VELOCITY: A SYSTEM FOR A SMART BIKE MANAGEMENT

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Abstract: *The present paper presents the development of the VeloCity project which seeks to promote the cycling as a part of daily transport and recreation. One of the main objectives is integration of bicycle into urban multimodal mobility and urban planning and other relevant policy sectors where cycling plays an important role. For obtaining the goal a survey is conducted locally and via Internet and the results are analyzed; user requirements analysis is conducted through information resources study, and a number of user scenario are defined.*
Basic parameters of a smart bicycle are defined through summarizing the most interesting and useful user scenarios, applicable for more safety, flexible and comfortable cycling. The user scenarios are the base for hardware and software development for a smart bicycle, selection of proper technologies, building of a prototype and experimental platform for the smart system testing.

Keywords: VELO-CITY, INTERNET OF THINGS, SMART CITIES, SMART MOBILITY

1. Introduction

The aim of the present paper is to develop a model of a smart bike prototype and a system for smart bike management based on technologies of the Future Internet, in particular the Internet of Things (IoT). First, it has been built a prototype of the experimental platform for monitoring as well as a smart bike management.

Second, it has been built a prototype of a data analysis system, integrating the smart bike into a smart system for city transport management. The results from that activities are as follows:

- Analysis, design and development of a software and hardware;
- Prototypes of a web and mobile application

The specific goals of the present paper are:

a) to perform a basic analysis of the current situation in the field of smart bike systems in Bulgaria, EC and worldwide. Particular attention is paid to the analysis of the results of European research and innovation projects.

b) to analyze the users needs of smart bike systems, infrastructure and services (through surveys and based on information sources); system requirements definition for smart bikes; user scenarios definition and scenario selection which are meeting the actual situation in Bulgaria and the profile of the participating partners.

c) to organize an experimental pilot in a Living Lab of the system and to test and analysis of the prototype of a smart bike system with potential users participation, experimental results analysis and definition of ways for system improvement.

d) to analyse the results in Bulgaria, EC and worldwide so, to identify the issues related to integration of a Pan-European cyber-physical infrastructure and special services dedicated to smart mobility schemes that embed smart bikes.

During the development phase a research has been done on a dedicated Cloud platform based on open source components (Future of Internet enablers) giving possibility for analysis of open and big data. A prototype of a back office platform has been developed as well as a web application and a mobile application.

For the purposes of the experimental development, we make use of object-oriented approach for system modeling by using open source - Future of Internet (FIWARE enablers), for development of Cloud operating system, web and mobile applications, data bases, data analytics, development of a prototype of a device for data gathering and light signaling on the base of a hardware with open code – Arduino.

An agile approach (responsive design) for web application development has been applied, giving possibility for work with it on desktop, smartphone and tablets. A study of the concept is done, a reference architecture of IoT has been implemented and the advantages of the use of common reference model of IoT have been outlined. The research is based on open hardware as well as on the base of the Arduino platform for development of innovative agile solutions for smart bike. Components of the open hardware are Arduino plates, software, shields for communication, Ethernet with SD Shield, Wireless SD Shield, WiFi Shield, GSM/GPRS Shield, Shields and drivers for engine management. Special attention is given to the sensors for temperature measurement, humidity and pressure, sensors for orientation and acceleration, sensors for illumination measurement, colors and gestures recognition and noise measurement. A prototype has been built for data collection and light signaling on the base of Arduino.

2. Development methodology

The main purpose of the present research is to study the possibilities for development of hardware and software for a smart bike based on IoT and open source software and open hardware (Arduino). An approach of open innovation as well as methods and tools of living labs is applied. In particular, the experience of Virtech, living lab VirtSOI and of many others from the EU network ENoLL is taken into consideration (http://www.openlivinglabs.eu/).

The proposed system aims at designing and development of a prototype of light indicators and user interface of a software for monitoring and smart bike management.

The basic model of the smart sensor system includes a software and user electronics and aims at increasing the level of bike safety.

During the development of the present project a bike signaling system is built up. The team has built up a prototype on the base of a hardware with open source as well as a device for data gathering by intelligent sensors has been built.

The project team is focused on the application of modern and innovative approaches and solutions, as follows:

1. Application of the methodology of IoT.
2. Application of a hardware with open code – Arduino.

Nowadays the companies are facing the pressure for new technology implementation due to the massive penetration of information technologies in our day life. In the last years the mobile

devices, cloud computing and IoT are influencing the business processes through new business models, globalization and the ever increasing volume of processed information. Looking back at the evolution of the Internet we could see the great influence of connectivity over the society and organizations – from the email and web through the connected economy till entire e-business. This is followed by the real experience – social relationship in Facebook and LinkedIn. The next step is IoT where people, processes, data and devices are connected. Every building block in this structure has its added value – the right person or device has to receive the right information for a given process just in time. Data is transformed into a valuable information ready for analysis and decision making, and the devices are connected with each other through Internet for a better service sets.

