for each metric along with corresponding confidence intervals. This is very important to ascertain that a given protocol is statistically better than another for a specific metric.

To help improve the aggregation and visualisation of the data and present them in dynamic form, a tool has been developed for that purpose (Using VC# 2008 as programming language). The tool can help in discovering the trend for any of the collected data (e.g.: number of exchange messages, max seen active nodes…) based on the number of hops and delay time. This approach makes us able to predict the optimum number of hops with the best delay time. We use it to establish the optimum parameters for the best performance of the algorithm (e.g.: reducing the number of exchanged messages over the most suitable delay time with the maximum number of recognized active nodes and the maximum number of non-active nodes).

Our software incorporates a logging subsystem, which generates trace files describing what it is happening during each experiment. Therefore, we can post-process such trace files and extract performance metrics and companion conclusions.

As the reader can see, we have made an effort in assuring that our algorithm are well designed for the operation in real networks. Next section enumerates the main contributions, which are derived from this thesis.

1.5 Main Contributions

It is clear that tomorrow's driving assistance systems can go far beyond their present capabilities by implementing co-operation and information exchange in order to collectively and cooperatively perceive the context. Making decisions dependent on the context can serve car drivers, ITS, environment and all people as general.

Here we briefly describe the main results obtained within the development of this project. They have been published in several international peer-reviewed conferences and journals. A list of such publications can be found in *List of Publication* Section.

The work consists of proposing a new algorithm for effective traffic conditions sensing and data distribution in wireless mobile ad-hoc networks environment. The parameters for optimum performance of the algorithm have been identified and reported. Simulation tool and tools for data analysis have been designed, developed and implemented.

1.5.1 Three Main contributions:

Here is the major three contributions:

- Novel algorithm for identifying road traffic conditions by utilising car-2-car communication (broadcast), cooperative knowledge gathering and positioning knowledge.
- Design a model to simulate the proposed algorithm for testing purposes by using real data as input.
- Build analysis tool for the huge data results we got from the simulation phase.

1.5.2 The stages of the research involved:

this research has those stages as the following:

- Preparing novel simulation models implementing the proposed algorithm and a programming implementation of a tool for results comparison because of the vast number of simulation runs results. Part of it will be presented as programming code. The research novelty here is to identify how the application of the algorithm can be used in different use case scenarios and evaluate the tool's ability to cope with given situation data.
- Project simulation runs with Nottingham traffic network (test/real-life) data for test and proof purposes (verification). This task includes investigating algorithm's behaviour in huge (real size) traffic topology networks.
- Design, implement and validate the algorithm for real-life use-case scenarios model to addresses its strengths and weaknesses. This task will first select several real-life test scenarios where the application of the algorithm will have most impact. The research work will identify the benefits of using the algorithm and will report the improvements achieved in applying the algorithm in such networks.
- Identifying and clarifying the boundary parameters for the transition from non-conclusive to conclusive data sets as a description for the desired environment.
- The collaborative data sensing has always been linked to sensor networks. This research will try to bridge the gap between the two domains and use the cars as sensors where the individually sensed data (referred to as non-conclusive set) from the cars are fused into a collaboratively generated knowledge (referred to as conclusive set) with regard to traffic situation.

- Analysis & validation of the results. Again, using the developed tool for that with some improvement in terms of data aggregation and presentation.
- Critical analysis based on liaisons with Nottingham Traffic Control Centre and taking into account the evaluations as perceived by the traffic control establishments and with reference to the wireless traffic research bed in the centre of Nottingham.
- Report of the results. To fit all the work that has been done on the algorithm in its context with specialist people in the field.

1.6 Organization of this Thesis

In this section we give a brief insight on this research work by showing the organization of the other Chapters. In detail, we have:

Chapter 2: Literature review

The Chapter provides the reader with the needed background on ad-hoc networking, emphasizing on MANET and VANET, to understand the rest of the document. This chapter highlights the most important issues, which affect communication in ad-hoc networking. Also, it is meant to introduce the basic concepts behind the emerging area of vehicular networks and data exchange, such as Ad-Hoc networks, Mobility issues, Mobile Ad-Hoc Networks (MANETs) and, at the same time, to provide an overview of the new technologies and standards for car communication systems.

Chapter 3: Data Gathering and Dissemination Techniques

This chapter surveys the different types of information exchange adopted in vehicular networks with common practices and methodologies that have been considered in research literature (e.g.: opportunistic exchange of resources between vehicles, vehicle assisted data delivery, cooperating downloading of information, etc.) with a special emphasis to the network coding technique.

Chapter 4: Traffic Conditions Detection Algorithm (TCDA)

This is the main Chapter offering a novel protocol for data dissemination built on the top of UDP. The new approach is explained in detail and the main experimental results are presented (CORP is compared to V2V, I2V and I2V2V data dissemination paradigms).

Chapter 5: Simulation

In this chapter, I present an overview of the most popular vehicular network simulators and mobility simulators, according to their integration components. Also, showing the designed model to simulate the proposed algorithm for testing purposes. Such tests exercise our data dissemination protocol and one of our gateway discovery algorithms, as proposed within this thesis. The experiments also shed light onto the performance of ad-hoc vehicular communications in real situation.

Chapter 6: Results (Analysis and outcome)

The final results are present in this chapter. Also, detailed analysis have been made and presented visually in graphs.

Chapter 7: Conclusions and future work

This Chapter highlights the main benefits of using the approach presented in Chapter 4. Also, this chapter concludes this document, summarizes some of the open research issues that are to be continued in the line of this work, and lists the most relevant publications, which report the results presented within this thesis.

CHAPTER 2

Literature Review

Chapter outline:

- Introduction.
- VANET's Overview.
- Standards of VANET.
- Routing.
- QoS parameters for VANET.
- Communication challenges.
- Conclusion

Chapter 2

2 Literature Review

The VANET, abbreviation from Vehicular Ad-Hoc Network, is a new type of network where there is no underlying connectivity infrastructure, all nodes are mobile (cars). The existence of such networks has been made possible by the latest developments in hardware, software and communication technologies. VANET has great (not utilised yet) capacity to bring improvements in the traffic situation and to help with: smooth progress of all journeys, vehicle safety, prevention of road accidents and it is a great source of real-time traffic information for the drivers as well as the passengers. Having attracted a healthy amount of attention in the past few years, VANET has been subject to rigorous research, standardization and development. Novel VANET design architectures and implementations also rely heavily on recent technological advances in areas such as routing, broadcasting, Quality of Service (QoS) and security. We present in this chapter a survey covering current research results in the mentioned areas [54, 55]and we formulate a review of wireless access standards for VANETs. Recently held VANET trials and advances that have been carried out in the US, Japan and the European Union are also looked into.

Moreover, few of the smulators that are presently available to VANET researchers for VANET smulations [56] are looked into and had their advantages and shortcomings also discussed. To advance the developments of VANETs even further, there is still need for some of the VANET research challenges to be considered, so that the global and extensive implementations of accessible, reliable, strong and secure VANET architectures, protocols, technologies and services can be achieved. These challenges are identified and discussed in this thesis.

There have been significant developments in the wireless technology in the past ten years, mainly in the form of 3G and WLAN technologies and the most recent standardization of WiMax [57]. All these have contributed to the idea of connectivity present everywhere at any time, i.e. globally and constantly. A lot of work has gone into putting this feature to use in vehicle surroundings [58], some examples being EU FP7 funded projects including WAVE (Wireless Access in Vehicular Environments Testbed) [59], SeVeCom (Security on the Road) [60], NOW (Network on Wheels) [61], SAFESPOT (Cooperative systems for road Safety) [62], CVIS (Cooperative vehicle-infrastructure systems) [63], CarTALK [64], AutoNomos (distributed, self-organizing traffic information system) [65]. These mark significant progress in the field of Intelligent Transportation Systems (ITS).

The main aim of there systems is to help the drivers enhance their road safety, effectiveness and comfort by providing advanced traffic information live channels. Among the many things that are required to fulfil this aim are: route planning, automatic control of traffic and collision avoidance [66]. This requires that relevant information be exchanged on regular intervals between vehicles and between vehicles and infrastructure and ensure that the mobile nodes (vehicles) cooperate with each other to maximise the effect of information exchange. One main feature of cooperative systems, crucial for suitable functioning, is how this information is spread to the surrounding vehicles. This spread of information must be efficient and quick and depends on how capable the core communications platform is. The main governing factor and concern, though, of the effectiveness and productivity of the applications is the communication technologies used in ITS. Till now, the idea of connecting car-to-car has not been explored fully and the predominant form of communication has been connecting a car to a cell station (infrastructure node) [67], which only makes it more important to build a new generation of wireless traffic information systems – car-to-car communication information systems. This can be achieved only by carrying out further research into the functioning of wireless mobile computers or Mobile Ad Hoc Networks (MANET) [1].

An assortment of autonomous nodes or terminals that form a multi-hop radio network to connect with each other and retain connectivity in a distributed manner is called a wireless ad hoc network [11]. These nodes have to bear noise, fading and interference, the effects of radio communication, since they have a communication over wireless links [25]. Added to this problem is that of the links having less bandwidth than they would have in a wired network. The message exchange protocol control in the wireless ad hoc network is spread among the nodes and each node acts as a host as well as a router.

The connectivity among the nodes can fluctuate according to time because of node departures, new node arrivals and the prospect of having portable nodes. Due to this, the network topology for such networks is mostly quite dynamic and vigorous. So, to let the nodes connect over multi-hop paths, which comprise of different links, without using unnecessary network resources, there's a requirement of effective information collection and distribution protocols. Many ad-hoc network routing protocols have been presented in the past years and can be generally categorized into three groups: proactive, reactive and hybrid. The function of these routing protocols is to deliver the functionality that is needed in such dynamic and vigorous environment [68].

2.1 Overview of VANET

2.1.1 Characteristics

The following VANET's distinctive features make it stand out when compared to MANET. They also make it a tough task to design VANET applications [20].

2.1.1.1 Dynamic topology

Consider this example: 2 vehicles are travelling at the speed of 20m/sec, with the radio range between them being 160 m. Dividing 160 by 20 (radio range by speed) will give us 8 seconds, which is how long the link between the two vehicles will last if they were heading in opposite directions. Because vehicles travel at such high speed, the topology of VANET keeps varying [15].

2.1.1.2 Frequent Disconnected Network

The above feature of vastly dynamic topology of VANET showed us that when two vehicles are exchanging information, there is a problem of repeated disconnections between them and these disconnections will be a common sight in sparse network.

2.1.1.3 Mobility Modelling

How vehicles move around and what are their mobility patterns depend on the following factors: traffic atmosphere, the structure of the roads, the speed of vehicles, driving performance of the driver, etc.

2.1.1.4 Battery Power and Storage Capacity

One good thing about modern vehicles is that their battery power and storage is not restricted which means it has sufficient computing power. This is absent in MANET. This feature helps in making communication efficient and in forming routing decisions [14].

2.1.1.5 Communication Environment

There can be two different communication environments: in sparse network and dense network. The routing approach of these two networks will be different too, since in a dense network, buildings, towers, tree and other objects act as hindrances, whereas in a sparse network, these things are not present, an example is that of a highway.

2.1.1.6 Interaction with On-Board Sensors

Another feature that helps in making communication efficient and in forming routing decisions is that the current position and the movement of nodes can be simply detected by on-board sensors – for example the use of a GPS device.

2.1.2 Vehicular Network Architectures

The current development in the field of wireless technology [10] and the recent and progressing developments in ad hoc network (Local Area Network) have led to a great proliferation of architectures for car networks in urban, highways and rural areas [69]. Such frameworks help the communication with close by cars, and also help nearby pre-set roadside tools to communicate with the cars. Thus vehicular networks can be set up through network operators and Internet access providers or with the help of incorporation of operators, a governmental power and providers.

There are three alternatives:

- Wireless last hops with wired backbone, which can be used as wireless VAN vehicular access point.
- A hybrid vehicle-to-road (V2R) architecture that can use a present infrastructure in a steady way for better performance and service access when it is available but does not depend on it. Such condition helps cars to communicate with the infrastructure in accordance with the position of the car with regard to the point of attachment with the infrastructure both in a single hop and multi hop manner. In fact V2V communication is included in the notion of V2R infrastructure.
- The network, which permits standalone vehicular communication without any infrastructural support, is a real wireless vehicle-to-vehicle ad hoc network (V2V)..

To differentiate the three fields i.e. ad hoc, in-vehicle, and infrastructure, reference architecture is planned inside the C2C-CC [8]. This reference architecture is shown in the figure 2-1.

The local network present in every car is known as in-vehicle domain [11]. It consists of two kinds of units: (i) one or more application units (AU) (ii) an on-board unit (OBU). AU is a tool which utilizes OBU's communication potentials and carries out one or more set of applications whereas an OBU is a tool fitted in the car which possess communication potentials (wireless and/or wired). Actually AU is attached to an OBU constantly and it can be an incorporated as part of a car. It is attachable or detachable dynamically with an OBU and it may be a transportable tool like PDA or laptop. A wire connection is used to connect AU and OBU but they can have a wireless connection with the help of Bluetooth, WUSB, or UWB. AU can also be included in a same physical unit and there exist a valid difference between AU and OBU.

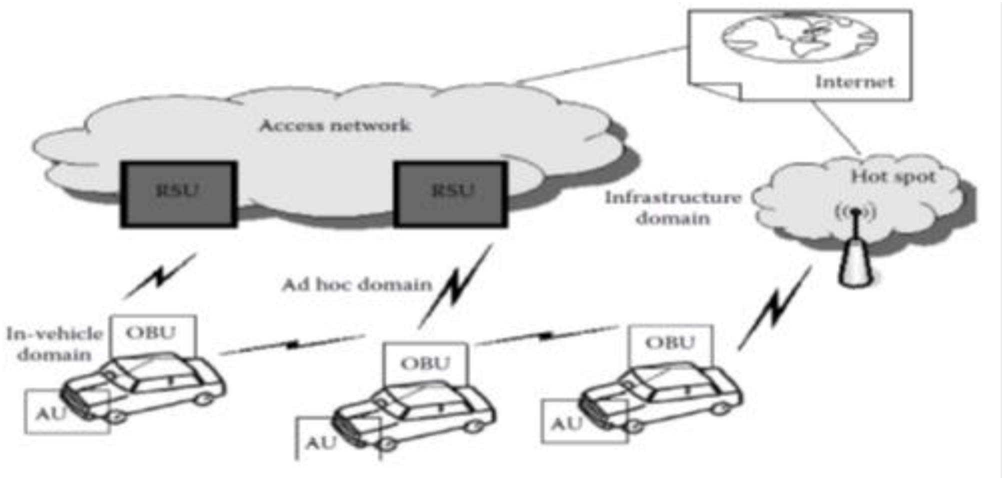


Figure 2-1: C2C-CC reference architecture [2]

The cars, which contain OBUs, and road side units (RSUs), that are fixed along the motorway, form a network called ad hoc domain. When an OBU includes communication tools together with a minimum short distance wireless communication device, which is used for motorway security purposes is called mobile ad hoc network (MANET). OBUs of different cars constitutes mobile ad hoc network MANET. A connection of Internet is made to an RSU, which is already connected with an infrastructure network. RSUs can also have a direct connection with each other or they can be connected through multi-hop, and the betterment of motorway security is basic function of RSUs, which is performed with the help of special programmes and also by transmitting, collecting, or forwarding information in the ad hoc domain.

2.1.3 Intelligent transport systems (ITS)

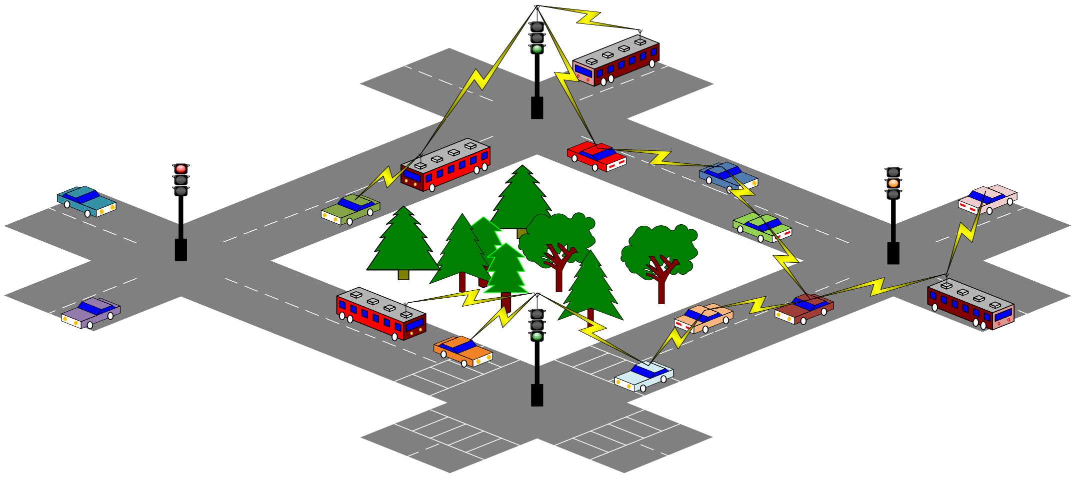


Figure 2-2: Possible communication Units in ITS

Basic assumptions for the architecture of ITS are discussed shortly here (Figure 2-2). Every car should act as a receiver, sender and router in intelligent transportation systems (ITSs) to transmit data to guarantee the security and free-flow of traffic. The hardware such as Global Positioning System (GPS) or a Differential Global Positioning System (DGPS) receiver should be incorporated in cars, which provide complete data about the position of cars. Some kind of radio interface or On Board Unit (OBU), which helps information of short-range wireless and ad hoc networks, should be fitted in cars [7]. To assist and facilitate communication there must be present RSUs, which are attached to the backbone network.

A specialist communication protocol helps to determine the amount and allocation of the roadside units. For example, some protocols need roadside units to be allocated uniformly all through the whole highway network; sometimes roadside units are required only at border regions, whereas sometimes there is a need of roadside units only at the junctions.

It is impractical that all cars must have wireless connections to highway units but it is true that to some degree infrastructure is present and occasionally cars can connect with it. These communications consist of vehicle to roadside communications, between the vehicles i.e. inter-vehicle communications and communications, which depend on routes i.e. routing-based communications.

To exchange data, application of precise and exact positioning systems and smart communication protocols are required. These positioning systems and communication protocols can help routing-based, inter-vehicle, and vehicle-to-roadside communications, which in turn depend on the exact, modern and advance information about the surrounding conditions. Smart communication protocols must assure rapid and consistent release of information to all cars in the surrounding area, which uses network infrastructure in which the communication medium is shared, highly unpredictable, and with restricted bandwidth [70]. It is very important to mention here that the technologies like that of IEEE 802.15.1 (Bluetooth), IEEE 802.15.3 (Ultra-wide Band) and IEEE 802.15.4 (Zigbee) [71] are used in intra-vehicle communication and such technologies also have applications in wireless communication inside a car but this issue is not the subject matter of this thesis and therefore it will not be discussed in detail here.

2.1.4 Inter-Vehicle Communication

By using the multi-hop broadcast/multicast, the inter-vehicle communication configuration is capable of transmitting traffic information through different hops to different receivers, at one time.

Intelligent transportation systems use vehicles that are focused primarily upon activities that are happening on the road in front of them instead of behind them. A good example of such an incident would be the relaying of emergency information spreading about a possible collision or changes that have happened in scheduled routes. The two other kinds of message forwarding, for inter-vehicle communications are: intelligent broadcasting [72] and naïve broadcasting. First, naïve broadcasting involves vehicles transmitting broadcast messages between themselves periodically.

Once the message has been received, any repeat messages that come from the vehicles behind are ignored. If new messages are received from a vehicle that is to the front, then the receiving vehicle relays this message to the vehicles behind in its own broadcast. The advantage of this method is that the enabled vehicles that are moving forward receive the broadcasted information. There are however, many drawbacks to this method. The first problem is that this method leads to the generation of a large amount of messages. This can lead to a higher risk of message collision, reduced message delivery rates and more time taken for the message to be delivered [73]. In intelligence broadcasting, there is an implicit acknowledgement that the problems faced in naïve broadcasting are dealt with. The messages being broadcasted are limited in nature, restricted for emergency events only. Once the emergency message has been relayed back, and the vehicle gets it from one of the back vehicles, the receiving vehicle assumes that the message has been passed on to the back. Accordingly, they will stop broadcasting then. What they are doing here is passing the responsibility backwards – once they have transmitted the message back (and they receive the same message back), they let that vehicle be responsible for passing on the word. Should any vehicle receive the same message from multiple sources, it will work on the first message received and no other.

2.1.5 Vehicle-to-Roadside Communication

In the vehicle to roadside communication set up [74] (figure 2-1), a singular hop broadcast occurs where a roadside unit transmits a message to all the ready vehicles within a certain distance. Vehicle-to-roadside communication configuration provides a high bandwidth link between vehicles and roadside units..

Roadside units are positioned every few kilometers or less. This manner of configuration offers a high bandwidth connection between roadside units and the vehicles. Thanks to this, high data rates can be maintained by the system, even when there is heavy traffic.

If we were to consider the broadcasting dynamic speed limits, it is possible for the roadside unit to calculate the right speed limits by utilizing available traffic conditions and its domestic timetable. Periodically, the roadside unit will transmit a message, which will relay the suitable speed limit. Additionally, it will make comparisons between vehicle data and directional or geographic limits to check which vehicles the speed limits would be applicable too, within a surrounding area. Should there be a vehicle violating the set speed limit that vehicle will receive a visual or auditory broadcast warning asking them to lower their vehicle’s speed.

2.1.6 Vehicle-to-Vehicle

As a decentralized system, V2V has a goal of organizing the interactions that happen between the vehicles and encourages collaborations between the vehicles. Information is exchanged at the 'local' level i.e. between vehicles that are close to each other in groups. To enable information interchange means that an agreement would have to be established between suppliers and car manufacturers, which would cover the protocols, communication technology etc. to be used for such a system. The frequency spectrum utilized would be within the 5.9 GHz range with harmonized basis within Europe and other parts of the United States of America (even though system compatibility is still an issue). This system would use Wireless LAN, which has its basis in IEEE 802.11 [75].

This method utilizes a routing algorithm that has its basis on the vehicle position. It is also capable of quickly managing any rapid changes that happen in network topology. There are different aspects to be considered in V2V: delays, safety and performance objectives and partial measurements, etc. [76]. This is why the system should have the capacity to make semi-automatic or automatic decisions and also give warning and information in case of any change. Any control technology is first applied to the local and top architectural layers before trickling down. Let us see how this system would work. If there is a pair, or more, of vehicles or roadside stations within radio communication range, an automatic ad hoc network would be established within the vehicles. This will allow the vehicles to share information like direction, speed and vehicle position. At the same time, every vehicle acts like a router and would transmit messages through multihop to the roadside stations and vehicles positioned further away.

2.2 Standards for Wireless Access in VANETs

By using standards, it is possible to lower costs, simplify and improve product development also let users make comparisons between rival products. By using set standards, we can guarantee heightened levels of interoperability and interconnectivity. Any new products that arise as a result would then be able to quickly implement any new technologies that are given birth. Regarding wireless access in the vehicular setting, there are many different standards available.

For example, there are protocols applicable to transponder technology and equipment. In the same way, there are communication protocols in place relating to routing, specification, interoperability and addressing services protocols.

2.2.1 Dedicated Short Range Communication (DSRC)

To support vehicle-to-roadside and vehicle-to-vehicle communications, dedicated short range communications (DSRC) was developed as a short to medium communication method. Through DSRC [7], it is possible to transmit low communication latency and high data transfers within small communication areas. There are numerous applications for this communications method, including the relaying traffic information, safety messages, drive-through payment, and toll collection etc. from vehicle to vehicle. DSRC used by the United States Federal Communications Commission (FCC) in the year 1999 was assigned 75 MHz of spectrum at the 5.9 MHz range. A few years later in 2003, the American Society for Testing and Materials (ASTM)[1] permitted the use of the ASTM-DSRC technique based upon IEEE 802.11a physical layer and a 802.11 MAC layer [37]

The Federal Communications Commission (FCC) works in the direction of six areas in the areas of broadband, competition, the spectrum, the media, public safety and homeland security. The FCC on February 2004 delivered a report concerning the rules and regulations of licensing for the usage of their “Dedicated short-range communication” (DSRC) band. However FCC doesn’t charge any fee for DSRC band usage but its usage is relatively limited and restricted [77].

The “Dedicated short-range communication (DSRC) are one or two way either short- to medium-range wireless communication channels precisely intended for automotive usage and a conforming set of protocols and criterions” [78]. Currently, the DSRC spectrum works in seven channels and their determinations are as follows:-

- Channel one is about the safety and is assumed the high priority over other channels. It also notifies drivers about forthcoming incidents.
- Channel two is about the security and protection of driver’s life.
- Channel three is about the high power community safety and security.

- The Channels four to channel seven are about the either safety or non-safety purposes.

Table 2-1: DSRC standards in Japan, Europe and the US [79]			
Features	**JAPAN (ARIB)**	**EUROPE (CEN)**	**USA (ASTM)**
Communication	Half-duplex(OBU)/ Full duplex (RSU)	Half-duplex	Half-duplex
Radio Frequency Band	5.8 GHz Band 80 MHz bandwidth	5.8 GHz Band 20 MHz bandwidth	5.9 GHz Band 75 MHz bandwidth
Channels	Downlink: 7, Uplink 7	4	7
Channel Separation	5 MHz	5 MHz	5 MHz
Data Transmission rate	Down/Up-link 1 or 4 MBits/s	Downlink: 500Kbit/s Uplink: 250Kbits/s	Down/Up-link 3-27 MBits/s
Coverage	30 meters	15-20 meters	1000 meters (max)
Modulation	2-ASK, 4-PSK	RSU: 2-ASK, OBU: 2-PSK	OFDM

ARIB: Association of Radio Industries and Businesses.
CEN: European Committee for Standardization.
ASTM: American Society **for Testing and Materials.**
OBU: Onboard Unit.
RSU: Road Side Unit.
ASK: Amplitude Shift Keying
PSK: Phase Shift Keying
OFDM: Orthogonal Frequency Division Multiplexing

Here, we relate some latest regional standards for DSRC in خطأ! لم يتم العثور على مصدر المرجع..For a further descriptive debate of DSRC (see [79] [80]).

2.2.2 IEEE 1609- Standards for Wireless Access in Vehicular Environment (WAVE)

A Compliant device 802.11a delivers wireless connectivity amongst moving cars with 54 Mbps [55]. The moving cars face difficulties in their wireless connections due to fluctuating driving speediness. It also faces different traffic and driving surroundings.

The Media Access Control (MAC) IEEE 802.11 setups also faces many challenges. For example safe vehicular security transportations necessitate fast data exchanges. However, the scanning of channels for an Access Point discovery is compulsory to form communication channels along with few handshakes. It can be with too much complications and high expenditures. And if both the cars are moving in contradictory direction then their communication will no longer be continued in this manner. Therefore to handle these situations, DSRC shifts to the IEEE 802.11 which is also known as IEEE 802.11p Wireless Access in Vehicular Environments (WAVE) [78].

Due to Regional standards of DSRC, it shifts and moves into IEEE 802.11 WAVE to become a standard which can be used all around the world. However IEEE 802.11p is limited by the space (Figure 2-3). And it works beneath Media access control and physical layers [37]. In addition, DSCR operations are handled by the upper coatings of IEEE 1609 criterions to avoid any disruptions and harm [81].

The above-mentioned standards and criteria support well the usage and importance of applications in the WAVE atmosphere and the foundations are grounded in a well-defined standard IEEE P1609.1. The security and safety protocols are demarcated in IEEE P1609.2 and the Network-layer protocol demarcated in IEEE P1609.3. The IEEE 1609.4 exists above the 802.11p and it supports the standards of the complex layers without disturbing and troubling the physical channel entree boundaries.

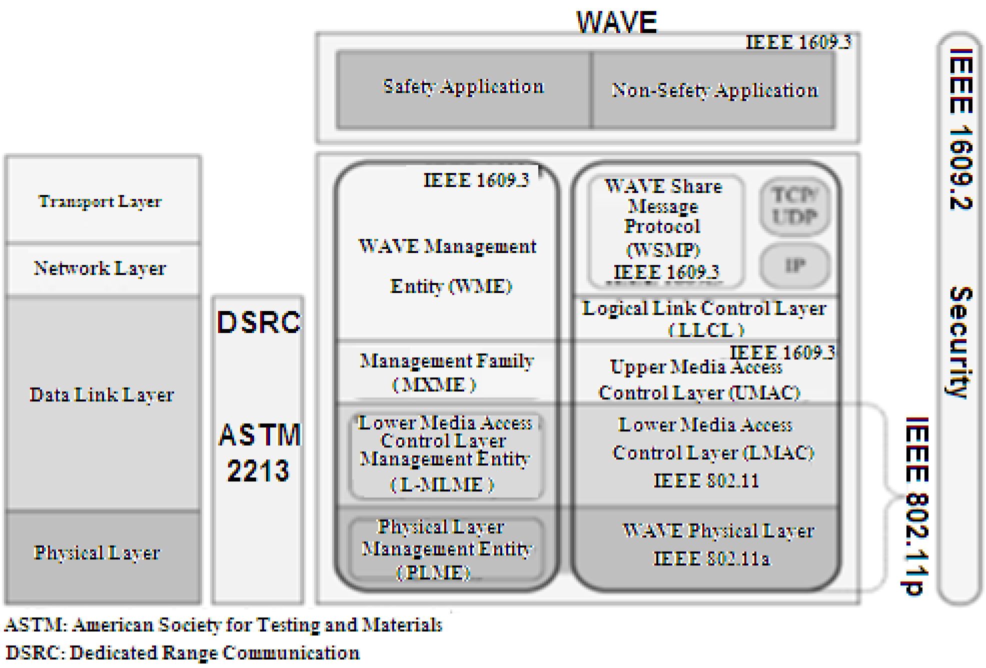


Figure 2-3: Wireless access in vehicular environments (WAVE), IEEE 1609, IEEE 802.11p and OSI reference model [37]

The Wireless Access in Vehicular Environment (WAVE) recognises two kinds of devices, which are as described below:

- Roadside unit (RSU).
- On-board unit (OBU).

The Roadside units are used for stationary devices and on the other hand the onboard units are used for mobile devices. They both can be a user or a service provider. The devices can also shift amongst or between the modes. There are many other devices, which are operated from the Roadside unit whose determination is to deliver services to the onboard unit. Therefore the Wireless access in vehicular environment (WAVE) standard defines applications that exist on the Roadside Unit (RSU). It is also planned and scheduled to support complex demands from distant applications. It delivers an extensive and wide access to the onboard unit (OBU).

A Wireless access in vehicular Environment (WAVE) uses 'Orthogonal Frequency Division Multiplexing' (OFDM) which is the determination to fragment the signal into numerous narrowband channels. Orthogonal Frequency Division Multiplexing (OFDM) has established itself as the prevalent structure for wideband digital communication. It also delivers a payload communication capability of 3, 4.5,6,9,12,18,24, and 27 Mbps in 10 MHz channels.

2.3 Routing

In Vehicular Ad-Hoc Network (VANET), the routing protocols are divided into five distinct classes which are as follows [82]:

- Topology based
- Position based
- Broadcast Routing

2.3.1 Topology based routing protocols

These Topology based routing protocols usually use association's information that occur in the network to support packet progressing. They are usually supplementary distributed into the following groups:

The proactive routing is about the routing information being collected and preserved prior to any communication transmission. The packets are continuously broadcast and logged amongst nodes to preserve the track, and then a counter is created inside a node, which specifies subsequent hop count in the direction of a target. The benefit of proactive routing protocols is that the route is already identified, but the drawback of this protocol is that it offers serious overhead communications, which causes reduction in the existing bandwidth. Some of the proactive routing protocols are as follows:

2.3.1.1 Fisheye State Routing (FSR)

The Fisheye State Routing (FSR) is similar to Link State Routing (LSR) protocol. However FSR node preserves a topology table (TT) grounded upon the up-to-date information established from nearest nodes and occasionally interchanges it with native neighbours. For huge networks to decrease the magnitude of communication the Fisheye state routing (FSR) customs the dissimilar interchange period for diverse entrances in routing tables. Routing table entries for a certain target are modernized rather with the neighbours taking little occurrence, as the distance to target rises. The problem with the FSR routing is that through the growth in network scope the routing table also become bloated.

2.3.1.2 Temporally Ordered Routing Algorithm (TORA)

The TORA-Temporary Ordered Routing Algorithm, is a part of family of link reversal routing. In TORA a cyclic graph is built through which the flow of packets is directed and their reachability to all nodes is ensured. The node will construct directed graphs by broadcasting query packets. If the query packet is received and the node do not have downward link to destination, it will drop the packet. But when a node does have a downward link it will broadcast a reply packet, which will update the height of receiving node. However, the height is only updated if the height of other packets is greater than replied packet. The TORA has an advantage of giving route to network nodes, however, these routes are difficult to maintain in VANET.

2.3.2 Position-based routing protocol

This class of routing algorithms is part of Position based routing. Both of them select their next forwarding hops by using geographic positioning information. No global route is required to be created and maintained between sending and receiving node as in position based routing the hop neighbour closest to destination receives the packet and it doesn’t need any map knowledge. This feature makes position based routing beneficial. Its two sub-divisions are Position-based greedy V2V protocol and Delay Tolerant Protocols.

2.3.2.1 Position Based Greedy V2V Protocols

In this type, the message is forwarded by the route to the farthest neighbour that is in the direction of next destination. Position of intermediate node, its neighbour and destination is required in greedy approach. They are also called min delay routing protocols as they transmit data packets to their destination as soon as possible. GSR, GPSR, SAR, GPCR, CAR, ASTAR, STBR, CBF, DIR and ROMSGP are various kinds of position bases V2V protocols.

2.3.2.2 Geographic Source Routing (GSR)

The greedy forwarding of message was incorporated in the GSR and it was started being used in VANET. Prior to it, GSR was used in MANET. Perimeter mode is a utilizing strategy that GPRS uses when there are no nodes in the direction of destination at any hop. Perimeter mode has two components- distributed planarization algorithm and online routing algorithm. Former one removes redundant edges of connectivity graph and converts it into planar graph while latter one operates on plan graph.

The VANET uses perimeter mode of GPRS. Upon any blockage or gap occurring in GPRS, algorithm enter perimeter mode and operation is started by plan graph routing algorithm. Messages are sent to intermediate neighbour instead of farthest node. However, long delays are introduced due to large number of hop counts. Rapid movement of vehicles causes dissemination of messages to long distances as it introduces routing loops. GPRS is not considered efficient method of VANET as it doesn’t take into account vehicle density of street while using street map and location information of each node.

2.3.3 Broadcast Routing

When message is required to be disseminated beyond transmission range broadcasting i.e. multi hops are used. It typically uses flooding to send a packet to all network nodes. This does deliver the packet but nodes receive duplicates and bandwidth is wasted. Traffic, weather and emergency, road condition among vehicles are shared and advertisement and announcements are delivered by VANET using broadcast routing. It performs better for smaller number of nodes in VANET. BROADCOMM, UMB, V-TRADE, and DV-CAST are some of the kind of broadcasting routing protocol.

2.3.3.1 BROADCOMM Routing Protocol

The protocol behaves in a manner similar to flooding – the base routing protocols meant for message broadcasting. The highway in BROADCOMM is divided into virtual cells that move in a way similar to vehicles. BROADCOMM relies upon hierarchal structure meant for highway network. The organization of the nodes in the highway is systemized into two standards of hierarchy: the first level comprises of all the nodes in a cell whereas the second level is characterized by cell reflectors, which are a few nodes situated nearby the geographical focus of cell. The cell reflectors manage the emergency messages received from the same members of the cell or close neighbours and act for certain level of time as cluster head.

2.3.3.2 Urban Multihop Broadcast Protocol (UMB)

The sender node in UMB attempts to choose the most distant node in the broadcast direction for conveying and acknowledging the packet devoid of any previous topological information. The UMB protocol has ability to act successfully at higher vehicle traffic densities and packet loads. The issues of interference, packet collision and unknown node problems during the process of message distribution in multi hop broadcast can be resolved through UMB which is specifically designed for this purpose.

2.3.3.3 Vector Based Tracing Detection (V-TRADE)

The basic concept of (V-TRADE) is the same as that of unicast routing protocols Zone Routing Protocol (ZRP). It is based on GPS based message broadcasting protocols. Depending upon the movement information and position, V-TRADE categorise the neighbours into numerous forwarding groups. In each group, message rebroadcasting involves a small subset of vehicles. The bandwidth usage may be enhanced by V-TRADE but the selection of subsequent forwarding node in every hop incorporates some routing overheads.

2.3.3.4 Geocast Routing

Routinely, Geocast is defined as a forwarding zone where it orients the flooding of packets in an organized way so as to reduce the network blockage and message overhead. These problems may arise due to unorganized flooding. It is basically a region or location based multicast routing. The aim of Geocast routing, which is considered to be a regional multicast service, is to transport the packet within a particular geographical location, from a source node to all other nodes (Zone of Relevance ZOR). The vehicles in Geocast routing that are not within ZOR are not cautioned to avoid excessive rapid reactions. Network partitioning is one of the major limitations of the Geocast. Other may include the inappropriate neighbours that may resist the forwarding of messages. The Geocast protocols include IVG, DG-CASTOR and DRG.

2.4 QoS PARAMETERS FOR VANETS

Specified under the IEEE standard 802.11p, the dedicated short range communication (DSRC) is provided. The specifications for both the Physical layer (PHY) and for the Medium Access Control layer (MAC) are provided by the IEEE 802.11 standards [83]. To get an improvement in the security and QoS, the MAC extensions have been introduced. The manner in which the physical layer operates is defined by the physical layer extensions. The IEEE 1609.x family of standards defines the PHY and MAC layers for the VANET planned communication, Wireless Access in Vehicular Environment (WAVE) [84]. There are two categories of the transmission technology for the Intelligent Transportation System (ITS) such as, Vehicle-to-Infrastructure communication (V2I) and Vehicle to Vehicle communications (V2V). An effective routing protocol is used to obtain the V2V according to the specific characteristics of the road information, relative car movements and the restrictions in the applications [85] [86][87].

2.4.1 Data Latency

The time duration between issuing a message from the sender and till the moment it is received by the receiver vehicles, is termed as the data latency. The transmission time delay should be considered in the sending and receiving of the data packet. It is used to calculate the throughput rate [88].

The topology of the network is changed quickly by the high speed moving vehicles, which lead to a potential link breakage of the delivering routes. The value of the data latency is high owing to a high probability of link breakage [89].

2.4.2 Efficient Bandwidth Utilization

The system's performance is deeply affected by the utilization of bandwidth. The available bandwidth is under estimated, if the bandwidth estimation is lower than that of the network capacity, while if the available bandwidth is more than estimated, then the estimated bandwidth is higher than that of the network capacity. An inaccurate evaluation will lead to a decrease in the system's performance. In comparison to the other wireless networks, the bandwidth utilization is more in VANET, owing to the high movement in nodes. The ability to integrate vehicles with equipments of different network characteristics is an important consideration in the design of the VANET. There may be variations in the range and bandwidth of the vehicle. Homogenous nodes are assumed to be hampered by the different properties of each protocol. Less bandwidth will be consumed by the vehicles with GPS information and velocity. The interference range was used by the authors in [90]to evaluate the bandwidth consumed. Communication between the nodes is easy, if the nodes are in the interference range. The sender will check its neighbour's bandwidth with its own bandwidth within an interference range before sending information. The sender will share its own bandwidth, if the neighbour has less bandwidth. A node will listen to its transmission channel and the ratio of the idle time and the busy time for the predefined interval to estimate the sender local bandwidth.

A roadside base station is used to assist the routing protocols in [91] and AODV [92]. The proposal for the bandwidth calculations is matched by the AODV. It should also be made sure that the bandwidth is appropriate for routing. The transmitted traffic determines the bandwidth utilization. The traffic was categorized as either real time or non-real time..

More bandwidth is used by the roadside base station in VANET, as each base station has more overhead and all the time is associated with every vehicle. A base station will inform the other base stations about its inability to receive routing data, if it has a scarce bandwidth.

2.4.3 Packet Delivery Ratio (PDR)

The ratio of the number of packets received by the destination to the number of packets sent by the sender is called the packet delivery ratio. The packet forwarding should consider this as the most important parameter. Other factors such as, packet size, group size, action range and node mobility also affect this ratio. At 100% packet delivery, the message transmission is considered as robust. By 100% it is meant that before the time expires, the receiver may receive all the packets sent by the sender node. The author in [93] explains the time for all the packet delivery for various VANET applications..

The selection of reliable routes is the main concept for the PDR. A longer predictable lifetime and less number of hops are required in the reliable routes. Instead of the shortest paths, the sender must select the other routes, as the shortest paths may break soon and require high maintenance. The number of packets transmitted on a route, irrespective of the uncast per node and the matter broadcast, will determine the routing overhead. In addition, the following can also be considered:

- The total number of routing packets received per node.
- The total number of routing bytes received per node.
- The number of routing packets. These are counted with the sequence number and are calculated on per node basis.

Two nodes are required to maintain the movement patterns in the link availability prediction during the prediction time [94] . The routing overhead will determine the availability of the route. One transmission is equivalent to each packet forwarded. The number of route changes happening in a simulation is related to this metric. Accuracy of the results in a routing performance are not the only benefit obtained from a realistic mobility model, but it is also helpful in predicting the next position of the vehicle and helps in the decision making process for the routing protocols in the VANET. The ability to provide robust routes was used to balance the hop minimization in [95]. A new metric known as the ‘expected disconnection degree’ (EDD) has been introduced under the global perspective of connectivity. The quality of a route based on factors such as, speed, vehicle position and trajectory are used as basis for the evaluation of the quality of a route through EDD. To indicate that a given path would be broken during the time interval is a part of the probability evaluation. A low EDD route is selected as a result. Assumptions about the stability of the route along a sequence of nodes should be made before the knowledge about the vehicle positions, speeds and trajectory are obtained. More stability is expected from routes that are moving in the similar direction at similar speeds.

A safeguard is provided in [96] to resolve the issue of path detachment. The connectivity route is mechanically adjusted by the safeguard when the direction or speed of the sender or the receiver changes.

A multicast or unicast connection is not possible due to the highly dynamic nature of the nodes [97, 98]. The connection between the two nodes will determine the packet delivery. Clustering, location aware broadcasting and aggregation [99] can be used as intelligent techniques to increase the performance of packet delivery ratio [100].

2.5 CHALLENGES OF VANET COMMUNICATION

The future application of the vehicular networks can be greatly hindered owing to the challenges posed by the special behaviour and characteristics of the vehicular networks. To deploy the vehicular networks, various technical challenges [20] need to be solved that will help in the provision of services for drivers and passengers in such networks. Scalability and interoperability within these networks need to be addressed. Various wireless technologies should be considered in the interoperability of the various protocols and mechanisms, while numerous vehicles should be covered in the scale of the network. The following sections provide further details about these issues.

2.5.1 Security

The future development and application of the vehicular networks are greatly dependent on the vehicular communication security [26], which is the greatest challenge faced in the vehicular networking. The convenience in the usage of service discovery protocols should not be an excuse of compromising the privacy and security of the networks. Services in foreign networks will be used more and more by the passengers. This in turn will increase the demand for service discovery, which will lead to huge security problems for the network users and providers as well. To secure the communication between participants, authorized and secure services access, it is important to introduce innovative solutions. These solutions should maximize the applicability of the concept of multihop authentication and communication [27]. This allows the extension of infrastructure coverage with minimum costs for the network operator and allows a secure communication. In addition, these solutions should also utilize the distributed based authentication as well to increase their effectiveness. Communication should be provided between the vehicles through an adequate security framework and should also allow various service accesses. Trust, authentication, access control and authorized and secure service access should be provided by a set of security mechanisms, which are suited to the vehicular network environment. The process of re-authentication can only be facilitated if the topic of authentication optimization is thoroughly studied for both the infrastructure based and infrastructure less communications. The vehicle mobility will be using the process of re-authentication. The security of communication and service delivery in vehicular networks is vulnerable to node behaviour and should be given importance. To allow a successful communication between the vehicular networks, the cooperation among nodes is an important factor owing to the open and dynamic environment of the vehicular networks. To save power and bandwidth, the nodes may act selfishly and not forward messages for others. They may also act so due to privacy and security concerns. Cooperation among the nodes should be established by identifying selfish behaviours among the nodes through an adequate mechanism.

