Improving Public Safety at Fingertips:  
A Smart City Experience

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Abstract—Nowadays, we are in the century of cities: there are more people living in the cities than in the countryside. In general, overpopulated cities around the world have common problems in several areas, such as city administration, education, health care, public safety, transportation, utilities, etc. In the particular case of Brazil, one of the major problems of cities is the high level of violence. This paper describes how the Brazilian city of Natal is implementing technological systems in the context of public safety to transform itself into a smart city, as a cooperation between university and government secretariat. More specifically, the paper presents ROTA, a smart city platform aiming at contributing to improve public safety. We also hereby describe a robust, scalable mobile application that fulfills the communication gap between control room and field personnel, as well as a Web dashboard intended to support data analysis and statistics about occurrences.

I. INTRODUCTION

Until the end of the last century, there were more people in the countryside than in the cities. However, this pattern changed in the first decade of the 21st century, the century of the cities: nowadays, there are more people living in cities than in the countryside. As cities grow, so increases the complexity and management challenges for government authorities in dealing with the various urban problems resulted from such a high population density. A solution adopted by many cities to face these challenges is the realization of the smart city concept. According to Caragliu et al. [1], a city becomes smart when investments in human and social capital and in modern information and communication technologies (ICTs), through participatory and engaged actions, harmoniously contribute to the sustainable economic growth and life quality.

Ideally, smart cities should be able to adapt itself on the fly by pulling readings from a vast array of sensors, feeding such data into software that can see the “big picture”, and taking proper actions. Indeed, the old city of concrete, glass, and steel now conceals a huge underworld of computers and software [2]. Through the Internet, such devices are being stitched together into a nervous system supporting the daily lives of billions in a world of giant and medium cities. Smart cities use smart computing technology to make the critical infrastructure components and services of a city (including city administration, education, health care, public safety, transportation, etc.) more intelligent, interconnected, and efficient [3].

One of the main issues to be handled in the today’s cities is related to public safety as it is an important requisite for achieving the well-being of the society and the general quality of life. For instance, many cities in Brazil have been struggled with violent crime and other social disorders, thereby creating an atmosphere of fear in neighborhoods and resulting in unacceptably high levels of criminality. In this context, implementing the smart city concept can surely have a significant impact in the improvement of public safety. Some police forces are now recognizing that integrating new ICTs platforms with other city resources can have a dramatic influence in driving down criminality rates and increasing public safety.

Despite the relevance of improving public safety in smart cities, the literature presents few works in this direction. Erickson et al. [4] present a Web-based Next-Generation Incident Command System (NICS), which provides (i) geolocation and situation awareness of a specific location of the city, (ii) support to request resources in case of criminal activity, (iii) reporting and collaborating via messages (text or multimedia), and (iv) standardized interfaces among system modules messages. IBM has also developed IBM Intelligent Operations Center (IBM-IOC) [5], a platform to support smart cities solutions that (i) allows supervisors to monitor and manage a range of services, (ii) enables agencies to respond rapidly to events in the city, (iii) provides situation awareness and reporting to the respective agencies, (iv) facilitates real-time collaboration, (v) streamlines management of resources and critical assets, etc. Another example is the one reported in an article published in The New York Times [6], which shows the use of technology as a support tool for police activity in combating crime through the sharing of police reports information via smartphones. Nonetheless, these solutions are proprietary and hence less adaptable to local particularities.

In 2015, Natal, a city of Northeastern Brazil, has joined the IEEE Smart City initiative as an affiliated city. This initiative aims to transform Natal into a smart city through the development of systems and applications to bolster the use of
ICTs as means of contributing to improve the life quality of its citizens. Regarding public safety, such an initiative intends to strengthen data quality and improve information sharing aiming to provide actionable, timely intelligence, as well as to support police operations. Monitoring and assessing the movement of police personnel is a key issue in improving the effective police activities, which in turn is directly applicable to the effective management of a smart city. For example, monitoring the movement of police personnel can help to effectively make plans for emergency response, determine mitigation priorities, analyze historical events, and predict future events. It can also help police officers to determine potential incident sites and facilitates to explore the relationship between incident and land use [7].

One of the systems developed under the Natal’s smart city initiative is ROTA, a platform aimed to improve public safety by integrating several information systems from different law enforcement agencies. Our previous work [8] has introduced preliminary ideas of the ROTA platform and presented the Patrol Supervisor Module (ROTA-PSM), a mobile application used by patrol supervisors to display the real-time position of all patrol vehicles and occurrences. In this paper, we describe a new version of ROTA by means of two new modules, namely the Patrol Vehicle Module (ROTA-PVM) and the Dashboard Module. ROTA-PVM is a mobile application built upon the ROTA platform and designed to fulfill the communication gap between control room and field personnel, thereby improving operational efficiency. By using this application, the field personnel can receive notifications about new incidents from control room, along with driving directions and historical information for proper situational awareness. Furthermore, the Dashboard Module available at the new version of the ROTA platform allows analyzing the trajectory of all patrol vehicles and assisting patrol decisions. For instance, the dashboard can indicate whether patrol workload is equitably shared among the existing patrol districts.

