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, in-vehicle sensor information and inter-vehicle collaboration which can be used to detect road conditions and determine the geographical area where this road condition exists – e.g. area where there is increased 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. to avoid bottlenecks or dangerous areas including accidents or congestion 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 could offer a live road condition information channel at - almost - no cost to the drivers and public/private traffic agencies and has the potential to become an 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 using Network Simulator II (NS2).

Keywords: 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.

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 Vehicular Adhoc Networks (VANETs) and collaborative data generation based on knowledge granularity (aggregation) [3]. It investigates the design, implementation and modelling of 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 an in-car traffic information and real-time control generator and distributor. [4].

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. Background

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:

1.1.1. *Flooding approach:* The algorithm for Simple Flooding [5] starts with a source node broadcasting a packet to all neighbours. Each of those neighbours in turn rebroadcasts the packet exactly one time and this continues until all reachable network nodes have received the packet. Broadcasting through flooding causes increased redundancy of messages, contention, collision, and wastage of channel bandwidth within the network.

1.1.2. *Probability Based approach:* The Probabilistic scheme is similar to Flooding, except that nodes only rebroadcast with a predetermined probability. In dense networks multiple nodes share similar transmission coverage. Thus, randomly having some nodes not rebroadcast saves node and network resources without harming delivery effectiveness. In sparse networks, there is much less shared coverage; thus, nodes won't receive all the broadcast packets with the Probabilistic scheme unless the probability parameter is high. When the probability is 100%, this scheme is identical to Flooding. But setting the broadcast probability value dynamically in different traffic situations is also a challenge.

1.1.3. *Cluster Based Approach:* Cluster-Based methods can enhance the performance of dense MANET [6]. In this scheme, the nodes in one network are divided into

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several clusters and each has a cluster head node. When broadcast is implementing, only cluster heads will rebroadcast the message, which minimizes broadcast flooding. The schemes use statistical and geometric characteristics divide the network into clusters. This kind of methods is more suitable to the scenario in which vehicles distribute to clusters spontaneously and the clusters can maintain for a period of time.

1.1.4. *Area Based Approach:* Suppose a node receives a packet from a sender that is located only one meter away. If the receiving node rebroadcasts, the additional area covered by the retransmission is quite low. On the other extreme, if a node is located at the boundary of the sender node's transmission distance, then a rebroadcast would reach significant additional area. A node using an Area Based Approach can evaluate additional coverage area based on all received redundant transmissions. Some methods has been proposed:

1.1.4.1. *Counter Based Scheme:* [7] show an inverse relationship between the number of times a packet is received at a node and the probability of that node being able to reach additional area on a rebroadcast. This result is the basis of their Counter-Based scheme. Upon reception of a previously unseen packet, the node initiates a counter with a value of one and sets a RAD (which is randomly chosen between 0 and T_{max} seconds). During the RAD, the counter is incremented by one for each redundant packet received. If the counter is less than a threshold value when the RAD expires, the packet is rebroadcast. Otherwise, it is simply dropped. The overriding compelling features of the Counter-Based scheme are its simplicity and its inherent adaptability to local topologies. That is, in a dense area of the network, some nodes won't rebroadcast; in sparse areas of the network, all nodes rebroadcast.

1.1.4.2. *Hop Count Ad hoc Broadcast (HCAB)*: it inherited from Counter Based Scheme after some modification [8]. In HCAB, upon receiving a broadcast message for the first time, the node initiates a flag R = true and records initial hop count value HC0 of this message. Meanwhile, this node sets a RDT value between 0 and T_{max}. During the RDT, the node compares the hop count of redundantly received message HC_x with HC_0 and flag R is set to false if $HC_x > HC_0$. When the random delay expires, the node will relay this message if R is true. Otherwise, it just drops this message.

1.1.4.3. *Distance Based Scheme*: exploits the geographical information of the node i.e., a distance threshold value is pre-defined. Upon reception of a previously unseen message, a RDT is initiated and redundant messages are cached. When the RDT is expired, all source node locations are examined to see if the node is closer than a threshold distance value. If true, the node doesn't rebroadcast

1.1.4.4. *Location Based Scheme*: In this method, the source node also appends its geographical position information with the message. The receiving node then calculates the additional broadcast coverage area with the help of positioning data sent by the source node. If the additional area is less than a threshold value, the node will not rebroadcast, and all future receptions of the same message will be ignored. Otherwise, a node assigns a RDT before delivery. If the node receives a redundant message during a RDT, it recalculates the additional coverage area and compares it with the threshold. This process is continued until the message is rebroadcasted or finally dropped [9].

