Special issue of the International Conference on Computational and Experimental Science and Engineering (ICCESEN 2014)

Mobile Environmental Sensing and Sustainable Public Transportation Using ICT Tools

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Intelligent transportations system is a complex information and communication technologies platform aimed for a better and cost effectiveness public transport organization. Our intent is to extend the basic of intelligent transportations system for the improvement of local transportation in marginal areas for suitable links with the existing network system. These tools are characterized by low cost if compared with the potential impact in improving direct and indirect transportation efficiency. The information and communication technologies mobile platform will have a double nature: on the one hand, it will be capable of gathering environmental data in real-time and at regular intervals serving as moving environmental city sensors. Information such as temperature, noise, humidity, gas levels, road conditions, and dust particle concentration can all be reported and analyzed. On the other hand, the platform will provide services to passengers such as internet/intranet access, through these connection resources, exploiting wisely a multi standard (3G cellular networks, WiFi networks) gateway. In exploring solutions to those challenges a balanced dual 3G mobile providers connectivity combined with a private WiFi network will be used for balanced data traffic and uninterruptable internet service for passengers. The same information and communication technologies platform is the aim of a basic intelligent transportations system platform and telematics fleet management.

DOI: 10.12693/APhysPolA.128.B-122

PACS: 89.20.Bb

1. Introduction

The public transport sector is not only confronted with rising numbers of passengers, but new user requirements as well. There is a trend toward "smart" passengers — users who are flexible in their mobility preferences and take advantages of digital and mobile technologies. A challenging problem faced by the government, researchers, and transit agencies is how to provide better transit service by using up-to-date technologies [1], to the new generation of "smart" passengers. In addition, impact of road traffic on local air quality is a major public policy concern. This problem has stimulated a substantial body of research aimed at improving underlying vehicle and traffic management technologies and informing public policy action [2–4]. Recent work has begun to exploit the capability of a variety of vehicle-based, person-based and infrastructure-based sensor systems to collect real time data on important aspects of driver and traffic behavior, vehicle emissions, pollutant dispersion, concentration and human exposure.

A key challenge is combining existing intelligent transportations system (ITS) technologies and state-of-the-art, sensor and positioning technologies, data fusion, traveler behavior, traffic modelling and emissions dispersion modelling techniques and vehicle/person-mounted sensors [5]. In this context, the proposed system utilizes public transportation vehicle intelligence and sensing to monitor a set of environmental parameters over a large area by "filling in the gaps" where people go but environmental monitoring sensor infrastructure has not yet been installed. While some types of sensors are already commonly present in ITS platform (e.g., geolocation, gyroscopic, etc.), other kinds of compact, low-power sensors (e.g., air quality) are not yet commonly included but offer the ability to collect additional data of individual and social interest.

The present work shows the capability of using environmental sensors over public transport vehicles and cooperation of the ITS infrastructure for getting real time geo-located data. The communication is reached via a mobile third generation radio connection during the entire vehicle trip. However, as a shared medium, mobile radio must provide a guaranteed bandwidth and quality of service for online data transmitting and offering to smart users a stable network getaway to the internet. To evaluate the quality of 3G signal, a survey is performed over the territory as the quality of the proposed service is highly influenced by the quality of existing 3G network [6, 7].

2. Information and communication technologies infrastructure sharing

The proposed information and communication technologies (ICT) architecture employs bidirectional data communication distributed structure. This platform will serve the high level scope as: fleet management, business specific services, info for driver and passengers, car and context info (mileage, localization data, speed,...), car driving information (parking spaces, limited access

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area,...), online internet access and obviously air pollution monitoring via adjoined sensor nodes. Locally collected information from environmental sensors is preprocessed by a local server that acts as gateway and uploads the information on-site via 3G network. In this project, the "WESTmote" sensor node used was developed at University of Aquila, Italy. The node can be populated with carbon monoxide (CO), nitrogen oxide (NO_x), ozone (O_3) gas sensors as well as temperature, relative humidity, and motion (3D accelerometer) sensors. Avoiding cabling and power issues, sensors nodes are powered by local battery and communicate wirelessly to the gateway. Local gateway is low cost and low power general-purpose computer with GNU/Linux installed with 3G modem network capabilities and global positioning system (GPS) device connected. For offering ITS capabilities to the driver and dispatch center, together with sensing capabilities, the gateway is equipped with ad hoc software.

The sensor node core is composed by Atmega 1281 microcontroller (8 bit AVR RISC architecture) equipped with 8 kB SRAM, 128 kB flash memory and 4 kB EEPPROM. For the communication module, a radio transceiver Atmel AT86RF212 is used with ISM frequency band 784/868/945 MHz capabilities, −110 dBm receiving sensitivity and up to 11 dBm output power. Also the sensor node have the capabilities of over the air programming which permits a better and easier software development or system upgrade also when the system is running.

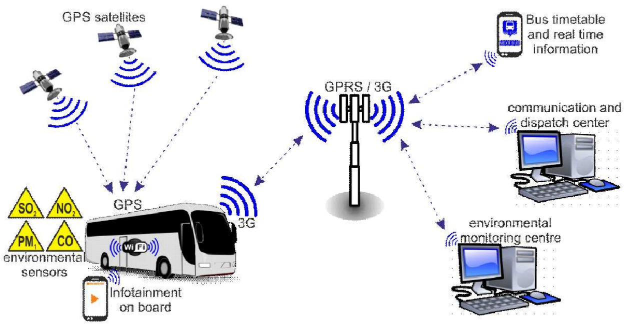

Fig. 1. Proposed ICT infrastructure for sharing services.

