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# Situation awareness and computational intelligence in opportunistic networks to support the data transmission of urban sensing applications

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ABSTRACT

Smart cities can be seen as large-scale Cyber-Physical Systems with sensors monitoring cyber and physical indicators and with actuators dynamically changing the complex urban environment in some way. In this context, urban sensing is a new paradigm that exploits human-carried or vehicle-mounted sensors to ubiquitously collect data to provide a holistic view of the city. A challenge in this scenario is the transmission of sensed data in situations where the networking infrastructure is intermittent or unavailable. This paper outlines our research into an engine that uses opportunistic networks to support the data transmission of urban sensing applications. It applies situation awareness and computational intelligence approaches to perform routing, adaptation, and decision-making procedures. We carried out simulations within a simulated environment that showed our engine had 12% less overhead than other compared approaches.

## 1. Introduction

According to [1], the physical world is becoming more and more saturated with the presence of a vast number of mobile devices. The integration of smart objects such as mobile and embedded computing devices with people and physical environments, which are typically tied by a communication infrastructure, inspired the development of the concept of cyber-physical systems (CPS). The concept of CPS encompasses systems ranging from a single smart house to an entire smart city. Smart cities are large-scale CPS with sensors monitoring cyber and physical indicators and with actuators dynamically changing the complex urban environment in some way [2]. Therefore, a key feature of smart cities is sensing of different aspects of the city in order to provide citizens with new services and improve their quality of life [3]. In order to facilitate this data collection, urban sensing applications are emerging as a promising way to “feel the pulse” of the city.

One challenge to implementing urban sensing applications is the transmission of sensed data using poor wireless infrastructures available in large-scale urban settings (i.e. with low coverage for the huge number of devices spread throughout the environment, low bandwidth available, wireless shadowing, frequent disconnections, etc.). Authors in [1,4,5] suggested that opportunistic networks could overcome a lack of connectivity in smart cities and, consequently, could be applied to support data transmission of CPS. In an opportunistic network, direct, physical contacts between nodes are opportunistically exploited to recognise and disseminate relevant information toward potentially interested nodes, without the need of centralised infrastructures or precomputed paths from source to destination [1].

In this paper, we propose an engine based on the opportunistic network paradigm to transmit data of urban sensing applications in scenarios where the networking infrastructure is intermittent or unavailable. The main differential of such engine is the application of situation awareness in conjunction with computational intelligence approaches to transmit data, perform routing, make adaptations and carry out decision-making. Furthermore, the engine will be used to underlie the opportunistic communication in Sensing module of our ubiquitous service-oriented architecture for urban sensing, UrboSenti [6].

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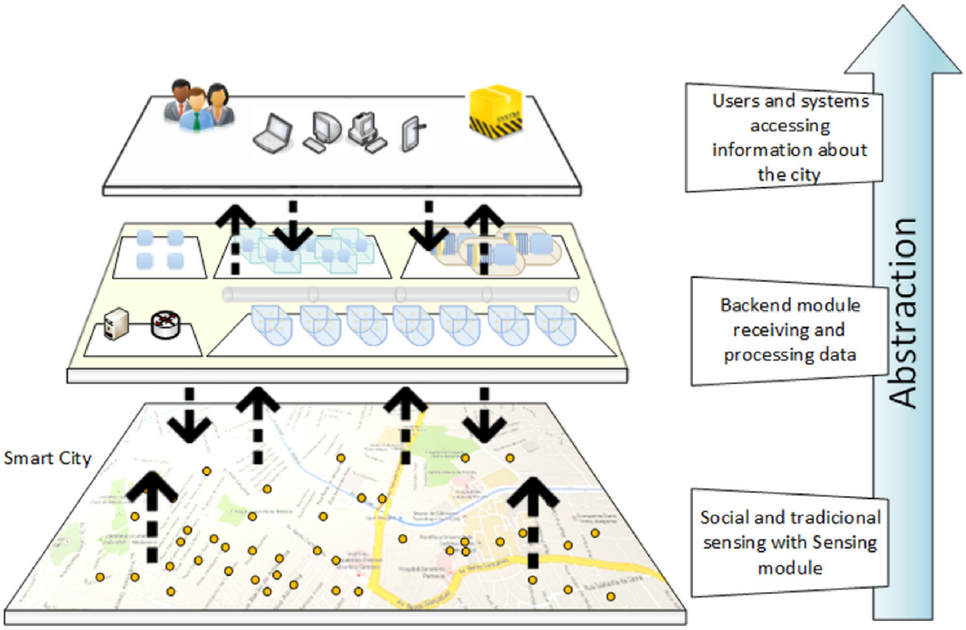

