Smart Maintenance to Support Digital Life

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Abstract. This paper describes experiments performed to validate the possibility of delivering smart maintenance to utilities and telecommunication operators. First, the paper describes the reference architectural model of smart cities and it introduces smart maintenance and social smart maintenance. Then, the paper outlines performed experiments and relative results.

Keywords: Social smart maintenance · Business process management · Agent technology · Workflow technology

1 Introduction

One of the most important annual reports that analyze various aspects of societal changes in Italy is entitled *Digital Evolution of the Species* [1]. The concept of the report is reminiscent of how, in the last two decades, the growth of the society–in Italy and in all other western countries–has been affected by technological innovations in a way so incisive as to suggest a new *species* of human being. Such a new species lives in technological territories–both real and virtual–where people and objects are interconnected, and where information circulates so fast that it causes revolutions in lifestyles, and in the whole social context. The digital evolution of the species is short, Darwinian metaphor of how the technological revolution has brought, worldwide, a profound transformation in the habits, up to the point of speaking about the today's digital life, in contrast to a recent past when mechanical and analog devices were used to support people in all aspects of their daily life.

Connectivity as one of the enabling elements of the digital life because it is the fuel without which there can be no digital exchange. The (real) technological territories, in which such exchanges have their highest concentration, are, with no doubt, the today's cities, and the tomorrow's *smart cities*.

This paper is organized as follows: Section 2 briefly recap the reference architectural model of smart cities that this work assumes. It also introduces *smart maintenance* and *social smart maintenance*. Section 3 describes ongoing experiments in the scope of social smart maintenance which targets utilities and telecommunication operators. Section 4 briefly concludes the paper.

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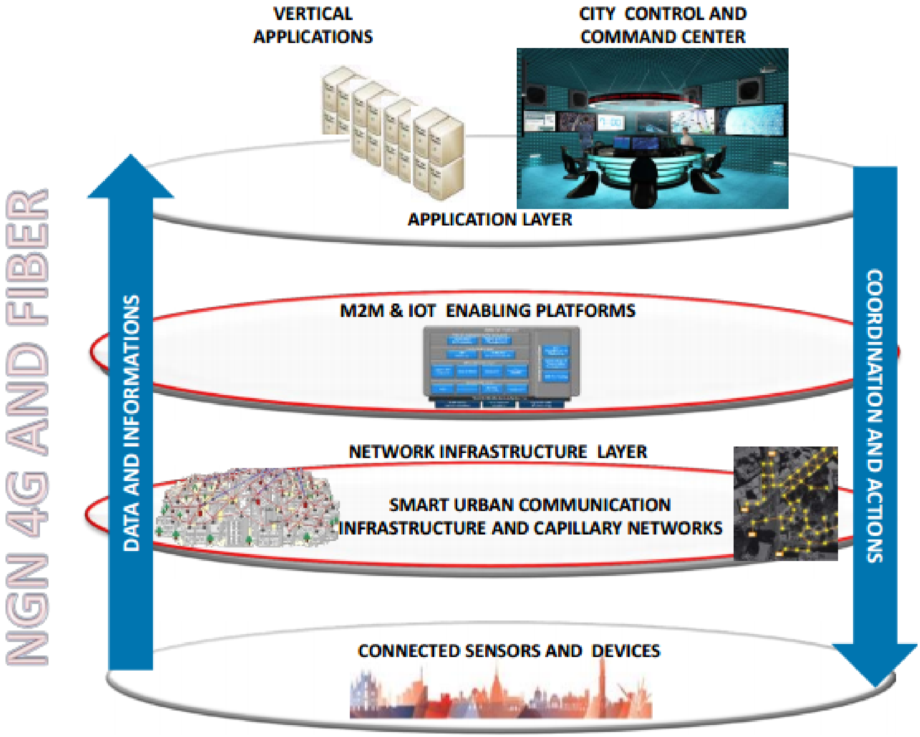

Fig. 1. Reference architectural model of a smart city

2 The Reference Architectural Model

The architectural model of upcoming smart cites, which is the reference for the work described in this paper, is shown in Fig. 1. This architectural model is simpler than other admissible models found in the literature, but it is structured just like all other models: a layered architecture ground on the possibilities that smart devices offer today, and will increasingly offer in the future.

