Ontology Driven Reputation Model for VANET

Renata M. P. Vanni[1]
Departamento de Informática
Federal Institute of Sao Paulo (IFSP)
Araraquara, Brazil
rportovanni@ifsp.edu.br
rporto@icmc.usp.br

Luz Marina S. Jaimes[1]
Engineering of Systems
University of Pamplona
Pamplona, Colombia
lsantos@unipamplona.edu.co
lsantosj@icmc.usp.br

Glenford Mapp
Department of Computer Science
Middlesex University
London, UK
g.mapp@mdx.ac.uk

Edson Moreira
[1]Instituto de Ciências Matemáticas e de Computação (ICMC)
University of Sao Paulo (USP)
São Carlos, Brazil
edson@icmc.usp.br

***Abstract*— As Vehicle *Ad Hoc* Networks (VANETs) become a key component of Intelligent Transportation System (ITS), trust is important in applications that besides traditional security requirements need to evaluate the behavior of different entities in VANETs. Highly dynamic environments of vehicles need an adapted form of trust establishment. There are efforts for evaluating trust in VANETs, based on reputation mechanisms. In this paper, we propose a definition of the reputation relying on the use of an ontology of VANETs, ensuring both an optimal coverage of the domain and a deep semantic rooting. This definition is based on the identification of the key aspects requiring the support of the ontology for their evaluation.**

Keywords- trust; ontology; VANETs; reputation model

I. INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) are a special type of Ad Hoc networks, formed by vehicles with processing and wireless communication ability, traveling on streets or highways. Commonly, the vehicles can communicate directly or by the use of a roadside unit (RSU) [1] – Fig. 1. Through this infrastructure, vehicles can access network services and obtain data from other networks, such as the Internet. Due to this nature, VANETs can be established in different environments such as in urban centers and highways [2]. The communication takes place both between vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), aiming to enable automated cooperation between different vehicles on the road.

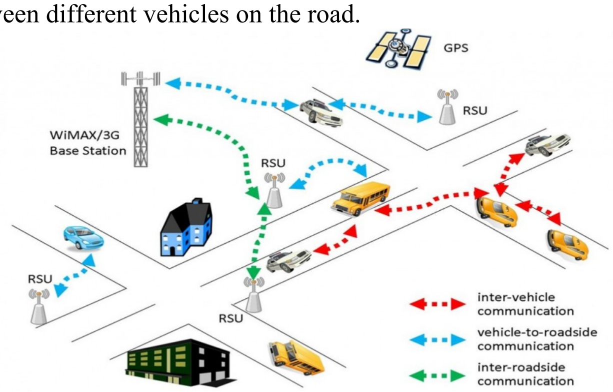

Figure 1. Example of an Intelligent Transport System (ITS) scenario [1]

The emergence of VANET has generated new challenges and requires an even deeper consideration of reputation, as it is one of the ways to trust in vehicles or drivers sending messages. Reputation mechanisms are meant to offer insightful information about the capacity of nodes in a system to accomplish specific actions. Inter-vehicle communications can only occur when two vehicles are within the transmission range of each other, which we refer to as opportunistic forwarding. One key design question is: how do the vehicle/driver decide to (or not to) forward the data to adjacent vehicle/driver when the type of message requires trustworthiness based on node's reputation?

By nature, VANETs' users may expect for opportunistic message forwarding than usual mobile users, as they intend to share information about traffic and road condition, for example. As such, the reputation of vehicles and drivers impact not only forwarding hops choice but also VANETs' users relying on each other, driving users toward trying to build and maintain higher reputation. We suggest that not only the vehicles are evaluated. For instance, drivers are also part of the ecosystem, and have to correctly use services. Given this consideration, it becomes natural that reputation has to be envisaged as a characteristic of message forwarding service, but also a characteristic of vehicles, drivers and passengers if associated with this service. This research considers that reputation management based on ontology could drive many aspects of VANETs, and more particularly can serve as a reference for the production of feedback that will then feed the Reputation of the nodes. A formal specification of conceptualization permits data interoperability and attributes of reputation among the different entities involved in transportation systems. Trust relations can be built by the nodes through the definition of trust rules. Based on these rules, the users will be able to decide to forward the data to the neighbor node.