**Fig. 1.** High-level view of UrboSenti.

It is our understanding that this is the first paper to adopt this kind of approach to smart cities with a focus on urban sensing applications. Additionally, the results of this study indicate areas in need of further research to be carried out in this area.

The rest of this paper is structured as follows. The next section describes the motivational scenario and raises some key issues about current computational developments. Section 3 provides a brief outline of some background concepts and related works. Section 4 describes the proposed architecture. Section 5 describes our experiments and analyses the results, and, finally, in Section 6 some conclusions are drawn and recommendations made for future research.

## 2. Problem scenario

Our research has been designed to address the problem-scenario of a smart city where several data sources are being used for sensing. Human-carried, fixed or vehicle-mounted sensors are utilized to obtain information about transit maps, air quality, noise levels, temperature, $CO_2$ concentration, etc. Moreover, data from social networks together with sensor data are crucial to understand the behavioural patterns of the city and to provide a holistic view of it.

Our Ubiquitous Service-Oriented Architecture for Urban Sensing (UrboSenti) is designed to collect, analyse, and provide feedback on sensed data obtained from several sources scattered around the city. The main purpose of UrboSenti is to provide support for the overall task of urban sensing. A high-level view of UrboSenti is depicted in Fig. 1.

Fig. 1 shows the division of UrboSenti into two key modules: the Backend module and Sensing module. Backend module operates in a data center infrastructure and, in short, is responsible for receiving sensed data, processing it and giving feedback to the public and other systems. Sensing module is responsible for urban sensing and encompasses activities involving intentional and non-intentional sensing. It operates in mobile devices (e.g. mobile phones, embedded systems in vehicles, etc.) and in fixed sensors scattered around the city. Vehicles and fixed sensors run a lightweight version of Sensing module that collects data without user interaction. In mobile phones, this module operates as an application that permits the users to report some events in the city or be configured to acquire data without user interaction when some threshold is triggered.

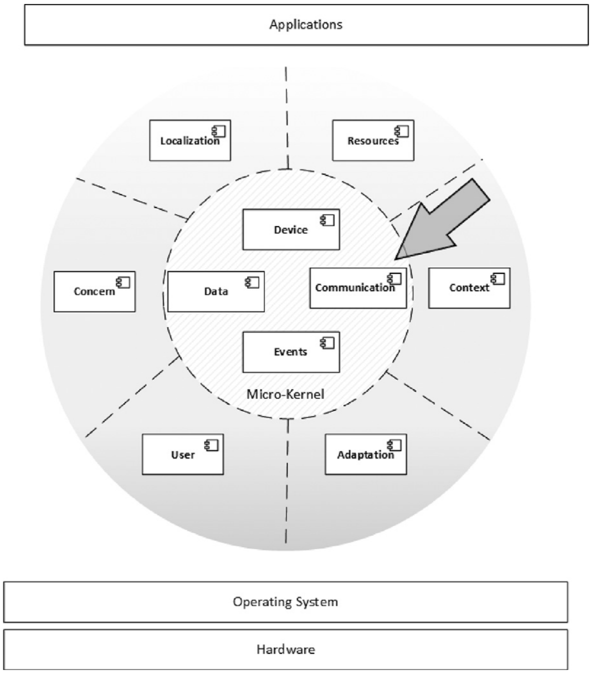

**Fig. 2.** Communication component highlighted in figure.

In both cases (with mobile and fixed devices), Sensing module has a microkernel with a set of components that can be plugged in “on demand” and are responsible for its essential features. These functions include Communication component (highlighted in Fig. 2) which is responsible for the management of all communication tasks.

The Communication component transmits sensed data using opportunistic networks paradigm when direct connection to the Internet is unavailable. In such approach, the contacts between nodes are used for data forwarding. The contacted node acts as

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