



# **SUMO and oneM2M in AUTOPILOT: validation by simulation of a Traffic Light Assist C-ITS service for Platooning**

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## **SUMO and oneM2M in AUTOPILOT: validation by simulation of a Traffic Light Assist C-ITS service for Platooning**

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### **Abstract**

Internet of Things is expected to progress Automated Driving beyond the state of the art to several Cooperative Intelligent Transport System services. In AUTOPILOT, a C-ITS service dedicated for car rebalancing in trial site Versailles named Traffic Light Assist has been developed. It aims to supervise platoon of autonomous vehicles and to provide useful decisions to cross intersections with traffic lights safely and without breaking the platoon. Since testing in real conditions is time and cost consuming and involves complex integration, the usage of simulation environment that can connects IoT to C-ITS is necessary to test components before actual tests and trial phases. SUMO is used to generate traffic data which are published into oneM2M in order to enable TLA to provide recommendations for platoon leading vehicle. Our approach using simulated environment showed multiple advantages and should be used for the development of future C-ITS or CCAM applications.

**Keywords:** Platooning, SUMO, GLOSA

### **Introduction**

In the very near future, vehicles and connected devices will interact directly with each other and with the road infrastructure thanks to Cooperative Intelligent Transport Systems (C-ITS) applications and services. This will allow road users and traffic managers to share information and use it to coordinate their actions. This cooperation enabled by digital connectivity between vehicles and between vehicles and transport infrastructure could be enhanced by the usage and sharing of IoT data. In AUTOPILOT [1], these new data sources are expected to significantly improve road safety, traffic efficiency and comfort in driving. They are expected as well to ease managing connected and automated vehicles in the context of platooning and car rebalancing use case. Thus, these tools should help the driver to take the right decisions and adapt to the traffic situation. Thanks to IoT data, communication between vehicles, infrastructure and other automated vehicles' operator is crucial to increase the safety of future automated vehicles and their full integration in the overall transport system. In particular, intersections with traffic lights can provide useful data about the traffic lights phase. These data can be consumed

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by the vehicles to optimise their speed accordingly for a safely and efficiently cross of the intersection. To test this hypothesis, a complex system had been developed in AUTOPILOT for a full field operational test. It included oneM2M [3] platform, autonomous vehicles, connected traffic lights and a service named Traffic Light Assist (TLA). However, the testing phase of the development of this system proved to be complex and costly to perform directly on the field. To address this challenge, we sought for a tool to simulate the vehicles as realistically as possible. We finally adopt SUMO [2] as a base to create the TLA Simulator. This simulator played a major role during the development phase of the TLA service as a new Cooperative, connected and automated mobility (CCAM) application for autonomous car rebalancing in urban area.

## **The AUTOPILOT project**

### *Overall description*

AUTOPILOT is a project that aims to transform connected vehicles into fully automated vehicles by introducing IoT technologies into the automotive world. An IoT open vehicle platform and an IoT architecture has been developed based on existing and forthcoming standards as well as open-source and vendor solutions. Therefore, in AUTOPILOT, the IoT eco-system will include vehicles, road infrastructure and surrounding objects as IoT objects, with careful attention to safety-critical aspects of automated driving. AUTOPILOT has developed new services on top of IoT to involve autonomous driving vehicles, like autonomous car sharing and rebalancing, automated valet parking, or enhanced digital dynamic maps to allow fully autonomous driving. These services are tested, in real conditions, at five permanent large scale pilot sites in Finland, France, Netherlands, Spain and Italy, which test results will allow multi-criteria evaluations (technical, user acceptance, business impacts, legal issues) of the IoT impact on pushing the level of autonomous driving.

### *Traffic Light Assist (TLA) for Platooning*

In AUTOPILOT, the car sharing business requires the establishment of a car rebalancing service. In order to reduce the time and effort required for the car rebalancing service, the solution adopted is to move multiple vehicles in platoon towards stations with fewer available cars. This mission is performed by a professional driver present in the leading vehicle of the platoon. This means that the leading vehicle is conducted manually by the driver while the other vehicles are autonomous vehicles following the leading vehicle all along the itinerary.