In this paper, we propose the complexity of reputation by defining a model relying on the use of an ontology of VANET. This ontology ensures semantic consideration of the different elements and provides the necessary expressiveness, openness and mechanisms to fully represent their intrinsic complexity. The remainder of this paper is organized as follow. Section II describes the decision process of opportunistic message forwarding. Section III addresses the reputation model researched. Section IV goes into details with respect to the proposed reputation model for VANET. Discussion and future work conclude the article.

ISBN: 978-1-61208-473-2

II. OPPORTUNISTIC FORWARDING DECISION

Everyday, vehicles transit in a city and along their trajectories they encounter other vehicles. The frequency of these encounters is influenced by many factors, such as: vehicle speed, destination, traffic condition, and the period of the day.

A possible scenario is a road with two roadways, where vehicles can receive, generate and forward messages between them (V2V) or with the infrastructure (V2I). To simplify, the vehicles can forward one message at a time (it is not possible to send in bulk) and the types of messages that are taken into account for each transaction should require a node reputation level. This model consists of three phases (discovery, forwarding and feedback) in six steps as follow.

The phase of discovery uses a HELLO-RESPONSE technique for detecting approaching vehicles. Vehicles carrying data (Message – M) send out periodic HELLO beacon [3]. If a neighboring node hears a HELLO message, it will send a RESPONSE message to announce its presence. The HELLO (H) and RESPONSE (R) messages will also contain reputation information about the nodes – Fig. 2.

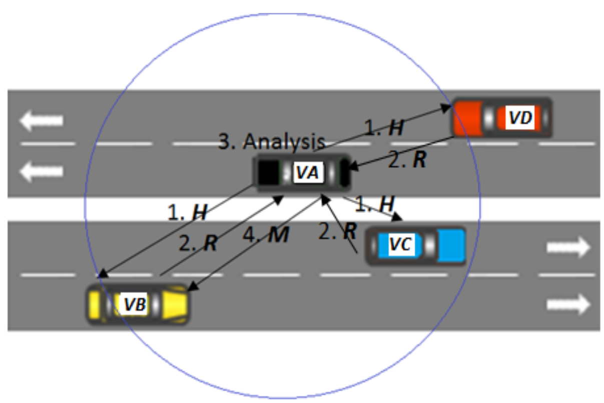

Figure 2. Scenario to opportunistic forwarding decision

The vehicle A (VA) sends "hello" beacon to its neighborhood. If vehicle B (VB) in the vicinity wants to interact with that VA, then it sends its reputation by a "response" beacon to VA.

Step 1 – Hello message.

VA is carrying data and waiting for a peer to forward its messages (M). VA sends out HELLO beacon every x seconds. Vehicles inside of range hear the HELLO message from VA and can send a RESPONSE message to announce their presence.

Step 2 – Response message.

VB hears a HELLO message from VA and sends a RESPONSE message to announce its presence.

In second stage, phase of forwarding, VA executes the process which defines the next hop of the message M forwarding. First, VA listens the responses then determines, through the application of the opportunistic forwarding algorithm, which neighbor vehicles could forward the message. Aspects as vehicles' direction, position, and relative velocity could be taken as inputs to the algorithm [3]. After that, VA analyzes the reputation of vehicles based on opportunistic forwarding algorithm to select the vehicle with the highest reputation to the next hop.

Step 3 – Analysis of reputation.

VA verifies the reputation of VB, VC and VD, and then decides which vehicle has the highest reputation to receive M, in the example, VB. The selected vehicle must be in the list of vehicles that sent responses to VA.

Step 4 – Forwarding Message.

VA adds to M its identification with its reputation and sends M to VB. If VB is not the final destination, VB will store M in cache and will restart from step 1, and so on, till M reaches its destination.

In third phase, phase of feedback, when M reaches the final destination, the destination node performs the process of feedback of each vehicle involved in forwarding phase.

