An ontology based approach to traffic management in urban areas

Hamza TOULNI, Benayad NSIRI, Mohammed BOULMALF, Tayeb SADIKI

***Abstract*—**Transportation plays an important role in economic and social development and can be a powerful catalyst for growth and development. However, the rapid growth of cities and increasing population mobility have produced a rapid increase in the number of vehicles on the roads, this involves several problems, particularly in terms of road safety, and waste of time and pollution. The construction and expansion of roads are solutions to address these problems and improve the performance of the road circulation, but these solutions are very expensive and also they require more space and permanent maintenance. An alternative would be to use the new technologies in the field of communication for sending traffic information such as treacherous road conditions and accident sites by communicating, for a more efficient use of existing infrastructure. In this paper, we propose an approach based on ontologies and we will use VANET as a transmission system to retrieve traffic information and to ensure the transmission of messages, which can help drivers in order to have a better trip.

***Keywords*—** Ontology, Traffic Management, Vehicular Ad-hoc Networks, Intelligent Transportation Systems, Safety.

I. Introduction

TRANSPORTATION is a key sector for the development of any country. Indeed, in a modern economy, transport plays a key role because it not only facilitates exchanges between economic agents, but also improves the flow of people, goods, ideas and services. For several decades, the number of vehicles is constantly increasing, especially in urban areas. This increase confronts the transport sector with significant challenges and problems of traffic congestion, declining efficient use of roads, high costs of traveling, increase in traffic accidents and pollution of the environment.

These transport problems reduce the economic development opportunities, and quality of life of citizens who are affected psychologically and physically. Among these problems that may be mentioned traffic congestion, increased energy consumption, waste of time, and limited mobility. Moreover, transport accidents are the most serious problems because of their socio-economic damages, including property damage and human losses. To remedy this problem, intelligent transportation systems (ITS) become an alternative to optimize traffic safely.

ITS have emerged as an effective way to improve circulation, it will help to use less energy in the travel, less distance to reach the desired position with a time and money, while respecting nature. On the other hand, the rapid development of wireless communication technologies, allow now the implementation of this technology in vehicles as VANET (Vehicular Ad-hoc NETwork) [1], in order to improve intelligent transport systems by the great benefits that can be derived from this technology with the aim of improve the fluidity of traffic and enhance road safety, this type of network allows communication between vehicles or between vehicles and infrastructure by roadside access points. Thus, a driver on the road could have a reliable and fast access to practical information with a wide range of applications, these applications are designed to enhance road safety, comfort, driving assistance and entertainment.

VANET are based on mobile ad hoc networks (MANET), where each vehicle is equipped with wireless communication devices, which are designed to ensure communication between vehicles and the road infrastructure, and therefore play a crucial role in providing innovative applications and services [1]-[2]-[3] in the road transport sector. These applications and services are designed not only to improve road safety but also for comfort, support and entertainment.

VANETs uses specialized short-range protocol communications (DSRC) [4]-[5] to broadcast messages at high speed in several directions [6]-[7] because its latency is low, but the coverage of this solution is very limited. To overcome this problem, researchers proposed V2V communication [8, 9], so that vehicles can further communicate with Road Side Unit (RSU), and VANETs does not require a significant investment for implementation. In addition to high-speed connectivity at lower cost, vehicles equipped with VANET devices can take advantage of multiple location technologies with high accuracy [10], either with a relative location [11]-[12] or even a global location [13]-[14].

In this paper, we propose an approach using ontologies and VANET to enable more efficient and optimal use of road infrastructure. The rest of this article is organized as follows. First, we give a literature review of traffic management systems. Second, we give an overview of the ontologies we

Hamza TOULNI is with LIAD Laboratory, Faculty of Sciences Ain Chock Casablanca, Hassan II University, Morocco. (E-mail: hamza.toulni07@etude.univcasa.ma).

Benayad NSIRI is with LIAD Laboratory, Faculty of Sciences Ain Chock Casablanca, Hassan II University, Morocco.

Mohammed BOULMALF is with International University of Rabat, Technopolis Rabat-Shore Rocade Rabat-Salé, Morocco (E-mail: mohammed.boulmalf@uir.ac.ma).

