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Tooled Methods for the Simulation of Deployment of Safe Services in the Internet of Vehicles

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Abstract

Cars are evolving into full mobile computers capable of executing advanced applications and communicating directly with each others using V2V (Vehicle to Vehicle) communications and with far end applications running in data centers or Cloud Computing using V2I (Vehicle to Infrastructure) communications. In this emerging context, it is now possible to envision innovative services such as information dissemination, safe driving, road accidents mitigation and so on that can be dynamically deployed in this infrastructure. The objective of this work is to investigate toolled methods for the simulation of such a new connected car environment in an exemplar services. The selected scenario is the waste collecting management service deployment in connected trucks operating in a city.

Keywords: Internet of Vehicles | Edge Computing | Cloud Computing | Transportation Services | Formal Modelling | SysML | SUMO Simulator | Distributed Systems.

1 Introduction

Nowadays vehicles have become essential items in daily life of people and in the management of big cities. The growing number of these vehicles on the roads increases the need to significantly reduce the traffics, pollution emission, risk of personal injury, material damage and so on. According to Transport and Environment organisation,¹ the almost a third of trucks tested emit dangerous levels of air pollution. Similarly, road safety situation report carried out by the World Health Organization (WHO), road accidents are responsible for 1.35 million² deaths every year worldwide. Many researchers have looked at the Internet of Vehicles (IoV) as one potential solution to help improving the situation. This concept originated to connect multiple users with vehicles to ensure safe and efficient road conditions through one communication from vehicle to any entity (V2X) which must be reliable and in real time.

Since vehicles are systems equipped with computing and communication capabilities and more and more edge computing infrastructure is being deployed (Edge Computing), vehicles can communicate directly together if close enough (V2V) and/or with the infrastructure (V2I) at any time. With their more and more increased computing capacity, they are also able to collect and process a large amount of information in real time (weather, road conditions, traffic conditions, etc.) coming from their embedded sensors or from the infrastructure [2]. However, since vehicles are mobile and move at variable speeds, the conditions in which they evolve are not fully predictable including their connectivity [5]. Hence some services can not be executed only onboard and therefore the vehicles need to interact with far-end applications, such as intelligent driving assistance, and high resolution maps creation services. Cloud Computing and Edge Computing are those technologies that will help to execute these applications and reduce

¹<https://www.transportenvironment.org>

²1.35 million: number from <https://apps.who.int/iris/bitstream/handle/10665/277372/WHO-NMH-NVI-18.20-fre.pdf>

the response times distributing the processing between the vehicles, the edges and the cloud computing. Thus, this system formed by connected vehicles, the edges and the cloud computing can be seen as a distributed system of fixed and mobile components, connected through an underlying communication infrastructure such as 5G [12].

In this paper, the objective is to model, analyze and validate a representative since that is a route optimization service for the collection, transportation and deposit of waste in a city. The aim is to formally design the waste management planning service and verify its operation and behaviour by simulation to increase confidence in the services before its real deployment. The used simulator is called SUMO (Simulation of Urban MObility) [10]. It is an open-source and highly portable simulator tool that allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians.

This paper is structured in 5 sections. Section 1 is a general introduction to the context. Section 2 presents the objectives of the paper. Section 3 presents the problem statement where we describe the system model and system properties formal modelling. Section 4 presents an implementation and an evaluation in SUMO. Section 5 is a performance evaluation after doing simulation tests in SUMO.

2 Related Works

Internet of Vehicles has been the topic of numerous contributions in the literature. Several surveys have been published [13] highlighting the challenges in the area in terms of infrastructures and mechanisms to support efficient services deployments and connectivity among vehicles and infrastructures and between vehicles [7]. More recently, more focused papers have been published addressing the interactions between the vehicles, the Edge and the Cloud Computing infrastructures (that corresponds to our considered context). For instance, in [9] authors present a framework to build advanced computing systems for autonomous vehicles. The paper addresses three categories of problems: cutting-edge computer system designs (real-time data processing as autonomous vehicles are mobile and often have power restrictions in term of energy), V2X applications (how vehicles cooperate with each other and with the infrastructure) and autonomous vehicle security (protecting autonomous driving on-board computer systems from attack). In [8] authors focus on the design of a web-based car monitoring solution that allows network vehicles to exchange their mobility information to get quick road awareness using the specification of the service vehicle information and vehicle signal specification. In [3], authors propose a solution to optimize waste collection and optimize vehicles service routes in real time based on signals sent by intelligent waste bins. In [11], authors investigate using artificial intelligence algorithms for solving the vehicle routing problem with time windows for a heterogeneous fleet of waste collection vehicles. Authors of [4] provide a contribution that aim to evaluate the performance and mobility of vehicular networks using the SUMO simulator used in this work. In [1], authors aim to reduce the delay and guarantee the delivery of messages in city environment where the density of vehicles is high. The authors introduce the concept of Dynamic Fog (DFCV) that consists on using the Fog Computing and Cloud Computing for the dissemination of messages.