The remainder of this paper is organized as follows. Section II describes some details of the Natal Smart City initiative. Section III presents the architecture and the implementation details of the ROTA platform and the developed mobile applications targeting public safety. Finally, Section V provides some concluding remarks.

II. THE SMART CITY INITIATIVE IN NATAL

To ensure harmony between sustainable urbanization, socioeconomic progress, and the safety of citizens, solutions are sought for feasible living conditions and sustainable city development. One solution adopted by many cities is to realize the smart city concept. Such a concept arises from the need to manage several problems caused by the expansion of urban population [9], thereby affecting the quality of several services, such as transportation, public safety, water, tourism, entertainment, electricity, etc. The main goal is to improve quality of life for citizens and the challenge is how to ensure sustainable urbanization in conformance to a triple that takes into account environmental, economic, and social progress.

The Natal City Council, in partnership with both public and private sectors, has defined a plan to transform Natal into a smart city. The purpose of the Natal Smart City initiative is to allow for and speed up the delivery of outcomes across various sectors through a truly integrated approach. Many actions have been implemented to realize this plan [10], [11]. For instance, the plan creates a network infrastructure named Giga Metropole, an optical backbone of approximately 160 km, as well as a passive network of approximately 300 km to interconnect public institutions in the state of Rio Grande do Norte. More precisely, the Giga Metropole network will benefit around 650 public and private institutions in the Natal Metropolitan Area, including 350 state and municipal public basic education schools, police stations, universities and technical schools, teaching laboratories, and ten hospitals.

In addition to the improvements on connectivity infrastructure, the Natal Smart City plan defines some strategies to improve the services provided to its citizens. Public safety is one of the key services. According to Brazilian Constitution, public safety is managed by state governments in terms of two different law enforcement agencies, one civilian and the other military. On the one hand, the Civil Police is responsible for criminal investigation. On the other hand, the Military Police is responsible for the operational policing [12], i.e., in particular patrolling to respond to citizens’ calls for help and civilian emergencies.

The operational policing comprises two main stakeholders, namely patrol supervisors and patrol officers. Patrol supervisors use patrol vehicles to monitor the execution of the patrol plan. The patrol plan covers the definition of area coverage (haven, ambush, and crime-prone areas), patrol teams, duration, stand-by points, and route plan. Patrol officers use patrol vehicles to respond to control room calls, patrol the assigned beats defined by the patrol plan, and observe and check suspicious people and vehicles. The closest and most important links for patrol officers are the control room and patrol supervisors, with intense communication through the radio communication system of the vehicles.

ICTs play a key role in the operational policing. The promise of technology to improve the effectiveness of controlling crime and enhance professional status and organizational legitimacy, has resulted in a long-lasting close affinity between technology and police work, the so-called e-policing [13], [14]. The main aspect of e-policing is to mobilize information towards making it available to officers through mobile computing [15]. In this context, the Natal Smart City Plan defines a set of strategies and actions to create smart city applications and platforms. One of these platforms is ROTA, which dispatches citizen calls to patrol vehicles and monitors the position and status of patrol vehicles during their daily duties.

III. ROTA: A PLATFORM TO IMPROVE PUBLIC SAFETY

ROTA is a smart city software platform aimed to improve public safety by integrating several information systems from different law enforcement agencies. This platform encompasses technologies to collect, process, share, store, and ana-
lyze a large amount of data coming from different sources in order to turn data into powerful insights. Therefore, the main expected benefits resulting from the adoption of ROTA are providing police officers with better, precise information, as well as improving the use of human and material resources at both individual and organizational levels.

The ROTA architecture (see Fig. 1) is composed of three layers. The Integration Layer integrates information from different law enforcement agencies, in particular the Integrated Center of Public Safety Operations (CIOSP), the State Transit Department (DETRAN-RN), and the Police Technical-Scientific Institute (ITEP-RN). CIOSP is a control room responsible for answering calls to an emergency telephone number for Police, firefighting, and ambulance services, similar to 911 in USA or 112 in Europe. In turn, DETRAN-RN maintains the registry of all circulating vehicles and supervises their transit, while ITEP-RN handles the identification of all citizens and maintains public records on their criminal history. The Integration Layer plays a significant role in this scenario as smart city applications may use multimodal information coming from heterogeneous sources [16].

