HELLENIC REPUBLIC
UNIVERSITY OF MACEDONIA

INTERDEPARTMENTAL PROGRAM OF POSTGRADUATE STUDIES IN INFORMATION SYSTEMS

Master Thesis

LETS APP – DESIGN AND IMPLEMENTATION OF SOFTWARE APPLICATIONS FOR SMARTPHONES FOR RECORDING RESPONSE DATA ON EGNATIA MOTORWAY

ZINOVIA I. ALEPIDOU

Submitted as required for the Master Degree in Information Systems

February 2015

The results - deliverables of this thesis can be used freely for research and academic purposes.

Contact information:
Ath. Saramourtsis (athsar@egnatia.gr), Ath. Iatropoulos (thiatro@egnatia.gr)
Egnatia Odos SA
PO 60030, 6th km. Thes / niki - Thermi, 57001 Thermi, Thessaloniki
Tel .: +30 2310 470200, Fax: +30 2310 475936
www.egnatia.eu

Acknowledgements

The author would like to express her deep appreciation to Professor Dr. Anastasios Economidis, her supervisor, for his continuous support and valuable guidance during the preparation of this master thesis. A special thank goes to Egnatia Odos S.A., more specifically to Mr. Athanasios Iatropoulos, Mr. Athanasios Saramourtsis and Mr. Athanasios Tsantsanoglou for their clear requirements and continuous assistance. Furthermore, it should be recognized that the development of LEtS APP application could not have been conducted without the precious help of Mr. Lambros Sakellariou, IT specialist at Egnatia Odos S.A. Finally, the author is thankful to her family for their endless support, love and understanding without which she would not be able to achieve these results.

Abstract

Intelligent Transportation Systems (ITS) and their applications are attracting significant attention in academia and industry. At the same time, the steadily increasing capabilities of mobile phones are transforming them from voice based communication devices to multimedia computers. New integrated features like cameras and GPS sensors extend the device functionality to areas where special equipment was previously needed. Thus, by using the sensing and communication technologies provided by smartphones, ITS can assist transportation authorities and vehicle drivers in making informative decisions and provide leisure and safe driving experience. Nonetheless, the new possibilities are not limited in just entertainment purposes, but can be applicable in work-related activities, as well. Using smartphones in field force management, like maintenance workers whose operating area is geographically large, is a promising aspect of ITS applications.

In the context of this thesis we assist Egnatia Odos S.A. on automating their business processes of road maintenance in Egnatia Motorway. Egnatia Odos S.A. typical supporting activities include variant tasks which in many cases are done face to face or involve crucial paperwork, i.e. filling in specific information forms. To this end, we developed LEtS APP, an innovative application for smartphones and mobile devices with Android O.S. LEtS APP aims to provide features for automatic registration of emergency patrol intervention and lights night survey related information. In addition, the application provides an efficient communication framework for data restoration and parameterization. The application was evaluated against the requirements and standards set by the company during the design phase. Although this thesis focuses on LEtS APP, we believe that the proposed system is applicable to similar projects, as well.

Contents

1. Introduction 6

2. Related Work... 9

2.1. Smartphone Use in Transportation 9

2.2. Mobile Navigation 12

2.3. Vehicle to Infrastructure Communication 15

2.4. Incident Detection.. 21

2.5. Concerns raised by the development of ITS 24

2.6. ITS initiatives in Greece 25

3. LEtS APP- Architecture and Methodology.. 28

3.1. Requirement Analysis 28

Functional Requirements.. 28

Non-Functional Requirements... 33

3.2. Use Cases... 34

Use Case 1: Activity Selection 35

Use Case 2: Feature Selection 35

Use Case 3: Sign in... 37

Use Case 4: Versioning 37

Use Case 5: Entry Creation 39

Use Case 6: Entry Display/Edit.. 40

Use Case 7: Entry Upload 41

3.3. Communication between Local and Central DB 42

4. Evaluation and Results 46

5. Conclusion and Future Work.. 51

References 53

1. Introduction

Intelligent Transportation Systems (ITS) consist of a wide range of cutting-edge technologies and innovative applications used in transportation for multiple purposes such as: accident warnings, reduction of driving workload, congestion avoidance and traffic management [24]. Miles & Chen (2004) describe ITS, also known as Advanced Transport Telematics (ATT), as systems, technologies and services aiming at providing safer and more efficient transport services, by increasing productivity, improving safety, reducing travel time, reducing costs and saving energy [37]. For instance, Google's driverless car [60] is one of the most innovative and challenging examples of ITS.

The idea behind ITS is to make transportation more efficient. According to Catling (1994) the first systematic step towards ITS application development was taken in the late 1980s in the USA, though earliest attempts were found in Japan in the 1970s, with the CACS project (Comprehensive Automobile Traffic Control System) [12]. The term ITS first occurred in the early 1990s, with the adoption of the Intelligent Vehicle Highway Systems Act of 1991 by the US Department for Transportation (Wootton, Garcia-Ortiz, & Amin, 1995) [61]. However, a European project on driverless vehicles and autonomous driving algorithms called PROMETHEUS (PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety) was the first ITS to be launched in 1986 (Catling, 1994) [12].

Nowadays ITS benefit from many innovative technologies such as sensors, RFID, wireless communications, data processing, networking, automatic control, video detection and identification, GPS and information dissemination [64]. This way, it is possible to develop applications aiming at the establishment of real-time, accurate and efficient management and control of transportation systems.

It is evident that as ITS evolve, new opportunities open up regarding novel digital services for traveler facilitation and new ways of managing and maintaining transport infrastructure. Zhou, Liu and Wang (2012) [64] state that the progress of intelligent transportation will drive the development of new applications like the smart car, the smart road, the smart rail, the smart waterways, etc., as well as applications for communication between vehicles and transport infrastructure and dynamic real-time traffic information dissemination.

As a consequence, there are many transportation infrastructure providers, as well as vehicle manufacturers worldwide, that transform their operational activities introducing ITS. In the context of this thesis, we make a thorough reference to Egnatia Odos S.A. use case and the development of a mobile application that automates the company's data gathering processes - LEtS APP.

Egnatia Odos SA (EOAE) [58] is responsible for the operation and maintenance of the 660 km motorway "A2 Egnatia Odos", which is part of TERN (Trans European Road Networks, TERN), as well as the vertical axes "A23-Komotini-Nymphaea-Greek-Bulgarian border", "A25-Lagkadas-Serres-Bastion" and "A29-Siatista-Krystallopigi".

After the establishment of two new regulations within the European Union, regarding the provision of road information, the company decided to proceed with the development of innovative applications, in order to give the Egnatia Motorway drivers access to updated information about the road condition. These applications are part of the company's ITS infrastructure consisted of both web-based and mobile systems. The most interesting functions are related to vehicles motion and traffic flow information gathering, as well as event recording.

According to company's regulations, the operation and maintenance activities are executed by contractors, meaning foster private companies. The contractors are responsible for the technical supervision of the road and the detection of incidents during patrols. To this direction, the contractors are supposed to employ the needed number of Direct Intervention Units (DIU), consisting of two properly trained technicians working in shifts 24/7, in order to conduct road supervision, respond to incidents and manage road traffic. The DIU are constantly patrolling the motorway using proper equipment and their responsibilities are described in detail in the relevant operational procedures of EOAE.

After responding to an emergency situation, the DIU are obliged to fill event specific data in standard forms. Additionally, the contractors are responsible for the inspection and maintenance of electrical installations along the motorway. To this end, specialized personnel conduct one night inspection of the electrical infrastructure per month. The inspection findings are submitted to EOAE in appropriate files.

In this thesis the objective is to design and implement a software application for smartphones and mobile devices, which will automate the data registration procedures, taking place after emergency patrol interventions and night lighting condition inspections, respectively.

This paper is organized as follows: Section 2 reviews the related work. Section 3 describes the requirements based on which LEtS APP was designed and implemented. The application is examined in detail through use case examples. In Section 4 the application is evaluated and the results of the test cases are presented. Section 5 concludes this works and proposes extended feature for future use of LEtS APP.

2. Related Work

As the number of vehicles worldwide increases, the traffic problems such as traffic congestion and road incidents become more and more serious. Recently, ITS applications have been really popular, as they can alleviate traffic problems by providing multiple functions. For instance, they inform drivers about road condition and propose optimal routes to minimize travel time. To this direction, Garcia-Ortiz, Amin, and Wootton (1995) [61] list six thrust of the ITS programme of the early 1990s, covering both intelligent infrastructure and intelligent vehicles: (a) advanced traffic management systems, (b) advanced traveler information systems, (c) advanced vehicle control systems, (d) commercial vehicle operations, (e) advanced public transportation systems and (f) advanced rural transportation systems.

2.1. Smartphone Use in Transportation

The increasing demand for efficient methods and tools for traffic monitoring has been the initiative for the development of Traffic Monitoring Equipment (TME) [8]. As a matter of fact, traffic state estimation has been one of the most important aspects of ITS, since traffic state estimation systems must provide not only accurate, but also real-time information. So far, traffic data collection has been based on fixed-point surveillance equipment, such as loop detectors [52], RFID readers [7] and video cameras [15]. However, the main weakness of these approaches lies on the fact that they provide limited coverage, since it is impractical to install a huge number of sensors in every street.

Recently there is an increasing interest in data collected from mobile stations. According to Turner et al. (1998) [56], Automatic Vehicle Identification (AVI) detectors and GPS are key technologies for mobile data collection. Nowadays, worldwide penetration rates of cellular phone (CP) usage offer an opportunity for large-scale traffic surveillance applications with minimum cost [8]. Since mobile phones are available everywhere the essential issues in traditional road-fixed traffic data collecting approaches, like coverage limitation, real-time effect, investment and maintenance cost can be overcome.

Research has proven smartphones very popular as data collection tools, especially when it comes to mobility patterns and transportation network performance. Gonzalez, Hidalgo, and Barabasi (2008) [26] have shown that human mobility has a high degree of spatial and temporal patterns, studying mobile phone user’s position. In addition, Tam and Lam (2008) [51] have used vehicles’ GPS data to estimate travel time. Bierlaire, Chen, and Newman (2013) [9] used smartphone GPS data to model individual route choice behavior, as well. It is evident that being embedded with various sensors like GPS and accelerometer promotes smartphone utilization as a means of studying users’ behavior responses to the transportation information services.

Chen and Bierlaire (2013) present a probabilistic method based on smartphone data that infers the transport modes and physical paths of trips [13]. More precisely, the method synthesizes various data from smartphone sensors like Global Positioning System (GPS), Wi-Fi spots, cellular radio, digital compass, video camera, microphone, Bluetooth and accelerometer. Acceleration data have been proven useful in recognizing the motion status of the mobile phone holder. Moreover, Bluetooth provides information regarding the smartphone’s context, i.e. if other Bluetooth devices exist in a public transport environment. The intention of this study is to investigate an integrated smartphone measurement model, that combines sensor models in a unified framework. In more detail, this model exploits traveler’s movement speed information in order to generate candidate paths in a transport network. The goal is to capture the dynamic of the smartphone’s holder state in the transport network. In addition, Magtoto and Roque (2012) have designed an Android application that is smart enough to act as a GPS device only once it enters a specific segment of a highway [34]. This saves processing cost since it only transmits data within the area of interest. The 3G connection of the mobile device is used afterwards to send location and other data to a designated server. The server is composed of an open source software system which is used for storing, processing and disseminating traffic status data over the internet.

Another research conducted by Basyoni and Talaat (2014) is based on the assumption that cellular phone (CP) network is a promising option for traffic data collection, given the high CP market penetration rate [8]. The study presents a bi-level procedure for the extraction of classified vehicular traffic counts for different vehicle types. At the first level, cellular phones on board the vehicle are clustered. At the second level, a Genetic Fuzzy Classifier (GFC) is used for vehicle classification into four different classes:

passenger car, truck, bus and minibus. Their research relies on data mining and artificial intelligence to achieve vehicular trip data extraction from CP data without the assistance of a secondary surveillance system.

Monitoring the varied road and traffic conditions in developing countries is challenging due to various socioeconomic reasons. Traffic monitoring systems based on cell phones like the one described are particularly suitable for developing countries, where the lack of resources for traffic monitoring infrastructure can be compensated by the high penetration rate of mobile phones [17]. According to [59] by the end of 2007 the penetration rate of mobile phones in population was over 50% in the world, ranging from 30% to 40% in developing countries. Hence, this approach can be useful for the development of ITS in several developing countries, where fixed-based surveillance infrastructure is unaffordable. To this end, Nericell [40] performs rich sensing by using the accelerometer, microphone, GSM radio and/or GPS sensors of mobile devices to detect potholes, bumps, braking and honking in the transportation network of developing countries. In addition, Perttunen et al. (2011) propose a mobile device based system to improve road-safety by collecting and distributing up-to-date road surface condition information [45]. With the use of accelerometer and GPS the application detects road surface anomalies that are related to road roughness.

In another survey, Minh et al. (2012) refer to M-TES, mobile phone based traffic estimation systems as a part of M-ITS, mobile phone based ITS technologies [38]. The major contribution of their work is the proposal of a traffic state quantification (TSQ) model which manages to identify the traffic state level with the use of accurate velocity and density estimation. Furthermore, they propose an intelligent content-aware velocity-density interference circuit (ICIC) by which contextual data extracted from mobile devices GPS are processed to provide accurate traffic state estimation.

Smartphones can be useful in Automatic Vehicle Location (AVL) applications, as well. AVL is a technology used to determine the geographic location of a vehicle. The output of AVL systems can be used for managing transportation systems [19]. This way, the users of public transport can overcome many difficulties like cognitive disability [11], transportation punctuality related anxiety [18] and confusion if the transportation is going to the right place [6].

