Cooperation of Smart Objects and Urban Operators for Smart City Applications

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Abstract This paper illustrates main research activities and results of the project "TETRis – TETRA Innovative Open Source Services" concerned with enabling innovative services for Smart City/Smart Territory by means of technological tools and intelligent platforms for collecting, representing, managing and exploiting data and information gathered from sensors and devices deployed in the territory. Technological tools and intelligent platforms are integrated into a complex smart environment that provides advanced services to citizen and operators for environmental monitoring, urban mobility and emergency management. Although the project is mainly based on the utilization of the communication protocol TETRA, the application scenarios may work with other network protocols as well.

Keywords: Smart Objects, Urban Monitoring, Urban Mobility, Intelligent Platforms, Wireless Sensor Networks.

1 Introduction

The concept of smart city is used all over the world with different nomenclatures, context and meanings [10,13,16]. The concept adopted in this paper is: a city is smart if it acts in a forward-looking way in economy, people, governance, mobility, environment, and living, using a suitable combination of endowments and activities of self-decisive, independent and aware citizens. Therefore, a smart city monitors and integrates conditions of all of its critical infrastructures, optimizes its resources, plans its preventive maintenance activities, and monitors security aspects while maximizing services to its citizens [11]. To be smart, a city must interconnect the physical infrastructure, the ICT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city [3,12]. The use of advanced ICT technologies is crucial to make its infrastructure components and services (including city administration, education, healthcare, public safety, real estate, transportation, and utilities) more intelligent, interconnected, and efficient and to identify new, innovative solutions to city management complexity, in order to improve sustainability and livability [15]. In sum, a smart city must strive to make itself “smarter” (more efficient, sustainable, equitable, and livable) [14].

The activities described in this paper are related to the design and prototypal implementation of innovative services aimed at an intelligent management of an urban territory for novel smart city application scenarios. Within these activities, a number of solutions and advanced technology platforms have been identified that enable the various entities operating in the area of interest (municipalities, provinces, regions, universities, etc.), as well as citizens and urban operators, to effectively cooperate for an efficient usage of urban resources. In fact, the wealth of information acquired on the territory through the use of sensors and devices interconnected by local and remote communication systems are suitably stored and processed to support high added-value services to improve the quality of the territory itself in terms of livability and sustainability. A crucial aspect is the involvement of citizens and urban operators who become the main tutors of the territory, the so-called "social sensors", for the detection of critical situations in the urban territory.

The innovation scenarios and solutions described in this paper have been realized within the project PON 2007 2013 - Research and Competitiveness "TETRis - TETRA Innovative Open Source Services" according to reference general frame of "Internet of Things" for supporting Smart City/Smart Territory [2], in which the acquisition of data by objects is applied to large territorial areas by exploiting the widespread availability of communication networks [9, 21]. The collected data, properly enhanced and enriched, foster innovative services oriented to the production and exchange of knowledge among the different actors interconnected in urban and regional networks. The development of these services has been realized through the cooperation of smart devices and objects as well as of operators and users of the services themselves.

A key role in Internet of Things, as well as in smart city scenarios and services, is played by the concept of *smart object*, first introduced in [17], which is a physical/digital object having a unique identifier that is used to digitally manage physical things (e.g., sensors), to track them throughout their lifespan and to annotate them (e.g., with descriptions, opinions, instructions, warranties, tutorials, photographs, connections to other objects, and any other kind of contextual information imaginable), and to consciously handle its relationships with other smart objects and with remote systems. In sum, a smart object is a physical/digital object augmented with sensing/actuating, processing, and networking capabilities that may embed human behavioral logic [18].

Smart objects are typically part of a *Smart Environment*, which is "a physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network" [20]. Smart Environments are often based on a suitable middleware that enables communication and management of smart objects in distributed applications [19, 22, 23].

The activities described in this paper refer to two main application scenarios identified within a Smart City context: (A) Urban Mobility (B) Territory Monitoring, Control and Maintenance.

The remainder of the paper is organized as follows: Section 2 presents an overview of the TETRis project and describes its main goal, Section 3 illustrates two meaningful innovative application scenarios for smart city/territory, Sections 4 and 5 focus on the scenario respectively of urban mobility and of urban monitoring and risk analysis and Section 6 withdraws the conclusion and discusses further work.