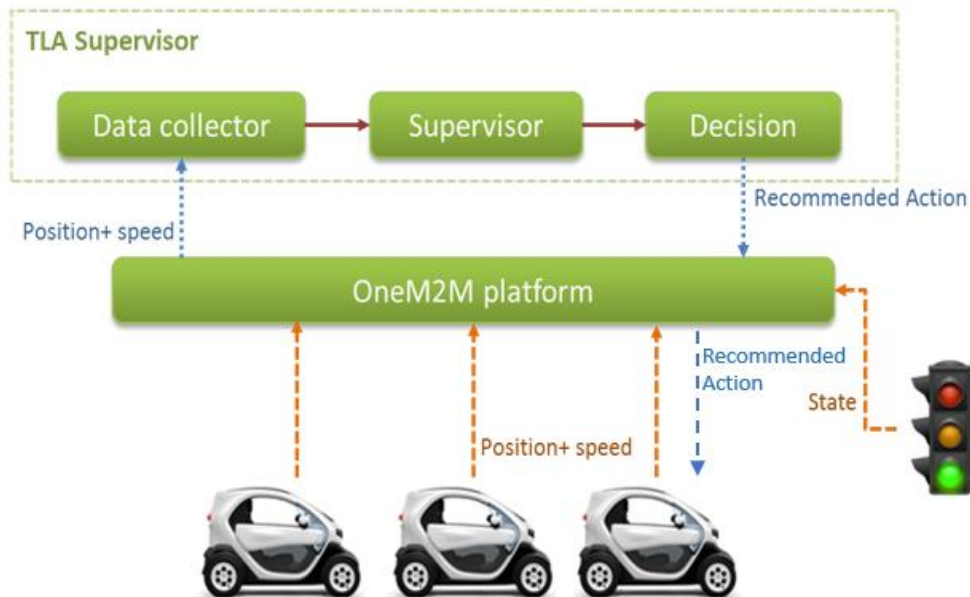
The main challenge facing the platooning scenario is to avoid platoon dislocation while crossing an intersection managed by a traffic light. Unfortunately, existing services like the Green Light Optimal Speed Advisory (GLOSA) systems fails to satisfy this need, since they are designed to advice one vehicle through traffic lights rather than a platoon. To address this issue, a C-ITS Traffic Light Assist (TLA) service was developed. It is a new service similar to GLOSA but dedicated for a professional driver of a convoy of automated cars. This service uses IoT Technologies to help platoons to cross traffic lights without being split.

By collecting data from traffic lights and vehicles, a recommendation is computed and provided to the

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driver in the leading vehicle. This recommendation informs the driver if he can pass the next traffic light considering the present phase (red or green) or if he should stop. Additionally, the TLA does provide a recommended speed (Acceleration Assistant) for the platoon to cross the intersection safely.

As depicted in Figure 1, TLA provides several functionalities like platoon supervision, data collection and decision generator. Relevant data like car position or traffic light state are retrieved from the IoT platform and used to compute a recommendation (decision) which is published into oneM2M and used to inform the driver. Data exchange is done through IoT platform capabilities. To compute a recommendation, TLA uses the next traffic light current state, the time remaining to the lead and last vehicles to reach traffic light. Finally, the recommendation is published as an IoT object containing an action (GO or NOGO), a recommended speed (0, current speed or maximum speed) and a failure flag in case of irrelevant or missing data.



**Figure 1: Traffic Light Assist**

### **Validation of a C-ITS service Traffic Light Assist for platooning by simulation**

Testing TLA services in real conditions appears to be complex and also time and cost consuming. It requires the integration of several components developed in parallel, the usage of autonomous vehicles, of connected traffic lights and a Fleet Management System (FMS) to create the platooning missions. Besides the test and integration phase doesn't enable a full system testing because the testing time during trial phase, which last 2-3 weeks, is limited to the strict minimum and cannot be extended. Thus the usage of a simulation environment that can connects our C-ITS service (TLA) to all IoT data providers (vehicles, traffic lights, FMS) is necessary to perform efficient test and validation of developed components before trial and piloting activities.

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The next section describes our approach and tools for testing TLA in its IoT environment using SUMO (Simulation of Urban Mobility) which will simulate all not available components.

## **Simulation using SUMO**

### *Overall description of SUMO*

“Simulation of Urban MObility” (SUMO) is an open source, highly portable, microscopic and continuous road traffic simulation package designed to handle large road networks. It allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians. Included with SUMO is a wealth of supporting tools which handle tasks such as route finding, visualization, network import and emission calculation. SUMO can be enhanced with custom models and provides various APIs to remotely control the simulation.

