Chapter 35
Cognitive Radio Techniques for M2M Environments

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ABSTRACT
Machine to Machine (M2M) communications have been recently introduced as a viable paradigm for allowing low cost and efficient communications among devices mainly in an autonomous manner. Even if M2M protocols need dedicated resources, a new paradigm, called Cognitive M2M (CM2M) communications, has been recently considered exploiting cognitive/opportunistic radio communications. After having introduced the problem of applying cognitive techniques in M2M scenarios, the authors focus their attention on the Medium Access Control (MAC) protocols for CM2M scenarios, with a particular attention on the OFDMA-based primary systems. Among other approaches, the authors focus on a data-aided approach for the access of the secondary devices aiming to reduce interference toward the primary system.

INTRODUCTION
Nowadays the wireless networks frequency assignment is regulated by a fixed policy implemented by governmental agencies. Although the fixed spectrum assignment allows an easier deployment for large scale communication systems, the limited available spectrum and the inefficiency in the spectrum usage necessitate a new communication paradigm to allow a dynamic access to the spectrum.

The key enabling technology for next generation networks is the cognitive radio (Mitola III & Maguire, 1999) (Akyildiz, Lee, Vuran, & Mohanty, 2006). It provides the capability to use or share the spectrum in an opportunistic way. The cognitive radio technology is based on two main characteristics:
cognitive capability and reconfigurability. Cognitive capability refers to the ability of sensing the radio environment in order to identify those portions of the spectrum that are unused at a specific time or location. Reconfigurability enables the radio to be dynamically adapted to the radio environment. More specifically, the cognitive radio can be designed to transmit and receive on a variety of frequencies and to use different transmission access technologies supported by its hardware design.

A cognitive network environment is composed by at least two network infrastructures: one primary network with a fixed allocation in terms of spectrum resources and a secondary network that is the effective cognitive network, aiming to exploit the unused portion of the spectrum of the primary network. In a very general case we can refer to environments where multiple independent secondary networks co-exist; however, in the following, we will refer to the most common case with one secondary network.

Once a cognitive radio supports the capability to select the available spectrum, the next challenge is to make the network protocols adaptive to it. Hence, new functions are required in a next generation network to support this adaptivity.

On the other hand, Machine to Machine (M2M) is a recently introduced network paradigm where several nodes are characterized by low data rate information exchange, short messages, and low priority communications. Typical M2M nodes are metering devices, sensors, and actuators. M2M communications are not focused on a specific communication system, while they aim to consider a scenario where multiple nodes needs to communicate among them. The main characteristics of M2M communications is that there are lots of nodes sending small amount of data. The main challenge when trying to address M2M communication is that, due to the high number of nodes and access requests to the network, a network congestion could occur. These characteristics, usually pursued in an autonomous manner (i.e., without any human intervention), can be made compliant with a cognitive radio environment; indeed, the exploitation of cognitive techniques for setting up M2M communications is a promising trend (Zhang, et al., 2012). A cognitive approach can lead to the definition of a scenario where M2M nodes are constrained to send data in specific bands and time intervals reducing the congestion issues. The Cognitive M2M scenario is thus characterized by the presence of multiple nodes that communicate among them by creating an underlay network with respect to the already deployed Wide Area Networks (i.e., the primary networks).

Differently from classical M2M approaches, in a cognitive M2M scenario, the devices can communicate only in an opportunistic way by exploiting the unused resources of a pre-existing (i.e., the primary) network infrastructure. This requires that the M2M devices need to be capable of at least two actions: discover the unused frequency resources and coordinate among them in order to decrease the negative effect of the multiple access of such of high number of devices. The M2M networks are characterized by an intermittent traffic. Moreover, the M2M devices need to reduce the latency of the access to the network. This imposes some constraints in the design of the cognitive access scheme to be used by the M2M network devices.

The Cognitive M2M scenario is characterized by the presence of two different communication networks that coexist in an almost transparent way, avoiding interference among them and with low performance degradation, by exploiting the cognitive approach. In particular, the primary is the network that pre-exist with respect to the cognitive application. Hence, we assume that it is a wide area network with lower adaptation capabilities. On the other hand, the secondary network (i.e., the M2M network) works in a cognitive way. Its main aim is to exploit the spectrum holes in the communication bandwidth