Dynamic road lane management study : A Smart City application

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A Smart City Application

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***Abstract*— Our SMART CITY contribution is transportation-oriented in that it proposes a dynamic road lane management system in order to share appropriately the space devoted to traffic. After a historical view of a series of solutions from physical to ICT supported, we present our proposal extensively supported by up-to-date ICT. Following a main presentation, we describe the system architecture and its working conditions. Then, we present the proposed simulator designed to study operating and driver's conditions with respect to the new traffic signs proposed. We also describe a Mock-up technology validation and give preliminary information on in-the-field deployment.**

This paper is an extended version of the paper [29] awarded at the IEEE 3rd International Conference on Advanced Logistics and Transport (ICALT'2014) conference.

***Keywords*— smart city; ambient intelligence; ubiquitous computing; data vitalization; location-based services; mobile internet; internet of things; dynamic lane allocation; simulations; acceptability studies**

INTRODUCTION

In recent years, the "Smart City" concept has emerged to describe how investments in human and social capital and modern Information and Communication Technologies (ICT) infrastructure and e-services fuel sustainable growth and quality of life for its inhabitants and workers.

In Smart City systems, two opposite approaches can be used: 1/ Elaboration of an opportunistic system allowing access to collected information and its "vitalization" by integration – interaction – aggregation in a non-predetermined way; 2/ Well-defined systems able to solve identified problems, working in a specific clearly-defined and modeled situation.

In the first case, according to Z. Xiong [1], the "Smart City" principle in opportunistic perception is based on the concept of "Data Vitalization". The idea is to give data life, to combine separated data by avoiding information islands, to build a combination between each type of data, and to increase utilization of data. The main issue concerns sharing and integration of data that were initially separated due to their types and different collection methods. New contextual access and use of these data are fundamental in relation with emerging non-expected situations.

While in our international China-France academic research project we study these two approaches, in this paper we focus on explaining the second approach oriented to a precise Smart City system, the goal of which is to solve a particular problem related to traffic management in confined circulation infrastructure, avoiding congestion by better allocation of traffic lanes. In this case "data vitalization" is not the main goal. In our case, we have chosen to study the design and implementation of a system, allowing appropriate use by private and professional vehicles and their drivers of a limited circulation infrastructure by extensive use of ICT (Information and Communication Technologies).

Consequently, our main contributions to this paper are: 1/ Identification of main characteristics and design of an intelligent road lane management system as a Smart City application; 2/ Integration of ICT and appropriate user interfaces in the system, allowing effective communication and collaboration among actors; 3/ Development of a simulator validating system function designed to study drivers' acceptability and security of proposed User Interfaces, mainly oriented towards new traffic sign understanding and interpretation in dynamic driving conditions; 4/ Technology validation of main ICT principles used in the mock-up, namely: Location-Based Services (LBS) and Internet of Things (IoT).

The next sections of this paper are structured as follows. After a state-of-the-art in dynamic management of road lines from historical, concrete and bibliographical points of view, we present the main characteristics of our extensive ICT-based dynamic road lane management system. Then, we describe its architecture from physical and digital point of views with the ICT technologies used. The following section is devoted to presenting the simulator with its organization, functionalities and main utilizations. A technology validation mock-up is explained in the next section, while the last section is devoted to presenting the results and the in-the-field deployment process. This paper ends with some conclusions and expected prospective actions.

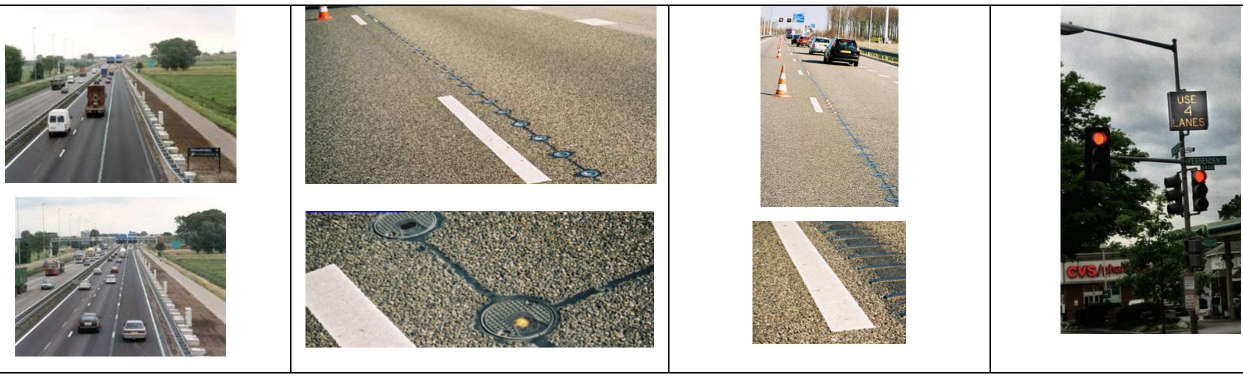
I. STATE-OF-THE-ART IN DYNAMIC MANAGEMENT OF ROAD LANES

Our study concerns dynamic management of road traffic, which is regularly increasing both in towns and outside built-up urban areas. The first approach designed to allow increase in traffic leads to solutions such as increasing the number of lanes, while the second approach aims at segmenting traffic according to categories (private vehicles, heavy vehicles, public transportation, priority vehicles) by proposing specific development and traffic rules, with, in particular, the creation of specialized lanes (bus, tram, trolley). This second choice can lead to satisfactory solutions provided that there is sufficient space.

a/ Heavy solutions

b/ Golden bridge SF manual dynamicity

c/ More easier solutions



d/ ICT based solutions with horizontal and vertical signs

e/ Emergency / Stop lane use and driving orientation reversibility

Fig. 1. Set of existing solutions [2]

When space is lacking and the frequency of this type of specialized traffic is not sufficient, there is a sense of waste and poor management. A third solution then emerges, i.e. dynamic allocation of lanes to different types of transportation. A significant study consisting of data gathering, analysis and classification was carried out by J. Nouvier from the CERTU (Center for studies on networks, transportation, urbanism and public construction) [2], (Figure 1).

J. Nouvier [2] collected and presented a large number of varied solutions, from the more physical (ad hoc movement of low walls with trucks) to the more informational (signposts with variable displays), enabling lesser or greater speed of dynamicity. For dynamic bus lane allocation it is important to mention Lisbon experiment [3, 4] We were also inspired by the works [5, 6].

II. Our ICT-based Dynamic road lane management system

It is an established fact today that telematics or embedded and/or mobile ICTs can provide solutions leading to a very high dynamicity (clear a lane for a bus or an ambulance in real time), provided that users are sufficiently informed and that regulations are complied with in terms of transportation (or suggestions to modify it) and, in particular, of user safety. Hereafter, we give a brief description of the ICT vision, in a system-perspective.

"Dynamic circulation lane allocation" aims at providing a system designed to share circulation lanes dynamically between public transportation (buses) or rescue services (fire-fighters and ambulances) and personal vehicle transportation in order to share traffic lanes appropriately in the context of low frequency of specialized traffic or lack of space (impossibility or inadequacy of static allocation of circulation lanes). When there are no buses, all lanes are allocated to general traffic. When a bus approaches and on the bus driver's request, the right-hand lane is reserved for it. Once the bus has passed, the reserved lane is returned to general traffic (Figure 2). However, if all lanes are already jammed, the system switches to "static mode", i.e. the right-hand lane is allocated to buses permanently. More sophisticated situations are also possible (Figure 3). In (3a & 3b) a one-way sharing line in the narrow part is alternatively used by opposite running buses. When two opposite running buses are present at the same time, two lanes are allocated to them and only one lane is devoted to personal vehicles (3c). In (3a &3b) the change in orientation of the central lane is proposed. Dynamicity is less in this case because, for security reasons, long periods of time are needed to be sure that no buses are still engaged in this lane at the time of change.

