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.

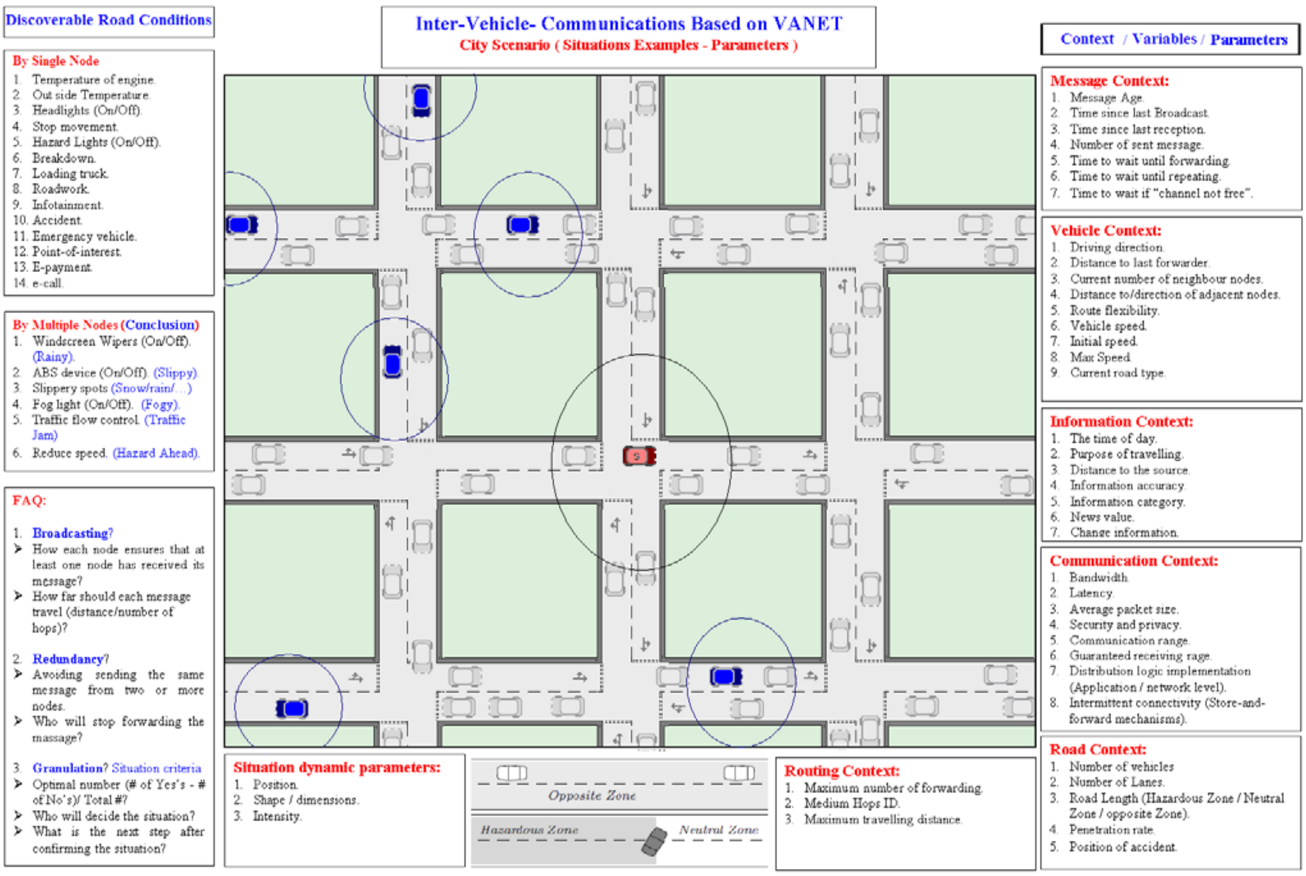

Figure 1: City Scenario (Discoverable Conditions)

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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)?

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:

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.

Figure 2: Street Map with vehicles in move (Black Dots)

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.

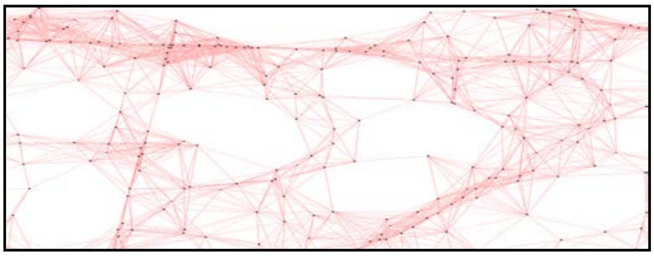


Figure 3: Establishing direct link between Vehicles

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.

