Chapter 22
Wireless Access Networks for Smart Cities

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ABSTRACT

Smart cities are envisioned to enable a vast amount of services in urban environments, so as to improve mobility, health, resource management, and, generally speaking, citizens' quality of life. Most of these services rely on pervasive, seamless and real-time access to information by users on the move, as well as on continuous exchanges of data among millions of devices deployed throughout the urban surface. It is thus clear that communication networks will be the key to enabling smart city solutions, by providing their core support infrastructure. In particular, wireless technologies will represent the main tool leveraged by such an infrastructure, as they allow device mobility and do not have the deployment constraints of wired architectures. In this Chapter, we present different wireless access networks intended to empower future smart cities, and discuss their features, complementarity and interoperability.

INTRODUCTION

Since 2009, more than half of the world's population now lives in urban areas, a proportion that exceeds 75% in developed countries and will grow to 60% worldwide by 2030 (United Nations, 2012). The rapid rise of cities yields new societal challenges with strong scientific and technological implications. As the population density starts to exceed 5.000 inhabitants per km^2, all type of living resources face a dramatic growth in demand. This applies to natural goods, such as water or gas, as well as to infrastructures, such as transportation systems, energy grids and telecommunication networks. The problem is the availability

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of such resources will not increase at the same rate as their demand, as testified by recent forecasts on sustainable development (United Nations, 2013), on road capacity and energy distribution (International Energy Agency, 2012), and on global mobile data traffic (Cisco, 2013).

The answer to the needs of mass urbanization lies then in the way the resources at our disposal are managed, and Information and Communication Technologies (ICT) are expected to play a key role in that process. The complete list of use cases for ICT in future smart cities is vast and varied, with a large number of applications that promise to have a significant impact on the efficient management of urban resources in just a few years from now. In fact, most such applications strongly rely on communication. The mobility and pervasiveness of the devices participating in the process commend that data transfers – at least those including end users – are mainly wireless. However, the nature of network access (by hundreds of thousands of autonomous or mobile devices) and the type of traffic generated (from small-size periodic data to high-definition video streaming) define new usages over large (i.e. metropolitan) scales, which cannot be accommodated solely via the traditional communication infrastructure. This makes the case for original networking solutions that can efficiently cope with the future communication demands of smart cities. On the one hand, there is the necessity to enhance the existing cellular infrastructure, especially in terms of radio access. Although connection speeds are expected to augment 7-fold by 2017 (due partly to the additional capacity provided by heterogeneous deployments, as well as to traffic offloading via femtocells and Wi-Fi), this will not suffice to manage the overall 13-fold increase in mobile data traffic by the same date (Cisco, 2013). On the other hand, short-range wireless technologies, such as Wi-Fi, DSRC, and Zigbee will empower ubiquitous meshed architectures, based on the M2M paradigm and specifically designed to manage the load offered by smart city services.

As a result, there is a clear need for innovative communication network models in the wireless last mile, i.e. that bridging end terminals – be they autonomous devices or mobile appliances under the control of users – to the wired network. In fact, the network paradigms envisioned to enable smart cities are not far from those studied by the research community over the last decade. One can find glimpses of the vision that accompanied studies on wireless sensor networks, mesh networks, vehicular networks, and ad hoc networks in general. However, there is more to smart city communication infrastructure than the direct implementation of state-of-the-art protocols proposed for the aforementioned wireless networks.

In this Chapter, we present wireless last-mile communication technologies for upcoming smart cities. The *"Background"* section presents the technologies that are currently employed to provide wireless access to users and devices. Such technologies, falling into the two wide categories of cellular and wireless local-area networks, have been dominating the market for over a decade: the presentation of their architecture and major features represents the natural starting point for our treatise. The *"Emerging wireless access technologies"* section presents a wide range of diverse solutions that are gaining momentum nowadays in the context of ICT for urban environments. Our discussion includes both direct evolutions of the cellular and wireless local area network paradigms as well as innovative and disruptive solutions, based on communication to, from and among sensors, vehicles and mobile terminals. The section provides a comprehensive overview of the underlying technologies that may contribute to the overall ICT architecture in upcoming smart cities. The *"Future research directions"* section outlines how the different technologies presented before – each dedicated to a specific need in terms of the smart city wireless communication infrastructure, and typically regarded in isolation – need ultimately to coexist. We thus introduce a unifying paradigm for wireless technologies in smart cities, under the term of *capillary networking*. We discuss future research challenges arising from such a holistic viewpoint on