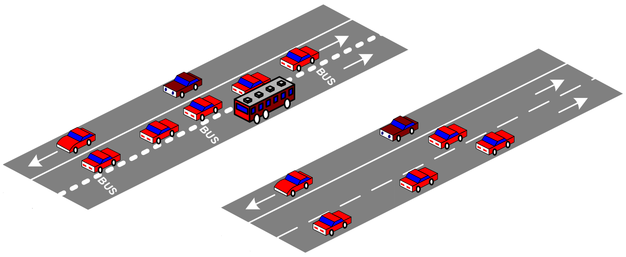


Fig. 2. Dynamic circulation lane allocation example

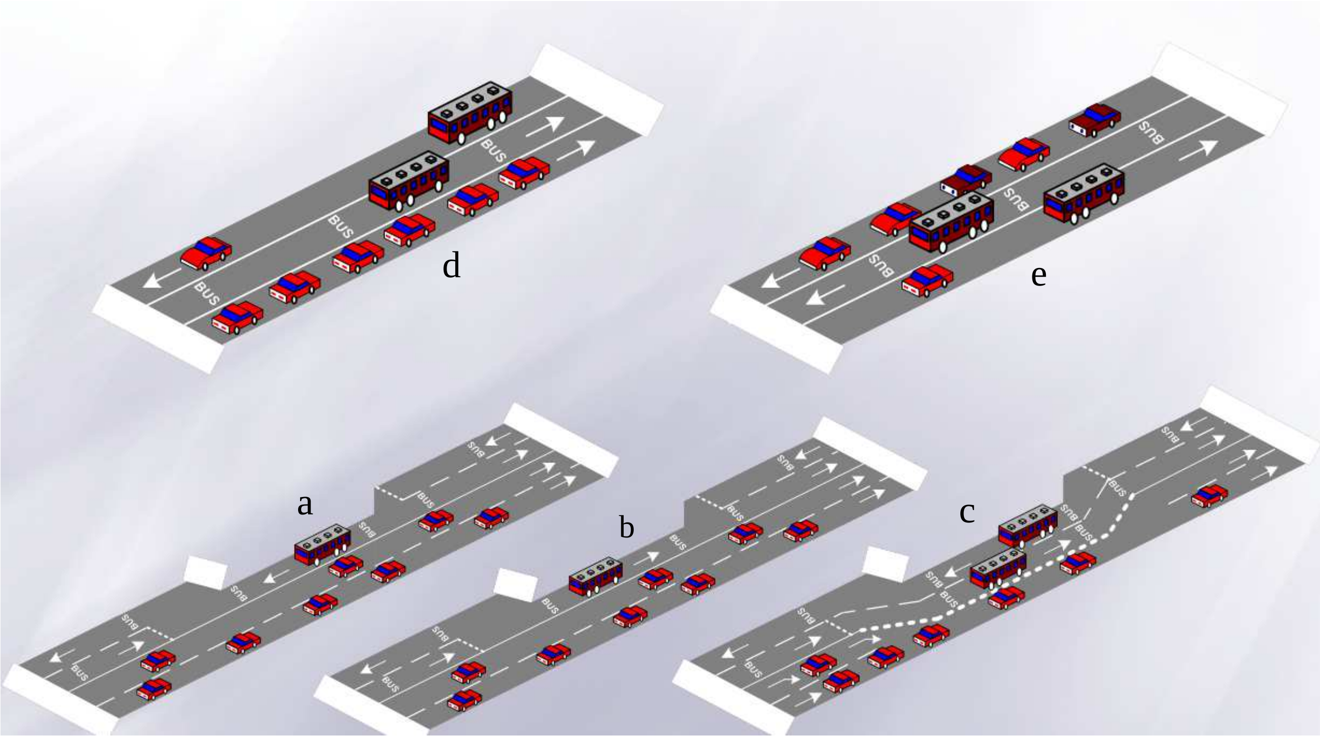


Fig. 3. More sophisticated situations are also possible

II.1 Overall view

The global view of our approach is shown in Figure 4. The infrastructure is based on a multi-lane road with sensors allocated under and near it, vertical and horizontal signs with associated actuators, and a management system connecting them. On the road, sensors, collecting traffic situations and specific demands from authorized drivers (buses, emergency vehicles, etc.), are able to communicate observed situations to the management system. This system is able to decide on appropriate reactions complying with the management policy elaborated by traffic authorities, and propagates appropriate commands to vertical and horizontal road signs as well as the new system status to all users by appropriate media (radio, GSM, Wi-Fi, etc.) to inform them of expected behavior (use of reserved lanes for a bus by non-priority drivers if no bus is expected, leaving a lane which is now reserved for priority drivers when a bus is approaching, etc.).

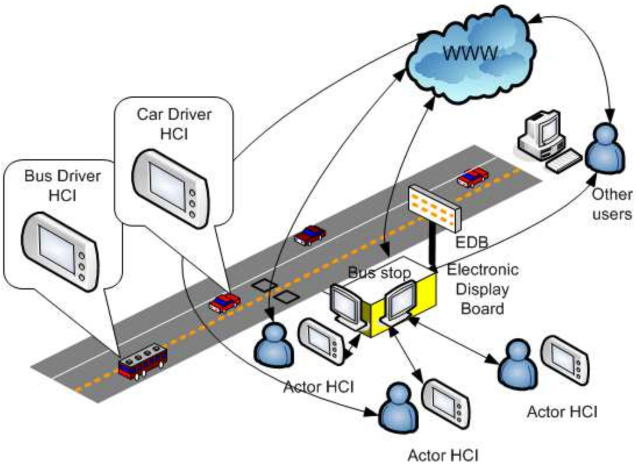


Fig. 4. Global view of the dynamic lane allocation environment

II.2 *System architecture*

System architecture aims at identifying the main components and information exchanges (Fig. 5). In and near the road lanes, information sensors are installed to collect the state of the traffic and priority requests. In and near the lanes, vertical and horizontal signaling is also implemented, able to receive positioning commands from the management system. Main users of the system are active users such as bus drivers, ambulances, firemen, possibly trucks with their vehicles which require behavioral changes on lane allocation. Passive users, mainly personal vehicles, are receivers of the imposed modifications either by observation of displayers' changes, or by means of more direct information sent to in-vehicle User Interfaces. Other circulation infrastructure users are pedestrians, cyclists, etc. also concerned by infrastructure changes. The last category of users consists of traffic and information managers, who are either decision-makers of regulation strategies or concerned by traffic information broadcast to external information systems such as specialized media, TV, etc.