2 Project Objectives of TETRis

The TETRis project main goal is to create high value-added services by exploiting and possibly extending the functionalities of the TETRA communication system. The Terrestrial Trunked Radio (TETRA) is an open standard for mobile radio communications developed by the European Telecommunications Standards Institute (ETSI) and specifically designed to support Professional Mobile Radio communications (PMRs) in a number of market segments such as public safety, transportation, utilities government, military, commerce, industry. TETRA is deployed in over 88 countries worldwide, and the main market is by far that of national public safety organizations. The primary goal of public safety is to carry out all the necessary actions for the prevention and protection from events, such as dangers, injuries, or damages, that could threaten the safety of the general public.

TETRA system is particularly suitable to meet the needs of professional users of emergency care organizations dealing with public utilities, public security forces, transport companies, and it represents also the answer to solve the growing needs of private mobile radio systems (PMR) users, both in terms of radio traffic decongestion and in enhancing voice and data services. TETRA is designed to provide operational and service communications between land mobile units, naval and air and their related control centers, in either voice and data modes, and it integrates with existing radio communication frameworks and commercial communication systems, thus ensuring maximum efficiency both in terms of transmission resources and in management and use.

TETRA provides a common and standard infrastructure for secure and reliable communications and also supports unique features such as group conversations, dispatcher centers, and direct communications. While the initial focus of TETRA has been on voice communications, data communications have been supported since the beginning and nowadays are gaining more importance. The prevention and management of critical situations related to public safety, requires the real-time acquisition of data from the field in order to react more consciously, faster and better.

The project acts along three main axes in order to enhance TETRA functionalities and to extend its usage to novel application domains:

1. The evolution and the opening of novel application fields for TETRA in order to define new information services for operators, exploiting new models and open source tools for the interconnection of TETRA with other networks and the identification of new type of TETRA-based devices suitably interoperated with existing sensors and sensor networks;

2. The modeling and prototyping of an Open Source framework implementing a Smart Objects cooperation model and enacting their management by means of so-called Smart Environments;
3. The identification of novel scenarios and application models in the perspective of Smart City/Smart territory services applied to territory monitoring, emergency management and intelligent support to urban mobility.

The specific objectives of TETRis project can be read as follows:

- Bringing economic and social benefits to the community through more targeted and effective actions by Public Administration and Public Security operators in application scenarios such as emergency management, environmental protection, mobility and services to citizens, with the contribution of the citizens themselves through the sharing of information and the use of innovative tools for social networking;
- Extending the pervasiveness and effectiveness of public administration services, instrumental bodies, local police, health operators, transport companies in the reference areas; Improving the quality of life and the sense of safety of citizens through the spreading of safe and reliable technology infrastructure "always on".

The project activities are organized in a number of work packages, each of them consisting of a number of Industrial Research and Experimental Development activities.

This paper describes the experimental activities conducted by the project in the following two application areas:

- "TETRis Smart Environments for mobility" - it concerns the implementation of a model for the detection of mobility problems in urban areas through the use of specific Smart Objects located in the territory and the use of a network of sensors connected to them. These data are collected and aggregated into a data warehouse feeding a Mobility Intelligence platform defined through the design of innovative techniques of space-temporal data analysis and mining of complex data, including trajectories.
- "TETRis Smart Environments for territory monitoring and delivery of services to citizens" - it defines a Smart Environment managing a network of physical sensors connected to Smart Objects that is enriched by "social" sensors which detect in real time the status of the territory. These so-collected data are stored and aggregated into a data warehouse feeding a Territory Intelligence platform, which enables the extraction and processing of knowledge for monitoring the territory.

Within the project two collaboration agreements have been signed with the municipalities of two towns in Southern Italy: (i) Cosenza as for the Urban Mobility area, and (ii) Rende as for Urban Monitoring area. The two municipalities have shown a high interest in the experimentation of innovative IT solutions and techniques in their view of pursuing the realization of a new model of a city, seen as an intelligent system that supervises on the compliance and control of the environment, and effectively manages resources through the use of technological ICT infrastructure and innovative tools in order to deliver high added-value services for citizens.