The security of the message content is a major concern besides introducing and managing trust in the vehicle-to-vehicle communication. To allow the usage of information as soon as possible, it is important to verify the content of the received message within a short time period (Table 2-2).

Table 2-2: Comparison of VANETs applications

Applications	Priority	Allowable Latency (ma)	Network Traffic	Message Range (m)
Life-Critical Safety	Class 1	100	Event	300
Safety Warning	Class 2	100	Periodic	50-300
Electronic Toll Collection	Class 3	50	Event	15
Internet access	Class 4	500	Event	300
Automatic parking	Class 4	500	Event	300
Roadside service Finder	Class 4	500	Event	300

Few main issues should be addressed by the VANET security as shown in [101]:

2.5.1.1 Authentication

The communication needs to be verified as authentic by the authentication service. Disseminating messages should be sent by vehicles as a response to the events. The legal senders will generate the messages. The senders of these messages need to be authenticated.

2.5.1.2 Integrity

The stability of a stream of messages is dealt by the integrity service. Their job is to make sure that no modifications, insertions, recordings or replays are added to the messages and the messages are received as sent.

2.5.1.3 Confidentiality

The communication content is deemed as confidential through this service. The privacy of the drivers against the unauthorized observers is guaranteed through this service. The security and the confidential issues are totally related. The personal data needs to be protected when the users are accepting it, as the vehicles are expensive devices. The private data can be protected through a variety of ways. Data can be collected from a number of source nodes and evaluated to protect the data.

2.5.2 Accessibility

The vehicular network is different from the conventional ad hoc network, as it has to deal with the various types of network densities and the speedy changes in the wireless link connections [22]. Highly dense networks are more likely to be created during the rush hour traffic in the vehicular networks on freeways or urban areas, while in sparsely populated rural freeways or during the late night hours, the network will experience frequent fragmentation. The vehicular networks handle a wide range of application varying from safety to leisure. Various transmission priorities are allowed according to the application type by the routing and the dissemination algorithms [23] that need to be efficient and should be adaptable to all types of characteristics and applications. Analysis of the routing algorithms have been the focus of many research works, as attempts are being made to deal with the broadcast storm issues in a highly dense network type [24],[25]. Until now the ability of the vehicular network to penetrate has been very weak and therefore these networks need to be relying upon an existent infrastructure to support the wide scale of deployment. Full penetration ability is expected to be developed in these networks for the future with a lesser infrastructural support required. To develop an efficient and a reliable routing protocol for the support of diverse network topologies, the need to address the disconnected network problems in the research is imperative.

A loss in accessibility can be experienced through attacks. Attacks are faced by even the most robust communication channels and these attacks will bring down the network. Alternate methods should be employed to support availability.

A digital signature is an important feature of the VANET, which acts as a building block. An important security requirement is the infrastructure for communication or communications inter-vehicle through authentication.

2.5.3 Scalability

A reasonably small performance degradation or even network outage can be used to increase the number of users or the traffic volume, which is termed as scalability. No change is introduced in the system's components and protocols.

The network density and the application type should be considered in the dissemination algorithms for the message dissemination. For instance, broadcast type message dissemination should be used in the safety related applications, which will assure that the message is sent to the required cluster of vehicles while also avoiding the broadcast storm. The best-suited option for message transfer in a non-safe application would be through a unicast or a multicast transmission.

2.5.4 Reliability

Multihop communications are experienced by the vehicular networks similar to the ad hoc networks, which has the potential to provide a virtual infrastructure among the moving vehicles through the extension of the network operator fixed infrastructure. A major challenge is created by the multihop wireless communication [21] with respect to the reliability of communication. A continuous adaptation to the dynamic environment of the vehicular networks is required with the efficient MAC protocols put in place while also giving due consideration to the message priorities of some of the applications. A need for fast association and low communication latency should be satisfied between the communicating vehicles despite the dynamic nature and the high mobility of this network. This is required to increase reliability for the safety applications with importance given to the time during the message transfer. This also needs to be done to assure quality and a continuous service for non-safety applications. The heterogeneous communications that will take place between the various wireless technologies also need to be considered by the MAC protocols.

It is hard to assure reliability of message reception and acknowledgement between communication vehicles on opposite direction, owing to the brief time of communication. Majority of the messages that are transmitted will be periodic broadcasted messages in the vehicular ad hoc networks. The state of the vehicle is declared to the neighbours through the periodic broadcast messages. More reliability is needed in the case of the broadcasted messages. A group of vehicles carrying the messages to improve the reliability was proposed by the authors in [102].

2.5.5 Media Access Control

Modifications need to be introduced in the media access control (MAC) layer, to create a wide scale vehicular ad hoc network [100]. Access to the shared medium, which is the wireless channel, is the main purpose of MAC layer. A large number of collisions will occur and the sent data would be lost, if there is no method used to coordinate the transmission of data.

2.5.6 IP Configuration and Mobility Management

The vehicular Internet access is provided by the vehicle-to-infrastructure architecture in addition to the other Internet related services to drivers and passengers, which creates a promising future for the vehicular network. But the infrastructure is disadvantaged by the mobility management and IP address configuration issues. The service quality and service continuity can be threatened by these issues. The IP address configuration should be conducted in an automatic and a distributed manner according to the characteristic of the vehicular network. The ad hoc networks are also facing this issue due to a lack of a standard for IP configuration. In the case of the vehicular networks, this issue gets even more complicated. Various standardization bodies are trying to solve this problem, all of the international committees defining architectures for vehicular communication have included a native IPv6 stack in their protocol stacks, namely, IEEE 1609, ISO TC 204 (CALM), C2C-CC, and the ETSI TC ITS [28-31] in addition to the efforts of IETF through the Autoconf WG for developing IPv6 solutions for ad hoc networks including vehicular network scenarios [32].

This has emerged as a crucial issue for non-safety applications for the mobility management as the dissemination of messages are not based on the broadcasting. Commercialization of services in vehicular networks is under a risk due to the absence of mobility management process. As all the Internet related services cannot guarantee stability and quality in their services, the vehicle-to-infrastructure architecture loses its importance.

2.5.7 Application Distribution

New distributed algorithms are required for building distributed applications that include passengers in various vehicles. As a result, the management of the group of participants and data sharing among the distributed programs require a distributed algorithmic layer. The neighbourhood instability could be treated as a fault by these algorithms. Fault tolerance techniques should be applied in the case of low reliability in communication. In this respect, the mobile participants in the vehicular networks should be given service access, with an acceptable quality, simultaneously with the exchange of messages between the vehicles.

2.5.8 Business Models

Service commercialization in the vehicular networks has to overcome the challenges created by the business models. Business models should be profitable for telecom operators and service providers to facilitate them in opening a new business that would let them attract more clients through service promotions. The cooperation between the mobile clients in the vehicular networks should be considered in making the business models cost effective and attractive for the clients. The nodes can be rewarded according to their role. The cooperation between the mobile nodes can be stimulated through special payment strategies where according to the contribution of each participant, a sort of remuneration can be proposed. As a result, a custom billing system is required with a special accounting system, which will also ensure an inter-domain accounting. A need for authentication and integrity is enforced in the system through an assurance provided by the operator for a secure communication, authentication and authorization between the clients to protect their data. The delays and constraints in the processing should also be considered. The data security will also help in the billing for the services utilized.

2.6 Conclusion

To conclude this chapter, we have to point out that VANET is not a new research field in network communication. MANET and VANET both share some common features of network. In this chapter, we have presented brief overview of VANET and the recent standards for wireless access in VANETs. Moreover, we viewed the methods and techniques used in VANET routing and explained few QoS parameters such as data latency, efficient bandwidth utilization and packet delivery ratio of VANETs, which affects the performance of network communication. Listing the challenges of VANET communication was important to finish up our complete presentation for VANET literature.

However, the performance of VANETs depends heavily on the mobility model, routing protocol, vehicular density, driving environment and many other factors. There are still quite a few parameters that have not been carefully investigated yet like network fragmentation, delay constrained routing, efficient resource utilization, and delay tolerant network. Focus of our future work would be on the above said parameters. Nevertheless, VANET shows its unique characteristics which impose both applications and challenges to the research communities.

CHAPTER 3

Data gathering and Dissemination techniques

Chapter outline:

- Introduction.
- Related work.
- Applications.
- Knowledge contribution.
- Performance metrics.

Chapter 3

3 Data gathering and Dissemination techniques

The literature from the following main fields of applications addresses the basic traffic scenarios such as, Traffic safety, Traffic efficiency and value added services. Other services will be allowed as applications by the architecture[103], which will help in the system introduction and also provide a sustainable business and operation model. An overview on the system idea is provided by a number of graphical illustrations (خطأ! لم يتم العثور على مصدر المرجع.) such as, connecting vehicles, roadside infrastructure and backend infrastructure. The traffic safety and efficiency was developed through this example.

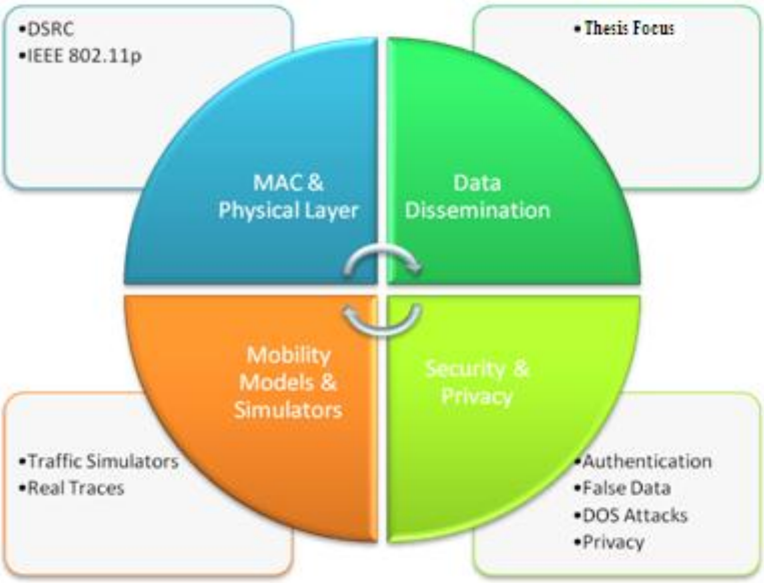


Figure 3-1: Basic Scenarios

Services such as lane departure warning, speed management, headway management, ghost driver management, hazard detection and various other services are supported by the traffic safety field of applications [104]. Services such as, urban traffic management, lane management, traffic low optimization, priority for selected vehicle types will be supported by the traffic efficiency applications. Journey planning, both pre-trip and on-trip travel data and location-based services will be the value added services provided by the applications. According to the implementation policy, the application for the road user charging will integrate into one or more of these fields [105].

The study has focused on many standard organizations, while technological developments are underway for the vehicular ad hoc networks and standardization of IVC, which requires a lot of trials and testing. To allow a wide scale usage of these networks, it is imperative to solve the technical challenges faced by these networks, in addition to the present standardization activities. The potential usage of IEEE 802.11p/WAVE standard, integration of multiple wireless technologies, data security, congestion control, data transport and others are still under debate.

To make this new technology a success, marketing strategies also need to be focused. It is expected for the next 3-5 years that the car models still in prototyping phase equipped with the Wi-Fi (802.11a/b/g) and DSCR technologies, such as BMW, Mercedes, Fiat, Ford, Toyota and Nissan, will be ready for usage on the road.

A static or a motionless environment and receivers are needed for a transmission to a specific address. Each message needs to be sent only once after the neighbour has been determined, which will lead to cut down in losses of time and capacity. Directional antennas and controllers may be required as special hardware for this solution.

3.1 Introduction

Current traffic information systems are centralised vehicular applications using technologies such as Traffic Message Channel (TMC), to provide information about road traffic conditions. However, it (i) suffers from long delay times (due to the centralised approach), (ii) averages information for large geographical areas (due to cost-sensitiveness of detailed sensor networks and limited radio resources) and (iii) does not have the opportunity to provide services for locally interesting and time-critical applications[106]. Moreover, as discussed in [107], implementation for complete coverage would require new as shown in [108] through a case study. Such systems would, for example, not meet the requirements of an accident avoidance application, because they have long delays and would require large capacity due to the large geographical area of service. In contrast, VANET-based systems can have short delays and the capacity can be reused more efficiently. Moreover, the structure of VANET can be distributed, which improves the level of independence, scalability and stability.

The vehicular application can be classified based on the improvement of safety and the time-critical nature of the service. Examples of application categories are safety applications (e.g. avoidance of collision, information about loss of control of the vehicle), which can improve road safety significantly (a new level of road safety assistance), but are highly time-critical. In comparison, a service about traffic condition information is less time-critical, as discussed in [109], due to the low level of variation of traffic conditions in a short time (traffic jams have to build up) and it has a lower impact on improvement of road safety than, for example, traffic accident assistance applications. This categorisation can be extended with expected improvement of safety or comfort level e.g. (example for safety) intersection collision avoidance; (for comfort) dissemination of free parking places in large parking lots [110].

It is important to note the significance of understanding the requirements of vehicular applications. Different applications might have significantly different needs for information-distribution properties (e.g. delay, distance). Therefore different dissemination strategies (including technology employed) need to be employed for various vehicular applications. We aim to find a model to study the effect of these diverse dissemination strategies on information spreading and how we can employ those strategies to identify the boundaries of sensed road conditions.

3.1.1 Dissemination strategies

Most VANET-based systems assume a priori knowledge about the underlying road network, which is usually interpreted as a weighted graph [111]. A common approach is to divide the roads into sections with different weights, but certainly not with the same length. The weights are given according to a certain property, which can be physical like a message traversal delay [112] or stochastic probability based on the distance between vehicles [113].

Vehicles are assumed to be equipped with sensors that provide data about the status of the vehicle e.g. speed, geographical position, temperature or even sensors to detect bumps, acceleration [114] or honking [115]. This status represents local information about a geographical area at a certain moment. Distribution of local information needs to be detailed within closer vicinity, and coarser with the increase of distance, as proposed in [116]. For example, a driver would be interested in the average speed of vehicles way ahead, but the exact speed of a vehicle 100 metres ahead to be able to avoid a collision.

Based on the **type of communication** three main categories can be introduced. First are vehicles sending their messages via a cellular system – and/or Road-Side Unit (RSU) – to a central server or to another peer as described in [117]. The disadvantage of such systems is the high cost of construction and maintenance of the infrastructure.

Second is the group of systems that do not use cellular systems, but another dedicated system like Urban Multi-hop Broadcast Protocol, as suggested in [118], or more general communication technologies for VANET (e.g. Wi-Fi) [119]. Last, a hybrid solution, a combination of both systems, seems to be the most powerful but most complex approach.

The fundamental idea of information dissemination for VANET is to have **periodic broadcast** messages for routine information, and event-driven messages for causes of emergency situations. Most of the time vehicles send messages about their current status (velocity, heading) and/or knowledge about the network performance (e.g. delay of certain links, density of cars at a road section). Data from multiple inputs are processed and a new message calculated and transmitted if the routing protocol requests it. The aforementioned information should be aggregated to fulfil scalability requirements.

Flooding, as a distribution method (where each message is sent to all) however, is not scalable, consumes large amount of energy, bandwidth and memory space while being inefficient. Therefore, techniques to reduce network load are required. The main goal is to provide less information with a higher distance to keep the system scalable, as shown in [120]. Atomic information (e.g. velocity) is aggregated with information from other nodes [106] or about road sections [112] to have aggregated messages. The message has to be aggregated with new information from the current node before another broadcast takes place.

For **aggregation**, geographically hierarchical approaches are being introduced. The level of hierarchy can, for example, be represented in different resolutions of the road network between landmarks, as suggested in [118]. Another approach is to form grids of different sizes based on various sizes of geographical area, as shown in [121]. In both cases the amount of information about a faraway geographical area is reduced, therefore data needs to be maintained as well. Dynamic store and forward approaches are used to maximise the probability that two messages are going to be present at the same time at the current node and it will have a chance to aggregate them into a single message and transmit it.

We have also identified an evolution in flooding and directed broadcast transmission to the target area to a distributed (Content Addressable Network (CAN)-based) subscriber/publisher approach [122]. The nodes subscribe to certain groups of information (for example, information about certain road sections on the route ahead) and push out messages in a distributed fashion (dissemination is distribution as well as the location of the stored data). Vehicles send (push into the network) information about their observations and abrupt events.

Data is preferably stored in a distributed fashion like CAN, which has a d dimensional key space that is used to give the address of a certain area based on its geographical position. It allows the possibility of reaching nodes that are responsible for storing data about a certain area without knowing their address

3.1.2 Dissemination characteristics

3.1.2.1 Keeping information alive

Information must migrate and be kept alive. This is achieved by retransmission. A message that is received and retransmitted gains two things. It survives a period in time, and it might migrate to new receivers. A retransmission can be done in two ways: either it retransmits to specific addresses, or it retransmits to everyone.

Transmission to specific addresses is most effective if the environment and receivers are static or motionless. Once the discovery and determination of neighbours is finished, each message needs to be sent only once, which saves capacity and time. This solution might demand special hardware such as directive antenna and controllers.

Flooding is like opening a door with a sledgehammer instead of a key. It is big, noisy and brutal, but it gets the job done. The biggest problem with flooding is the sheer number of messages that are received, when each node transmits all new messages to any receiver within reach.

If there are 10 receivers within reach (Figure 3-), this will cause the sender to receive 9 messages that are of no value. If all the other receivers can reach nine nodes, 90 messages are wasted. This will unfortunately introduce interference, and possible loss of each other's messages; the message will be received n*(n-1) times

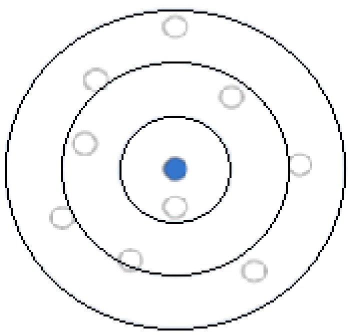


Figure 3-2: Flooding to nearby nodes (n=10)

The problem that presents itself is that we do not have a master in the network. Then who is going to be responsible for updating the information in the system? With no master the responsibility lies within each vehicle. An approach to this is presented in this thesis.

3.1.2.2 Keeping the information consistent

The mechanisms used to keep messages alive might cause problems with keeping the information consistent and updated. Retransmissions and replication might produce duplicate messages. This introduces the need for telling the messages apart.

The information in the system depicts the real environment as truthfully as possible. As time passes, the conditions – once observed in the environment – might have changed, moved or disappeared.

A major issue is that there might be many different interpretations about what the 'truth' is. Each vehicle, or node, in the system might have a slightly different perception of what is the overall status in the network.

A bigger problem is the arrival of new vehicles. How can they get an impression about what the status is?

The vehicles most likely to have the most complete picture of what the status is in the network are probably those that are closest to the centre of the network. These vehicles have the highest probability of having received all messages that have migrated through the network.

A new vehicle will have difficulties discovering these centrally located vehicles, so an easier solution might be to rely on the nearest vehicle instead. Due to the many interpretations about status, it is not enough to ask just one neighbour. A majority vote between any vehicles within reach would provide a fairly good estimate about what the status is at this part of the network. This is definitely a 'best-effort' task.

3.1.3 Infrastructure

The goal is to produce a robust, self-configuring and autonomous network. If the network is reliant on infrastructure the network might be limited to operations in areas where the infrastructure is in place.

It is better for the network to be independent of existing infrastructure, but use whatever resources are available. A lamppost equipped with the same communications equipment as the vehicles might be regarded as a very slow-moving vehicle (as seen from the network). This permanent equipment can be used to supply the network with important information from ‘the outside’ (i.e. traffic information or congestion warnings) and might gather information for some centralised services (statistical information about troublesome areas).

Permanent infrastructure might be helpful to cover ‘black holes’ or difficult positions (i.e. can cover both sides of a difficult corner). The directivity and mounting height of the antenna plays a major part in the connectivity [9]. On a vehicle the most natural choice is an omni-directional antenna. The mounting height of this is limited by the vehicle and aesthetic concerns. On a permanent structure it is possible to use very different equipment depending on the location, and needs, of the area.

There is another type of infrastructure that might be useful. Buses and trams use a predictable route at predictable times. The bus or tram might work as a buffer, they get information from a source, and they can release this information when they get to new areas. A moving infrastructure comes in handy for gathering statistical information, as it covers a large area at regular intervals.

3.1.4 Applications built on Inter-Vehicle Communication (IVC)

The vast class of IVC applications can make driving safer and more comfortable for vehicle occupants [123] [124]. IVC services can be achieved through different methods by exchanging data between vehicles and sometimes through roadside infrastructure units. Figure 3- shows the classification of vehicular communication applications. It helps us to focus on specific equipment to fulfil services and solve diverse problems.

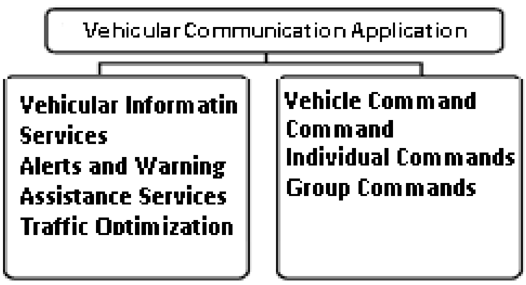


Figure 3-3: Classification of vehicular communication applications

To clarify the exchange approaches we propose in this project, it will be useful to present some examples of the possible road situations (conclusions) we can come up with based on sharing individual car sensor data.

Some road conditions can either be derived (assessed) from the activity of the individual cars' electronic helpers like (lights (ON/OFF) or windscreen wipers (ON/OFF), or alternatively, sensors embedded in the individual vehicle may provide this information. The summary in the Table 3-1 is summary of the most common road situations with the causes of those situations considered as Non-conclusive Individual Car Sensed Data:

Table 3-1: Possible Road Situations (examples)

Individual Car sensors data	Possible Reasons
Windscreen Wipers (goes ON)	Rain / cleaning / By Accident
ABS Control (Slippery Road)	Snow / Oil spot / bad tires / Bad driving
Fog light (ON).	Fogy / By Accident / Since yesterday
Movement Speed (Slow).	Traffic Jam / Driver using the phone/radio
Reduce Speed (Unexpected)	Hazard Ahead/saw a friend or interesting place

But if we can share this data among all nearby cars, by Combining Individual Car Sensed Data, the result will be looks like Table 3-2 (the numbers quoted in Table 3-2 are representative rather than conclusive for the condition and represent a matter for future investigation in real-life experiments).

Table 3-2: Examples of some situations

	Individual Car sensors data	threshold (example/case)	Possible Conclusion
1	Windscreen Wipers	30% of cars = ON	Rainy
2	ABS Control.	5 cars = ON	Slippery (snow)
3	Slippery Oil Spot.	2 cars	Slippery spot
4	Fog light.	50% of cars ON	Foggy
5	Traffic flow Speed.	(60%) Slow/Stop	Traffic Jam
6	Reduce Speed.	5 cars within 1sec	Hazard Ahead

We can consider that column two contains, in effect, Search Condition Limitation numbers. Assuming that this Search Condition Limitation is reached then a zone with the condition (third column) is identified and the information system can tell other nearby cars to be aware of the situation within that zone if they plan to pass through it.

Each message needs to be in a format that is small in size and rich in content. Two methods of collaboratively collecting data by exchanging messages based on vehicle-to-vehicle communication have been identified.

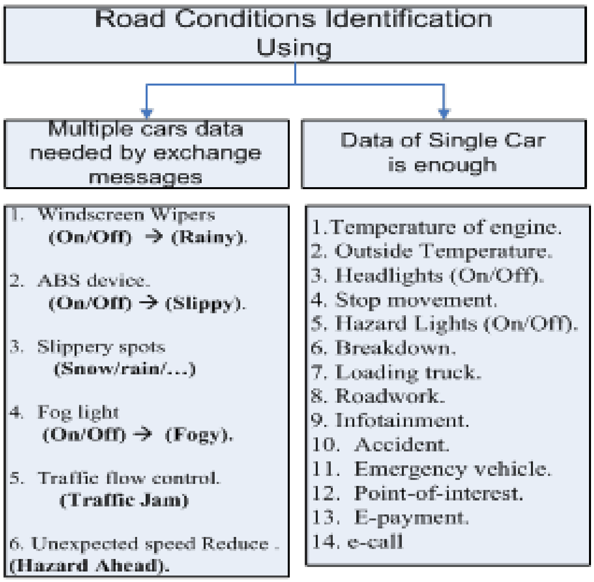


Figure 3-4: Single or Multiple cars needed for spaceific situation

Figure 3- and خطأ! لم يتم العثور على مصدر المرجع. classifies the recognisable road conditions based on the number of cars needed for it. The examples are of discoverable road situations that need just a single car to identify the road condition/problem to generate a warning message and broadcast it to all nearby cars, and of road conditions that need multiple cars' information by exchanging messages (their data) to identify the conditions of the road they are on. So, two stages are needed: first, exchange of messages to discover whether the road has a certain condition or not; and second, generation of a warning message to inform all nearby cars of the discovered condition, if any.

Table 3-3: Detailed Information for each Raod Situations

Inter-Vehicle- Communications Based on VANET

City Scenario (Situations – Parameters)

Parameters \ Situations	Single Nodes														Multiple Nodes (Conclusion)								Travelling Parameters
	1. Temperature of engine.	2. Out side Temperature.	3. Headlights (On/Off).	4. Stop movement.	5. Hazard Lights (On/Off).	6. Breakdown.	7. Loading truck.	8. Roadwork.	9. Infotainment.	10. Accident.	11. Emergency vehicle.	12. Point-of-interest.	13. E-payment.	14. e-call	1. Windscreen Wipers (On/Off)(Rainy)	2. ABS device (On/Off)(Slippy).	3. Slippery spots (Snow/rain/…)	4. Fog light (On/Off).(Fogy).	5. Traffic flow control(Traffic Jam)	6. Reduce speed (Hazard Ahead).	7. Stop Movement (Traffic jam).	8. Headlights (Dark).	
Massage Context:																							NO
1. Massage Age (still live or not).	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
2. Time since last Broadcast/Forwarding.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
3. Time since last reception.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
4. Number of massage sent/forwarding times.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
5. Waiting Time to forwarding.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
6. Waiting time to re-forwarding/regenerating.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
7. Time to wait if "channel not free".	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Vehicle Context:																							Yes
1. Driving direction.			√	√	√	√	√	√		√	√					√	√		√	√			
2. Distance to last forwarder.																							
3. Current number of neighbour nodes.															√	√	√	√	√	√	√	√	
4. Distance to/direction of adjacent nodes.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
5. Route flexibility.																							
6. Vehicle speed.	√	√	√		√						√				√	√	√	√	√	√	√	√	
7. Vehicle ID.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
8. Max Speed.			√	√				√		√					√	√	√	√	√	√	√	√	
9. Current road type.					√										√	√	√	√	√	√	√	√	
Information Context:																							Yes
1. Time stamp.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
2. Purpose of travelling.									√			√											
3. Distance to/Distance of the source.		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
4. Information accuracy.																							
5. Information category.	√																						
6. News value.																							
7. Change information(Situation Dynamic).	√	√			√	√										√		√		√			
Communication Context:																							No
1. Bandwidth.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
2. Latency (Important or Not).					√	√	√	√		√	√			√	√	√			√	√	√	√	
3. Average packet size.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
4. Security and privacy.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
5. Communication range.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
6. Guaranteed receiving rage.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
7. Distribution logic implementation(Net/App).	N	N	N	N	N	N	N	N	N	N	N	N	N	N	A	A	A	A	A	A	A	A	
8. Intermittent connectivity (Store-n-forward).	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
Road Context:																							Yes
1. Number of vehicles																							
2. Number of Lanes.																							
3. Road Length .																							
4. Penetration rate.																							
5. Position of Situation.				√		√	√	√		√		√		√	√	√	√	√	√	√	√	√	
Routing Context:																							Yes
1. Medium Hops ID.															√	√	√	√	√	√	√	√	
3. Maximum number of Forwarding.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
3. Maximum travelling distance.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
4. Maximum travelling time.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	

Complexity	Massages Types	Nodes & Situation Zone	Massage ID
1) Deterministic/Non-Deterministic	1) Before Confirming the situation.	1) the node inside the zone.	1) Vehicle ID.
2) Objective/Subjective.	2)Situation Confirmation Massage.	2) the node Outside the zone.	2) Position of Situation.
3) Situation Dynamics:	3) After Confirming the situation.	3) the node at the zone boarder.	3) Time Stamp.
a) Position.		4) Zone boarders.	
b) Intensity.			
c) Shape / Dimensions.			

3.2 Related Work

Designing a data dissemination protocol is still one of the open research questions being investigated in VANETs. Some protocols that have been proposed for Mobile Adhoc Networks MANET are summarised here (Figure 3-):

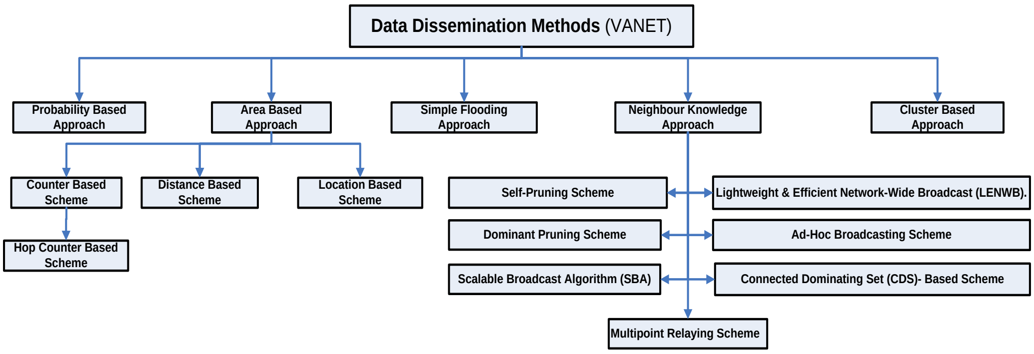


Figure 3-5: Data Dissemination Approaches (VANET)

3.2.1 Flooding approach:

A source node broadcasts a packet to all the neighbours to initiate the algorithm for Simple Flooding [125]. Exactly once, each of these neighbours will in turn broadcast the packets. The process will continue until all the reachable network nodes have received the packet. Messages may tend to become redundant and there will be increased chances of contention, collision and wastage of channel bandwidth within the network in broadcasting through flooding.

3.2.2 Probability Based approach:

The nodes in the probabilistic scheme will rebroadcast with a predetermined probability, which creates the only differing feature from flooding. Similar transmission coverage is shared by the multiple nodes in the dense networks. Nodes and network resources are saved after some nodes are not allowed to rebroadcast randomly. The delivery of messages is also not affected. Much less coverage is shared in a sparse network, which implies that the nodes will not receive all the broadcast packets with the Probabilistic scheme unless the probability parameter is high enough. This scheme is same as flooding, when the probability is 100%. To consider the varying traffic situations while setting the broadcasting probability value dynamically is complicated.

3.2.3 Cluster Based Approach:

The performance of dense MANET can be improved by the usage of Cluster based methods [126]. The nodes in one network are divided into several clusters in this scheme and each has a cluster head node. Only the cluster heads will rebroadcast the message in broadcasting, which will reduce the broadcasting flooding. Statistical and geometric properties are used by the scheme to divide the network into clusters. In cases where the vehicles can distribute to clusters spontaneously and the time period is maintained by the clusters, these methods are the most appropriate for usage.

3.2.4 Area Based Approach:

A sender located only one meter away sends a packet to the node and if this node rebroadcasts, then a low additional area is covered by the retransmission. If the node is located at the boundary of the sender's node's transmission distance in another case, then a significant additional area will be covered by the rebroadcast. Additional coverage area can be evaluated by the node using an AREA BASED Approach for all the received redundant transmissions. Some methods have been suggested ahead:

3.2.4.1 Counter Based Scheme:

An inverse relationship between the number of times a packet is received at a node and the probability of that node to reach additional area on the rebroadcast is shown in [127]. The counter based scheme is based on this notion. The node will start a counter with a value of one after receiving a previously unseen packet and then sets the random access delay (RAD) randomly selected between 0 and Tmax seconds. The counter is incremented by one for each redundant packet received during the RAD. The packet will be rebroadcast, if the counter is less than a threshold value when the RAD expires. In the other case it will be simply discarded. The simplicity of usage and adaptation to local types has made the counter based scheme an attractive offer. This implies that all the nodes will rebroadcast in a sparse areas of the network, while some nodes will not rebroadcast in dense areas.

3.2.4.2 Hop Count Ad hoc Broadcast (HCAB):

After some modifications were introduced in the counter based scheme, the HCAB system was achieved [11]. The nodes initiate a flag R=true and records the initial hop count value HC0 for a message, after the broadcast message is received for the first time. The random delay time RDT value is set between 0 and Tmax by the node. The hop count of the redundantly received message HCx with HC0 is compared by the node, after which the flag R is set to false if HCx>HC0. The nodes will relay this message if R is true, when the random delay expires. On the other hand the message will be just simply discarded.

3.2.4.3 Distance Based Scheme:

The geographical data of the node is used by this such as, the distance threshold value. A RDT is initiated and redundant messages are cached after the previously unseen message is received. All the source node locations are studied to assess if the node is closer than the threshold value distance when the RDT expires. The node will not broadcast, if the node is found closer than the threshold value distance.

3.2.4.4 Location Based Scheme:

The source node in this method will add the geographical location data to the message. The additional broadcast coverage area is then calculated by using the positioning data sent by the source node. The node will not rebroadcast, if the additional area is less than the threshold value and all the future reception of the message will not be considered. A RDT is assigned to the node before delivery in cases other than this. The additional coverage area is recalculated, if the nodes are receiving a redundant message during a RDT. Until the message is rebroadcasted or finally dropped, the process will continue [128].

3.2.5 Neighbour knowledge Based Approach:

The neighbourhood data is exchanged among the hosts in this [129]. This scheme applied two approaches. Firstly, each node will maintain the data of its neighbours in the self-pruning approach, by periodically exchanging the ‘Hello’ messages. The neighbour’s list is first compared to that of the sender’s by the receiving node. If the additional nodes can be covered by the receiving node, then only will the message be rebroadcasted. All the nodes have knowledge about their neighbours reaching to a two hop radius in the scalable broadcast algorithm (SBA), which makes is quite similar to the self-pruning approach.

The manner in which the car to car message exchange can be used to create collaborative data and knowledge generation for the discovery of the road conditions will be considered in the design of the proposed algorithm in this project. The functionality of an intelligent node and the possible message formats will be defined in this project as well [130][131].

3.3 Applications

A full time connectivity is ensured by the VANET to the mobile users on the road. Intelligent Transport System is facilitated by the provision of an efficient vehicle, which allows the control of traffic flow, cooperative traffic monitoring, prevention of collisions and blind crossings. The passengers are allowed to interact and communicate with the other vehicles conveniently through the comfort application. Passengers can send emails, download music or watch movies online through the internet connectivity offered by VANET to the vehicular nodes during the movement.

The industry and academic research community have appreciated the vehicular networking as its usage increases. The efficiency and safety of the future transportation is dependent on the vehicular networking. Various innovative vehicular applications are under discussion after the wireless technology is becoming pervasive and cheap. There are two main types of these applications:

- Safety Related [132, 133]: Applications like the collision alert, road condition warnings, merge assistance, deceleration warnings come under the category of safety related. The timely dissemination of safety critical alerts to the nearby vehicles is the main criteria in this type.
- Internet Connectivity Related [12]: Emails access, web browsing, audio and video streaming are some of the applications coming under the category of internet connectivity. The availability of bandwidth stable internet connectivity is the main focus of these applications.

A more generic framework is assumed by the VANET that includes both the vehicle to vehicle communication (V2V) and limited V2I communication with higher emphasis on the V2V communication, while Infostations and 3G/4G primarily provide the vehicle to infrastructure (gateway) communication (V2I) in the context of vehicular communication [107]. VANET does not have a well-defined V2I communication model and most of the current proposals assume that intermittent internet connectivity is available. A comparative analysis between the pure V2V and a pure V2I based solutions will be presented and the integration of the V2V and V2I functionality will be argued as the best option for the future vehicular applications. A 4G approach is expected to develop from the Well-defined V2I communication infrastructure in VANET, where the opportunistic usage of the best access network is available. The high bandwidth, low latency V2V infrastructure and the delay tolerant internet connectivity based applications will compensate for the latency concerns associated with the safety applications. The V2I infrastructure will address the need for a secure application.

The adoption of the VANET architecture for the future vehicular applications is based on the following parameters:

1) Safety applications need low latency.
2) Interactive and multimedia applications need extensive development.
3) Security and privacy concerns.

Prior to the widespread application of VANET, there are several issues that need to be addressed, although it offers various benefits that will encourage its adoption. Issues of security, privacy and data dissemination techniques are among the challenges.

3.3.1 Examples of VANET's Applications

A number of applications with diverse requirements can use VANET communications effectively. Safety, convenience and commercial related activities can be carried out through VANET. The surrounding roads, approaching vehicles, surface and curves of the roads will be monitored through the safety applications. Traffic management will be carried out through the convenience applications, while driver will be granted entertainment and services as web access, streaming audio and video as part of the commercial applications.

3.3.1.1 Traffic Signal

The technologies of the VANET can be used to create the communication from the traffic lights. A Slow Stop Vehicle Advisor (SVA) will be used for the safety applications in which a slow or a motionless vehicle will broadcast alert message to its neighbourhood. The road congestion conditions are identified and reported by the Congested Road Notification (CRN). This information can prove helpful in planning route and journeys. At the toll booths, the toll collection [119] is yet another application for vehicle toll collection which can take place without stopping the car. Traffic management is dependent on the vehicular networks for instance; road tolling is widely applied through the vehicle to infrastructure solutions.

3.3.1.2 Vision Enhancement

Drivers are presented with a clear view of the vehicles and the obstacles in the heavy fog conditions within the vision enhancement strategy and the vehicles hidden by the obstacles, buildings and other vehicles can be located and notified through this technology.

3.3.1.3 Weather Conditions

An application can update the weather information through the DSRC in cases where the vehicle sensors are not reliable or available. Warning messages will be broadcasted by a vehicle involved in an accident as a post-crash notification. The notification will inform about the position of the trailing vehicle, which can help in taking decisions beforehand or the driver can pass the information to highways patrol for support. Space availability can be assured through the Parking Availability Notification (PAN) in parking lots for a certain geographical area according to the weather conditions. Highway and urban area maps are available for the vehicle that will allow the passenger to avoid traffic jams and accident conditions. The driver can commute to their destination going through the shortest path indicated by the map.

3.3.1.4 Driver Assistance

Driving military exercises can be supported through the vehicular networks, where information can be provided to the driver about an unseen condition. Messages can be sent to inform cars in their locality, if a vehicle has dramatically changed the direction [134] showing abnormal driving patterns. The potential hazards can be identified to the drivers beforehand, which will give the driver enough time to think and react to the situation accordingly. Supportive decision making is another facility provided by the vehicular networks.

3.3.1.5 Automatic Parking

A vehicle can park itself without the need for the driver to intervene through the automatic parking application. A vehicle needs to have an accurate distance estimator or a localization system with sub-metres precision to allow an automatic parking.

3.3.1.6 Safety

Immediate collision warning, emergency message dissemination, highway rail collision avoidance, forward obstacle detection and avoidance, left/right turning assistant, lane change warning, stop sign movement assistant and road condition warning, cooperative driving and intersection decision support are among the safety applications offered by the system [135, 136].

3.3.1.7 Searching Roadside Locations and vehicle's Direction

The GPS sensors and database can extract data from the nearest roadside base station, which will calculate the data to help the drivers new in the locality to locate shopping centres and hotels.

3.3.1.8 Entertainment

Passengers spending long time in transit can be entertained through a number of applications. Passengers can play games and communicate through FleetNet [137] that will provide an internet access and a communication system between cars in the same vicinity. These applications cannot be addressed by pure V2V bases solutions. VANET are equipped with a V2I support system, so it is necessary to have a V2I infrastructure as well.

Life critical safety applications can be supported by the VANETs. These applications may include, warning applications, electronic toll collection, internet access, automatic parking, roadside service finder, etc. Parameters such as, priority, latency and network traffic and message range are used in the comparison between the above applications. This comparison is shown in the خطأ! لم يتم العثور على مصدر المرجع.

There are two categories for the main application of VANET which are; safety and non-safety application. A broadcast communication is used in the safety applications, while on demand communication is used in the non-safety application, which are usually based on requests.

3.4 *Knowledge contribution*

Before describing the algorithm, let us clarify the big picture to put the work in its context compared with the existing systems. Those systems can be divided (theoretically) into three levels each one with its own technologies and role (Figure 3-).

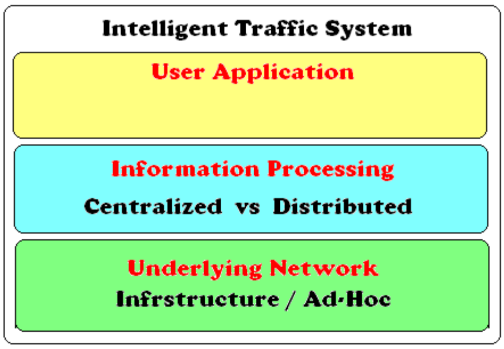


Figure 3-6: Intelligent Traffic System

1. Underlying Network: is describing the used infrastructure, hardware and the physical connection. This level has been researched by many project (see section 1.2) and some of them have proposed technical standards.
2. Information Processing: this level offering the data and the services for the top layer (User Application). This data comes out from certain processing which could be done locally by each node (Distributed processing) or in a data centre (Centralized processing).
3. User Application represents all possible implementations based on the data and the services obtained from the lower level (e.g. Find a friend, counting the cars in certain area, POI, ...)

This research is focusing on the middle level which is Distributed Information Processing. By another word, it has some restriction or minimum underlying network requirement and it does focus offering on the data needed to build a lot of useful user applications. So, the big difference between the proposed system and the systems that are already in place is the following:

- TCDA DOES NOT rely on any kind of roadside units or infrastructure, just car to car communication for collaborative data sharing and processing without using any kind of cauterization (processing or storage).
- TCDA DOES NOT rely on central processing, each node in the system is identical and DOES have the same functionality (routing messages if needed, processing the received information, generating new messages,…).

The relationship between the existing developments and that proposed in this research collaborative data generation, control and distribution approach is given in Figure 3-.

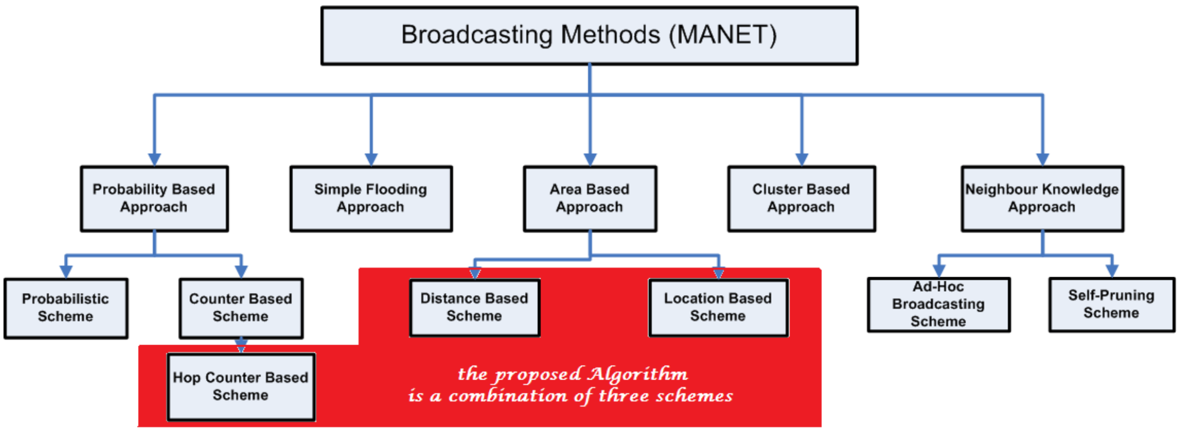


Figure 3-7: The proposed Algorithm is a combination of three schemes.