In the context of this project, SUMO provides a simulation environment. It simulates vehicles running in a platooning configuration using the embedded Sumo platooning module along a predefined itinerary in Versailles. SUMO simulates also the traffic lights encountered in the itinerary and enables the visualisation of platoon, traffic lights and TLA decisions.

### *Platooning in SUMO*

SUMO is capable of managing the behaviour of vehicles while considering the itinerary as well as other vehicles. As such, producing a platoon behaviour in SUMO consists in defining the itinerary the vehicles should follow and enforcing certain behaviours that keep the platoon together like spacing between the vehicles, the max speed and lane to follow. Finally, to apply TLA’s recommendation, SUMO’s API is used to instruct the leader vehicle to follow the speed and intersection crossing recommendations.

## **The experimental setup**

### *The objectives of the experiment*

The goal of the experiment is to create a simulation environment to test and validate TLA service. The vehicles and traffic lights are expected to continuously send their data to the oneM2M server. Therefore, TLA Simulator will create and send these data to oneM2M server and all communication between the TLA Service and the TLA Simulator will be achieved through oneM2M server. The Figure 2 illustrates the architecture used during the experiment:

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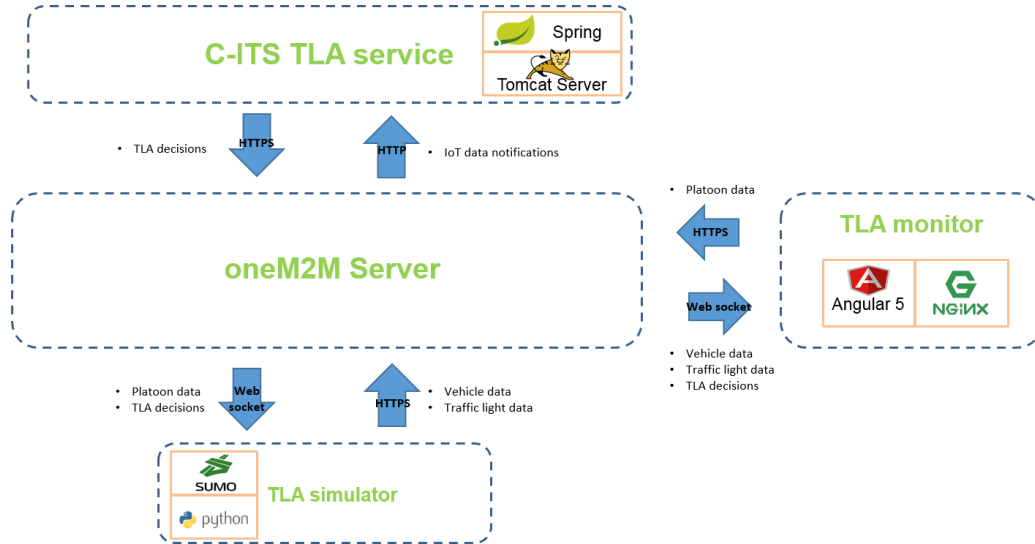


Figure 2: The experiment environment architecture

The architecture contains four main components:

**oneM2M** platform provided by Sensinov<sup>1</sup> to the project.

**TLA service** is a JEE server developed using the Spring-Boot framework and deployed on a Tomcat server. This component sends decisions to oneM2M using HTTPS protocol and uses HTTPS protocol to receive IoT data notifications (vehicle data, traffic light data and platoon data).

**TLA simulator** is a Python program developed using the Traffic Control Interface to access the SUMO simulation and PLEXE [5] add-on to manage platoons in the simulation. It sends IoT data to oneM2M during the simulation using HTTPS protocol, and uses a web socket to subscribe and receive platoon data and TLA decisions from oneM2M.

**TLA monitor** is a web application developed with Angular and deployed on an NGINX server. It uses the protocol HTTPS to communicate platoon data to oneM2M and web socket standard to receive IoT data from oneM2M (vehicle data, traffic light data and TLA decisions).

**oneM2M** “is the global standards initiative that covers requirements, architecture, API specifications, security solutions and interoperability for Machine-to-Machine and IoT technologies.”[6]. oneM2M is a platform that can receive IoT Data and notify any subscriber. Thanks to oneM2M notification system, TLA service and TLA Simulator receive and react to each new notification.