3 Design of the Applications Scenarios for Smart City

The two scenarios that have been identified for a typical application in support of a Smart City share the same basic architecture that includes the following elements:

- *Actors* - divided into three categories:
  - *Government Body*, which is responsible for managing the Smart Environment and the Smart Object network distributed throughout the area;
  - *External Local Authorities*, which are interested in the services of the Smart Environment and Smart Objects with which they interact;
  - *Individuals*, who can be either citizens or workers (operators) performing their duties in the area under the directions of the managing body;
- *Government central systems*, which are responsible for the overall application functioning and for the control of the Smart Object networks distributed on the territory;
- *External Local Authorities systems*, which interact with the Government central systems and the Smart Objects on the basis of operating protocols agreed with the central systems and that can also interact with other external authorities systems;
- *Smart phones APPs*, used by individuals;
- *Smart Objects*, which are distributed on a territory under the management of the central system, and perform two types of communication:
  - *Remote communication*: (i) with the Government central system through TETRA, (ii) with External Local Authorities systems through commercial telecommunications protocols (GSM, UMTS, etc.) and possibly also with TETRA;
  - *Local communication*: (i) with operators through WiFi and NFC technology for instant activation and personalization of the interaction, (ii) with citizens through WiFi, (iii) with physical objects, that are related to a Smart Object and are distributed over the territory, typically using ZigBee protocol or RFID.
- *Sensors*, which can be:
  - classical traffic detection sensors, related to a Smart Object, connected together with ZigBee network protocol or RFID;
  - classical sensors for environmental conditions detection (temperature, humidity, sound, CO, dust, etc.) connected together with an ad hoc network;
  - social sensors, that means citizens and operators having a mobile device provided with applications for signaling and/or monitoring events that occur in the territory of interest;
  - devices, sensors/actuators of urbotic (i.e., automation at urban level) that can either directly interact with Smart Objects using low power protocols but with high performance, such as Cliffside and Wibree, or through a dedicated control kit using WiFi connection.

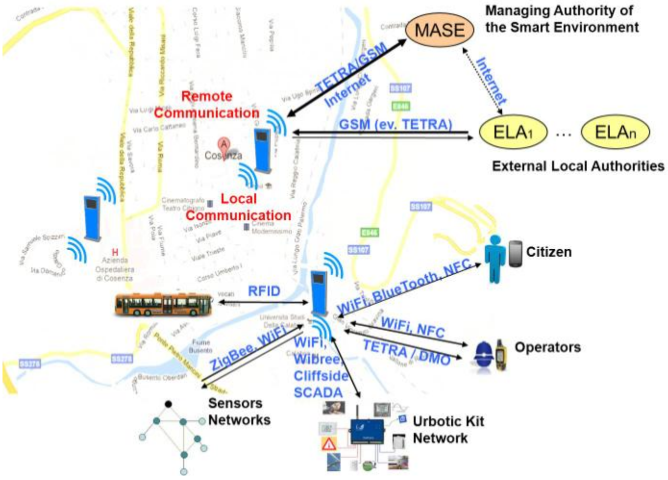

Fig. 1. A Smart Object Usage Scenario

Figure 1 shows the overall picture of a typical scenario of Smart Objects usage within a Smart City with an indication of the various components and their interactions. Smart Objects use remote communication protocols, such as GSM, TETRA and/or Internet, for information exchange with Government Body and External Local Authorities concerning urban monitoring and emergencies management. Smart Objects may also exchange data with citizen and operators using local communication protocols, such as: WiFi, Bluetooth and NFC, when interfacing with citizen smartphone applications; WiFi, NFC, TETRA, when communicating with operators devices; RFID, for bus mobility detection; WIFi, ZigBee, Cliffside for sharing information with sensors networks.

Figure 2 shows a general architecture of a Smart Object where some relevant components are identified: the Smart Object software intelligence, which collects data coming from sensors networks, citizens and operators apps, processes them on the basis of some alerting and control criteria, and delivers the results to external entities using local and/or remote communication protocols and specific interfaces, depending on the target users. The Smart Object architecture can vary depending on the scenario taken into consideration and it can be seen as a three level architecture with the following tiers: (1) a basic level, where social sensors communicate information through the usage of smartphone apps and physical sensors can detect some specific determined measures and continuously transmit data to the government central system; (2) a middleware level, which is able to collect data transmitted by sensors and which is provided with an alerting system - data collected at this stage feed operational and informational dashboards that are used by citizens and operators; (3) a business intelligence system which integrates data coming from different internal and external sources and provides territory, mobility and security intelligence services to Government Bodies and External Local Authorities by means of decision support dashboards.