Starting from the bottom of Fig. 1, the first layer is the layer of sensors and actuators, which are spread all around the smart city. In the smart city they become smart devices, and they become always interconnected devices. Ambient sensors, smart streetlights, surveillance cameras, media totems, traffic sensors, are just few examples of the wide range of devices that are spread around urban areas to enable *smart services* to citizens. In this simple model, also citizens' smart appliances are part of the network of sensors, and citizens themselves become sensors–*smart citizens as smart sensors*–and actuators with a high degree of autonomy. Increasingly often applications in traffic, weather, pollution, and tourism, are based on the possibility for users to provide information. Users become sensors of application-specific parameters and they also enrich basic information, with user-generated contents, that add value to the basic services. But citizens can also be somehow driven, and in this sense they become smart actuators. Gaming is a key ingredient in turning smart citizens into smart actuators, and their smart appliances are part of this picture because they allow ludic content to be delivered to citizens to engage them into games that can be used to control their collective behavior (see, e.g., [2]).

The middle layer in Fig. 1 is that of the network infrastructure and of the connectivity. In smart cities such a layer is not limited to broadband connectivity, either wired or wireless, but it also encompasses short-range connectivity–the so called *capillary networks*–which is of crucial importance for populating of smart objects the *Internet of Things* (*IoT*), and for implementing innovative services in the city. Such networks are made of gateways and concentrators which gather data from sensors via low-power wireless links. This network infrastructure is shared among a large number of services, and it carries a large amount of data. Data coming from sensors and devices of the lower layer are sent in the network through gateways, which serve as connection points between the short range networks of sensors and traditional long range networks.

The third is the layer of *Machine-2-Machine* (*M2M*) management platforms and of cloud computing. This is the layer where storage capacity and computational capabilities reside, and where management processes are found. Such processes enable and control connections, they analyze and route data, they guarantee the security of transactions and the *Quality of Experience* (*QoE*), and they also ensure to service providers the ability to interface their applications and to create new applications and services.

Finally, the last layer, enabled by management platforms, we find vertical application responsible for the management of services and objects deployed in cities. This layer contains vertical applications, like e-school, e-health, smart mobility, smart lighting, smart metering, and smart waste management. This is the layer in which *city command centers* are deployed–real or virtual–places that support service management of a smart city, and where decision makers can have an overview of the QoE that the city as a whole is providing to citizens. The city command centers gather information from underlying layers and they provide synthetic views via dedicated real-time *dashboards* offering, e.g., views of the correlation of integrated phenomena, graphical maps with views of the vitality of the city, and views dedicated to the early detection of critical levels of important parameters like pollution, noise, and environmental hazards.

Regardless of the size of the domain that various stakeholders of the smart city exert on the elements of the architectural model in Fig. 1, it is crucial to emphasize that an increasingly rich and diverse connectivity available to citizens, businesses, utilities and governments make the places where such a connectivity is more dense–the smart cities–real accelerators of digital life, thus activating a virtuous circle of benefits for all stakeholders.

Telecom Italia uses the presented architectural model for various research and experimental activities, like the ones demonstrated in the *Open Air Lab* in Turin[1]. The Open Air Lab is a new laboratory dedicated to digital life, and to the changes that ICT is driving in urban scenarios. As depicted in Fig. 2, the Open Air Lab provides a unified view of various research subjects, including smart mobility and smart parking, efficient waste management, urban surveillance, and smart metering of services.

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[1] Open Air Lab app: *https://play.google.com/store/apps/details?id=it.telecomitalia.openairlab*

