An Innovative Osmotic Computing Framework for Self Adapting City Traffic in Autonomous Vehicle Environment

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***Abstract*—In recent years, autonomous driving is becoming a very hot topic for both researchers and car manufacturers. Indeed, around the world new discoveries have been published. In this work we present an innovative Osmotic Computing solution for self adapting city traffic in autonomous vehicle environment. The Vehicular-to-Vehicular (V2V) and Vehicular to Edge-Cloud (V2EC) interactions inside specific areas of the City are considered: the interconnections. The Framework we are creating is able to adapt on a Dynamic Environment where Vehicles, Pedestrians and Physical Infrastructures can interact each other, offering continuous information on interconnections status and city traffic in general.**

***Index Terms*—Autonomous Vehicle, Autonomous driving, Osmotic Computing, Cloud Computing, Edge Computing, IoT and Microservices.**

I. Introduction

In recent years, autonomous driving is becoming a very hot topic for both researchers and car manufacturers. Indeed, around the world new discoveries have been published. In parallel, legal issues have also been considered with a view to paving the way for commercial exploitation. Thus, several US states, as well as some European Countries, have recently approved specific regulations for the use of self-driving cars on their roads.

In recent years, many car manufacturers such as Daimler, Tesla and Nissan have successfully presented cars with automatic driving in urban scenario [1]. Similar outcomes have been carried out from the scientific community, such as the University of Parma in [2].

Intersections are probably the most complex scenarios to manage for automated cars, especially in urban areas, given that the level of interaction with other drivers or automated cars is significantly high. Automated vehicles can take a great deal of different actions when approaching an intersection. Thus, speed modulation is one of those possible actions. On some occasions, reducing or increasing speed at the right time can contribute to increase the efficiency of intersection management in congested conditions. Needless to say that taking the right decision regarding the time to enter into the intersection is essential for appropriate traffic flows. When traffic density is low such decisions are easy to be taken in an automatic manner. However, this task becomes much more complex in congested condition. Automated cars of the future might have the ability to make intelligent and well informed decisions about the change of priority when approaching intersections in order to deploy the most efficient policy in cooperation with all other vehicles in the proximity. Clearly, a well harmonized group strategy is needed to achieve such purpose. In the above reported decision making task, one important role is covered from the information exchanged in the intersections. In particular, in this paper we discuss an autonomous vehicle algorithm based on Vehicle-to-Vehicle (V2V) communication and present an innovative Osmotic Computing Vehicle-to-Cloud-Edge (V2EC) solution aimed at solving such problems.

This paper is structured as it follows: Section II highlights the motivations that bring to create an innovative framework adopting the Osmotic Computing paradigm. Section III describes in which context we are targeting the framework introduced. Section IV reports the main concepts of Osmotic Computing useful to drive the discussion. In Section V we targeted in a concrete use case. The related Works are presented in Section VI. Final remarks in the Conclusion Section along with some highlights for the Future concludes the dissertation.

II. Motivation

The scientific community is in agreement that automatic driving will become increasingly reliable by increasing the capacity for cooperation among vehicles and between vehicles and infrastructure. Indeed, is widely accepted that the cooperative automated driving is much more reliable than standalone self-driving.

Indeed, if we replace all currently existing cars with latest generation autonomous cars, even if they performed perfectly

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well (with no accidents at all), road traffic would still be utterly chaotic, given that self-driving cars still behave like conservative, unintelligent drivers. Proof of this is the speeding ticket received by Googles self-driving car from the Mountain View police in Silicon Valley in November 2015, after driving at an excessively low speed, causing congestion and long queues on the road [3].

A. The Algorithm in Brief: the Original Approach

One of the most critical aspects of managing vehicles without drivers is their behavior at intersections. In particular, the priority of vehicles. In this paper it is managed according to different factors: vehicle speed, position, size, characteristics, pre and post crossing congestion. The intersection management algorithm for driverless vehicles is provided, in what is the state of the art, in most cases by an intersection operator. The limits of implementation of this type of approach are related both to costs and the impossibility of rapid installation of such systems for all the existing intersections; the Osmotic Computing might overcome these limitations. The original approach is based on V2V which offers the advantage that no installation of intersection operator (AIM) is necessary with the limit of the maximum communication distance between vehicles near the intersection.