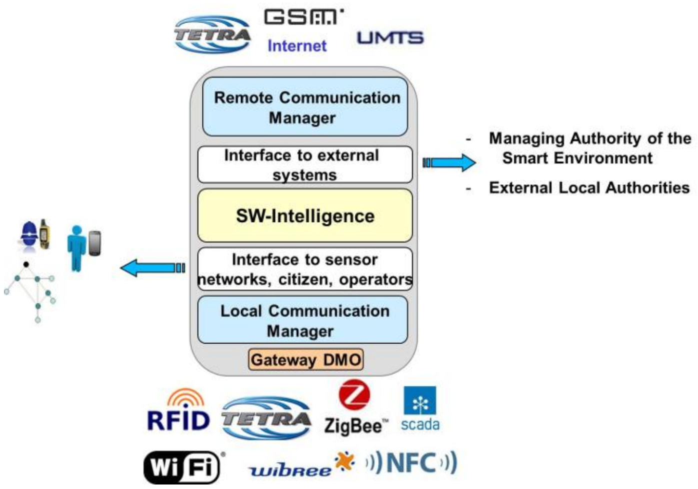

Fig. 2. Smart Object Architecture

4 Urban Mobility

The Urban Mobility scenario implements a model based on a network of smart objects and connected sensors network providing in real time data related to the mobility in a urban area. The model also includes amenities to deliver services to operators and citizens through the use of mobile devices.

Data collected from sensors and smart objects geographically distributed are collected and aggregated into a data warehouse feeding a Mobility Intelligence platform that performs on-line knowledge-based analysis in order to deliver real-time information about the smart management and usage of mobility systems to both urban operators and citizens.

The experiment has been carried out on the territory of the municipality of Cosenza along two main macro areas of development:

- Urban traffic detection and management by means of stationary smart objects, placed at critical points in the city of Cosenza, which collect frames and videos from webcams and traffic detection sensors;
- Detection and management of any violation made by cars on bus corridors by means of moving smart objects installed on buses of the public city transportation company.

The Mobility Intelligence platform processes data in real time, according to the most recent lines of research in OLAP systems analysis and data mining, and performs as a decision support system supporting operators to extract, quickly and in a flexible way, all the information needed to meet citizens mobility needs [8]. A dashboard offers the possibility to the interested authorities to take strategic/operational decisions and to better plan interventions on road infrastructure, public transport routes, available parking spaces and multimodal communication infrastructure with citizens. The analysis of data through the intelligence platform can also offer a valid support for the definition of the urban traffic plan through a calibration activity of the model in order to update the plan and to adapt it to the observed actual reality.

Thanks to an effective integration of data mining tools and geo-referenced data analysis, the platform is also able to depict spatial data, models and results on a geographical map.

Within the urban mobility scenario, the following classes of applications for citizens and operators have been also implemented available:

1. APPs for citizens, providing information on
   - bus tracking: arrival times, their timetable, the positions of the nearest bus stops;
   - available parking places: their location on the map, the number of vacancies and the way to reach them;
   - real-time traffic updates and traffic jam reports;
   - the city life: places of interest, restaurants, hotels and clubs.

   All information is contextualized according to the geo-localization of citizens.
2. APPs for operators enabling them to monitor the traffic and public transport status, to analyze alerts about traffic jams, parking in double row, other disruptions;
3. App for issuing fines, by recording the violation of the rule with its geo-localization and by possibly attaching a photo as a proof.

The same services delivered by the apps are also made available using a Web portal.

The following further analysis tasks were conducted to define the model for urban mobility [1,4,7]:

1. Assessment to check the actual possibility to replace part of private mobility in the urban area of Cosenza by public transport together with highlighting of deficiencies, waste of resources and with suggesting for improvements / upgrades;
2. Discovery of public bus frequent moving patterns in their routes from the mining of bus logs and trajectories;
3. Reachability evaluation of the city and surrounding areas, using data on both public transport routes and bus logs to compute the actual time distances among the various areas of Cosenza during the day;
4. Profiling of Population Mobility, using data from a mobile phone company to detect how phone callers move among the various city areas and to classify them on the basis of their behaviors.

5 Urban Monitoring and Risk Analysis

The Urban Monitoring and Risk Analysis application scenario activities concerns the definition of a Smart Environment integrated with a network of smart objects located throughout the territory for the management and maintenance of the urban environment and for the delivery of timely and innovative services to citizens. During the experimentations, a number of physical and "social" sensors have been deployed in the territory to detect in real time the status of the territory itself and the associated risks. The scenario includes a Territory Intelligence platform that first collects data supplied by smart objects and social sensors and, then, as a result of the appropriate phases of integration and data processing using advanced techniques of data warehousing, it makes the information available to various parties with which the platform interacts in order to properly monitor urban areas.