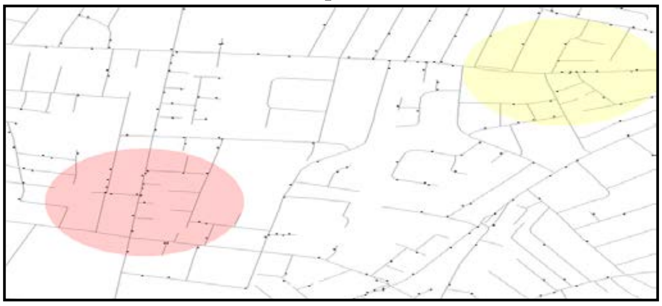


Figure 4: Situation Zones has been identifier

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.

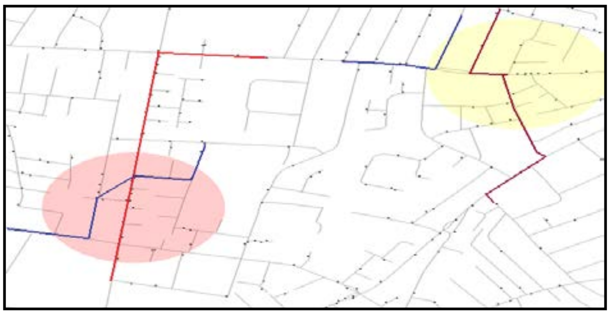


Figure 5: Pre-planned Traveling paths

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,…).

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 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 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.

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.*

Definitions of the used Terms:

i) 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.
ii) 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).
iii) 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:

iv) 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).

v) 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).

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:

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

$B_i \longleftarrow$ neighbor set of current node N_i

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

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

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

SWM $\longleftarrow$ 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 ← {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 $\longleftarrow$ ***NAN_i*** U ***NAN_i***
AN_i $\longleftarrow$ ***AN_i*** U ***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 ***← {N_i(id) , Sl_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

RESULTS

Results Analysis:

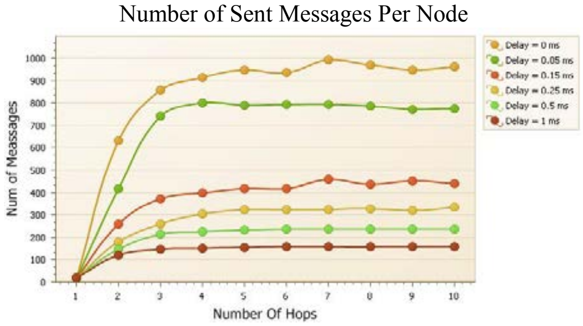
As we are looking for the optimum number of hops to discover the whole local area and, at the same time, the optimum Delay time each node should use before resending any message, we analyse all the available data from the simulation with these two parameters (Num of Hops & Delay Time) as variables separately.

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:

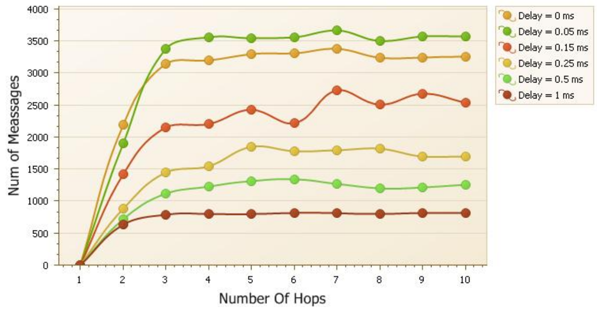
Number of Exchanged Messages Per Node

Those figures 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



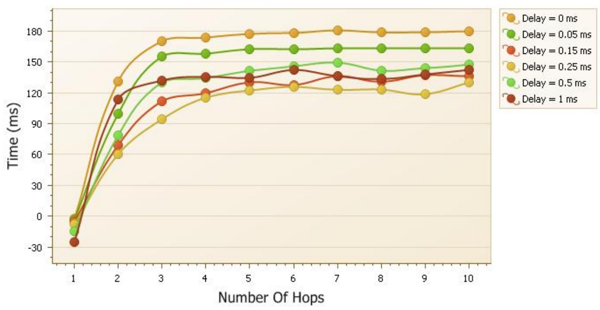
Number of Received Messages Per Node



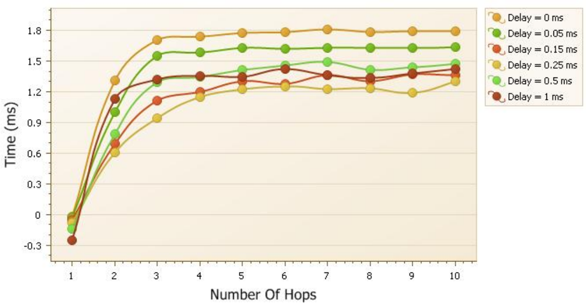
Message Exchange Time Needed to Discover the area