The algorithm is based on dynamic priority management according to the parameters of the vehicles involved at the intersection. Any change at the intersection will change priorities by allowing an in-line crossing with the parameters of the affected vehicles.

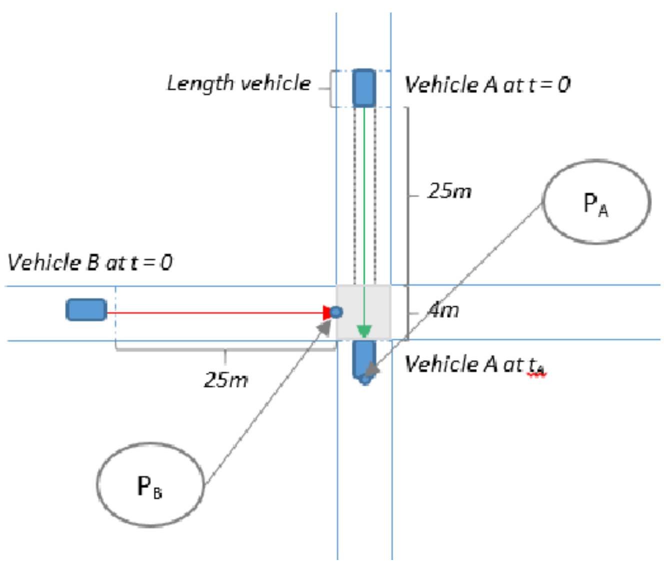

Fig. 1: Priority management algorithm

With reference to the Figure 1 we discuss the intersection management with only 2 vehicles. We can consider as target point of each vehicle the distance to the end of the intersection. The algorithm is based on FRFP approach (first to reach the end of the intersection first to pass). Considering the vehicle A represented in Figure 1 near to the intersection, it communicates to vehicle B its position [s_A], speed [v_A] and therefore the estimated arrival time [t_A] at the end of the intersection (point P_A). Same information are computed and sent by vehicle B. The vehicle that can arrive in less time at the end of the intersection has the priority. The vehicle with less priority (in this case B) calculates the deceleration [a_B] that it has to maintain in order to minimize fuel consumption and usury of the car. Vehicle A communicates regularly [s_A, v_A, t_A] during its trip, so the vehicle B can constantly check that the calculation made at start does not have to be modified.

The algorithm works even in presence of several vehicles, indeed it will calculate a priority list. Each vehicle will traverse the intersection after all vehicles with highest priority. The system, also, foresees two changes of status in case of congestion before or after crossing. In particular, in case of congestion before crossing, the priority list manages the group crossing (platoon) entering in balance state. In this case the vehicle on the congested lane could have a short gap and the priority may never be released to the vehicle on other lane. In the event of post-crossing congestion, vehicles that are located before the intersection in the same lane of congested vehicles are blocked at the intersection (freeze state). This state avoids creating useless blocks of the intersection.

To extend its capabilities we are looking to share much more data in intersections and modifying it accordantly. The next Section highlights the basic elements necessary to add in our proposed architecture useful to improve the Original Approach above described.

III. Our Main Outcomes

The potential of the proposed system is that it adapts to the parameters of vehicles, managing priorities in real time. Like reported above the limits of the original approaches are linked to the maximum communication distance among vehicles near to the intersection. It is rather clear that this limit is eliminated by using V2EC for the preventive management of the vehicle already at a great distance from the intersection. The V2EC can allow vehicles to know the status of the lane of a given intersection even at a considerable distance from it. Thus the V2V communication limit can be extended without any limitation by means of the V2EC communication.