The IoT builds out from today's internet by creating a pervasive and selforganising network of connected, identifiable and addressable physical objects enabling application development in and across key vertical sectors through the use of embedded chips, sensors, actuators and low-cost miniaturization.

IoT is the connection between autonomous computing devices through the existing Internet infrastructure. Communication between devices is done at a high level by means of a set of protocols, domains and applications. Thanks to that connectivity the automated processes are assured in almost all fields as well as smart applications are built up at a new level.

As identified by Atzori et al. [3], IoT can be realized in three paradigms—internet-oriented (middleware), things oriented (sensors) and semantic-oriented (knowledge). Although this type of delineation is required due to the interdisciplinary nature of the subject, the usefulness of IoT can be unleashed only in an application domain where the three paradigms intersect. IoT has been identified as one of the emerging technologies in IT.

The vision of IoT can be seen from two perspectives—'Internet' centric and 'Thing' centric. The Internet centric architecture will involve internet services being the main focus while data is contributed by the objects. In the object centric architecture, the smart objects take the center stage.

The devices can be with totally different application – devices for
heart rate monitoring, implemented in a pocket biochips, cars with sensors, etc. There are already smart thermostats and domestic devices with remote control. A study of Gartner reveals that till 2020 there will be 26 million connected devices. The integration of these devices with Internet is done through IPv6 protocol, due to the limited space of the IPv4 standard (up to 4.3 mil. IP addresses). The devices not only transmit data, but also can manage a particular activity (electrical bulbs, locks, etc.). Due to the character of these devices it is necessary to use platforms with lower energy consumption as the analysis of gathered data is done in dynamic computational data centers.

The proposed system VeloCity gives effective bike management through integrated multisensory software and hardware system for bike management and monitoring, user and traffic conditions. As well, it provides increased safety and enhanced communication with the other participants in the traffic through an effective light signalization.

Sofia is one of the cities which has a strategy and plan for bike transportation development. The present research is contributing to the project of bike transportation development on the territory of Sofia Municipality 2012-2017.
(http://www.sofiatraffic.bg/bg/cycling_not_working/340/plan-za-razvitie-na-velosipedniia).

Available on the market are protective helmets with smart signalization, smart lights for embedding the helmets, etc. Some other innovations do exist that have not yet been implemented in practice and need financing, for example: Helios Bars

(http://www.kickstarter.com/projects/kennygibbs/helios-bars-transform-any-bike-into-a-smart-bike), Velodroom's Smart Bicycle Light (http://www.kickstarter.com/projects/velodroom/velodrooms-smart-bicycle-light) or SMART - The world's first smart cycling helmet (http://www.indiegogo.com/projects/smart-the-world-s-first-smart-cycling-helmet). Although a significant research have been done so far in technology and in methods for similar systems for other transportation modalities, it does not yet exist an integral smart transport system for bike transportation in the world market. At a national and European level similar developments that have been implemented in practice are not yet available.

Existing alternatives on the market

So far there are several similar devices on the market like "LED Bike Turn Signal (in Amazon), "Bicycle Turn Signal Brake LED Light & Horn" (in SintekStore), Bike Light Kit (Global Murchants). [5]. What is clear is that after intelligent bracelets and smart watches it is time for the smart bikes.

Scientists from Massachusetts Institute of Technology have developed a particular system for smart bike (http://senseable.mit.edu/copenhagenwheel/), in which the bike wheel has a battery that saves the energy (produced by pedals) and can use it when one is cycling. This is a model of a hybrid bike for use in the city. Moreover, the bike is provided with a Bluetooth technology which allows the data exchange with smartphones and other mobile devices. By means of a special mobile application (iPhone) the bike could monitor the speed, direction, destination, road conditions, traffic, etc.

Another similar development is the social bike (SoBi Social Bicycle) of AT&T:
(http://www.att.com/att/InnovationStore/products/social-bicycles/#fbid=a5hRs1OKzMH). The social bike has to be available for everyone. It has an integral system for locking and GPS as well as mobile applications –bike booking (in a system for bike sharing), access to interactive maps, etc.
The project Instant Mobility (http://instant-mobility.org) demonstrates the need for city transport optimization through realization of multimodal transport scheme with IoT application and data in real time from the transport infrastructure, the public vehicles, citizens, open public data, etc. Bike are also an option, but real user scenarios and real experiments have not been done yet. The same holds true for the projects from the 7FP program: TEAM (http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=13355104) and WISETRIP (http://www.wisetrip-eu.org/).