In [28], Ito et al. (2011) propose an AVL system where the data transmitted via the passengers' smartphones are used for geographically locating a public transportation vehicle. Currently, only big cities can provide real-time information to public transport users via AVL systems, because of the high cost of these types of infrastructure. On the contrary, the proposed approach determines a public transportation vehicle's location by the data sent via the passengers' smartphones. This information can be adopted by an AVL system with reduced cost of implementation.

Finally, Ansar et al. (2014) evaluate the capabilities of smartphones for real-time multi-horizon traffic prediction by assigning a part of the computation power to the user's mobile device. In other words, they proposed network extrapolation on user's device. They utilized smartphone performance to extrapolate results for the entire network by focusing only on subset of "representative" road segments. This type of decentralized infrastructure can significantly reduce the communication overhead and enhance the development of cooperative, peer to peer networks for the NextGen ITS applications [4].

2.2. Mobile Navigation

Mobile navigation is becoming more and more popular. Apart from the ease of use, the advantages of mobile navigation applications are many. To begin with, mobile devices are practical, as the user has one device for every function. In other words, the user is not obliged to have a separate device other than their mobile phone in order to make use of navigation functions. In addition, mobile devices can be used for navigation by everyone, including pedestrians and cyclists and not only motorists.

Mobile devices can be used as data sensors, since they can estimate user's location and provide information regarding other traffic parameters, like average speed and velocity. The same concept has already been used for in-vehicle navigation systems. However, the main difference is the extra cost for including sensors in the guidance system itself. Since mobile devices are expected to saturate the market, large amounts of sensing data will be available for applications, providing information about real-time traffic conditions and potential incidents.

The acceptance of the mobile navigation by the market is shown in a survey conducted by GfK Retail and Technology [22]. The survey was about the use of navigation devices. According to the findings, 53% of the respondents in Germany, 48% in the United Kingdom and 39% in France believe that mobile phones with new navigation features will gain an important share in the market in the near future.

Gkiotsalitis and Stathopoulos (2014) in [25] present an application for mobile navigation, which is targeted to users who either do not have access to private vehicle or would like to combine a vehicle with public transportation as long as it guarantees the reduction of their total travel time. Furthermore, the proposed application exploits the user's individual preferences in an attempt to suggest intermodal transport means that fulfill the user's custom needs when it comes to navigating in complex urban networks.

This application differs from common mobile navigation applications since it provides the user with integrated information about private and public transport at the same time. Hence, the user is informed about where to drive, where to park, what transport means to use, which is the station where they need to change transport mode and how to reach eventually their final destination. In case a private vehicle is not available, the user is informed about the fastest path via public transport only. Another significant advantage of the application is that it has access to real-time traffic congestion information, train and bus schedules and more. Finally, the combination of all this information leads to the proposition of a route based on optimal paths with respect to the user's preferences.

In addition, Liu et. al (2013) propose a traffic information system which recognizes driving status, detects the driving route and updates the traffic condition, by collecting real-time information from the user's smartphone [32]. In details, firstly the roads are modelled into virtual maps which are then stored into a topology relational database. Secondly, a lightweight driving status tracking algorithm is proposed based on the smartphone's accelerometer and compass. Finally, sensor readings are combined with user's driving status and the database to automatically provide real-time route recognition. Moreover, Zheng et. al (2014) proposed iTrip [63], a novel community sensing service which utilizes smartphone accelerometer in order to detect and predict accurate traffic signal schedules. Vehicle events like start and stop moving can be detected by accelerometers installed in on-vehicle mobile devices. By collecting and processing these data, iTrip can predict the traffic signaling in the near future by estimating the traffic signal schedule.

Crowdsourcing has inspired a variety of novel mobile applications. Kashif et. al (2012) proposed a crowdsourcing-based ITS schema, named CrowdITS [5], in order to support the development of ITS applications, such as congestion free path re-routing. In CrowdITS human inputs (i.e. voice) along with data collected from mobile phone sensors (i.e. GPS) are communicated to a processing server. The idea is to enable ITS applications without the need of any sophisticated sensors or complex communication devices. This way, human input is extended with multiple information sources and localized according to driver's geo-location. CrowdITS supports also communication to the opposite direction, as server pushes out events of possible interest to the driver according to their geo-location.

Moreover, Chen et. al (2012) studied smart parking to investigate features of crowdsourcing that can be used in mobile navigation systems. According to their findings [14], mobile crowdsourcing enables data collection through a large number of mobile devices. Furthermore, the collected data come primarily from the surroundings of people's everyday life. This collaborative data collection enables the design and implementation of services like smart parking. To this end, they designed a mobile crowdsourcing framework used for the integration of smart parking into a road navigation system. The only sensing device needed for this purpose is the road navigation system the driver already uses.

Mobile navigation may even be applicable for pedestrians using their smartphone. WalkCompass [48], a system that exploits smartphone sensors to estimate the direction in which the user is walking, is proposed by Roy et. al (2014). They managed to develop a stable technique to estimate the user's walking direction within few steps regardless of the orientation of the mobile device they possess. First, the vibration generated when the user strikes their heel on the ground while walking is reflected on the accelerometer data across all holding positions, even when the user is holding the mobile device against their ear. WalkCompass uses this vibration as reference, scans the signal backwards and extracts specific sample while the user is dominantly in the heading direction. Afterwards, the signal is processed with the gyroscope data. Finally, the motion vector is projected to the plane orthogonal to gravity and averaged over the few first steps to indicate the local walking direction.

Finally, surveys like the one conducted by Bustillos et al. (2011) concentrate on modeling the user's navigation behavior after the announcement of a road incident [10]. Modeling impacts of incidents and their associated management strategy is an important topic in ITS planning and operations. This research focuses on addressing several aspects of real-time and en-route diversion due to an incident scenario. The results have shown that when a traveler is informed about accident disruption on their selected route, they are triggered to consider an alternative one. According to the spatial and temporal availability of this information, the re-routing decision can be taken either at the beginning or in the middle of the journey.

2.3. Vehicle to Infrastructure Communication

The important role of communication within ITS is evident even in nature and especially the ant world. Due to their cooperative nature and communication mechanisms, ants have the ability to flow free, by maintaining the same velocity even after density increase [39]. In ITS communication can be distinguished in: communication between vehicles knows as Vehicle-to-Vehicle (V2V) communication, communication between a vehicle and a base called Vehicle-to-Infrastructure communication (V2I) [42] and Vehicle-to-X (V2X) communication [46].

V2X technologies in general have the potential to improve safety of everyday road travel, as it is estimated that these systems could address 81% of all-vehicle target crashes [43]. Diewald et. al (2012) have implemented a V2X based prototype named DriveAssist [41] in an Android device. This solution is able to combine traffic information from different sources and offer several modes for informing and assisting the vehicle passengers. The combination of data from V2X and Central Traffic Services (CTSs) allow a good operability even when there are only a few vehicles equipped with V2X communication. In the context of this thesis, we will focus specifically on architectures for V2I communication platforms.

Vehicular Ad-Hoc Networks (VANETs) allow vehicles to communicate with other nearby vehicles and with the infrastructure [55]. This communication can be realized by the use of On Board Units (OBUs). However, according to estimations it will take more than 10 years for the OBUs to achieve a penetration rate around 80% [55]. Moreover, experience shows that only luxury vehicles tend to incorporate this type of high-tech devices. Simultaneously, smartphones have already reached 50% of penetration in developed countries. The advantages of smartphones over OBUs when it comes to VANETs are mainly the ease of deployment without the need of any special installation of hardware equipment and the low cost of mobile devices. As a proof of concept, Tornell et al. in [55] present an implementation of an ITS warning system based on VANETs for Android smartphones. Their application diffuses ambulance's warnings in nearby vehicles and it can be easily customized to support any type of alerts like slippery road surface or accident.

According to Gkiotsalitis and Stathopoulos (2014) [25], mobile internet is one of the main advantages of mobile devices, especially when it comes to mobile navigation. One of the main benefits is that the user is not obliged to purchase digital maps, let alone keeping them up-to-date with frequent installations of new versions. Moreover, the mobile device can have access to digital maps (i.e. Google Maps) anywhere, provided that internet connection is available. Thus, the user takes advantage of access to digital maps wherever they are, without having to worry about pre-installation and recurrent updates. The application presented in [25] uses information exchange architecture, where a mobile device communicates with an external server. It is named Mobile Device - External Server Partnership (M-ESP).

Typical client-server architecture is described in [32] and an overview can be found in Figure 1. In this architecture smartphones are approached as clients that communicate with a central server. Each smartphone uploads its traffic information to the server. Hence, the server collects the information from the mobile devices and updates the traffic information database. The server can also respond to client requests, i.e. download customized road topology database. Client-Server architecture was also used in iTrip [63] where on-vehicle smartphones (clients) sense data and report their own individual knowledge to the server. Thereafter, the server composes all provided data to estimate the traffic signal scheduling.

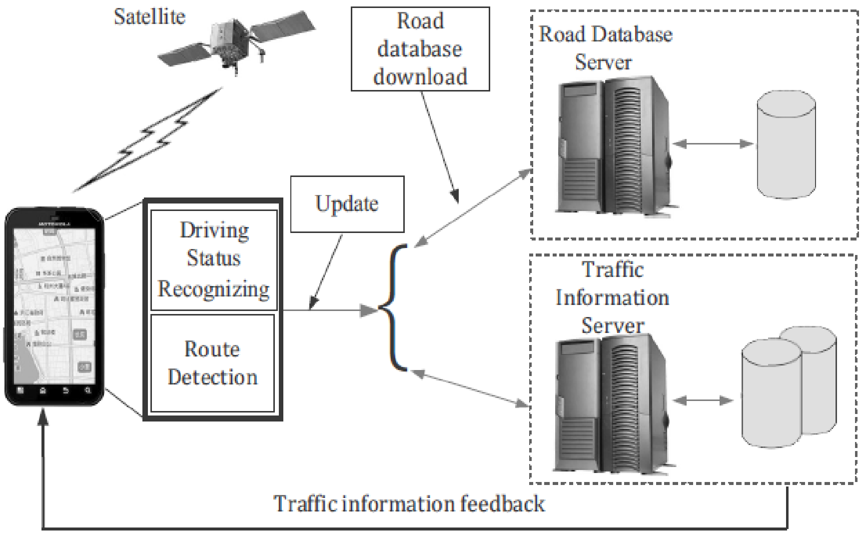

Figure 1: Client-Server Architecture

Another communication platform is described by Wofson and Lin (2010) in [33]. It is called ITS Information Platform (IIP) and it is intended to be used as a common data management and communication services platform facilitating and easing applications development. The architecture of IIP is presented in Figure 2.

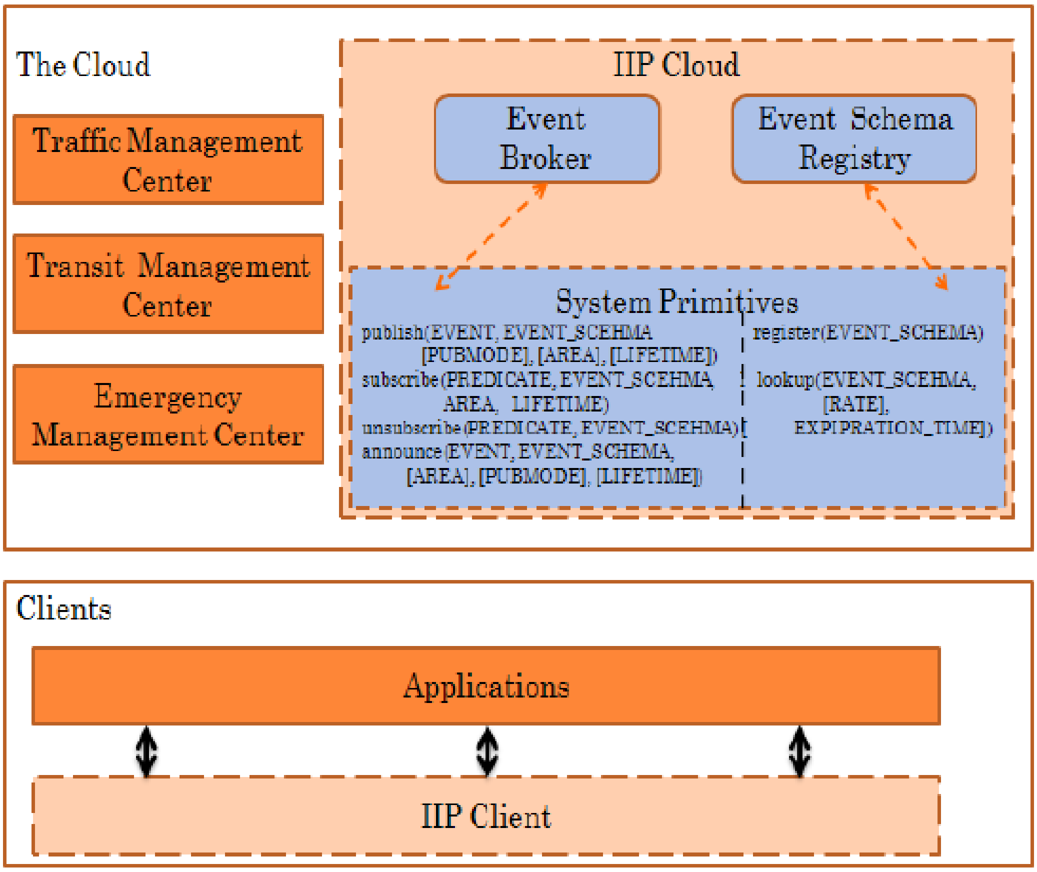

Figure 2: ITS Information Platform Architecture

IIP combines two main components, the IIP Cloud Component and the IIP Client Component. The former provides publish/subscribe functions to both traffic management facilities and mobile devices. The latter, provides mobile devices with publish/subscribe functions which allow communication between the device and the IIP Cloud Component, as well as between different devices. Hence, by including heterogeneous data sources and multiple communication mechanisms to ITS, IIP can support a variety of ITS applications.