1.1.5. *Neighbour knowledge Based Approach*: exchange neighborhood information among the hosts. There are two major approaches in this scheme [9]. In *Self-pruning*, each node maintains the knowledge of its neighbors by periodically exchanging the "Hello" messages. The receiving node first compares its neighbor list to that of sender's list, and rebroadcast the message only if the receiving node can cover additional nodes. The *Scalable Broadcast Algorithm* (SBA) is similar to self-pruning except that all nodes have knowledge of their neighbors within a two hop radius

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 [10][11][12].
While designing the proposed algorithm this paper will try to answer the question "How can we establish collaborative data and knowledge generation for the discovery of road conditions based on car-to-car message exchange?" and also define the functionality of an intelligent node and possible message formats

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 windshield wiper status or the humidity allow the weather conditions local to a vehicle (such as rainfall, ice or fog) to be determined. Through collaboratively sharing such information a driver may have sufficient knowledge to elect to choose an alternative route that is known (again through collaborative data exchange) to offer a safer or less congested route.. Of course there are subtleties that need consideration such as assessing rainfall by the windshield wipers status; this should be distinguished from cleaning the windshield..

2.1.1Scope of the TDCA algorithm

The TDCA algorithm aims at identifying road conditions on the basis of exchanging sensor 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) *Information dissemination*: Define node behaviour in terms of message routing. 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 borders of the zone and then generate and broadcast a warning message around.

2.1.2Examples of situations detected by the TDCA Algorithm:

To put the algorithm in its context, it will be useful to present some examples of the possible road 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

Table 1:Examples of some situations

We can consider that column two is in effect a Search Condition 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.

2.1.3Algorithm 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) *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 borders separately (even if they are overlapped). Then report them in one or multiple warning messages.

iii) *Delay for data collection*: Random time slots are used to delay the forwarding of received messages (this increases the collecting information period but reduces the number of exchanged messages).

2.2 Algorithm Description:

2.2.1Assumptions:

i) All nodes are identical, mobile and in an active state.

ii) Each node is able to determine its position (e.g. equipped with a GPS onboard).

iii) The distributions, density, distance between nodes, active nodes selection are completely random. But the movement patterns are fixed.

iv) Message delivery reliability is assumed to be standard wireless networks reliability with all the delays, packet loss or interference inherent to such networks.

2.2.2Definitions of the used Terms:

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 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).

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

Table 2: Node reaction to receive new message

ii) 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.

iii) 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).

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:

v)

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).

Table 3: SDM format

vi) 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)

Table 4: SWM format

2.2.3Algorithm Description:

If a node detects or senses any of the identifiable road conditions it becomes an active node – AN, and if it has not received other nodes' SDM with the same condition discovery requests within a certain time out period it initiates a traffic condition discovery sequence, 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 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 or until it becomes non-active (NAN).

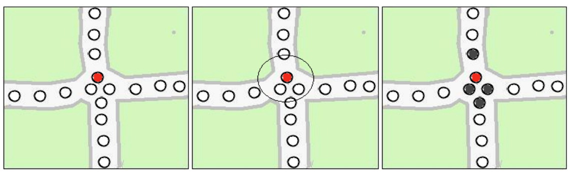

Figure 1a: Cross road Scenario - First Hops

If the maximum number of hops is not reached (SDM reaches the maximum number of hops if transmitted successively 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).

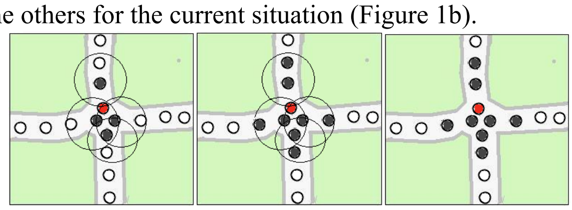

Figure 1b: Cross road Scenario - Second Hops

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.