We propose TCDA as a new hybrid method of the three following methods and study the different variants through simulations. Our preliminary results in the various density scenarios indicate that the proposed hybrid method TCDA outperforms conventional back-off delay techniques and adaptively operates in extremely congested network conditions. The TCDA scheme includes provisions for the most popular broadcast reduction schemes in the literature:

- **Hop Counter based scheme [HCBS]:** As discussed in [141,142], this scheme works with three variables: a random assessment delay (RAD), a threshold K, and a counter k which counts the number of redundant messages. If k > K when RAD expires, the message is dropped. Otherwise, the message is rebroadcast. With this approach, when the network density is high, some nodes do not broadcast. Otherwise, all the nodes broadcast.

- **Distance based scheme [DBS]:** this approach uses the distance, d, between the receiving node and the source node to decide whether to drop the message or rebroadcast it. After the RAD expires, if d>D then the message is dropped, otherwise it is rebroadcast. This approach needs accurate GPS devices on-board.

- **Location based scheme [LBS]:** In this approach, all messages contains the location of its sender. The possibility of covering additional area will be calculated by the receiving node to rebroadcast. Otherwise, the message is dropped. The main problem with this approach is the cost of calculating additional coverage areas [143].

In the various threshold-based techniques proposed in the aforementioned methods, such as the counter-based, distance-based, and location-based schemes, a node receiving the broadcast packet compares the predetermined threshold value with its local information, (e.g., the number of duplicate packets received or the relative distance between itself and the sender). The criteria adaptively adjust the thresholds according to the targeted road situation and the number of neighbours. The results show that with the aid of a positioning device such as GPS, the location-based scheme seems to offer the best performance in terms of packet penetration rate and link load. Although our scheme (TCDA) employs a similar concept to the above schemes, it uses a lightweight distributed algorithm before rebroadcasting to calculate the forwarding possibilities and/or waiting time based on the desired road situation (See Table 3-2) instead of using a single threshold value.

Instead of making the decision to rebroadcast all messages by the source node , each node that receives the message can decide whether it will drop the message or continue rebroadcasting which in turn leads to reducing the network overhead (if the message restricted to certain location or distance).

A sender-based multipoint scheme is presented in [145] where the sender controls the number of retransmissions by selecting a subset of its neighbours to relay the message to. Although this scheme can significantly reduce broadcast redundancy, the amount of overhead introduced may be high as it requires that each node has perfect knowledge of its one- and two-hop neighbours in real time in order to properly choose the set of relay nodes. In this work the proposed schemes do not require nodes to keep track of their neighbours.

The retransmission logic set by either the sender or receiver tackles the broadcast storm problem by using the available conditions based on each road situation. The broadcast transmission scheme employed in this thesis is, however, the pure flooding approach. The choice was made so as to allow easy comparisons between the results presented here and previous research done in the area. Overall, we have chosen the pure flooding approach to compare and verify results for the following reasons:

- The pure flooding approach is the baseline against which everything else is compared – i.e. it is popular in the literature and makes the results presented here immediately comparable with other approaches.
- The networking traffic generated by the proposed technique in this thesis is relatively low and so we can employ a technique that does not compromise on reachability. Typically broadcast-thinning techniques incur some penalty in terms of reachability as a consequence of reduced broadcasts. As broadcast storms in this case are not an issue, none of the optimised techniques are necessary.
- The extra features/information that the proposed algorithm offers, like counting the number of cars that have reported certain traffic road situation and/or the total number of cars within a predefined area, may be compromised by a broadcast thinning technique which does not allow all vehicles to provide information on their status but instead focuses on reducing the number of broadcasts. Specifically, there is particular need for the broadcasting technique employed to ensure that all nodes should be contacted and/or counted – broadcast reduction techniques do not guarantee that.
- The proposed algorithm offers more than one condition to control the message lifetime (i.e., when the message is dropped or considered outdated). Specifically, it is possible to determine how far the message will travel away from the source

node either in terms of physical distance or number of hops that can be used and, further a predefined timeout may be employed. None of the broadcast thinning solutions (Hop Counter Based, Distance Based and Location Based Schemes) use a combination of those conditions, which makes comparing the proposed algorithm with them unfair.

3.4.1 Performance metrics description:

In [138], evaluation of some of the aforementioned methods (FL, PB, CB, HCAB & DB) has been made. They measured the performance of broadcasting protocols under different vehicles' speed (1 - 25m/s) and host densities (25-100 nodes) by using three performance metrics:

- ***Awareness***: is the reachability of the data to be disseminated.
- ***Saved Rebroadcast (SRB):*** is the ratio between the number of host receiving the message and the number of hosts actually rebroadcasting the message.
- ***Latency***: the interval from the time the broadcast was initiated to the time the last host finishing its rebroadcasting. It includes buffering, queuing, retransmission and propagation delays. Latency is an important metric to figure out the suitability of a protocol for delay sensitive applications like safety applications.

They concluded their study by showing that DB, CB and HCAB are the best choice as following:

Table 3-4: Comparison between DB, CB and HCAB

	Speed (0-25 m/s)	Density (25-100 cars)
SRB	Distance Based	Distance Based
Awareness	Counter Based	Counter Based
Latency	Hop Counter Based	Hop Counter Based/ Counter Based

We will use only two indicators for measuring the performance of the algorithm against all possible parameters (Table 3-4). Those parameters including for examples : Total number of sent/received/discarded messages, Time needed (Total and Per node), number of nodes which saw xx% of other nodes, …etc.

Those performance metrics will be:

- *Optimum number of hops* needed for each message journey to scan the whole area. By another word, how far will each message go away from its original node. This is the performance metric for measuring and controlling the number of messages the system will generate and then exchange between nodes. Minimizing this indicator will result in minimizing the noise of the network.
- *Best delay time* we can use before rebroadcasting the message in each node. This indicator, also, controlling the noise of the network by waiting for certain period of time to collect as much data as each node can to rebroadcast them in one single message.

CHAPTER 4

Traffic Condition Detection Algorithm (TCDA)

Chapter outline:

- Algorithm overview.
- Algorithm Features.
- Algorithm description.
- TCDA Pseudo-code.
- Conclusion.

Chapter 4

4 Traffic Condition Detection Algorithm

4.1 *Algorithm Overview:*

The proposed Algorithm is serving urban traffic management in cooperative and distributed way with vehicle-to-vehicle direct communication (infrastructure-less manner). It offers a channel for real-time detecting of road situation for all cars based on sharing the individual car data. This mechanism – knowledge aggregation or knowledge granularity – is simply “a conclusion knowledge based on individual data”.

4.1.1 Scope:

The algorithm deals with conditions, which can only be identified through collaboration between all the cars in a given region and leaves conditions that can be detected by a single car only outside the scope of the project.

The algorithm can sense ad-hoc nodes’ conditions in a fast and lightweight manner. The illustration of the capabilities of the algorithm is illustrated with an example, which identifies road urban traffic conditions. Some road conditions can either be derived (assessed) from the activity of the individual cars’ electronic helpers like ESP or ABS, or alternatively, sensors embedded in the individual vehicle may provide this information. There are heuristic rules for deciding whether one is in danger of hydroplaning, or how to assess whether the road in front of the vehicle is icy or not. Measuring the temperature, the amount of rainfall or snow, or the humidity can make the driver able to choose alternative routes, if a section turns out to be icy, foggy or rainy strongly. Theoretically, rainfall case can be assessed by the windshield wipers statues, by distinguishing cleaning the windshield and cleaning it from rain water. The summary in the Tables (Table 3-1, Table 3-2) is summary of the most common road situations with the causes of those situations considered as Non-conclusive Individual Car Sensed Data.

By comparing the two tables (Table 3-1, Table 3-2), it can be noticed that in each case in the first table the event could happen because of many reasons, which make it non-conclusive piece of information. But in the second table, if we know the number of nearby cars that are in the same situation (the numbers quoted in the table are representative rather than conclusive for the condition and represent a matter of future investigation in real-life experiments), we will be certain about the reason for that situation. This mechanism transfers the non-conclusive individual car sensed data into very important (conclusive) data to describe the surrounding road conditions. We should notice that the threshold number in the Table 3-2 should be predefined and updatable by the system itself.

4.1.2 Examples of situations detected by the Algorithm:

To put the algorithm in its context, it will be useful to present some examples of the possible situations (conclusions) we can come up with based on sharing individual car sensors data (Table 4-1).

Table 4-1: Conclusions of possible situations

Application	Description
Decentralized Floating Car Data, Traffic jam , Road Works, Slippery Road, Fog, Rain, Wind.	Any vehicle can detect and signal to other vehicles such events on the road.
Car Breakdown Warning	Any vehicle immobilized on the road as a result of a breakdown should signal this immobilization to other approaching vehicles.
Cooperative Forward Collision Warning	Driver is assisted to avoid or mitigates the effects of a collision with the rear-end of vehicles in a forward path of travel.
Post-Crash Warning	Any vehicle in an accident should alert other approaching vehicles of the risk for them associated to this dangerous situation. In this case, the post-crash warning is communicated by Cooperative Awareness messages where vehicle status is “in accident”.

4.1.3 Algorithm Features:

The algorithm is very flexible and has several variable parameters which influence the final outcome and this thesis presents our conclusions in determining the optimal set of values:

1. Using Variable Conditions Search Limitation (CSL): Control the searching area for any situation by using selection of parameters (number of hops from source, certain timeout, and/or distance from source).
2. Multi-zones detection: in case of more than one zone, it can detect the borders of each situation zone separately (even if they overlap). Then report them in one or multiple warning messages.
3. Delay for data collection: Random time slots delay used before forwarding the received messages (which increase the collecting information period to end up by reducing the number of exchanged messages).
4. Infrastructure less system: the algorithm does not rely on any kind of infrastructure equipment to process messages, it does work on V2V communication.

4.2 *Algorithm Description:*

4.2.1 Definitions:

1. Active Node (AN): a node with sensors indicating that a certain road condition(s) is present and is to be reported to other nearby cars or nodes.
2. Non-Active Node (NAN): a node with sensors indicating that a certain road condition(s) is NOT present (the node will serve as a router to forward messages coming from nearby nodes).
3. Situation Discovery Message (SDM): a message generated by AN or, in some cases, by NAN. It has three parts (Table 4-2): unique SDM ID (nodeNo : timestamp : Position), SDM limitation conditions (Hops : timeout : distance) and Nodes seen (NodeID : Time : Situations : position). Its purpose is to establish zone identification and contains:

Table 4-2: Situation Discovery Message (SDM) structure.

Fields	Data in field
#1	unique Message ID (nodeNo:timestamp:Position)
#2	Message limitation conditions (Hops:timeout:distance).
#3 .. etc	Nodes seen (NodeID:Time:Situations:position).

4. Situation Warning Message (SWM): generated by when node discovers a situation zone. It contains the fields (Table 4-3): unique SWM ID (SourceNo : timestamp : Position), SWM travel conditions (Hops : timeout : distance) and Zones detected (NodeID : Time : Situations : position).

Table 4-3: Situation Warning Message (SWM) structure

Fields	Data in field
#1	unique Message ID (SourceNo:timestamp:Position)
#2	Message travel conditions (Hops:timeout:distance).
#3 .. etc	zones detected (NodeID:Time:Situations:position).

5. Node behaviour: the reaction of the node (car) when receiving a message. The reaction can be to:
   - Forward the message if it is a message received for the first time, otherwise discard.
   - Discard the message if it is redundant.
   - Generate new Situation Discovery Message (SDM) if the received message carries new information compared to the existing information, so the generated message will travel in all directions (broadcast).

Here is the reaction table (Table 4-4) for a node based on the result of comparing the received message data with the pre-existing data from prior received messages.

Table 4-4: Node reaction for receiving new message

Existing information	Received Information	Node Reaction to received Message
Yes	Yes	Generate new SDM
Yes	No	Discard
No	Yes	Forward received SDM
No	No	Discard

If the received message carries NO new information about any new nodes discovered nearby, compared with the existing data in the current node, then the received message will be ignored and discarded by the current node. The justification for such action is: as long as NO new information about new nodes situations around has been received, there is, no point in forwarding the received message with its previously known data, because we assume all the surrounding nodes already know the same information - because of prior message exchanging - that the current node does know.

But, in case where the received message has new information about any new situations discovered nearby, the reaction of the current node will be two steps: the first step will be updating the local stored data in receipt node to be used for future message processing. The second step is Generate new SDM message with all data known in the current node, in order to update all the nearby nodes.

4.2.2 Assumptions:

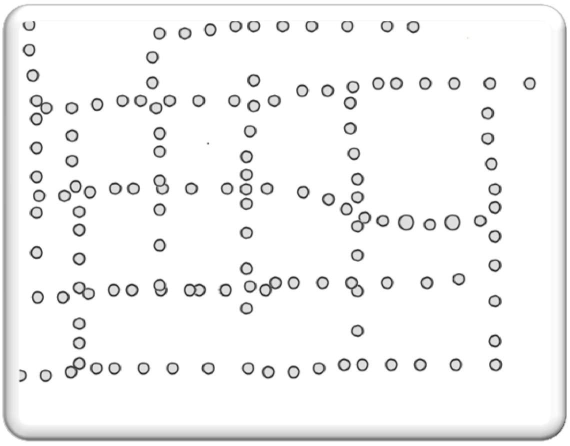
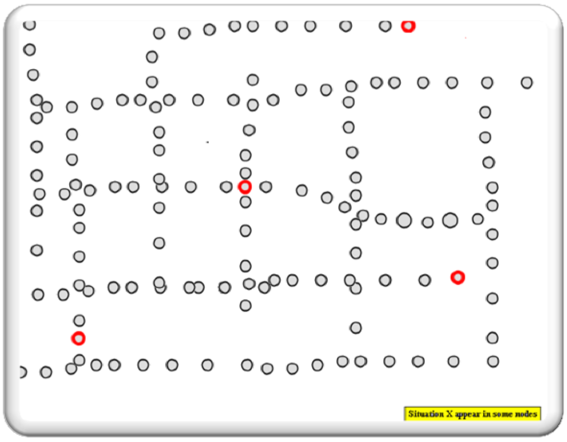
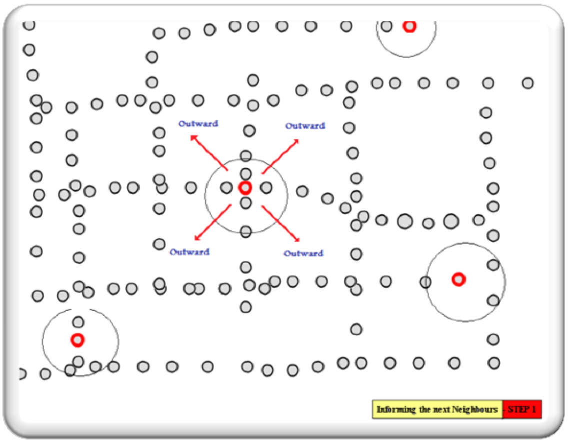
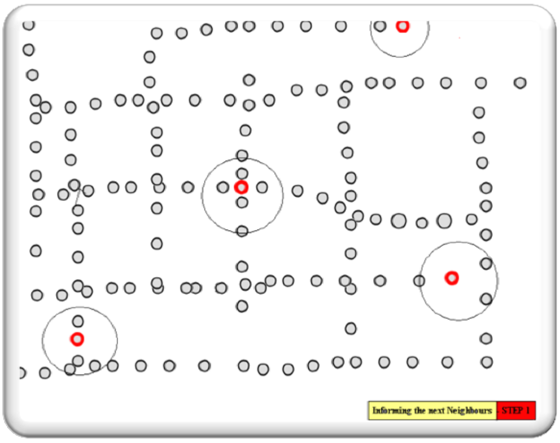
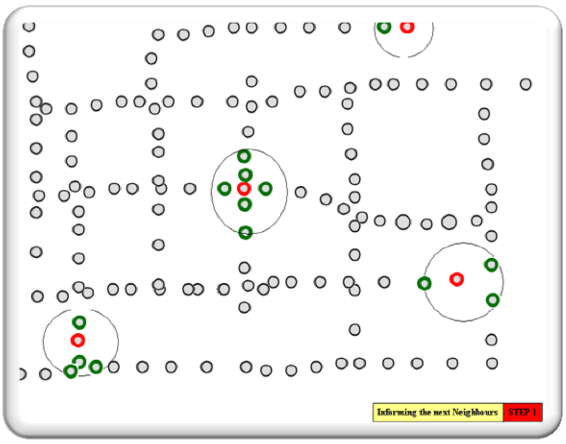
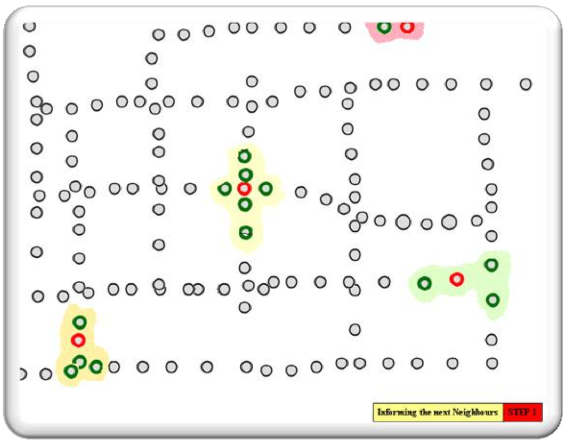
1. All nodes are identical, mobile and in an active state.
2. Each node is able to determine its position (equipped with a GPS on-board).
3. The distributions, density, distance between nodes and active nodes selection are completely random, but the movement patterns are fixed.
4. Message delivery reliability is assumed to be standard wireless networks reliability with all the delays, packet loss or interference inherent to such networks.

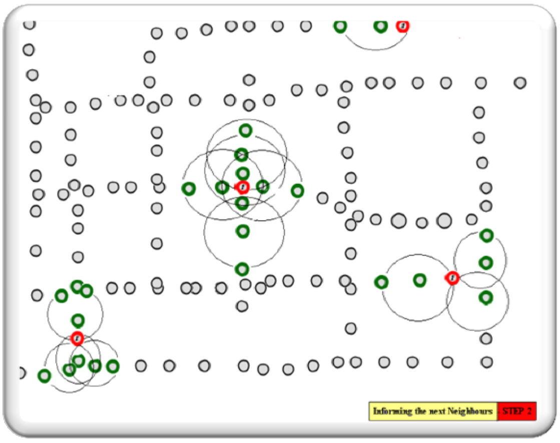
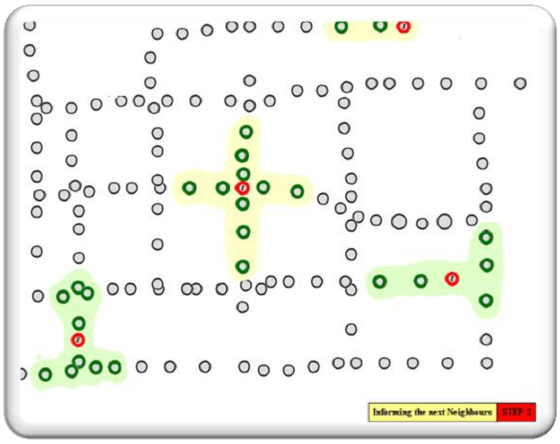
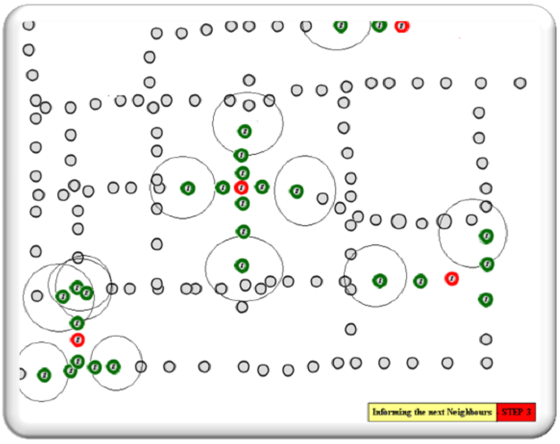
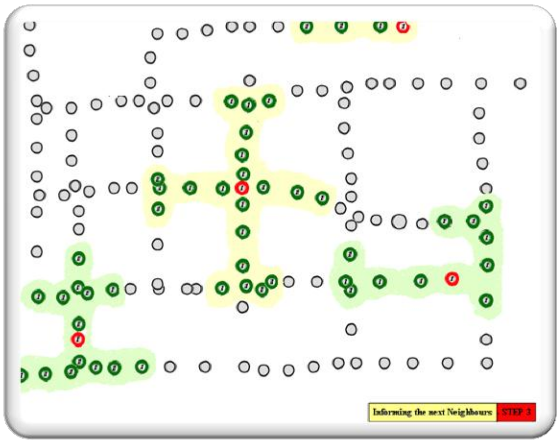
4.2.3 Description scenarios for the proposed algorithm mechanism:

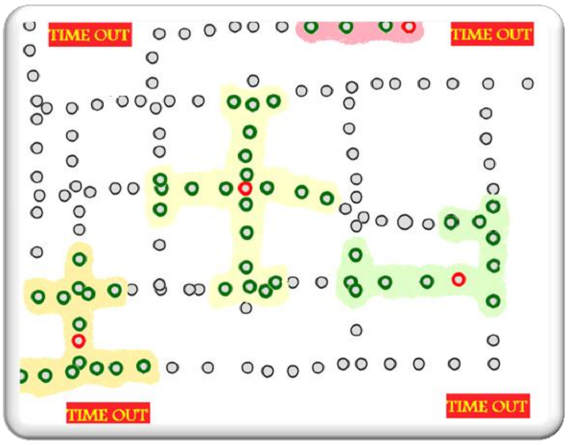
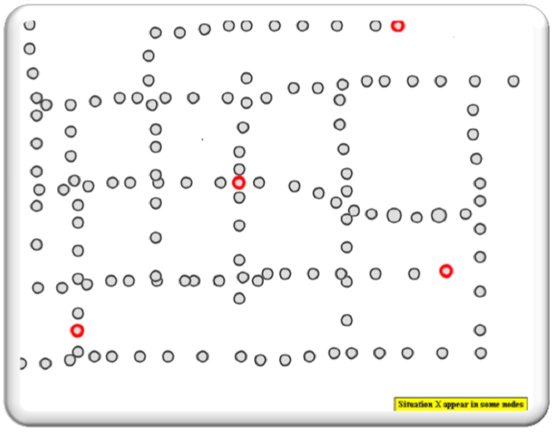
In this section, I will demonstrate the algorithm in different scenarios. They will describe the behaviour of the algorithm and how it disseminates messages, shares data and identifies the situation zone(s).

4.2.3.1 Scenario #1: 4 active nodes, no overlapping in the situation zones:

The first scenario consists of 4 active nodes which will start the sharing of the data within the region they are in. No overlapping between the situation zones will appear.

1	 No active nodes among cars (No cars have sensed any situation within the region so far).	 ` Four nodes has sensed a certain situation. So, all of them became active nodes.
2	 All nodes that became active nodes will generate SDM (situation discover message) and send it outward (1th Wave or First Hop).	 Cars within the range of the ANs will receive the SDMs.
3	 All cars that received the message, will be informed about the nearby AN/NAN nodes.	 Cars within the colored zones are already informed about the nearby AN/NAN nodes.

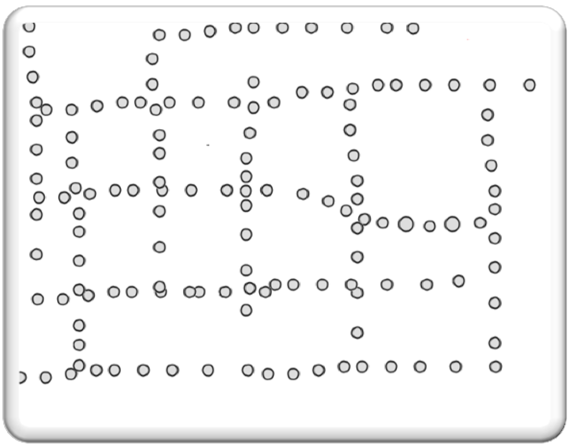
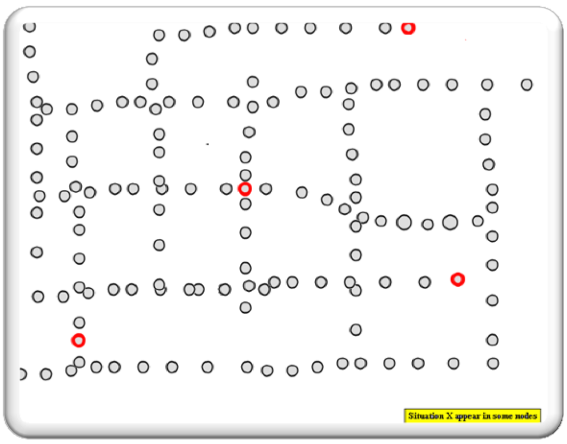
4	 Cars (in the ends) will update their local information, then update the SDM with all avaliable data before they send it again (2^{nd} wave).	 New nodes will informed about the active nodes, so, the discovered area increases.
5	 Again, cars (in the ends) will update their information, then generate new SDM to send it again (3^{th} wave).	 Again, new nodes will be informed about the active nodes, so that, the discovered area increases.

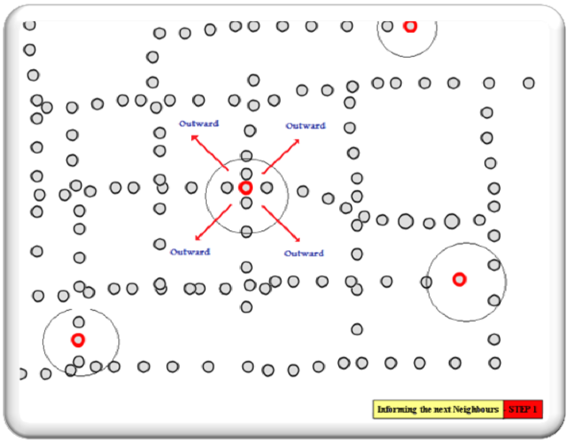
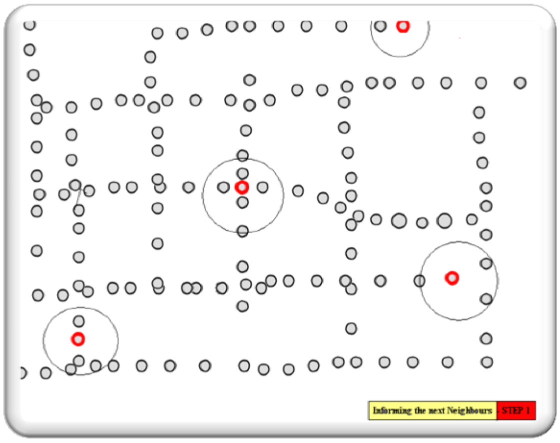
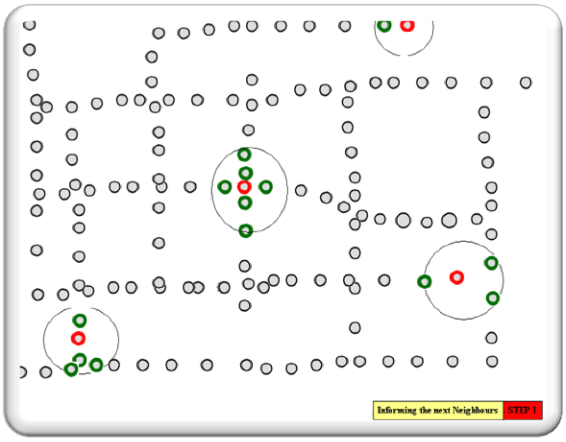
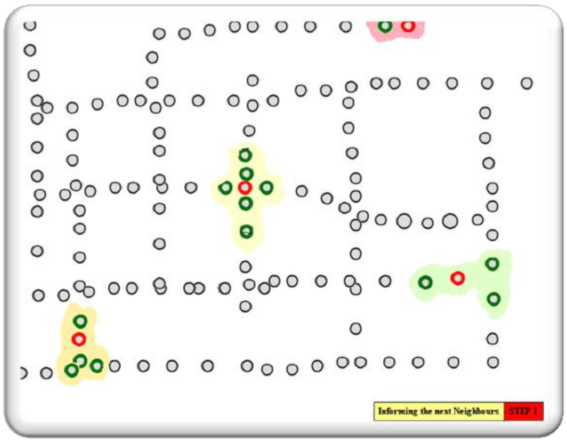
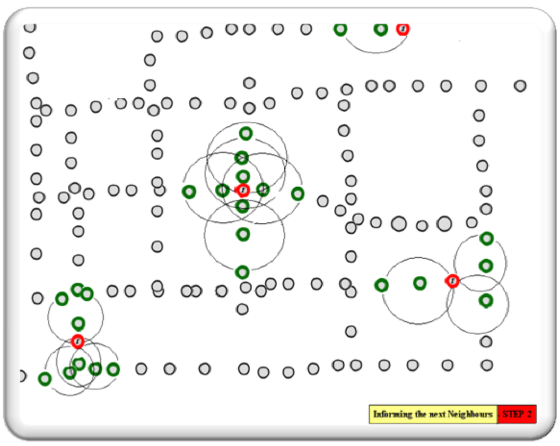
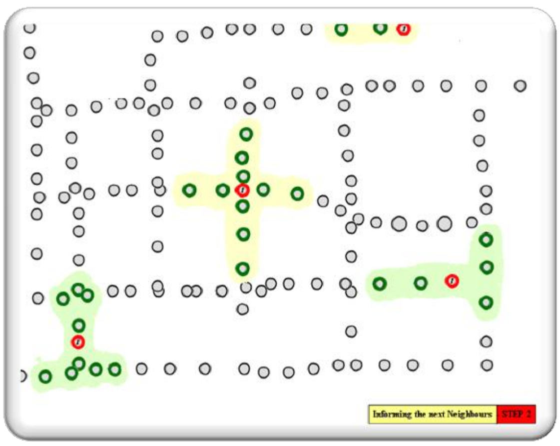
6		
	After a while, either the maximum number of hops number will be exceeded, or time out will be flasing (data expired).	The AN will start again the same process, generate SDM with the recent information, send it to the next which will update SDM and resend it again, … and so on.

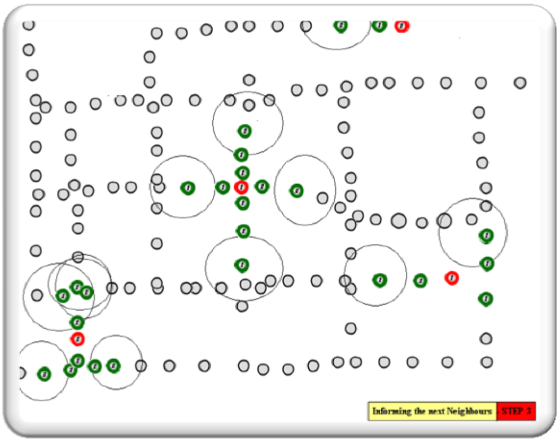
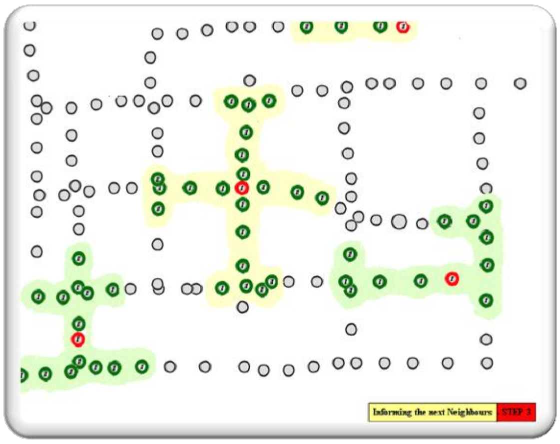
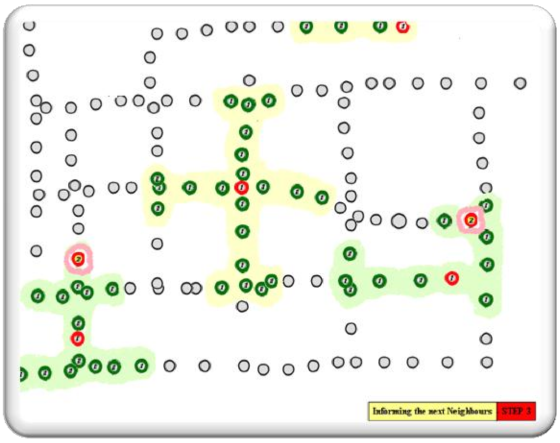
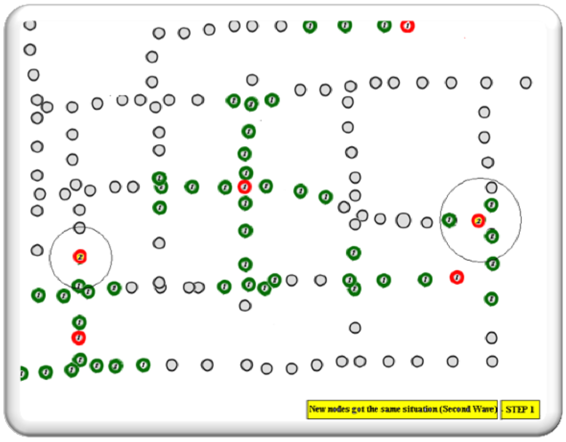
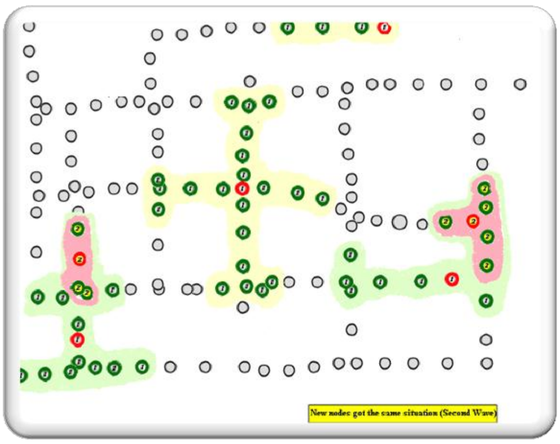
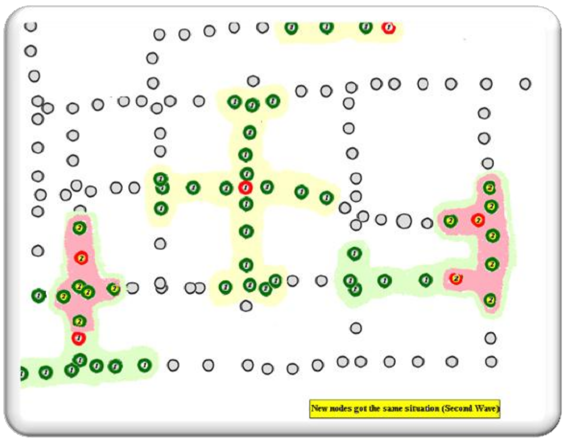
If neither of the conditions for Max hops and Time out has occured, and the condition of optimal number has been reached in node N’, this node will calculate the boundary of the situation based on the AN position, then it will generate new WM and broadcast it to all surrounding nodes.

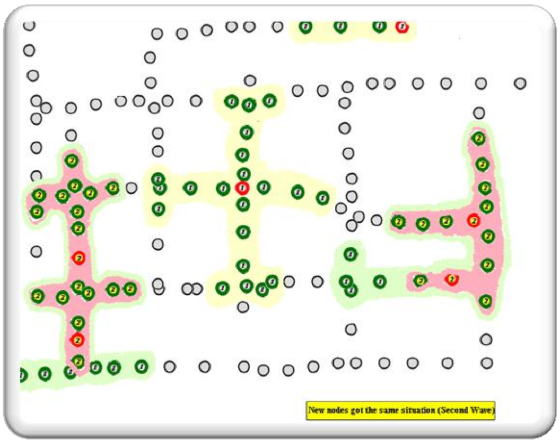
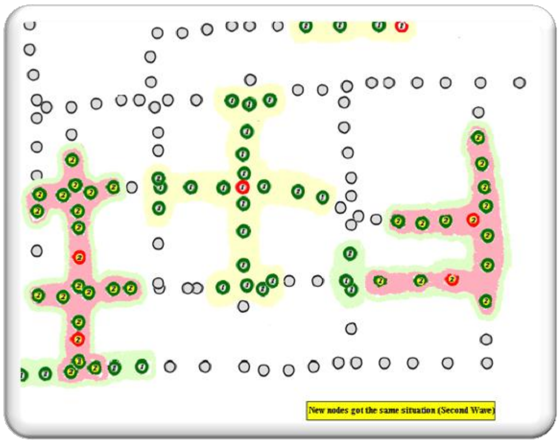
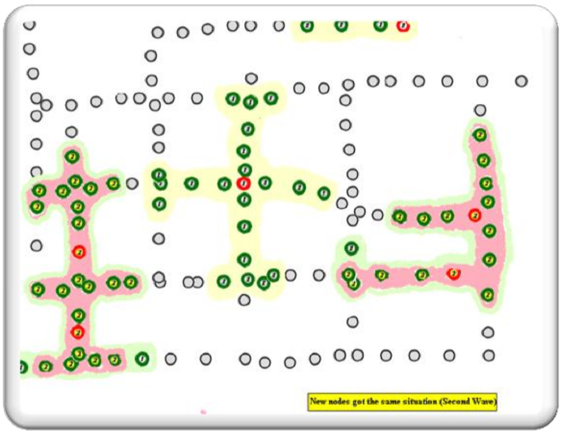
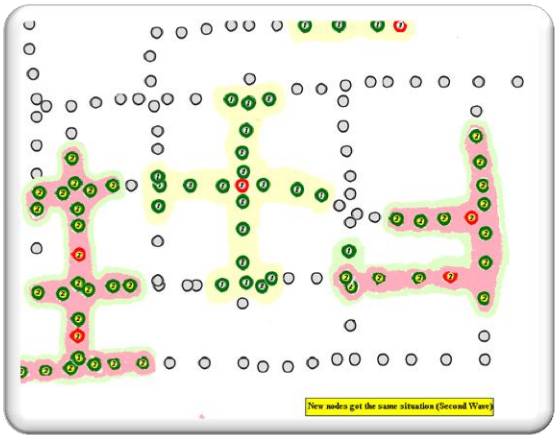
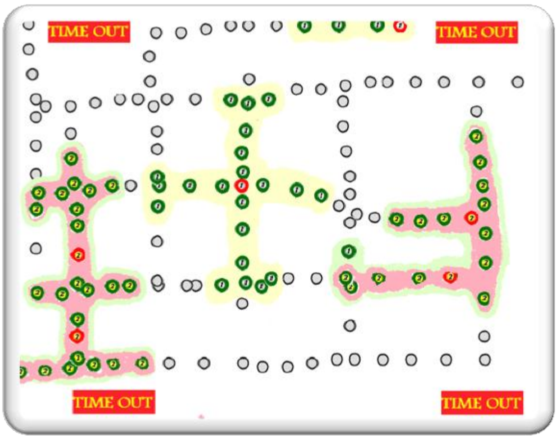
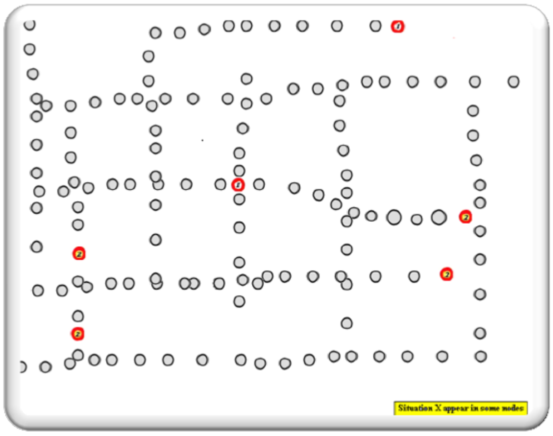
4.2.3.2 Scenario #2: 4 active nodes + 2 later, no overlapping:

The second scenario is similar to the first one; it consists of 4 active nodes which will start the sharing of the data within the region they are in. No overlapping between the situation zones will appear.

1		
	No active nodes among cars (No cars have sensed any situation within the region so far).	` Four nodes has sensed a certain situation. So, all of them became active nodes.

2	 All nodes that became active nodes will generate SDM (situation discover message) and send it outward (1[th] Wave or First Hop).	 Cars within the range of the ANs will receive the SDMs.
3	 All cars that received the message, will be informed about the nearby AN/NAN nodes.	 Cars within the colored zones are already informed about the nearby AN/NAN nodes.
4	 Cars (in the ends) will update their local information, then update the SDM with all avaliable data before they send it again (2[nd] wave).	 New nodes will informed about the active nodes, so, the discovered area increases.

5	 Again, cars (in the ends) will update their information, then generate new SDM to send it again (3^{th} wave).	 Again, new nodes will be informed about the active nodes, so that, the discovered area increases.
6	 After a while, new 2 nodes become active nodes. So, they will send SDM around with the whole information they already have about the nearby nodes.	 The new active nodes start the process of informing the nearby cars (1^{st} wave again).
7	 The colored zones demonstrates the nodes' knowledge range (how far each node knows about the surrounding nodes). Still in the 1^{st} Wave.	 Now, a new wave will start again with the AN in the terminals of the red zone (1^{st} Wave).

8	 After the new 1st wave.	 The 2nd wave.
9	 After the 2nd wave	 The 3th wave.
10	 After a while, either the maximum number of hops number will be exceeded, or time out will be expire (data expired).	 The AN will start again the same process, generate SDM with the recent information, send it to the next, the next car will update the SDM and resend it again, … and so on.

4.2.3.3 Scenario #3: 8 active nodes, with overlapping in the situation zones:

Here again, by using the same mechanism, Figure 4-1 illustrate the scenario of having 8 active nodes (box #1 of the figure 4-1) which will generate the SDM and broadcast it (as first wave) to the nearby cars, in order to inform them about the situation they sensed. After that, all cars will add any additional local information known (e.g.: they already heard about another active nodes around from SDM received early) to the message SDM, and rebroadcast it to the next nearby cars (box #2 of the figure 4-1). I call this step the second wave dissemination.

After the 2nd wave finished (box #3 of the figure 4-1), the situations zones start overlapping. This will have the result that all cars in the overlapping area will reset the number of hop counter in the SDMs, update SDM's with the available local information, regenerate the SDM's and then broadcasting them again. This will make that the messages SDMs which originated by the nodes in the overlap area will travel away from the original nodes up to default number of hops for that situation (we assumed that the default number is 3, in our scenarios).

When the nodes send its SDMs (to form what we called 3th wave), those SDMs will travel until the counter of the number of hops is zero. So, in (box #4 of the figure 4-1) illustration of the cars and its knowledge of the surrounding area, which cars know about which. When one of the cars (AN or NAN) finds out that the threshold of that situation has been reached, at that moment, this car will generate Situation Warning Message (SWM) and disseminate it to all cars in the region.