VoCell application development framework is presented in [44]. It intergrades a set of components that ease the development of smartphones applications for vehicular networking systems. VoCell facilitates developers to access internal and external sensing components and share these data to servers, with the use of suitable APIs for cloud/web-based services development. VoCell is implemented as a library for the Android SDK. The framework is presented in Figure 3.

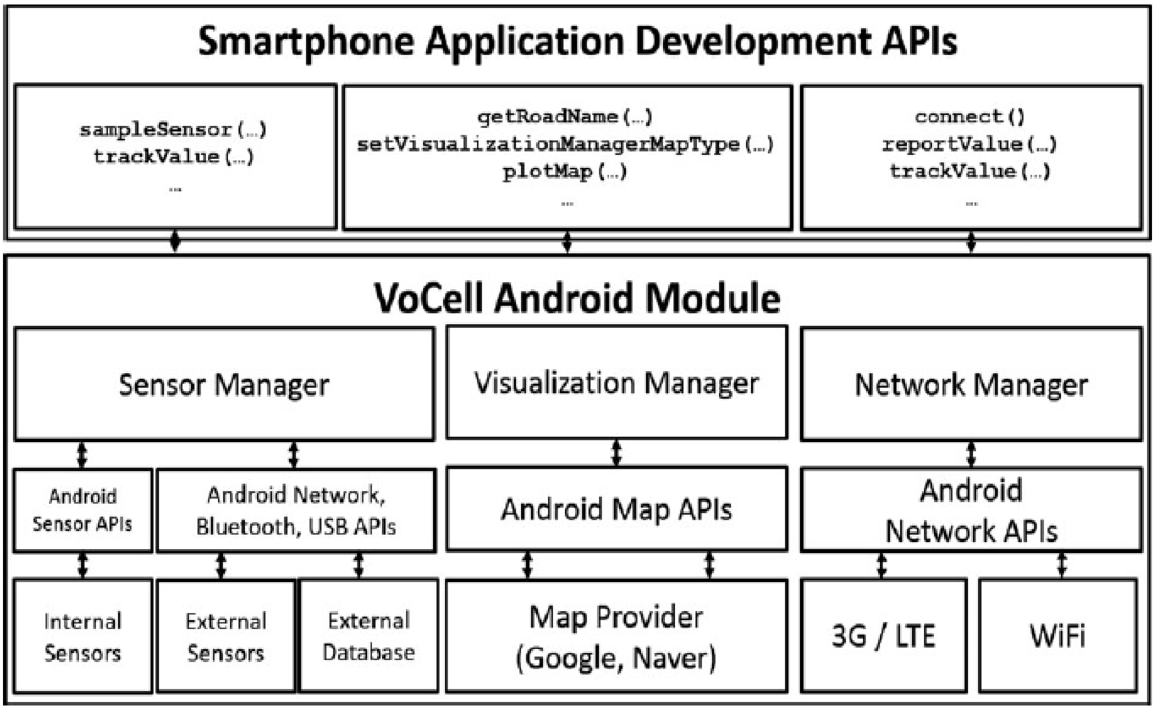

Figure 3: Architecture of the VoCell application development framework for the Android SDK

An infrastructure based on semantic feedback from mobile device users is presented in [20]. Garrigos and Zapater (2012) study a semantic approach with the goal of managing real-time information on ITS applications. The system gathers real-time information about the travel time in a specific road segment. Afterwards, this information is processed in order to provide feedback to the users of the application regarding road conditions, i.e. support the decision of allowing the entrance or not to incoming vehicles. This semantic infrastructure system is presented in Figure 4.

The design of this architecture is based on Semantic Web principles. Concepts and rules related to the specific domain have previously been modeled into ontologies using OWL (Ontology Web Language). The system allows adding external ontologies, as well. The infrastructure processes are able to reason about the facts contained in the system, by combining information stored in the Knowledge Database (KB), third-party ontologies and data information. Hence, the system is able to perform different actions and provide different final services to clients.

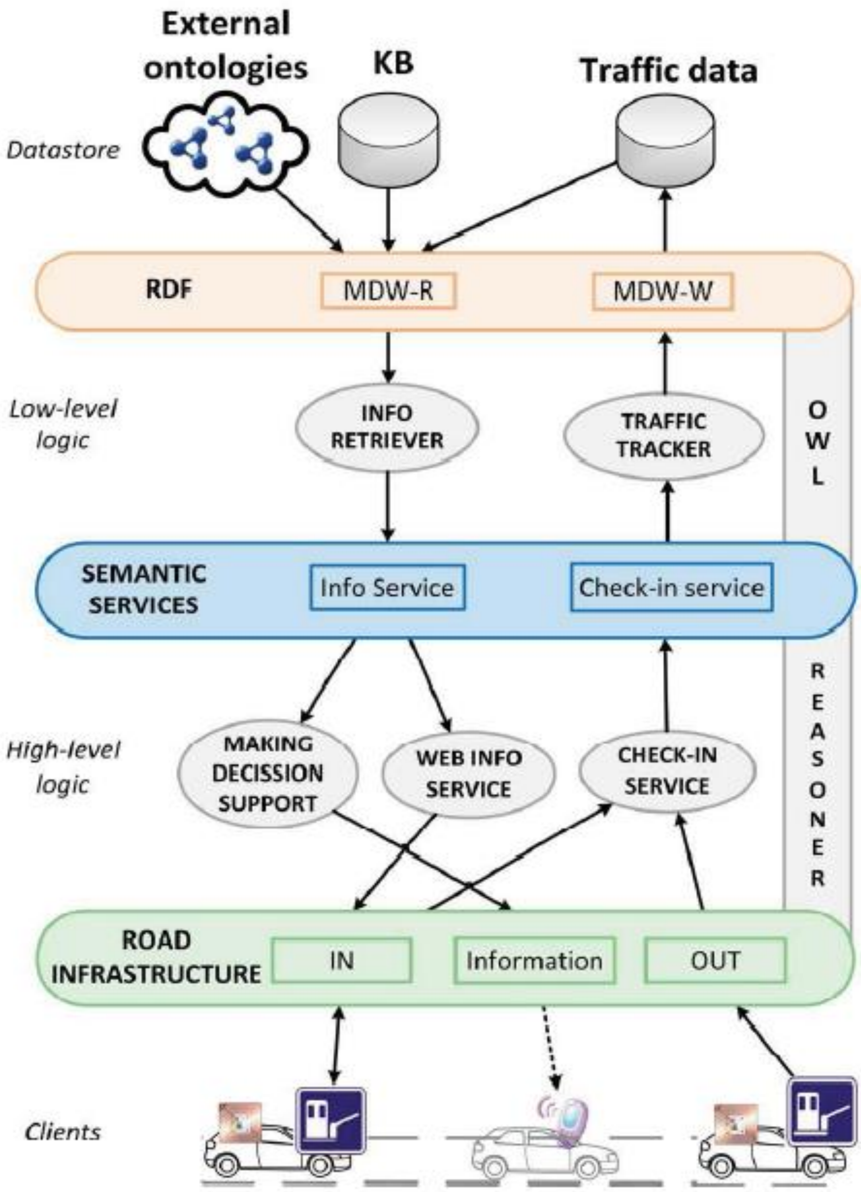

Figure 4: Semantic-based infrastructure managing system with feedback

Pyykönen et al. (2014) suggest a new schema for combining functionalities from the personal ITS station and vehicle ITS station, using Co-operative Mobility Services of the Future (CoMoSeF) project [57]. The proposed architecture is depicted in Figure 5 [47].

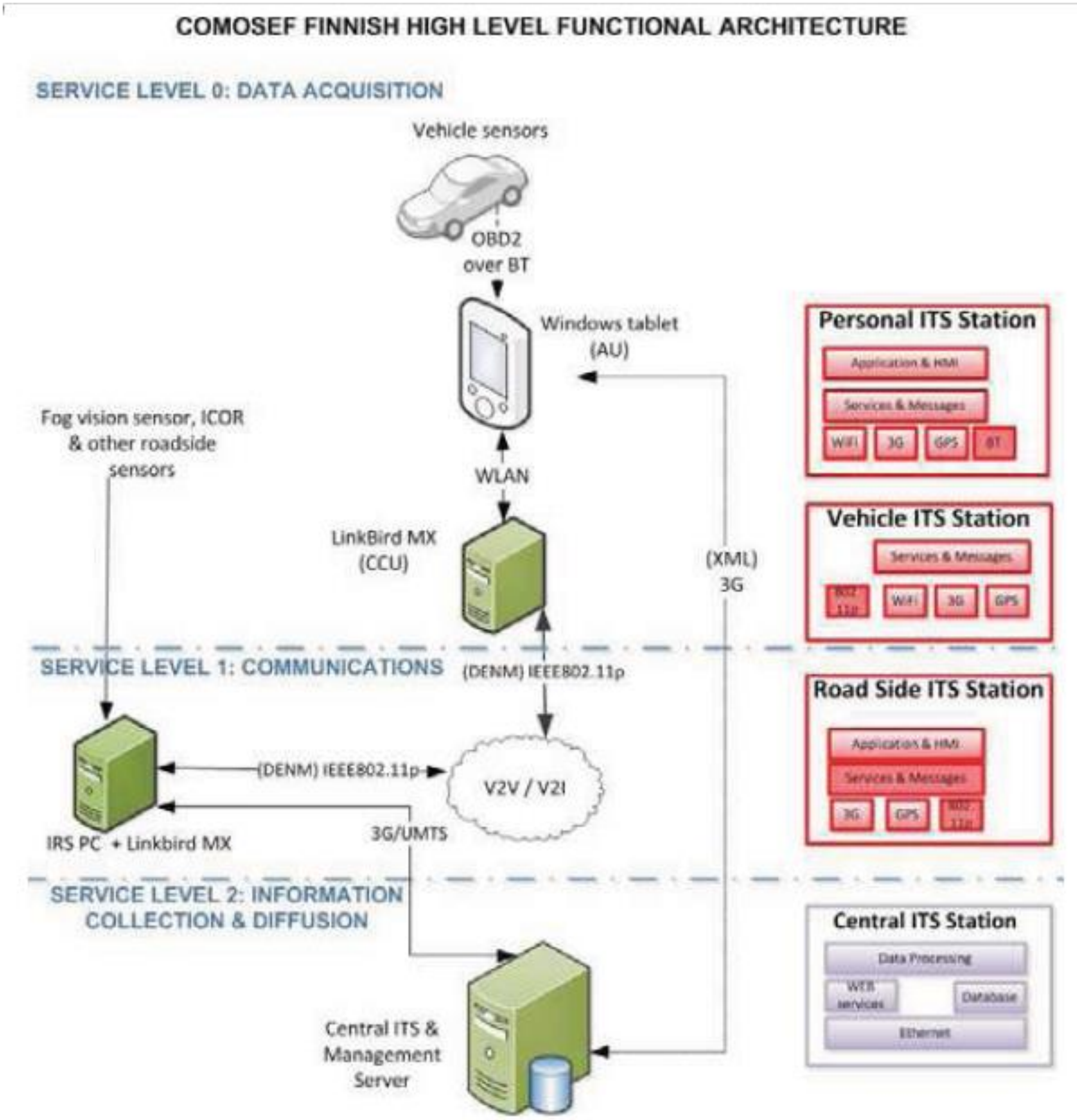

Figure 5: CoMoSeF High level functional architecture

On the left side, there are the data connections and data flows and on the right side the main components. Three service layers can be distinguished:

- The *data acquisition* layer, which is composed of all the sensors and cameras which provide the information and the data gathered from OBD2 (via Bluetooth).

- The *communication* layer, responsible for ensuring inter-station communication between field infrastructure and management center. It also includes the road side ITS station. The communication between the road side ITS station and the vehicle is realized over 3G networks. In this specific implementation a fog detection system plays the role of the road side ITS station.
- The *information collection and diffusion* layer is in charge of processing the data, gathering and storing them in databases for future use.

Finally, the applicability of LTE networks in V2I communications is examined by Abid et. al (2012). Smartphones enriched with LTE capabilities are suitable for vehicle communication especially thanks to the rapid penetration of 4G networks [1]. The simplified architecture of LTE is shown in Figure 6.

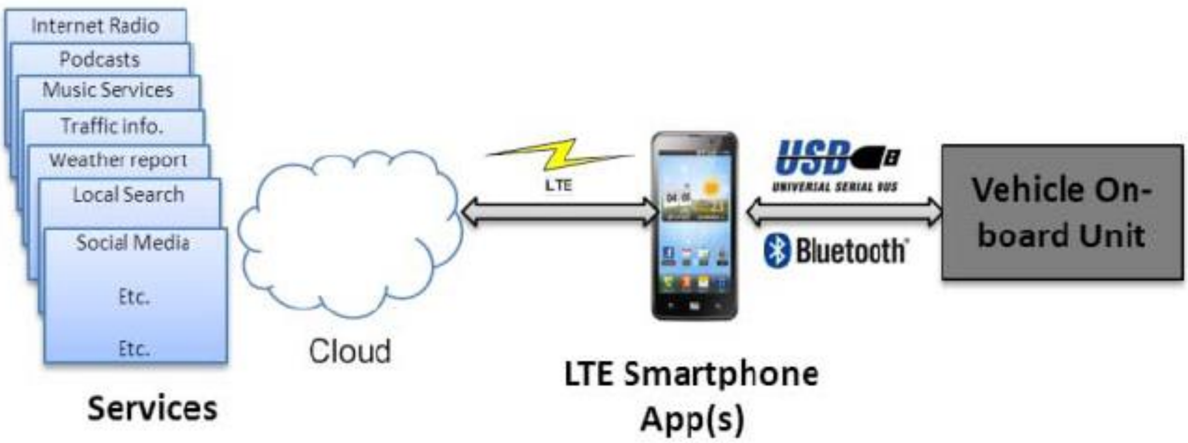

Figure 6: Accesing Information Services from Cloud

The passengers make use of their LTE smartphone devices, as the vehicle is moving on a highway. In this case, the smartphone is attached to an OBU system through a proper interface like USB or Bluetooth.