Aiming at offering important insights from processing and analyzing input data provided by different sources, the Analytics Engine Layer is responsible for reasoning on patterns and on pertinent background knowledge (such as occurrences and patrol vehicle data), making correlations with spatial and temporal information, and displaying relevant visualizations to users. Information handled in the Analytics Engine Layer also allows analyzing historical events and defining patrol plans. Data handled by the Analytics Engine Layer are accessed via the Facade Layer.

The first version of ROTA [8] was validated by means of a mobile application, the Patrol Supervisor Module (ROTA-PSM). ROTA-PSM is an Android mobile application that displays the real-time position of patrol vehicles and georeferenced occurrences in the last 24 hours. Fig. 2 shows a screen of ROTA-PSM that displays in real-time the position of all patrol vehicles (triangles) and CIOSP’s occurrences (circles). This application is used only by patrol supervisors and allows them to figure out the position of patrol vehicles and whether they are following the assigned patrol plan. As an example, a patrol supervisor can use ROTA-PSM to find out which patrol vehicles should be (re)located to cover regions with larger concentration of occurrences and low policing.

By offering a real-time monitoring of both patrol vehicles and occurrences, the ROTA-PSM application has become a valuable work tool against criminality and to improve public
safety. As important benefits resulting from the use of ROTA-PSM, we can mention an easier management of the policing areas and relevant subsidies to help to patrol supervisors in decision-making processes, such as intervening on the redistribution of patrol vehicles or not. This directly contributes to improve the population’s safety feeling by noticing the presence of patrol in areas with a significant number of occurrences.

IV. NEW DEMANDS AND FUNCTIONALITIES

Despite the benefits of the first version, the ROTA platform had some limitations regarding the communication between control room and patrol officers. For instance, to deal with a citizen call, the data flow normally begins when a person (usually a crime victim) makes a call to CIOSP (control room) and an occurrence is recorded. Next, a telephone operator records information about the occurrence and all related details at a dispatch system, so that he/she uses radio communication to assign a patrol vehicle to the location where the crime was noticed. After handling the occurrence, the patrol officer informs CIOSP that the occurrence was handled and it must make a report about the situation itself, victims, and arrested people. In this context, note that the whole communication between patrol officers and CIOSP is verbal and takes place via radio, with several drawbacks: (i) high traffic and sound pollution in the radio data communication channel; (ii) high probability of human failure when transmitting or memorizing information about an occurrence; (iii) transferring information via radio requires more time since repeated voice checks are necessary to confirm the provided information [17]; (iv) low precision on statistics about the time at which occurrences are effectively handled; and (v) low precision on the exact occurrence location as the person that has made the emergency call may be unable to so.

The previously mentioned limitations have motivated us to develop tools aimed to improve response time to occurrences and patrol efficiency, culminating in two new modules that use resources provided by the ROTA Platform. The first one is the Patrol Vehicle Module (ROTA-PVM), a mobile application used by patrol officers to support its operations and improve occurrence handling. The second module is a Web dashboard intended to support reporting, analysis, and statistics on occurrences and trajectories of patrol vehicles.

To cope with the functionalities of both ROTA-PVM and dashboard, it was necessary to add new data flows to the ROTA platform, a flow that takes information to the ROTA Dashboard and a two-way data flow between ROTA-PVM and the Facade Layer. The two-way data flow responsible for integrating the ROTA platform with the dispatch system was the most complicated one to be implemented because the CIOSP uses a legacy dispatch system with no source code available. For this reason, it was necessary to substantially change the dispatch system database in order to monitor and change the dispatch system database and send the occurrence to be handled by ROTA-PVM running in that assigned patrol vehicle. The same happens when the patrol officer uses ROTA-PVM to change the status of the assigned occurrence. This new status must be updated in the dispatch system database in order to be seen by the telephone operator. The following two subsections details the new ROTA functionalities.

A. The Patrol Vehicle Module (ROTA-PVM)

ROTA-PVM is an Android mobile application installed in Motorola ET1 tablets deployed in the patrol vehicles. These resistant, durable tablets run Android version 4.1.1 and they are compatible with WiFi and mobile (3G) networks. The main purpose of ROTA-PVM is to support patrol in its operations, thus making occurrence handling easier and faster. By adopting ROTA-PVM, the occurrence handling flow no longer requires using radio communication, except when strictly necessary. When an occurrence is registered, a notification appears on the screen of the patrol vehicle’s tablet. Upon confirming that the received notification was seen, the policeman is provided with all relevant data regarding the occurrence, such as location, type, suspect’s characteristics, and the transcription of the call made by the citizen to CIOSP. With these information in hands, it is possible to improve occurrence handling without requiring it to CIOSP. During the operation, the patrol officer can notify any change regarding the occurrence, e.g., his/her arrival on scene, the need of an additional displacement, finishing occurrence, and occurrence reports.