Hence, our research is focused on two fundamental aspects:

- managing the intersections, through V2V communication, to make their crossing efficient, with the aim of reducing congestion, consumption and emissions. The system under assessment is an algorithm that adapts in real time to the parameters of the vehicles involved in the intersection;
- getting much more parameters to be analysed in the nesting streets/roads and/or in crossing areas by means of V2EC. The data analysed over time can be used to set limits such as speed or presence of cars in order to minimize congestion, emissions, fuel consumption or to make safer areas with greater pedestrian presence compared to another one.

In the algorithm, having the V2CE communication approach we can remark many benefits:

- The vehicle can adapt itself to the predicted situation in advance, thus eliminating abrupt changes and therefore limiting consumption. Clearly the situation will be confirmed through V2V communication when the vehicle is close to the intersection;
- The data analyzed over time can be used to set limits such as speed or presence of cars in order to minimize congestion, emissions, fuel consumption ;
- The route, the number or the speed of automatic vehicle could be different depending on external conditions such as CO2 emission limit.

All of those could also be linked to weather conditions that may be or may be not contribute to the presence of CO2 in the atmosphere.

IV. About Osmotic Computing

Since 2016 [4], an innovative paradigm has been proposed: the **Osmotic Computing** (OC). The purpose of this new paradigm is the integration of IoT, Edge and Cloud layers in order to increment QoS, availability and reliability of applications. These features properties are of interest for this scientific work, which aims to overcome the limits imposed by the existing technologies in order to implement the first Osmotic service. Specifically, knowing an Osmotic application has a failover behavior, we focus on an owner model to achieve that. Furthermore, the abstraction of microservices allows to overcome hardware differences of IoT devices. Indeed OC, considering different domains (Cloud, Edge and IoT), harmonizes capabilities that are equals but described in a different way. The idea is to manage devices in an abstracted way where the user-context and services is the real focus of the matter. Moreover with the introduction of Microelements (Microservices + data, in the following MELs) we harmonizing Elements that need to move and migrate among systems along with the definition of homogeneous labeled contexts where MELs can freely move and interact each other.

V. Satisfying a real use case leveraging Osmotic Computing and its MELs

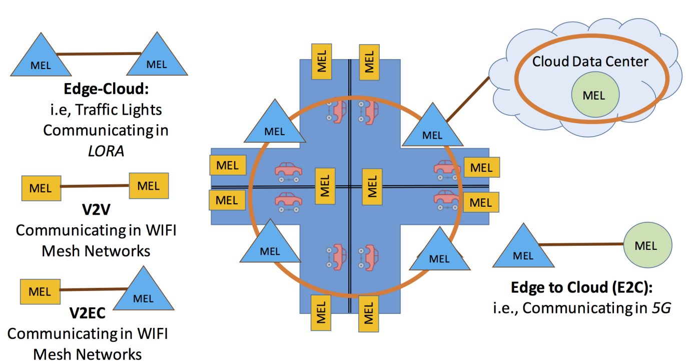

Fig. 2: A real representation of an Intercession where 4 roads join in.

Looking at the intersection of Figure 2 it is possible to identifying all possible benefits we can achieve applying the framework in this kind of scenarios. The flexibility of the Osmotic Computing and its MELs characterization allows to define any type of configuration and deployment. Example Triangle-shape MELs are deployed on traffic lights where Raspberry-like boards can be mounted on. Other Triangle-shape MELs can be deployed on ESP32 with LORA. Vehicles talks each other using WiFi in Mesh configuration, this means that waiting in queues in the interception. Vehicles create the on-fly Mesh Net using Rectangle-shape MELs downloaded from the remote Cloud (Circle-shape). In order to improve the reliability of the system, in each vehicle a Watchdog service, as discussed in [5], is implemented. In our view, other intersection and streets in the City can interact each other, exchanging data and parameters leveraging our framework.