2.4. Incident Detection

Automatic Incident Detection Algorithm (AIDA) is used for the automatic detection of incidents mostly along freeways [35]. AIDAs are able to detect incident-induced spatial and temporal variations of traffic parameters. Usually, traffic detector systems collect traffic information which is used as input in an AIDA. Incident occurrences in signalized urban arterials are usually the reason for traffic jams and congestion. As a consequence, travel-time delays, reduction in arterial capacity and air pollution are some of the main effects observed daily on busy urban street networks. Thus, AIDA implementation becomes essential when early detection of operational problems is crucial for the re-establishment of normal urban traffic conditions.

Mak and Fan (2013) evaluated an algorithm fusion procedure for incident detection, developed for the Central Expressway (CTE) in Singapore [36]. Their goal was to demonstrate its transferability potential in detecting lane-blocking incidents in the freeways of Melbourne. Although there has been adequate research on AIDAs that remotely detect incident occurrences in highways and freeways, Ghosh and Smith (2014) argue that there has been little research towards automatic incident detection in urban arterials [23]. They claim that incident detection in urban transportation differs from the one taking place in highways, since the traffic patterns are different. Street parking, side streets, as well as traffic signals can interrupt steady traffic flow resembling incident traffic patterns. To this end, in [23] a new strategy of customizing AIDAs, in order to render them adaptable to signalized urban transport networks is proposed. Although, urban arterial incident detection research has been based mostly on the development of urban arterial-specific AIDAs, this strategy focuses on preprocessing the urban traffic data before they are used as input to an AIDA used for freeways/highways incident detection. This procedure attempts to lessen the effect of traffic signals and to initiate the preprocessed input urban patterns in highway-based incident conditions. This way, existing AIDAs can be incorporated in incident management systems (IMS) used in signalized urban networks, without any extra instrumentation or operation cost.

A different approach to small-scale incident detection with the use of microblogs is presented in [50]. Schulz et. al (2013) propose a solution for a real-time identification of small-scale incidents using microblogs, hence allowing to increase the awareness about a given situation by eliciting additional information on incidents. This approach is based on a machine learning algorithm combining text classification and semantic analysis of microblogs context.

The idea behind this approach lies on the assumption that citizens act as observers in crisis situations and provide potentially valuable information on different social media platforms. Small-scale incidents, like car crashes, usually have narrow geographic and temporal coverage on social media. In [50] tweets continuously collected using Twitter

Search API[1] are used as input into classifiers, after special spatial and temporal filters are applied. This way, machine learning and semantic web technologies can be combined to identify small-scale incident related tweets.

Incident detection with the use of smartphones has already been studied. Aldunate et. al (2013) presented a method for vehicle crash detection via smartphones [3]. In case of a car accident, prompt assistance to the people involved has significant impact on the consequences of the crash. Some car manufacturers include technology embedded on the vehicle to communicate automatically with emergency agencies in case of an accident. However, this approach increases the cost of vehicle manufacturing and is only available in a small proportion of vehicles in most urban transport networks. Research [3] has shown that cell phones equipped with sensors like accelerometer and microphone can be used by people carrying them as means for vehicle accident detection and remote notification of such events.

Furthermore, smartphones can be combined or even replace OBUs in order to detect accidents in highways. The increasing dominance of ITS faces a strong limitation: the slow pace at which vehicles become "smarter", whereas smartphone industry is advancing quickly. Zaldivar et al. (2011) propose an Android-based application that monitors the vehicle through an On Board Diagnostics (OBD-II) interface, in order to detect accidents. In their solution, smartphones are used as alternative to OBU, accessing the information in the vehicle's internal bus wirelessly. The requirement for this approach is that the vehicle supports the OBD-II standard [27].

More specifically, the application monitors the vehicle's speed and airbag triggers to detect a potential accident occurrence. In particular, this solution relies on Bluetooth technology to establish data connection between the mobile device and the Bluetooth-enabled OBD-II interface. Hence, the application reacts to a positive detection by sending details about the accident through either e-mail or SMS to predefined destinations, using either the WiFi or 3G interface. The exact GPS location of the accident is included in the accident details, as well. Simultaneously, an automatic phone call to the emergency services takes place. Experimental results have proven that the application is able to react to accident events in less than three seconds.

[1] https://dev.twitter.com/rest/public/search

2.5. Concerns raised by the development of ITS

In [42], Musika and Rashid (2014) argue the use of agent technology in ITS and more specifically to autonomous driving. According to their research, existing multi-agent technologies used in autonomous cars are not designed for security, making them vulnerable to attacks. These attacks may target the car's brakes, anti-lock brake system (ABS) or even GPS.

The subject of secure vehicle registration to cloud services is raised in [53] by Timpner et. al (2013). Therefore, their research proposes a secure smartphone-based registration and key deployment process, which is highly independent from central authorities and feasible security audits thanks to an open protocol design. In other words, by means of smartphone-based registration and key deployment process for Vehicle-to-Cloud (V2C) communications, it is possible to achieve a high degree of user independence from third parties, since nobody but the owner has access to the vehicle's private key. Moreover, the open and easily auditable proposed protocol guarantees user trust in the underlying cryptographic principles.

Security techniques for Smartphone-to-Cloud communication should be based on established and well-studied standards [53]. However, minimizing the hassle of requiring the user to repeatedly login before usage may result in unlimited user session on a single mobile device. Therefore, it is obvious that revocation of user sessions is crucial. Imagine for example the case where a user has their mobile device stolen. Avoiding storing passwords on the mobile device and providing access revocation can prevent from intrusion into the user's personal information. In addition, SSL connections where certificate checking is performed without using a list of trusted Certificate Authorities (CAs) allows to shift the trust from outsourced CA management to the smartphone application itself by including the public key in the binary.

Another important aspect of mobile application is related to privacy. Since mobile devices communicate with external applications privacy protection has to be taken seriously into account. As mentioned in [32], traditional information collection systems upload GPS data directly to central servers. This way, user's sensitive information such as permanent residence and work location could be revealed. Data downloaded from central servers are also vulnerable. Therefore, the action taken in [32] is on one hand to upload traffic information instead of GPS data and on the other hand to dynamically generate data to be downloaded, which prevents deciphering.

2.6. ITS initiatives in Greece

As member of the European Union, Greece participates in many European projects which aim to the introduction of innovative ITS infrastructure in the European highways. One of these projects is iMobility[2]. The goal of iMobility is to foster the deployment of intelligent mobility in Europe by organizing iMobility forum activities. Stakeholder networking, deployment support, awareness raising and dissemination of results, are some of the initiatives taken in the context of iMobility project. In May 5th 2014 a workshop on "EU legal framework to certify automated road transport systems in urban areas" was held in Athens[3]. The idea behind this workshop was to discuss the legal and regulatory framework and to start formulating proposals for needed measures regarding certification of Automated Road Transport Systems (ARTS) in urban areas. Therefore, experts in guided transport systems and ITS, represented 12 European Transport Ministries in order to discuss automation technologies and the risk assessment framework.

Furthermore, Greece participates in HeERO[4], a European ITS project that addresses the in-vehicle call service eCall. eCall is based on 112, the common European emergency number. From January 2011 to December 2013 Greece was one of the nine European countries forming HeERO 1 consortium that carried out the start-up of an interoperable and harmonized in-vehicle emergency call system. The term eCall describes an emergency call generated either automatically via activation of in-vehicle sensors or manually by the vehicle passengers. When the service is triggered, it provides notification and location information to public authorities. By means of a mobile network, eCall service notifies about incidents that require response from the emergency services and establishes an audio channel between vehicle passengers and public services.

---

[2] http://www.imobilitysupport.eu/

[3] http://www.imobilitysupport.eu/component/acymailing/archive/view/listid-2-imobility-forum-members-mailing-list/mailid-34-workshop-in-athens-on-automated-road-transport-systems

[4] http://www.heero-pilot.eu/view/en/home.html

The main advantage of eCall service is the immediate notification of the emergency services the moment an accident takes place. In fact, the response time of emergency services reduces significantly not only because of the early notification but also because the authorities are given the exact location of the accident through the transmission of the GPS coordinates [17]. On the other hand, there is strong resistance against the installation of eCall services in vehicles. The resistance lies mainly on the fear of constant monitoring and intrusion on the driver's private life [21]. Moreover, eCall services are limited only to luxury cars, on a specific geographic market or even in a specific brand.

In terms of road safety, Greece participates in South East Europe Safe Routes (SENSoR) Project[5]. In South East Europe, more than 10,000 people lose their lives annually, with a further 100,000 seriously injured. The cost of all road crashes (excluding traffic delay costs) exceeds 2% of the region's GDP annually. These numbers raise road safety to a major issue that needs immediate action. To this end, the European Union and development banks have new safety requirements for the road projects they support. Thus, European Road Safety Area has been proposed to ensure that road networks are consistently safe for travel between European countries.

Development banks globally have jointly announced their support for safety ratings measurably. The SENSoR project takes safety measurements one step forward by identifying the risks that road users face from infrastructure. To do so, Project Partners apply the latest tools from the International Road Assessment Program (iRAP)[6] a charity supporting countries and financial institutions worldwide. The results give GPS-mapped sites where improvements, often as simple as barriers, school crossings or roadside hazard clearance, can make a difference.

Except from the participation in European initiatives, in Greece ITS Hellas[7], the Hellenic, non-profitable Intelligent Transportation Systems Organization, has been established in order to promote the development and use of ITS infrastructure in Greek transportation networks. ITS Hellas is formed by public institutions, companies and research organizations that aim to the implementation and the evaluation of ITS

[5] http://sensorproject.eu
[6] http://www.irap.org/en/
[7] http://www.its-hellas.gr/purpose.html

applications. ITS Hellas activities focus on all four transportation areas: shipping, road, rail and air transport. Moreover, they cover a wide range of research fields, such as transport infrastructure, vehicle technologies, communications, telematics, development of software and hardware, socioeconomic issues, transportation and traffic management, etc.

As far as Greek transportation companies are concerned, major motorway operation and maintenance organizations have introduced ITS applications to their activity lifecycle. In an attempt to increase road safety, Nea Odos, the concession company which has undertaken the study, design, construction, operation, exploitation and maintenance of "Ionia Odos" concession project[8], has introduced an ITS infrastructure to keep track of the accidents happening on Ionia Odos [49].

In details, Nea Odos has deployed a unified system based on three entities: a road surface condition management system where pavement condition data are registered, an accident database where georeferenced pictures of accidents are stored and finally meteorological stations. Thereby, with the combination of the above information and the use of GIS, Nea Odos is able to relate accidents to road surface failures and weather conditions. As the system maintains history records, it can keep track of accident frequency in specific road sections, thus indicating those motorway segments where the need for extra safety measures is vital.

In the context of this thesis we study the implementation of an ITS application to the existing ITS infrastructure of Egnatia Odos S.A. The company uses a Routine Maintenance Management System (RMMS) for the effective routine motorway management [29]. The system provides control over the work of maintenance contractors, in order to improve quality and effectiveness of the maintenance services. The RMMS database stores information related to the geographical location of the road network, maintenance requirements, required resources for planning of maintenance works and the performance of the contractors. The mobile application LEtS APP presented below has been developed in order to extend the ITS capabilities of Egnatia Odos S.A.

[8] http://www.neaodos.gr

3. LEtS APP- Architecture and Methodology

Continuous growth and sustainable development are the main goals of each organization which wants to lead its way into the future. To this direction, Egnatia Odos S.A. has decided to introduce new ITS technologies in order to make everyday operations more efficient in an ultimate attempt to offer Egnatia Motorway travelers a wide variety of services. In this section, a mobile application for data gathering automation LEtS APP is described.

Despite the fact that there has been thorough research on smartphone usability in ITS applications, a few studies focus on the use of mobile devices in road maintenance. A mobile tool for road maintenance workers has been developed by Ahtinen et al. (2007). This application has three main features: automatic GPS data collection and upload to a dedicated server via 3G or GPRS, depending on network availability, creation of location specific notes and finally GPS location conversion to a standard road address [2].

As previously mentioned, Egnatia Odos S.A. follows a Business Process Strategy (BPA), in order to automate the procedure of incident intervention and night lighting inspection data registration. Existing mobile tools and technologies were not used, as the company's specific requirements could only be met by a customized solution. Therefore, this thesis describes a novel application for smartphones and mobile devices that will be used by the DIU during their ordinary patrols.

3.1. Requirement Analysis

In this section we make a detailed reference to the requirements posed by the company regarding the application.

Functional Requirements

<u>General</u>

FG.1. The application will provide the following features:

- Egnatia Odos Emergency Patrol Intervention_ App (*EO-EPI_App*): This application will automate the registration of data concerning the outcome of emergency patrol interventions taking place after incident detection on the motorway.
- Egnatia Odos Lights Night Survey_App (*EO-LNS_App*): This application will automate the registration of data concerning regular night lighting condition inspections, happening once each month.

FG.2. The user will fill the relevant information in “blank forms” after each intervention or inspection.