In addition to the agility resulted from the adoption of ROTA-PVM, the five aforementioned problems are solved. First, the radio communication channel will be used only in urgent situations, such as reinforcement forces. Second, with all information about the occurrence (including the transcription of the call made by the citizen), the patrol officer becomes more confident on how to proceed according to the current situation. Furthermore, notifying the arrival of the patrol vehicle using the mobile device increases the precision of the exact occurrence location and of the displacement time.

Besides occurrence handling, ROTA-PVM encompasses other independent components able to provide other functionalities that are relevant to patrol officers:

- search for vehicle registration plate number, which can be used to obtain more information about a given vehicle such as trade, year, color, etc., including checking the integrity of a vehicle ownership (regular or stolen), as well as any other pendencies;
- search for civil information, thereby allowing to check the verity of documents or data given by a citizen;
- search for arrest warrant decreed against the person addressed in police action, thus not requiring a displacement to a police station or information request via radio;
- map tracing, which displays the location of all occurrences in the city and allows calculating the shortest path to the location of the assigned occurrence.
The components of ROTA-PVM communicate with the ROTA platform by making requests to RESTful Web services (Facade Layer) that provide all information used in the mobile application. In turn, these Web services perform multiple queries to the public agencies that collaborate with Police, such as ITEP-RN and DETRAN-RN. It is important to highlight that the architecture of ROTA-PVM was conceived to be modular (see Fig. 3), so that all functionalities are independent from each other. Therefore, development and maintainability become more scalable and flexible since new solutions and functionalities relevant to policemen can be easily incorporated into ROTA-PVM.

Even though Internet connection is required to fulfill most of the offered functionalities, ROTA-PVM was designed to be continuously used, despite the lack of access to a mobile Internet connection. In these situations, the occurrence handling component (the most sensitive to this eventuality) allows the user to proceed with the occurrence handling flow by temporarily storing all information in a local database. Once the Internet connection is reestablished, all updates about the occurrence handling are sent to the ROTA platform. Therefore, patrol officer activities are not interrupted, even with no Internet access.

Fig. 4 shows three screenshots of the ROTA-PVM mobile application. The first one (top) refers to a pop-up notification displayed when a new occurrence is assigned to the patrol vehicle. By tapping the “Accept” button, the notification is accepted and the patrol officer is redirected to the occurrence handling screen (middle), which shows all details regarding the occurrence and a transcript of the call made by the citizen. When arriving on scene, the patrol officer taps the “Arrived on scene” button and confirms his/her arrival (bottom).

B. The Web Dashboard

In order to provide ROTA with trajectory analysis and occurrence statistics, we have developed a layered Web Dashboard relying on OpenStreetMap [18]. As shown in Fig. 5, the current version of the dashboard supports four layers: (i) AISPs, strategical regions of the city delimited by Police; (ii) trajectory of all patrol vehicles within a time interval; (iii) position tracking of patrol vehicles at a given time instant; (iv) different occurrences, which are shown using different colors according to their type, e.g., person in suspicious behavior, theft, possible threats, etc; and (v) a heatmap representing the density of occurrences in certain areas.

Two main sources feed the ROTA dashboard. Data about occurrences (as location and type) shown in the dashboard are provided by CIOSP and supported by the ROTA-PVM mobile application. In turn, the HERMES Moving Objects Database [19] is used to provide information about the patrol vehicles and to support both spatial and temporal queries on available trajectory data. HERMES integrates several data
The ROTA dashboard is extensible and hence other layers can be easily added to it. For instance, crime statistics for specific AISPs are interesting information that can be displayed on the dashboard, which can make use of data coming from the ROTA platform itself towards offering an intelligent decision-making method to assign patrol vehicles along the city.

V. FINAL REMARKS AND FUTURE WORK

This paper presented the new version of ROTA, a smart city platform aimed to improve public safety by collecting, integrating, analyzing, and sharing information about occurrences and patrol vehicles. Such a new version delivers a dashboard able to analyze the trajectory of all patrol vehicles and assist many patrol decisions. Additionally, this paper described ROTA-PVM, a robust, scalable mobile application that fulfills the communication gap between control room and field personnel. By using ROTA-PVM, field personnel can receive notification of new incidents from control room, with driving directions and historical information for proper situational awareness. Therefore, ROTA-PVM can significantly enhance safety and improves operational efficiency, besides adding value to police forces. From the use of the developed solutions, it is already possible to observe a paradigm shift for patrol officers, who now acknowledge the importance of technological tools to support the execution of their daily activities. This new version of ROTA platform is operational since April 2016 and has been used by 40 patrol supervisors and 200 patrol officers.

In terms of future work, the next steps of this project are to evaluate the usability, intuitiveness, availability, and efficiency of the ROTA dashboard and the ROTA-PVM mobile application. We also intend to develop a mobile application to be used by citizens in order to create emergency occurrences instead of phone calls to the CIOSP (control room).