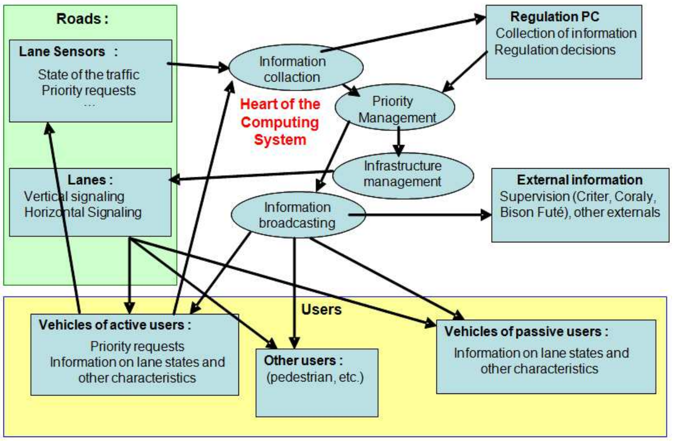


Fig. 5. System architecture diagram

All the elements are included in the management system, i.e. collecting, aggregating, processing and broadcasting the appropriate information to all users. This system vision (Figure 5) involves the main elements, namely:

- sensors in the lane concerned by collecting traffic situations and priority requests;
- vehicles of users who request priority and receive information regarding the state of the lanes (allocation of lanes, authorized or unauthorized dynamic priority requests) for on-board display;
- vehicles of passive users who cannot take action, but who receive information regarding the state of the lanes (whether or not they are dynamically allocated to different user categories: prohibited lanes, lanes reserved for priority vehicles, unmarked lanes);
- the regulation PC. This is a vital component for coordination, which chooses the lane management mode: static allocation when traffic is heavy with a large number of buses or prioritarized vehicles justifying static allocation of prioritarized lanes, or dynamic allocation if bus traffic is less and there are more personal vehicles. Action by the regulation PC is not systematic, and occurs only when the management mode changes (from static to dynamic and vice versa).

The core of the management (computing) system is structured in four modules:

- The information collection module, charged with receiving the information sent by in-environment sensors and propagating it to the priority manangers and the Regulation PC.
- The priority manager is responsible for applying the lane road allocation strategy as decided by the Regulation PC: static mode if traffic is heavy, or dynamic mode if it seems better to blend the traffic and allocate lanes on request.
- Instrastructure management propagates priority manager choices to vertical (variable message signs) and horizontal (on the road) signaling;
- The information broadcasting module is charged with propagating the current situation to all circulation users and media.

In this dynamic system, real time data exchange between vehicles and infrastructure must take place as automatically as possible and in compliance with environmental constraints. Human participation in these activities must be limited to essential situations, as human resources are the most critical, and must be primarily devoted to driving activities. In this way, communication must be established between things (in the IoT approach), allowing actuators (in vehicles), sensors (on the road) and other system elements to communicate mainly without human participation.

II.3 Internet of Things

The Internet of Things allows static and dynamic environmental objects to communicate and update real situations. The basic idea behind the concept of the Internet of Things (IoT) is the pervasive presence around us of a variety of things or objects - such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [7].

At first glance, the concept of the IoT recalls the idea of Ambient Intelligence (AmI) and Ubiquitous Computing (UC). The former refers to electronic environments that are sensitive and responsive to the presence of people. In an AmI world, devices work together to support people in carrying out their everyday life activities, tasks and rituals in an easy, natural way, using information and intelligence that are hidden in the network connecting these devices; when devices are smaller and more integrated into our environment, only the user interface remains perceivable by users [8]. UC focuses on the omnipresence of processing devices, which are small, inexpensive, robust, networked, and distributed at all scales [9]. The concept of the IoT is closely linked to AmI and UC, but its central issues are to make full interoperability of interconnected devices possible, providing them with an ever higher degree of smartness by enabling their adaptation and autonomous behavior, while guaranteeing trust, privacy and security [10].

As stated by the author of [11], advanced cars, trains, buses as well as bicycles along with roads and/or rails are becoming increasingly more instrumented with sensors, actuators, and processing power; roads themselves and transported goods are also equipped with tags and sensors that send important information to traffic control sites and transportation vehicles to better route traffic and help manage depots. Several works have been carried out to describe IoT applications in the transportation and logistics domain. We can state that parking sensor information and traffic data from the streets of Barcelona are processed by API web services to provide output on available parking places in the designated area, including traffic conditions and estimated arrival time for each parking spot.

From a technological point of view, to integrate “anything” into the Internet, identification, sensing and communication technologies are key elements. One of the most widely used is RFID systems, consisting of readers and tags. The tags are attached to each object with its unique identifier and related information stored inside it. When receiving appropriate signals from the reader, a tag nearby can respond to the query to announce its presence and transmit the information contained. Thus, RFID systems could be used to supervise the status of objects in real-time, where objects do not necessarily have to be within sight. Due to the cheap cost and low energy consumption of RFID systems, their use has become widespread in industry, especially in the trading network [12]. Auto-ID Labs [13], a leading global network of academic research laboratories in the field of networked RFIDs, has made tremendous efforts towards standardization with its successor EPCglobal [14].

Sensor networks are also crucial parts in the IoT architecture. According to the author of [10], sensor networks are able to cooperate with RFID systems to better track the status of objects, i.e., their location, temperature, movements, etc. Sensor networks are made up of a large number of nodes distributed in a certain way, which will report sensing results to a small number of nodes (sink). A huge amount of research work has been carried out on sensor networks in recent decades, to tackle problems at all layers of the protocol stack [15]. Besides ordinary objects, devices in which a certain degree of intelligence is embedded also need to be included in the network. Varying according to implementation, communication technologies in smart devices could be Zigbee, Bluetooth, low-power WIFI and 6LoWPAN [16] [17] [18], enabling their connections to the network.

Due to the heterogeneity of the objects and the diversity of the applications and services based on them, the IoT architecture usually contains a software layer or a set of sub-layers which is interposed between the low level of objects and the high level of applications. The layer(s) can also be referred to as middleware. In recent years, the Service Oriented Architecture (SOA) approach has been widely adopted to build the IoT middleware solution [19] [20], since the SOA contains a service composition layer and/or a service management layer and allows easy reuse or mash-up of services. More technical explanations would seem out of the scope of this paper and its audience.

II.4 Location-Based Services

Contextualization is a second important aspect of this kind of systems. All exchanges in the system must be carried out just in time and, for the most part, depend on location. Communication between a bus and a detection sensor on the road, the goal of which is to inform the system that a bus is approaching, thus leading to a lane allocation change, must be conducted at an appropriate distance, in order to allow system reaction according to the actual fluidity of the traffic [21]. The Location-Based approach is the answer to this problem [22].

Location-Based Services (LBS) provide mobile users with personalized services according to their locations. In actual fact, LBS have evolved from online map services and other internet Geographical Information Systems (GIS) applications to the current form where more lightweight mobile devices (smart phones, wearable computers, etc.) are used to deliver services, thanks to the development of Global Positioning Systems (GPS) and other location sensing technologies [23]. The authors of [24] view the evolution of LBS from other perspectives, (a) from reactive to proactive, (b) from self- to cross-referencing and (c) from single- to multi-target: reactive LBSs are explicitly invoked by the user, while proactive LBSs are automatically initiated when a predefined event occurs; user and target coincide in self-referencing LBSs, while cross-referencing LBSs make use of one target location for service-provisioning of another user; the major focus is on tracking one target's position in single-target LBSs, while in multi-target LBSs, the focus is rather on interrelating the positions of several targets. Integration of proactive and cross-referencing LBSs contribute to our system design when integrating the IoT, which allows static and dynamic environmental objects to communicate and collaborate with each other. Just as in other interactive systems, user modeling is a basic consideration in LBS as the services finally delivered must correspond to user needs. We have to make sure right from the start who the users are and what kind of services they need. One description of user modeling could be "the acquisition or exploitation of explicit, consultable models of either human users of systems or the computational agents which constitute the system" [21]. We are pleased to extend these "computational agents" to objects in the IoT, since an object could either provide or consume LBS in the form of a "Web Service".