FG.3. The application will apply two database systems:

- A Central DB, located in a remote server, where the information regarding each intervention or inspection will be stored permanently.
- A Local DB, located in each mobile device, where the information regarding each intervention or inspection will be stored temporarily until they are uploaded to the Central DB. Parametric tables used during data registration will be also stored in the Local DB.
- A special mechanism will be used to synchronize the above mentioned DB systems

FG.4. Entries stored in the Local DB can be next-day verified/ locked before the batch upload to the Central DB

FG.5. The user will be able to read/edit older entries, as long as they haven’t been permanently stored to the central database system.

FG.6. Data transfer will take place:

- From the central server towards the mobile device, each time there is a change or update in the elements of the parametric tables used in the application (e.g. road sections, road sections descriptions, event types, etc.). There will be a special mechanism used for versioning, in order to ensure the fact that the application uses the latest version of the parametric tables.
- From the mobile device towards the central server, each time an intervention patrol of light night survey is concluded and the registered outcome is inspected by the responsible head of the patrol.

FG.7. After successful upload to the central database, the local database will be automatically cleaned, deleting entries older than one month.

FG.8. The option to select specific data from the parametric tables (e.g. road section) according to the inspection area may be taken into account during the design.

FG.9. Further development of search filters, reports, statistics or visualization on maps using Geographic Information Systems (GIS) should be considered optional depending on the progress and the time availability.

Egnatia Odos Emergency Patrol Intervention_ App (*EO-EPI_App*)

FEPI.1. This application shall automate the registration of the outcome of an emergency patrol intervention, which may take place after an incident occurrence on the Egnatia Motorway.

FEPI.2. The user is expected to fill in the data presented in Table 1:

Table 1: Egnatia Odos Emergency Patrol Intervention_ App (EO-EPI_App)

DESCRIPTION	TYPE	COMMENTS
ROAD SECTION	M	e.g. A2/23_22 The list with the available options will be pre-loaded before the application is launched
ROAD SECTION DESCRIPTION	O	e.g. A/K Ιωνίας - A/K Ευκαρπίας It will be selected automatically according to user's selection of Road Section
UNIVERSAL REFERENCE KM POSITION	M	e.g. 3+300
RELEVANT KM POSITION	O	e.g. E410+200
TRANSVERSE POSITION	M	The list with the available options will be pre-loaded before the application is launched

EVENT CATEGORY	M	The list with the available options will be pre-loaded before the application is launched
EVENT DESCRIPTION	O	Free text edited by the user describing the incident
WEATHER CONDITIONS	M	The list with the available options will be pre-loaded before the application is launched
ACTION	M	Free text edited by the user describing the actions that the user followed after the incident
NOTES	O	max 50 characters
USER	M	The username provided by the user during sign in
DATE - TIME	M	The date and time of the entry

FEPI.3. The user will be able to edit older entries of emergency patrol interventions, provided that they are not permanently stored in the Central DB

FEPI.4. The user will be able to initiate the batch upload of the records stored in the Local DB to the Central DB

FEPI.5. The system could potentially be enriched with features like automatic geo-reference position (coordinates), multimedia recording and DB synchronization (automatic or by selection) via the Internet or local network. For example, taking pictures of the incident scene and uploading them to the central DB could be an option.

Egnatia Odos Lights Night Survey_App (*EO-LNS_App*)

FLNS.1. This application shall automate the registration of light night survey gathered during scheduled on-site inspections happening once per month.

FLNS.2. The user is expected to fill in the data presented in Table 2:

Table 2: Egnatia Odos Lights Night Survey_App (EO-LNS_App)

DESCRIPTION	TYPE	COMMENTS
ROAD SECTION	M	e.g. A2/23_22 The list with the available options will be pre-loaded before the application is launched
ROAD SECTION DESCRIPTION	O	e.g. A/K Ιωνίας - A/K Ευκαρπίας It will be selected automatically according to user's selection of Road Section
UNIVERSAL REFERENCE KM POSITION	M	e.g. 3+300
LIGHT POLE TYPE	M	The list with the available options will be pre-loaded before the application is launched
FAILURE ID	M	e.g. HF01 The list with the available options will be pre-loaded before the application is launched
FAILURE DESCRIPTION	O	It will be selected automatically according to user's selection of Failure ID
REPAIR ID	M	e.g. /012 The list with the available options will be pre-loaded before the application is launched
REPAIR DESCRIPTION	O	It will be selected automatically according to user's selection of Repair ID
LAMP FAILURES NUMBER	M	
NOTES	O	max 50 characters

USER	M	The username provided by the user during sign in
DATE - TIME	M	The date and time of the entry

FLNS.3. The user will be able to edit older entries of light night surveys, provided that they are not permanently stored in the Central DB

FLNS.4. The user will be able to initiate the batch upload of the records stored in the Local DB to the Central DB

Non-Functional Requirements

Operational

NF.1. The application will be implemented for the Android O.S.

NF.2. The application will use the following technologies:

a. ORACLE 10g
b. RDBMS
c. MySQL
d. Content Management Systems for Mobile Apps

NF.3. The Central BD will run on Oracle, whereas the Local BD on SQLite

NF.4. The development of the application will be done with IDE Eclipse Juno with adt-bundle-windows-x86_64-20140702 package. The following tools will be used:

a. Android SDK Tools, Rev. 23.0.5
b. SDK Platform Android 4.4.2, API 19, revision 4
c. Android Wear ARM EABI v7a System Image, Android API 20, revision 2
d. Android Wear Intel x86 Atom System Image, Android API 20, revision 2

Performance

NF.5. The application should be able to run as standalone in case of low quality GSM connectivity.

NF.6. It is recommended to have a SQLite DB for parametric tables installed in each mobile device, and depending on the volume of data either a DB that will hold the results of all inspections or a separate DB for each inspection.

NF.7. In addition to the amount of data, the overhead of each SQLite installed on the mobile device should also be calculated.

Security

NF.8. The user will be able to sign in the application after authentication

NF.9. The user's session will expire after an hour, in order to prevent unauthorized access to potential device holders.

3.2. Use Cases

In this section, the application features are described thoroughly. In order to understand better how the application works, we will present its behavior through use case examples. The use case diagram is depicted in Figure 7. A detailed list of the use cases can be found below. The application language, as well as the presented UI is in Greek, the native language of the target user group.

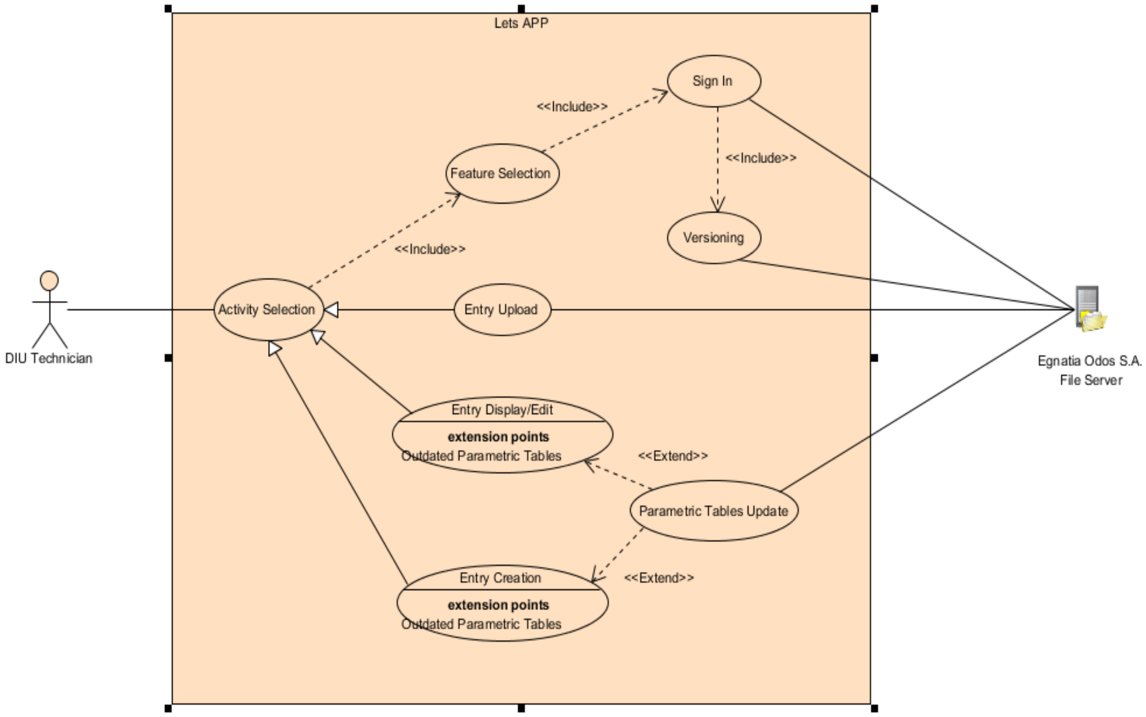

Figure 7: LEtS APP Use Case Diagram

Use Case 1: Activity Selection

LEtS APP is used by DIU technicians mainly for three purposes:

- Register an incident
- Display/Edit a registered incident
- Upload incident registrations for final disposal

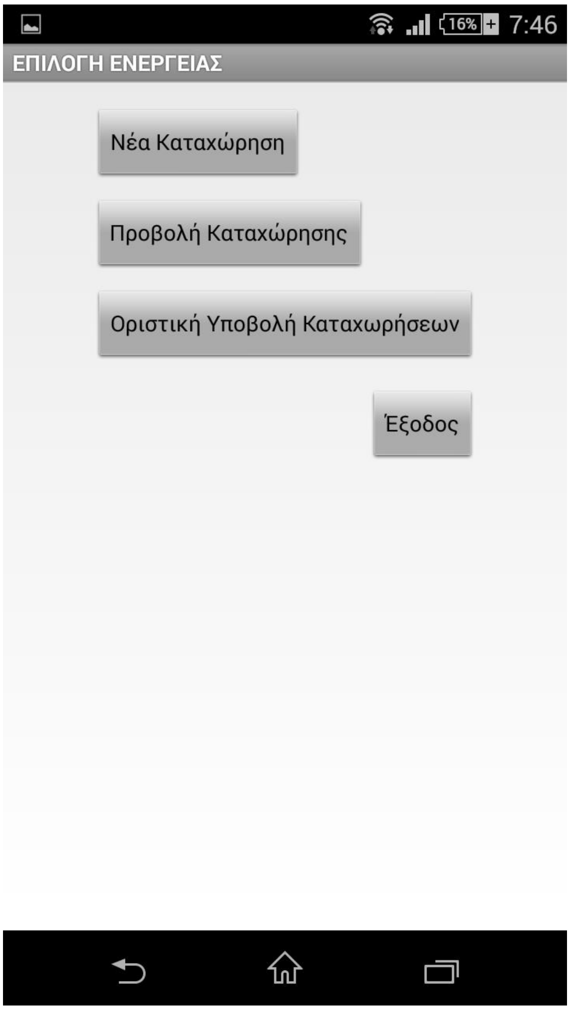

Figure 8: Activity Selection

The above actions, plus a set of functions that support the overall operation of the application are presented in the following use cases.

Use Case 2: Feature Selection

The application is used by the DIUs in two situations:

- After an Emergency Patrol Intervention, in order to register information regarding an incident that has taken place unexpectedly on Egnatia motorway

- During a scheduled Light Night Survey that takes place once every month, in order to register failures of the electrical infrastructure of Egnatia Motorway.

To this end, after successful launch of the application, as described in *Use Case 3*, the user needs to select feature (FG.1). The user's choice depends on which one of the previously mentioned situations they are involved into.

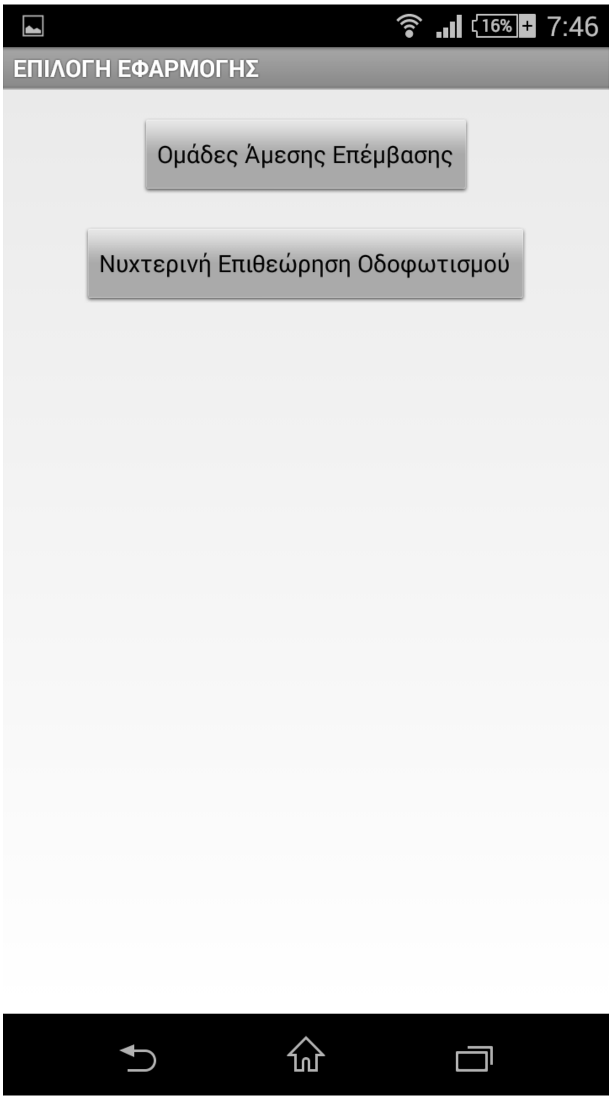

Figure 9: Feature Selection

Use Case 3: Sign in

As mentioned in (NF.8), in order to use the application the device holder has to sign in. Upon launching the application an authentication procedure, where the user has to provide their username and password, takes place. The credentials are given to the DIUs by the Egnatia Odos S.A. The company has the right to create user accounts, used by the contractors during emergency patrol interventions and night light condition inspections.