The developed software is capable of managing the sensing environment and acts as a wireless internet gateway for passengers. In Fig. 1 there is presented a schematic of the proposed architecture.

The proposed infrastructure has the capabilities to save the monitored data locally and in case of 3G network missing during the bus route, the information can be extrapolated via WiFi at permanent bus stop.

This infrastructure permits to create a more attractive public transport for the next generation of "smart" users and to have a sustainable impact to the environment as better end efficient fleet management can be obtained. For this purpose, post-processing software tools need to be developed as to extrapolate maximum of useful information from gathered data [2–4] from the proposed platform.

3. 3G signal measurement

As can be understood, the quality of the radio frequency (RF) 3G signal and its coverage over the entire bus route highly influences the proposed services. Testing 3G infrastructure quality of signal over the entire project area normally will require specialised staff with spectrum analysers or other high cost tools. In addition, a survey campaign is time and cost expensive. In our philosophy of sustainable and low cost system, the project team developed ad hoc software, which runs over standard modern smartphones equipped with Android operating system. The applications extrapolates from the smartphone the quality of signal for a given operator at a given time and position. In this case, we are able to perform signal monitoring simply by activating the application and using the public transport. This survey shows the exact condition of the available 3G signal coverage by mobile operators for the roots where the public transport is offered.

The post-processing of the survey data is done by integrating the capability of a PHP scripting for webservers and maps interfaces. Both these tools are used for integrating monitored data to the geographical maps for a better and easier data interpretation. In Fig. 2 monitored signal quality is shown for the Tirana (Albania) main streets (Fig. 2a) where more than 3560 geo-referenced survey points are presented. The same typology of survey is also performed in Tirana neighbor where the bus lines connects the Lunder rural area to the Tirana metropolitan area. In this case 1082 survey geo-referenced points are performed. The results are provided in Fig. 2b where a lower signal strength respect to city center is evident if we compare both figures.

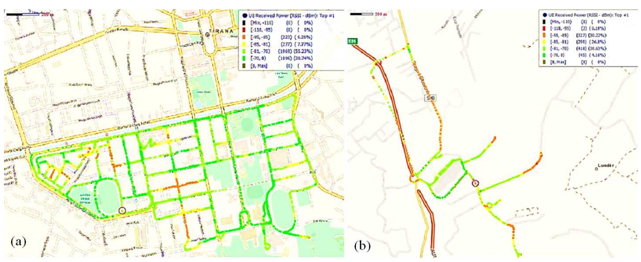

Fig. 2. Measured 3G network signal strength on main bus streets for AMC mobile operator in 2013: (a) Tirana city center, (b) Lunder (Tirana neighbor).

For easier comparison survey results are provided in Table where we can see that the city center and in general the metropolitan area have high quality of signal strength where around of 86% of the monitored area have a signal quality better than −81 dBm. The same signal power is monitored only in 43% of the rural area. The value that is more critical for 3G signal reception in moving users is the signal strength less than −85 dBm which in Tirana city center is monitored only in 6% of the total surveyed area. The same quality is present in more than 30% of the rural area.

The difference in signal level observed is coherent with mobile operator strategy and operating cost. Normally they have a better and more uniform signal coverage in areas with higher user density as is normally Tirana city center, which is not the case of the area analyzed in Fig. 2b. This was what we accepted to observe for mobile operators signal coverage map.

Regarding internet connections for vehicles, mobile radio is the medium of choice. However, as a shared medium, mobile radio does not provide a guaranteed bandwidth; rather, the bandwidth varies from one radio cell to the next depending on the number of connected devices and the internet connection of the radio cell as shown in Fig. 2. Additionally, a radio cell only covers an area of small extent, so that receivers in motion have to select a new radio cell again after a short time. On top of that, the mobile networks from individual providers differ regarding coverage area.

TABLE

Measured 3G signal quality on fast moving mobile devices for AMC mobile operator in 2013.

Signal strength [dBm]	Tirana city centre [%]	Lunder (Tirana neighbour) [%]
[min, –110)	0.00	0.00
[–110, –95)	0.00	0.18
[–95, –85)	6.26	30.22
[–85, –81)	7.77	26.80
[–81, –70)	55.23	38.63
[–70, 0)	30.74	4.17

A solution for stable broadband internet on board of a vehicle must therefore consist of bundled wireless connections from multiple providers. In this way, the bandwidth of individual links can be added together. Then, the failure of a single connection only causes a reduction of total bandwidth available, while user sessions of applications are maintained. Passengers will not be interrupted surfing the web and the sensing data will be uploaded at monitoring centers during the entire vehicle trip for real time post-processing at dispatch center and at environmental monitoring center.

4. Conclusion

The proposed information technology architecture permits to improve public transport impact and performance on quality of life. The infrastructure permits via sensor nodes to collect real time data on important aspects of driver and traffic behavior, vehicle emissions, pollutant dispersion, concentration and human exposure. In addition, the same infrastructure is used for offering online access to mobile users as added value for the public transport.

In this work a mobile application is developed and used as low cost RF probe for 3G and 3.5G signal power. This tool is ease of use and enables the team to evaluate the mobile network quality from mobile providers.

The signal power strength with a sufficient level for offering a qualitative web surfing is present only in the metropolitan area and not in the rural area. Offering the same ICT platform for environmental sensing, web surfing and ITS will require in this case an access to the web using two or more different mobile operators avoiding connectivity loss.

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