Tayeb SADIKI is with International University of Rabat, Technopolis Rabat-Shore Rocade Rabat-Salé, Morocco (E-mail: tayeb.sadiki@uir.ac.ma).

show the main ITS solutions based on ontologies. In section IV we present our approach. Finally, the conclusions and future research are shown in section V.

II. Literature Review

In recent years, several articles have been published about the management of urban traffic, these articles fall into two broad categories: Estimated circulation and the optimization of traffic.

The traffic estimate is mainly based on analytical modeling of data collected by sensors installed all along the roads, or even vehicles.

The information collected in real time are also used in the optimization of traffic, but the techniques and methods change.

For example, the works presented in [15]-[16] the road is defined congested state when the vehicle travel time exceeds the normal travel time of this road, the normal travel time of each segment of a road must be calculated by the vehicle for a day and then stored in a centralized entity.

In [17]-[18] the authors introduced mechanisms to detect traffic jams, which are mainly based on messages regularly broadcast by vehicles. The estimate of the traffic and the status of various routes are evaluated by analysis of the information broadcast messages.

However, the problem that arises in these mechanisms is overload of the communication channel, because they requires the exchange of a large number of packets.

In [19]Authors propose a solution to the vehicle traffic control problem using coordinated fuzzy logic controllers, they use a new hierarchical structure of the fuzzy logic rule set to implement the path global priorities on the local controllers and to diminish the rule set dimension. The computation of the optimization of urban vehicle traffic using genetic algorithm for an individual evaluation needs approximately 55 seconds on a bi-processor computer. The use of a multiprocessor system and a parallel implementation decreases this duration and makes possible the application of the dynamic priority solution to a real time constrained system.

In [20] authors propose an architecture of a hierarchical city traffic control system based on the use of wireless sensor-actuator networks. This hierarchical control provides flexibility for changing the control application. The hierarchical of this system is devised in three-level strategy. The lowest level controls single intersection traffic lights using a wireless sensor-actuator network cluster, the second level executes the zonal traffic coordination, and the highest level is Traffic Coordination unit (TCU) that optimizes the traffic parameters for the city. But authors don’t give details to use the collected information in this system.

In[21] authors propos an Adaptive Traffic Control Systems (ATCSs) utilize real time traffic data in an attempt to optimize the timing and length of the traffic light signals. As a result, effective ATCSs aim to minimize stop times and delays in a bid to reduce traffic congestion in major urban areas.

Another strategy in urban traffic management is to optimize traffic signals [22]-[23]-[24] deployed at intersections by analyzing the data collected in real-time traffic. The goal of this optimization is to minimize waiting times in an intersection and increase the number of vehicles crossing the intersection. Then you have to synchronize the lights different intersections to improve traffic in all directions

However, a local synchronization for an intersection influence on all other intersections of the road network, thus the optimizing desired goals include the minimizing of the waiting time and the length of the queue will not be achieved in other intersections, which could cause more congestion. For this, researchers have proposed to favor roads with high demand but for special events or temporary changes such as road closures due to construction or other, which results inadequacy of this strategy if the traffic is huge.

III. Ontologies In ITS

Nowadays, ontologies are highly valued in almost all areas, for this reason we find many definitions of an ontology, the simplest and most popular since 1993 until now is the definition of Tom Gruber [25] who has said: “An ontology is a formal, explicit specification of a shared conceptualization.”

In other words, an ontology is a structured set of terms and concepts representing the information and the relations between them, in a specific domain, these relations can be semantic relations, or relations of composition and inheritance. The power and usefulness of ontology is the reuse of information and the definition of a common vocabulary, and in addition any domain can be modeled using ontologies [26] [27] [28].

The main element required for the construction of ontology is language, it is designed to describe the information and allow their reuses. In the last few years, many languages have been developed to the implementation, these languages are classified into four levels: informal, semi-informal, semi-formal and formal, this is why the ontologies are not all built by the same way, but the choice of language is a challenge for construction.

Otherwise, several articles have been published on ontologies as solutions to the problems and the challenges of ITS. In [29] authors present the VEhicular ACcident ONtology (VEACON) designed to improve traffic safety, and for enabling interoperability between vehicles, RSUs, authorities and emergency vehicles. This ontology combines the information collected when an accident occurs, and the data available in the General Estimates System (GES) accidents database.