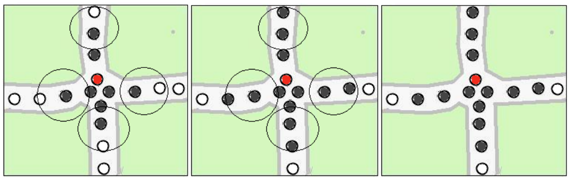

Figure 1c: Cross road Scenario - Third Hops and so on …

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 by the node - in two different lists, the first list for AN's and the second for NAN's.

If any node – at any Hops – has the same/new situation, a 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 have acquired all information 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 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. But in the case where this number has been achieved, a new Situation Warning Message (SWM) will be generated and broadcast and a new CSL will be setup to determine the life time of the SDM.

3 Simulation Stage

3.1 Simulation parameters:

A model of an adhoc network was set up to simulate the adhoc vehicular network using NS2. Chosen parameters to simulate real life scenarios were , assigned as follows:

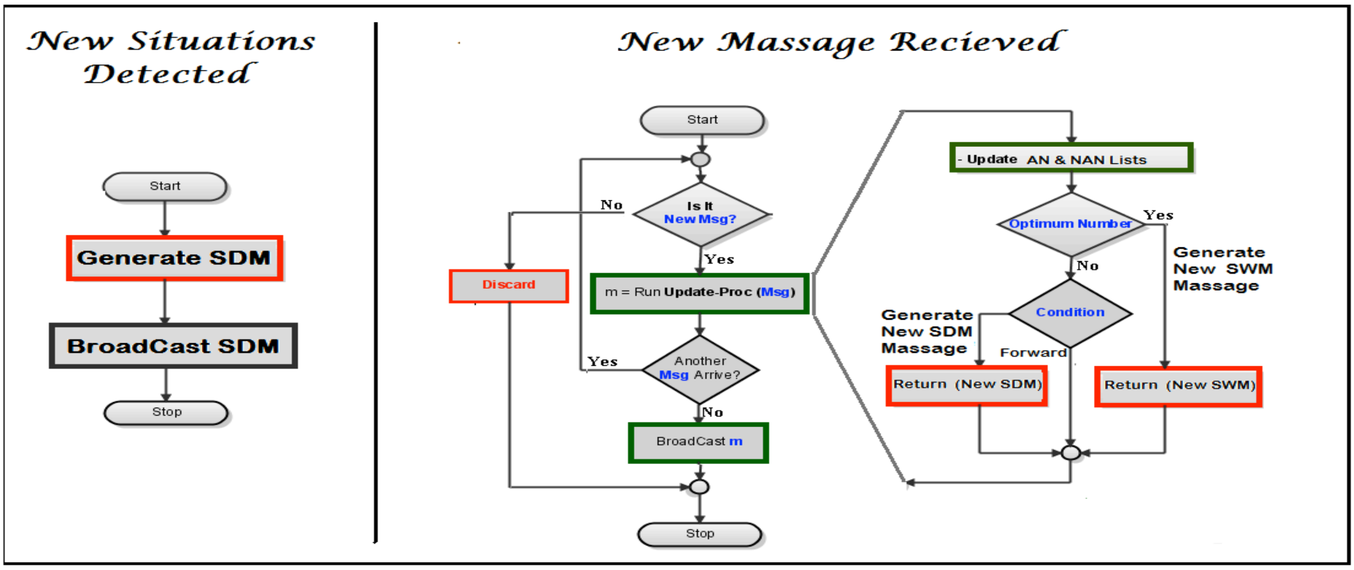

Figure 2: Node Behavior (Case A: New Situation Detection | Case B: New message Received)

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	Fixed/Partial Random selection

Table 5: the used parameter

3.2 Iteration in simulation:

Our diagrams are aggregated and averaged from data collecting after repeating the simulation a number of times. As illustrated in Figure 3, the following data is 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 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.