In the platooning test scenario, oneM2M provides TLA Simulator with platoon data in order to create the appropriate configuration for the simulation process; namely, it recovers the vehicles making up the platoon and the platoon state itself. Once the TLA simulator confirms a platoon in a platooning state it subscribes to the decision container and starts simulating the vehicles defined in the platoon. During the TLA test phase, platoon data is created and pushed in oneM2M by TLA monitor.

This TLA monitor is also capable of subscribing to oneM2M resources. This allows it to receive the data generated by the simulator as well as the TLA decisions in real time. Therefore the TLA monitor

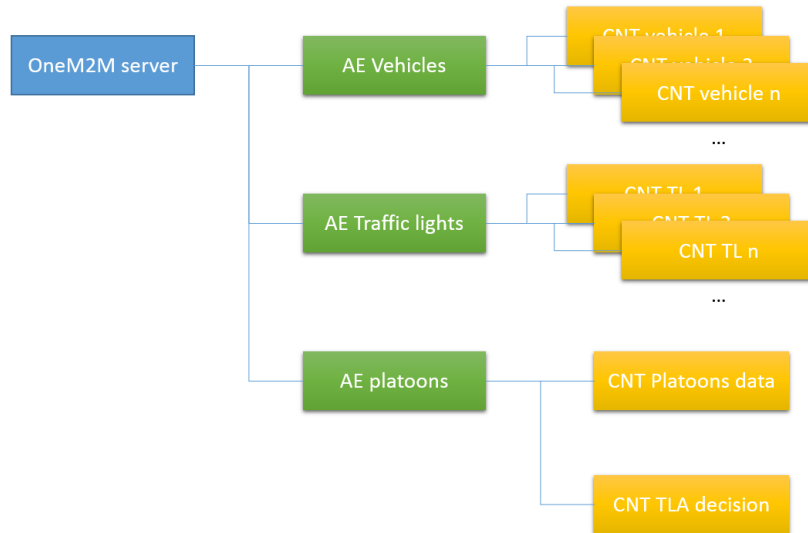
<sup>1</sup> [https:// www.sensinov.com](https://www.sensinov.com)

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can be used as a tool for visualisation. For the experiment, the TLA simulator is operating in similar conditions to the defined scenario of the AUTOPILOT platooning use case. Thus, oneM2M is managing IoT data in the same way as defined for the project. Additionally, TLA simulator is using the same itineraries as the mission's ones for its simulations. The following section will describe these configurations and demonstrate the itineraries used in the experiment.

### *Management of IoT data in OneM2M*

In oneM2M standard, IoT applications are organized as *Application Entities* (AE). Each AE can contain multiple *Containers* (CNT), which in their turn contain multiple *Content Instances* (CIN). Finally, the CIN are the entities that store IoT data. Following oneM2M recommendations, an AE for each of vehicles data, traffic lights data and platoons data are created. Each vehicle will have its own unique container in the vehicles AE. The same repartition is applied to the traffic lights. However, all platoon data share the same CNT. As for the TLA decision, these data have a unique CNT under the platoon AE tree as depicted in Figure 3.