In [30] authors present an ontology for a reliable Traffic Information System. This ontology had been developed in OWL, and it is based on road traffic, and on possible scenarios of vehicles traveling in a highway. It is composed by classes, properties, attributes and relations between classes. The ontology is included in each agent executing the Traffic Information System. Each agent may ask for traffic information based on the ontology, and also based on its knowledge base.

In [31] authors propose a method to increase situation awareness during emergency transportation of patients. Their approach combines semantic reasoning with the emergingCar-2-X technology. The developed system continuously matches data retrieved from inter-vehicular communication with structured knowledge from vehicular ontologies and OpenStreetMap.

In [32] authors present the Car Accident lightweight Ontology for VANETs (CAOVA). The instances of our ontology are filled with: (i) the information collected when an accident occurs, and (ii) the data available in the General Estimates System (GES) accidents database. We assess the reliability of our proposal in two different ways: one via realistic crash tests, and the other one using a network simulation framework.

In [33]-[34] authors propose ontology-based approaches for adding reasoning capabilities to autonomous vehicles. The main use case is at self-assessment of the perception system to monitor co-driving. The module designed for situation assessment formalizes knowledge such as: environment conditions, moving obstacles, driver state, navigable space, which are also relevant concepts for VANET.

IV. Our Approach

Improving road safety requires constant supply of traffic information to the driver, this information should also improve the driving quality and keep traffic moving. But it is difficult to acquire all information and interpreted by the pilot in this context our approach is involved to enable more effective use of road infrastructure safely.

VANET can provide information faster and more pertinently in real time, but the interpretation of this information by the driver and his reflexes are not always precise. For this we propose an ontology that will ensure the best presentation of collected information.

A. Overview

We propose an ontology using VANET in order to facilitate driving and interpretation of messages to the driver. This ontology is integrated directly into each vehicle to facilitate communication between them, and also facilitate communication with the infrastructure to obtain real-time traffic information Fig. 1.

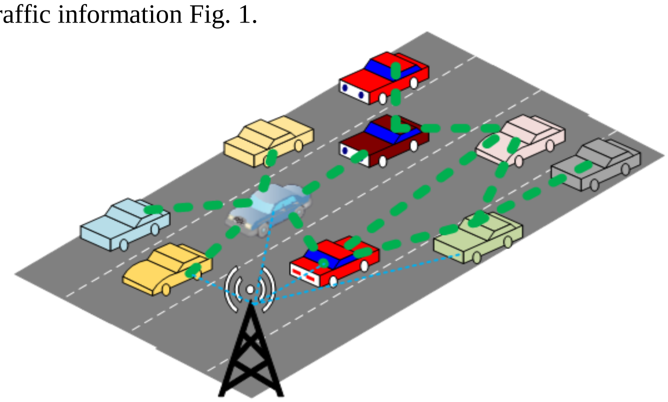

Fig. 1 Communication between vehicles and infrastructure.

So our proposed approach consists of three main phases:

A learning phase is to collect information on the infrastructure, in order to reconstitute the map and the connections between roads.

A phase of knowledge acquisition of acquiring the information necessary for the driver.

And finally a Knowledge Representation phase.

This ontology Fig. 2 consists of four subclasses: Vehicle, Infrastructure, Traffic Control and Message. These concepts that relate to each other.

B. Language

We choose the Web Ontology Language (OWL) as a language to describe and organize knowledge for our ontology, it is developed and recommended by the World Wide Web Consortium (W3C). OWL is designed for use by applications that need to process the content of information instead of just presenting information to humans. OWL facilitates greater machine interpretability of the content that supported by XML, RDF, and SRDF.