Location modeling is also a central part of LBS. One static location can be represented either as a geometric coordinate such as "48°51′29.6″N, 2°17′40.2″E", in the World Geodetic System (WGS) [22], or as a symbolic expression such as "Champ de Mars, 5 Avenue Anatole France, 75007 Paris". The difference stems from the two distinctive models for representing space [23]: geometric models that "treat location and objects as points, areas and volumes within a reference coordinate system" and symbolic models that consider locations as sets and located objects as members of sets, so that "interrelationships are established among a set of locations and a set of located objects". Geometric models are largely adopted by GIS applications, while symbolic models are more easily accepted by the general public. Depending on the scenarios of applications or the degrees of accuracy, it would be helpful to carry out some combinations or merges of these two models. For example, a semantic location model was developed by the authors of [27], able to create location hierarchy (belonging to one location and being a boundary point from and into which an entity can leave and enter) and exit hierarchy automatically without manual intervention. Dynamic location data, in other words spatiotemporal data, could provide more information (especially in real-time management systems), making modeling and processing of spatiotemporal data hot topics in LBS.

III. SIMULATOR DESIGN, IMPLEMENTATION AND USE

III.1 Simulator design

In the ADVICE project, which was a research project devoted to feasibility studies, our role was to propose system architecture and demonstrate feasability by a simulator and a mock-up, validating technological aspects. After describing functionalities and architectural aspects, this section will present simulation design, implementation and use.

We decided to use a Multi-Agent approach implemented in Java using multi-thread technology, such that each active element can run at its own pace unless there are tasks that would involve more than one element (synchronization of threads is possible). This approach aims at integrating elements into a unique framework, whose goal is to simulate the IoT, and at testing communication and collaboration between the elements.

Main components of the simulator are: The road is represented as a rectangular area and is made up of several lanes (35 for the current version), where each lane takes a straight line form. Each lane is divided into a series of squares for relative location modeling, so that the positions of vehicles and signaling facilities as well as sensors can be found easily. The squares can also receive horizontal signaling to inform users about the current status of lane allocation, for example "open to all", "reserved for bus" or "closed to all", where the number of squares shows the length of the allocation area. A top view of the representation is shown in Figure 6.

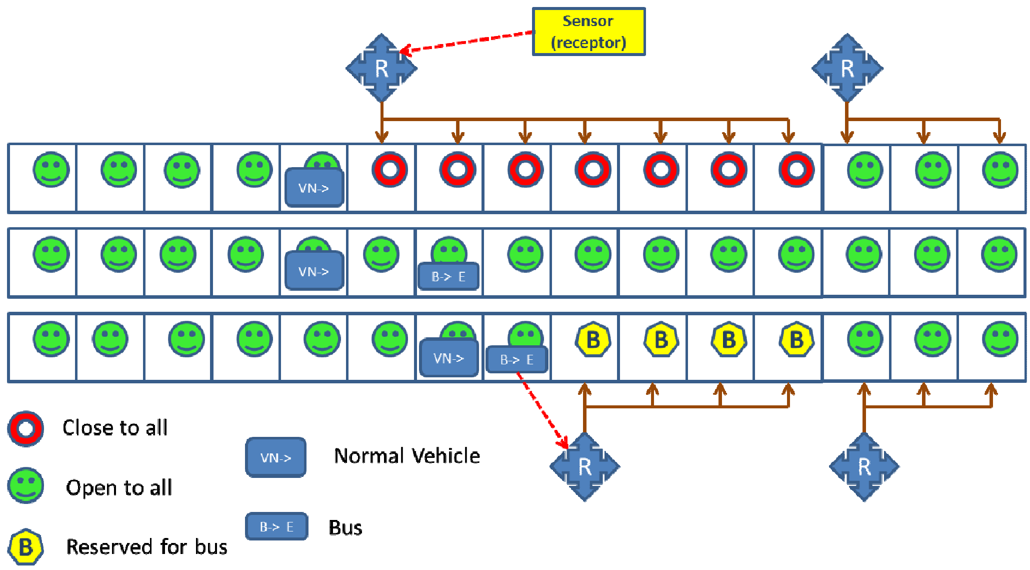


Fig. 6. Simulation scenario view

Communication and collaboration among objects complying with IoT (Internet of Objects) simulation is: a set of sensors is located on the lane to automatically detect the presence of priority vehicles, where each sensor is in charge of only a certain range of region and is able to notify the management center to perform operations according to their locations (proactive LBS). On the other hand, priority vehicles could send a priority request to the nearest sensor in front, to initiate lane allocation (reactive LBS). When a priority vehicle leaves the region, the sensor detects it and notifies the management center, which gradually sets the allocation back to normal. The sensor is also responsible for delivering information about current traffic status within its range of region via displayers such as vertical signaling. The information collected can also be presented as an embedded interface in the vehicle on-board display.

In order to use this simulator appropriately, we created a simulator environment designed to prepare simulation scenarios and assess the results. Its main functionalities are:

- Scenario editor in charge of simulated area specification,
- Distribution of sensors and vertical signs and their association to sections of lanes.
- Traffic generator based on priority and non-priority vehicles.
- Visualization tools allowing observation and a variety of usability and acceptability tests

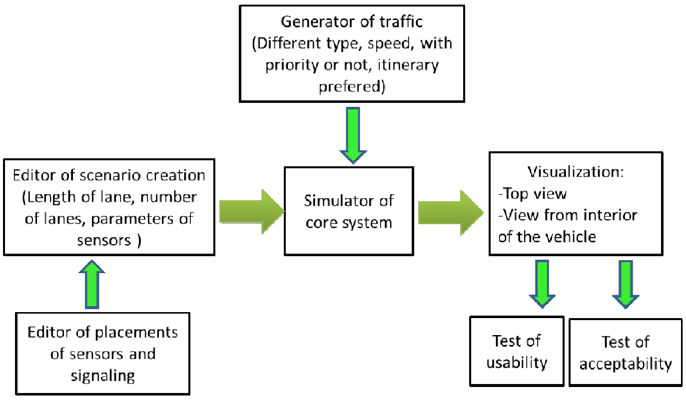


Fig. 7. Simulator environment functionalities

A **scenario editing tool** completes the simulator. Its goal is to specify simulation parameters such as lane length, number of lanes, duration of simulation, number of sensors and initial status of lane allocation. This graphic editor tool (Fig. 8) also includes a sensor editor toolkit able to set sensors at appropriate locations, to adjust sensor parameters such as range of region in charge, or to test the influence of different placements. All parameters are saved into "line file" used by the simulator.