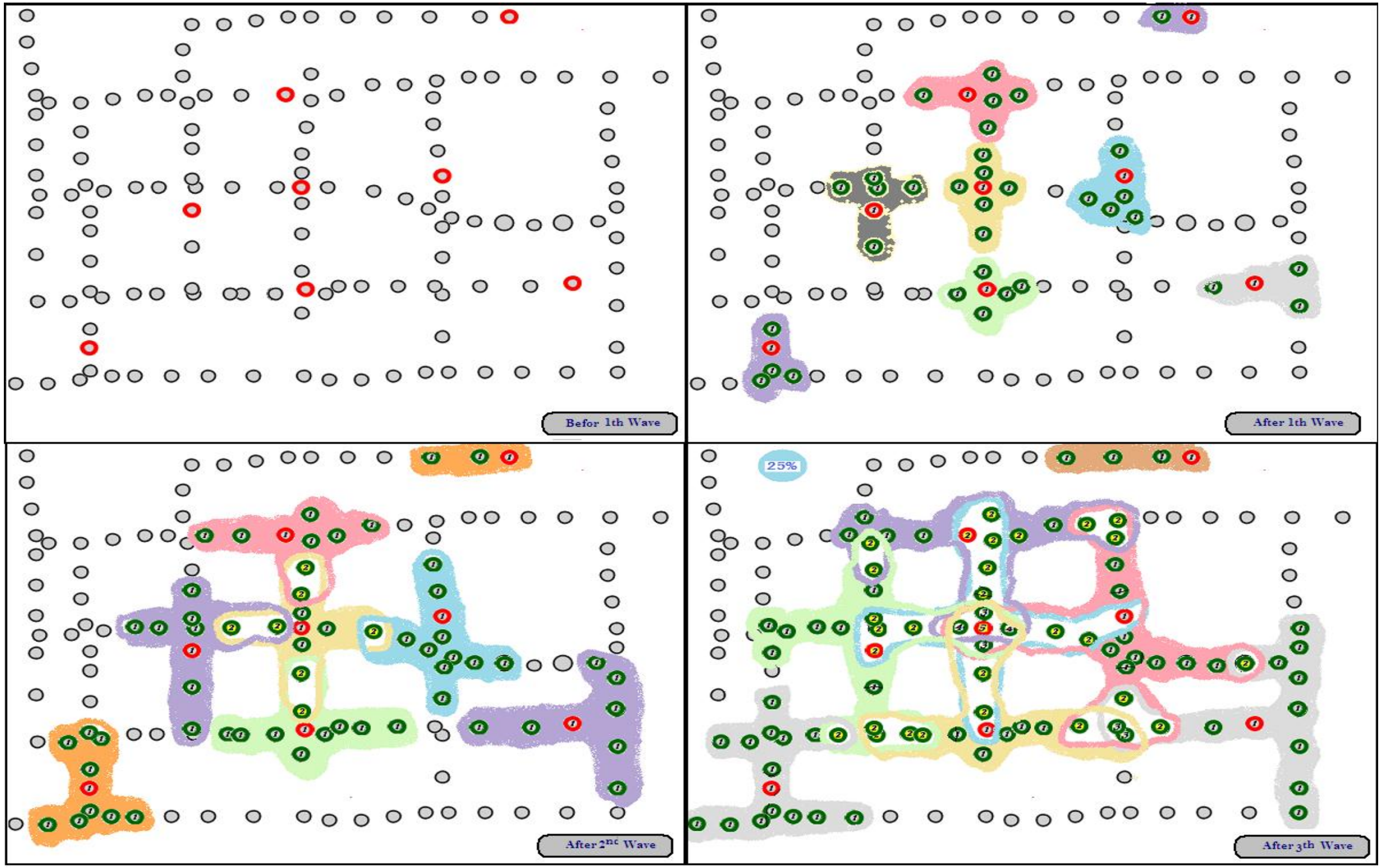


Figure 4-1: Scenario #3, 8 active nodes, with overlapping in the situation zones

4.2.4 The Algorithm mechanism:

This is two phases approach. First phase is to scan the region for any detected traffic conditions (using discovery message generated by nodes who sensed that situation) to identify the boundaries of the situation zone. The second phase is to issue warning message broadcasts to inform all nearby nodes for the situation and its boundaries. By using this approach, we investigate and identify the optimum value for two parameters: ① the number of hops used by the discovery message (How large the scanned area is), and ② the best possible delay time used in each node before rebroadcasting (to reduce the noise in the network) This mechanism involves the following steps (Figure 4-2):

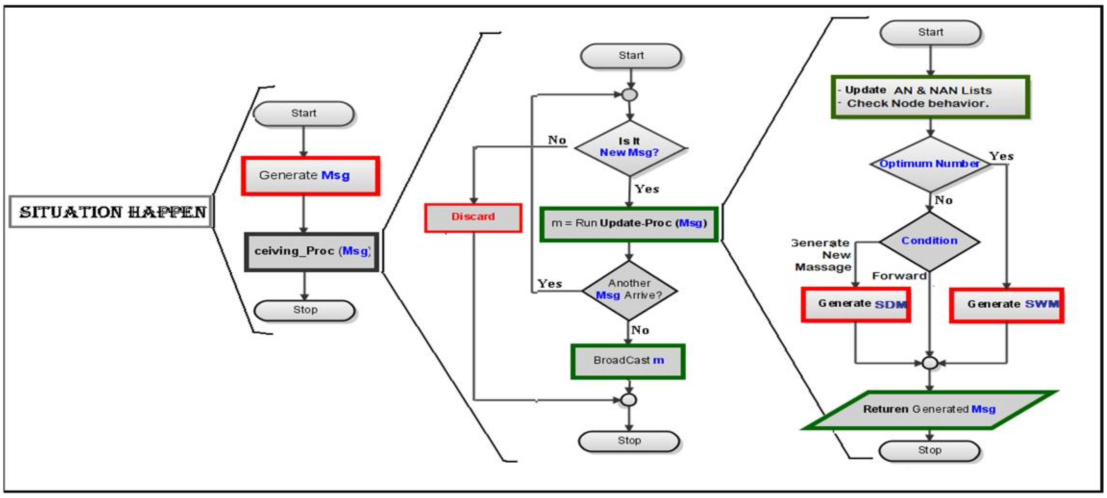


Figure 4-2: Road Situation Detection Algorithm (RSDA) – Nodes Mechanism
(Situation Detection → Generate Message → Update & Sent → Update Local data)

1) If a node detects or senses any identifiable road conditions it becomes an active node (AN).

a. If it has not received other nodes' SDMs (*Situation Discovery Message*) with the same condition discovery requests within a certain past time-out period, it generates an SDM and broadcasts it to all nodes in its range as a first wave (called first hop) to inform all nodes of its current situation (Figure 4-3) and to enquire if other nodes have the same condition.

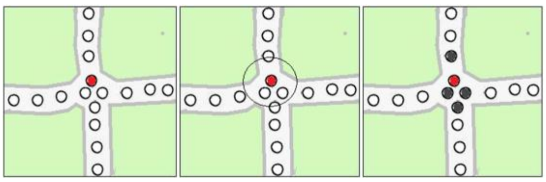


Figure 4-3: Crossroad scenario – first hops

b. Periodic regeneration and rebroadcasting of SDM after the time-out expires will be performed, until either the situation disappears (becomes a Non-Active Node (NAN)), or a new, different, SDM is received which shows another node has sensed the same situation (become AN) and it recognizes the current one as AN.

2) In each node that receives the SDM,

a. If the maximum hops number is not reached (an SDM reaches the maximum number of hops if the pre-set number of hops are transmitted by nodes) and if none of the nodes have the same situation, they forward the same SDM to the next neighbour nodes as a second wave (second hop) to inform the others of the current situation (Figure 4-4).

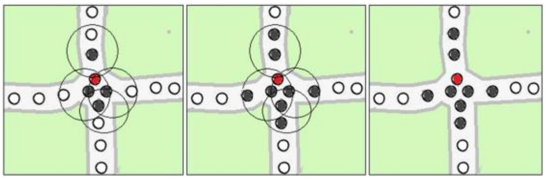


Figure 4-4: Crossroad scenario – second hops

b. However, if one of its neighbours has a new situation at the same time as receiving the message, it will generate a new SDM that contains its current condition and also all the information it has previously identified about the nearby nodes.

c. Again, all nodes forward the same SDM to the next neighbour as a third hop (Figure 4-5) after they have updated the message on the current situation. These steps are repeated until the Conditions Search Limitations (CSL) become true or the maximum number of hops is reached.

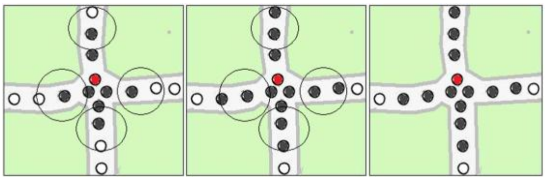


Figure 4-5: Crossroad scenario – third hops and so on …

3) Each node is capable of:

a. Keeping track of all seen messages, which allows it to discard all redundant messages. Also each node keeps all the information it has about all 'seen' nodes – all nodes contained in the messages received in the node – in two different lists: the first for ANs and the second for NANs.

b. If any node – at any hops – has the same/new situation, a new SDM will be generated containing additional information as well as the information it holds about the other surrounding nodes and broadcasts it to all nearby nodes. Previous steps will be repeated until – again – the CSL becomes true.

4) *After a short period* of exchanging SDMs:

a. Nodes will have obtained all possible information about the surrounding nodes. Each node should hold three lists: a seen messages list (to reduce redundancy), an active node seen list and a non-active node seen list.
b. Each time a node receives a message it updates its lists and checks whether the optimum number for each detectable situation is achieved or not. If it is not, it will forward an SDM to the next hops.

In the case of an optimum number or threshold of certain situation being achieved, the car which got this information will *calculate the boundary of the situation zone* based on the information it already has about the surrounded cars (Figure 4-5). Then, a new Situation Warning Message (SWM) will be generated and sent to warn all nearby cars by the situation and its position. Also, a new CSL will be set up for an SWM to determine the lifetime.

4.2.5 The Algorithm pseudo-code:

Pseudo-code of TCDA

Input:

Road situation detection messages (SDM) received. It is generated by any node (I called it Active Node) which senses any road problem or certain road situation, each has at least the following information: Message id, two lists of nodes and its positions: active nodes and non-active nodes.

Initialize:

$i \leftarrow \{ 0 \ldots number\ of\ nodes - 1\}$

$N \leftarrow set\ of\ sll\ nodes;$

$(id) \leftarrow \text{Message ID} = \{\text{Unique Message ID}, \text{time Stamp}, \text{curennt node Position}\}$

$N'(id) \leftarrow Source\ node\ of\ id;$

$N_i(id) \leftarrow$ Current Node ID

$= \{$ Unique Message ID , time Stamp , curennt node Position$\}$

$CSL \leftarrow$ Message Condition Search Limitation

$= \{$ Num of Hops , time out , distance from N$'\}$

$B_i \leftarrow neighbor\ set\ of\ current\ node\ N_i;$

$AN_i \leftarrow detected$ $\underline{Active\ Nodes\ IDs}$ $set\ by\ N_i;$

$NAN_i \leftarrow detected$ $\underline{Non\ Active\ Nodes\ IDs}$ $set\ by\ N_i;$

$SDM \leftarrow road\ Situation\ Detection\ Message.$

$SWM \leftarrow Situation\ Warning\ Message.$

$SN_i \leftarrow situations\ zones\ set,;$

Functions:

Function Calculate-Zone*: define the boarders of the geographic zone which contain all* AN_i

Functions Update-list: add/remove information from the lists AN_i or NAN_j.

Function Generate: Generate a new message based on its type SDM or SWM by creating *id* of the message, pre-set CSL and the lists of AN and NAN .

Forward Message: rebroadcast a certain message (SDM or SWM).

Event: new situation has been detected in the current node N_i

Pre-set CSL; **Update-list** AN_i and NAN_j.

Generate $SDM \leftarrow \{ N_i(id)$, CSL, AN_i , NAN_i $\}$

Forward SDM

Event: new SDM_j message arrived at the current node N_i

Extract from SDM_j data sets: $SDM_j(id)$, AN_j , NAN_j;

if SDM_j is redundant **then**

Discard SDM_j;

else **Update-list** $\left.\begin{array}{r} NAN_i \leftarrow NAN_i \cup NAN_j \\ AN_i \leftarrow AN_i \cup AN_j \end{array}\right)$ // update local lists of known AN & NAN

if $\frac{\text{length}\{AN_i\}}{\text{length}\{AN_j\}+\text{length}\{NAN_i\}} \geq threshold$ **then** // using Hop-Count Data

Calculate-Zone // identifier situation zone by using AN list (NodeID and Position)

Generate $SWM \leftarrow \{N_i(id),\ SN_i, Zone,\ AN_i\}$ //generate new warning Message

Broadcast SWM

// check the distance Between N' and N using Positioning information (Distance-based scheme

// & Location Based Scheme)

else-if $distance$ in $- between\ AN_i$nodes $\geq threshold$ **Or** timeout **then**

Generate $SDM_i \leftarrow \{N_i(id),\ AN_i,\ NAN_i\}$ //generate new warning Message

Forward SDM

else

Wait tolerant-time // to receive and collect more data to broadcast all in one message.

update AN_i, NAN_i; // update lists based on known AN & NAN

Generate $SDM_i \leftarrow \{N_i(id),\ AN_i,\ NAN_i\}$ //generate new warning Message

Forward SDM

end-if

end-if

Event: new SWM_i situation has been received in the current node N_i

update AN_i, NAN_i; // update lists based on known AN & NAN

Calculate *Zone* // identifier zone situation by using AN list (NodeID and Position)

Generate $SDM_i \leftarrow \{N_i(id),\ AN_i,\ NAN_i\}$ //generate new warning Message

Forward SDM

4.3 Conclusion

This algorithm is aimed at identifying road conditions on the basis of exchanging sensors information shared between the vehicles on the road (as opposed to identifying the conditions on the basis of individual cars' sensors). The identification process has several important outcomes/features:

- Traffic condition sensing: share detected individual cars' status and their data (Average speed / Windscreen wipers on/off / slippery strength / …) by exchanging messages between nodes which leads to detecting road conditions.
- Routing: define node behaviour in terms of algorithm routing. Use intelligent routing mechanism to exchange messages. This mechanism depends on comparing the received data with the known data in each node.
- Zone Identification: Define node behaviour in terms of road condition zone identification. Based on the available shared data, each node knows about the surrounding nodes' status and any node can identify the borders of the zone and then generate and broadcast a warning message around.
- Optimum number of cars needed to declare a situation node: obtain the minimum number of cars that have the same situation within certain area, in order to identify the situation zones. It could vary between situations, in other words; each situation has its optimum number (threshold).

What makes the proposed algorithm distinct among all pre-existing algorithms is that the proposal algorithm does not rely on any kind of infrastructure, just utilization of wireless technology which will be soon embedded in each car. Also, the algorithm can identify multiple zone conditions for multiple road conditions and send information about their boundaries in one single warning message.

Moreover, it can work independently from any specific underlying network or any specific kind of node (mobile, semi-mobile or even static). Also, the algorithm can count how many cars have sensed a specific situation and how many did not, this information can be useful for ITS application (e.g.: amendable traffic light time cycle or density of cars inside certain pre-known road capacity).

CHAPTER 5

Simulation

Chapter outline:

- Introduction.
- Algorithm simulation.
- Simulation parameters.

Chapter 5

5 Simulation

Simulation is the best substitution of the reality for the researchers in both the academic and industrial research owing to the high costs of actual deployment. No common standard simulator is available and a vehicular mobility simulator is commonly used to generate a mobility trace, which is then fed to the wireless network simulator. As connectivity will determine the performance in vehicular networks, it is important to select the right mobility simulator. The nodal movements in turn affect connectivity. The most popular vehicular network simulators and mobility simulators will be presented in this chapter in accordance with the integration component.

5.1 Introduction

Networking and mobility component are required for the simulation of a VANET. Two independent simulators will provide the two functionalities in majority of the cases so that the researchers can create a topology and a trace is produced in turn for the vehicular movement through the mobility simulator. This is then in turn fed to the network simulator. The trace can range from tenths of milliseconds up to seconds and will contain all the coordinates of the vehicles [139].

Feedback is now possible between the two components owing to the several integrated simulators that contain both the networking and vehicular mobility components [140]. The usage of two separate simulators is a routine practice.

Tightly integrated or loosely integrated VANET simulators have been presented through the years. The loosely integrated simulators use separate mobility simulators and network simulators. The mobility of the vehicles is generated by the mobility simulator, which records the vehicular movements into trace files. There is no direct interaction between the two simulators, although the network simulator imports the trace files. In the opposite, the mobility simulator and the network simulator are embedded into a single vehicular simulator instead of using the traces by the tightly integrated simulators. In some cases, the feedback is provided from the network simulator to adjust parameters of the vehicular movement, as there is communication between the mobility model and the network model. The receipt of certain network messages may result in a vehicle to change its path in the traffic congestion notification systems. Network messages in the collision avoidance system may result in a vehicle to slow down and prevent an accident. The loose integration of mobility and network simulators do not support this type of feedback. Separate mobility and network simulators will be first discussed, as the loosely integrated simulators are more commonly used. Various types of tightly integrated simulators will be discussed later on.

5.1.1 Mobility simulators:

The VANET mobility simulators generate traces of the vehicles. These data are saved and later on imported into a network simulator to study the performance of the protocol or application. It is important to generate a realistic movement traces for a thorough evaluation of the VANET protocol. As connectivity will determine the overall performance and the movement traces will in turn determine the connectivity, the generation of realistic movement becomes an important factor.

5.1.2 Network simulators:

The most used network simulators in the research field will be discussed in this section. The simulation of ISO-OSI layers is allowed through these applications, which consider the propagation and fading effect of the radio signals.

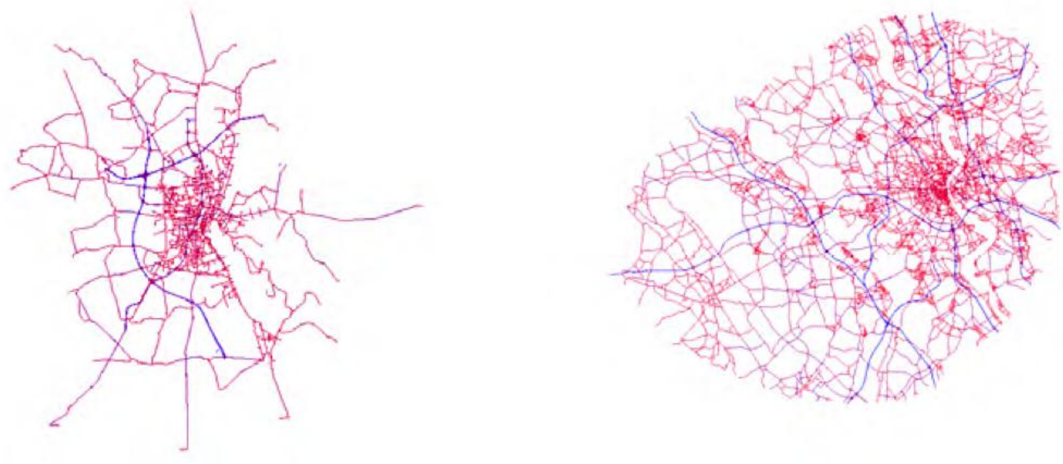


Figure 5-1: Illustration for cars on the maps

Node movement (Figure 5-1: Illustration for cars on the maps) traces are generated by the mobility simulator that is fed into the network simulator. The communication between the mobile nodes is then controlled by the network simulator. Most of these network simulators include at least a simple node mobility model, as they support the wireless communications. The following models are included among the simple node mobility models; Random Drunken Model 1, Random Waypoint Model, Trace file2 [140].

5.2 Algorithm Simulation:

The Network Simulation version 2.3 is a simulation tool created at the UC Berkley for the simulation of a variety of IP networks, as it is an event driven network simulator. I chose the Network Simulation version 2.3 for usage as a simulation tool. Network protocols such as TCP and UPD are applied by the network with FTP, Telnet, Web, CBR and VBR as the traffic source behaviour. It uses the Drop Tail, RED and CBQ as the router queue management mechanism and Dijkstra as the routing algorithm. Multicasting and some of the MAC layer protocols are implemented by the NS for the LAN simulations. The tools for simulation results display, analysis and converters that convert network topologies generated by well-known generators to NS formats are among the projects of the VINT for development and NS project has also been made a part of the VINT project. The availability of NS written in C++ and OTcl is made possible in the current scenario [50].

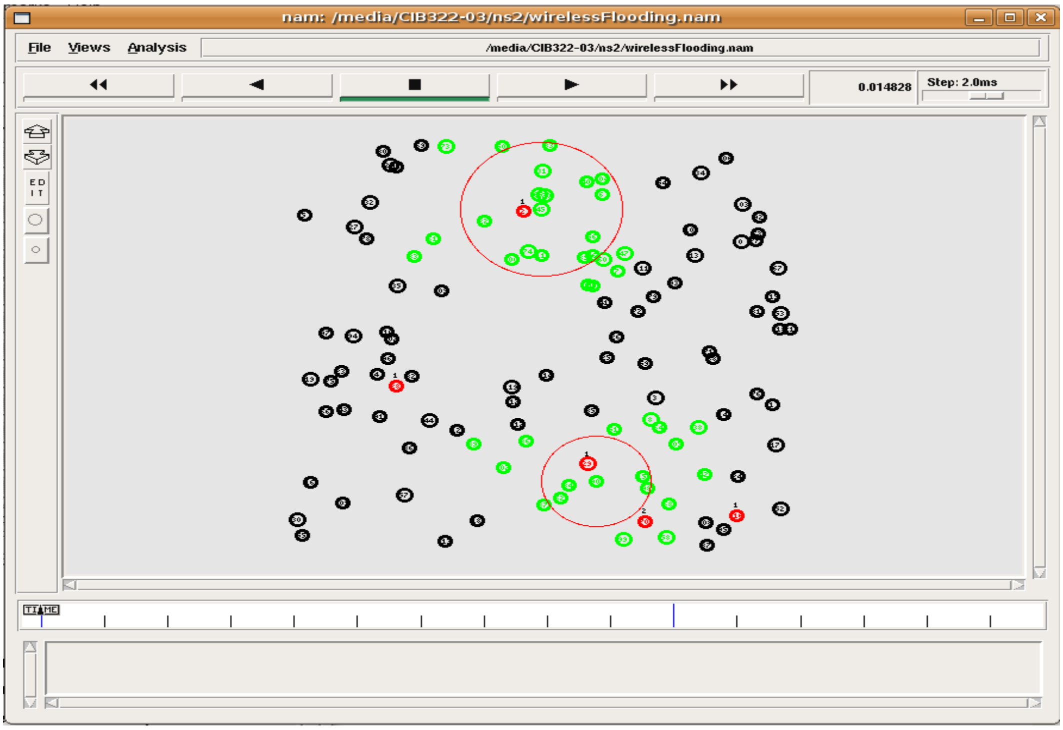


Figure 5-2: Snapshot of the simulation – starting stage

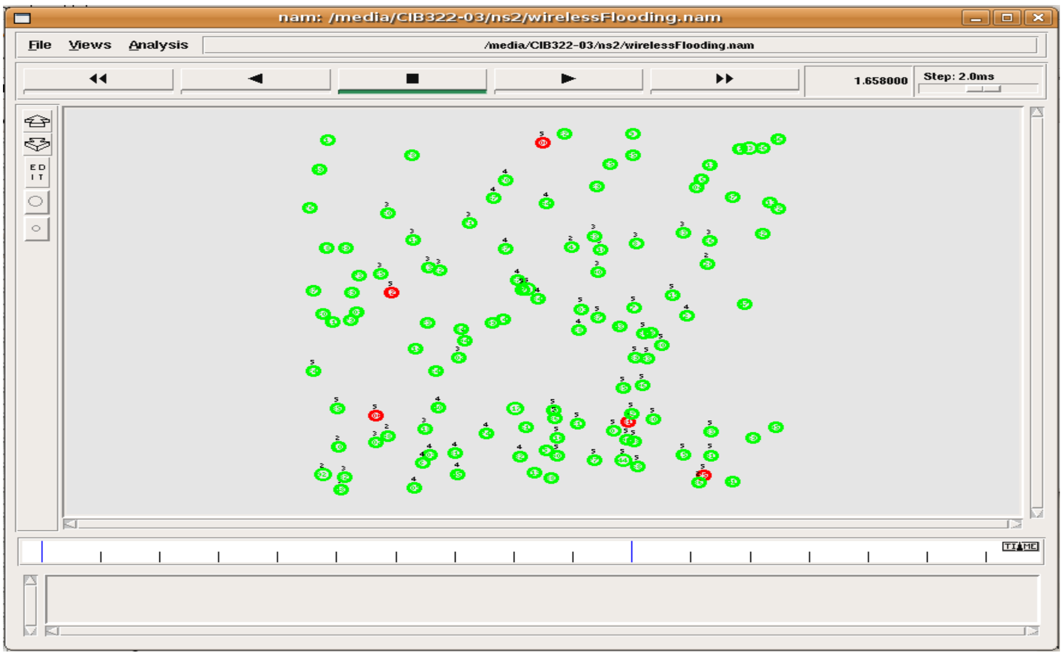


Figure 5-3: Snapshot of the simulation – finishing stage

Red nodes in Figure 5-2 and Figure 5-3 represent ANs - Green nodes represent NANs – Number above each node show how many active nodes does each node seen – nodes with no number has not seen any active node.

5.2.1 Parameters

The design of the simulation model reflects the real life scenario in many ways and many terms. First, the topology size is defined to be 1 Km2, with different number of random distributed nodes {50, 100, 150 or 200}. This ensures the required variety for density of nodes and in between cars distance. Second, the simplest setting is used in defining the used channel type, radio propagation model, network interface type, Mac type, routing protocol and queue type. This makes the model more general and applicable on the top of advanced setting networks (Table 5-1 shows the exact value for each parameter). Finally, all nodes are mobile and the movement pattern for those nodes is completely random generated in each run of the simulation.

Chosen parameters values as following:

Table 5-1: Simulation Parameters

Simulation Parameter	Assigned Value
Channel Type	Channel/WirelessChannel
network interface type	Phy/WirelessPhy
MAC type	Mac/802_11
interface queue type	Queue/DropTail/PriQueue
link layer type	LL
Routing Protocol	DumbAgent
Topology Type/Size	Flat Grid /(1000mX1000m)
Nodes Distribution	Complete Random
Movement Pattern	Complete Random

5.2.2 Iterations

The diagrams are aggregated and averaged from data collecting after repeating the simulation a number of times in order to get as much possibilities as possible. The variable values (in each iteration) are as follows (خطأ! لم يتم العثور على مصدر المرجع.):

- Total number of nodes: four different numbers {50, 100, 150 and 200} with random distribution in each time.
- Number of Active nodes: five different numbers of AN {5, 10, 20, 25 and 35} among the total number of nodes with random selection.
- Maximum number of Hops: to define the optimum number of hops each message can travel, different number of hops have been tried {1, 2, 3, 4, 5, 6, 7, 8, 9 and 10}.
- Maximum data collection Delay Time: to avoid noisy system, I tried to use data collection delay time to reduce the number of exchange messages. For

that purpose, I tried with fifteen different delay time {0.00, 0.005, 0.01, 0.025, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.5, 1.0 and 2.0}.

- In each time from the about iteration (3000 times), I repeat each iteration ten times with different movement pattern, nodes distribution and random selection of active nodes.

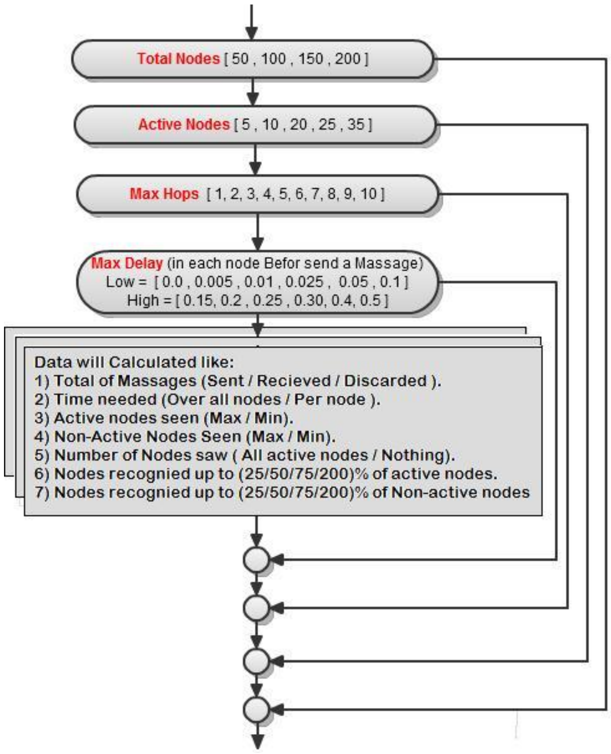


Figure 5-4: Simulation Iteration Illustration

This approach can give the entire picture and help decide the optimum numbers to be used to get better results in terms of combining the number of hops with data collection delay time.

As illustrated on Figure 5-4, the following data are calculated:

- Total number of Messages (sent / received / discarded).
- Simulation Time needed (by all nodes / per node).
- Active nodes seen (Max / Min) among all nodes.
- Non-active nodes seen (Max / Min) among all nodes.
- Number of nodes saw (all active nodes / nothing).
- Number of nodes recognize (0%-25% / 25%-50% / 50%-75% / 50%-100%) of the whole active nodes.
- Number of nodes recognize (0%-25% / 25%-50% / 50%-75% / 50%-100%) of all non-active nodes.

The simulation results are compiled on the basis of average results of running the simulation 10 times per each assumption (each Delay Time × each max Hops × each Active node number × each total number of all nodes) with complete random selection of active nodes, but the movement patterns I tested are two cases: first case, complete random generation in each round, second case, the same movement pattern for all rounds with the same delay and number of hops.

5.2.3 Simulation Setup

It was applied in the NS-2 to evaluate the performance of the scheme proposed, which would help in the comparison of it with the generic 802.11 based scheme. A simple scenario is first simulated to initiate the process where 150 vehicles pass through a one way road that has vehicles travelling at a speed of 45 miles/hour (20m/s). After an exponential distribution with a mean of 0.1 to 2 vehicles/second, the vehicles move into the road randomly. This is equal to a mean inter-vehicle space of 10 to 200 meters.

Network traffic is generated by the 5% to 30% of the vehicles out of the 150 vehicles. A situation discovery message is initiated by each selected vehicle, which sends the data to the nearby nodes without delay. Until the current situation is lost, the car will continue to generate and send the data. The data needs to be linked to the available data based on the pre-known surrounded nodes information and the situation sensed.

Table 5-2: Simulation Setup

Parameter Value	Simulation area 2000m× 500m
Number of vehicles	150
Vehicle coming rate	0.1 - 2 vehicles/second
Vehicle velocity	45 miles/hour
MAC layer module	802.11b
Bandwidth	2 Mbps
Data packet size	1440 byte

The simulation parameters are setup based on our experimental results to evaluate the link quality of a real environment. A 110 meter transmission range is provided by tuning the transmission power level in the simulator that matches or experimental results where no packets are received beyond the 110 meter limit.

The experimental results led to the packet loss ratio at the various distances from the originator, as shown in the next chapter.

CHAPTER 6

Results

Analysis & Outcome

Chapter outline:

- Results aggregation
- Results analysis
- Results outcome

Chapter 6

6 Results: Analysis and outcome

6.1 *Results Aggregation:*

The simulation has been repeated 30,000 times with varying parameters and the aggregate results will be presented in the next section.

To help improve the aggregation and visualisation of the data and present them in dynamic form, a tool has been developed for that purpose using Visual Studio 2008 (Figure 6-1). The tool can help in discovering the trend for any of the collected data (e.g.: number of exchange messages, maximum seen active nodes…) based on the number of hops and delay time. This approach makes us able to predict the optimum number of hops with the best delay time. I used it to establish the optimum parameters for the best performance of the algorithm (e.g.: reducing the number of exchanged message over the most suitable delay time with the maximum number of recognized active nodes and the maximum number of non-active nodes).

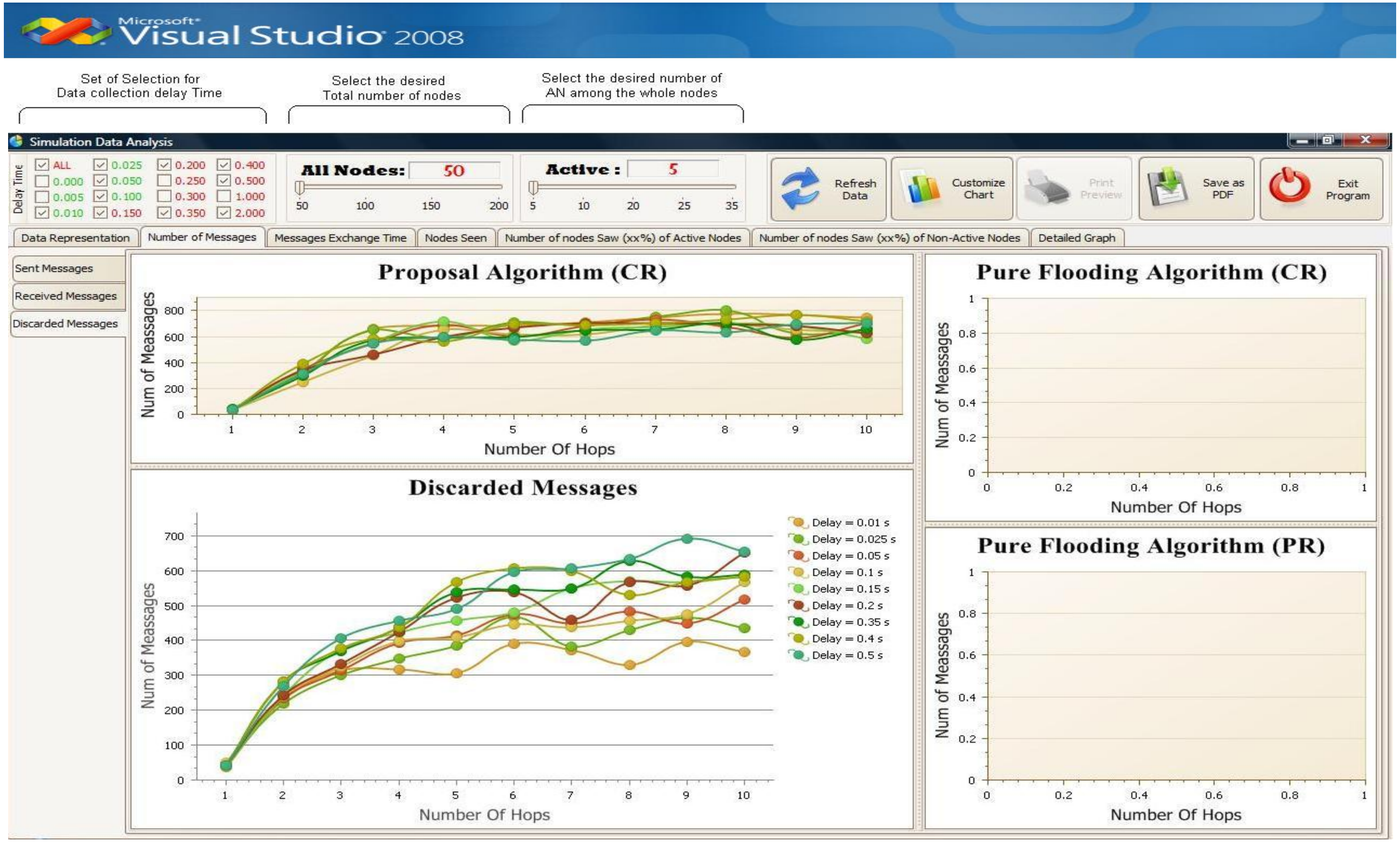


Figure 6-1: Snapshot for the Developed Tool (Simulation Data Analysis Tool)

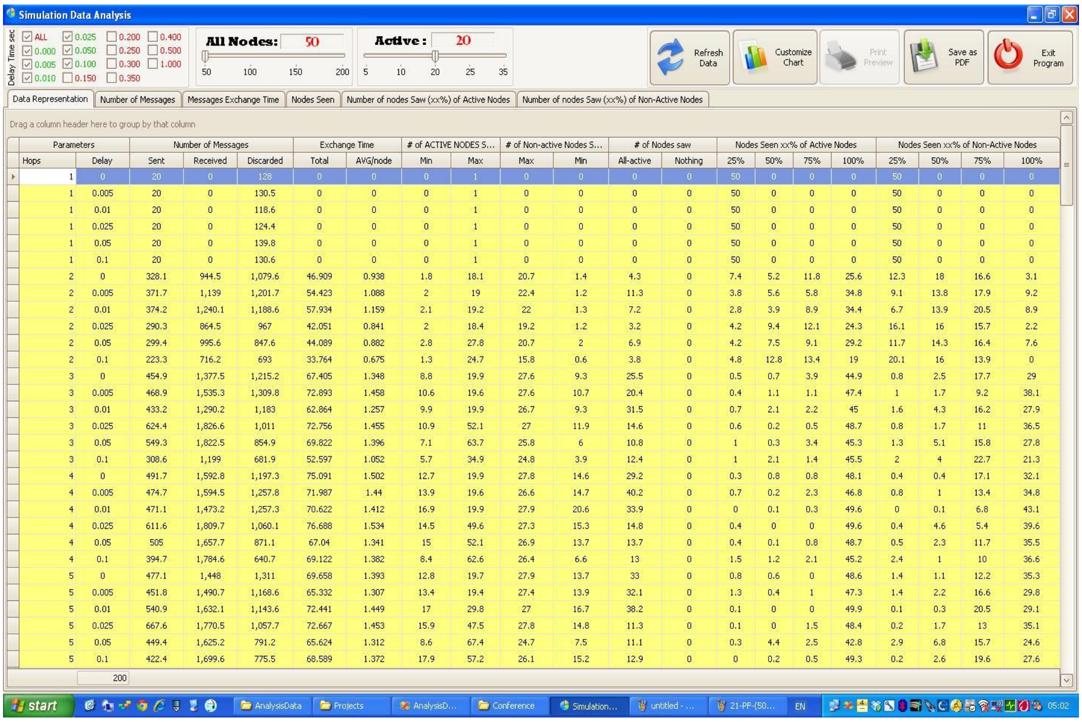
6.2 *Results Analysis:*

As I am looking for the optimum number of hops enough to discover the whole local area and, at the same time, the optimum Delay time each node should use before resending any message, I will analyse all the available data from the simulation with these two parameters (Number of Hops and Delay Time) as variables separately.

Number of exchange messages needed, Messages Exchange Time and number of recognized nodes (AN/NAN) will be used as indicators for the best results and will be enough to detect any Traffic Condition if I consider the following indicators:

6.2.1 Data Representation:

Knowing the ratio between AN and NAN (or simply their numbers) is crucial to detect whether the situation is present or not. The results of the experiments presented on the next two diagrams present the number of recognised nodes as a function of the number of hops parameter (See Figure 6-2).



Parameters		Number of Messages			Exchange Time		# of ACTIVE NODES S...		# of Non-active Nodes S...		# of Nodes saw		Nodes Seen xx% of Active Nodes				Nodes Seen xx% of Non-Active Nodes			
Hops	Delay	Sent	Received	Discarded	Total	AVG/node	Min	Max	Max	Min	All-active	Nothing	25%	50%	75%	100%	25%	50%	75%	100%
1	0	20	0	128	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
1	0.005	20	0	130.5	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
1	0.01	20	0	118.6	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
1	0.025	20	0	124.4	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
1	0.05	20	0	139.8	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
1	0.1	20	0	130.6	0	0	0	1	0	0	0	0	50	0	0	0	50	0	0	0
2	0	328.1	944.5	1,079.6	46.909	0.938	1.8	18.1	20.7	1.4	4.3	0	7.4	5.2	11.8	25.6	12.3	18	16.6	3.1
2	0.005	371.7	1,139	1,201.7	54.423	1.088	2	19	22.4	1.2	11.3	0	3.8	5.6	5.8	34.8	9.1	13.8	17.9	9.2
2	0.01	374.2	1,240.1	1,188.6	57.934	1.159	2.1	19.2	22	1.3	7.2	0	2.8	3.9	8.9	34.4	6.7	13.9	20.5	8.9
2	0.025	290.3	864.5	967	42.051	0.841	2	18.4	19.2	1.2	3.2	0	4.2	9.4	12.1	24.3	16.1	16	15.7	2.2
2	0.05	299.4	995.6	847.6	44.089	0.882	2.8	27.8	20.7	2	6.9	0	4.2	7.5	9.1	29.2	11.7	14.3	16.4	7.6
2	0.1	223.3	716.2	693	33.764	0.675	1.3	24.7	15.8	0.6	3.8	0	4.8	12.8	13.4	19	20.1	16	13.9	0
3	0	454.9	1,377.5	1,215.2	67.405	1.348	8.8	19.9	27.6	9.3	25.5	0	0.5	0.7	3.9	44.9	0.8	2.5	17.7	29
3	0.005	468.9	1,535.3	1,309.8	72.893	1.458	10.6	19.6	27.6	10.7	20.4	0	0.4	1.1	1.1	47.4	1	1.7	9.2	38.1
3	0.01	433.2	1,290.2	1,183	62.864	1.257	9.9	19.9	26.7	9.3	31.5	0	0.7	2.1	2.2	45	1.6	4.3	16.2	27.9
3	0.025	624.4	1,826.6	1,011	72.756	1.455	10.9	52.1	27	11.9	14.6	0	0.6	0.2	0.5	48.7	0.8	1.7	11	36.5
3	0.05	549.3	1,822.5	854.9	69.822	1.396	7.1	63.7	25.8	6	10.8	0	1	0.3	3.4	45.3	1.3	5.1	15.8	27.8
3	0.1	308.6	1,199	681.9	52.597	1.052	5.7	34.9	24.8	3.9	12.4	0	1	2.1	1.4	45.5	2	4	22.7	21.3
4	0	491.7	1,592.8	1,197.3	75.091	1.502	12.7	19.9	27.8	14.6	29.2	0	0.3	0.8	0.8	48.1	0.4	0.4	17.1	32.1
4	0.005	474.7	1,594.5	1,257.8	71.987	1.44	13.9	19.6	26.6	14.7	40.2	0	0.7	0.2	2.3	46.8	0.8	1	13.4	34.8
4	0.01	471.1	1,473.2	1,257.3	70.622	1.412	16.9	19.9	27.9	20.6	33.9	0	0	0.1	0.3	49.6	0	0.1	6.8	43.1
4	0.025	611.6	1,809.7	1,060.1	76.688	1.534	14.5	49.6	27.3	15.3	14.8	0	0.4	0	0	49.6	0.4	4.6	5.4	39.6
4	0.05	505	1,657.7	871.1	67.04	1.341	15	52.1	26.9	13.7	13.7	0	0.4	0.1	0.8	48.7	0.5	2.3	11.7	35.5
4	0.1	394.7	1,784.6	640.7	69.122	1.382	8.4	62.6	26.4	6.6	13	0	1.5	1.2	2.1	45.2	2.4	1	10	36.6
5	0	477.1	1,448	1,311	69.658	1.393	12.8	19.7	27.9	13.7	33	0	0.8	0.6	0	48.6	1.4	1.1	12.2	35.3
5	0.005	451.8	1,490.7	1,168.6	65.332	1.307	13.4	19.4	27.4	13.9	32.1	0	1.3	0.4	1	47.3	1.4	2.2	16.6	29.8
5	0.01	540.9	1,632.1	1,143.6	72.441	1.449	17	29.8	27	16.7	38.2	0	0.1	0	0	49.9	0.1	0.3	20.5	29.1
5	0.025	667.6	1,770.5	1,057.7	72.667	1.453	15.9	47.5	27.8	14.8	11.3	0	0.1	0	1.5	48.4	0.2	1.7	13	35.1
5	0.05	449.4	1,625.2	791.2	65.624	1.312	8.6	67.4	24.7	7.5	11.1	0	0.3	4.4	2.5	42.8	2.9	6.8	15.7	24.6
5	0.1	422.4	1,699.6	775.5	68.589	1.372	17.9	57.2	26.1	15.2	12.9	0	0	0.2	0.5	49.3	0.2	2.6	19.6	27.6

Figure 6-2: Data representation for the simulation output.