So the description of our ontology is going to be like this:

```
Prefix(owl:=<http://www.w3.org/2002/07/owl#>)
Prefix(rdf:=<http://www.w3.org/1999/02/22-rdf-syntax-ns#>)
Prefix(xml:=<http://www.w3.org/XML/1998/namespace>)
Prefix(xsd:=<http://www.w3.org/2001/XMLSchema#>)
Prefix(rdfs:=<http://www.w3.org/2000/01/rdf-schema#>)

Ontology(<http://www.semanticweb.org/hamza/ontologies/2201/02/UrbanTrafficManagement-ontology>)
```

And the description of the class classes is done like this:

```
Declaration(Class(<http://www.semanticweb.org/hamza/ontologies/2015/02/UrbanTrafficManagement-ontology#Infrastructure>))

Declaration(Class(<http://www.semanticweb.org/hamza/ontologies/2015/02/UrbanTrafficManagement-ontology#Message>))

Declaration(Class(<http://www.semanticweb.org/hamza/ontologies/2015/02/UrbanTrafficManagement-ontology#TrafficControl>))

Declaration(Class(<http://www.semanticweb.org/hamza/ontologies/2015/02/UrbanTrafficManagement-ontology#Vehicle>))
```

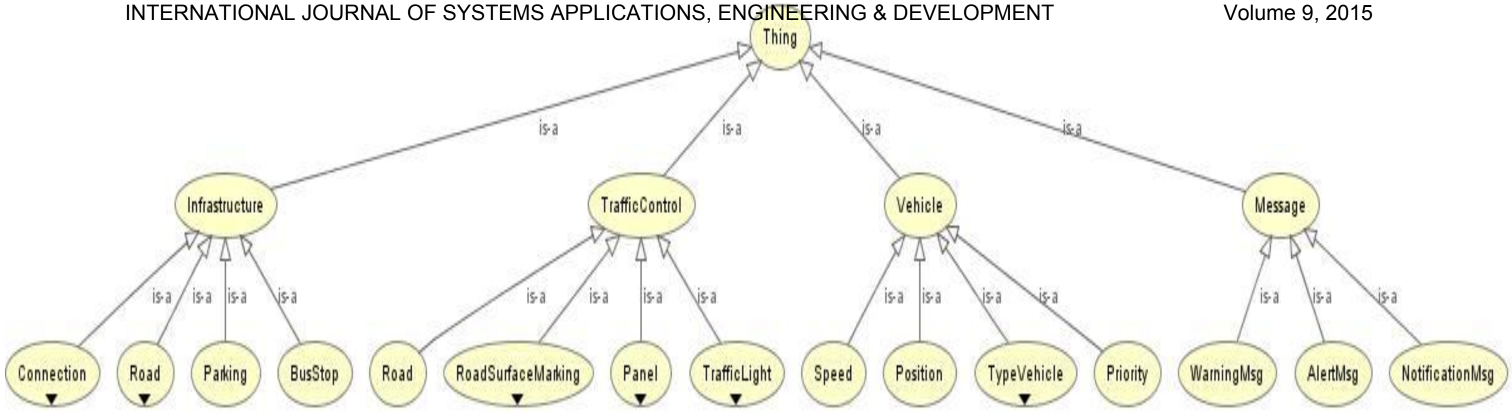

Fig. 2 The elements of our Ontology

And the description converted into RDF of our ontology is going to be like this:

```
<!DOCTYPE rdf:RDF [
    <!ENTITY owl "http://www.w3.org/2002/07/owl#" >
    <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
    <!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
    <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
    <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#"
>
]>
<rdf:RDF
xmlns="http://www.semanticweb.org/hamza/ontologies/2015/0
2/UrbanTrafficManagement-ontology#"

xml:base="http://www.semanticweb.org/hamza/ontologies/201
5/02/UrbanTrafficManagement-ontology"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-
ns#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
    <owl:Ontology
rdf:about="http://www.semanticweb.org/hamza/ontologies/201
5/02/UrbanTrafficManagement-ontology"/>
```

C. *Design*

Our ontology was designed using Protégé [35], it begins with a super class named Thing Fig. 3, which all other classes are subclasses. This brings us directly to the concept of inheritance, therefore inherited classes are: Vehicle, Infrastructure, Message and TrafficControl.

The first class is Vehicle Fig. 4, which include the properties of Vehicle, such as Priority, Position and Speed. Vehicle comes in three types: simple car, bus and emergency vehicles. TypeVehicle describes the vehicle's physical properties and their priority.