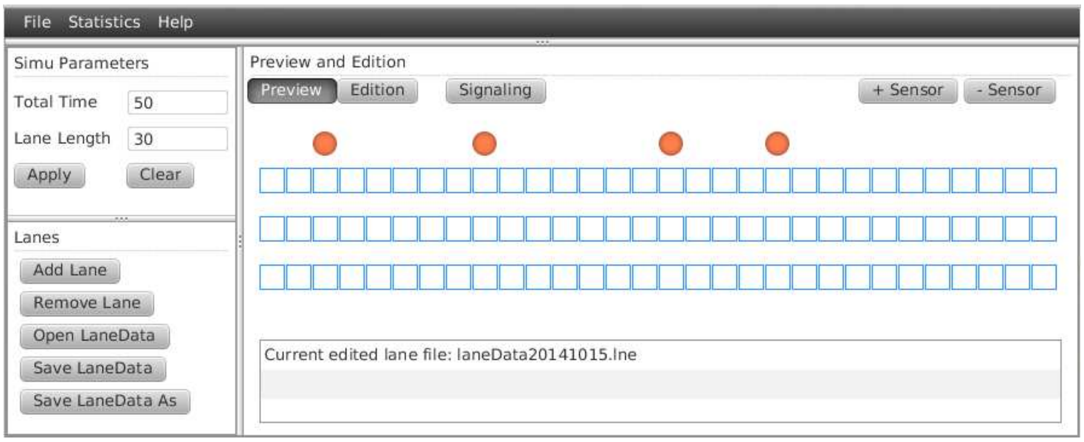


Fig. 8. Scenario editing tool

Vehicles, priority or non-priority, will travel through the area from left to right, with distinctive parameters (speed, initial time, etc.), strictly respecting signaling of lane allocation throughout the process. A **traffic generator tool** (Fig. 9) is used to generate traffic flow, in which there are priority and non-priority vehicles. Also, different parameters can be chosen as well as possible itinerary preferences. Moreover, this generator tool helps choose how to launch traffic flow, with different time intervals and densities. Just as for the Scenario editing tool, traffic data are saved in a “vehicle data file” to be used by the simulator.

Fig. 9. Traffic generator

Prior to simulation, the experimenter creates the simulation scenario with the scenario editing tool (Fig. 8) and indicates the traffic situation to be generated using the traffic generator (Fig. 9). During and mainly after simulation, we need to observe the results in several graphic visualization forms allowing their utilization in usability and acceptability studies.

We have decided to provide 2 views for visualization of simulation results, namely a 2D or 3D top view and a 3D view from the interior of the vehicle. The top view is used for a global bird’s eye view of system functioning, and for observing the behavior of vehicles in different parameter settings of lanes, sensors, etc. The observer can choose the simulation result file to load and then watch the animation play. Pause and resume are supported as in other replay applications. Fig. 10 shows the 2D top view of a scenario in which a bus, represented by a green rectangle, is running alone in a reserved section (brown area), while other vehicles, represented by black rectangles, are running elsewhere (on general traffic sections in white). In Fig. 11, a 3D top view is presented, allowing observation of the general traffic scenario.

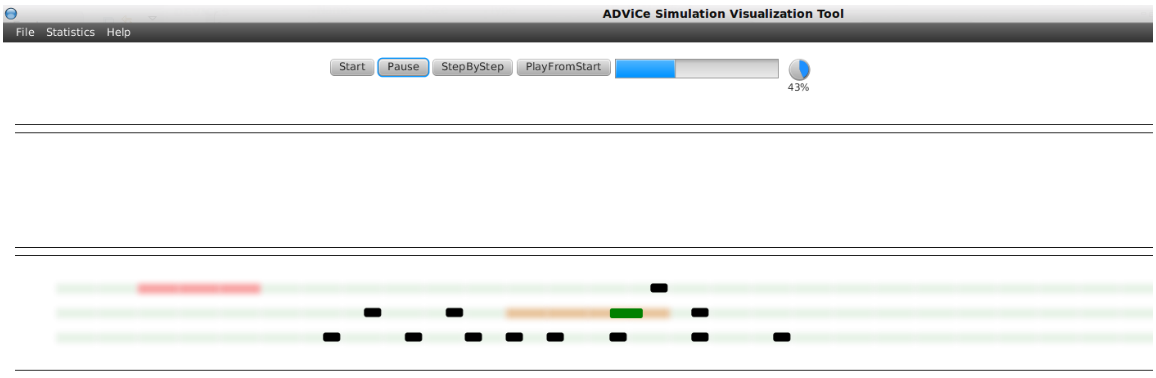


Fig. 10. 2D top view of visualization

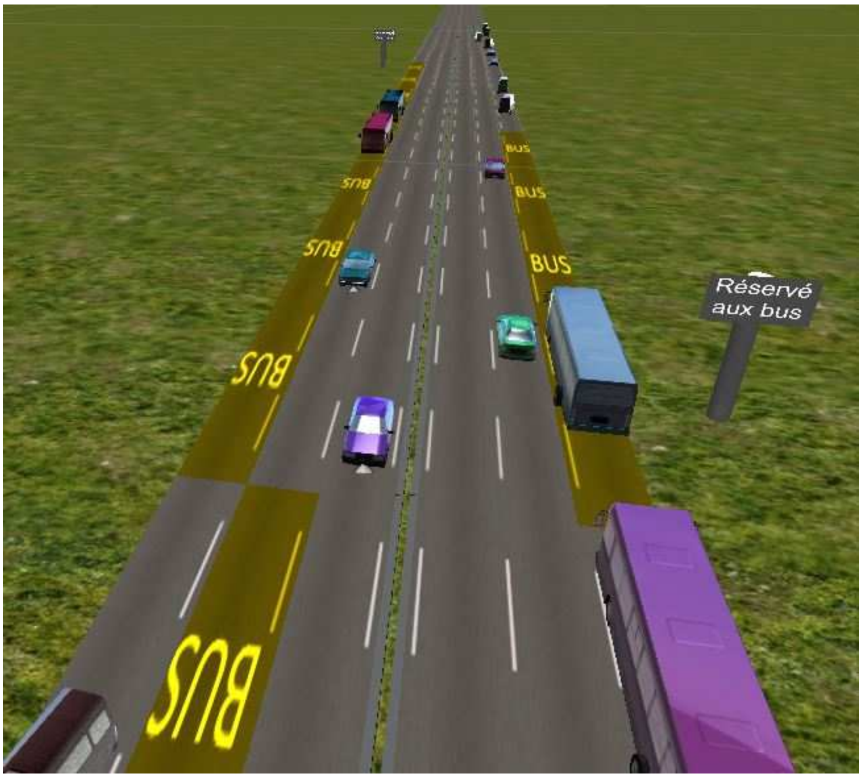


Fig. 11. 3D top view of visualization

The view from the interior of the vehicle (Fig. 12) is used to present either static or dynamic driving situations. In the first case, a static situation interpretation test can be conducted and user behavior observed. In the second case, a dynamic test presents the driving scene in real time with the corresponding simulated elements and assesses whether user scene interpretation and reaction are compatible with temporal. The driver can see the vertical signaling on the roadside as well as the horizontal signaling on the ground from the front window of the vehicle. Moreover, the surrounding circumstances are also reflected in the vehicle rearview mirrors.

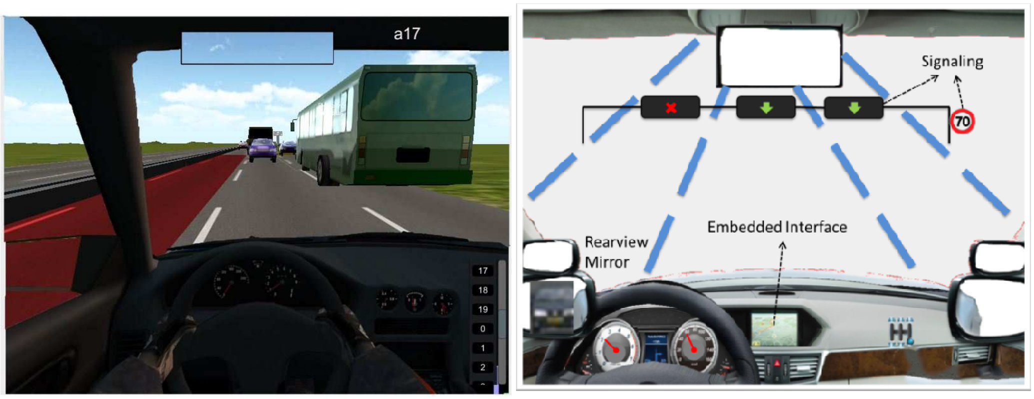


Fig. 12. 3D views from the interior of the vehicle

III.2 Simulator use for capacity studies and driving situation usability testing

The goal of the simulator is to allow capacity studies and ergonomic studies for acceptability of this kind of approach to dynamic lane management. Several levels of tests can be produced, using different views. A map view using the global bird's eye view, as shown in Fig. 10 & 11, is used to study capacity behavior to determine when static behavior must be used and when dynamic behavior is appropriate.. A subjective view, i.e. a view from the interior of the vehicle (Fig. 12), is used to test drivers' behaviors, either static or dynamic.