All these works have been inspiring this contribution. However our focus in this contribution is different as it aims to address the specification of a vehicular service evaluate its behavior in term of adaptation in a dynamic context that is the collection of waste in a city.

3 Problem Statement

The research questions we aim to address in this paper are the following: How to model a vehicular service using a formal modelling language? How to model constraints in terms of mobility starting points and ending points (i.e. trucks parks)? And how to model constraints in terms of collecting point of waste containers?

The used method consists on specifying the different representative scenarios of the waste containers collection and identify the functional and non-functional goals (i.e. requirements) of such a service in the frame of these scenario. In addition, the method aims also to identify the constraints on the connected vehicles in the context of each scenario i.e. the context in which the waste collection planning service will be deployed (i.e. planning of paths of connected trucks in a city to collect waste containers) and verify whether the designed service is compliant with the identified requirements at run-time.

4 Proposed Solution

4.1 System Model

The used high level defined scenario is the following : A company is responsible of waste collection in a city. It has deployed a set of waste collection points in the city where a set of connected containers are installed. Citizens use these containers to deposit their waste over time. Containers could only be unloaded at specific time intervals by the company defined by the city regulation. For that, the company has a set of electrical and connected trucks that are used for collecting the waste. Trucks are parked in different sites in the city. Containers are also installed in different sites in the city. When they are filled above a certain predefined level (threshold), a message is sent by the containers embedded sensors to the back-end waste collection management service deployed in the cloud (via appropriate wireless network and protocol). At periodic time, this cloud service processes the messages and identifies the set of containers that need to be unloaded and their respective GPS positions. Next, this cloud service selects the set of trucks to use for the collection of waste and plan accordingly all their trips.

The proposed system model introduces three layers namely the connected vehicles layer (i.e trucks), the Edge layer and the Cloud layer:

- The three layers are connected together using network infrastructures. The Cloud Computing and the Edge layers are connected via fixed backbone network.
- The Edge layer consists on a set of road side computing and networking infrastructure to which vehicles (in the vehicular layer) can connect using wireless communications technologies (e.g. 802.11p).
- The terminal layer is composed of all the connected vehicles, connected waste containers, traffic lights, etc. These objects are responsible for the collection of data environment and transmit it to the edge layer so that data can be processed and stored.

The Cloud layer contains all services that are accessible by the connected vehicles. It is responsible for processing and storing the information received from each Edge node and sometimes returns a response following a request.

4.2 System Properties Model

The services offered by the distributed system (based on mobile and fixed components) in connection possibly with the safety of vehicles and the safety of passengers and pedestrians, may have requirements and constraints in terms of reliability and response time (so-called functional requirements) and so-called non functional requirements that result from the cooperation between distributed components of the system, fixed (Edge and Cloud) and mobile (vehicles).

Non functional requirements are not directly related to the services offered by the system, but can be nevertheless critical for the proper functioning of the system. These requirements may be related with time and/or space: V2I and V2V communication constraints (e.g. delay, speed), availability of processing resources (e.g. CPU, memory), in relation to arrivals and departures of vehicles (e.g. mobility model, breakdowns). These requirements may also be neither temporal nor spatial, but simply resulting from a failure or unavailability of resources in the infrastructure. Therefore, these non-functional requirements may no longer be satisfied (temporarily, partially or totally) over time.

In order to model the system properties, we will base on specific use-cases to identify them. These properties include the functional and the non functional requirements. Once these requirements are identified, we will derive sub-goals from these goals which will identify sub properties of the system. The process will stop when we'll know that these properties are either intrinsic properties of the vehicles, network, edge computing or cloud computing infrastructure or these are properties that should be provided by the cloud services or the connected vehicles controllers.