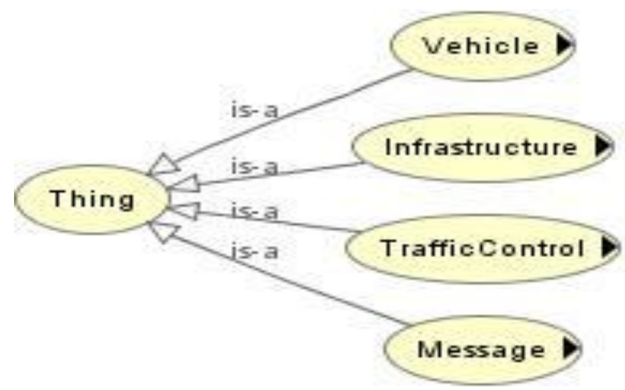

Fig. 3 High Level Ontology.

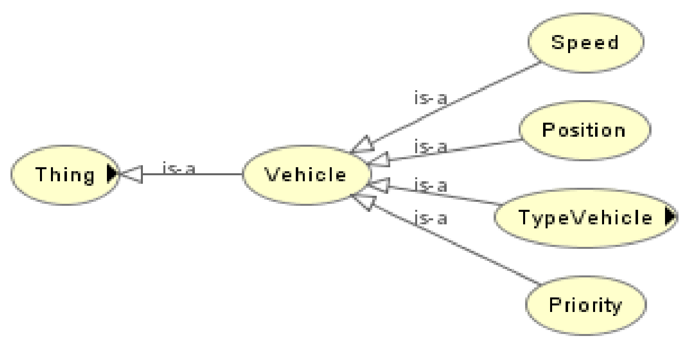

Fig. 4 Description of vehicle.

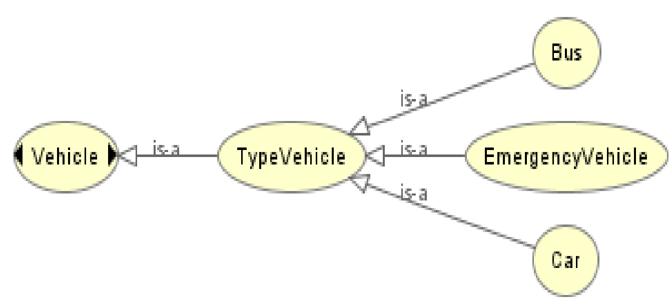

Fig. 5 Type of vehicle.

The class Infrastructure Fig. 6, which is composed of Connection, Road, Parking and BusStop for bus station.

Connection Fig. 7, is the area in which vehicles traveling a road to another, which include its kind such as a simple roundabout or with traffic lights. It also contains the source and destination routes.

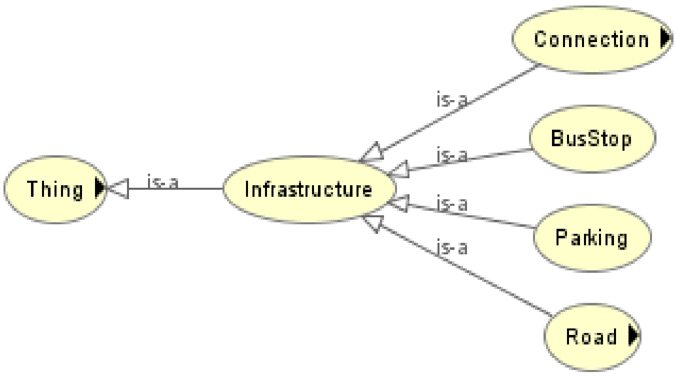

Fig. 6 Description of Infrastructure.

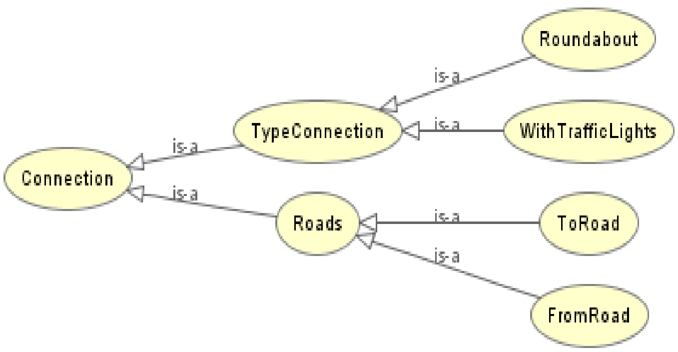

Fig. 7 The elements of Connection.