III.2.1 Capacity studies

With several simulation situations, we are able to determine working conditions of priority vehicles in relation with general traffic. We can observe the time needed to cross the simulated section in dynamic working conditions compared to static conditions, i.e. compared to time with predefined priority lanes. If this time is considerably more, then the number of private vehicles and buses is too large to allow dynamic behavior, requesting personal vehicles to alternate between mixed and specialized use of lanes. The main reason is that the large number of participating vehicles is incompatible with rapid freeing of a lane that has become specialized by the arrival of a priority vehicle. In this kind of situation the static operating mode must be applied [24, 24].

III.2.2 Usability tests

A scenario screen shot of the acceptability study is shown in Fig. 15. In the test, a set of photos was produced to simulate statically different situations. These photos show a multiple lane configuration with insertion of appropriate vertical and horizontal signaling. The pictures are shown to a driver, letting him / her observe the situation, after which questions are asked, requesting him / her to choose the appropriate behavior. If signaling is not easy to observe or understand, the driver may not choose to behave correctly. This static approach allows us to know whether understanding of different traffic signs is appropriate, but we do not have the sufficient reaction and interpretation times. The tester can take as long as needed to respond to each situation.

Fig. 13. An acceptability study scenario

This first test study was conducted by our IFSTTAR partners [33], who studied understandability of appropriate vertical and horizontal traffic signs and road signs. These signs are either static or, in the majority of situations, dynamic (electronic display signs), according to dynamic lane evolution. Fig.14 shows several of these signs.

Internet-based evaluation was conducted for 6 weeks in September 2013, and 187 exploitable anwers were collected. Questions concerned direct sign understanding and their use in situations (Fig.14). With respect to understanding, signs #5, 6 8 & 9 had a low level of understanding, i.e. 50% while with respect to understanding situations completed by horizontal signs (roadway integrated lights changing from red to green), understanding increased.

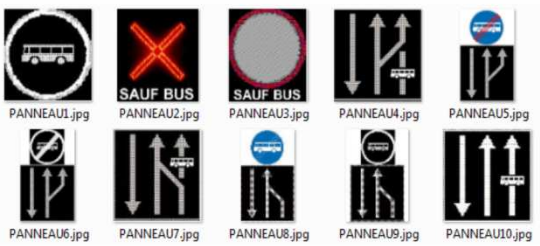


Fig. 14. Traffic signs tested

To examine understandability and acceptability in greater depth, we need to study the temporal behavior of drivers. It is not sufficient to observe appropriate interpretation of driving situations, if the user can take all the time he / she needs to think about the situation. Rather than creating driving situations by using static photos, our simulation goal is to support dynamic behavior in which the subjective view during simulation is related to driving speed. The situation corresponding to that shown in Fig. 15 can be used to conduct dynamic tests. Speed is not the only dynamic property; external vehicle traffic can also be taken into account, for instance, to what extent a user adapts him/ herself to a more complex situation with the change in surrounding circumstances such as a car appearing in the rearview mirror and the change in message on the panel or signaling.

III.3 On-board enbedded user interface design and testing

We are also currently studying the design of an embedded interface, which will be integrated into the dash-board for passive users and active users allowing them to receive information and/or priority requests (as we will describe later on).

With respect to users identified in the system vision, the user aspect must be dealt with as soon as possible, by designing and implementating appropriate human-machine interfaces: as observed, active users (requestors - beneficiaries of the system), passive users (subjected to the system) and also regulation managers. While for the latter category, regulation managers, the User Interface is a classical large-screen control user interface, which is commonly defined, we are concerned with design and usability studies of in-vehicle user interfaces. For these interfaces, it is essential that this information and these actions comply with the work context and the corresponding requirements:

- regarding vehicle compatibility with the dual task – driving and managing; in a regulation work station for example, it is efficiency which dominates;
- when information is displayed outside, it has to be compatible with meteorological constraints of visibility – legibility.

Therefore, design of these User Interfaces also forms an important part of the system and conditions its acceptability. We proposed different User Interfaces for different kinds of users with a main constraint: use human participation only when it is necessary, in order to avoid dual task problems and cognitive overloads. Examples of embedded interfaces, which we expect to test, are shown in Fig. 15. The GPS, LANE INFOS and the REPORT ACCIDENT entries are open to all users, while the PRIORITY screen is reserved for active users.

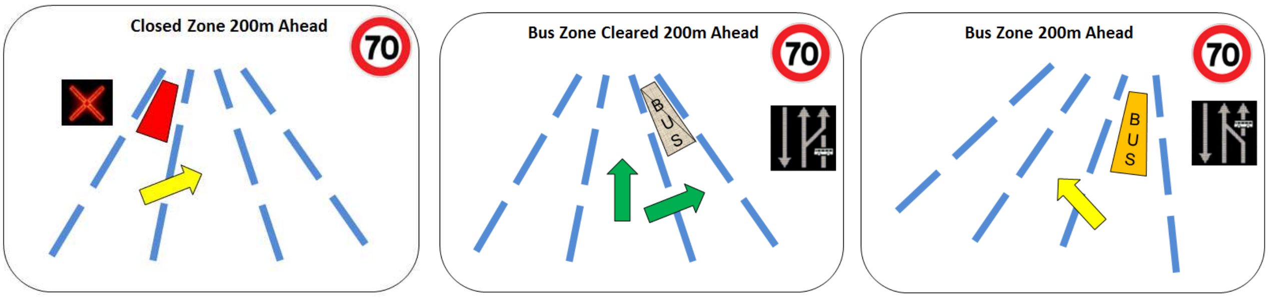


Fig. 15. In-car embedded interfaces

These embedded user interfaces will be integrated in usability tests in order to study their impact on drivers' behavior. The goal is to determine whether this kind of interface is able to increase, functionally and temporally, drivers' understanding and interpretation of corresponding driving situations.

III.4 Mock-up Technology Validation

The digital simulator can provide us with much useful information while designing and developing the system, since it can easily generate different scenarios for comprehensive consideration. However, it is still necessary to conduct a technological validation before in-the-field deployment. Therefore, we created a preliminary mock-up with a scenario to show what can happen in our simulation study. In this scenario, a vehicle with priority is detected, after which a section of lane is reserved and closed to other vehicles during priority vehicle presence.

Figure 16 shows an overview of the mock-up: 3 lanes are painted on the cardboard, the reserved section will be found on the right lane, and a display panel is placed over the cardboard as horizontal signaling. Detection of the vehicle with priority takes place both at the beginning and at the end of the section: when a vehicle with priority is detected at the entrance, the display panel will show that the lane is closed to other vehicles, and when the vehicle is detected at the exit, the display panel will change the signaling, showing that the lane is now open to all vehicles.