Step 5 – Feedback.

The destination node elaborates feedback of VA that generated M and feedbacks of the intermediary vehicles that forwarded M. Vehicles VA, VB and VK will receive feedbacks with weights according to the ontological structure (section IV). It is important to notice that no feedback will be generated if message M do not reach the destination. Feedbacks of intermediary vehicles depends on their mutual collaboration. Feedback of VA that generated M will be based in a subjective feedback related to message content.

Step 6 – Feedback Reporting.

The destination node sends the feedbacks to a Reputation Server via RSU/4G/LTE, as shown in Fig. 3. In the server, the reputation of each vehicle is recalculated based on old and new feedbacks and updated. We represent feedback and reputation in section III.

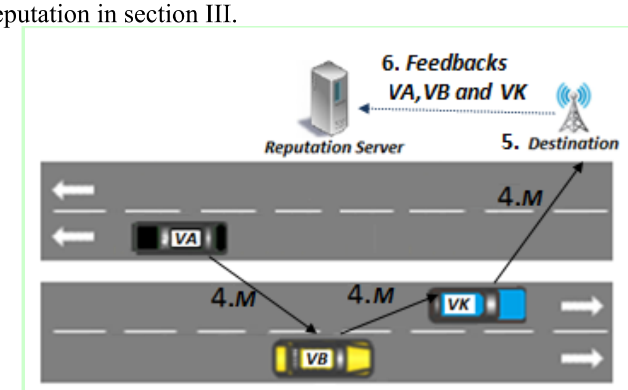

Figure 3. Feedbacks in opportunistic forwarding decision

Besides the feedback, other aspects should be considered to calculate the reputation, for example type of message, content, context, time to delivery, etc,.

III. REPUTATION MODEL

We initiated our research from the work of Hamadache [4][5], which provided the basis for the construction of an ontology driven reputation model for service-oriented computing in clouds. According to the general consensus, the reputation of service-oriented computing is characterized by an aggregation of the feedback provided by the different actors of the service ecosystem. Starting from this idea, the first concept to formalize is 'feedback'. Different representations of feedback have been provided in the literature [6], according to the needs of their associated reputation. In our research, we decided to adopt a variation of Sabater [7] and Hamadache's feedback tuple [4] using a 6th element "time – T".

$$\text{Feedback: } F = (A, S, K, X, V, T). \quad (1)$$

Equation (1) defines Feedback as a 6-tuple composed of the following elements: A is the actor (vehicle, driver, passenger, etc.) giving the feedback, S is the service on which the feedback is given, K stands for the service characteristic evaluated by the feedback (forwarding, alert, chat, etc.), X represents the context in which the feedback was given, V is the value of the feedback, and finally, T is the time at which the feedback was provided. The actual Feedback "F" represents the evaluation of the characteristic K of service S, by actor A in context X, at time T. Context can encompass a wide range of information, from the neighborhood on which the feedback was given, to the type of message being sent at the time of feedback.

The time dimension provides information for different aspects of the reputation. The aspect "decay", for example, will be associated to a lower weight to older feedback.

As suggested by Hamadache[4], the following notations will help to represent sets of feedback matching certain patterns. Equation (2) is the first notation, it follows a similar approach as the one used by Sabater [7] and depicts the set of feedback provided by a specific actor A.

$$\text{Actor Feedback Set: } AFS = \{F \mid (a, -, -, -, -, -). \quad (2)$$

From this first notation, a set of similar notations is derived for the different elements of the feedback:

$$\text{Service Feedback Set: } SFS = \{F \mid (-, s, -, -, -, -). \quad (3)$$

Service Feedback Set contains all the feedback given about a specific service.

$$\text{ASK Feedback Set: } ASKFS = \{F \mid (a, s, k, -, -, -). \quad (4)$$

ASKFS contains feedback provided by an actor on the characteristic of a specific service. A wide range of additional notations can be used, such as those used as illustrative samples.