Each Road Fig. 8 has a number of lanes for the rolling of the vehicle, and a maximum speed not to exceed by vehicles, and her type which include the properties of road.

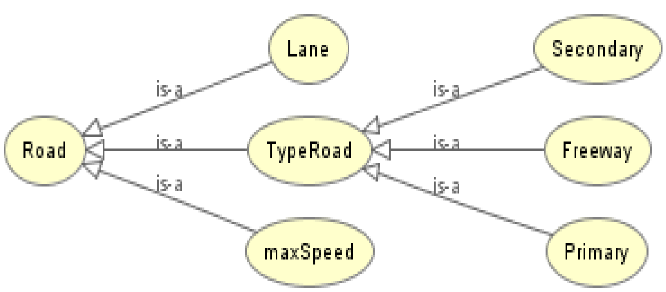

Fig. 8 The elements of Road.

The class Message Fig. 9, which include the type of Message, it can be an AlertMsg for emergency situations, Warning for unpredictable situations or NotificationMsg for the information. These messages are sent by the other driver in the event of a request or change of situation.

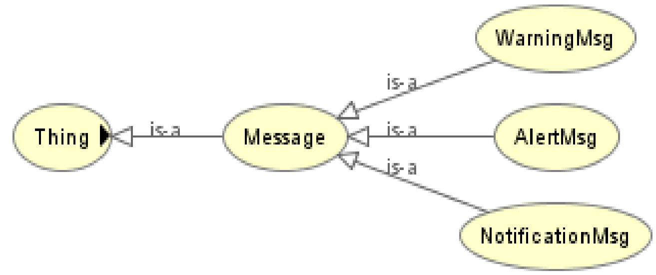

Fig. 9 Description of Message.

The class Traffic Control Fig. 10, which include the Panel of Traffic Control and Traffic Light to provide important information as a message to help drivers to respect traffic law.

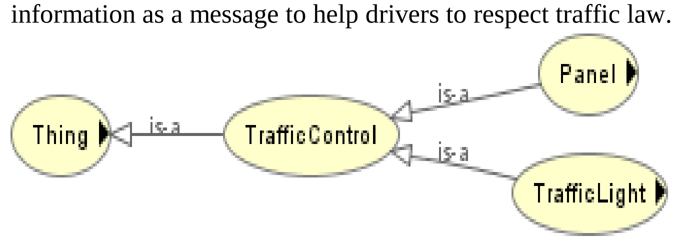

Fig. 10 Description of Traffic Control.

Panel Fig. 11, is used to guide vehicle traffic. There are three types of Panel, type one whit notification message, type two whit warning message, and type three whit alert message.

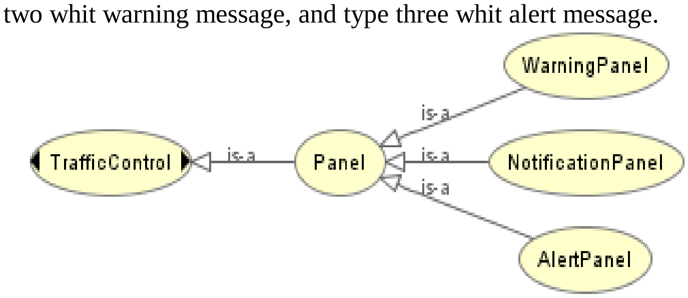

Fig. 11 Description of Panel.

TrafficLight Fig. 12 is used to describe the state of the traffic light is green, yellow or red.

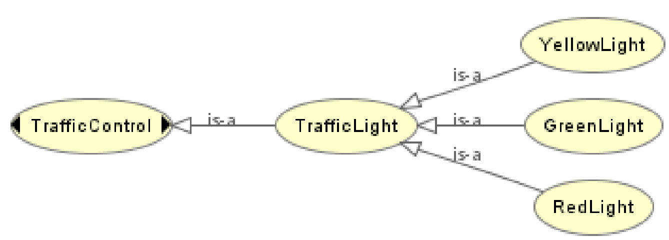

Fig. 12 Description of Traffic Light.