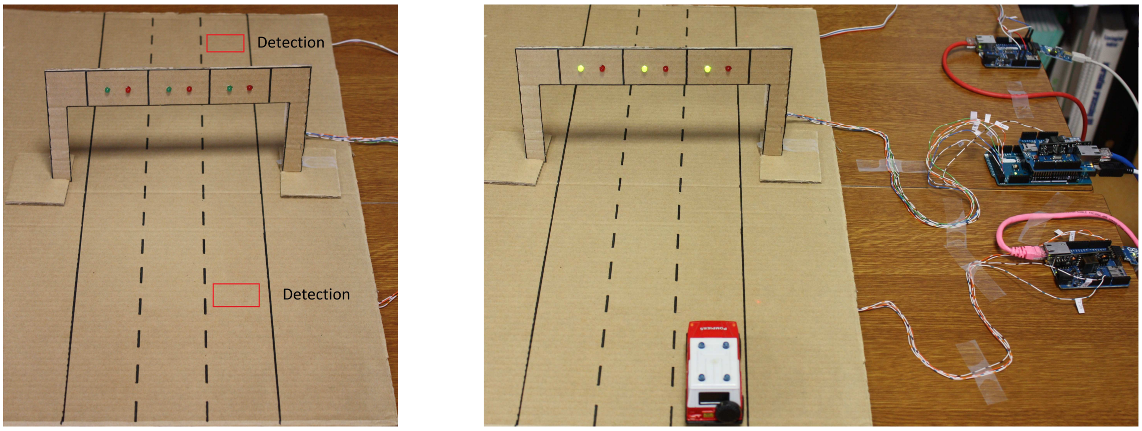


Fig. 16. Overview of the prototype

To collect the information "Priority vehicle detected!" and actuate the signaling, we use Arduino cards (figure 17). These cards contain a set of analog/digital input/output pins and several types of data bus (SPI, I2C and RS232), controlled by a microcontroller. With the addition of an Ethernet cable, the data processed by the microcontroller can be transmitted via a TCP/IP network. The card plays the same role as the regulator in our system. We also implement a server to centralize management of Arduino cards, and, more generally, to centralize sensor and actuator information networks. The server can also provide application tools as an API to simplify management and use of Arduino cards

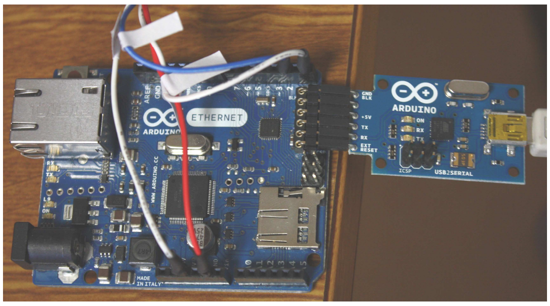


Fig. 17. Arduino card

With respect to signaling, for simplicity's sake, we use red LEDs for "closed to other vehicles" and green LEDs for "open to all". To integrate the LED into the TCP/IP network or Web, we connect the LEDs to the digital outputs of an Arduino card, and we use the REST architecture with two sets of resources, "analogs" and "digitals", including the pin numbers. For example, we can expect an output of a LED status by using the HTTP GET method with the URI http://ipArdress/digitals/2 if the LED is connected to the digital pin 2 of the Arduino card; if we want to modify the status of the LED, we use the same URI, but with the HTTP POST method and a value (0 or 1) as parameter. The resource representations are available in the JSON (JavaScript Object Notation) format.

With respect to vehicle detection, we decide to use a RFID reader, which is able to read information from a RFID tag within a 10cm diameter area, where the tag is attached to the vehicle, as shown in figure 18 (a more powerful solution will be needed at the time of in-the-field deployment). The RFID readers are pasted at the back of the cardboard (Fig. 19). Given the fact that once a vehicle is detected, the information must be sent without a request, we cannot use the traditional HTTP query/response model. The solution we adopted is that an HTTP request is sent to the central server when a tag is detected, then the server interprets the request and uses a WebSocket to send messages (a method modifying a LED status for instance) to potential clients, in a synchronous way.

Fig. 18. Vehicle and RFID tag

Fig. 19. RFID reader

We can observe the change in signaling in figure 20. On startup, a WebSocket connection is established between the server and the Arduino cards. Once the priority vehicle is identified at the entrance, API methods are called to turn off the green LED and turn on the red LED on the display panel. When the priority vehicle is detected at the exit, the server sends a message via WebSocket to tell the Arduino cards to execute methods that turn on the green LED and turn off the red LED.

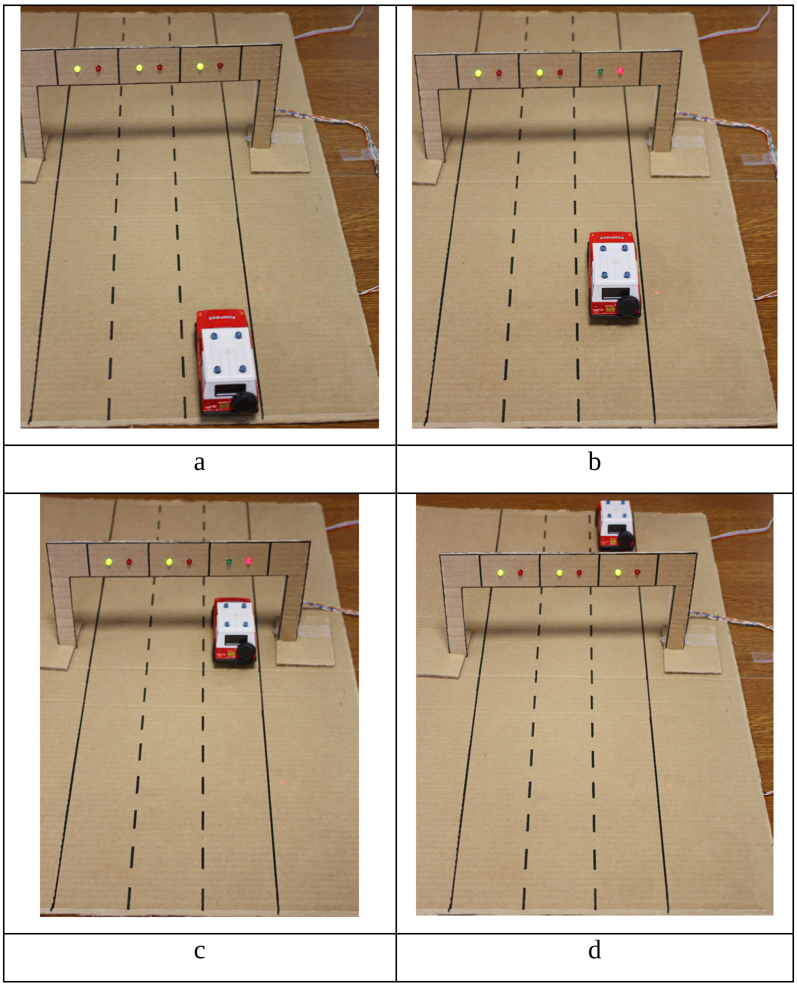


Fig. 20. Scenario (a) Initial status, (b) Vehicle detected at the beginning, (c) Vehicle in the middle of the reserved section, (d) Vehicle detected at the end

Although the mock-up is rough and the scenario is simple, collection of data, integration of objects, transmission of information and dynamic allocation are all involved and well supported. Therefore, we demonstrate the feasibility of our dynamic road lane management system and will gradually add more functionalities to the mock-up to complete the technology validation step in the future work.