Within this scenario a number of contextual applications have been made available to citizens and operators working for territory maintenance through their mobile devices. These applications allow them to immediately communicate with the public administrations and utilities to report critical situations, malfunctioning in urban networks, road failures and intervention requests for restoring the conditions of good livability of the territory. Events to be reported are classified into the following categories: dangers on the road, stray animals, services and networks, urban refurnish and green, waste depot. The collected data and reports can also be inquired via a Web portal that can be seen of as a managing console in order to: assign the requests to an operator or a group of operators for the appropriate intervention activities; monitor the status of the actions; check the status of the smart objects distributed in the area of interest; implement an overall urban safety system by the immediate involvement of urban operators.

The experiments were carried out on the territory of the Municipality of Rende with focus on the monitoring of urban and extra-urban areas through real-time information coming from sensor networks connected to smart objects suitably distributed in the urban territory.

Real-time information from smart objects and social sensors feed the model used to draw up new plans of action, or to update/modify the current ones so that a local government can better relate resource planning to the needs in a dynamic and timely way. Sensors distributed throughout the territory have been also designed to detect the exceeding of prefixed "thresholds", which require contingent changes to maintenance plans by the government bodies.

Within the Urban Monitoring scenario, a Risk Analysis model has been also implemented for road traffic monitoring in urban areas in order to identify and assess the risks hanging over the system under observation and to take the necessary countermeasures. The identification of the possible risk events and the activities for monitoring them enable, in a more easy and rational way, local authorities to implement action plans to prevent the occurrence of risks or to reduce their impact, to promptly detect ongoing risks and to alert urban operators for their immediate intervention, possibly involving also citizens both in the detection of critical situations and in the immediate assistance.

The experiments within Urban Monitoring scenario have also made usage of wireless sensor networks for monitoring the surrounding environment [5], forwarding the acquired information to a collection center (a sort of a gateway smart object) through the construction of a multi-hop ad-hoc network. This converge-cast communication schema is particularly suitable for collating data on a territory and for communicating them to a central sink (a smart object), in order to make data available for other processing. The adopted protocol is CTP - Collection Tree Protocol [6]. Every sensor periodically communicates data to its parent (selected on the basis of the communication protocol policy) going up to the sink in order to forward data to the Territory Intelligence platform.

Two main experimental domains have been identified:

1. Indoor working environment monitoring;
2. Buildings monitoring.

In the first domain, a wireless sensor network have been installed to monitor the quantity of CO2, CO and dust, the temperature and humidity levels in a specific area. Collected data cover a period of several weeks and they are made accessible in real-time and, later on, summarized in a report. At the end of the monitoring process in the specific site, the network can be dismantled and used in a new place (building, urban area) in order to reduce costs and to repeat the same analysis in a different site.

Finally, a further wireless sensor network has been used for the monitoring of the statics of buildings in order to provide evidence of whether the situation is to be considered "under control" or is instead critical and, therefore, a prompt intervention is needed or some alarm signal has to be sent.

6 Conclusion

We have illustrated some of the activities and results of the TETRis project concerned with the study and experimentation of innovative solutions for the regeneration of urban contexts according to the emerging integrated strategic vision of the Smart City. Experiments were made possible thanks to collaboration agreements with two Southern-Italy municipalities and to the proactive involvement of their representatives in the design and implementation of novel smart city application scenarios in order to provide more effective and efficient services to citizens. A crucial role in the application scenarios is played by the so-called 'social sensors', i.e. the citizens themselves and operators (municipality and utility employees) who are supposed to communicate in real time with all the institutions to report all critical situations such as traffic jams, vandalism and neglect, presence of waste, road holes, various inefficiencies.
The paper has described two relevant smart city application scenarios: (1) Urban Mobility and (2) Territory Monitoring, Control and Maintenance. The two scenarios share the same architecture based on a network of stationary and moving smart objects located in the urban areas and on Intelligent Software platforms supporting the delivery of innovative services to both urban operators and citizens. Thanks to the pervasive usage of advanced ICT tools, the two scenarios enhance the direct line citizens - Public Administration, thus enabling the citizens to become an integral component of good administrative practices.

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