**Figure 3: oneM2M resources tree**

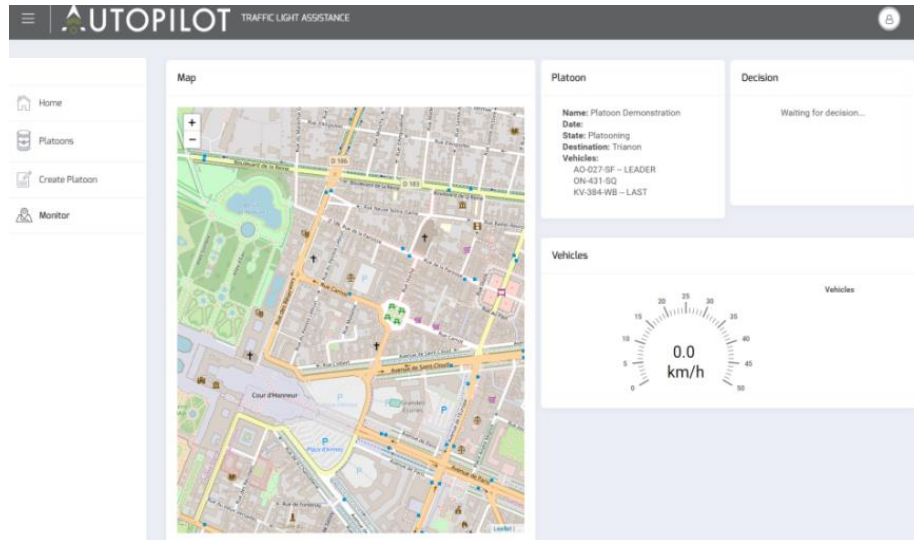
### *Management of itineraries:*

For platooning tests, since we dispose of two stations: “*Hôtel de Ville*” and “*Trianon*”, two itineraries were defined for the trial test (Itinerary1: “*Hôtel de Ville*” → “*Trianon*”, Itinerary2: “*Trianon*”. → “*Hôtel de Ville*”) as showed in Figure 4 with six traffic lights for each itinerary. The TLA web tools as depicted in Figure 5 shows the platoon monitoring graphical user interface.

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**Figure 4: Platooning Use Case stations and itineraries**



**Figure 5: The TLA monitor interface**

In the platooning scenario, platoon data is created and sent to oneM2M with a dedicated service when it detects the need for a platoon. As result, the TLA reacts by loading the data and starts supervising the concerned vehicles and traffic lights. Therefore, these platoon data are necessary to simulate the scenario as closely as possible. Hence, we created the TLA monitor to perform this task for the experiment. This tool is able to create the necessary platoon data; it is capable of identifying available vehicles and itineraries to propose them to the user during the creation process. This tool eases the creation and the manipulation of platoon data, which allows for faster experiments initialisation phases and supervision.

The TLA monitor is equipped with a visualization interface as well. This interface subscribes to oneM2M directly in order to get the data necessary to visualize the movement of the platoon. It shows the vehicles position, the traffic lights position on the map, the vehicles speed and the TLA decisions

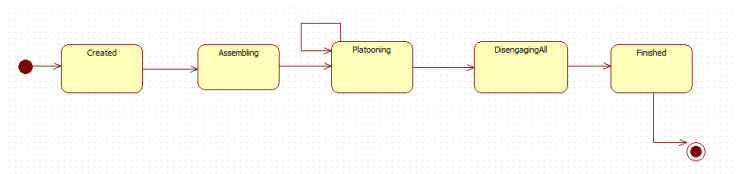
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generated in real time thanks to the oneM2M notification system. Finally, when the platoon ends the TLA monitor can recover the TLA generated logs, which allowed the assessments of the TLA capabilities.

## Experiments and results

### *How to launch an experiment*

With the TLA monitor, platoons can easily be created and manipulated. However, a platoon must go through all its possible state in the correct order from its creation to its end; this condition is necessary for the well-functioning of the TLA as the unconformity to this rule causes an error otherwise, hindering the TLA utility as a result. Figure 8 depicts these states and the possible transitions in-between.

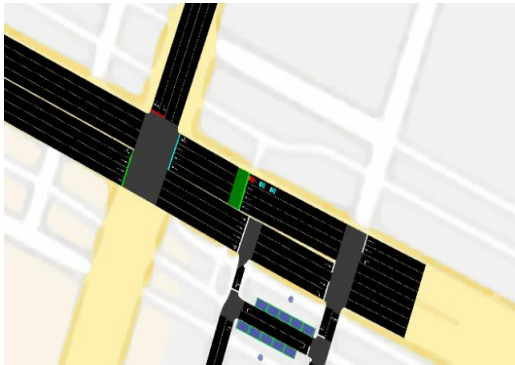


**Figure 6: platoon state diagram**

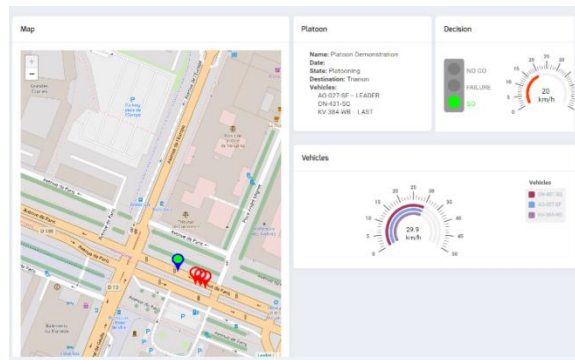
The TLA simulator is configured to only start the simulation when the platoon enters the Platooning state. This condition is meant to ensure that TLA has already subscribed to oneM2M resources in order avoid losing data.