In the following, we present the different considered scenario to identify these system properties and model them formally using SysML modeling language [6]. SysML supports all the cycle of software engineering from the specification, analysis, design, to the verification and validation of systems and systems-of-systems design. This language is chosen in this work for its high capacity to model any engineered system and also because it is a full ISO standard since 03/2017 [6].

The requirements of the system have been captured in Papyrus SysML and specified as shown in figure 1. We mention in the diagram to verify that certain requirements are indeed satisfied by blocks from the block diagram. To also make a verification using the activity diagram.

The block diagram describes the architecture of a system as a block which can be decomposed recursively into other blocks to the basic elements of the structure. The structure of system which resulting is therefore a hierarchy of blocks. The blocks are linked together by relation which can mainly be either a composition or an aggregation relation. Our system is essential made up of vehicles, wastes containers, edges nodes and Cloud, hence the use of composition link to connect our different blocks. The wastes containers are equipped with an electronic card and sensor for their operation. However we will not enter into the composition of the vehicle. In each block we define the different variables, operations to be performed and if necessary the constraints.

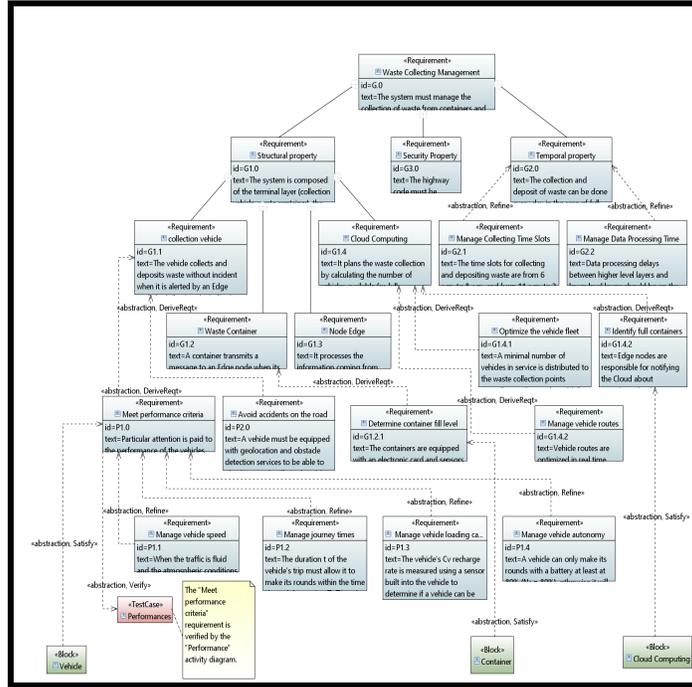


Figure 1: SysML Requirements Diagram Specification

5 Preliminary Implementation and Evaluation

We have implemented these scenarios and corresponding use cases in the SUMO simulator (Simulation of Urban MOBility).¹ In this tool, each vehicle is individually simulated and has its own route. We have then used SUMO version 1.14.1 for Windows and OpenStreetMap² to create a map of the City of Evry (in France), convert it in a format understood by the simulator using **netconvert** tool and finally imported it in SUMO. Next, We have added additional objects (polygons) in the map representing mobility constraints (e.g building, rivers, etc.)³.

6 Conclusion and future work

In this paper, we presented a work which objective was to formally model a innovative service in the context of connected vehicles. The chosen services is the waste collecting management service in a city and the chosen modeling language is SysML.

We have conducted all the phase of the proposed tooling method from the formal specification of the service towards its simulation in a realistic urban mobility simulator that is SUMO. The learned lesson is that this global process is very important for the specification, development and test of innovative services in the context of Internet of Vehicles to understand their functioning and make them more optimized and safe.

¹<https://www.eclipse.org/sumo/>

²<https://www.openstreetmap.org>

³<https://sumo.dlr.de/docs/Networks/Import/OpenStreetMap.html>

Our future work is to advance the modelling part by introducing more artefact in the formal models related to this ecosystem and also enhance the capaV2V communications that have not been considered in this work. These V2V communication can be of paramount benefit to this future ecosystem to leverage the provided services.

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