6.2.2 Number of Exchanged Messages as a function of the number of Hops:

The following diagrams, which show the number of sent, received, lost and redundant messages in each node, will indicate how noisy the system is, when both pure flooding and TCDA are used as methods. Furthermore, it will give indication as to the optimum value for the hops parameter.

6.2.2.1 Sent Messages:

The graphs below, clearly shows how much less noisy the network will be if it uses the proposed method instead of the pure flooding method. The difference between the level of noise inside the network based on the method is at least 3 times more than with the proposed algorithm.

For example, if we use 5 as a maximum number of hops each message will travel, and 0.01s as time delay in each node, we will find that about 1250 messages will be sent in total (over the whole network) with pure flooding (Figure 6-4), while in case of using the proposal algorithm (Figure 6-3), there would only be 120 messages.

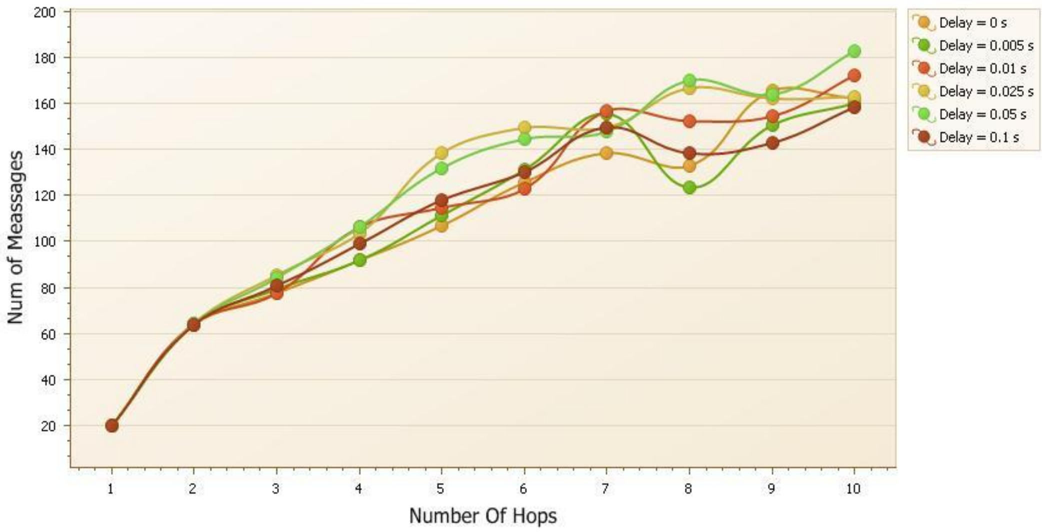


Figure 6-3: TCDAlgorithm

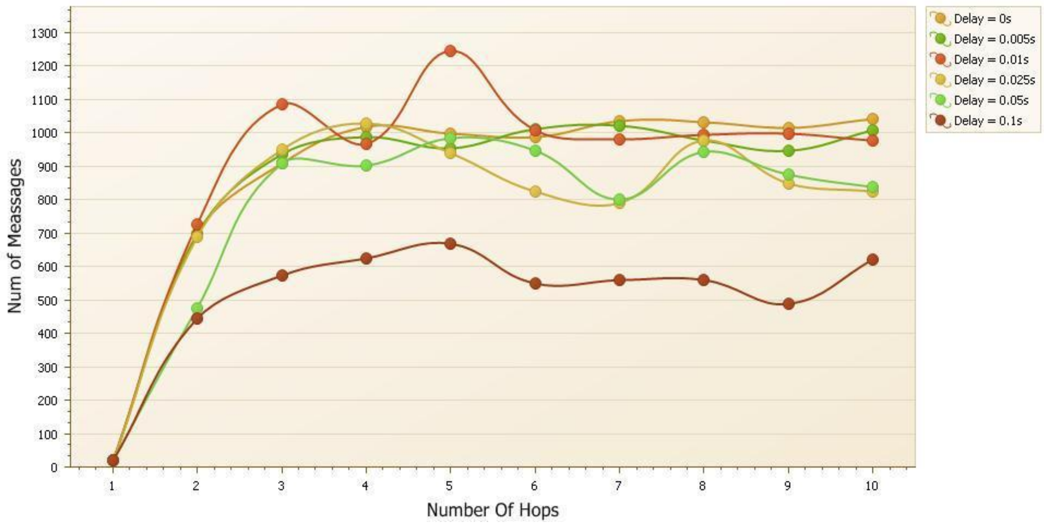


Figure 6-4: Pure Flooding Algorithm

6.2.2.2 Received Message:

In terms of the number of received messages, the graphs below shows a big difference in the network because the pure flooding algorithm saturates the system with sometimes unnecessary messages in order to get packets across the network. The difference between the noise level inside the network based on this method is sometimes up to 20 times more than its level in the proposal algorithm.

For example, By using a maximum number of hops each message will travel equal to 5 and 0.01s as time delay for each node, we will find that about 4000 messages will be received in total (over the whole network) in pure flooding algorithm (Figure 6-6) , while only 270 messages will be received in case of the proposal algorithm (Figure 6-5).

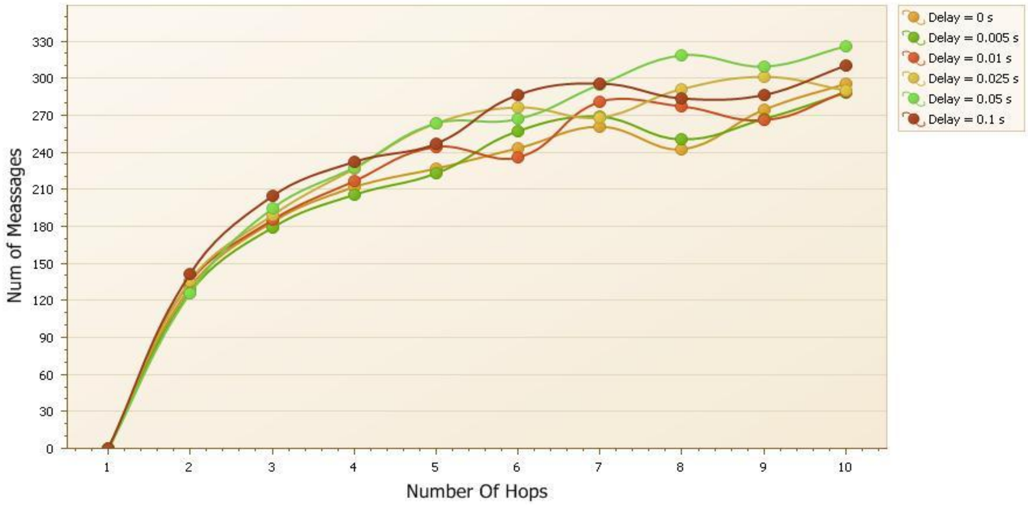


Figure 6-5: TCD Algorithm

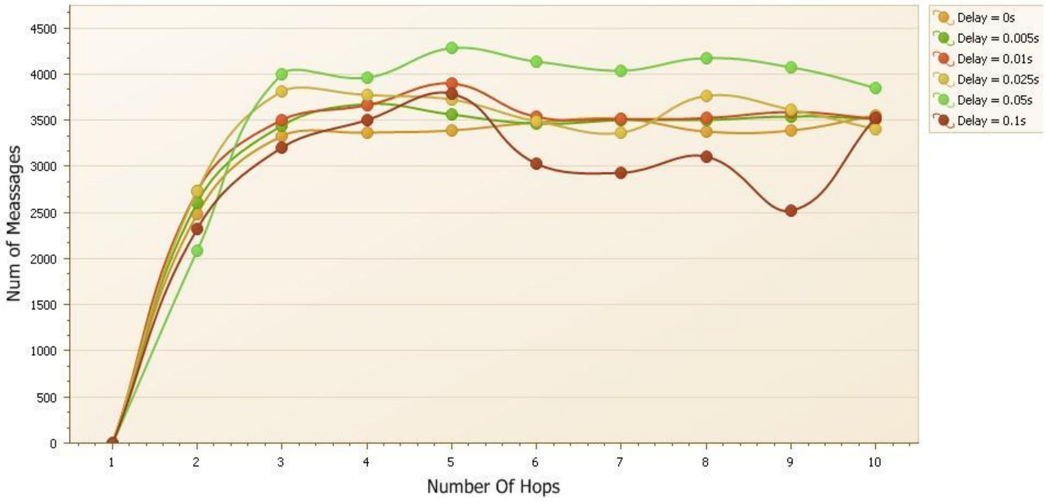


Figure 6-6: Pure Flooding Algorithm

6.2.2.3 Discarded Messages:

By calculating the dropped messages, the graphs below shows the extent to which fewer messages are discarded over the same number of hops while comparing the TCDA and the pure flooding algorithm. The difference between the level of noise inside the network with this method is about a ratio of 5 : 1 with regards to pure flooding and TCD algorithm.

For instance, checking the number of discarded messages in case of using 0.01s time delay with maximum number of 2 hops for message to travel, pure flooding algorithm shows (Figure 6-8) that 2000 messages are received in total (over the whole network), while only about 325 messages are received in case of the proposal algorithm (Figure 6-7).

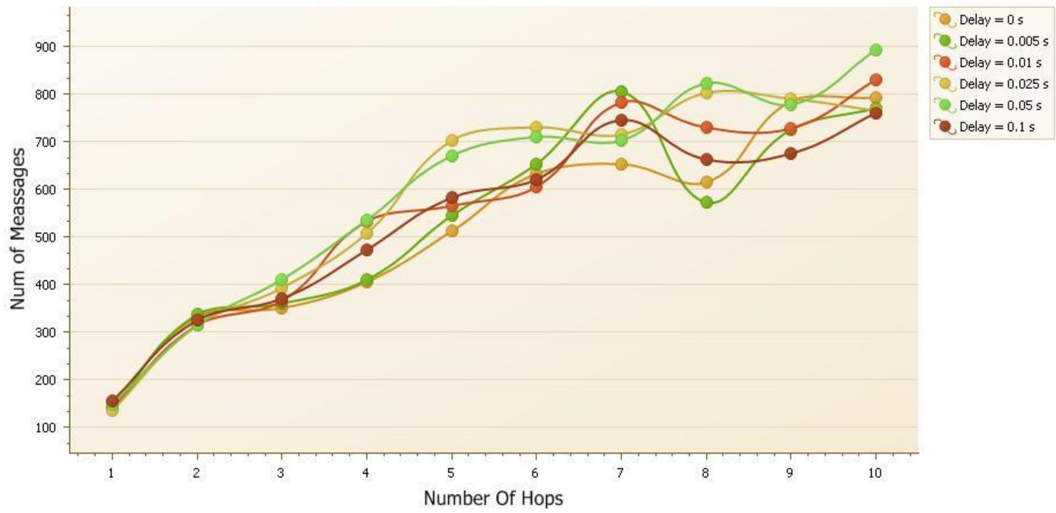


Figure 6-7: TCD Algorithm

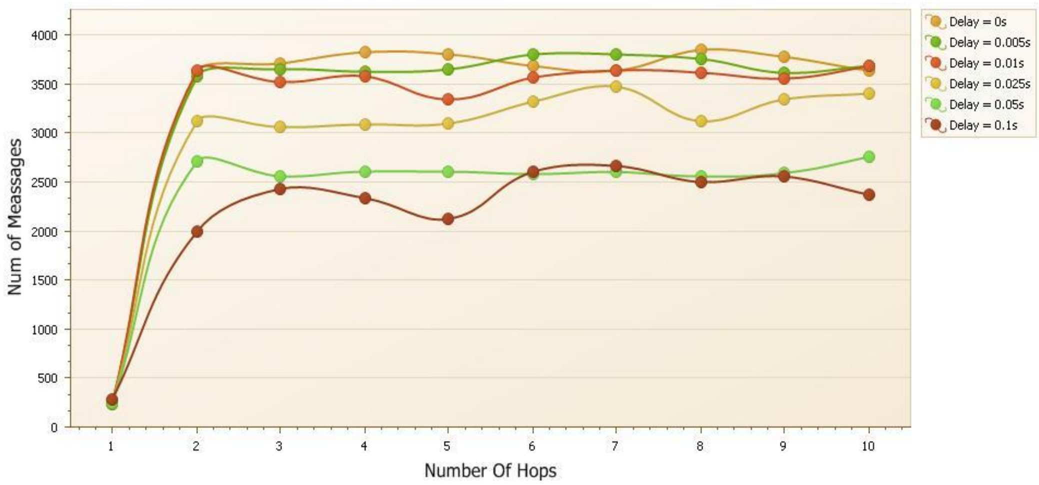


Figure 6-8: Pure Flooding Algorithm

6.2.3 Total Time for area discovery as a function of the number of hops:

The diagrams below show the total time needed for the algorithm to finish as a function of the number of hops parameter. Choosing the shortest total time needed to exchange all messages in order to detect a certain situation, is important for the detection speed and also for the timeout needed to wait before re-initiating the discovery sequence.

So, total time and time per node has been calculated during the experiments to show up the difference in the performance – in terms of time - between pure flooding algorithm and the proposal algorithm. The total time will show the whole time needed to finish the process of scanning the whole area designed in the simulation model. While the time per node is the required time needed per each node to scan the whole area in one round. Here are the outcome results:

6.2.3.1 Total time:

It’s clear that pure flooding consumes more than TCDA. The following graphs show the total time needed for each algorithm to scan the area based on the chosen number of hops. Both algorithms have been tested in the same scenarios many times.

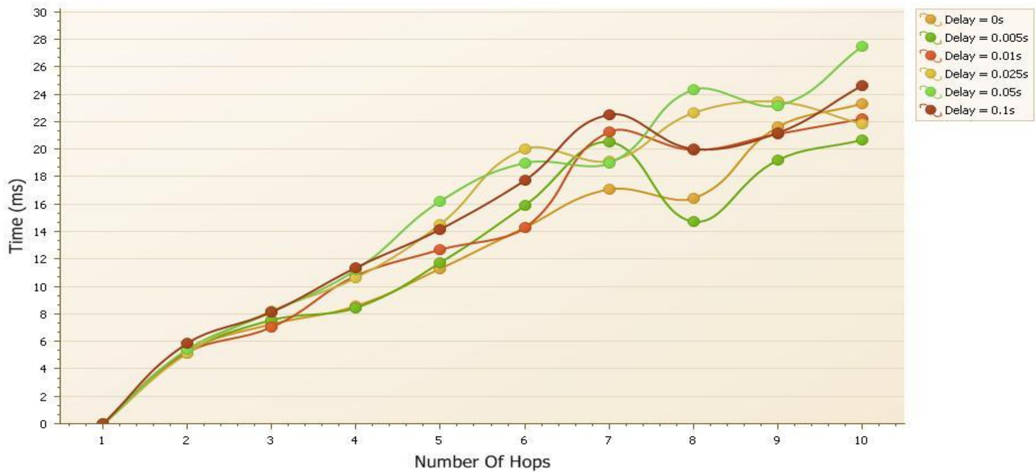


Figure 6-9: TCD Algorithm

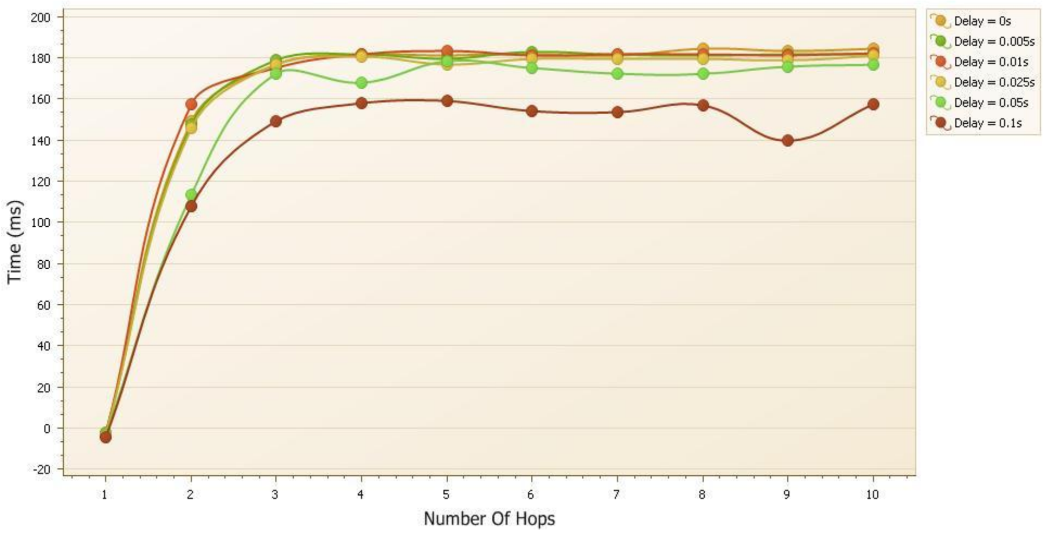


Figure 6-10: Pure Flooding Algorithm

By comparing those graphs, it’s clear that the required time for proposed algorithm TCDA (Figure 6-9) is more than 30 times better than pure flooding algorithm (Figure 6-10) in the range of choosing 2-4 as a maximum number of hops. Moreover, raising the number of hops to over 5 up to 10 still shows a big gap between the performance of the algorithms, where the total time needed still 8-10 times more in pure flooding algorithm compared with the proposed algorithm.

6.2.3.2 Time / node:

By checking the time per node needed to finish one round of discovery scan for the whole area, it will be clear how much time TCDA will save.

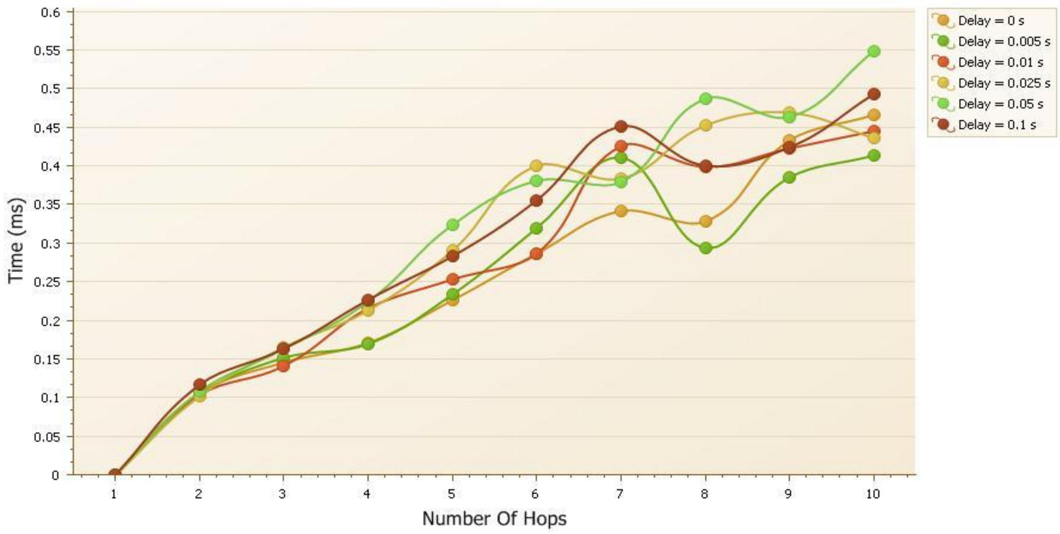


Figure 6-11: TCD Algorithm

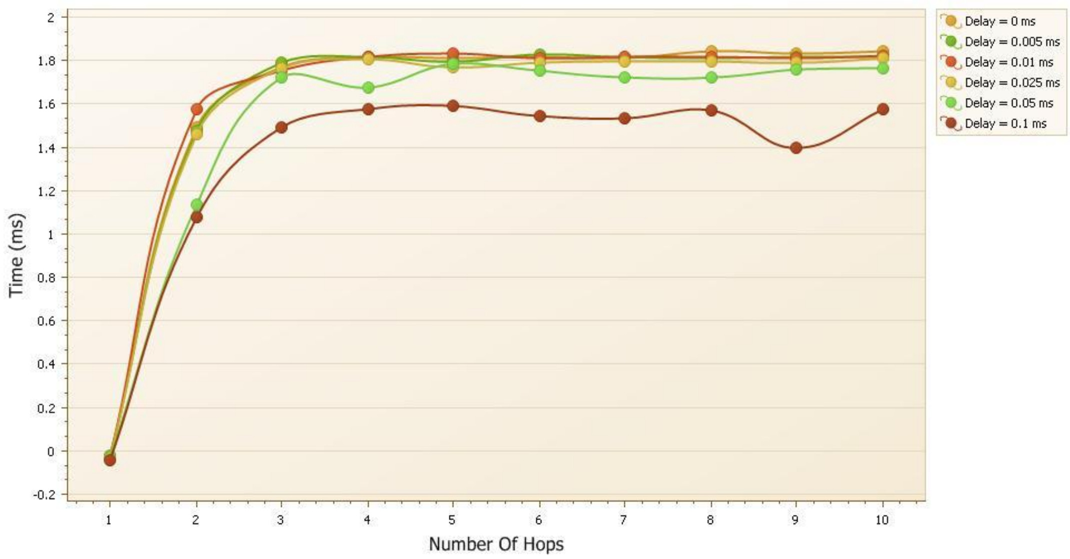


Figure 6-12: Pure Flooding Algorithm

It can be observed from the graphs that the pure flooding algorithm (Figure 6-12) needs more than 10 times of the time needed by TCDA (Figure 6-11) when 2 is the maximum number of hops. Then, as the number of hops increases, the ratio declines gradually to around 3 times more.

6.2.4 Number of recognized nodes (AN / NAN):

Knowing the ratio between AN and NAN (or simply their numbers) is crucial to detect if the situation is present or not (e.g.: 10% of cars should have foggy light ON to declare foggy situation in the area). The results of the experiments presented on the next two diagrams present the number of recognised nodes as a function of the number of hops parameter.

6.2.4.1 Number of nodes that are aware of all active nodes (AN):

After one complete cycle of scanning (exchange messages) between all cars in the whole area, TCDA can calculate how many nodes have seen all active nodes. This is indication for how many nodes have seen all ANs, or how many cars can draw the boundary of the current road situation (situation zone boundaries).

Here both methods are working almost the same with a little advantage for the pure flooding method (Figure 6-13, Figure 6-14).

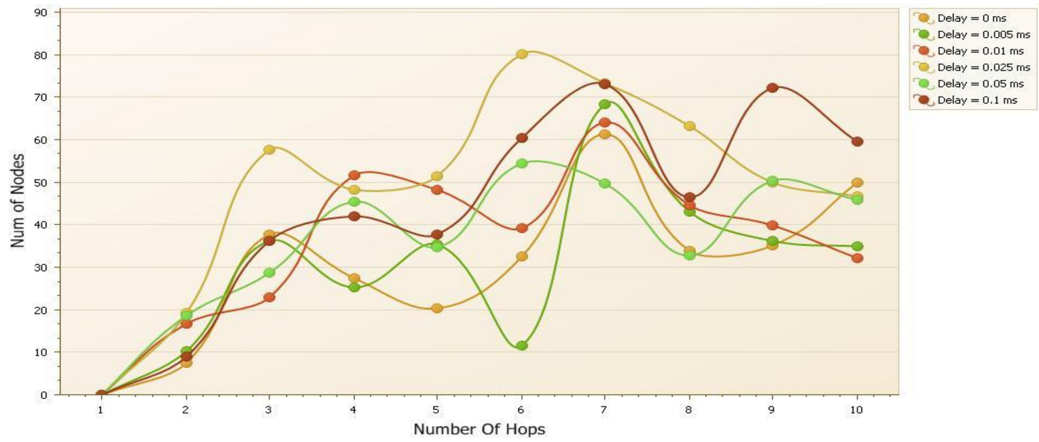


Figure 6-13: TCD Algorithm

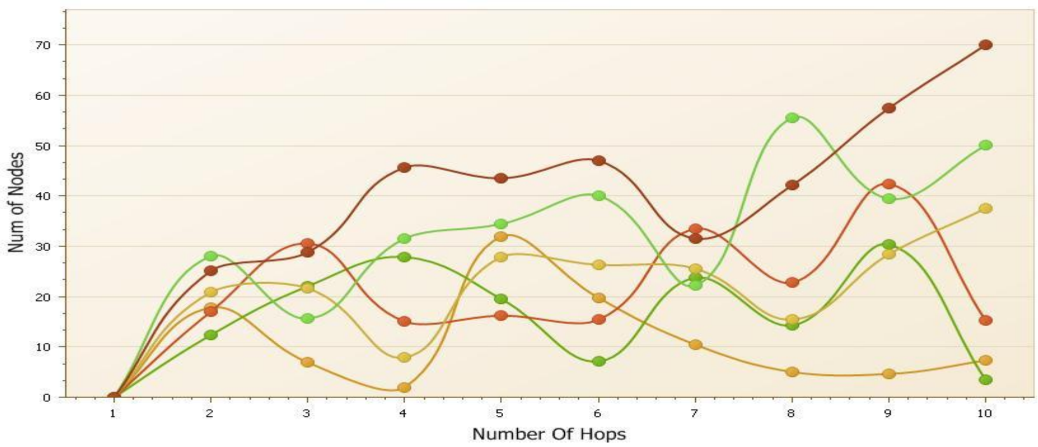


Figure 6-14: Pure Flooding Algorithm

6.2.4.2 Number of nodes that are aware of all Non-Active nodes (NAN):

This is identical to the previous idea, except this time the Non-Active nodes are counted. Knowing the number of NAN around the area, will enable us to calculate the ratio between the AN and the NAN to find out how much a certain situation spreads between cars.

TCDA - in (Figure 6-15) – shows higher performance in detecting most of NAN with using 3 hops comparing with pure flooding algorithm (Figure 6-16). For example, chosen 3 hops is enough for TCDA to detect up to 65 NAN (out of 100 NAN), while pure flooding algorithm need more 10 hops mechanism to reach that.

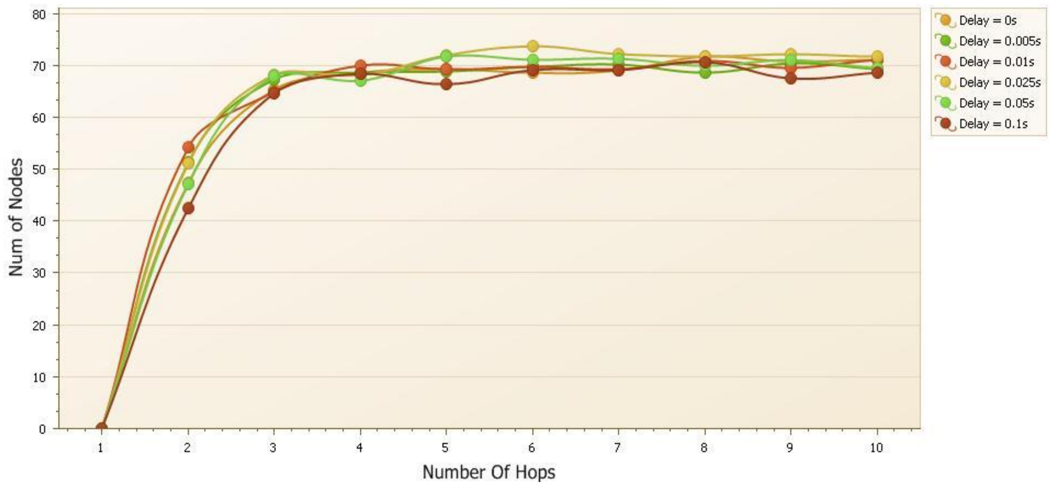


Figure 6-15: TCD Algorithm

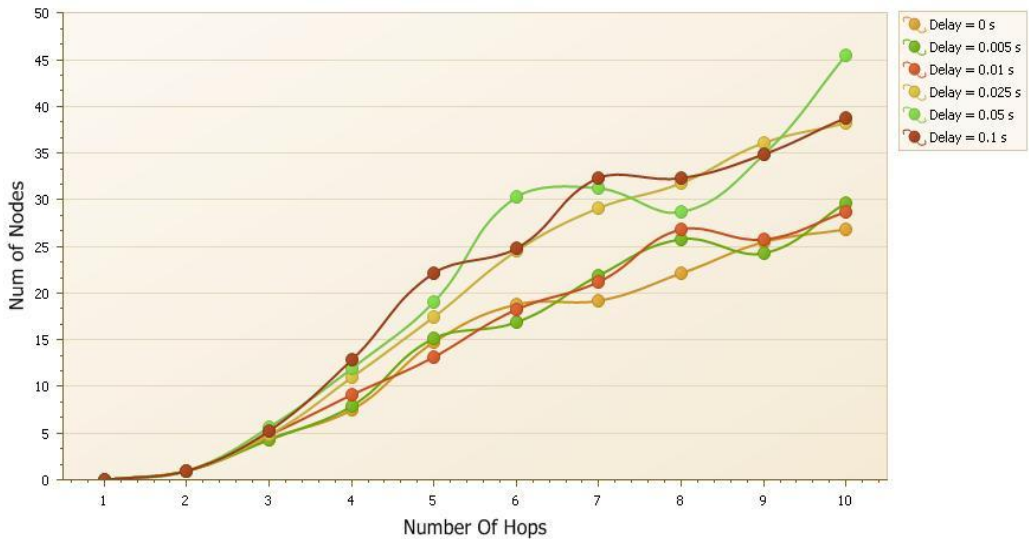


Figure 6-16: Pure Flooding Algorithm

6.2.5 Number of nodes That are aware of (xx %) of Active nodes:

Again, knowing the ratio of AN (or simply their numbers) is useful to identify the road conditions (certain situation is present or not) and for certain applications like (dynamic traffic light cycles). The next graphs present the results of the experiments of the number of recognised nodes as a function of the number of hops parameter.

6.2.5.1 Number of nodes that are aware of between 0% and 50% of AN:

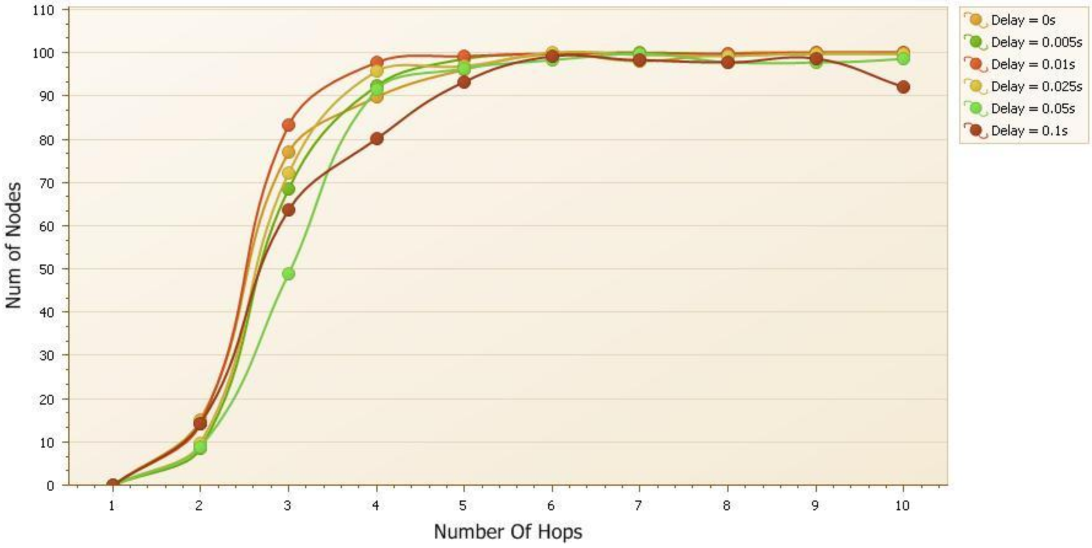


Figure 6-17: TCD Algorithm

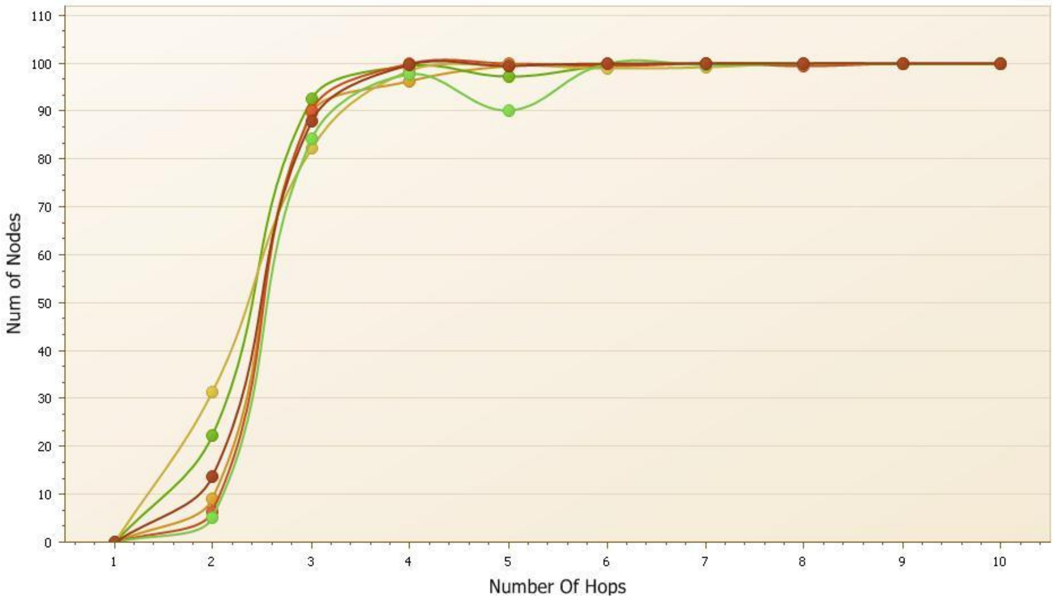


Figure 6-18: Pure Flooding Algorithm

6.2.5.2 Number of nodes that are aware of 50%-100% of AN:

Pure flooding algorithm (Figure 6-20) shows better results in case of number of Active nodes which has been detected/seen by other nodes. For example, in case of 3 hops as maximum number of hops each message will be travel, you can see in pure flooding algorithm 82-92 nodes of total 100 nodes can see from 75% up to 100% of all active nodes (AN) regards what delay time we use.

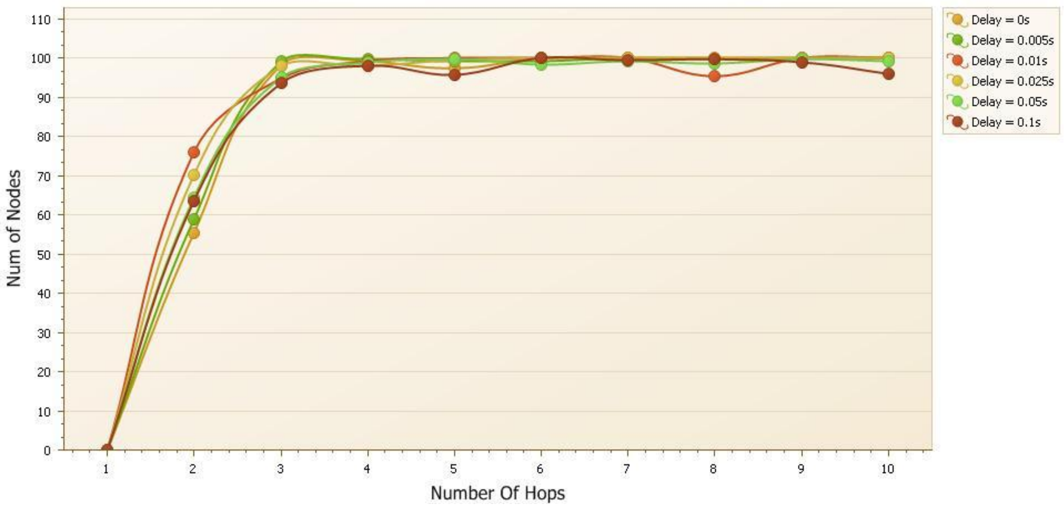


Figure 6-19: TCD Algorithm

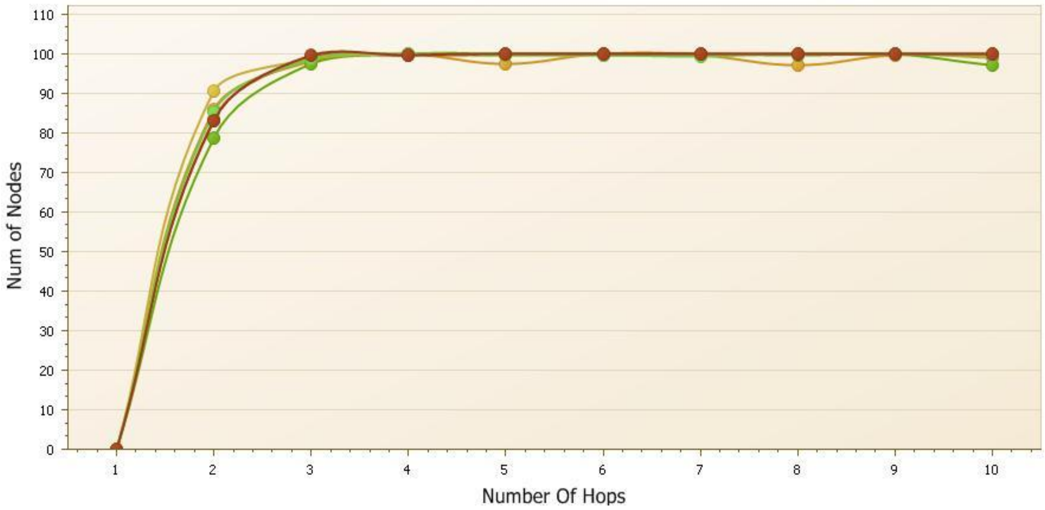


Figure 6-20: Pure Flooding Algorithm

6.2.6 Number of nodes That are aware of (xx %) of Non-Active nodes (NAN):

Calculating the ratio of non-active nodes (NAN) to all nodes in the area or simply their numbers opens the door for the implementation of many useful and helpful applications in terms of traffic assistant and driver comfort (e.g. : feeding traffic control centre by real-time data).

6.2.6.1 Number of nodes that are aware of 0%-50% of NAN:

By checking how many nodes has seen up to half of NAN will indicate new effective the algorithm is in offering new data. Also, how far the algorithm can make all nodes discoverable. Using these indicators, both algorithms doing almost the same with a little advantage to the pure flooding algorithm (Figure 6-22) .

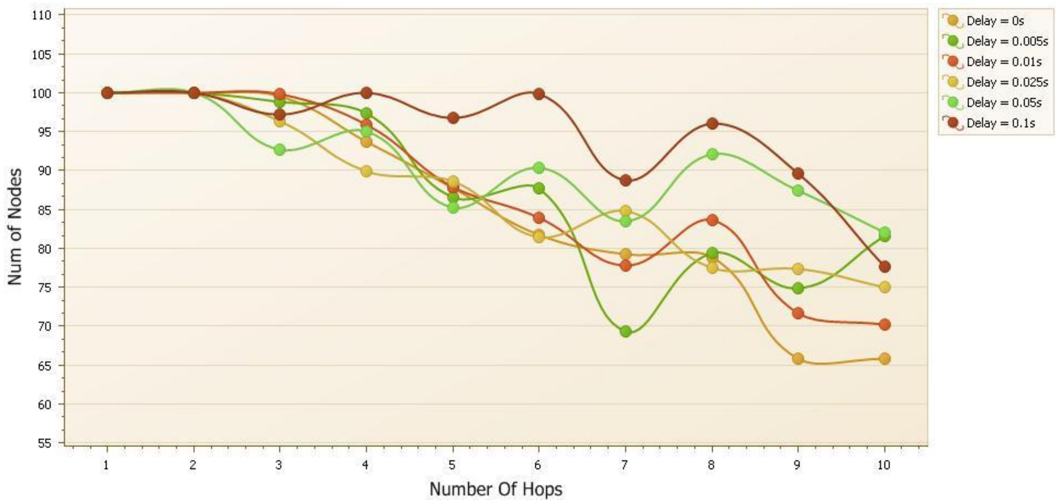


Figure 6-21: TCD Algorithm

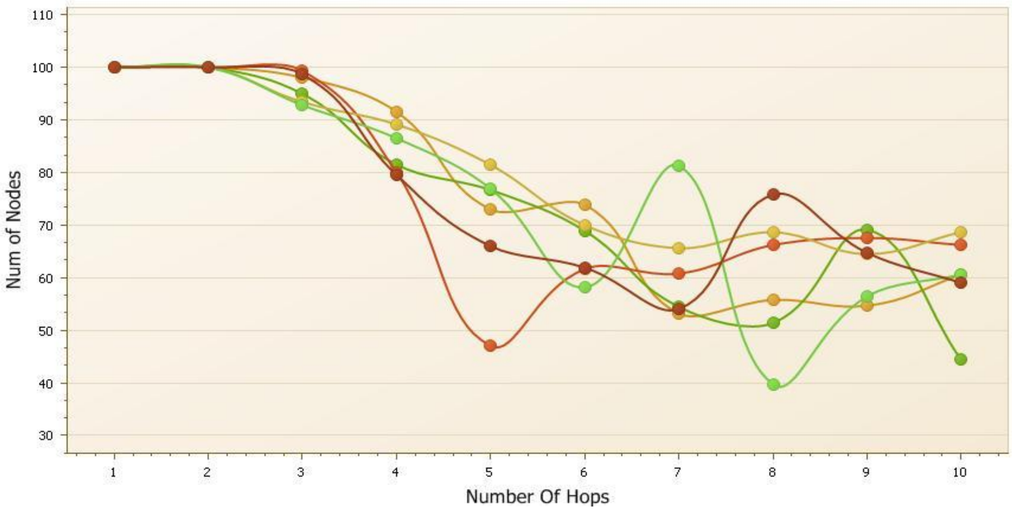


Figure 6-22: Pure Flooding Algorithm

6.2.6.2 Number of nodes that are aware of 50%-100% of NAN:

This shows how many nodes have seen more than the half of NAN to see how reliable is the algorithms for the applications which need such data (number of cars with in certain area). The graphs which represent this indicator show that using the pure flooding algorithm (Figure 6-24) is better than using TCDA (Figure 6-23) by almost a factor of two.