A. The communication framework adopted in Osmotic Computing

Figure 2 highlights like more MELs are able to interact each other using different technologies of communication. Osmotic Computing allows us to deploy the right MELs over the correct device maximising the use of technologies it exposes. In our scenario we are considering devices like ESP32 or Raspberry 3 B+ capable to leverage many communication technologies. ESP32 has already on-boarded Bluetooth and WiFi version g (2.4GHz) and recently also LORA. This latter allows to create low-bandwidth links among static positioned devices at very long distance (even KMs); good for on Traffic Lights and Poles installation. Raspberry 3 B+ has already on-boarded Bluetooth, WiFi version g and a (2.4GHz and 5GHz). Moreover Raspberry with a simple 4G/5G dongle is able to gain access to the mobile infrastructure. All these devices can be powered from photo voltaic panels. The WiFi technology guarantees the setup of V2V and V2EC Mesh Networking. In Vehicles we have not any power supply limitation.

A final remark is about the capability of OC in working by design even with partially connected infrastructures; possible disconnection of networks does not create any serious misbehavior of the system. Cloud and Edge-Cloud do not need to be always on-line in the Internet. The MULE approach (using Drones) can be easily adopted.

VI. Related Work

In paper [6] authors proposed an innovative approach able to calculate the distance among vehicles. The project is based on Vehicle to Veichle (V2V) and Vehicle to Infrastructure (V2I). In particular by means of the vehicular network communication they estimated the vehicle density of a specific area. A similar work considering VANETs has been made in [7] by authors.

In [8] author presented a solution able to prevent accidents among vehicles and to monitor road traffic. The system uses IoT sensors installed on vehicles in order to collect data. A cloud application, based on OpenGTS is able to gather data from vehicles, to store them into a no-SQL database (MongoDB) and to send alarms when risky conditions occur.

In [9] authors presented I9Vanets, an innovative cloud platform for Vehicular ad hoc networks (VANETs). The goal of the platform is well known problems related to VANETs, such as:

1) Security;
2) Topology;
3) Low or High traffic.

Authors in [10] analised problems related to VANET. In particular, they analised performances of IDTAR (Intersection-based Distance and Traffic-Aware Routing), a well known protocol for trasport in smart cities.

Authors in [11] proposed a Vehicular Data Center (VDC) for specific road segments (RSs) during the trafic jam. In particular, each car stores specific data. Vehicles leaving out of the area sends data to the cars that are flowing into the RS.

In the paper [12] was involved the new paradigm of Vehicular Cloud Computing (VCC) to propose a data collection model for the benefit of Intelligent Transportation System (ITS).

In [13] authors presented a traffic big data analysis system developed by means of a network recommender. The system, exploiting both VANET and cellular network, assures pervasive connectivity of cars.

In [14], considering a vehicular ad-hoc network, authors proposed clustering method for gathering data related tovehicles movements. The purpose of the work is to extend the green wave. In particular, traffic lights, communicating with vehicles are able to make decisions and to change line priority.

In [15] authors proposed a system for updating transport informations dynamically. In particular, the system is able to send information to city control centres, transport operators and mobile commuters.

VII. Conclusions and Future Work

Self driving vehicles has become a very hot topic for both researchers and car manufacturers all across the globe. In this paper we have presented an innovative Osmotic Computing solution for self adapting city traffic in autonomous vehicle environment. The V2V and V2EC interactions inside specific areas of the City are considered: the interconnections.

The work is in early stage, after this phase of design we are approaching a real implementation of it in lab for understanding the capabilities and limitations of the overall system. All technologies will be tested like the MULE approach (using Drones), LORA and WiFi Mesh Networks on the field with the use of many ESP32s.

One of the main concerns in adopting our framework is also liked to the security aspects that the architecture might suffer. A Blockchain version of it should avoid any risk. In the Future we plan to work on designing and developing an advanced framework leveraging the Private/Federated in City Blockchain HyperLedger, where Vehicles and infrastructures trust each others in a distributed and scalable way. The Private/Federated HyperLedger does not presents scalable issues, crucial aspect in these scenarios.

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References

[1] J. Ziegler, P. Bender, M. Schreiber, H. Lategahn, T. Strauss, C. Stiller, T. Dang, U. Franke, N. Appenrodt, C. G. Keller, E. Kaus, R. G. Herrtwich, C. Rabe, D. Pfeiffer, F. Lindner, F. Stein, F. Erbs, M. Enzweiler, C. Knoppel, J. Hipp, M. Haueis, M. Trepte, C. Brenk, A. Tamke, M. Ghanaat, M. Braun, A. Joos, H. Fritz, H. Mock, M. Hein, and E. Zeeb, "Making bertha drive #x2014;an autonomous journey on a historic route," *IEEE Intelligent Transportation Systems Magazine*, vol. 6, pp. 8–20, Summer 2014.