A. Individual Perception

Starting from this consideration of feedback information (Feedback Set – FS), it is possible to build the individual perception (IP) of a service characteristic (SK) for a given actor (A) at a period of time t.

$$\mathrm{SKIP}^t(ASKFS) = \sum_{SKIP \in Fi} \rho(\mathrm{t}, \mathrm{t}i).\mathrm{V}i. \quad (5)$$

Here it is considered all feedback (Fi) provided by the actor (A) on the service characteristic (SK). Then it is aggregated the value ($\mathrm{V}i$) of each feedback by weighting them according to the time it was given. In this perspective, $\rho(\mathrm{t}, \mathrm{t}i) \in [0,+1]$ is a function giving higher values to more recent feedback. This function is used as a basis to compute the individual perception of the service itself. The principle of computing this value relies on the aggregation of all feedback provided on all the characteristics of the service and weighting each characteristic, not only according to the service but also according to its context. This leads to formula (6):

$$\mathrm{SIP}^t(ASFS) = \sum_{Fi \in ASFS} \Upsilon(Fi) \,.\, \rho(\mathrm{t}, \mathrm{t}i).\mathrm{V}i. \quad (6)$$

On (6), $\Upsilon(Fi)$ is the weight of the characteristic K_i. This weight is not always the same from one execution to another, as the actor may have varying expectations over time and may have, for example, sent/forwarded different message type, implying variability in the importance of the service characteristic. In order to compute this weight, it was proposed by Hamadache [4] to base the function on the ontological representation of service execution's context.

B. Ontology and Reputation

The term ontology is used in the field of semantic web and refers to a structured set of concepts in a particular field of knowledge. There are generally two global entities in ontology. The first aims terminology, which defines the nature of the elements making up the field of ontology in question, as the definition of a class in oriented object programming in definition of the nature of the objects that we will manipulate later. The second part of ontology contains explicit relationships between multiple instances of the classes defined in the terminology. Thus, within ontology, concepts are defined in relation to each other (a graph model of the organization of knowledge), which enables reasoning and manipulation of knowledge.

We can identify at least two functions that should be computed with the help of ontology.

1) Weight of Message Type

All characteristics of a message do not convey the same importance of the user and it may be completely irrelevant to consider that a message is sent/forwarded well but did not reach the final destination. Several approaches can be envisaged to tackle this need: establish a mapping between message types and importance of characteristics, asking users explicitly when they provide the feedback to rank the importance of the different parameters, or deducing the

 ISBN: 978-1-61208-473-2

importance level from the context in which the message is sent and from the interaction between the peers.

Finding an efficient way to evaluate the importance of characteristics implies to consider what would be user's loss if the characteristic fails. Comparing the needs of each type of message and establishing a rank between them should evaluate this importance – (see (7)).

$$\gamma(\mathrm{F_i}) = \begin{cases} \text{importance evaluated by user} \\ \gamma_\mathrm{r}\ (\mathrm{F_i}, \mathrm{K^s}) \end{cases} . \quad (7)$$

The rank of characteristic K_i within the set of characteristics K^s of the service with feedbacks (F_i) of user (r) – $\gamma_r\ (F_i, K^s)$ – should take advantage of the previous evaluation of characteristic weight.

2) Similarity of Message Types

This is an important aspect of our work. Defining the similarity of message types, it is possible to prioritize the forwarding of some message types, define the necessary level of trust for each group, and associate the context during the execution of the message forward.

IV. REPUTATION MODEL FOR VANET

The proposed Reputation Model for VANET (REMOVAN) considers the ideas suggested by The Regret system [7]. The Regret system structure is based on three dimensions of reputation. If we consider only direct interactions between nodes to establish reputations it is said that the decision is based on the **individual dimension**. If information coming from other nodes and their social relations are used, we are talking about the **social dimension**. Finally, if we consider that the reputation of a node is not a single and abstract concept but rather a multi-facet concept, it is considered an **ontological dimension**. For example, the reputation of being a suitable forwarding node summarizes the reputations of respond HELLO messages and generates messages about road conditions. The different types of reputation and how they are combined to obtain new types are the bases of the third dimension of reputation, the ontological dimension.