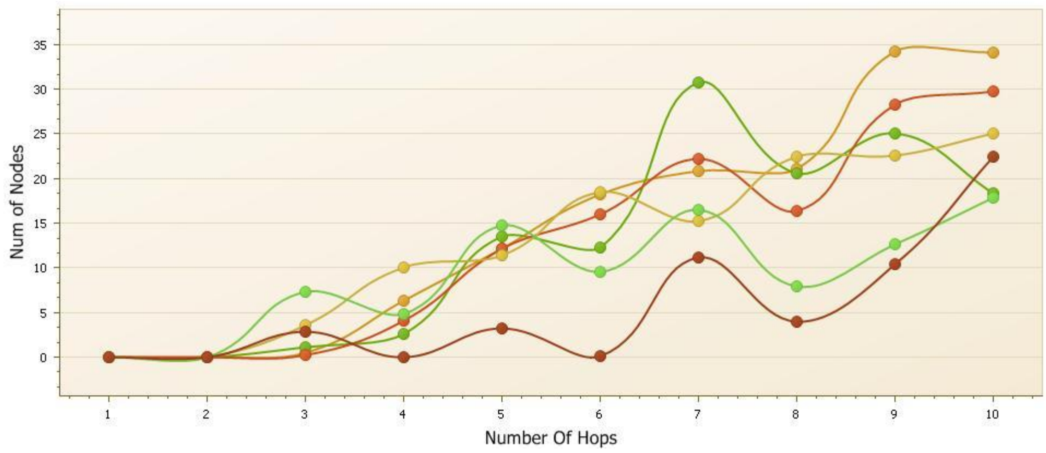


Figure 6-23: TCD Algorithm

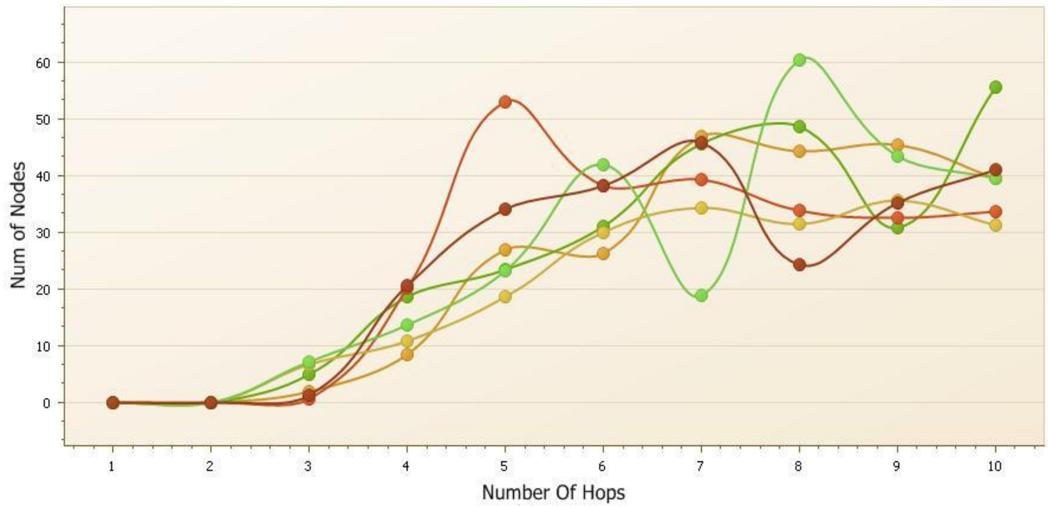


Figure 6-24: Pure Flooding Algorithm

6.3 Results outcome:

As mentioned previously, different situations are detected by different number of recognized AN/NAN. Therefore it would be incorrect if I suggest just one fixed number - as optimum number – for the best delay time or number of hops. Furthermore, a range of numbers will be proposed by this study, which will suit most situations detection cases. Based on this assumption, looking for the best results, which can recognize from 50% up to 100% of active nodes will be enough to cover all cases.

These results identify the optimum parameters where the effectiveness of the algorithm is maximised.

6.3.1 Recommended Number of Hops:

The results clearly shows that using 3 to 5 hops will be enough to detect any traffic conditions if I consider the mentioned indicators.

6.3.2 Recommended Delay Time:

The results show that the biggest delay time will reduce the number of exchanged messages, but it will increase the total time needed to recognize the biggest possible number of AN/NAN. This is a difficult compromise between time and noise, so the best delay time will be between 0.01 and 0.1 second.

Chapter 7

Conclusion

Chapter outline:

- Summary.
- Conclusion.
- Future work

Chapter 7

7 Conclusion

7.1 Summary

The first scientific contribution of this project is described in Chapter 3, where identifiable road traffic conditions have been researched, classified and systematically earmarked as suitable for cooperative algorithms.

The second scientific contribution, described in Chapter 4, is a comprehensive solution to support the data aggregation and dissemination for vehicles at the various locations in the metropolitan wide VANET. Several techniques were discussed as a solution, which was adjusted according to the relative location to roadside units of the vehicles to gain optimized results. The following is the summary of these techniques.

The real time road traffic discovery algorithm was thoroughly explained in Chapter 4. To calculate the optimal delivery paths, the historical road traffic statistics were used by the various data dissemination schemes. But every road does not have its historical data preserved and available for usage. The real time road traffic conditions in some special events are not perfectly captured by the historical data such as, in the road construction or traffic redirection. The forwarding of the path selection for data delivery can be greatly improved by the knowledge of the real time vehicular traffic condition.

The road situation discovery messages are suggested to be flooded to obtain a real time reply message. The fast vehicular movement is making the node connectivity extremely unreliable in VANET and the forwarding nodes present the situation that is of less importance. The redundant transmissions can be eliminated through the technique presented in Section 4.2.4 when used in the discovery flooding. Each node can be forced to hold the packet and wait for a short duration in this technique. The source can leverage the real time vehicular traffic information to create a road-based path after the discovery reply has been received. The road-based path may be built upon successions of road intersections with a high probability and network connectivity. This algorithm can deliver good results by adding a reasonable overhead. The vehicle traffic dynamics in the real time can be efficiently handled.

A data scheme was proposed to obtain a real time road traffic condition in Chapter 5. This would deal with the problem of data dissemination in the densely populated areas in VANET. The data in the TCDA is periodically broadcasted along the roads to reach the vehicles. The data delivery ratio was significantly improved through the proposed TCDA scheme and the network traffic was also reduced, as evident from the simulation results. The dissemination capacity of the proposed schemes was explored through the analytical models proposed. To choose the system parameters, guidelines were provided by the analytical models to increase the dissemination capacity under various data delivery ratio requirements.

An analysis tool was developed and presented in the Chapter 6 to show the advantage of the proposed approach. The design was evaluated for a large scale network through simulations, as our tool is at a small scale. The pure flooding approach used in the traditional 802.11 based mesh networks were surpassed in performance by the proposed approach, as shown through the simulation results. An excellent performance was achieved owing to the removal of majority of the processing overhead.

7.2 Conclusion

The overall aim for this part of the research – to suggest effective algorithm for collaborative data sensing and distribution and identify its optimum parameters has been achieved.

As an infrastructure-less vehicle-to-vehicle communication algorithm in terms of data sharing and collaborative generating information, it is highly efficient protocol for road traffic conditions identification. Also, it is capable of discovering traffic conditions within certain areas with dynamic variable search limitations conditions as well as using intelligent routing mechanism. However, it does pose numerous unique and novel challenges from network evolution to event detection and dissemination.

The work so far consists of proposing a new algorithm for effective traffic conditions sensing and data distribution in wireless mobile ad-hoc networks environment. The parameters for optimum performance of the algorithm have been identified and reported. Simulation tool and tools for data analyses have been designed, developed and implemented.

7.3 Future work

When cooperation and information exchange are applied to collectively and cooperatively perceive the context, it becomes evident that the tomorrow's driving assistance systems can go far beyond the present capabilities. Car drivers, ITS, environment and other people can benefit by the decisions made on the basis of the context.

A consistent solution for the dissemination of data in metropolitan wide VANETS is provided through this project. The field of constructing practical VANETs is open for discussion and research is still in progress to find ways to implement the urban VANET. This area is open for further research. I have given a few suggestions for the future research on this topic which is as follows:

1. The reduction of bandwidth used with the bonded delays. Different delay requirements are included in the VANET. To ensure that enough bandwidth for on time delivery of more time stringent data is available, the network

should maintain a low level of channel utilization. The reduction of the bandwidth consumed by the more delay tolerant data is important. One can use the wireless forwarding and 'store and carry' strategies in alternate by using the knowledge of the available traffic statistics. Vehicles are better to carry the data for a longer time period before they are forwarded, in cases of data not requiring immediate delivery. The data then can be delivered within the required time frame later on. The more delay tolerant data uses the store and carry strategy to minimize the use of the wireless medium, while the time stringent data is forwarded through the wireless forwarding strategy to reduce the delivery delay. The delay restrictions imposed by the applications will be followed as the communication overhead is reduced by this approach.

A similar path discovery as the DSR can also be applied. Data popularity can be considered in the data dissemination. Pure peer-to-peer data sharing without the infrastructure involved will be more used as wireless enabled vehicles are increasingly used. As VANET is an intermittent connected network, this poses a big challenge. The connection duration is often short and unreliable, as the network connectivity among the vehicles is by chance. There is no system to guarantee the time limit is followed and whether the vehicle can get a specific data item from other nodes. A shorter time may be required, if the vehicle requests a popular data item which is densely disseminated in the network, as there are higher chances of meeting one vehicle with the popular data. The accessibility of the popular data should rather be improved as compared to making all the data accessible in such an opportunistic DTN network. This is a more logical approach owing to the reasons discussed above. The most popular data item should be returned as a relevant request, when a vehicle receives a data request from the neighbouring node. Data is not only consumed but also carried by the receiver, which can use the data to serve more users with similar interests in the future. The client's current interest and overall demand in the network should be considered when the sender decides to deliver the data. Dissemination of the more popular data is assured through the individual decision. Further developments in the overall probability of getting a useful data for every user are introduced.

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Appendix A : Example of the data

AllNodes	Active	Hops	Rounds	maxWait	NumOfSentMsg	NumOfReceivedMsg	NumOfDiscardedMsg	TotalTime	AVGTimePerNode	ActiveNodesSeenMax	ActiveNodesSeenMin	NonActiveNodesSeenMax	NonActiveNodesSeenMin	NodesSawAllActive	NodesSawNothing	upto25ofActiveNodesRegonized	upto50ofActiveNodesRegonized	upto75ofActiveNodesRegonized	upto100ofActiveNodesRegonized	upto25ofNonActiveNodesRegonized	upto50ofNonActiveNodesRegonized	upto75ofNonActiveNodesRegonized	upto100ofNonActiveNodesRegonized	ActiveNodesList	ID
50	5	1	1	0	36	209	177	3537	71	2	0	2	0	0	0	38	12	0	0	50	0	0	0	26 28 34 40 9	1
50	5	1	1	0.01	56	348	217	5267	105	3	0	5	0	0	0	26	10	14	0	50	0	0	0	0 15 19 22 37	2
50	5	1	1	0.01	41	220	180	3538	71	2	0	2	0	0	0	34	16	0	0	50	0	0	0	14 22 28 32 43	3
50	5	1	1	0.03	109	819	594	20569	411	5	0	11	0	11	0	18	3	5	24	50	0	0	0	12 3 30 39 45	4
50	5	1	1	0.05	50	351	266	5530	111	2	0	4	0	0	0	28	22	0	0	50	0	0	0	19 23 31 42 6	5
50	5	1	1	0.1	46	269	213	6066	121	2	0	4	0	0	0	30	20	0	0	50	0	0	0	11 14 26 40 43	6
50	5	1	2	0	93	664	47	1546	30	5	0	9	0	6	0	13	17	0	20	50	0	0	0	23 29 3 37 9	9

							0	7	9																
50	5	1	2	0.01	44	274	208	5496	110	3	0	4	0	0	0	27	22	1	0	50	0	0	0	0 18 22 28 35	10
50	5	1	2	0.01	86	594	434	13809	276	4	0	9	0	0	0	24	0	11	15	50	0	0	0	0 19 2 29 3	11
50	5	1	2	0.03	39	249	208	3416	68	2	0	3	0	0	0	42	8	0	0	50	0	0	0	13 3 43 44 47	12
50	5	1	2	0.05	127	1038	740	26934	539	5	0	15	0	14	0	9	1	9	31	36	14	0	0	22 37 41 48 9	13
50	5	1	2	0.1	90	681	529	17357	347	4	0	8	0	0	0	9	19	16	6	50	0	0	0	0 1 38 42 45	14
50	5	1	3	0	72	532	316	13037	261	4	0	11	0	0	0	18	2	29	1	50	0	0	0	23 3 31 42 5	17
50	5	1	3	0.01	68	437	317	8344	167	3	0	5	0	0	0	16	27	7	0	50	0	0	0	3 37 41 46 47	18
50	5	1	3	0.01	38	236	184	4708	94	3	0	5	0	0	0	37	8	5	0	50	0	0	0	0 3 32 33 47	19
50	5	1	3	0.03	73	552	436	13549	271	5	0	7	0	17	0	23	7	2	18	50	0	0	0	0 17 25 33 39	20
50	5	1	3	0.05	38	216	155	3351	67	2	0	4	0	0	0	31	19	0	0	50	0	0	0	11 12 19 23 5	21
50	5	1	3	0.1	81	626	528	16661	333	5	0	8	0	11	0	25	3	7	15	50	0	0	0	17 38 40 43 7	22
50	5	1	4	0	49	229	141	3929	79	3	0	5	0	0	0	28	15	7	0	50	0	0	0	31 33 39 40 8	25
50	5	1	4	0.01	70	519	405	9906	198	4	0	7	0	0	0	19	20	0	11	50	0	0	0	13 14 15 31 43	26
50	5	1	4	0.01	60	377	284	7986	160	3	0	6	0	0	0	25	15	10	0	50	0	0	0	0 15 41 7 9	27

50	5	1	4	0.03	57	466	353	8010	160	2	0	6	0	0	0	20	30	0	0	50	0	0	0	18 29 3 34 5	28
50	5	1	4	0.05	46	346	284	7109	142	2	0	4	0	0	0	28	22	0	0	50	0	0	0	2 32 37 48 8	29
50	5	1	4	0.1	36	196	165	4550	91	2	0	2	0	0	0	45	5	0	0	50	0	0	0	10 29 34 36 6	30
50	5	1	5	0	76	491	372	9454	189	4	0	9	0	0	0	26	5	4	15	50	0	0	0	2 21 22 35 37	33
50	5	1	5	0.01	45	302	237	5466	109	3	0	3	0	0	0	37	0	13	0	50	0	0	0	0 10 33 47 5	34
50	5	1	5	0.01	67	443	300	10771	215	3	0	8	0	0	0	21	4	25	0	50	0	0	0	2 27 28 33 5	35
50	5	1	5	0.03	83	529	331	12131	243	5	0	10	0	13	0	25	1	11	13	50	0	0	0	10 11 19 29 48	36
50	5	1	5	0.05	102	806	465	19748	395	4	0	15	0	0	0	19	1	2	28	38	12	0	0	12 14 16 43 6	37
50	5	1	5	0.1	82	544	379	13739	275	4	0	6	0	0	0	21	10	2	17	50	0	0	0	11 15 27 30 41	38
50	5	1	6	0	108	837	539	20957	419	5	0	12	0	18	0	16	6	0	28	44	6	0	0	3 34 35 38 5	41
50	5	1	6	0.01	51	279	214	6356	127	3	0	5	0	0	0	24	18	8	0	50	0	0	0	19 20 29 37 42	42
50	5	1	6	0.01	52	352	288	7600	152	3	0	5	0	0	0	29	9	12	0	50	0	0	0	20 21 26 27 29	43
50	5	1	6	0.03	67	453	339	8605	172	3	0	7	0	0	0	22	14	14	0	50	0	0	0	1 14 15 39 40	44
50	5	1	6	0.05	48	310	267	5794	116	3	0	3	0	0	0	41	2	7	0	50	0	0	0	22 26 39 48 8	45
50	5	1	6	0.1	48	313	24	7618	15	3	0	4	0	0	0	35	3	12	0	50	0	0	0	11 18 21 44	46

							6		2															9	
50	5	1	7	0	32	215	188	3383	68	1	0	1	0	0	0	50	0	0	0	50	0	0	0	11 26 29 37 8	49
50	5	1	7	0.01	38	218	176	3298	66	3	0	3	0	0	0	41	4	5	0	50	0	0	0	10 23 3 40 43	50
50	5	1	7	0.01	52	354	280	8298	166	3	0	4	0	0	0	27	18	5	0	50	0	0	0	11 22 31 7 9	51
50	5	1	7	0.03	67	485	364	13095	262	3	0	8	0	0	0	27	0	23	0	50	0	0	0	1 23 28 40 47	52
50	5	1	7	0.05	78	660	421	14562	291	4	0	12	0	0	0	24	0	25	1	49	1	0	0	1 21 26 47 9	53
50	5	1	7	0.1	63	395	298	7166	143	2	0	4	0	0	0	20	30	0	0	50	0	0	0	18 19 21 22 7	54
50	5	1	8	0	63	405	290	10240	205	3	0	5	0	0	0	25	7	18	0	50	0	0	0	11 12 13 14 32	57
50	5	1	8	0.01	47	284	240	5140	103	2	0	2	0	0	0	34	16	0	0	50	0	0	0	0 17 23 24 29	58
50	5	1	8	0.01	43	259	214	4073	81	2	0	3	0	0	0	36	14	0	0	50	0	0	0	25 34 38 42 46	59
50	5	1	8	0.03	46	364	311	7365	147	2	0	3	0	0	0	36	14	0	0	50	0	0	0	0 12 31 33 9	60
50	5	1	8	0.05	42	245	208	4755	95	2	0	2	0	0	0	43	7	0	0	50	0	0	0	23 25 29 3 35	61

Appendix B : Code of Simulation (TCL code)

```
#
==========================================================================
#                    Wireless Flooding - xxx nodes
==========================================================================
#
# Each agent keeps track of what messages it has seen
# and only forwards those which it hasn't seen before.

# Each message is of a list of lists, where the frist two elements in Message
# list are indicating Message_ID and Message life Conditions information.
# Message ID is concatenation of Node_id, sent Time and its position (x,y).
# Message life Conditions is list of max number of travelling Hops , time
# out, max distance for travelling and Message type ("DM"/"WM"). the rest
# of the message identifier the DATA of nodes it got.  In order to reduce
# memory usage, the agent stores the message ID and seen nodes. The Message
# will be looks like :
#   Msg List : element #1 { $nodeid$endTime$xPos$yPos }
#           element #2 { $numHops $timeout  $distance  "DM"}
#           element #3 { $nodeid  $cond  $sendTime $xPos $yPos }
#           element #4 { $nodeid  $cond  $sendTime $xPos $yPos } ... etc

# Note that I have not put in any mechanism to expire old message from the
# list of seen messages.  There also isn't any mechanism to use all the
#  conditions (time out / distance), I just use the max number of hops.

#
==========================================================================
#                    Define Enviroment options
#
==========================================================================
```

```
Mac/Simple set bandwidth_ 2Mb

set MESSAGE_PORT 42
set BROADCAST_ADDR -1

remove-all-packet-headers
add-packet-header DSR ARP LL MAC CBR IP

# ============   handling command-line parameters first ============
if {$argc > 0} { set activeNodes [lindex $argv 0]} else { set activeNodes 5 } ;# Nodes have certain situation
if {$argc > 1} { set numHops     [lindex $argv 1]} else { set numHops     3 } ;# Message traveling steps
if {$argc > 2} { set numNodes    [lindex $argv 2]} else { set numNodes  121 } ;# Totle number of nodes
if {$argc > 3} { set numRounds    [lindex $argv 3]} else { set numRounds    1 } ;# defines the number of rounds
if {$argc > 4} { set maxWait       [lindex $argv 4]} else { set maxWait    0.01} ;# minimum waiting before re/send the Msg

puts " Starting Sim - activeNodes=$activeNodes --- numHops=$numHops --- numNodes=$numNodes --- numRounds=$numRounds --- maxWait=$maxWait "

# ======= the number of (active) nodes and Message life Conditions =====
# ==================   (numHops, Timeout & distance)  ==================
set nodeSize      25            ;# Node size
set minNodesInside 8             ;# minimum red nodes inside zone

set timeOut       0.5           ;#  Message Time out
set distance      500           ;# Message Max traveling distance from source
set percentage    0.25          ;# (redNodes / totalNodes) inside zone

array  set   discardedMsgs    {}
array  set   recievedMsg     {}
```

```
array set sentMsgs       {}
array set firstMsgRec    {}
array set lastMsgRec     {}
array set regonizedrNodes {}
array set regonizedgNodes {}

# size of the topography
set xSize          1000
set ySize          1000
set t ""

# =================== Flag for control each round ===================
set opt(intervall)        10                    ;# Time between each round (seconds)
set namFlg                0                     ;# Descide if NAM is to be used (yes = 1)
set DefaultWait           0.01                  ;# Default delay befor sending content
# ========= files used for input (random movement patterns) & output =============
if {$numNodes ==  50} { set opt(sc) "Scenario_050.txt"; set resultFile "wirelessFlooding2_050_Node.txt";}
if {$numNodes == 100} { set opt(sc) "Scenario_100.txt"; set resultFile "wirelessFlooding2_100_Node.txt";}
if {$numNodes == 150} { set opt(sc) "Scenario_150.txt"; set resultFile "wirelessFlooding2_150_Node.txt";}
if {$numNodes == 200} { set opt(sc) "Scenario_200.txt"; set resultFile "wirelessFlooding2_200_Node.txt";}

# ========= Flag for control the generation of random (movement) patterns =============
set randomFlg       1                           ;# Descide to make new random patterns(yes=1)
set opt(duration)   [expr $opt(intervall)]      ;# duration of the simulation
```

```
set opt(speed)       10.0                  ;# defines the Max speed of the nodes (m/s)
set opt(pause)       0.10                  ;# defines the pause befor the nodes move

# ===================== Define Operation options ====================
set opt(cbr_size)     50000                          ;# orginalt 500
set opt(cbr_interval)           0.002                  ;# delay
set val(chan)         Channel/WirelessChannel    ;# Channel Type
set val(prop)         Propagation/TwoRayGround   ;# radio-propagation model
set val(netif)        Phy/WirelessPhy          ;# network interface type
set val(mac)                  Mac/802_11               ;# MAC type (Mac/802_11, Mac and
Mac/Simple)
set val(ifq)          Queue/DropTail/PriQueue    ;# interface queue type
set val(ll)           LL                   ;# link layer type
set val(ant)          Antenna/OmniAntenna       ;# antenna model
set val(ifqlen)        50                    ;# max packet in ifq
set val(rp)           DumbAgent               ;# DumbAgent, AODV, and DSDV work.  DSR
is broken

# ========= Initialize the simulator & set up topography object ========
set ns_ [new Simulator]

set f [open wirelessFlooding2.tr w]
$ns_ trace-all $f

# set nf [open wirelessFlooding.nam w]
 #$ns_ namtrace-all-wireless $nf $xSize $ySize
# $ns_ use-newtrace

# ================[ set up topography object ] ======================

set topo       [new Topography]
$topo load_flatgrid $xSize $ySize
```

changes the queuetype when running DSR, prevents "Segmentation fault (core dumped)"

```
if { $val(rp) == "DSR" } { set val(ifq) CMUPriQueue
} else { set val(ifq) Queue/DropTail/PriQueue }
# ====================== Define colors ================================
$ns_ color 0 red          ; $ns_ color 1 blue
$ns_ color 2 green        ; $ns_ color 6 gold
$ns_ color 7 black

# ======= creates the God entity & configures the node template ========
set god_ "God"

create-god $numNodes

$ns_ node-config -adhocRouting $val(rp)     -llType $val(ll)    \
        -macType $val(mac)         -ifqType $val(ifq)  \
        -ifqLen $val(ifqlen)       -antType $val(ant)  \
        -propType $val(prop)       -phyType $val(netif) \
        -topoInstance $topo        -agentTrace ON      \
        -routerTrace OFF           -macTrace ON        \
        -movementTrace OFF         -channel [new $val(chan)]

# ============== generates random movment pattern
=====================
if { $randomFlg == "1"} {
        puts "*** NOTE: Random pattern generated  .... Started."
    exec ./setdest -n $numNodes -p $opt(pause) -M $opt(speed) -t $opt(duration)
-x $xSize -y $ySize > $opt(sc)
        puts "*** NOTE: Random pattern generated .... Finished."
}

#
=====================================================================
#           Traveling Messages Generation & Update & Merage
```

```
# 
==========================================================================

# ==================[ Generate First Message ]========================
proc firstMsg {nodeid sendTime} {
      global  numHops                  ;# Message traveling steps

  set msgID "$nodeid$sendTime"        ; # Create Msg ID
  set Cond  $numHops                ; # Create Message life Conditions + Message type
  set data  $nodeid
  return [list $msgID $Cond $data ""];
}

# ==================[ append current Message ]========================
proc appendMsg {data nodeid cond } {
        if { $cond == 1 } {
      if { [llength [split [lindex $data 2] ":"]] > 0 } {
            if { [lsearch [split [lindex $data 2] ":"] $nodeid] == -1 } {
          set  data [lreplace $data 2 2 "[lindex $data 2]:$nodeid"]
            }
          } else { set  data [lreplace $data 2 2 $nodeid]}
        } else {
      if { [llength [split [lindex $data 3] ":"]] > 0 } {
           if { [lsearch [split [lindex $data 3] ":"] $nodeid] == -1 } {
          set  data [lreplace $data 3 3 "[lindex $data 3]:$nodeid"]
        }
          } else { set  data [lreplace $data 3 3 $nodeid] }
        }
  return $data
 }

# 
==========================================================================
#     subclass Agent/MessagePassing to make it do flooding
```

```
#
=========================================================================
Class Agent/MessagePassing/Flooding -superclass Agent/MessagePassing
#                    =======================[                      Recieve
Message ]==========================
Agent/MessagePassing/Flooding instproc recv {source sport size data} {
  $self instvar messages_seen     node_
  $self instvar Status           node_
$self instvar redNodesSeen      node_    #  array to carry red nodes info
$self instvar greenNodesSeen    node_    #  array to carry green nodes info

  global    ns_    BROADCAST_ADDR       numNodes    numHops    regonizedrNodes
regonizedgNodes
global discardedMsgs  recievedMsg sentMsgs firstMsgRec lastMsgRec maxWait

# extract message ID from message
  set message_id         [lindex $data 0]
  set Hops               [lindex $data 1]

set now           [$ns_    now]
set currentNode     [$node_ node-addr]

set discard  0  ;   set showlabel 0 ; set flg 0 ;

  if {($firstMsgRec($currentNode) == 0)} { set   firstMsgRec($currentNode)  $now }
  set   lastMsgRec($currentNode)     $now
  incr  recievedMsg($currentNode)

  if { ( [lsearch $messages_seen $message_id] == -1 ) && ( $Hops > 0 ) } {

     set  data       [appendMsg $data $currentNode  $Status]
     set  updatedMsg  [lreplace [lrange $data 0 1] 1 1 [expr $Hops - 1] ]

    if { [llength $messages_seen] > 0 } {
```

```
                set redFlag     [$self keepTrack [lrange $data 2 end]]
            if { $redFlag == 1 } {          # (new Msg)
                set updatedMsg [lrange [firstMsg  $currentNode  $now] 0 1]
                set showlabel 1
            } elseif { $redFlag == -1 } {     # (discard)
                set discard 1
            } elseif { $redFlag == -2 } {
                if { $Status == 1 } {     # (reset Hops)
                  set updatedMsg  [lreplace $updatedMsg 1 1 $numHops]
                }
            }
        } else {
            set redNodesSeen     [lindex $data 2]
            set greenNodesSeen   [lindex $data 3]
        }

        set     updatedMg   [list   [lindex   $updatedMsg   0]   [lindex   $updatedMsg   1]
$redNodesSeen $greenNodesSeen]

            set prompt      [format "%d" [llength [split $redNodesSeen ":"] ] ]
                if {($showlabel == 1) || ($Status == 1) } { $ns_ at $now "$node_ label
$prompt" }

        set prompt $redNodesSeen

                if { $Status == 1 } { $ns_ at $now "$node_ color red"} else { $ns_ at
$now "$node_ color green" }

            lappend messages_seen $message_id
        if { $discard == 0 } {
                # incr sentMsgs($currentNode)
            # $self sendto $size  $updatedMg $BROADCAST_ADDR $sport
             set  sendTime [expr ($now + double (rand() * $maxWait))]
            $ns_  at $sendTime "$self send_message $size {$updatedMg} $sport"
```

```
            }
          } else { incr   discardedMsgs($currentNode) }
        set regonizedrNodes($currentNode)   [llength [split $redNodesSeen     ":"]]
        set regonizedgNodes($currentNode)   [llength [split $greenNodesSeen   ":"]]

         }

         #                              =========================[                              send
Message ]=============================

         Agent/MessagePassing/Flooding instproc send_message {size data port} {
            $self instvar messages_seen      node_
        $self instvar redNodesSeen       node_     #  array to carry red nodes info
            global ns_ BROADCAST_ADDR sentMsgs

         if { ([lsearch $messages_seen [lindex $data 0]] == -1) && ([lindex $data 3] == "") &&
([llength [split [lindex $data 2] ":"]] == 1)  } {
            lappend messages_seen  [lindex $data 0]
            lappend redNodesSeen   [lindex $data 2]
      }

        set currentNode       [$node_ node-addr]
        incr   sentMsgs($currentNode)
            $self  sendto $size $data $BROADCAST_ADDR $port
         }
         # ==================[ keep track of the current Message ]==============
         Agent/MessagePassing/Flooding instproc keepTrack { newEntry } {
        $self instvar redNodesSeen       node_     #  array to carry red nodes info
        $self instvar greenNodesSeen     node_     #  array to carry green nodes info

          set newrNodes 0; set oldrNodes 0;
          set newgNodes 0; set oldgNodes 0;

          set newrEntry [split [lindex $newEntry 0] ":"]
```

```
set newgEntry [split [lindex $newEntry 1] ":"]

  if { [llength [split $redNodesSeen " "]] > 1 } {
      if { (1 <= [llength [split [lindex [split $redNodesSeen " "] 1] ":"]] < 3) } {
        set redNodesSeen [lindex [split $redNodesSeen " "] 0]
      }
   }
  if { [llength [split $greenNodesSeen " "]] > 1 } {
      if {1 <= [llength [split [lindex [split $greenNodesSeen " "] 1] ":"]] < 3 } {
        set greenNodesSeen [lindex [split $greenNodesSeen " "] 0]
      }
   }

 if { [llength $newrEntry] > 0 } {
          foreach nodeid $newrEntry {
             if { [lsearch [split $redNodesSeen ":"] $nodeid] == -1 } {
          if {[llength [split $redNodesSeen ":"]] > 0 } {
               set  redNodesSeen "$redNodesSeen:$nodeid"
          } else { set  redNodesSeen "$nodeid" }
               incr newrNodes
             } else { incr oldrNodes }
          }
  }



 if { [llength $newgEntry] > 0 } {
          foreach nodeid $newgEntry {
             if { [lsearch [split $greenNodesSeen ":"] $nodeid] == -1 } {
          if {[llength [split $greenNodesSeen ":"]] > 0 } {                  ; #   exist   Old
Recieved |  Reutrn
               set  greenNodesSeen "$greenNodesSeen:$nodeid"              ; #  ---------
--------------+---------
          } else { set  greenNodesSeen "$nodeid" }                        ; #     0     0      0
|  -1
```

```
                    incr newgNodes                                ; #   0   0   1  |  0
                  } else { incr oldgNodes }                        ; #   0   1   0  |  -1
                }                                             ; #   0   1   1  |  0
            }                                             ; #   1   0   0  |  -1
                                                          ; #   1   0   1  |  1
        set exrNodes [expr [llength [split $redNodesSeen     ":"]] - $newrNodes -
$oldrNodes] ; #   1   1   0  |  -1
        set exgNodes [expr [llength [split $greenNodesSeen ":"]] - $newgNodes -
$oldgNodes] ; #   1   1   1  |  1


          if { (($exrNodes == 0 ) && ($oldrNodes > -100) && ($newrNodes > 0)) } { return
0 } \
        elseif { (($exrNodes >  0 ) && ($oldrNodes > -100) && ($newrNodes > 0)) } { return
1 } else { return -1 }
        #elseif { (($exrNodes >  0 ) && ($oldrNodes >  0  ) && ($newrNodes > 0)) } { return
1 }
    }

        #
=====================================================================
        #               create a bunch of nodes
        #
=====================================================================
        for {set i 0} {$i < $numNodes} {incr i} {
          set node_($i) [$ns_ node]
      $node_($i) color "black"

          set discardedMsgs($i)   0 ;   set recievedMsg($i)     0 ;   set sentMsgs($i)   0
          set firstMsgRec($i)    0 ;   set lastMsgRec($i)      0
      set regonizedrNodes($i) 0 ;   set regonizedgNodes($i)  0
        }
        # ========= Provide initial (X,Y) co-ordinates for the nodes ===========
```

```
if { $opt(sc) == "" } {
            puts "*** NOTE: no scenario file specified."
            set opt(sc) "none"
    } else {
            source $opt(sc)
            puts "Random positioning ...."
    }

    # ================= initialise the nodes & their agents =================

    for {set i 0} {$i < $numNodes} {incr i} {
      $ns_ initial_node_pos $node_($i) $nodeSize

  # attach a new Agent/MessagePassing/Flooding to each node on port $MESSAGE_PORT
      set a($i) [new Agent/MessagePassing/Flooding]
      $node_($i) attach  $a($i) $MESSAGE_PORT

      $a($i) set messages_seen     {}       ;#  array to carry the ID of messages seen
      $a($i) set Status          0        ;#  Set the status of each node
  $a($i) set redNodesSeen      ""         ;#  string of red nodes id's sperated by ':'
  $a($i) set greenNodesSeen     ""         ;#  string of green nodes id's
    }

    # ====================================================================
    #                   now set up some events
    # ====================================================================
    set now [$ns_ now]
set ta ""

    set i 0
while {$i < $activeNodes} {
```

```
set start_time    [expr double (rand() * $maxWait + $now)] ;
# set start_time       [expr double (rand()*0.015 + 0.015)] ; # [expr double (rand()*0.015 + $j*$opt(intervall) ) ]
set random_node   [expr int(rand()*($numNodes-1))]

 #puts " ===== Active node $random_node    will start at $start_time =========="
if { $i > 0 } {
        if { [lsearch [split $ta ":"] $random_node] == -1 } {
    set  ta "$ta:$random_node"
    } else { continue ; }
} else { set  ta $random_node }
incr i

$a($random_node)  set Status 1
$ns_ at $start_time "$node_($random_node) label 1 "
$ns_ at $start_time "$node_($random_node) color red "

    set msg    [firstMsg   $random_node  $now]
       $ns_ at $start_time "$a($random_node) send_message 1000 {$msg} $MESSAGE_PORT"
}
    $ns_ at  2.0 "print"

# ============= Tell nodes when the simulation ends ==================
#for {set i 1} {$i < $numNodes } {incr i} {
#          $ns_ at [expr $opt(duration) +10.0] "$node_($i) reset";
#}

# $ns_ at 0.0 "$ns_ set-animation-rate 0.500ms"
   $ns_ at 2.0 "finish"
```

```
        #
===================================================================

        proc clear {} {
            global discardedMsgs  recievedMsg sentMsgs firstMsgRec lastMsgRec
         global regonizedrNodes regonizedgNodes

                for {set i 0} {$i < $numNodes} {incr i} {
                    set discardedMsgs($i)   0 ;   set recievedMsg($i)      0 ;    set sentMsgs($i)
0
                    set firstMsgRec($i)    0 ;   set lastMsgRec($i)      0 ;
                set regonizedrNodes($i) 0 ;   set regonizedgNodes($i)  0

                $node_($i) color "black"
                $node_($i) label ""

            $a($i) set messages_seen      {}        ;#  array to carry the ID of messages seen
                $a($i) set Status           0         ;#  Set the status of each node
             $a($i) set redNodesSeen      ""          ;#  string of red nodes id's sperated by ':'
             $a($i) set greenNodesSeen     ""          ;#  string of green nodes id's

                }

        }

        # Procedure to print relevant information
        #
===================================================================
        proc print {} {
                global numRounds  resultFile maxWait
            global discardedMsgs  recievedMsg sentMsgs firstMsgRec lastMsgRec
         global numNodes activeNodes numHops t ta regonizedrNodes regonizedgNodes
```

```
set rec 0; set sent 0; set dis 0; set t   0; set n   0; set maxr 0; set maxg 0; set minr $numNodes; set ming $numNodes
set mr1 0; set mr2 0; set mr3 0; set mr4 0; set mg1 0; set mg2 0; set mg3 0; set mg4 0; set act 0; set nact 0; set nonact 0;

for {set i 0} {$i < $numNodes} {incr i} {
    set   rec   [expr $rec + $recievedMsg($i)]
    set   sent  [expr $sent + $sentMsgs($i)]
    set   t     [expr $t + (($lastMsgRec($i) - $firstMsgRec($i))*1000)]
    set   dis   [expr $dis + $discardedMsgs($i)]
  if { $maxr < $regonizedrNodes($i) } { set maxr $regonizedrNodes($i) }
  if { $maxg < $regonizedgNodes($i) } { set maxg $regonizedgNodes($i) }
  if { $minr > $regonizedrNodes($i) } { set minr $regonizedrNodes($i) }
  if { $ming > $regonizedgNodes($i) } { set ming $regonizedgNodes($i) }

  if { $activeNodes == $regonizedrNodes($i) } { incr act  }
  if { $regonizedrNodes($i) == 0 } { incr nact }

  if {  [expr double($regonizedrNodes($i))/double ($activeNodes) ] < 0.25 } { incr mr1 } \
  elseif {  [expr double($regonizedrNodes($i))/double ($activeNodes) ] < 0.5  } { incr mr2 } \
  elseif {  [expr double($regonizedrNodes($i))/double ($activeNodes) ] < 0.75 } { incr mr3 } else {  incr mr4 }

  if {  [expr double($regonizedgNodes($i))/double ($numNodes - $activeNodes)] < 0.25 } { incr mg1 } \
  elseif {  [expr double($regonizedgNodes($i))/double ($numNodes - $activeNodes)] < 0.5 }  { incr mg2 } \
  elseif {  [expr double($regonizedgNodes($i))/double ($numNodes - $activeNodes)] < 0.75 } { incr mg3 } else {  incr mg4 }

    incr  n
}
```

```
set    tta    [format "%0.3f" [expr $t / $numNodes]]
set    tt     [format "%0.3f"  $t ]
    #puts " \n\n============ Start over $numNodes nodes with $activeNodes active nodes and $numHops hops============"

 #puts " the active nodes are : [llength [lsort -unique [split $ta ":"]]] # [lsort [split $ta ":"]] #\n"

    #puts "       sent messages : $sent message(s)"
        #puts "    recieved messages : $rec message(s)"
        #puts "   average total time : [expr $t / $numNodes] ms"
        #puts "   Redendant Messages : $dis message(s)\n"

        #puts "   Max red nodes seen : $maxr red Node(s)"
        #puts " Max green nodes seen : $maxg red Node(s)"
        #puts "   Min red nodes seen : $minr red Node(s)"
        #puts " Min green nodes seen : $ming red Node(s)\n"

        #puts " Nodes saw all active Nodes : $act Nodes(s)"
        #puts "         Nodes saw nothing : $nonact Nodes(s)\n"

        #puts "  red nodes regonized/node (< 25% , upto 50% , upto 75% , upto 100% ) : ($mr1 , $mr2 , $mr3 , $mr4) of red Node(s)"
        #puts "green nodes regonized/node (< 25% , upto 50% , upto 75% , upto 100% ) : ($mg1 , $mg2 , $mg3 , $mg4) of green Node(s)\n"

    #puts " ============ Start over $numNodes nodes with $activeNodes active nodes and $numHops hops Round = $numRounds ============ \n\n"

        set fhandle [open $resultFile a]
        puts $fhandle "$numNodes,[llength [lsort -unique [split $ta ":"]]],$numHops,$numRounds,$maxWait,$sent,$rec,$dis,$tt,$tta,$maxr,$minr,$maxg,$ming,$act,$nonact,$mr1,$mr2,$mr3,$mr4,$mg1,$mg2,$mg3,$mg4,[lsort [split $ta ":"]]"
        close $fhandle
```

```
}

#
==============================================================================
proc finish {} {

    global ns_ f nf namFlg activeNodes numRounds numNodes numHops

        $ns_ flush-trace
        close $f
        # close $nf

 if { $namFlg == 1 } {
        puts "running nam..."
        exec nam wirelessFlooding.nam &
 }
puts " Ending Sim - activeNodes = $activeNodes ---- numHops = $numHops ----
numNodes = $numNodes --- numRounds = $numRounds -"
    exit 0

}
#
==============================================================================

puts "Starting Simulation ..."
    $ns_ run
```

Appendix C : Publications

Traffic Condition Detection Algorithm (TCDA) for VANET Nodes in Wireless Intelligent Transportation Information Systems

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Abstract: Vehicle to vehicle communication (V2VC) is one of the modern approaches for exchanging and generating traffic information with (yet to be realised) potential to improve road safety, driving comfort and traffic control. In this paper, we present a novel algorithm which is based on V2V communication, uses in-vehicle sensor information and in collaboration with the other vehicles' sensor information can detect road conditions and determine the geographical area where this road condition exists – e.g. geographical area where there is traffic density, unusual traffic behaviour, a range of weather conditions (raining), etc. The built-in automatic geographical restriction of the data collection, aggregation and dissemination mechanisms allows warning messages to be received by other cars, not necessarily sharing the identified road condition, which may then be used to inform the optimum route taken by the vehicle? (Avoid bottlenecks or dangerous areas including accidents or congestions on their current routes).

The Traffic Condition Detection Algorithm (TCDA) - which we propose here - is simple, flexible and fast and does not rely on any kind of roadside infrastructure equipment. It will offer live road conditions information channels at - almost - no cost to the drivers and public/private traffic agencies and has the potential to become indispensable part of any future intelligent traffic system (ITS).

Keywords: Wireless, Ad hoc network, VANET, Vehicular Networks, Collaboration, ICT, ITS, collaborative knowledge generation, traffic information systems.

1 INTRODUCTION

One of the main advantages of the ad-hoc networks is the opportunity to use collaborative effort in connecting and delivering network messages as necessary [1]. This opportunity is under-utilised so far in the area of traffic control and traffic information systems where every car can be considered to be a node in an ad-hoc network [2]. Our aim is to investigate the possibility of bringing ad-hoc collaborative information generation and control into such systems and investigate how the functionality of the ad-hoc node (within the vehicle) affects the quality of the traffic wireless information systems in ITS. The project covers the middle ground between MANET and collaborative data generation based on knowledge granularity (aggregation) [3]. It will investigate the designing, implementing and modelling the functionality of a condition identification algorithm for an intelligent node in ITS wireless information system that will be at the same time be an active participant in the formation, routing and general network support of such systems and also represent in-car traffic information and real-time control generator and distributor. [4].

The main research objectives are to design the algorithms' functionality and to program a model of the network with the required node features which in turn lead to a real-life case study implementation. The preferred language for the implementation of the algorithm is java out of portability considerations.

1.1 Background

In recent years, mobile computing has enjoyed a tremendous rise in popularity. The continued minimization of mobile computing devices and the extraordinary rise of processing power available in mobile laptop computers combine to put more and better computer-based applications into the hands of a growing segment of the population. At the same time, the markets for wireless telephones and communication devices are experiencing rapid growth. Projections have been made that nowadays there are more than billion wireless devices in use (according to the number of wireless service subscriptions worldwide). This inevitably has trickled into the way we communicate in and out from our cars. So far however, the main way of communication has been to connect from the car to a cell station (infrastructure node) and the opportunity to communicate car-to-car has been neglected [5]. The combination of limited bandwidth for car to infrastructure communication, increased number of cars on the roads and the increased amounts of data relevant to traffic in cars however requires the development and design of new distributed approaches to building new generation traffic control and information systems. It is clear therefore, that research into how the wireless mobile computers or Mobile Ad Hoc Networks (MANET) can be utilized for building wireless traffic information systems has become essential, especially if we look at the amount of knowledge we can extract from data if we share it between cars. [6]

A wireless ad hoc network is a collection of autonomous nodes or terminals that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner [7]. Since the nodes communicate over wireless links, they have to contend with the effects of radio communication, such as noise, fading, and interference [8]. In addition, the links typically have less bandwidth than in a wired network Each node in a wireless ad hoc network functions as both a host and a router, and the control of the network is distributed among the nodes. [3]

The network topology for such networks is generally very dynamic, because the connectivity among the nodes may vary with time due to node departures, new node arrivals, and the possibility of having mobile nodes. Hence, there is a need for efficient information gathering and distribution protocols to allow the nodes to communicate over multihop paths consisting of possibly several links in a way that does not use any more of the network "resources" than necessary [7]. Some of these features are characteristic of the type of packet radio networks that were studied extensively in the 1970s and 1980s. To provide the functionality required in such dynamic environments, many routing protocols have been proposed over the last few years. These protocols can be broadly classified onto three categories, namely, proactive, reactive, and hybrid. [9][10]

1.2 Problem definition & novelty:

Most of the existing systems in use today work through establishing direct connection between a mobile node and pre-existing infrastructure node, which immediately raises questions about the compatibility, required services, updating devices, cost …etc. when we move to collaborative ad-hoc networking and in the same time, the systems already in place have relatively high cost [11][12][13].