The system VeloCity has several substantial advantages in particular, the utilization of IoT and infrastructure based on big and open data (big/ open data) in the transportation field. Besides, the system is based on innovative model for multifunctional (prefabricated) bike. The system is applicable also in the fast growing segment of electric and hybrid bikes: (http://www.treehugger.com/bikes/closer-look-smarts-award-winning-ebike.html).

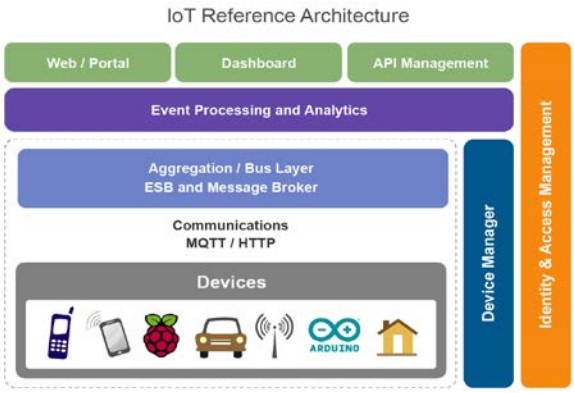
According to Pike research, the world market of e-bikes is increasing with a rate of 7.5% in the period 2012-2018, and will reach sales more than 47 million bikes per year 2018. In the present research the experience of Virtech LtD. in projects from FP7 ICT-2011.11.3 "Experiential Living Labs for the Internet Of Things" - ELLIOT is also taken into account. [6]

2.1 Reference Architecture of Internet of Things

The advantages of common reference model of IoT are as follows:

1. The architecture enables the discussion as it gives the participants a language to communicate that everyone could understand and that is interiorly connected with the architecture, systems, and the environment of IoT.
2. There is a view from a higher level so, it gives a broad view to the environment. This could help users who are new to this area to find their way and to understand the specific characteristics of IoT.

3. The reference architecture of IoT can help project managers in the field of IoT to plan activities. For instance, the groups of functions identified in the functional view of the reference architecture could be used as a base for team tasks definition.
4. The reference architecture of IoT makes possible the identification of structural components of IoT systems. This gives valuable information when we deal with system modularity, processors architectures, options of third party providers, reuse of already developed components, etc.



On Fig. 1 is shown a reference architecture of IoT.

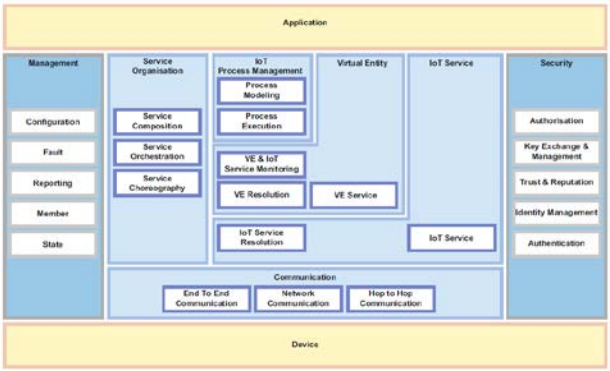


Fig.1 *Reference architecture of IoT*

Platform architecture

The architecture which enables data exchanged between user and the platform is connected through Internet and in particular by means of the architecture type client-server. There is one basic server with a data base and several other servers which makes use of one and the same data base. They give to the users content in the form of a web site in Internet. The users could communicate with the system (platform) by means of Internet browser and connection to Internet. The type of user devices (desktop, laptop, smartphone, tablet) has no particular importance (see Fig. 2).

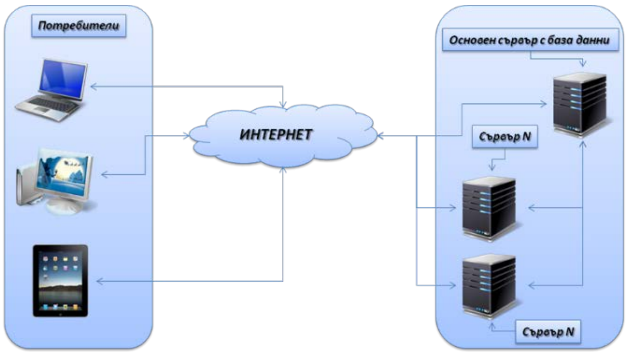


Fig. 2 *Arduino platform architecture*

Hardware with an open code. Arduino platform

Arduino (Fig. 2) is used in many education programs worldwide, in particular from designers and painters who would like to create prototypes, but they do not have to know more about the technical details beyond their developments. As this platform is dedicated to people who do not have any experience with programming and technical questions, the software includes variety of tools on the platform [1].