When the application is launched for the first time it connects with the file server (for details refer to 3.3) in order to download a complete list with all the user accounts which are granted the right to use the application. The list is stored in one of the tables contained in the Local DB, which is located in each mobile device used by the DIUs. Once the account table is created, it needs to be updated only when versioning procedure (*Use Case 4*) needs to take place.

While signing in the user provides their unique username and password. The credentials are verified against the account table of the Local DB. If a matching entry exists in the table then the user is successfully signed in. Otherwise, the user will be prompt to provide a valid username and password.

In addition, according to (NF.9) the user will be automatically logged off the application after one hour of inactivity. If the mobile device falls into sleeping mode for at least an hour, the user will have to sign in before using the application. The same procedure of authentication as the one described above is followed.

Use Case 4: Versioning

In (FEPI.2 and FLNS.2} it is implied that certain application fields have to be filled with values provided by Egnatia Odos S.A. These fields are visualized in Android O.S. as drop down menus, where the user selects the relevant value.

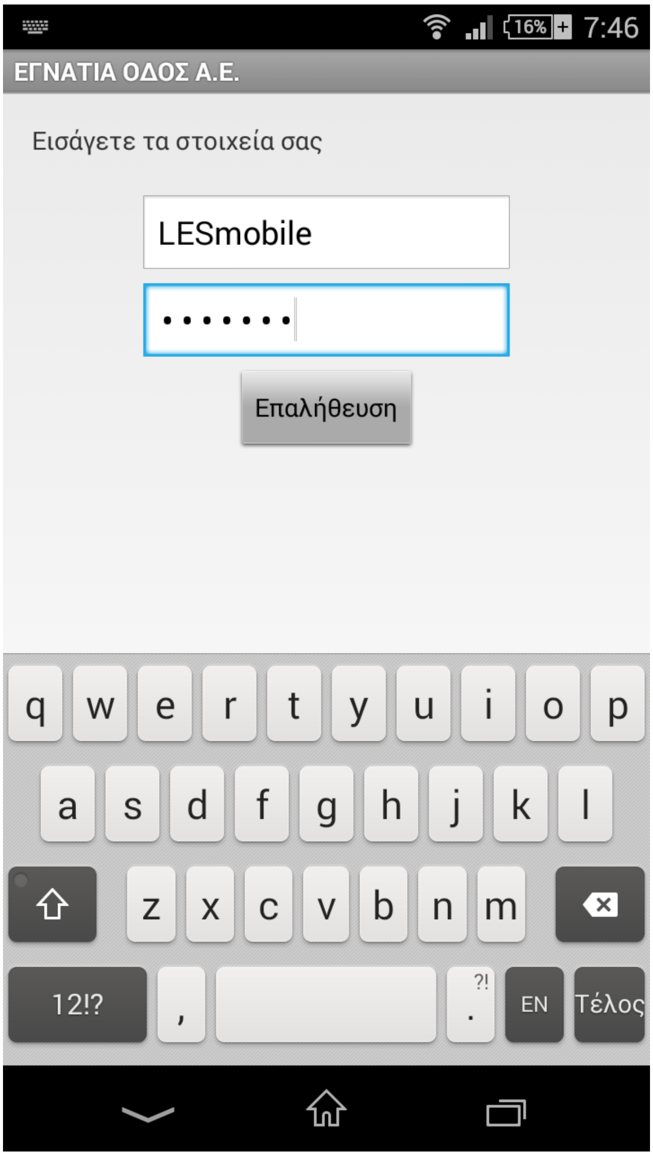

Figure 10: Sign In

The elements used in these drop down menus are stored in the parametric tables of Local DB located on the mobile device, after they are downloaded from the file server. Therefore, each time the application is launched, a versioning process takes place in order to ensure that the application has the latest values of the parametric tables (FG.6). Thereby, this procedure guarantees that the application is updated every time with the latest available information.

In more detail, when a new version of one or more parametric tables is introduced by Egnatia Odos S.A., the company updates a file with the newest version of each table. The file is uploaded by the company to the file server. This way, every time the application is started, the versions of the parametric elements are checked against the mentioned file. In case when a table is found outdated, the latest values are downloaded from the file server and stored into the Local DB of the device.

Use Case 5: Entry Creation

After choosing the appropriate feature, whether an emergency patrol intervention or a light night survey takes place, the user of the application is able to create a new registration of the appropriate information. In the former case, the user is prompt to fill in a series of drop down menus and text fields with the data of the emergency patrol intervention, as presented in (FEPI.2). Additionally, in the latter case, the user chooses the appropriate values of drop down menus and fills in text fields in order to provide the data mentioned in (FLNS.2).

Then, the user can choose to save the registered data in the Local DB. There are two tables created upon the application's first launch. The first one is used to store emergency patrol intervention data and the second light night survey data, respectively. Every time the user completes a registration and chooses to save the provided data, a new entry is created to one of the two tables, according to the situation the user is involved in.

However, if the user chooses to end the activity without saving the data, the registered data is lost, since according to the requirements (FG.2), the user fills the relevant information in blank forms every time. This function ensures that the user has finished with the creation of an entry, before proceeding to the next one, thus making the application less prone to human errors.

Use Case 6: Entry Display/Edit

Following the registration of an entry, the user is able to read or even edit their registrations (FG.5). This option is available as long as the entries have not been permanently uploaded to the Central BD (*Use Case 7*).

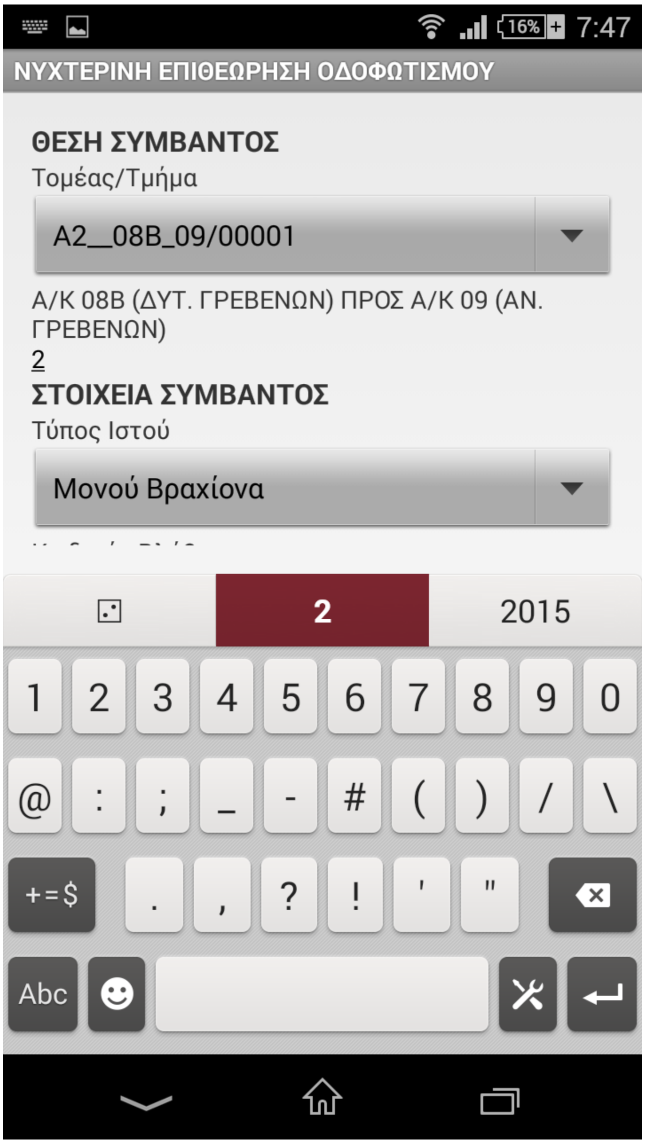

Figure 11: Entry Creation

Provided the user has already selected the appropriate feature, whether in case of an emergency patrol intervention (FEPI.3) or a light night survey (FLNS.3),they are able to display/ edit their past registrations. When the user decides to display/edit a past entry, they need to select the relevant option from the application's menu. Thereafter, a list with all the past entry entries registered by the specific user is displayed. Each entry is characterized by the date and time it was registered. This way the user is able to select the entry they would like to display/edit.

Then, the selected entry appears in the same form that was used during its creation (*Use Case 5*). The user can simply inspect the information provided during the creation of the entry and/or modify the relevant data. However, the change is applied only when the user finalizes the process by saving the modified entry. Otherwise, in case the user chooses to end the activity without saving, the changes are lost and no modification takes place. Finally, it is important to mention that the entries can be edited as many times as the user decides, provided that they have not been upload to the Central DB (FG.4).

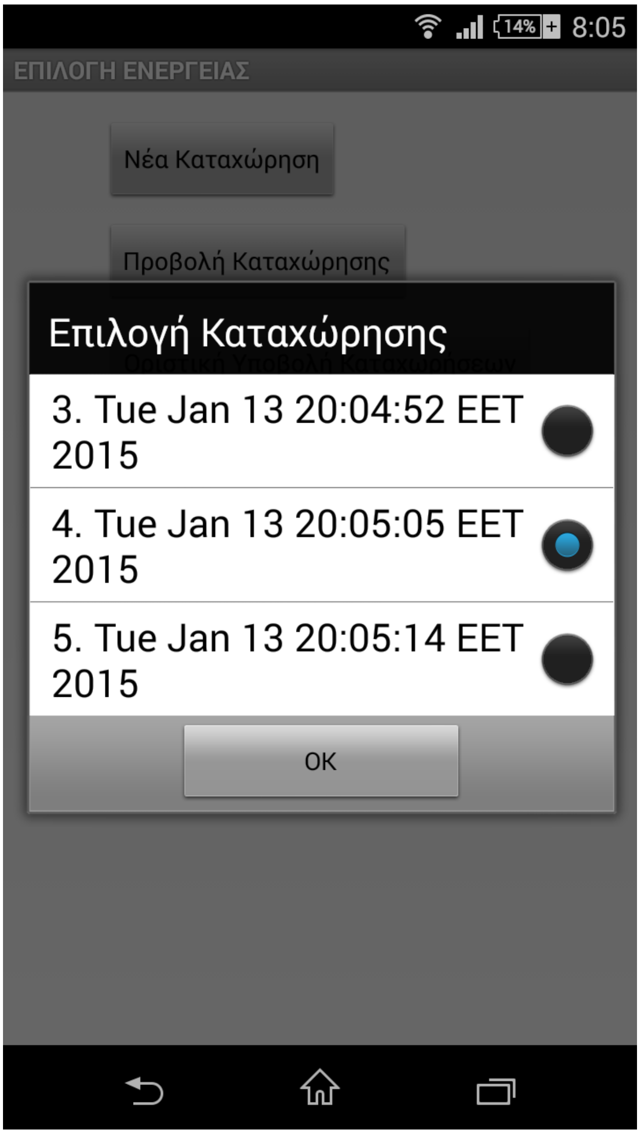

Figure 12: Entry Display/Edit

Use Case 7: Entry Upload

When the emergency patrol intervention or the light night survey, respectively has ended, the user is able to upload their entries to the file server. By selecting the relevant option from the applications menu the system prepares the batch uploading of the registered entries, which have not yet been marked as permanently stored.

Providing that the mobile device has connectivity with the file server, the entries are uploaded and stored in files in order to be reviewed by the contractors responsible engineer (FG.4). The communication between the mobile device and the file server is explained in detail in 3.3. Thereafter, the entries are permanently inserted in the Central DB. On the other hand, if the mobile device fails to connect with the file server, due to low GSM quality (NF.5), the registered entries remain stored in the Local DB of the mobile device, until the next batch upload is initiated. In any case, the user is informed about the successful or unsuccessful result of the upload attempt with relevant messages.

After the successful upload to the file server, the entries are not deleted from the Local BD. Instead they are marked as "permanently sent". In this way, there are no longer editable (FG.5) and they cannot be re-sent during the next batch upload. Hence, the user has no access to the uploaded entries, even if they are still stored in the Local BD.

As far as the size of the Local DB is concerned, according to requirements (NF.6, NF.7), measures to keep DB capacity to minimal need to take place. Thus, after each successful upload a mechanism is triggered and uploaded registered entries order than one month are deleted from the local DB (FG.7).

3.3. Communication between Local and Central DB

So far, it has already been implied that there is no direct communication between the Local DB, which is located in the mobile device and the Central DB which is located in a dedicated server. Instead, the two databases communicate via a file server. The file server is actually a cloud storage deployed using ownCloud.