While designing the proposed algorithm this paper will try to answer the following questions:

i) What features of the algorithm are essential for the functionality of an intelligent node in a wireless traffic information system?
ii) How can we establish collaborative data and knowledge generation road conditions discovery based on car-to-car message exchange.
iii) What are the possible message formats and what outcomes can we establish through simulation?
iv) What are some of the implications and benefits of deploying such wireless systems for drivers, local authorities and society?

All designs and suggestions regarding the questions mentioned above must be a subject rigorous evaluation and scrutiny process and this process will be going in iterative steps (design feature – simulate – evaluations) in order to achieve its maximum potential. Each iteration will be aiming at focusing on the most promising feature, developing new ones, and finally refining and enhancing the different prototypes.

2 Traffic Condition Detection Algorithm (TCDA)

2.1 Algorithm Scope:

Some road conditions can either be derived from the activity of the individual cars' electronic helpers like ESP (Electronic Stability Program) or ABS (Anti-locking Brake System), or alternatively, sensors embedded in the individual vehicle may provide this information. There are heuristic rules for deciding whether one is in danger of hydroplaning, or how to assess whether the road in front of the vehicle is icy or not. Measuring the temperature, the amount of rainfall or the humidity can make the driver able to choose alternative routes, if a section turns out to be icy, foggy or rainy strongly. Theoretically, rainfall case can be assessed by the windshield wipers status, by distinguishing cleaning the windshield and cleaning it from water.

2.1.1 Things that the algorithm cover:

This algorithm aims at identifying road conditions on the basis of exchanging sensors information shared between the vehicles on the road (as opposed to identifying the conditions on the basis of individual cars' sensors). The identification process has several important outcomes/features:

i) *Traffic condition sensing:* share detected individual cars' status and their data (average speed, windscreen wipers on/off, slippery strength …) by exchanging messages between nodes which leads to determining road conditions.

ii) *Routing*: Define node behaviour in terms of algorithm routing. Use intelligent routing mechanism to exchange messages. This mechanism depends on comparing the received data with the known data in each node.

iii) *Zone Identification*: Define node behaviour in terms of road condition zone identification. Based on the available shared data each node knows about the surrounding nodes status and any node can identify the boarders of the zone and then generate and broadcast a warning message around.

2.1.2 Beyond the algorithm scope:

Here are some issues outside of the scope of the algorithm and a matter of future analysis and investigation:

i) Geographical situation zone identification: what is the optimum number (or percentage) of cars having the same situation (comparing to the total number of cars have been seen) which make us identifier situation zone (or zone with certain conditions). Those numbers varies and depending on the type of situation (e.g: to consider rainy situation, 50% should have windscreen wipers on. While 5 cars are enough to identifier slippery spot).

ii) Zone Search Limitations: how far geographically a single zone covers (what percentage/number of cars with identified condition is enough for declaring the zone exists) and when to join two adjacent zones in one bigger zone (zone conditions Search limitation).

iii) Security and privacy.

iv) Application implementation (network/application level).

v) Physical Communication and intermittent connectivity.

2.1.3 Examples of situations detected by the Algorithm:

To put the algorithm in its context, it will be useful to present some examples of the possible situations (conclusions) we can come up with based on sharing individual car sensors data (the numbers quoted in the table are representative rather than conclusive for the condition and represent a matter of future investigation in real-life experiments).

	Individual Car sensors data	Optimum Num example/case	Possible Conclusion
1	Windscreen Wipers	30% of cars = ON	Rainy
2	ABS Control.	5 cars = ON	Slippery (snow)
3	Slippery Oil Spot.	2 cars	Slippery spot
4	Fog light.	50% of cars ON	Foggy
5	Traffic flow Speed.	(60%) Slow/Stop	Traffic Jam
6	Reduce Speed.	5 cars within 1sec	Hazard Ahead

We can consider that column two is in effect Search Conditions Limitation number. Assuming that this Search Conditions Limitation is reached then a zone with the condition (third column) is identified and then the information system can inform the rest of nearby cars to be aware of the situation within that zone if they plan to pass through it.

2.1.4 Algorithm Features:

The algorithm is very flexible and has several variable parameters (e.g. variable number of Hops used to scan any area) which influence the final outcome and this paper presents our conclusions in determining the optimal set of values:

i) Using variable *Conditions Search Limitation* (CSL): Control the searching area for any situation by using selection of parameters (number of hops from source, certain timeout, and/or distance from source).
ii) *Multi-zones detection*: in case of more than one zone, it can Detect each situation zone boarders separately (even if they are overlapped). Then report them in one or multiple warning messages.
iii) *Delay for data collection*: Random time slots delay used before forwarding the received messages (which increase the collecting information period to end up by reducing the number of exchanged messages).

2.2 Algorithm Description:

2.2.1 Assumptions:

i) All nodes are identical, mobile and in active state.
ii) Each node is able to determine its position (equipped with a GPS onboard).
iii) The distribution, density, distance between nodes, active nodes selection, movement patterns are completely random.
iv) Buffer size: should be large enough to avoid buffer overflow and to be able to hold some data about the nearby nodes (the size of the message is designed to be optimal and there is no real danger of overflowing).
v) Message delivery reliability is assumed to be standard wireless networks reliability with all the delays, packet loss or interference inherent to such networks based on the default values built in the NS2 network simulator.

2.2.2 Terms definitions:

i) Node behaviour: Node behaviour is the *reaction* of the node (or car) when receiving a message. The reaction can be:
   a. Forward the message if it is message received first time, otherwise discard.
   b. Discard the message if it is redundant.
   c. Generate new Situation Discovery Message (SDM) if the received message carries new information compared to the existing information, so the generated message will travel in all directions (broadcast).

Here is detailed reaction table for a node based on the result of comparing the received message with the existing data from old messages (case a, b, c – algorithm description 2.2.3) for one, two or more hops cases:

Existing information	Received Information	Node Reaction to received Msg
Yes	Yes	Generate new SDM
Yes	No	Discard
No	Yes	Forward received SDM
No	No	Discard

ii) Active Node (AN): is referring to any node with sensors indicating that certain road condition(s) is present within it and is to be reported to other nearby cars or nodes.
iii) Non-Active Node (NAN): is referring to any node with sensors indicating that certain road condition(s) is NOT present within it (the node will serve as a router to forward messages coming from nearby nodes).
iv) Situation Discovery Message (SDM): a message generated by AN or - in some cases - by NAN (see previous table). Its purpose is to establish zone identification and contains:

Fields	Data in field
#1	unique SDM ID (nodeNo:timestamp:Position)
#2	SDM limitation conditions (Hops:timeout:distance).
#3 ..	Nodes seen (NodeID:Time:Situations:position).

v) Situation Warning Message (SWM): generated by any node discover a situation zone. It contains the fields:

Fields	Data in field
#1	unique SEM ID (SourceNo:timestamp:Position)
#2	SWM travel conditions (Hops:timeout:distance).
#3 .. etc	Zones detected (NodeID:Time:Situations:position)

2.2.3 Algorithm Description:

If a node detects or senses any of the identifiable road conditions it becomes active node – AN, and if it has not received other nodes' SDM with the same condition discovery requests within certain past time out period it initiates traffic condition discovery sequence, generates SDM and broadcasts it to all nodes in its range as first wave (called first hop) to inform all nodes for its current situation (Figure 1a) and enquire if other nodes have the same condition. From that time point onwards it initiates the traffic condition discovery sequence every time after the time out expires until it becomes non-active – NAN.

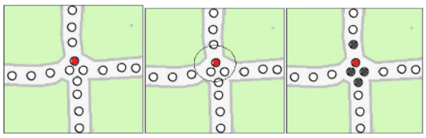

Figure 1a: Cross road Scenario - First Hops

If the maximum hops number is not reached (SDM reaches the maximum number of hops if transmitted the required number of hops by NAN nodes) and if none of nodes have the same situation, they forward the same SDM to the next neighbour's nodes as a second wave (second Hop) to inform the others for the current situation (Figure 1b) .

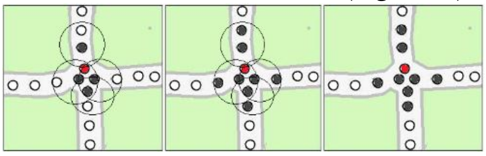

Figure 1b: Cross road Scenario - Second Hops

But, if one of its neighbours has got any new situation at the same time of receiving the message, it will generate new SDM that contains its current condition and also all the information it has previously identified about the nearby nodes.

Again, all nodes will forward the same SDM to the next neighbour's as third hop (Figure 1c) after they update the message by its current situation. Those steps will be repeated until the CSL become true or the maximum number of hops is reached.

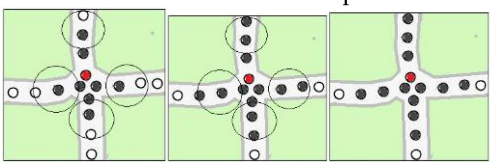

Figure 1c: Cross road Scenario - Third Hops and so on …

Each node is capable of keeping track of all seen messages, which allows it to discard all redundant messages. Also each node keeps all the information it has about all "seen" nodes – all nodes contained in the messages received in the node - in two different lists, the first list for AN's and the second list is for NAN's.

If any node – at any Hops – has the same/new situation, new SDM will be generated containing its additional information as well as the information it holds about the other surrounding nodes and broadcast it to all nearby nodes. Previous steps will be repeated until – again – the CSL becomes true (Figure 2).

After short period of exchanging SDM's, nodes will be informed about the surrounding nodes. Each node should hold three lists: Seen Messages list (to reduce redundancy), active node seen list and non active nodes seen list. Each time node receives a message it updates its lists and checks whether the optimum number for each detectable situation is achieved or not. If it is not, it will forward SDM to the next hops. But in case of optimum number has been achieved, new Situation Warning Message (SWM) will be generated and broadcasted and new CSL will be setup for SDM to determine the life time.

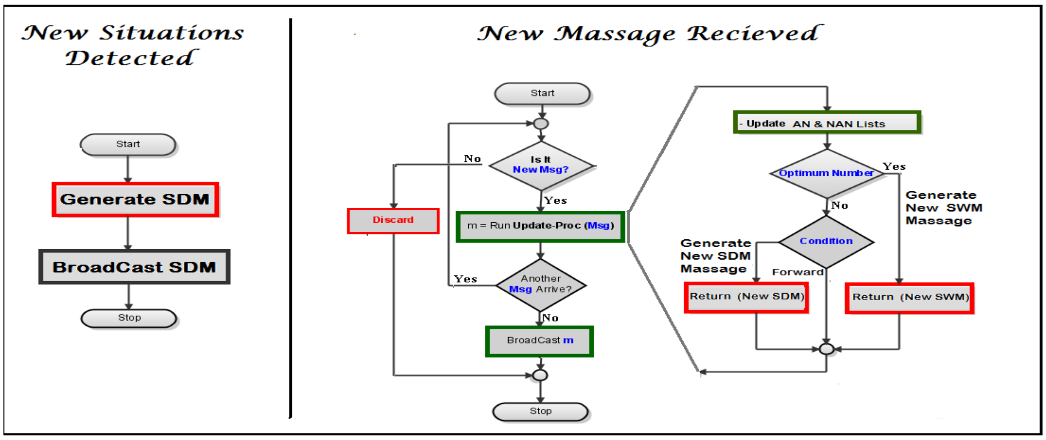

Figure 2: Node Behavior (Case A: New Situation Detection | Case B: New message Received)

3 Simulation Stage

3.1 Simulation parameters:

Chosen parameters (for ad-hoc network is based on NS2) simulate the real life scenarios by assigning a variety of values, as follows:

Simulation Parameter	Assigned Value
Channel Type	Channel/WirelessChannel
radio-propagation model	Propagation/TwoRayGround
network interface type	Phy/WirelessPhy
MAC type	Mac/802_11
interface queue type	Queue/DropTail/PriQueue
link layer type	LL
Routing Protocol	DumbAgent
Topology Type/Size	Flat Grid /(1000mX1000m)
Nodes Distribution	Complete Random
Movement Pattern	Complete/Partial Random

3.2 Iteration in simulation:

Our diagrams are aggregated and averaged from data collecting after repeating the simulation a number of times.

As illustrated on Figure 3, we calculate the following data:

- Total number of Messages (sent / received / discarded).
- Simulation Time needed (by all nodes / per node).
- Active nodes seen (Max / Min) among all nodes.
- Non-active nodes seen (Max / Min) among all nodes.
- Number of nodes saw (all active nodes / nothing).
- Number of nodes recognize up to (25/50/75/100) % of the whole active nodes.
- Number of nodes recognize up to (25/50/75/100) % of all non-active nodes.

The simulation results are compiled on the basis of average results of running the simulation 10 times per each assumption (each Delay Time × each max Hops × each Active node number × each total number of all nodes) with complete random selection of active nodes. The movement patterns we tested are two cases: first case, complete random generation in each round, second case, the same movement pattern for all rounds with the same delay and number of hops.

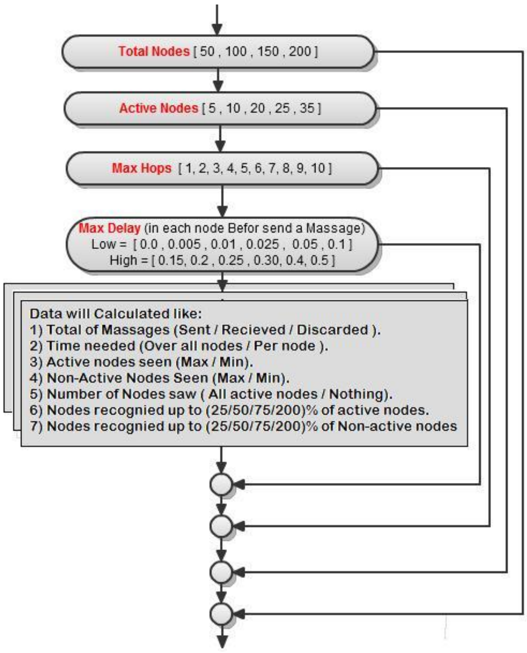

Figure 3: Simulation Iteration Illustration

4 Results

4.1 Results Aggregation:

The simulation has been repeated 32,000 times and the aggregate results are presented on (Fig 4), (Fig 5) and (Fig 6).

To help improve the aggregation and visualisation of the data and present them in dynamic form, a tool has been developed for that purpose (Using VC# 2009 as programming language). The tool can help in discovering the trend for any of the collected data (e.g.: number of exchange messages, max seen active nodes…) based on the number of hops and delay time. This approach makes us able to predict the optimum number of hops with the best delay time. We use it to establish the optimum parameters for the best performance of the algorithm (e.g.: reducing the number of exchanged message over the most suitable delay time with the maximum number of recognized active nodes and the maximum number of non-active nodes).

4.2 Results Analysis:

As we are looking for the optimum number of hops enough to discover the whole local area and, at the same time, the optimum Delay time each node should use before resending any message, we will analyse all the available data from the simulation with these two parameters (Num of Hops & Delay Time) as variables separately.

Number of exchange messages needed, Messages Exchange Time and number of recognized nodes (AN/NAN) will be used as indicators for the best results and will be enough to detect any Traffic

Condition if we consider the following indicators:

4.2.1 **Number of Exchanged Messages as a function of the number of hops:**

Figure 4 shows the number of sent, received, lost and redundant messages in each node and indicates how noisy the system is. It also gives an indication of the optimal value for the number of hops parameter.

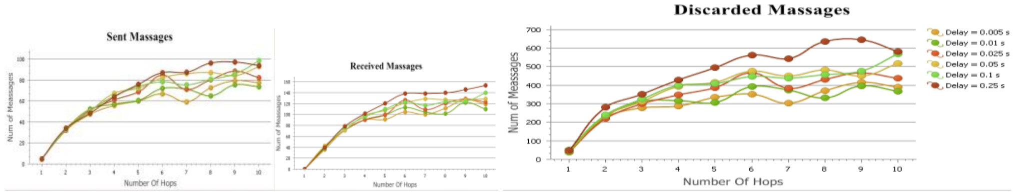

Figure 4: Numbers of sent, received and Discarded Messages

4.2.2 **Total Time for area discovery as a function of the number of hops:**

Figure 5 shows the total time needed for the algorithm to finish as a function of the number of hops parameter. Chosing the shortest Total time needed to exchange all messages to detect certain situation is important for the speed of detection and also for the timeout needed to wait before re-initianting the discovery sequence.

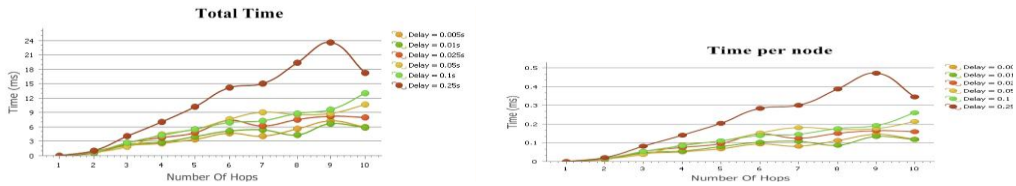

Figure 5: Total Time and Time per node

4.2.3 **Number of recognized nodes (AN / NAN):**

Knowing the ratio between AN and NAN (or simply their numbers) is crucial to detect if the situation is present or not. The results of the experiments presented in Figure 6 show the number of recognised nodes as a function of the number of hops parameter.

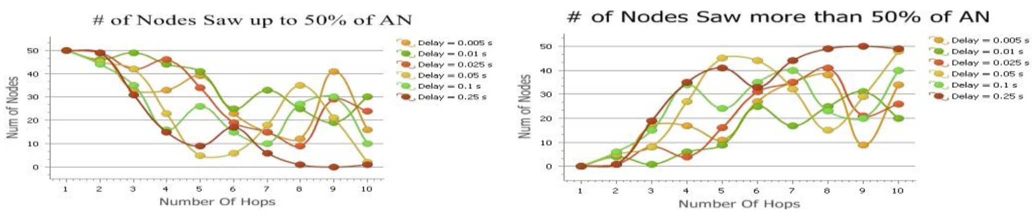

Figure 6: Active nodes Recognition

4.3 **Results outcome:**

This study identifies the best value for two algorithm parameters – number of hops and delay time. Some of the findings in this paper are as follows:

As mentioned in section 2.1.3 in this paper, the assumption is that different situations are detected by different number of recognized AN/NAN (e.g: situation is rainy if 33% of nodes is AN, or slippery spot can by detected by 3 AN regardless the number of NAN). Analysing the graphs presented there is no clear dividing line and therefore it would be incorrect if we suggest just one fixed number - as optimum number – for best delay time or best number of hops. Subsequently, a range of numbers for these two parameters will be proposed by this study which will suit most situations detection cases. Based on these assumptions, we are looking for the best results which can recognize from 50% up to 100% of active nodes which will be enough to cover all cases.

4.3.1 Recommended Number of Hops:

In the graphs presented we are looking for the point of saturation i.e. standard increase in the value of the investigated parameter gives relatively small improvement in the quantity of sent/received/discarded messages. The results show clearly that using **from 3 up to 5 hop**s is optimum to detect any Traffic Condition if we consider the mentioned indicators.

4.3.2 Recommended Delay Time:

The results show that the biggest delay time will reduce the number of exchanged messages, but it will increase the total time needed to regonize the biggest possible number of AN/NAN. This is difficult compromise between Time and noise, so choosing the best delay time will be **between 0.01 and 0.1 second**.

5 Conclusion

As an infrastructure-less vehicle-to-vehicle communication algorithm in terms of data sharing and collaborative generating information, it is highly efficient protocol compared to pure flooding – the only algorithm reported so far capable of discovering reliably the information on an ad-hoc basis. Also, it has been proved that the algorithm can discover traffic conditions within certain areas with dynamic variable search limitations conditions as well as using intelligent routing mechanism.

6 Future work

It is clear that tomorrow's driving assistance systems can go far beyond their present capabilities by implementing co-operation and information exchange in order to collectively and cooperatively perceive the context. Making decisions dependent on the context can serve car drivers, ITS, environment and all people as general. This paper demonstrates a way of achieving this goal and paves the way for new and improved algorithms which to use car-to-car communication for traffic context identification. In this context the algorithm itself can be improved by identifying dynamically the boundary conditions as well dynamic change of the traffic condition for identification and employing dynamic parameter restrictions.

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Sensing Traffic Conditions in VANET For Building new generation in Wireless Intelligent Transportation Information Systems

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Abstract: Vehicle to vehicle communication (V2VC) is one of the modern approaches for exchanging and generating traffic information with (yet to be realised) potential to improve road safety, driving comfort and traffic control. In this paper, we present a novel algorithm, which is based on V2V communication, uses in-vehicle sensor information and in collaboration with the other vehicles' sensor information can detect road conditions and determine the geographical area where this road condition exists.

The Traffic Condition Detection Algorithm (TCDA) - which we propose here - is simple, flexible and fast and does not rely on any kind of roadside infrastructure equipment. It will offer live road conditions information channels at - almost - no cost to the drivers and public/private traffic agencies and has the potential to become indispensable part of any future intelligent traffic system (ITS). The benefits from applying this algorithm in traffic networks are identified and quantified through building a simulation model for the widely used Network Simulator II (NS2).

Index Terms: Ad hoc network, Vehicular ad-hoc networks (VANET), Vehicular Networks, collaborative knowledge generation.

1 INTRODUCTION

One of the new types of ad hoc networks, the recently emerging VANETs, are networks, which consider every vehicle as a node in the wireless network. Broadcasting in ad hoc network is an elementary operation to support many applications in VANET [1] thus encouraging vehicle manufacturers and researchers to invest more in the techniques of information gathering and dissemination in VANETs. Nowadays, so many vehicles are running on roads that serious traffic problems including traffic accidents and traffic jams are becoming a serious problem. In the US, about six millions of injuries occurred every year [5]. In 2007, more than 325k traffic accidents occurred in China, which caused more than 80k deaths and more than 380k injuries. Investigations show that most traffic accidents are collisions, however, 60% of crashes would be avoided by 0.5 sec earlier warning [9]. One obvious conclusion is that an attempt should be made to distribute the safety messages earlier to the vehicles with possibility of accidents. On the other hand, the traffic conditions of big cities become terrible, which results in time wasting, gasoline exhausting and serious air pollution. Some works should be done to make drivers know which ways can be selected to avoid traffic jams. Broadcasting in VANETs can disseminate assisting traffic condition messages to all vehicles within a certain geographical area to make drivers of vehicle control models pre-act to avoid accidents and pre-select ways to avoid traffic jams. In this mode, VANETs rely heavily on broadcast to transmit emergency message efficiently in modern road traffic environment [12].

The VANETs are considered as a specific case of MANETs, therefore they have MANETs characteristics, they are multi-hopped, decentralized and self-organized etc. In VANETs, vehicles running on the road can constitute decentralized, burst and temporary networks. The shape of the network can be determined using the different approaches. For example, the vehicle infrastructure Integration (VII) initiative in US proposes that the information about an accident should be communicated through VANET within half a second to all equipped vehicles in a 500m range [8]. Because of the shared wireless medium, a simple broadcast scheme, which is called flooding, may lead to frequent contention and collisions in transmission among neighbours [7]. The inherent problem of the plain flooding technique is the huge amount of superfluous retransmissions that consume the limited network resources [2]. These may lead to lower reliability and more latency [11]. At an extreme condition, the channels may be blocked and broadcasts may fail, this phenomenon is called broadcast storm. In reality, traffic jams often occur in big cities at the traffic peaks, more than 1 Km long saturated traffic jams are common. The investigation shows that the traffic become saturated when the density reach 133 vehicles/Km/lane [9]. The flooding scheme is infeasible in dense VANETs, because it brings us serious contentions, redundancies and collisions.

One of the main advantages of the ad-hoc networks is the opportunity to use collaborative effort in connecting and delivering network messages as necessary [6]. This opportunity is under-utilised so far in the area of traffic control and traffic information systems where every car can be considered to be a node in an ad-hoc network [10]. Our aim is to investigate the possibility of bringing ad-hoc collaborative information generation and control into such systems and investigate how the functionality of the ad-hoc node (within the vehicle) affects the quality of the traffic wireless information systems in ITS. The project covers the middle ground between VANET and collaborative data generation based on knowledge granularity (aggregation) [3]. It will investigate the designing, implementing and modelling the functionality of a condition identification algorithm for an intelligent node in ITS wireless information system that will be - at the same time - an active participant in the formation, routing and general network support of such systems and also act as in-car traffic information and real-time control generator and distributor [4].

Let us start by classify the discoverable road conditions based on ❶ how many cars needed to discover certain road condition? Also, ❷what kind of parameters and variables needed to put it in its context (determine the road condition)? We tried to present the associated frequent asked questions, which may raises in terms of:

1) Broadcasting: How each node ensures that at least one node has received its message? How far should each message travel form the generated node (distance / number of hubs / time)?
2) Redundancy: Can we avoid sending the same message from multiple nodes? Who will stop forwarding the message?
3) Collecting data: (Granulation) what is the optimal number for each condition? (Percentage: number of cars with specific condition vs. total number of nearby cars). Which car will announces the warning message of the discovered road condition?

The main research objectives are to design the algorithms' functionality and to implement a model of the network with the required node features, which it is anticipated, will form the basis of a future real-life case study implementation.

2 Traffic Condition Detection Algorithm (TCDA)

Some road conditions can either be derived (assessed) from the activity of the individual cars' electronic helpers like ESP or ABS, or alternatively, sensors embedded in the individual vehicle may provide this information. The summary in the table 1 is summary of the most common road situations with the causes of those situations considered as Non-conclusive Individual Car Sensed Data:

Table 7-1: Possible Road Situations (examples)

Individual Car sensors data	Possible Reasons
Windscreen Wipers (goes ON)	Rain / cleaning / By Accident
ABS Control (Slippery Road)	Snow / Oil spot / bad tires / Bad driving
Fog light (ON).	Fogy / By Accident / Since yesterday
Movement Speed (Slow).	Traffic Jam / Driver using the phone/radio
Reduce Speed (Unexpected)	Hazard Ahead/saw a friend or interesting place

But if we can share this data among all nearby cars, by Combining Individual Car Sensed Data (Table 2), the result will be:

Table 7-2**: Certain Road Situation (examples)**		
Individual Car sensors data	Optimum Num	The Reason
Wipers	10% of cars ON	Rainy
ABS Control.	5 cars = ON	Slippery (snow)
Slippery Spot.	2 cars	Slippery spot
Fog light.	50% cars ON	Fogy
Movement Speed	60%Slow/Stop	Traffic Jam
Reduce Speed	5 cars in 1sec	Hazard Ahead

By comparing the two tables, you will notice that each case in the first table could happen because of many reasons, which make it non-conclusive piece of information. But in the second table, if we know the number of neighbouring cars that got the same situation (the numbers quoted in the table are representative rather than conclusive for the condition and represent a matter of future investigation in real-life experiments), we will be certain about the reason for that situation. This mechanism transfers the non-conclusive individual car sensed data into very important (conclusive) data to describe the surrounding road conditions. We should notice that the optimum number in the above table should be predefined and updatable by the system itself.

2.1 Algorithm Features:

The algorithm is very flexible and has several variable parameters, which influence the final outcome, and this paper presents our conclusions in determining the optimal set of values:

- Using Variable Conditions Search Limitation (CSL): Control the searching area for any situation by using selection of parameters (number of hops from source, certain timeout, and/or distance from source).
- Multi-zones detection: in case of more than one zone, it can Detect each situation zone boarders separately (even if they are overlapped). Then report them in one or multiple warning messages.
- Delay for data collection: Random time slots delay used before forwarding the received messages
- Infrastructure less system.

2.2 Algorithm Description:

Pseudo-code of TCDA

Input:

Road situation detection messages (SDM) received. It generated by any node (I called it Active Node) who senses any road problem or certain road situation, each has at least the following information: Message id, Two lists of nodes and its positions: active nodes and non-active nodes.

Initialize:

$i \leftarrow$ { 0 … number of nodes -1 }

$B_i \leftarrow$ neighbor set of current node N_i

AN_i *$\leftarrow$ detected Active Nodes IDs set by N_i*

NAN_i *$\leftarrow$ detected Non Active Nodes IDs set by N_i*

SDM *$\leftarrow$ road situation Detection Message.*

SWM $\leftarrow$ situation Warning Message.

Event: new situation has been detected in the current node N_i

Add the current node ID to the local ***AN_i {if $AN_i \neq \emptyset$ }***

Generate ***SDM $\leftarrow$ {$N_i(id)$, AN_i , NAN_i }***

Forward ***SDM*** via 802.11

Event: new ***SDM_j*** message has been arrive at the current node N_i

extract from *SDM_j* data sets : *$SDM_j(id)$, AN_j, NAN_j* ;

if SDM_j is redundant ***then***

discard ***SDM_j*** ;

else

NAN_i $\leftarrow$ ***NAN_i*** $\cup$ ***NAN_i***

AN_i $\leftarrow$ ***AN_i*** $\cup$ ***AN_i*** ***// update local lists of known AN & NAN***

if $\frac{\text{length}\{AN_i\}}{\text{length}\{AN_j\}+\text{length}\{AN_i\}} \geq$ *optimum Number* ***then***

// all data is Known

Calculate *Zone* ***// identifier zone situation by using AN list (NodeId and Position)***

Generate S***WM*** ← ***{N_i(id) , SI_i ,zone, AN_i } // generate new warning Message***

Broadcast *SWM* via 802.11

else-if ***(****distance between fairest two nodes in AN_i ≥ Optimum number****) OR (****timeout****)*** ***then***

Generate S***DM_i*** ← ***{N_i(id) , AN_i, N AN_i }*** //

generate new warning Message

Forward S***DM_i*** via 802.11

else

Wait tolerant-time // ***to receive and collect***

more data to broadcast all in one message.

update AN_i , NAN_i // update lists based on known AN & NAN

Generate S***DM_i*** ← ***{N_i(id) , AN_i, N AN_i }***

//***generate new Discovery Message***

Forward S***DM_i*** via 802.11

end-if

end-if

Event: new S***WM_i*** situation has been received in the current node N_i

update AN_i , NAN_i // update lists based on known AN & NAN

Calculate *Zone* // identifier zone situation by using

AN list (NodeId and Position)

Generate S***DM_i*** ← ***{N_i(id) , AN_i, N AN_i }*** //generate new

warning Message

Forward S***WM_i*** via 802.11

3 Results

A model of an Adhoc network was set up to simulate the VANET using NS2 to generate traffic. Chosen parameters to simulate real life scenarios were assigned. The scenarios we have used to test our algorithm were extracted from a real data monitoring system in Nottingham traffic control centre. This support increases the reality of our scenarios in all aspects (real road map, cars movement, road density, cars speed, … etc). We should point out here that, the factor of having natural obstructs (building, Walls, Mounts, …) is not considered in our test model because of the difficulty of implementing or representing this factors in NS2 models. Ignoring these natural obstacles will boost up somewhat the number of dropped messages (interference) in our system, but – by percentage - we assume that this will not affect our results because of the minor effect and the iteration techniques that we used to calculate our results.

The simulation results are compiled on the basis of average results of running the simulation 10 times per each assumption (each Delay Time × each max Hops × each Active node number × each total number of all nodes) with complete random selection of active nodes. The movement patterns we tested are two cases: first case, complete random generation in each round, second case, the same movement pattern for all rounds with the same delay and number of hops.

3.1 Results Aggregation:

The simulation has been repeated 32,000 times. To help improve the aggregation and visualisation of the data and present them in dynamic form, a tool has been developed for that purpose. The tool can help in discovering the trend for any of the collected data (e.g.: number of exchange messages, max seen active nodes…) based on the number of hops and delay time. This approach makes us able to predict the optimum number of hops with the best delay time. We use it to establish the optimum parameters for the best performance of the algorithm (e.g.: reducing the number of exchanged message over the most suitable delay time with the maximum number of recognized active nodes and the maximum number of non-active nodes).

3.2 Results Analysis:

As we are looking for the optimum number of hops to discover the whole local area and, at the same time, the optimum Delay time each node should use before resending any message, we analyse all the available data from the simulation with these two parameters (Num of Hops & Delay Time) as variables separately.

The number of exchange messages needed, message exchange time and number of recognized nodes (AN/NAN) are used as indicators for the best results and are sufficient to detect any Traffic Condition. The results for each are considered in the following:

Number of Exchanged Messages Per Node

Those figures (1a, 1b, 1c) show the number of sent and received messages at each node and indicates how noisy the system is. It also gives an indication of the optimal value for the number of hops parameter

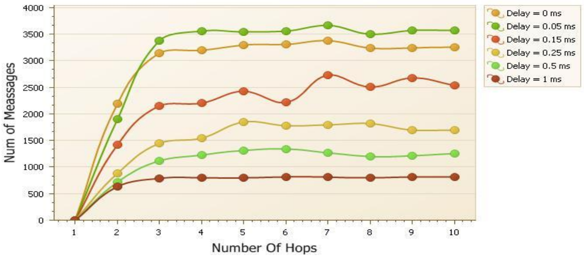

Figure 1a:Number of Received Messages /Node

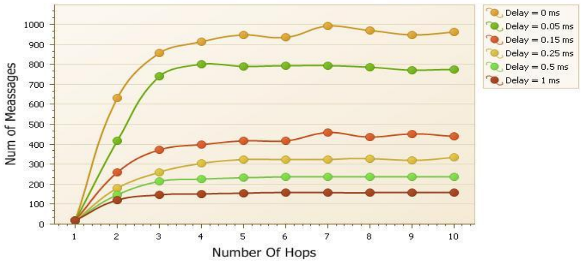

Figure 1b:Number of Sent Messages / Node

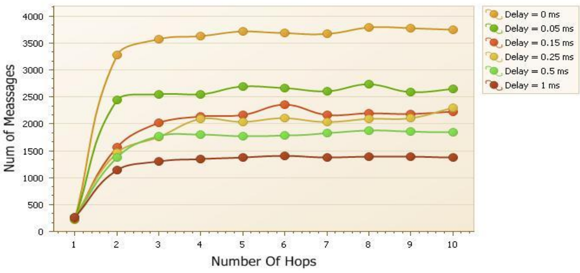

Figure 1c:Number of Discarded Messages/Node

Message Exchange Time Needed to Discover the area: The Figures (2a,2b) shows the total time needed for the algorithm to finish as a function of the number of hops parameter. Choosing the shortest total time needed to exchange all messages to detect a certain situation is important for the speed of detection and also for the timeout required before re-initiating the discovery sequence.

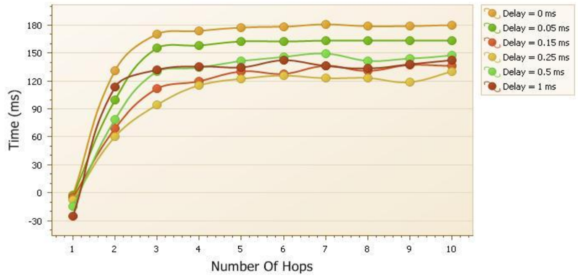

Figure 2a:Message Exchange Time (Total Time)

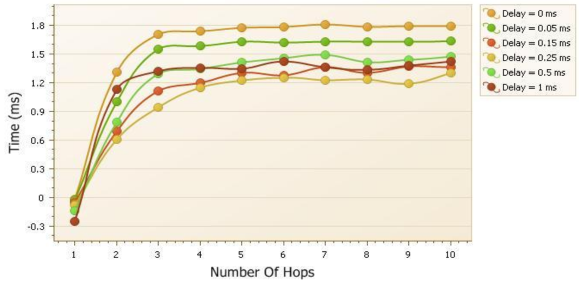

Figure 2b:Message Exchange Time(Time/Node)

Number of recognized nodes (AN / NAN)

Knowing the ratio between AN and NAN (or simply their numbers) is crucial to detect if the situation is present or not. The results of the experiments presented in the figures (3a, 3b, 3c, 3d) show the number of recognised nodes as a function of the number of hops parameter.

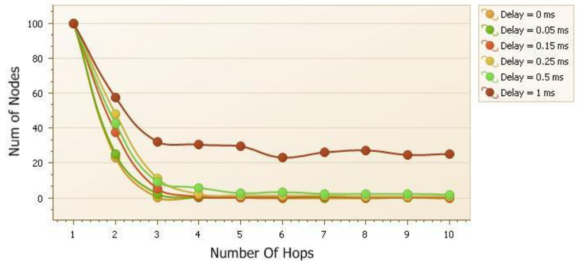

Figure 3a: # of Nodes Saw up to 50% of AN

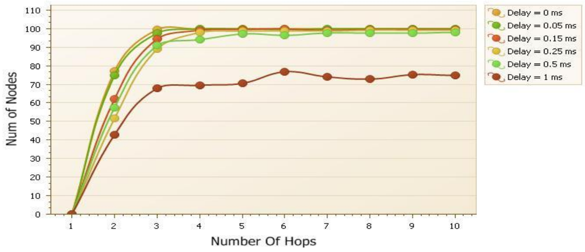

Figure 3b:# of Nodes Saw more than 50% of AN

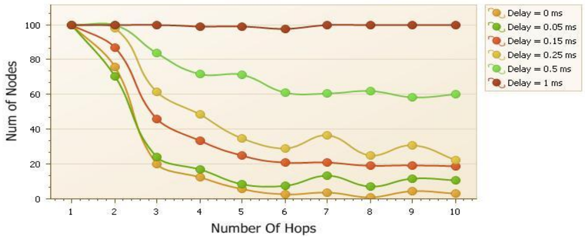

Figure 3c:# of Nodes Saw up to 50% of NAN

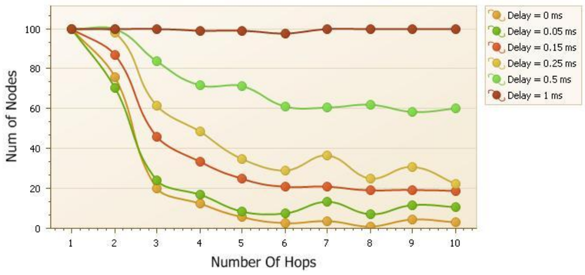

Figure 3d:# of Nodes Saw more than 50% of NAN

3.3 Results outcome

This study attempts to identify the optimum value for two algorithm parameters; number of hops and delay time. The assumption is that different situations are detected by different numbers of recognized AN/NAN (e.g: situation is rainy if 33% of nodes are AN, or a slippery spot can be detected by 3 AN regardless the number of NAN).

Analysis of the graphs presented indicates that there is no fixed optimum number either for delay time or number of hops. Consequently a range of numbers for these two parameters must be considered dependant on the detection cases. Based on these assumptions, we are looking for the best results that can recognize from 50% up to 100% of active nodes, which will be enough to cover all cases.

In the graphs presented the point of saturation i.e. where an increase in the value of the investigated parameter gives relatively small improvement in the quantity of sent/received/discarded messages. The results show clearly that using **from 3 up to 5 hops** is optimum to detect any Traffic Condition if we consider the mentioned indicators.

The results show that the greatest delay time will reduce the number of exchanged messages, but will increase the total time needed to recognize the biggest possible number of AN/NAN. This is a difficult compromise between Time and noise, though a figure **between 0.01 and 0.1 second** seems to be indicated.

4 Conclusion & Future work

An infrastructure-less vehicle-to-vehicle communication system in terms of data sharing and collaborative generation of information, as well as the characterized particular vehicular networks (moved nodes, road constrains mobility and variable communication conditions) is hot issue and research challenge for academics. Several dissemination protocols were proposed in research works. They could be sorted into two classes: (i) protocols for infotainment services (e.g. advertisement applications) that have constraints related to the bandwidth, and (ii) protocols for emergency services (e.g. road safety services) that have end-to-end delay and delivery ratio constraints. Also, Vehicular networks can be considered as the portal of many services, ranging from safety to traffic information and location based services (LBS). These services generally require efficient routing and dissemination protocols.

The proposed TCDA is a highly efficient protocol compared to pure flooding – the only algorithm reported so far capable of discovering reliably the information on an ad-hoc basis. Also, it has been proved that the algorithm can discover traffic conditions within certain areas using both dynamic variable search limitations and an intelligent routing mechanism. Optimal values for recommended number of hops and delay time have been identified and reported.

It is clear that tomorrow's driving assistance systems can go far beyond their present capabilities by implementing co-operation and information exchange in order to collectively and cooperatively perceive the driving environment. Making decisions dependent on the environment can serve car drivers, ITS, environment and people more generally. This paper demonstrates a way of achieving this goal and paves the way for new and improved algorithms which to use car-to-car communication for traffic context identification. In this context the algorithm itself can be improved by identifying dynamically the boundary conditions as well as dynamic change of the traffic conditions for identification and employment of dynamic parameter restrictions.

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Utilization of Broadcast Methods for detection of the road conditions in VANET

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Abstract: *Vehicle to vehicle communication (V2VC) is one of the modern approaches for exchanging and generating traffic information with (yet to be realised) potential to improve road safety, driving comfort and traffic control. In this paper, we present a novel algorithm which is based on V2V communication, uses in-vehicle sensor information and in collaboration with the other vehicles' sensor information can detect road conditions and determine the geographical area where this road condition exists – e.g. geographical area where there is traffic density, unusual traffic behaviour, a range of weather conditions (raining), etc. The built-in automatic geographical restriction of the data collection, aggregation and dissemination mechanisms allows warning messages to be received by other cars, not necessarily sharing the identified road condition, which may then be used to identify the optimum route taken by the vehicle e.g. avoid bottlenecks or dangerous areas including accidents or congestions on their current routes.*

The Traffic Condition Detection Algorithm (TCDA) - which we propose here - is simple, flexible and fast and does not rely on any kind of roadside infrastructure equipment. It will offer live road conditions information channels at - almost - no cost to the drivers and public/private traffic agencies and has the potential to become indispensable part of any future intelligent traffic system (ITS). The benefits from applying this algorithm in traffic networks are identified and quantified through building a simulation model for the widely used Network Simulator II (NS2).

Index Terms: Wireless, Ad hoc network, Vehicular ad-hoc networks (VANET), Mobile ad-hoc networks (MANET), Vehicular Networks, Collaboration, ICT, ITS, collaborative knowledge generation, traffic information systems.

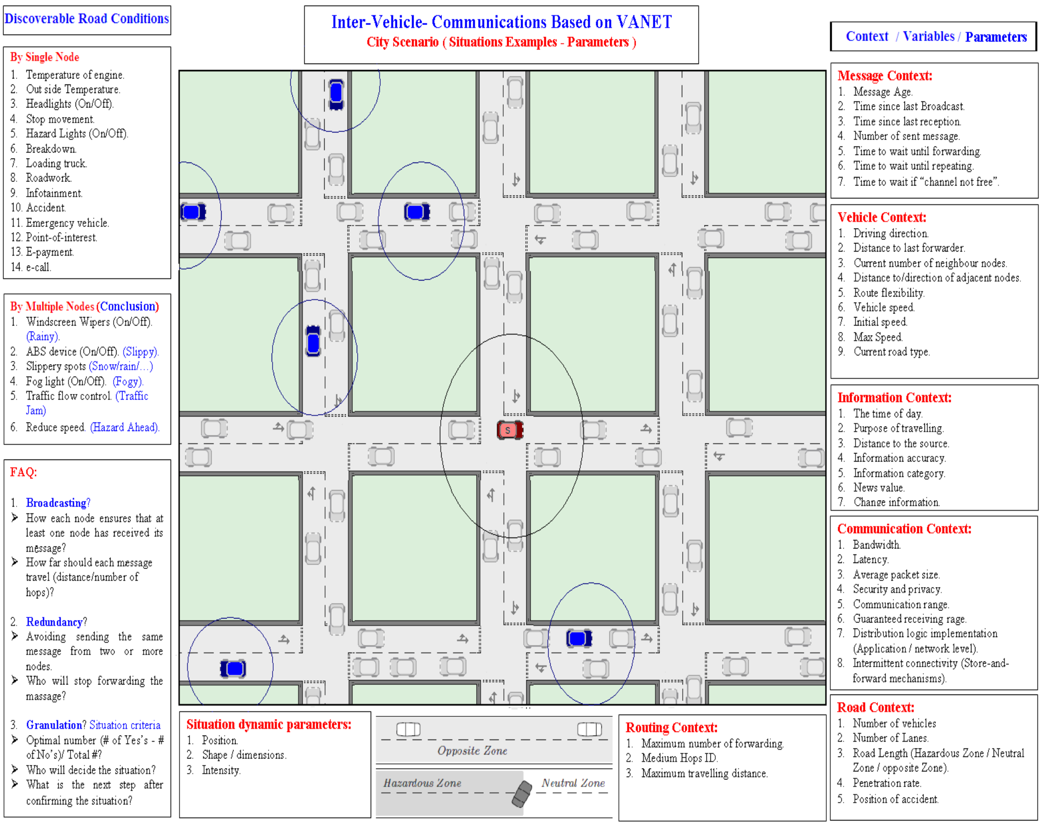


Figure 1: City Scenario (Discoverable Conditions)

1 INTRODUCTION

One of the main advantages of the ad-hoc networks is the opportunity to use collaborative effort in connecting and delivering network messages as necessary [1]. This opportunity is under-utilised so far in the area of traffic control and traffic information systems where every car can be considered to be a node in an ad-hoc network [2]. Our aim is to investigate the possibility of bringing ad-hoc collaborative information generation and control into such systems and investigate how the functionality of the ad-hoc node (within the vehicle) affects the quality of the traffic wireless information systems in ITS.