CONCLUSIONS

In this paper we briefly explained our view of the Smart City in the context of transportation and citizens' everyday life on which we are currently working [26, 27, 28]. We gave the main principles and techniques used and presented a precise application based on the IoT and LBS. Before in-the-field deployment of this kind of system, it is important to validate it theoretically from technological and human acceptability points of view. For this reason, we created a simulator allowing us to design and simulate different scenarios of infrastructure behaviors. We also use this simulator for user acceptability studies, the goal of which is to validate (or invalidate) acceptability of new driving situations from the driver's point of view. In a static view we tested the user's (driver's) behavior in relation with new vertical and horizontal road signs (fig. 16). By connection between our simulator and several 2D and 3D visualization tools we are able to assess dynamic behavior. We are also and in particular able to study, through a vertical (driver's top) view presentation, dynamic driver's reactions related to vertical and horizontal road signs depending on the behavior of other vehicles around the driver. Acceptability studies of In-car embedded interfaces are also possible. We also elaborated a mock-up of our dynamic line management system, allowing us to show its behavior based on actual technologies.

We also wish to mention that, in the project, another study has been conducted by our industrial partners with an aim to identifying the technologies to be used in real implementation of this approach in the field. CEA-LETI is an industrial research lab working on ICT solutions. It is currently studying a variety of sensors and actuators, which will be industrialized and potentially used in in-the-field implementation. LED-based horizontal signs are also studied to be integrated into the roadway. EGIS-Mobility is a company working in roadway construction, specializing in new ICT–based technologies for road security and control. It has experience in construction of dynamic road lane allocation solutions, for the most part less dynamic than those presented in this paper, but having operated for at least 8 years near Grenoble, where an urgent lane can be dynamically allocated to bus circulation if the existing lane is totally jammed. These studies are out of the scope of this paper and also subject to industrial secrecy.

After these mainly research- and evaluation-oriented studies supported by the ADVICE project, we are currently preparing a more practical project, the goal of which will be in-the-field implementation integrating the results of the ADVICE project. A contract for this final step is currently being negotiated.

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REFERENCES

[1] Z. Xiong. Smart City and Data Vitalisation, The 5th Beihang Centrale Workshop, 7th January 2012.

[2] J. Nouvier. Entrez dans le monde des ITS = Enter the world of ITS, Lyon: CERTU, cédérom TU CE12 10450 disponible auprès du département Systèmes du CERTU, 2007.

[3] Viegas, J. et Lu, B. (2004). The intermittent bus lane signal settings within an area. Transportation Research Part C, 12, 453-469.

[4] Viegas, J., Roque, R., Lu, B., Viera, J. (2007). Intermittent bus lane system: demonstration in Lisbon, Portugal. Paper submitted to the Transportation Research Board Annual Meeting.

[5] US Dept. of Transportation. Bus Lane with Intermittent Priority (BLIMP) Concept Simulation Analysis, Final Report: November 2009 Report Number: FTA-FL-26-7109.2009.8

[6] Guler S.I., Menendez M. Empirical Evaluation of Bus and Car Delays at Pre-signals, STRC, 13th Swiss Transport Research Conference, Monte Verità / Ascona, April 24–26, 2013

[7] Ambient Intelligence Laboratory. http://www.ami-lab.org, consulted on 11/04/2013

[8] M. Weiser, J. Brown. The coming age of calm technology. http://http://www.johnseelybrown.com/calmtech.pdf, consulted on 11/05/2013

[9] L. Atzori, A. Iera and G. Morabito. The Internet of Things: A survey. Computer Networks 54 (2010) 2787-2805

[10] L. Atzori, A. Iera and G. Morabito. The Internet of Things: A survey. Computer Networks 54(2010) 2787-2805

[11] Yu, M., Zhang D., Cheng Y., Wang M.S. An RFID electronic tag based automatic vehicle identification system for traffic IoT applications. Control and Decision Conference, 2011.

[12] National Intelligence Council. Disruptive Civil Technologies - Six Technologies with Potential Impacts on US Interests Out to 2025. Conference Report CR 2008-07, April 2008

[13] Auto-Id Labs, http://www.autoidlabs.org, consulted on 11/04/2013

[14] The ECPglobal, http://www.gs1.org/epcglobal, consulted on 11/04/2013

[15] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci. Wireless sensor networks: a survey. Computer Networks 38(4), pp:393-422, 2002

[16] J.W. Hui and D.E. Culler. Extending IP to low-power, wireless personal area networks. IEEE Internet Computing, 12(4):37-45, 2008

[17] J.W. Hui and D.E. Culler. IP is dead, long live IP for wireless sensor networks. In Proceedings of the 6th ACM conference on Embedded network sensor systems, pages 15-28, 2008

[18] IPSO alliance: Enabling the internet of things, http://www.ipso-alliance.org, consulted on 11/05/2013

[19] Jiang B.,Yao X. Location--﹣based Services and GIS In perspective. Computer Environment Urban Syst(2006), doi:10.1016/j.compenvurbsys.2006.02.003

[20] Bellavista P., Kupper A., Helal S.. Location-Based Services: Back to the Future. IEEE Pervasive Computing Magazine, vol.7 (No.2), Avril-Juin 2008.

[21] A, Csinger. Users models for intent-based authoring. Dessertation, The University of British Columbia, 1995

[22] World Geodetic System, http://en.wikipedia.org/wiki/World_Geodetic_System, consulted on 12/10/2013

[23] H. Hu and D. Lee. Semantic location modeling for location navigation in mobile environment. In Proceedings of the 2004 IEEE international conference on mobile data management, pp:52-61, 2004

[24] Daganzo, C. F., Geroliminis, N. (2008). An analytical approximation for the macroscopic fundamental diagram of urban traffic. *Transportation Research Part B: Methodological*, 42, 771-781.

[25] Chiabaut, N., Xie, X., Leclercq, L. (2012). Road capacity and travel times with Bus Lanes and Intermittent Priority Activation: Analytical Investigations. Transportation Research Record: Journal of the Transportation Research Board, 2315, 182-190.

[26] B. David, R. Chalon, B. Favre. ICT and new human-machine interactions for trucks and buses in the future: e-Truck and e-Bus perspectives. In C. Kolski (Ed.), Human-Computer Interactions in Transport, ISTE Ltd and John Wiley & Sons, Inc., ISBN: 978-1-84821-279-4, pp. 157-201, 2011.

[27] B. David, C. Yin, Y. Zhou, T. Xu, B. Zhang, H. Jin, R. Chalon. SMART-CITY: Problematics, techniques and case studies. ICCM'2012, 8th International Conference on Computing Technology and Information Management, Seoul, Korea. pp. 168-174. Computing Technology and Information Management (ICCM) 1. IEEE Conference Publications . ISBN 978-1-4673-0893-9. 2012.

[28] B. David, T. Xu, H. Jin, Y. Zhou, R. Chalon, B. Zhang, C. Yin, C. Wang. User-oriented System for Smart City approaches. 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, August 11-15, 2013, Las Vegas, Nevada, USA. pp. 333-340. IFAC / Elsevier; ISSN 1474-6670. 2013.

[29] C. Wang, B. David, R. Chalon. "Dynamic Road Lane Management: A Smart City Application".IEEE 3rd International Conference on Advanced Logistics and Transport (ICALT'2014), Hammamet. pp. 72-77. 1-3 May 2014.