V. Conclusion

Transportation plays a crucial role in the development of pay, but traffic management is the most critical problems, especially in urban areas. Advanced techniques and methods as VANET have the potential to solve this problem, but the interpretation by the driver does not reach the desired goal.

Our solution is to integrate ontology in vehicles, to facilitate the interpretation of the information collected by VANET.

Our approach will also allow the implementation of traffic management solutions more efficient and reliable. Currently our ontology does not contain sufficient concepts for complex scenarios. In the future, this approach will be enhanced to include several concepts. Subsequently, we propose to build a platform for validation, which could show the effectiveness of our approach.

REFERENCES

[1] G. O. Young, "Synthetic structure of industrial plastics (Book style with H. Hartenstein, K. P. Laberteaux, VANET Vehicular Applications and Inter-Networking Technologies, John Wiley & Sons, Ltd, 2009

[2] J Kargl F., "Vehicular Communications and VANETs," Talks 23rd Chaos Communication Congress, 2006.

[3] Mahlknecht S. and Madani S., "On Architecture of Low Power Wireless Sensor Networks for Container Tracking and Monitoring Applications," in Proceedings of 5th IEEE International Conference Industrial Informatics, 2007,pp. 353-358.

[4] Yu, Fan F. and Biswas, S. A Self-Organizing MAC Protocol for DSRC based Vehicular Ad Hoc Networks, ICDCS Workshops 2007.

[5] Cseh C., "Architecture of the Dedicated Short-Range Communications (DSRC) Protocol," in roceedings of IEEE Vehicular Technology Conference, 1998, pp. 45-49.

[6] W. Whyte, "Safe at Any Speed: Dedicated Short Range Communications (DSRC) and On-road Safety and Security," RSA Conference 2005

[7] Vehicle Safety Communications Consortium, "Vehicle Safety Communications Project Task 3 Final Report,Identify Intelligent Vehicle Safety Applications Enabled by DSRC," March 2005.

[8] D. W. Franz, "Car-to-car Communication –Anwendungen und aktuelle Forschungsprogramme in Europa, USA und Japan", in Kon-gressband zum VDE-Kongress 2004 – Innovationen für Menschen, VDE, October 2004.

[9] S. Eichler et al., "Strategies for context-adaptive message dissemination in vehicular ad hoc networks", in Proceedings of the 2nd International Workshop on Vehicle-to-Vehicle Communications (V2VCOM), July 2006.

[10] R.Parker and S.Valaee, «Vehicle Localization in Vehicular Networks », Vehicular Technology Conference, 2006. VTC-2006 fall. IEEE 64th, pp. 1–5.

[11] A.Benslimane, « Localization in vehicular Ad-hoc networks », Proceedings of the 2005 Systems Communications (ICW'05).

[12] V. Kukshya, H. Krishnan, and C. Kellum, « Design of a system solution for relative positioning of vehicles using vehicle-to-vehicle radio communications during GPS outages », in Proceedings of IEEE Vehicular Technology Conference (VTC), September 2005.

[13] B. Hofmann-Wellenho, H. Lichtenegger, J. Collins, Global Positioning System: Theory and Practice, 4th ed., Springer-Verlag, 1997.

[14] E.D. Kaplan, Understanding GPS: Principles and Applications, Artech House, 1996.

[15] Marfia, G.; Roccetti, M., "Vehicular Congestion Detection and Short-Term Forecasting: A New Model With Results," Vehicular Technology, IEEE Transactions on, vol.60, no.7, pp.2936,2948, Sept. 2011.

[16] R. Bauza, J. Gozalvez, and J. Sanchez-Soriano,"Road traffic congestion detection through cooperative vehicle-to-vehicle communications," IEEE 35th Conference on Local Computer Networks (LCN), 2010.

[17] I. Leontiadis, G. Marfia, D. Mack, G. Pau, C. Mascolo, and M. Gerla,"On the effectiveness of an opportunistic traffic management system for vehicular networks", IEEE Transactions on Intelligent Transportation Systems, Vol. 12 , Issue 4, 2011.

[18] A. Lakas and M. Cheqfah, "Detection and dissipation of road traffic congestion using vehicular communication," Mediterranean Microwave Symposium (MMS), 2009.