A. Individual Dimension

The individual dimension models the direct interaction between two nodes. The reputation that takes into account this dimension is the most reliable. This is because it takes into account all the peculiarities of the target node. The called *outcome reputation* (noted as $R\ a \rightarrow b\ (\delta)$ where δ is the reputation type) is the reputation calculated from direct interactions between nodes.

The subset of issues of an outcome taken into account to calculate a given reputation type δ is domain dependent. It is defined by a grounding relation (*gr*) as the relation that links a reputation type δ with a list of issues (*i.e.*, other reputations). This set of issues allows the selection of the right subset of outcomes from the general outcomes' database. Each issue is a tuple with the form $(I_i, \{+, -\}, \alpha_i)$ [7]. The first parameter (I_i) is a label that identifies the issue. The second parameter $(\{+, -\})$ indicates how an increment of the value of the issue affects the reputation, that is, a + means that if the value of the issue increases, the reputation also increases while a − means that if the value of the issue increases, the reputation decreases. Finally, the last parameter is the weight that issue has in the general calculation of the reputation. As an example, the grounding relation for an intermediate node, which could forward a message, in our scenario should be defined as in TABLE **I**.

TABLE I. TABLE TYPE STYLES

$\boldsymbol{\delta}$	gr($\boldsymbol{\delta}$)
To_forward_message	{(Forward, +, 0.8)}
To_generate_message	{(Generate, + 0.2)}
To_refuse_message	{(Refuse, −, 0.8)}
To_have_ traffic_ticket	{(Traffic_ticket, −, 0)}

To calculate an outcome reputation it is desirable to use a weighted mean of the outcomes evaluation, giving more relevance to recent outcomes [4].

B. Social Dimension

For an interaction between two nodes, past experiences of direct interaction is the most reliable source of information to define a reputation [1]. Unfortunately, the social dimension of VANETs does not permit the generation of reputation based just on direct experiences. Not only because the node can be a newcomer but also because for large networks such as the Internet, there will be a considerable amount of direct interactions to evaluate. We suggest indirect reputation processed by a broker of System Reputation. That reputation should be based on all direct experiences sent to a centralized database and used to calculate the individual reputation.

C. Ontological Dimension

Along the individual and social dimensions, reputation is always linked to a single behavioral aspect (an issue). With the ontological dimension it is added the possibility of combining reputations on different aspects to calculate complex reputations [5]. To represent the ontological dimension, graph structures are used.

Fig. 3 shows an ontological dimension for a vehicle in our scenario. In this case, the reputation of being a **suitable vehicle** to forward a message is related with the reputation of forwarding messages and the reputation of generate messages about road conditions. For the owner of this ontological structure, having traffic ticket is something irrelevant to be considered as a suitable vehicle to forward. Hence, to calculate a given reputation taking into account the ontological dimension, the reputation has to be calculated for each of the related aspects that, in turn, can be a node of another subgraph with other associated aspects. The reputations of those nodes that are related with an atomic aspect of the behavior are calculated using the individual and social dimensions. For instance, using the ontological structure in Fig. 3, we can calculate the reputation of B as a suitable vehicle to forward a message from A's perspective using (8):

$$R_{A \to B}(\text{suitable}) = 0.8 * R_{A \to B}(\text{to\_forward}) + 0.2 * R_{A \to B}(\text{to\_generate\_message}). \quad (8)$$

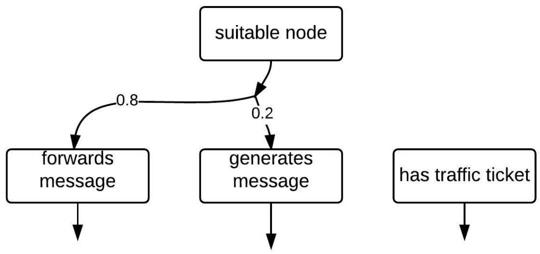

Figure 4. Ontological structure for a suitable vehicle

V. RELATED WORK

Reputation modeling has attracted the interest of researchers in the field of e-commerce and cloud computing [4]-[6]. Hamadache *et al.* [4][5] has focused on reputation of services in cloud computing in the basis of ontologies for Service Level Agreements. Vavilis *et al.* [6] has investigated reference models for reputation systems using subjective user's feedbacks in e-commerce. However, these works mainly focused on the description of the rules and the math involved in reputation calculation. They do not propose a hybrid model from different sources for evaluating feedbacks based on collaborative activity as message forwarding. Our work goes one step further, since it attempts to monitor and update the evaluation of the feedbacks during the whole message forwarding, including the context of user feedback to create and feed a meaningful reputation management system for VANETs.