### *Results*

With the TLA simulator, it becomes possible to simulate a platoon of vehicles besides traffic lights. The simulated vehicles were able to follow the defined itinerary while providing the TLA with necessary data in the defined format allowing relevant decisions to be made. The simulated traffic lights as well provided data needed in the appropriate format. It was even possible to indirectly manipulate the vehicle behaviour to respect the TLA decisions (forcing the platoon to stop at traffic light if the decision received is a NoGO decision for instance).



**Figure 7: example of a GO decision SUMO-GUI**



**Figure 8: example of a GO decision TLA monitor**



Figure 9: example of a NOGO decision SUMO-GUI

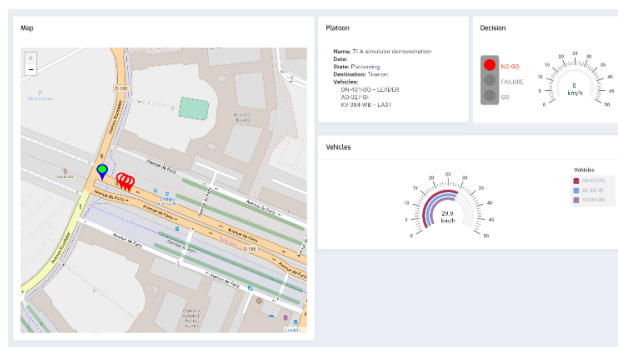


Figure 10: example of a NOGO decision TLA monitor

The figures above show examples of a GO and a NOGO decision. In the first example, the simulated vehicles did manage to cross the intersection without encountering any issue proving that the TLA decision was correct for that situation. On the other hand, in the second example, the remaining time before the traffic light turn to red would not allow all vehicles to cross. Hence, the NOGO decision was generated by the TLA.

Similarly, SUMO allowed assessing the performances of the decision algorithm of the TLA without the need of actual vehicles nor connected traffic lights on the field. It manages to replicate potential situations to compare the outcome with the expected behaviour. As a result, this tool helps identify multiple bugs to fix and potential improvements to the algorithm that were implemented even before the automated vehicles were ready for the operational field test.

Furthermore, the SUMO-GUI has shown to be a very useful tool for visualization as it allowed featuring decision data generated by TLA service and retrieved from oneM2M (like the decision featured in the example above as coloured polygon on the intersection to cross).

SUMO has shown to be effective as a traffic simulator. It allows multiple configurations to control the behaviour of the vehicles. Furthermore, these data was retrievable to be stored elsewhere, which constituted multiple logs useful for the pre-assessment of the service. The data retrieved was even used as IoT data supplying the oneM2M platform, which allowed testing the performance of the notification mechanism of the platform as well. By using the subscription mechanism of oneM2M, the usage of SUMO created a test similar to the final scenario sought for the project.

Thanks to SUMO's functionalities, TLA service got a useful testing tool allowing for a faster development and maintenance process. SUMO has proved to be a precious tool that can be used for different kind of Field Operational Test in order to pre-test the algorithms developed without operating actual vehicles.

## Conclusion

In AUTOPILOT Field Operational Test FOT experiments, testing activities are time and cost consuming. Indeed, piloting activities require a complex environment involving multiple stakeholders (traffic light environment, autonomous car running in a platoon configuration, drivers, experimental

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environment requiring authorization) which reduce the testing phase duration and increases the risk of failure during piloting. Our approach using SUMO as data provider to IoT platform and an IoT data consumer associated to TLA monitoring tools appears to be very efficient to reproduce real condition for testing the usage of IoT in Versailles platooning use case. As a data provider, SUMO simulates data that can be generated by multiple autonomous cars running in a platoon using SUMO embedded platooning module (see [5] about PLEXE), and by a traffic light controller simulating all connected traffic lights available in planned itinerary. The TLA cloud service takes advantage of this simulation environment to test and validate all its features (data collection, cars and traffic lights tracking, distance computation, IoT data querying optimisation). As an IoT data consumer and by using the subscription mechanism of oneM2M, SUMO receives IoT data advices generated by TLA service and displays in its GUI in real-time the recommendations, easing the validation of functional behaviour of TLA services' components. For future development of CCAM application using intermodal traffic systems including road vehicles, public transport, IoT data and pedestrians, our approach showed multiple advantages and thought it can be generalised.

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