Arduino is an open code platform suitable for wide range of projects. The controller is able to extract data from different sensors, for instance for light, sound, temperature and finger print as well as to transform the enter data into input data, engine ignition, lights or to publish something in Internet, to send a message to a smartphone, many other examples do exist. Besides sensors and moving mechanisms (like electromotor, LEDs, piezo speakers, etc. [1], Arduino could communicate on both sides having software programs as Flash, Pure Data (PD), Processing, etc. Developed in a learning environment, the platform Arduino not only includes plate, but also includes a programming environment (IDE) easy for use and very suitable for ones who are new to the robotics and interactive projects. Although it is very easy for use, Arduino is very powerful platform with thousands of applications which makes it the most popular among "do-it-yourself' enthusiastic in the world for the last years [4].

It is used for various projects as: controllers for computer games; robots, automation of buildings, monitoring and safety system, board computers. Arduino is different from the rest of the platforms on the market with the following:

- the platform is developed in a learning environment which makes it ideal for quick understanding by a beginner.
- it works under different operation systems– Windows, Mac and Linux.
- the programming environment is based on the Processing language, under the project Wiring.
- the programming is done not by serial port, but by means of USB cable. This is particularly useful, because most of the recent computers do not have serial port.
- the software and hardware are open code – one can download the scheme from the website of Arduino, buy the parts and assemble the plate by himself, without paying to the developers of Arduino.

The programs in Arduino are written in C and C++. The development environment Arduino has software library called „Wiring (See Fig. 3).

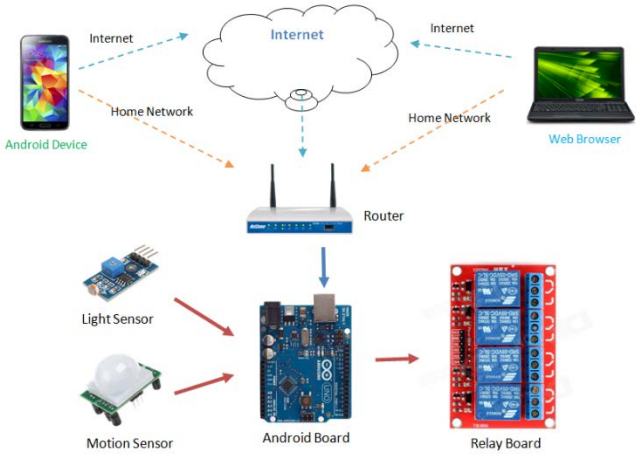


Fig. 3 *Configuration based on the Arduino platform*

3. Concluding discussion

Based on the present study some conclusions can be drawn, as follows:

1. The application of IoT as a most recent paradigm for collecting big data in real time is applicable in a system for smart bike.
2. The use of hardware with open code – Arduino - allows for quick prototyping of wide range hardware, realizing the paradigm of IoT.

The future research direction of the present study are:

1. Development of the platform on the base of IoT.
2. Development of a device for data gathering, which could communicate with a smartphone through Bluetooth protocol.
3. Further development of the light signalization and custom design of the plate for building up in a lighting body.

The web application VeloCity is used for giving geographic location and pulse of the user. The application could send in real time the location and pulse in the data base by means of Internet connection of the mobile device.

The present prototype is a system for data analysis and information necessary for the integration of the smart bike in a city transportation management system.

The performed study and analysis of the user experience and requirements are the base for building up the experimental environment and identifying indicators to be measured.

The platform performs the following analyses:

- Analysis of data relevant to the cyclist's behavior.
- Analysis of data relevant to the functional condition of the cyclists.
- Analysis of data relevant to the cyclists' environment.

Bike-sharing programs have expanded rapidly throughout Europe in recent years as cities search for ways to increase bike usage, meet increasing mobility demands and reduce adverse environmental impacts. The introduction of smart technology has resolved many of the vandalism and theft problems of earlier bike-sharing programs and has made bike sharing popular and trendy, especially among younger users. The bike sharing can be fully integrated with other transport modes by adopting a single smart card ticketing system for instance. A key ingredient for success in any city is the availability of an extensive and continuous bike lane/path or car free network. Equally important is the combination of a bike friendly topography and climate [7].

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