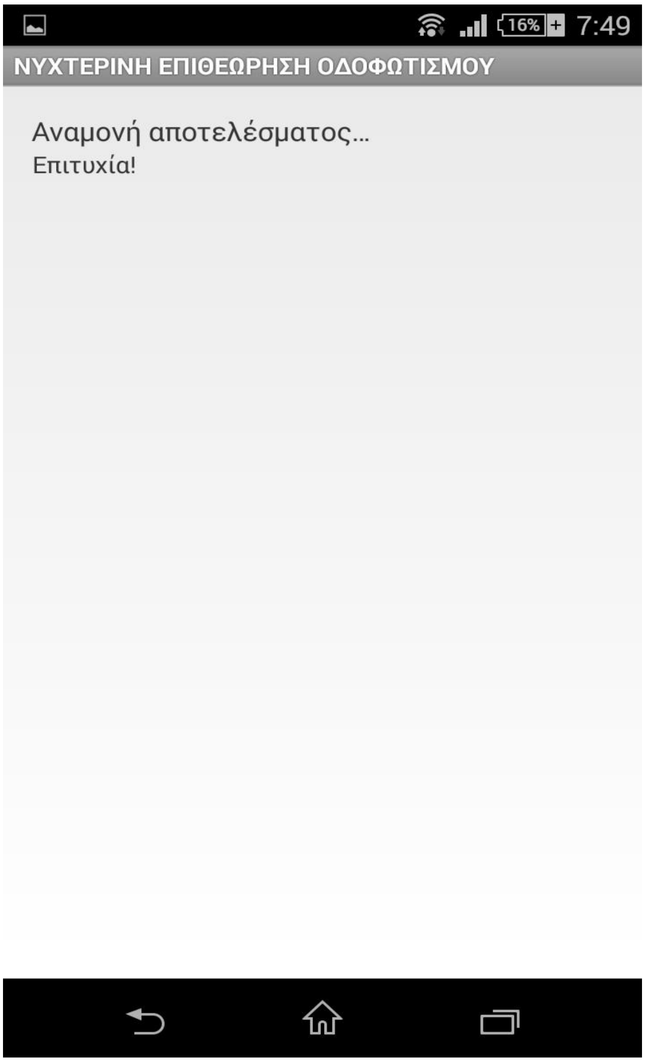

Figure 13: Entry Upload

OwnCloud[9] is cloud-based open source software, used for data storage. It offers an Android API which makes the communication with Android devices very efficient and easy to develop. Egnatia Odos S.A. has deployed ownCloud in a private server. The company has used ownCloud so far in many of their ITS applications. Therefore using ownCloud in the application developed in the context of this thesis is considered the best solution, as it is effective, it does not require additional resources and it guarantees compatibility with the company's ITS infrastructure.

As mentioned earlier, the application collects all registered data into the Local DB. The Local DB is created the first time the application is launched. User's entries are stored

[9] http://en.wikipedia.org/wiki/OwnCloud

in the Local DB when they decide to save the registered data (*Use Case 3*). Additionally, the Local DB is updated when there is a change in the parametric data.

The Local DB communicates with the file server by the use of ownCloud Android API. When the user decides to upload the registered entries in order to save them permanently to the Central DB, ownCloud Android API establishes an SSL connection with the file server. It is important to mention that the credentials need to authenticate the connection are pre-installed in the mobile device upon application installation. When the uploaded data are inspected by the contractor's responsible engineer, they are inserted to the Central DB with a mechanism developed by Egnatia Odos S.A., where they are stored permanently.

A similar procedure takes place when there is an update to the parametric data used by the application. When there is a new version of the parametric tables by Egnatia Odos S.A., the updated information is stored by the company to the file server. Using the versioning mechanism mentioned earlier (*Versioning*) the application is triggered to download the latest revision of the parametric tables. Once again, ownCloud Android API establishes an SSL connection with the file server, user the credentials of the mobile device. Thereafter, the updated parametric data are downloaded to the mobile device and stored into the parametric tables of the Local DB, accordingly.

Figure 14: LEtS APP communication architecture using ownCloud

The advantages of this synchronization method are plenty. We have already referred to the effectiveness of the described technique, as well as to the fact that the solution is compatible with Egnatia Odos S.A. ITS infrastructure. Furthermore, this approach allows multiple simultaneous connections to the file server. This is an important factor, keeping in mind that there will be multiple mobile devices uploading/downloading data at the same time. Secure communication with the file server is also guaranteed thanks to SSL connection and the use of credentials.

In addition, the file server acts as a medium between the mobile application (Local DB) and the main ITS infrastructure of Egnatia Odos S.A. (Central DB). This way, the user of the mobile application has no access to the company's main infrastructure. Thereby, there is no chance of data corruption in the Central DB, since the data are first stored in the file server and then inspected by the contractor's responsible engineer before they are inserted in the Central DB. Finally, Central DB is shield against malicious attacks, as the credentials used by the application permit access only to the file server and not to the company's IT systems.

4. Evaluation and Results

It has to be made clear that LEtS APP was designed and implemented based on the requirements of Egnatia Odos S.A. Thus, the evaluation of the application was against the company's specific requirements and standards. Below a list of the test cases to which LEtS APP was submitted is presented. The application was installed in a Sony Xperia T3 smartphones running Android 4.4.4 version. The testing activities took place in environments where both WiFi and 3G connectivity to the network were available.

Sign-In

Description	Acceptance Criteria	Executed by the author	Executed by EOAE
Successful Sign-In	Log-in the application after providing the right username and password	YES	YES
Unsuccessful Sign-In	Application prevents log-in in case wrong username or password is provided	YES	YES
Required Sign-In after an hour of inactivity	Log-in is required if the application stays inactive for more than an hour	YES	YES

Feature Selection

Description	Acceptance Criteria	Executed by the author	Executed by EOAE
EO_EPI App	Selection of "Emergency Patrol Intervention" button leads to the corresponding activity menu	YES	YES
EO_LNS App	Selection of "Light Night Survey"	YES	YES

	button leads to the corresponding activity menu		

EO_EPI App

<u>Description</u>	<u>Acceptance Criteria</u>	<u>Executed by the author</u>	<u>Executed by EOAE</u>
Create Entry	● The corresponding form is presented to the user. ● The entry is successfully stored in Local BD only if all required fields are filled in. ● Otherwise an error message prompts the user to fill in the required fields.	YES	YES
Display Entry	● The user is prompt to edit only those entries that can be edited, meaning entries registered by the specific user and which have not been uploaded to the file server yet. ● The selected entry is displayed in the corresponding form ● Upon user request the entry is successfully updated in the Local DB	YES	YES
Upload Entry	● Upon user request the entries are uploaded to the file server for permanent storage. ● Only the entries that have not already been uploaded are sent to the file server ● The user is informed in case of successful upload and the entries are no longer editable in Local DB ● The user is informed in case of	YES	YES

	unsuccessful upload and the entries remain stored and editable in Local BD		

EO_LNS App

Description	Acceptance Criteria	Executed by the author	Executed by EOAE
Create Entry	● The corresponding form is presented to the user. ● The entry is successfully stored in Local BD only if all required fields are filled in. ● Otherwise an error message prompts the user to fill in the required fields.	YES	YES
Display Entry	● The user is prompt to edit only those entries that can be edited, meaning entries registered by the specific user and which have not been uploaded to the file server yet. ● The selected entry is displayed in the corresponding form ● Upon user request the entry is successfully updated in the Local DB	YES	YES
Upload Entry	● Upon user request the entries are uploaded to the file server for permanent storage. ● Only the entries that have not already been uploaded are sent to the file server ● The user is informed in case of successful upload and the entries are no longer editable in Local DB ● The user is informed in case of	YES	YES

	unsuccessful upload and the entries remain stored and editable in Local BD		

Versioning

Description	Acceptance Criteria	Executed by the author	Executed by EOAE
Successful indication for parametric tables update	Upon sign-in the application downloads (provided connectivity availability) the file where the latest updates of the parametric tables are stored	YES	NO

Local Database

Description	Acceptance Criteria	Executed by the author	Executed by EOAE
Successful Creation	The Local DB is created the very first time the application is launched in a mobile device	YES	NO
Successful Update	Parametric tables are updated in case versioning procedure has indicated new versions available	YES	NO
Entry Creation	Local DB is updated every time a new entry is registered	YES	NO
Entry Update	Entries of Local DB can be updated provided that they have not been permanently uploaded to the file server Entries that have been sent to the file server are marked accordingly and no	YES	NO

	further updates are possible		
Entry Deletion	Entries older than a month are permanently deleted from the Local DB	YES	NO

The outcome of the testing activities was approved by Egnatia Odos S.A. Testing the application under real circumstances in actual emergency patrol intervention or light night surveys on Egnatia Motorway is out of scope of this thesis.

5. Conclusion and Future Work

The study of ITS refers to the management of transportation infrastructure and vehicles. The main goal of ITS applications is to optimize existing resources, thus minimizing the impact of traffic congestion and incidents. The estimation of 8.5 million driving-related deaths by the year 2020 is one of the motivations behind numerous academic, commercial and governmental decisions concerning the transportation industry [5].

ITS have gained more and more attention in recent years. Advanced Travel Information Systems (ATIS) is a key component for efficient utilization of existing traffic infrastructure [4]. ATIS reduce the total travel delay, improve passenger's comfort and satisfaction, decrease the pollution and noise caused by congestions in urban areas and enhance the overall productivity within a transportation network [54]. Nowadays, many ITS projects run worldwide. For example, iMobility [10] initiative and PReVENT initiative[11] funded by European Commission, VICS[12] in Japan, TAIWAN iTS1 [31], as well as various ITS initiatives in US prove the global interest of authorities and affiliated organizations in ITS applications.

Given the variety of sensory capabilities, such as accelerometers, electronic compass, GPS, microphones, etc. and the processing power that new generation of smartphones, the question whether this technology can be used to complement and even improve ITS infrastructure emerges naturally. With their easy-to use characteristics, high penetration rate and powerful performance, smartphones play important role in both sensing and delivering traffic information. Furthermore, the use of smartphones minimizes the hardware cost and eliminates most of the adoption barriers. Moreover, users will no longer have to install new dedicated devices in their vehicles. Instead they will simply have to install an application in their smartphones. Hence, as we have already shown smartphones and mobile devices in general can be used in a wide range of ITS applications, such as traffic condition estimation, mobile navigation, incident detection, V2I communication etc.

---

[10] http://www.imobilitysupport.eu/

[11] The integrated Project PReVENT http://www.prevent-ip.org/

[12] http://www.vics.or.jp/english/about/history.html

In the context of this thesis we exploited the knowledge gained by studying state-of-the-art ITS technologies in order to support Egnatia Odos S.A. in automating their road maintenance activities on Egnatia Motorway. Before presenting our approach in detail, we made a thorough reference to innovative ITS applications where the use of smartphones and mobile devices plays a crucial role in the efficient management of transportation networks. The main contribution of this thesis is the development of LEtS APP, an application for smartphones and mobile devices with Android O.S. used in order to automate the registration of emergency patrol intervention and lights night survey related data.

The goal of this thesis is to provide an automated environment to road-maintenance technicians and at the same time guarantee the real-time and accurate information update on the maintenance activities and Egnatia Motorway status. The communication schema presented in Figure 14 allows multiple simultaneous connections, which keep the company's main infrastructure up-to-date and robust to malicious entries. The application was implemented following strict requirements and high standards posed by the company and reviewed during all development phases. Moreover, it was evaluated against these standards by the author and the company engineers, as well. However, we believe that the success of the application will be judged when it will be tested by the targeted users, meaning the road-maintenance technicians under real circumstances.

In the future we intend to take advantage of the sensing capabilities of smartphones. LEtS APP could be extended with the use of mobile device sensors like GPS and camera. The idea is to help the road-maintenance technicians provide as less input as possible, though in the meantime the application could mark user entries with GPS location data. In addition, the user could simply provide photos taken with the available smartphone's camera. This way, user entries can be automatically included in a GIS system giving a more precise picture of Egnatia Motorway condition.

In conclusion, the success of LEtS APP will be defined by the level of acceptance within the target user group, meaning DIU technicians. The experience clearly indicated the importance of the opinion of the end user of an application. Egnatia Odos S.A. will be able to re-prioritize the implementation of different features allowing the most urgent feature to be extended earlier, according to the user's feedback after testing LEtS APP on field.

References

[1]. Abid, H., Chung, T., Ch., Lee, S., Qaisar, S. 2012. "*Performance Analysis of LTE Smartphones-Based Vehicle-to- Infrastructure Communication*". 2012 9th International Conference on Ubiquitous Intelligence & Computing and 9th International Conference on Autonomic & Trusted Computing (UIC/ATC). DOI: 10.1109/UIC-ATC.2012.155

[2]. Ahtinen, A., Nurminen, J.,K., Häkkilä, J. 2007. "*Developing a Mobile Reporting System for Road Maintenance - User Research Perspective*". MC'07 (Mobility'07). Singapore, September 10-12, 2007

[3]. Aldunate, R., G., Herrera, O., A., Cordero, J., P. 2013. "*Early Vehicle Accident Detection and Notification Based on Smartphone Technology*". Ubiquitous Computing and Ambient Intelligence. Context-Awareness and Context-Driven Interaction Lecture Notes in Computer Science. Vol 8276. pp. 358-365

[4]. Ansar, R., Sarampakhul, P., Ghosh, S., Mitrovic, N., Asif, M.,T., Dauwels, J., Jaillet, P. 2014. "*Evaluation of smart-phone performance for real-time traffic prediction*". IEEE 17th International Conference on Intelligent Transportation Systems (ITSC). DOI: 10.1109/ITSC.2014.6958173

[5]. Ali, K., Al-Yaseen, D., Ejaz, A., Javed, T., Hassanein, H., S. 2012. "*CrowdITS: Crowdsourcing in Intelligent Transportation Systems*". Wireless Communications and Networking Conference (WCNC), 2012 IEEE. DOI: 10.1109/WCNC.2012.6214379

[6]. Arikawa, M., Konomi, S., Onishi, K. 2007. "NAVITIME: Supporting Pedestrian Navigation in the Real World". IEEE Pervasive Computing, 21-29

[7]. Ban, X., Li, Y., Skabardonis, A., Margulici, J., D. 2007. "*Performance evaluation of travel time methods for real time traffic applications.*" 11th World Conference on Transport Research, Berkeley, CA, June 2007.