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)



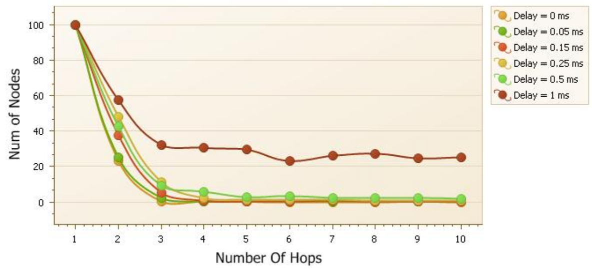
Message Exchange Time (Time / Node)



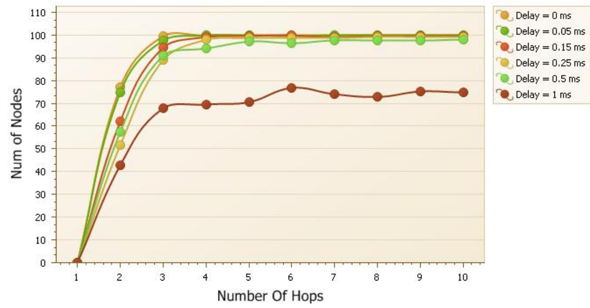
Number of recognized nodes (AN / NAN)

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.

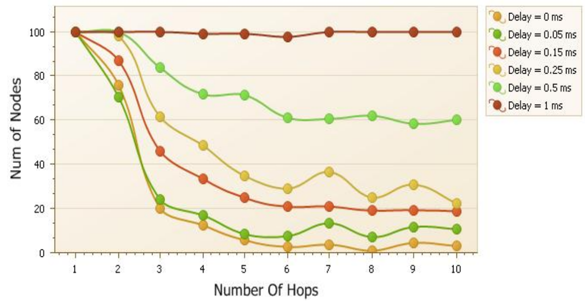
# of Nodes Saw up to 50% of AN



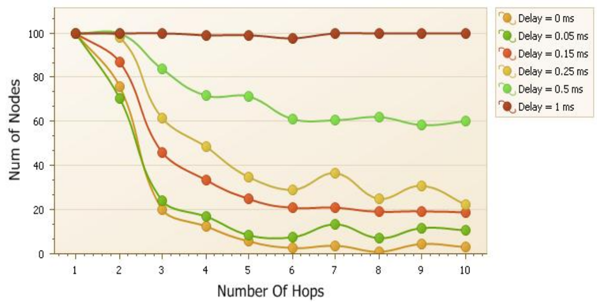
# of Nodes Saw more than 50% of AN



# of Nodes Saw up to 50% of NAN



# of Nodes Saw more than 50% of NAN



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 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.

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.

REFERENCES

[1] L. Krishnamachari, D. Estrin, and S.Wicker. The impact of data aggregation in wireless sensor networks. In ICDCSW '02: Proceedings of the International Conference on Distributed Computing Systems, pages 575–578, 2002.

[2] Thomas, M.; Peytchev E.; Al-Dabass D.; "Auto-sensing and distribution of traffic information in vehicular ad hoc networks", International Journal of Simulation, January 2004, PP 59-63, Volume: 5(3), ISSN: 1473-804X

[3] M. Raya and J.-P. Hubaux. The security of vehicular ad-hoc networks. In SASN '05: Proceedings of the 3rd ACM workshop on Security of ad hoc and sensor networks, pages 11–21, 2005.

[4] C. L. Robinson, L. Caminiti, D. Caveney, and K. Laberteaux. Efficient coordination and transmission of data for cooperative vehicular safety applications. In VANET '06: Proceedings of the 3rd ACM International Workshop on Vehicular Ad Hoc Networks, pages 10–19, 2006.

[5] Xue Yang, Jie Liu, Feng Zhao, and Nitin Vaidya, "A Vehicle-to-Vehicle Communication Protocol for Improving Road Safety," The 1st International Conference on Mobile and Ubiquitous Systems: Networking and Services (Mobiquitous 2004), Boston, MA, Aug. 22-26, 2004.

[6] Agafonov, E., Bargiela, A., Burke, E., Peytchev, E., Mathematical justification of a heuristic for statistical correlation of real-life time series, *European Journal of Operational Research* , 198, 2009, 275-286, doi:10.1016/j.ejor.2008.06.040

[7] Bargiela A., Peytchev E., Intelligent transportation systems: Towards integrated framework for traffic/transport telematics applications, Proc. IEEE Vehicular Technology Conference, Atlantic City, Oct. 6-10, 2001