Let us start by classify the discoverable road conditions based on ❶ how many cars needed to discover certain road condition? Also, ❷what kind of parameters and variables needed to put it in its context (determine the road condition)?

4.1 Problem definition:

Most of the existing systems in use today work through establishing direct connection between mobile nodes in MANET and pre-existing infrastructure node, which immediately raises questions about the compatibility, required services, updating devices …etc. when we move to collaborative ad-hoc networking and in the same time, the systems already in place have relatively high cost [3][4][5]. The proposed algorithm does not depend on the network topology but the connectivity between the cars can influence the region definitions while identifying traffic conditions. It is clear that the more cars we have on the road the more effective the algorithm will be since the algorithm works on the basis of collaborative data generation and the more cars we have linked in one ad-hoc network the more entities will take part in the collaborative process. Here is small scenario which illustrates the idea:

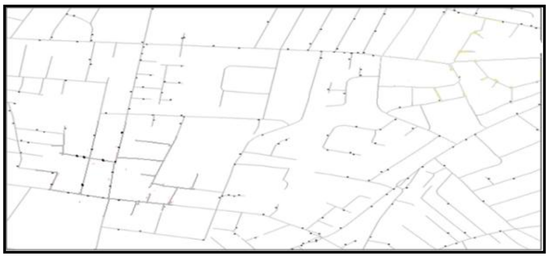


Figure 7: Street Map with vehicles in move

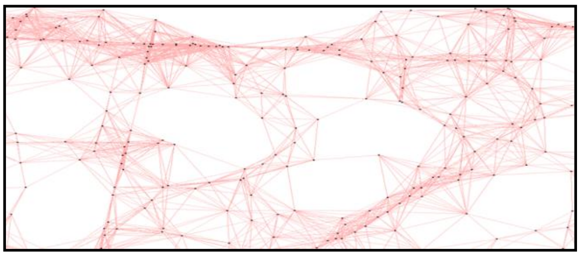


Figure 3: Establishing direct link between

1) Here is (Figure 3) snapshot of certain area (the lines are roads; the black small points are nodes or vehicles). In urban areas, density of cars in streets is high which make us able to formulate network between cars if we put a small wireless device to enable the communication between the cars.

This will establish direct communication channel between each two cars in the range of each other (Ad-Hoc network). This makes sharing non-valuable individually sensed data among cars more effective, useful and less expensive than any infrastructure communication for generating new knowledge.

2) The network has been established, the nodes start talking, the exchange messages –called discover message- to share all the data they have (their own sensed data or data they already received about nearby cars). Each node is able to calculate the percentage of cars - within certain area – who got the same situation. If this percentage is big enough to consider this area has that situation (Figure 4), warning message will be generated and broadcast it by that node to inform as much and far cars as possible with the routing feature in each node.

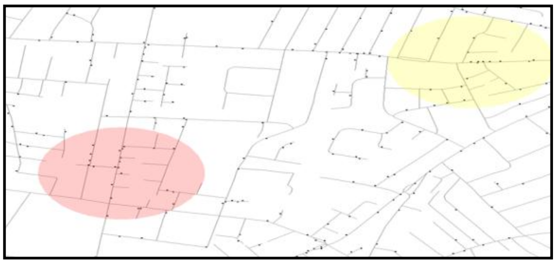


Figure 4: Situation Zones has been identifier

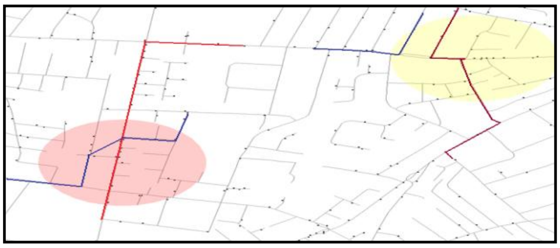


Figure 5: Pre-planned Traveling paths

3) Certain areas will be declared as situation zones (Figure 5) for a while, each node or vehicle can know about them by receiving the warning message. This declaration will last for a period of time, if this information did not confirmed again– by receiving new message each car will consider the situation has been finished and the normal condition got back to the roads in that area.

4) This will make each GPS or driver itself avoid these zones if it/he was planning to pass through them (Figure 6) to avoid any risk or delay.

2 Traffic Condition Detection Algorithm (TCDA)

TCDA foundation rules:

- TCDA DOES NOT rely on any kind of roadside units or infrastructure, just car to car communication for collaborative data sharing and processing without using any kind of cauterization (processing | storage).
- TCDA DOES NOT rely on central processing, each node in the system DOES have the same functionality (routing messages if needed, processing the received information, generating new messages,…).

4.2 Algorithm Overview:

Some road conditions can either be derived (assessed) from the activity of the individual cars' electronic helpers like ESP or ABS, or alternatively, sensors embedded in the individual vehicle may provide this information. The summary in the table below (Table 1) is summary of the most common road situations with the causes of those situations considered as Non-conclusive Individual Car Sensed Data:

Table 2-1: Possible Road Situations (examples)

Individual Car sensors data	Possible Reasons
Windscreen Wipers (goes ON)	Rain / cleaning / By Accident
ABS Control (Slippery Road)	Snow / Oil spot / bad tires / Bad driving
Fog light (ON).	Fogy / By Accident / Since yesterday
Movement Speed (Slow).	Traffic Jam / Driver using the phone/radio
Reduce Speed (Unexpected)	Hazard Ahead/saw a friend or interesting place

But if we can share this data among all nearby cars, by Combining Individual Car Sensed Data (Table 2), the result will be:

Table 7-2: Certain Road Situation (examples)

Individual Car sensors data	Optimum Num	The Reason
Wipers	10% of cars = ON	Rainy
ABS Control.	5 cars = ON	Slippery (snow)
Slippery Spot.	2 cars	Slippery spot
Fog light.	50% of cars ON	Fogy
Movement Speed.	(60%) Slow/Stop	Traffic Jam
Reduce Speed	5 cars within 1sec	Hazard Ahead

By comparing the two tables, you will notice that each case in the first table could happen because of many reasons which make it non-conclusive piece of information. But in the second table, if we know the number of neighbouring cars that got the same situation (the numbers quoted in the table are representative rather than conclusive for the condition and represent a matter of future investigation in real-life experiments), we will be certain about the reason for that situation. This mechanism transfer the non-conclusive individual car sensed data into very important (conclusive) data to describe the surrounding road conditions. We should notice that the optimum number in the above table should be predefined and updatable by the system itself.

4.3 Algorithm Features:

The algorithm is very flexible and has several variable parameters, which influence the final outcome, and this paper presents our conclusions in determining the optimal set of values:

i) Using Variable Conditions Search Limitation (CSL): Control the searching area by number of hops from source, certain timeout, and/or distance from source.

ii) Multi-zones detection: in case of more than one zone, it can Detect each situation zone boarders separately (even if they are overlapped). Then report them in one or multiple warning messages.

iii) Delay for data collection: Random time slots delay used before forwarding the received messages.

iv) Infrastructure less system.

4.4 Definitions of the used Terms:

vi) Active Node (AN): refers to any node with sensors indicating that a certain road condition(s) is present and is to be reported to other nearby cars or nodes.

vii) Non-Active Node (NAN): refers to any node with sensors indicating that a certain road condition(s) is NOT present (the node will serve as a router to forward messages coming from nearby nodes).

viii) Situation Discovery Message (SDM): a message generated by AN or - in some cases - by NAN. It has three parts: unique SDM ID (nodeNo:timestamp:Position), SDM limitation conditions (Hops:timeout:distance) and Nodes seen (NodeID:Time:Situations:position). Its purpose is to establish zone identification and contains:

ix) Situation Warning Message (SWM): generated by any node discover a situation zone. It contains the fields: unique SEM ID (SourceNo:timestamp:Position), SWM travel conditions (Hops:timeout:distance) and Zones detected (NodeID:Time:Situations:position).

x) Node behaviour: Node behaviour is the *reaction* of the node when receiving a message. The reaction can be:

a. Forward the message if it is message received for the first time, otherwise discard.
b. Discard the message if it is redundant.
c. Generate new Situation Discovery Message (SDM) if the received message carries new information compared to the existing information, so the generated message will travel in all directions (broadcast).

4.5 The Algorithm mechanism:

Pseudo-code of TCDA

Input:

Road situation detection messages (SDM) received. It generated by any node (I called it Active Node) who senses any road problem or certain road situation, each has at least the following information: Message id, Two lists of nodes and its positions: active nodes and non-active nodes.

Initialize:

$i \leftarrow$ { 0 … number of nodes -1 }

$B_i \leftarrow$ neighbor set of current node N_i

AN_i $\leftarrow$ *detected <u>Active Nodes IDs set</u> by N_i*

NAN_i $\leftarrow$ *detected <u>Non Active Nodes IDs set</u> by N_i*

SDM $\leftarrow$ *road situation Detection Message.*

SWM $\leftarrow$ situation Warning Message.

Event: new situation has been detected in the current node N_i

Add the current node ID to the local ***AN_i {if $AN_i \neq \emptyset$ }***

Generate ***SDM $\leftarrow$ {N_i(id) , AN_i , NAN_i }***

Forward ***SDM*** via 802.11

Event: new ***SDM_j*** message has been arrive at the current node N_i

extract from *SDM_j* data sets : *SDM_j(id), AN_j, NAN_j* ;

if SDM_j is redundant ***then***

discard ***SDM_j*** ;

else

NAN_i $\leftarrow$ ***NAN_i*** $\cup$ ***NAN_i***

AN_i $\leftarrow$ ***AN_i*** $\cup$ ***AN_i*** ***// update local lists of known AN & NAN***

if $\frac{\text{length}\{AN_i\}}{\text{length}\{AN_j\}+\text{length}\{AN_i\}} \geq$ *optimum Number* ***then***

```
        // all data is Known
          Calculate Zone // identifier zone situation by using AN list (NodeId and Position)
        Generate SWM ← {Ni(id) , SIi ,zone, ANi } // generate new warning Message
                    Broadcast SWM via 802.11
      else-if (distance between fairest two nodes in ANi ≥ Optimum number) OR (timeout) then
          Generate SDMi ← {Ni(id) , ANi, N ANi } //
                              generate new warning Message
                    Forward SDMi via 802.11
      else
          Wait tolerant-time   // to receive and collect more data to broadcast all in one message.
         update ANi , NANi // update lists based on known AN & NAN
         Generate SDMi ← {Ni(id) , ANi, N ANi } //generate new
                                          Discovery Message
          Forward SDMi via 802.11
      end-if
    end-if

Event: new SWMi situation has been received in the current node Ni
  update ANi , NANi // update lists based on known AN & NAN
  Calculate Zone  // identifier zone situation by using AN list
                        (NodeId and Position)
  Generate SDMi ← {Ni(id) , ANi, N ANi } //generate new
                                          warning Message
  Forward SWMi via 802.11
```

3 **Results**

4.6 Results Analysis:

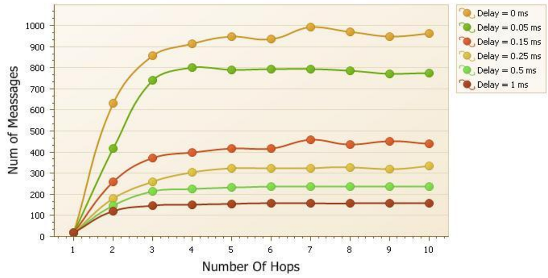
As we are looking for the optimum number of hops to discover the whole local area and, at the same time, the optimum Delay time each node should use before resending any message, we analyse all the available data from the simulation with these two parameters (Num of Hops & Delay Time) as variables separately.

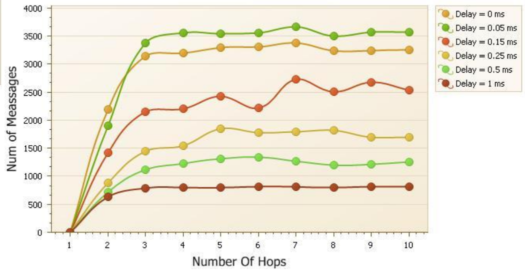
The number of exchange messages needed, message exchange time and number of recognized nodes (AN/NAN) are used as indicators for the best results and are sufficient to detect any Traffic Condition. The results for each are considered in the following:

4.6.1 **Number of Exchanged Messages Per Node**

Those figures show the number of sent and received messages at each node and indicates how noisy the system is. It also gives an indication of the optimal value for the number of hops parameter.

Number of Sent Messages Per Node



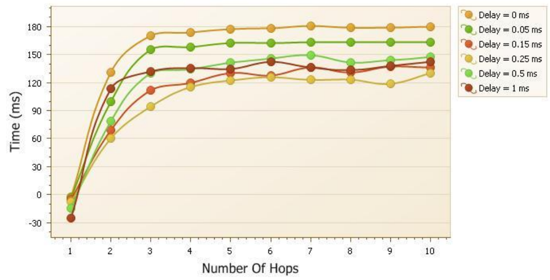


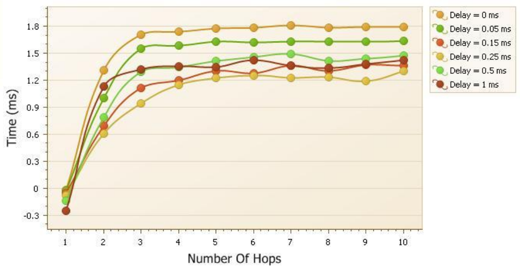
Number of Received Messages Per Node

4.6.2 **Message Exchange Time Needed to Discover the area**

The following Figures shows the total time needed for the algorithm to finish as a function of the number of hops parameter. Choosing the shortest total time needed to exchange all messages to detect a certain situation is important for the speed of detection and also for the timeout required before re-initianting the discovery sequence.

Message Exchange Time (Total Time)



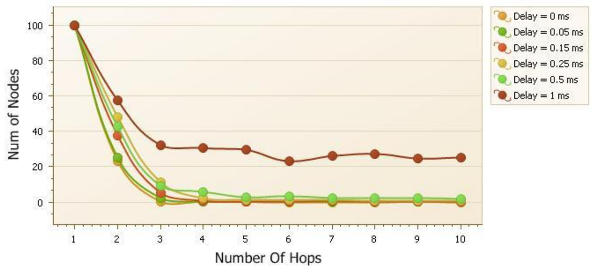


Message Exchange Time (Time / Node)

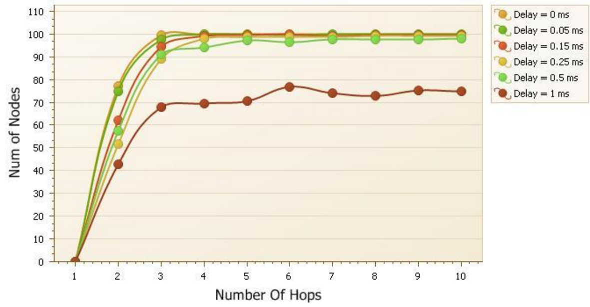
4.6.3 **Number of recognized nodes (AN / NAN)**

Knowing the ratio between AN and NAN (or simply their numbers) is crucial to detect if the situation is present or not. The results of the experiments presented in the following figures show the number of recognised nodes as a function of the number of hops parameter.

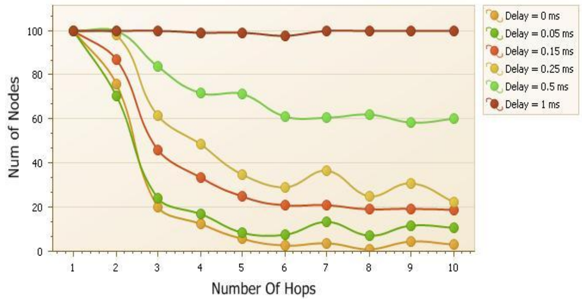
# of Nodes Saw up to 50% of AN



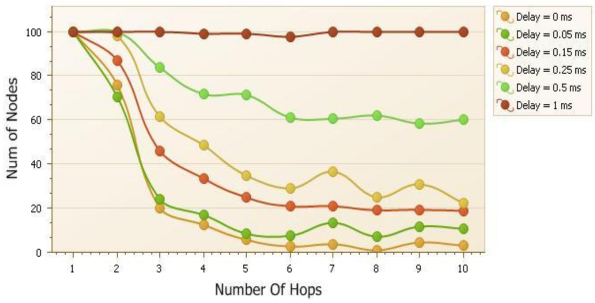
# of Nodes Saw more than 50% of AN



# of Nodes Saw up to 50% of NAN



# of Nodes Saw more than 50% of NAN



4.7 Results outcome

This study attempts to identify the optimum value for two algorithm parameters; number of hops and delay time. The assumption is that different situations are detected by different numbers of recognized AN/NAN (e.g: situation is rainy if 33% of nodes are AN, or a slippery spot can by detected by 3 AN regardless the number of NAN).

Analysis of the graphs presented indicates that there is no fixed optimum number either for delay time or number of hops. Consequently a range of numbers for these two parameters must be considered dependant on the detection cases.. Based on these assumptions, we are looking for the best results which can recognize from 50% up to 100% of active nodes which will be enough to cover all cases.

In the graphs presented the point of saturation i.e. where an increase in the value of the investigated parameter gives relatively small improvement in the quantity of sent/received/discarded messages. The results show clearly that using from 3 up to 5 hops is optimum to detect any Traffic Condition if we consider the mentioned indicators.

The results show that the greatest delay time will reduce the number of exchanged messages, but will increase the total time needed to recognize the biggest possible number of AN/NAN. This is a difficult compromise between Time and noise, though a figure between 0.01 and 0.1 second seems to be indicated.

4 **Conclusion & Future work**

An infrastructure-less vehicle-to-vehicle communication system in terms of data sharing and collaborative generation of information, as well as the characterized particular vehicular networks (moved nodes, road constrains mobility and variable communication conditions) is hot issue and research challenge for academics. Several dissemination protocols were proposed in research works. They could be sorted into two classes: (i) protocols for infotainment services (e.g. advertisement applications) that have constraints related to the bandwidth, and (ii) protocols for emergency services (e.g. road safety services) that have end-to-end delay and delivery ratio constraints. Also, Vehicular networks can be considered as the portal of many services, ranging from safety to traffic information and location based services (LBS). These services generally require efficient routing and dissemination protocols.

The proposed TCDA is a highly efficient protocol compared to pure flooding – the only algorithm reported so far capable of discovering reliably the information on an ad-hoc basis. Also, it has been proved that the algorithm can discover traffic conditions within certain areas using both dynamic variable search limitations and an intelligent routing mechanism. Optimal values for recommended number of hops and delay time have been identified and reported.

It is clear that tomorrow's driving assistance systems can go far beyond their present capabilities by implementing co-operation and information exchange in order to collectively and cooperatively perceive the driving environment. Making decisions dependent on the environment can serve car drivers, ITS, environment and people more generally. This paper demonstrates a way of achieving this goal and paves the way for new and improved algorithms which to use car-to-car communication for traffic context identification. In this context the algorithm itself can be improved by identifying dynamically the boundary conditions as well as dynamic change of the traffic conditions for identification and employment of dynamic parameter restrictions.

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Collaborative Data Dissemination Methods in VANETs for Identifying Road Conditions Zone boundaries

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Abstract: Vehicle to vehicle communication (V2VC) is a modern approach to exchanging and generating traffic information with (yet to be realised) potential to improve road safety, driving comfort and traffic control. In this paper, we present a novel algorithm which is based on V2V communication, uses in-vehicle sensor information and, in collaboration with other vehicles' sensor information, can detect road conditions and determine the geographical area where these road conditions exist e.g. an area where there is traffic density, unusual traffic behaviour, a range of weather conditions (raining), etc. The built-in automatic geographical restriction of the data collection, aggregation and dissemination mechanisms allows warning messages to be received by other cars not necessarily sharing the identified road conditions, which may then be used to inform them of the optimum route to take (to avoid bottlenecks or dangerous areas including accidents or congestion on their current routes).

We propose two approaches in this paper that are simple, flexible and fast and do not rely on any kind of roadside infrastructure equipment. They will offer live road condition information channels at – almost – no cost to drivers and public/private traffic agencies and have the potential to become an indispensable part of any future intelligent traffic system (ITS).

Keywords: Networking, VANET, Protocols, Routing, Dissemination, Broadcasting,

1 Introduction

Currently used traffic information systems are centralised vehicular applications using technologies like Traffic Message Channel (TMC), which provides information about road traffic conditions. However, it (i) lacks short delay times (due to the centralised approach), (ii) averages information for large geographical areas (due to cost-sensitiveness of detailed sensor networks and limited radio resources) and (iii) does not have the opportunity to provide services for locally interesting and time-critical applications [vi]. Moreover, as discussed in [vii], implementation for complete coverage would require new infrastructure that is cost-sensitive, as shown in [viii] through a case study. Such systems would, for example, not meet the requirements of an accident avoidance application, because they have long delays and would require large capacity due to the large geographical area of service. In contrast, VANET-based systems can have short delays and the capacity can be reused more efficiently. Moreover, the structure of VANET can be distributed, which improves the level of independence, scalability and stability.

The vehicular application can be classified based on the improvement of safety and the time-critical nature of the service. Examples of application categories are safety applications (e.g. avoidance of collision, information about loss of control of the vehicle), which can improve road safety significantly (a new level of road safety assistance), but are highly time-critical. In comparison, a service about traffic condition information is less time-critical, as discussed in [ix], due to the low level of variation of traffic conditions in a short time (traffic jams have to build up) and it has a lower impact on improvement of road safety than, for example, traffic accident assistance applications. This categorisation can be extended with expected improvement of safety or comfort level e.g. (example for safety) intersection collision avoidance; (for comfort) dissemination of free parking places in large parking lots [x].

It is important to note the significance of understanding the requirements of vehicular applications. Different applications might have significantly different needs for information-spreading properties (e.g. delay, distance). Therefore different dissemination strategies (including technology employed) need to be employed for various vehicular applications. We aim to find a model to study the effect of these diverse dissemination strategies on information spreading and how we can employ those strategies to identify the boundaries of sensed road conditions.

2 Dissemination strategies

Most VANET-based systems assume *a priori* knowledge about the underlying road network, which is usually interpreted as a weighted graph [xi]. A common approach is to divide the roads into sections with different weights, but certainly not with the same length. The weights are given according to a certain property, which can be physical like a message traversal delay [xii] or stochastic probability based on the distance between vehicles [xiii].

Vehicles are assumed to be equipped with sensors that provide data about the status of the vehicle e.g. speed, geographical position, temperature or even sensors to detect bumps, acceleration [xiv] or honking [xv]. This status represents local information about a geographical area at a certain moment. Distribution of local information needs to be detailed within closer vicinity, and coarser with the increase of distance, as proposed in [xvi]. For example, a driver would be interested in the average speed of vehicles way ahead, but the exact speed of a vehicle 100 metres ahead to be able to avoid a collision.

Based on the ***type of communication*** three main categories can be introduced. First are vehicles sending their messages via a cellular system – and/or Road-Side Unit (RSU) – to a central server or to another peer as described in [xvii]. The disadvantage of such systems is the high cost of construction and maintenance of the infrastructure.

Second is the group of systems that do not use cellular systems, but another dedicated system like Urban Multi-hop Broadcast Protocol, as suggested in [xviii], or more general communication technologies for VANET (e.g. Wi-Fi) [xix]. Last, a hybrid solution, a combination of both systems, seems to be the most powerful but most complex approach.
The fundamental idea of information dissemination for VANET is to have ***periodic broadcast*** messages for routine information, and event-driven messages for causes of emergency situations. Most of the time vehicles send messages about their current status (velocity, heading) and/or knowledge about the network performance (e.g. delay of certain links, density of cars at a road section). Data from multiple inputs are processed and a new message calculated and transmitted if the routing protocol requests it. The aforementioned information should be aggregated to fulfil scalability requirements.

Flooding, as a distribution method (where each message is sent to all) however, is not scalable, consumes large amount of energy, bandwidth and memory space while being inefficient. Therefore, techniques to reduce network load are required. The main goal is to provide less information with a higher distance to keep the system scalable, as shown in [xx]. Atomic information (e.g. velocity) is aggregated with information from other nodes [1] or about road sections [7] to have aggregated messages. The message has to be aggregated with new information from the current node before another broadcast takes place.

For ***aggregation***, geographically hierarchical approaches are being introduced. The level of hierarchy can, for example, be represented in different resolutions of the road network between landmarks, as suggested in [13]. Another approach is to form grids of different sizes based on various sizes of geographical area, as shown in [xxi]. In both cases the amount of information about a faraway geographical area is reduced, therefore data needs to be maintained as well. Dynamic store and forward approaches are used to maximise the probability that two messages are going to be present at the same time at the current node and it will have a chance to aggregate them into a single message and transmit it.

We have also identified an evolution in flooding and directed broadcast transmission to the target area to a distributed (Content Addressable Network (CAN)-based) subscriber/publisher approach [xxii]. The nodes subscribe to certain groups of information (for example, information about certain road sections on the route ahead) and push out messages in a distributed fashion (dissemination is distribution as well as the location of the stored data). Vehicles send (push into the network) information about their observations and abrupt events.

Data is preferably stored in a distributed fashion like CAN, which has a *d* dimensional key space that is used to give the address of a certain area based on its geographical position. It allows the possibility of reaching nodes that are responsible for storing data about a certain area without knowing their address

3 Dissemination characteristics

3.1 Keeping information alive

Information must migrate and be kept alive. This is achieved by retransmission. A message that is received and retransmitted gains two things. It survives a period in time, and it might migrate to new receivers. A retransmission can be done in two ways: either it retransmits to specific addresses, or it retransmits to everyone.

Transmission to specific addresses is most effective if the environment and receivers are static or motionless. Once the discovery and determination of neighbours is finished, each message needs to be sent only once, which saves capacity and time. This solution might demand special hardware such as directive antenna and controllers.

Flooding is like opening a door with a sledgehammer instead of a key. It is big, noisy and brutal, but it gets the job done. The biggest problem with flooding is the sheer number of messages that are received, when each node transmits all new messages to any receiver within reach.

If there are *n* receivers within reach (Figure 1), this will cause the sender to receive nine messages that are of no value. If all the other receivers can reach nine nodes, 90 messages are wasted. This will unfortunately introduce interference, and possible loss of each other's messages; the message will be received n*(n-1) times.

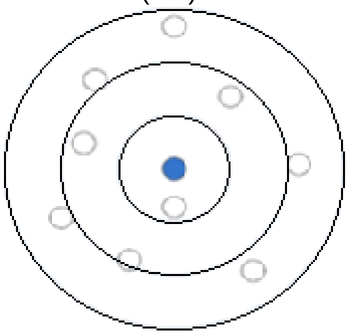

Figure 3-2: Flooding to nearby nodes (n=10)

The problem that presents itself is that we do not have a master in the network. Then who is going to be responsible for updating the information in the system? With no master the responsibility lies within each vehicle. An approach to this is presented in this paper.

3.2 Keeping the information consistent

The mechanisms used to keep messages alive might cause problems with keeping the information consistent and updated. Retransmissions and replication might produce duplicate messages. This introduces the need for telling the messages apart.

The information in the system depicts the real environment as truthfully as possible. As time passes, the conditions – once observed in the environment – might have changed, moved or disappeared.

A major issue is that there might be many different interpretations about what the 'truth' is. Each vehicle, or node, in the system might have a slightly different perception of what is the overall status in the network.

A bigger problem is the arrival of new vehicles. How can they get an impression about what the status is?

The vehicles most likely to have the most complete picture of what the status is in the network are probably those that are closest to the centre of the network. These vehicles have the highest probability of having received all messages that have migrated through the network.

A new vehicle will have difficulties discovering these centrally located vehicles, so an easier solution might be to rely on the nearest vehicle instead. Due to the many interpretations about status, it is not enough to ask just one neighbour. A majority vote between any vehicles within reach would provide a fairly good estimate about what the status is at this part of the network. This is definitely a 'best-effort' task.

3.3 Infrastructure

The goal is to produce a robust, self-configuring and autonomous network. If the network is reliant on infrastructure the network might be limited to operations in areas where the infrastructure is in place.

It is better for the network to be independent of existing infrastructure, but use whatever resources are available. A lamppost equipped with the same communications equipment as the vehicles might be regarded as a very slow-moving vehicle (as seen from the network). This permanent equipment can be used to supply the network with important information from 'the outside' (i.e. traffic information or congestion warnings) and might gather information for some centralised services (statistical information about troublesome areas).

Permanent infrastructure might be helpful to cover 'black holes' or difficult positions (i.e. can cover both sides of a difficult corner). The directivity and mounting height of the antenna plays a major part in the connectivity [9]. On a vehicle the most natural choice is an omni-directional antenna. The mounting height of this is limited by the vehicle and aesthetic concerns. On a permanent structure it is possible to use very different equipment depending on the location, and needs, of the area.

There is another type of infrastructure that might be useful. Buses and trams use a predictable route at predictable times. The bus or tram might work as a buffer, they get information from a source, and they can release this information when they get to new areas. A moving infrastructure comes in handy for gathering statistical information, as it covers a large area at regular intervals.

3.4 Applications built on Inter-Vehicle Communication (IVC)

The vast class of IVC applications can make driving safer and more comfortable for vehicle occupants [xxiii][xxiv]. IVC services can be achieved through different methods by exchanging data between vehicles and sometimes through roadside infrastructure units. Figure 2 shows the classification of vehicular communication applications. It helps us to focus on specific equipment to fulfil services and solve diverse problems.

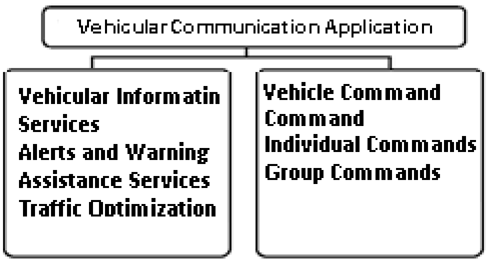

Figure 7-1: Classification of vehicular communication applications

To clarify the exchange approaches we propose in this paper, it will be useful to present some examples of the possible road situations (conclusions) we can come up with based on sharing individual car sensor data (the numbers quoted in (table 1) are representative rather than conclusive for the condition and represent a matter for future investigation in real-life experiments).

	Individual Car sensors data	Optimum Num example/case	Possible Conclusion
1	Windscreen Wipers	30% of cars = ON	Rainy
2	ABS Control.	5 cars = ON	Slippery (snow)
3	Slippery Oil Spot.	2 cars	Slippery spot
4	Fog light.	50% of cars ON	Foggy
5	Traffic flow Speed.	(60%) Slow/Stop	Traffic Jam
6	Reduce Speed.	5 cars within 1sec	Hazard Ahead

Table 1:Examples of some situations

We can consider that column two contains, in effect, Search Condition Limitation numbers. Assuming that this Search Condition Limitation is reached then a zone with the condition (third column) is identified and the information system can tell other nearby cars to be aware of the situation within that zone if they plan to pass through it.

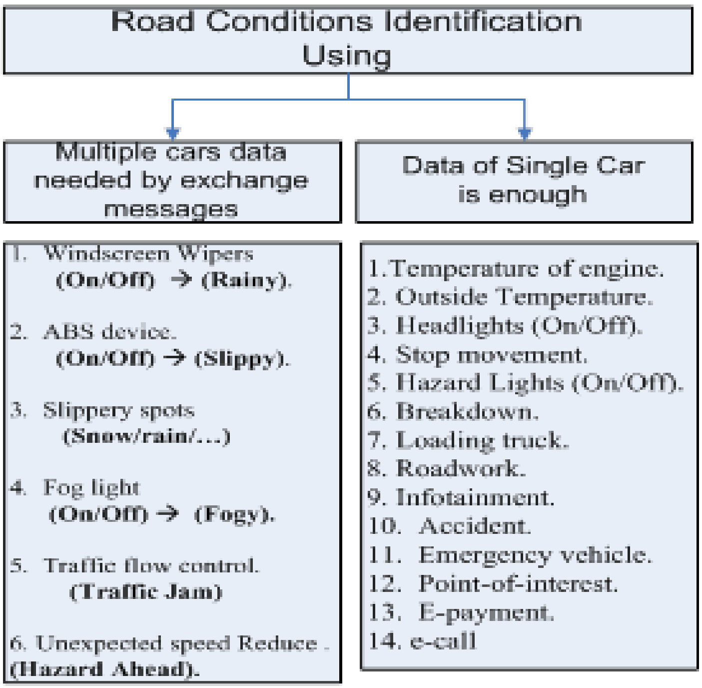

Figure 3: Aggregate data

Each message needs to be in a format that is small in size and rich in content. Two methods of collaboratively collecting data by exchanging messages based on vehicle-to-vehicle communication have been identified.

Figure 3 classifies the recognisable road conditions based on the number of cars needed for it. The examples are of discoverable road situations that need just a single car to identify the road condition/problem to generate a warning message and broadcast it to all nearby cars, and of road conditions that need multiple cars' information by exchanging messages (their data) to identify the conditions of the road they are on. So, two stages are needed: first, exchange of messages to discover whether the road has a certain condition or not; and second, generation of a warning message to inform all nearby cars of the discovered condition, if any.

4 Schemes for road condition zone boundary identification

In both proposed approaches we consider a scenario in which multiple cars' data is needed to identify a road situation. So, exchange information between nodes (cars) is needed in a way that each node requests/sends information from/to the other vehicles to collectively identify the conditions of the road. This is gathering information about how many vehicles have sensed the same specific conditions. It can be something like 'How many cars have their fog light ON?', 'Are there any queues in front of me?'. The answers to such questions should be extracted from the conclusion of the aggregated data for the cars in the zone. In the following section the mechanism for the proposed approaches to data collection from nearby nodes is given.

4.1 Blind Zone Scan Scheme (BZS)

This is two phases approach. First phase is to scan the region for any detected traffic conditions (using discovery message generated by nodes who sensed that situation) to identify the boundaries of the situation zone. The second phase is to issue warning message broadcasts to inform all nearby nodes for the situation and its boundaries. By using this approach, we investigate and identify the optimum value for two parameters: ① The number of hops used by the discovery message (How large the scanned area is), and ② the best possible delay time used in each node before rebroadcasting (to reduce the noise in the network) This mechanism involves the following steps:

5) If *a node detects or senses any identifiable road conditions* it becomes an *active node* (AN).

a. If it has not received other nodes' SDMs (*Situation Discovery Message*) with the same condition discovery requests within a certain past time-out period, it generates an SDM and broadcasts it to all nodes in its range as a first wave (called first hop) to inform all nodes of its current situation (Figure 4a) and to enquire if other nodes have the same condition.

b. Periodic regeneration and rebroadcasting of SDM after the time-out expires will be performed, until either the situation disappears (becomes a Non-Active Node (NAN)), or a new, different, SDM is received which shows another node has sensed the same situation (become AN) and it recognizes the current one as AN.

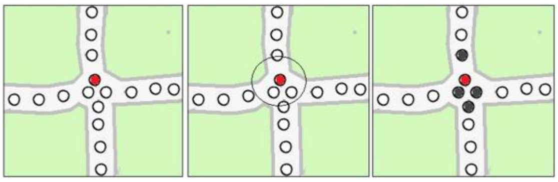

Figure 4a: Crossroad scenario – first hops

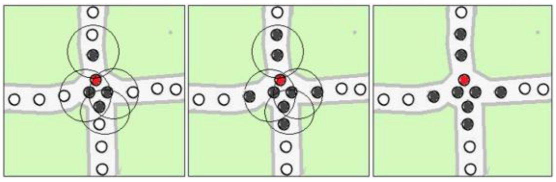

Figure 4b: Crossroad scenario – second hops

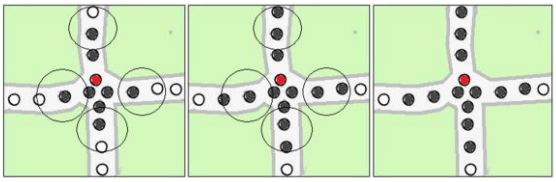

Figure 4c: Crossroad scenario – third hops and so on …

6) *In each node that receives the SDM*,

a. If the maximum hops number is not reached (an SDM reaches the maximum number of hops if the pre-set number of hops are transmitted by nodes) and if none of the nodes have the same situation, they forward the same SDM to the next neighbour nodes as a second wave (second hop) to inform the others of the current situation (Figure 4b).

b. However, if one of its neighbours has a new situation at the same time as receiving the message, it will generate a new SDM that contains its current condition and also all the information it has previously identified about the nearby nodes.

c. Again, all nodes forward the same SDM to the next neighbour as a third hop (Figure 4c) after they have updated the message on the current situation. These steps are repeated until the Conditions Search Limitations (CSL) become true or the maximum number of hops is reached.

7) *Each node is capable* of:

a. Keeping track of all seen messages, which allows it to discard all redundant messages. Also each node keeps all the information it has about all 'seen' nodes – all nodes contained in the messages received in the node – in two different lists: the first for ANs and the second for NANs.

b. If any node – at any hops – has the same/new situation, a new SDM will be generated containing additional information as well as the information it holds about the other surrounding nodes and broadcasts it to all nearby nodes. Previous steps will be repeated until – again – the CSL becomes true.

8) *After a short period* of exchanging SDMs:

a. Nodes will have got all about the surrounding nodes' information. Each node should hold three lists: a seen messages list (to reduce redundancy), an active node seen list and a non-active node seen list.

b. Each time a node receives a message it updates its lists and checks whether the optimum number for each detectable situation is achieved or not. If it is not, it will forward an SDM to the next hops.

9) In the case of an optimum number being achieved, the car which got this information will *calculate the boundary of the situation zone* based on the information it already has about the surrounded cars (Figure 5). Then, a new Situation Warning Message (SWM) will be generated and sent to warn all nearby cars by the situation and its position. Also, a new CSL will be set up for an SWM to determine the lifetime.

10)

Figure 5: Situation Zones has been identifier

4.8 4.2 Cloud Zone Scan Scheme (CZS)

Based on real life, road conditions occur in certain places that will affect groups of nearby cars inside that zone. For instance, usually if a car discovers foggy weather (fog light goes ON), mostly, all nearby cars have the same condition. Or, if a car senses rain (windscreen wipers go ON), often, all nearby cars have the same situation or – at least – will sense the same very soon.

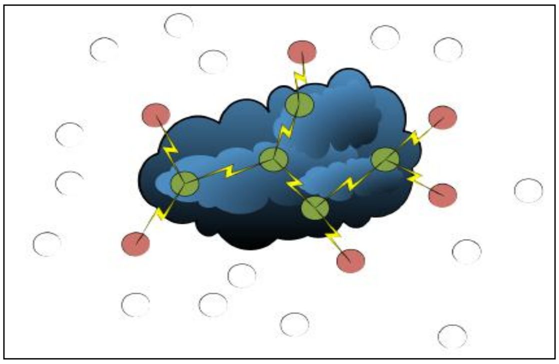

Figure 6: Raincloud

CZS scheme is based on this assumptions and *the cars which sense a situation (AN) will trigger SDM*:

1) This SDM will travel from car to car, until reaching the first node that does not have (sensed) the same situation, which will not retransmit the SDM (stopping the forwarding of the SDM).
2) It will reply toward the source node of the SDM message with its geographic position to inform all nearby cars that the boundary of the situation is here (its position), meaning, that this approach looks for the nodes (cars) located on the borders of a situation zone (e.g. raincloud).

Figure 6 illustrates five vehicles inside a raincloud. These vehicles communicate with each other, and with the vehicles just outside the cloud. The vehicles on the outside of the cloud respond by returning their positions, and information that they don’t sense rain, to the vehicles inside the cloud. The vehicles inside the cloud update their information tables, and pass this information to the other vehicles inside the cloud. Based on the data in the information tables the vehicles can calculate the area that the cloud covers, generate SWM and broadcast it to the cars in the region.

5. Results & Conclusion

We propose in this paper schemes that are using ‘intelligent flooding’ instead of blind flooding broadcasting (selected nodes will retransmit the messages). These were tested using an NS2 simulator, these experiments showed that ‘intelligent flooding’ was faster and less resource consuming than ‘pure flooding’, thereby confirming our hypothesis. The results of the simulator were as expected, and the simulation proved that ‘intelligent flooding’ produced far fewer messages, and is significantly faster than ‘pure flooding’. It also showed that ‘intelligent flooding’ is vulnerable to interference, and because of that important packets could be lost. Resolving these issues the focus of further research..

As aforementioned, The BZS scheme attempts to identify the optimum value for two parameters: *the number of hops* and *the delay time* needed to scan the area and identify the boundary of the situation zone. The assumption is that different situations are detected by different numbers of recognised ANs/NANs (e.g. the situation is rainy if 33% of nodes are AN, while, a slippery spot can be detected by three ANs regardless the number of NANs).

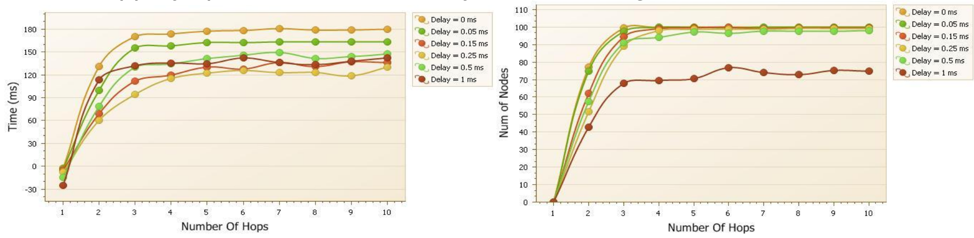

Figure 7: Message Exchange Time
And # of Nodes Saw more than 50% of AN

Analysis of the graphs’ trends (the results simulate this scheme–Figure 7) indicates that:

a. There is no fixed optimum number either for delay time or number of hops. Consequently a range of numbers for these two parameters must be considered dependent on the detection cases. Based on these assumptions, we are looking for the best results that can recognise from 50% up to 100% active nodes (ANs), which will be enough to cover all cases.

b. Also, the graphs present the point of saturation i.e. where an increase in the value of the investigated parameter gives relatively small improvement in the quantity of sent/received/discarded messages. The results show clearly that using from three up to five hops is optimum to detect any traffic condition if we consider the abovementioned indicators.

c.

d. The results show that the greatest delay time will reduce the number of exchanged messages, but will increase the total time needed to recognise the biggest possible number of ANs/NANs. This is a difficult compromise between time and noise, though a figure between 0.01 and 0.1 seconds seems to be indicated.

There is much work to be done in calculating the specific details based on the information gathered from ‘intelligent flooding’. The migration of the common status is also an interesting aspect that would benefit from further study. A study of behaviour with different technologies could provide useful information.

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