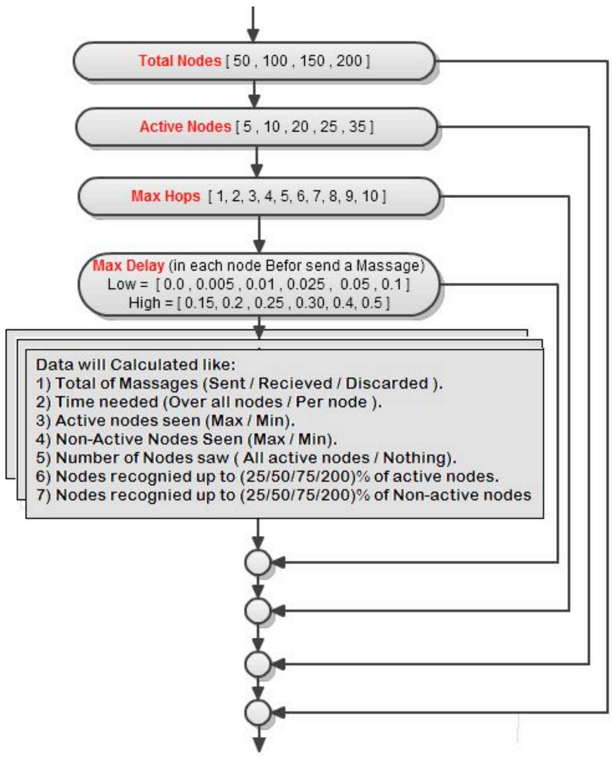

Figure 3: Simulation Iteration Illustration

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 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:

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

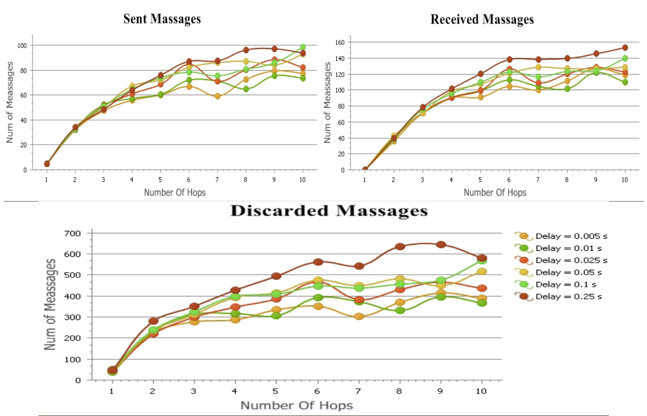

Figure 4: Numbers of sent, received and Discarded Messages

Figure 4 shows the number of sent, received, lost and redundant 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.

4.2.2Total 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. 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.

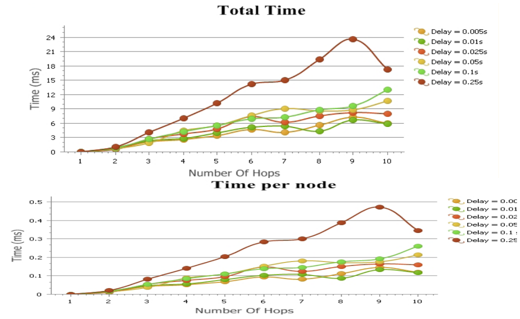

Figure 5: Total Time and Time per node

4.2.3Number 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.

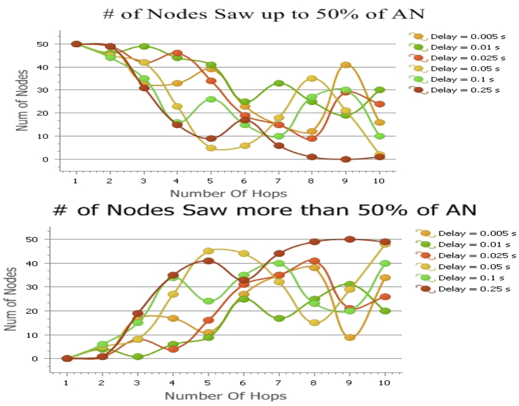

Figure 6: Active nodes Recognition

!.3 Results outcome

This study attempts to identify the optimum value for two lgorithm parameters; number of hops and delay time. The ssumption is that different situations are detected by lifferent numbers of recognized AN/NAN (e.g: situation is ainy 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 hop**s 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.

5 CONCLUSION

As an infrastructure-less vehicle-to-vehicle communication algorithm in terms of data sharing and collaborative generation of information, 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.

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 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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