[8]. Basyoni, Y., Talaat, H. 2014. "*A Bilevel Traffic Data Extraction Procedure via Cellular Phone Network for Intercity Travel*". Journal of Intelligent Transportation Systems: Technology, Planning and Operations, DOI:10.1080/15472450.2014.892380

[9]. Bierlaire, M., Chen, J., Newman, J. P. 2013. "*A probabilistic map matching method for smartphone GPS data*". Transportation Research Part C: Emerging Technologies, 26, 78–98

[10]. Bustillos, B.,I., Chiu, Y., Papayannoulis, V. 2011. "*Pre-trip and en-route multi-modal travel decisions considering habitual travel times under unexpected incident scenarios*". 2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC). DOI: 10.1109/ITSC.2011.6082876

[11]. Carmien, S., Dawe, M., Fischer, G., Gorman, A., Kintsch, A., Sullivan, J. and James, F. 2005. "*Socio-technical environments supporting people with cognitive disabilities using public transportation*". ACM Trans. on Computer-Human Interaction 12, 233-262

[12]. Catling, I. 1994. "*Advanced technology for road transport: IVHS and ATT*". Boston, MA: Artech House,Inc.

[13]. Chen, J., Bierlaire, M. 2013. "*Probabilistic Multimodal Map Matching With Rich Smartphone Data*". Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, DOI:10.1080/15472450.2013.764796

[14]. Chen, X., Santos-Neto E., Ripeanu, M. 2012. "*Crowdsourcing for on-street smart parking*". 2nd ACM international symposium on Design and analysis of intelligent vehicular networks and applications (DIVANet '12). ACM, New York, NY, USA, 1-8. DOI=10.1145/2386958.2386960

[15]. Cho, Y., Rice, J. 2006. "*Estimating velocity fields on a freeway from lower solution videos*". IEEE Trans. Intell. Transp. Syst. Vol. 7. No. 4. pp. 463–469

[16]. Diewald, St., Möller, A., Roalter, L., Kranz, M. 2012. "*DriveAssist - A V2X-Based Driver Assistance System for Android*". Automotive HMI Workshop at Mensch und Computer. Konstanz. September 11, 2012

[17]. El houssaini, S., Badri, A., 2013. "*Review on monitoring systems of the road network*". International Journal of Engineering and Technology (IJET). Vol 5. No 2. April-May, 2013. pp 1942-1954

[18]. Ferris, B., Watkins, K., Borning, A. 2010. "*OneBusAway:Results from providing real-time arrival information for public transit*". CHI 2010, ACM Press. 1807-1816

[19]. Figueiredo, L., Jesus, I., Machado, J., Ferreira, J. and Martinsde Carvalho, J. 2011. "*Towards the development of intelligent transportation systems*". Intelligent Transportation Systems IEEE (2001), 1206-1211

[20]. Garrigos, D.,T., Zapater, J.,J.,S. 2012. "*Semantic infrastructure system with feedback: Application on traffic*". 6th Euro American Conference on Telematics and Information Systems (EATIS)

[21]. Geuens, C., Dumortier, J., 2010. "*Mandatory implementation for in-vehicle eCall: Privacy compatible?*". Computer law & security review (26), 385–390

[22]. GfK Retail and Technology. (2010). Retrieved January 10, 2015 from http://www.gfktechtalk.com/2011/02/02

[23]. Ghosh, B., Smith, D., P. 2014. "*Customization of Automatic Incident Detection Algorithms for Signalized Urban Arterials*". Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, 18:4, 426-441, DOI: 10.1080/15472450.2013.806843

[24]. Giannoutakis, K., N., Li, F. 2012. "*Making a Business Case for Intelligent Transport Systems: A Holistic Business Model Framework*". Transport Reviews: A Transnational Transdisciplinary Journal, 32:6, 781-804, DOI: 10.1080/01441647.2012.740096

[25]. Gkiotsalitis, K., Stathopoulos, A. 2014. "*A Mobile Application for Real-Time Multimodal Routing Under a Set of Users' Preferences*" Journal of Intelligent Transportation Systems: Technology, Planning, and Operations, DOI: 10.1080/15472450.2013.856712

[26]. Gonzalez, M. C., Hidalgo, C. A., Barabasi, A., L. 2008. "*Understanding individual human mobility patterns*". Nature, 453(7196), 779–782

[27]. International Organization for Standardization. 2004. "ISO 15765: Road vehicles, Diagnostics on Controller Area Networks (CAN)"

[28]. Ito, M., Sasama, T., Kawamura, T., Sugahara, K. 2011. "*An effective tracking technique of public transportation toward passenger generated vehicle location system*". 13th international conference on Ubiquitous computing (UbiComp '11). ACM, New York, NY, USA, 551-552. DOI=10.1145/2030112.2030208

[29]. Karakaidou, I., C., Evangelidis, D., E., Bantelas, G., A., Voudouris, P., K. 2002. "*Routine maintenance management system of Egnatia Odos*". 3rd International conference on bituminous mixtures and pavements. Thessaloniki, Greece. November 2002. pp. 695-705

[30]. Lee, K., J., Ro, S., Ahn, H., S. 2012. "*Electric Vehicle Charging Control System Hardware-In-the-Loop Simulation(HILS) with a Smartphone*". Computer Applications for Database, Education, and Ubiquitous Computing Communications in Computer and Information Science. Vol 352. pp. 258-264

[31]. Lee Tsu-Tian. 2008. "Research on intelligent transportation systems in Taiwan". CCC '08

[32]. Liu, X., Wang, Zh., Wang, Zh., Lv, Sh., Guan, T. 2013. "*A Novel Real-Time Traffic Information Collection System Based on Smartphone*". Advances in

Wireless Sensor Networks Communications in Computer and Information Science. Vol 334. pp. 291-303

[33]. Ma, Sh., Wolfson, O., Lin, J. 2010. "*IIP: an event-based platform for ITS applications*". 2nd International Workshop on Computational Transportation Science (IWCTS '10). ACM, New York, NY, USA, 1-6. DOI=10.1145/1899441.1899443

[34]. Magtoto, J., Roque, A. 2012. "Real-time traffic data collection and dissemination from an Android Smartphone using proportional computation and FreeSim as a practical transportation system in Metro Manila". TENCON 2012 - 2012 IEEE Region 10 Conference. DOI: 10.1109/TENCON.2012.6412332

[35]. Mak, Ch., L, Fan, H., S., L. 2014. "*Algorithm fusion method to enhance automatic incident detection on Melbourne freeways*". Transportation Planning and Technology, 37:2, 169-185, DOI: 10.1080/03081060.2013.870790

[36]. Mak, C. L., H. S. L. Fan. 2006. "*Algorithm Fusion for Detecting Expressway Incidents on Singapore's Central Expressway*". Journal of Transportation Engineering 132 (4): 321–330. doi:10.1061/(ASCE)0733-947X(2006)132:4(321)

[37]. Miles, J., Chen, K. 2004. "*The intelligent transport systems handbook (2nd ed.)*". Swanley, UK: The World Road Association (PIARC)

[38]. Minh, Q., T., Baharudin, M., A., Kamioka, E. 2012. "*Context-Aware Mobile Intelligent Transportation Systems*". Vehicular Technology Conference (VTC Fall), 2012 IEEE. Quebec City, QC. September 3-6, 2012

[39]. Mohan, B. C., Baskaran, R. 2012. "A survey: Ant Colony Optimization based recent research and implementation on several engineering domain". Expert Systems with Applications, 39, 4618–4627

[40]. Mohan, Pr., Padmanabhan, V., N., Ramjee, R. 2008. "*Nericell: rich monitoring of road and traffic conditions using mobile smartphones*". 6th ACM conference on Embedded network sensor systems (SenSys '08). ACM, New York, NY, USA, 323-336. DOI=10.1145/1460412.1460444

[41]. Möller, A., Roalter, L., Konstanz, M., Kr. 2012. "*DriveAssist – A V2X-Based Driver Assistance System for Android Stefan Diewald*". Automotive HMI Workshop at Mensch und Computer 2012. September 11, 2012

[42]. Mukisa, S., Rashid, A. 2014. "*Cyber-security challenges of agent technology in intelligent transportation systems*". 1st International Workshop on Agents and CyberSecurity (ACySE '14). ACM, New York, NY, USA, , Article 9 , 4 pages. DOI=10.1145/2602945.2602953

[43]. Najm, W. G., Koopmann, J., Smith J. D. & Brewer, J. 2010. "*Frequency of Target Crashes for IntelliDrive Safety Systems*". Washington D.C.: U.S. Department of Transportation – National Highway Traffic Safety Administration

[44]. Park, Y., Ha, J., Kuk, S., Kim, H., Liang, C.,J.,M., Ko, J. 2014. "*A Feasibility Study and Development Framework Design for Realizing Smartphone-Based Vehicular Networking Systems*". IEEE Transactions on Mobile Computing. Vol 13. No 11. pp 2431- 2444. DOI: 10.1109/TMC.2014.2309959.

[45]. Perttunen, M., Mazhelis, O., Cong, F., Kauppila, M., Leppänen, T., Kantola, J., Collin, J., Pirttikangas, S., Haverinen, J., Ristaniemi, T., Riekk, J. 2011. "*Distributed Road Surface Condition Monitoring Using Mobile Phones*". Ubiquitous Intelligence and Computing, 2011, Vol 6905. ISBN : 978-3-642-23640-2. pp. 64-78

[46]. Popescu-Zeletin, R., Radusch, I., Rigani, M. 2010. "Vehicular-2-X Communication: State-of-the-Art and Research in Mobile Vehicular Ad Hoc Networks". Heidelberg: Springer

[47]. Pyykönen, P., Kauvo, K., Viitanen, J., Eloranta, P. 2014. "*Vehicle ITS station for C2X communication*". 2014 IEEE International Conference on Intelligent Computer Communication and Processing (ICCP). DOI: 10.1109/ICCP.2014.6936997

[48]. Roy, N., Wang, H., Choudhury, R., R. 2014. "*I am a smartphone and i can tell my user's walking direction*". 12th annual international conference on Mobile systems, applications, and services (MobiSys '14). ACM, New York, NY, USA, 329-342. DOI=10.1145/2594368.2594392

[49]. SENSoR Project (2015) Retrieved January 5, 2015 from http://sensorproject.eu/news.php?new=15

[50]. Schulz, A., Ristoski, P., Paulheim, H. 2013. "*I See a Car Crash: Real-Time Detection of Small Scale Incidents in Microblogs*". The Semantic Web: ESWC 2013 Satellite Events Lecture Notes in Computer Science. Vol 7955. pp. 22-33

[51]. Tam, M. L., & Lam, W. H. 2008. "Using automatic vehicle identification data for travel time estimation in Hong Kong". Transportmetrica, 4(3), 179–194

[52]. Tang, S., Wang, F., Y. 2006. "*A PCI-based evaluation method for level of services for traffic operational systems*". IEEE Trans. Intell. Transp.Syst. Vol. 7. No. 4. pp. 494–499

[53]. Timpner, J., Schürmann, D., Wolf, L. 2013. "*Secure Smartphone-based Registration and Key Deployment for Vehicle-to-Cloud Communications*". ACM

Workshop on Security, Privacy & Dependability for Cyber Vehicles (CyCAR '13). pp. 31–36. ACM. Berlin, Germany. ISBN:978-1-4503-2487-8

[54]. Toledo, T., Beinhaker, R. 2006. "*Evaluation of the potential benefits of advanced traveler information systems*". Journal of Intelligent Transportation Systems. Vol. 10. No. 4. pp. 173–183

[55]. Tornell, S.,M., Calafate, C.,T., Cano, J.,C., Manzoni, P., Fogue, M., Martinez, F.J. 2013. "*Evaluating the Feasibility of Using Smartphones for ITS Safety Applications*". Vehicular Technology Conference (VTC Spring), 2013 IEEE 77th. DOI: 10.1109/VTCSpring.2013.6692553

[56]. Turner, S. M., Eisele, W. L., Benz, R. J., Holdener, D. J. 1998. "*Travel time data collection handbook*". Federal Highway Administration,U.S. Department of Transportation. No. FHWA-PL-98-035

[57]. Web Site of CoMoSeF. Co-operative Mobility Services of the future. http://www.comosef.eu/. Last Accessed: 15-01-2015

[58]. Web Site of Egnatia Odos S.A. "Egnatia Motorway S.A.". http://www.egnatia.eu/page/. Last Accessed: 12-10-2014

[59]. Web Site of Itu. ICT Statistics. http://www.itu.int/ITU-D/ict/statistics/ict/index.html. Last Accessed on 12-01-2015.

[60]. Web Site of Wikipedia. "Google driverless car". http://en.wikipedia.org/wiki/Google_driverless_car. Last Accessed: 05-01-2015

[61]. Wootton, J.R., Garcia-Ortiz, A., Amin, S.M. 1995. "*Intelligent transportation systems—a global perspective*". Mathematical and Computer Modelling, 22(4–7), 259–268

[62]. Zaldivar, J., Calafate, C.,T., Cano, J.,C., Manzoni, P. 2011. "*Providing accident detection in vehicular networks through OBD-II devices and Android-based smartphones*". IEEE 36th Conference on Local Computer Networks (LCN). DOI: 10.1109/LCN.2011.6115556

[63]. Zheng, J., Cao, J., He, Z., Liu, X. 2014. "*iTrip: Traffic signal prediction using smartphone based community sensing*". IEEE 17th International Conference on Intelligent Transportation Systems (ITSC). DOI: 10.1109/ITSC.2014.6958162

[64]. Zhou, H., Liu, B., Wang, D. 2012. "*Design and Research of Urban Intelligent Transportation System Based on the Internet of Things*". Communications in Computer and Information Science. Vol. 312. pp. 572-580