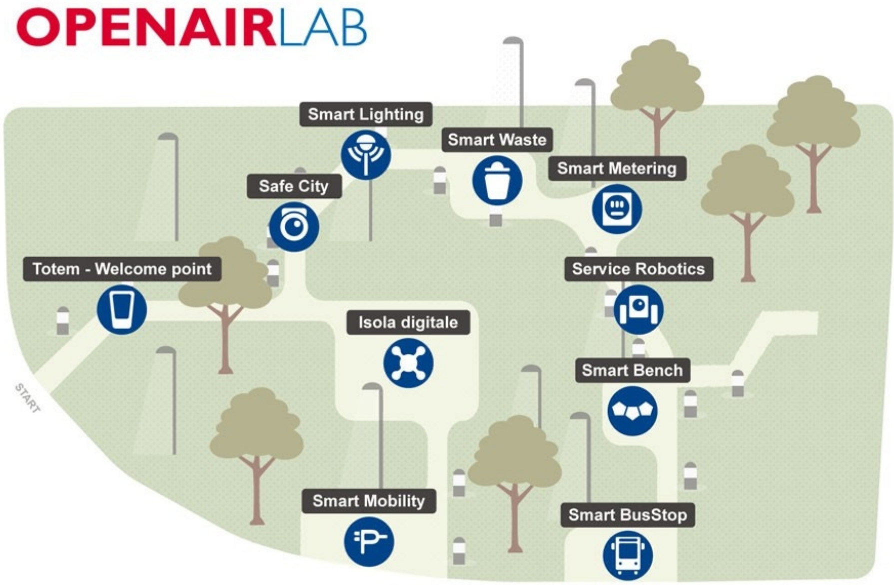


Fig. 2. The structure of the Open Air Lab in Turin

In the scope of a smart city, also maintenance functions and processes can exploit the availability of the infrastructures briefly summarized in Fig. 1 to improve their quality of service to service providers and to citizens. We say that smart cities provide the tools to enable *smart maintenance*, the evolution of the ordinary infrastructure maintenance by means of systematic and synergic use of smart devices (from the bottom layer), undisrupted connectivity (from the second layer), M2M and IoT (from the third layer), and applications (from the top layer). Given that smart maintenance is structured just like citizens' daily activities, it is reasonable to allow citizens entering in the maintenance processes, turning smart maintenance into *social smart maintenance*. Smart citizens become sensors of maintenance processes, and they contribute user-generated contents to support maintenance activities. This is the case, e.g., of citizens proactively signaling problems in the urban infrastructures, taking part of social games that award proactive participation in maintenance processes. Moreover, social smart maintenance can sometimes use smart citizens as actuators capable of performing entry-level maintenance activities, like self-configuration or self-repair of infrastructures.

3 Experiments

Maintenance is traditionally a core function of service providers and it is normally assumed that only professionals with specific skills can execute maintenance tasks with the required quality. This is main reason why smart maintenance is entering the vocabulary of service providers quite slowly. Skilled professionals do not need technological help to carry out their tasks; they do not need automatized (and rigid) help because they are the real field experts. Similarly, social smart maintenance includes average citizens in the picture, and it implicitly assumes that maintenance processes would benefit from such an inclusion. We have significant evidence that such assumptions are false, and the experiments described in the rest of this paper are primarily meant to validate the values of smart maintenance. For the sake of brevity, similar experiments targeting social smart maintenance are left for another paper.

3.1 An Experiment in Network Management

In order to support its workforce of over 10,000 technicians engaged in actions related to network configuration and repairing network failures and malfunctions, Telecom Italia designed and implemented a specific software system called Wizard [3]. Wizard has been in constant and effective use since 2007, and its value in daily operations is recognized and appreciated within the company. Wizard is considered today a cornerstone in the management of one of the most penetrating broadband networks in Europe, which counts 6.9 million retail broadband accesses and 13 million retail connections over copper and optical fibers in 2013 [4].

From the practical point of view of field technicians, Wizard guides them in a complete, integrated and exhaustive way throughout all steps of problem-solving activities. Wizard provides technicians with a direct connection with back-end systems responsible for all tasks related to network and service management. Technicians agree that Wizard is a direct responsible for significantly reducing the duration of problem-solving activities because it monitors the activities that they perform in real time, and because it can proactively trigger suitable crosschecks with relevant OSS (Operations Support Systems).

Fig. 3. A screenshot of the application used to support maintenance of network elements

From a methodological point of view, Wizard is considered a valuable tool to support network and service management because it enforces the use of a formalized notation based on workflows to represent the operative knowledge of the company. The methodological approach that Wizard promotes enables a significant reduction of durations and costs of maintenance activities because technicians are provided with a friendly and unambiguous description of the activities that they are demanded to perform in common and uncommon situations.

Today, Wizard is the primary means to support the work of field technicians, and it is in everyday use by technicians to manage an average of 5,000, and a peak of 15,000, work requests. Such work requests are nontrivial maintenance tasks that directly involve technicians–and sometimes customers–and that often allow direct resolution of access network malfunctions.