[19] TIBERIU S. LETIA, MIHAI HULEA, FLORIN DINGA. "Optimization of Urban Vehicle Traffic Using Genetic Fuzzy Logic Control". Proceedings of the 2nd WSEAS International Conference on URBAN PLANNING and TRANSPORTATION, 2009, pp. 171-176.

[20] Daniel-Ioan CURIAC, Constantin VOLOSENCU. "Urban Traffic Control System Architecture Based on Wireless Sensor Actuator Networks". Proceedings of the 2nd International Conference on Manufacturing Engineering, Quality and Production Systems. (MEQAPS'10). Constantza, Romania, September 3-5, 2010.

[21] Zhao, Y. & Tian, Z.,An Overview of the Usage of Adaptive Signal Control System. Applied Mechanics and Materials Volumes 178-181, pp. 2591-2598. 2012

[22] Maslekar, N., Boussedjra, M., Mouzna, J., Labiod, H., "VANET based Adaptive Traffic Signal Control"‖, IEEE 73rd Vehicular Technology Conference (VTC Spring), pp. 1-5, 2011.

[23] Gradinescu, V., Gorgorin, C., Diaconescu, R., Cristea, V., Iftode, L., ―Adaptive Traffic Light Using Car-to-Car communications‖, IEEE 65th Vehicular Technology Conference (VTC Spring), pp. 21-25, 2007.

[24] Barba, C.T.; Mateos, M.A.; Soto, P.R.; Mezher, A.M.; Igartua, M.A., "Smart city for VANETs using warning messages, traffic statistics and intelligent traffic lights," Intelligent Vehicles Symposium (IV), 2012 IEEE , vol., no., pp.902,907, 3-7 June 2012

[25] Gruber T. "A Translation Approach to Portable Ontology Specifications", Knowledge Acquisition, pp. 199-220, 1993.

[26] Daniel Hunyadi , Iulian Pah, Ontology used in a e-learning multi-agent architecture, WSEAS Transactions on Information Science and Applications, v.5 n.8, 2008, p.1302-1312

[27] Pinto F., Santos M., Marquez A. – Database Marketing Intelligence Supported by Ontologies, WSEAS TRANSACTIONS on BUSINESS and ECONOMICS, Issue 1, 2009

[28] Mehdi Abid, Benayad Nsiri, Yassine Serhane, Interoperability between Different Port Information Systems, INTERNATIONAL JOURNAL OF MATHEMATICS AND COMPUTERS IN SIMULATION, Vol.8, 2014, pp. 156-161.

[29] J. Barrachina, P. Garrido, M. Fogue, F. Martinez, J.-C. Cano, C. T. Calafate, and P. Manzoni, "Veacon: A vehicular accident ontology designed to improve safety on the roads," Journal of Network and Computer Applications, vol. 35, no. 6, pp. 1891 –1900, 2012.

[30] Sérgio Gorender, Ícaro Silva; "AN ONTOLOGY FOR A FAULT TOLERANT TRAFFIC INFORMATION SYSTEM", 22nd International Congress of Mechanical Engineering (COBEM 2013),November 3-7, 2013, Ribeirão Preto, SP, Brazil.

[31] A. Groza, A. Marginean, B. Iancu, Towards improving situation awareness during emergency transportation through Ambulance-2-X communication and semantic stream reasoning, MEDITECH2014, Cluj-Napoca, Romania, 5-7 June 2014.

[32] J. Barrachina, P. Garrido, M. Fogue, F. J. Martinez, J.-C. Cano, C. T. Calafate, and P. Manzoni, "Caova: A car accident ontology for vanets," in Wireless Communications and Networking Conference (WCNC) IEEE, 2012, pp. 1864–1869.

[33] Morignot, P.; Nashashibi, F, "An ontology-based approach to relax traffic regulation for autonomous vehicle assistance," CoRR, vol. abs/1212.0768, 2012.

[34] Pollard, E.; Morignot, P.; Nashashibi, F., "An ontology-based model to determine the automation level of an automated vehicle for co-driving,» In 16th International Conference on Information Fusion, Istanbul, Turquie, July 2013.

[35] Protégé http://protege.stanford.edu/.