[2] A. Broggi, P. Cerri, S. Debattisti, M. C. Laghi, P. Medici, D. Molinari, M. Panciroli, and A. Prioletti, "Proud #x2014;public road urban driverless-car test," *IEEE Transactions on Intelligent Transportation Systems*, vol. 16, pp. 3508–3519, Dec 2015.

[3] "Google car pulled over for being too slow." http://www.bbc.com/news/technology-34808105. Accessed: 2018-04-20.

[4] M. Villari, M. Fazio, S. Dustdar, O. Rana, and R. Ranjan, "Osmotic computing: A new paradigm for edge/cloud integration," *IEEE Cloud Computing*, vol. 3, pp. 76–83, nov 2016.

[5] A. Celesti, L. Carnevale, A. Galletta, M. Fazio, and M. Villari, "A watchdog service making container-based micro-services reliable in iot clouds," in *2017 IEEE 5th International Conference on Future Internet of Things and Cloud (FiCloud)*, pp. 372–378, Aug 2017.

[6] J. Wang, Y. Huang, Z. Feng, C. Jiang, H. Zhang, and V. C. M. Leung, "Reliable traffic density estimation in vehicular network," *IEEE Transactions on Vehicular Technology*, vol. PP, no. 99, pp. 1–1, 2018.

[7] Y. Huang, J. Wang, C. Jiang, H. Zhang, and V. C. M. Leung, "Vehicular network based reliable traffic density estimation," in *2016 IEEE 83rd Vehicular Technology Conference (VTC Spring)*, pp. 1–5, May 2016.

[8] A. Celesti, A. Galletta, L. Carnevale, M. Fazio, A. ay Ekuakille, and M. Villari, "An iot cloud system for traffic monitoring and vehicular accidents prevention based on mobile sensor data processing," *IEEE Sensors Journal*, vol. PP, no. 99, pp. 1–1, 2017.

[9] G. L. Junior, R. P. C. d. Nascimentos, M. A. R. Dantas, and D. D. J. d. Macedo, "A platform for vehicular networks in the cloud to applications in intelligent transportation systems," in *2017 IEEE 26th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE)*, pp. 101–106, June 2017.

[10] A. I. A. Ahmed, A. Gani, S. H. A. Hamid, S. Khan, N. Guizani, and K. Ko, "Intersection-based distance and traffic-aware routing (idtar) protocol for smart vehicular communication," in *2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 489–493, June 2017.

[11] N. Mensi, M. Guizani, and A. Makhlouf, "Study of vehicular cloud during traffic congestion," in *2016 4th International Conference on Control Engineering Information Technology (CEIT)*, pp. 1–6, Dec 2016.

[12] M. Chaqfeh, N. Mohamed, I. Jawhar, and J. Wu, "Vehicular cloud data collection for intelligent transportation systems," in *2016 3rd Smart Cloud Networks Systems (SCNS)*, pp. 1–6, Dec 2016.

[13] Y. Liu, X. Chen, C. Chen, and X. Guan, "Traffic big data analysis supporting vehicular network access recommendation," in *2016 IEEE International Conference on Communications (ICC)*, pp. 1–6, May 2016.

[14] H. Rashid, M. J. F. Ashrafi, M. Azizi, and M. R. Heydarinezhad, "Intelligent traffic light control based on clustering using vehicular adhoc networks," in *2015 7th Conference on Information and Knowledge Technology (IKT)*, pp. 1–6, May 2015.

[15] A. Maitra, S. Bhadkaria, C. Ghosh, and S. Paul, "An integrated transport advisory system for commuters, operators and city control centres," in *2012 First International Workshop on Vehicular Traffic Management for Smart Cities (VTM)*, pp. 1–3, Nov 2012.