VANET research Group at Middlesex University is developing a set of simulations to evaluate a VANET mobility model [8]. At University of Sao Paulo, we are using a simulation environment to evaluate our model and integrate it with their work. Our environment is composed by those tools: Simulation of Urban Mobility (SUMO) [9] to set up the mobility model, object-oriented modular discrete event network simulation framework (OMNET++) [10] to support the network model, and the framework Vehicles in Network Simulator (Veins) [11] to implement the propagation model and communications between vehicles. In our mobility model, a grid scenario of 1 Km^2 is considered. A group of 100 vehicles enter to the scenario and stay there, traveling the time it takes the simulation; a RSU is fixed in the center of the scenario and it is connected to the reputation server. The maximum speed of the vehicles is 13.9 m/s. We configured 20% of vehicles generating messages. The final destination is located in a fixed position. REMOVAN is being implemented on the WAVE Short Message Protocol (WSMP) stack [12]; it has adopted the standard IEEE 802.11p [13] and the Simplified Path-Loss model. In TABLE II is showed the parameters of mobility and network.

The goal of our simulations is to evaluate the performance of the reputation system in VANETs. So, the response variable that will be evaluated at the beginning is the average of the reputation of the vehicles in the reputation server. We supposed an initial reputation with neutral value (0), each time the destination receives a message; it generates and sends the feedbacks to the reputation server. The server will increase the reputation of the vehicles that generated and forwarded messages.

TABLE II. SIMULATION PARAMETERS

Parameter	Value
Urban area	(1km x 1km) 1km^2
Number of vehicles	100
Packet format	WAVE Short Message
Beacon Interval in the RSU	1s
MAC Protocol	802.11p
Transmission rate	6Mbps
Communication range	320m
Simulation time	600s

The main concepts of the ontology to be used in our model and their relationships are described in Figure 5. The main concepts are: Actor, Message, Feedback, Reputation and Broker. Context was omitted from this representation; it will be included into the ontology in next simulation. A Message *is generated by* an Actor. Car *is an* Actor, as are Passenger and Driver. So a Message can be *generated by* one of them. We are also categorizing cars in their types (Truck, Bus, Taxi, etc) to be further used on Context. A Message *has a* Content; Subjective Feedback *is based on* it, in other words, a Destination *gives* Feedback (Subjective Feedback) *based on* a Content of a Message. A Destination also gives Objective Feedback, but in this case, a route table is consulted in order to list all intermediary cars, which collaborated in message forwarding. A Message *is addressed to* a Destination. In future simulations, it should be addressed to more than one Destination or to all in the way, for example, an alarm message. A Broker (Reputation Server) *receives* Feedbacks and *generates* Reputation. Then Reputation *is generated by* a Broker. Reputation, as was said before, is an important concept in this work because message forwarding will take it into account. Note that Car *has* Reputation and not all Actors. It happens because Driver and Passenger will be linked to a car.