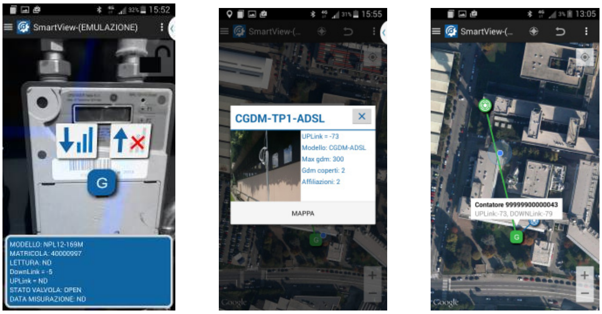
Wizard was developed on top of WADE (Workflows and Agents Development Environment) [5, 6], the BPM (Business Process Management) platform that evolves the popular agent platform JADE (Java Agent and DEvelopment framework) [7]. Both platforms are open source and they share the support mailing list and the Web site *jade.tilab.com*. JADE and WADE are considered by a large community of users and developers one of the most advanced incarnations of agent technology, and they provide Wizard with the advanced work coordination capabilities of agents (see, e.g., [8, 9]) . Technically, JADE is a software framework that facilitates the development of interoperable multi-agent systems. JADE has a long and outstanding tradition of mobile developments [10, 11] that has been recently revitalized with a specific support for Android [12]. WADE is built on top of JADE and it enriches JADE with the workflow metaphor to provide developers with a robust environment for embedding workflows into agents. WADE is a solid technology that has proven its solidity in large-scale network and service management for over 5 years [10].

The presented experiments integrate Augmented Reality (AR) in network operations (see, e.g., [13]) via Metaio SDK (*www.metaio.com/sdk*) version 5, and they were meant to simulate in a controlled environment the critical parts of so called port change workflows. Such workflows are normally activated to support maintenance of faulty ports in network equipment at customers' premises. They require the technician identifying two ports in the network equipment and performing a manual rerouting of connections. Such workflows are quite common in the daily operations of technicians and they are performed for more than 10% of the work requests managed by Wizard. Fig. 3 exemplifies the class of network equipment considered in the first experimental campaign. The equipment shown in the figure was used to validate the possibility of adopting AR to: identify the actual equipment that the technician is facing by visually searching it into a database of installed equipment; and point the technician to the two ports that would need to be rerouted by highlighting their position in the scene with appropriate markers. The gray markers in Fig. 3 inform the user that the equipment was identified, while the green and the red circles point the technician to the port to disconnect and connect, respectively.

3.2 An Experiments in Smart Metering

Telecom Italia is involved in the design of capillary networks that can be used by multiple utilities. Sensors in such networks send measured data to the services that the management platform provides. SmartView is a mobile application that helps gathering data and that support assurance actions on gas meters. SmartView can be used with full functionality by Telecom's field technicians involved in maintenance and delivery; it can be used with reduced functionality by personnel of the utility; and it can even be used with minimal functionality by citizens. In this last case, SmartView is an interesting example of social smart maintenance.

SmartView uses AR technology via the Metaio SDK to identify and track real-world objects and to augment the view of the world that it feeds to the user with contextual information. It is normally used with a tablet, but it was successfully experimented with smartphones and smartglasses. The technician involved in maintenance activities at a specific gas meter is driven to the place and uses a tablet to picture the meter. Contextual information immediately appears on the screen of the tablet to help the technician in performing the maintenance activities. Such contextual information include, as needed, commercial information about the contract and the service usage. Moreover, the technician can perform actions on the meter directly from the tablet. The technician can activate, deactivate, reset or set up the network connection of the meter. Moreover, the technician can read the power of signals upstream and downstream, as shown in Fig. 4a. Finally, Fig. 4b and Fig. 4c show that the technician can use SmartView to visualize the geolocalized assets of the capillary network, which involve antennas, repeaters, and gas meters.



(a) (b) (c)

Fig. 4. View of (a) the contextual information; (b) the concentrator node; (c) the assets.

4 Conclusions

Today we live in a world where the push towards digital life come both from the top, i.e., from institutions, and from the bottom, i.e., from social habits and from the market. Cities now tend to become smart, to become territories where the connectivity becomes dense, thus favoring the digital life of citizens. In such a scenario, the research which supports the creation of innovative capillary networks is of paramount importance because it is one of the primary enablers of the desired connectivity. In the long term, such decentralized networks would cause serious maintenance issues that would require maintenance to become smart. Above smart maintenance, the decentralized nature of capillary networks would call for a decentralized approach to maintenance, and social smart maintenance would become essential to support the services offered in smart cities.

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