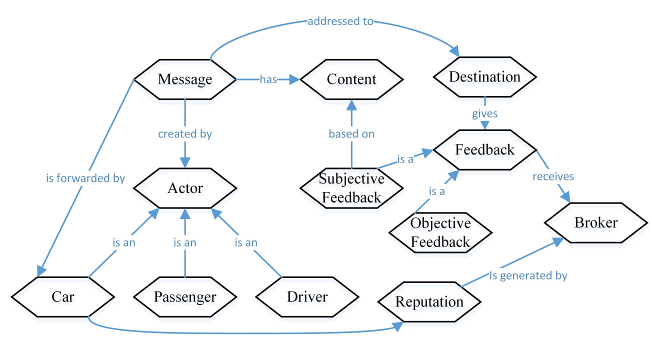

Figure 5. Ontology High Level Concepts

VI. CONCLUSION

In this paper, we have presented our reputation model for VANET. The very next steps for this research will consist in the refinement of ontological structure and testing implementation of the proposed algorithms and their evaluation against simulated scenarios and from real testbeds [8]. This will ensure the coherence and the common ground on which ontologies are built. By ensuring the coherence, the goal is the long-term evolution of feedback and reputation.

ACKNOWLEDGMENT

Federal Institute of Education, Science and Technology of São Paulo (IFSP) supports this work of post doctorate. University of Pamplona, Vehicle Ad-Hoc Networks Research group at Middlesex University and at University of Sao Paulo (USP) support the collaboration of coauthors.

REFERENCES

[1] VANET research Group at Middlesex University. [Online]. Available: http://www.vanet.mdx.ac.uk/. [retrieved: March, 2016].

[2] A. Boukerche, H. A. B. F. Oliveira, E. F. Nakamura, and A. A. F. Loureiro, "Vehicular ad hoc networks: A new challenge for localization- based systems," Computer Communications, vol. 31, no. 12, July 2008, pp. 2838– 2849

[3] J. LeBrun, Chen-Nee Chuah, D. Ghosal, and M. Zhang, "Knowledge-based opportunistic forwarding in vehicular wireless ad hoc networks," in Vehicular Technology Conference, 2005. VTC 2005-Spring , vol.4, May 2005, pp. 2289-2293 , doi:10.1109/VETECS.2005.1543743

[4] K. Hamadache, "Ontology Driven Reputation Model for the Cloud," in IEEE 6th International Conference on Cloud Computing Technology and Science (CloudCom), Singapore, December 2014, pp. 735-738. doi: 10.1109/CloudCom.2014.156

[5] K. Hamadache and S. Rizou, "Holistic SLA Ontology for Cloud Service Evaluation," Advanced Cloud and Big Data (CBD), 2013 International Conference on, Nanjing, 2013, pp. 32-39. doi: 10.1109/CBD.2013.18

[6] S. Vavilis, M. Petković, and N. Zannone, "A reference model for reputation systems", in Decision Support Systems, vol. 61, May 2014, pp. 147–154, doi:10.1016/j.dss.2014.02.002

[7] J. Sabater and C. Sierra, "REGRET: A reputation model for gregarious societies," in Proceedings of the Fourth Workshop on Deception, Fraud and Trust in Agent Societies, 2001, pp. 61-69, Montreal, Canada,. doi:10.1145/375735.376110

[8] A. Ghosh,, V. V. Paranthaman, G. Mapp, O. Gemikonakli and J. Loo, "Enabling seamless V2I communications: toward developing cooperative automotive applications in VANET systems," in Communications Magazine, IEEE , vol.53, no.12 December 2015, pp.80-86, doi:10.1109/MCOM.2015.735557

[9] Intitute of Transportation Systems - DLR, "Sumo – simulation of urban mobility," 2014. [Online]. Available: http://www.dlr.de/ts/en/desktopdefault.aspx/tabid-9883/16931_read-41000/. [retrieved: May, 2016]

[10] OMNeT++, "Omnet++ community," 2014. [Online]. Available: http://www.omnetpp.org/. [retrieved: May, 2016]

[11] C. Sommer, "Veins - vehicles in network simulation," 2014. [Online]. Available: http://veins.car2x.org/. [retrieved: May, 2016]

[12] IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services," in IEEE Std 1609.3-2010 (Revision of IEEE Std 1609.3-2007) , Dec. 30 2010, pp.1-144, doi: 10.1109/IEEESTD.2010.5680697

[13] D. Jiang and L. Delgrossi, "IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments," Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE, Singapore, 2008, pp. 2036-2040. doi: 10.1109/VETECS.2008.458