Spectrum Sharing Strategies for Machine Type Communication in Cognitive Networks

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***Abstract*— In this work we investigate spectrum sensing strategies for enabling machine-to-machine applications in broadband communication systems. Our studies are carried out in two fronts: (i) experimental testbed using a dedicated software based on proprietary application programming interface for firmware spectrum analyzer; and (ii) computational implementations by means of the Monte Carlo approach. Our results show that cognitive radio effectively enables opportunistic spectrum access between primary and secondary users. In fact, we observed a gain about 10 dB when comparing our best spectrum sharing strategy against the reference (non cognitive radio) deployment scenario.**

***Keywords*— MTC, M2M, IEEE 802.11, cognitive radio, self-organization, spectrum sensing.**

I. Introduction

Machine Type Communication (MTC) has been introduced in release 10 of 3rd Generation Partnership Project (3GPP) specifications so as to enable machine to machine communication over the air interface, while sharing not only data information but spectrum resources with cellular systems [1]. MTC is a key technology for the emerging Internet of Things (IoT) providing the means to deploy autonomous networks such as smart houses, smart factories and networked cars. Such wireless personal area networks rely on short range communication technologies, for example Bluetooth, ZigBee and UWB, and coexist with Wi-Fi deployments [2].

Moreover, the 5th generation of communication networks will incorporate a multitude of services and applications. The upcoming networks will be essentially heterogeneous and will need to share all the available resources, namely meager spectrum resources. Besides, the cognitive radio identifies which channels are available in certain time and location and selects the best radio parameters to be adopted, considering the best use of spectrum and avoiding interference to the licensed user. In this context, self organization plays a determinant role to guarantee autonomous and seamless operation, while improving utilization of RF spectrum [3]. As a result, secondary systems can effectively share (underused) spectrum bands with primary users in a dynamic manner (space and time) [4].

Herein, we consider ad hoc networks of MTC devices such as networked vehicles, home appliances, surveillance devices, actuators and sensors. These devices need to share the available spectrum with minimum or no human intervention. Therefore, we establish a basic framework to model, analyze and evaluate the impact of spectrum sharing, if it improves the spectrum usage and if it continues effective in large scale deployments. To do that, we implemented a system-level simulator based on the Monte Carlo approach, as well as a hardware testbed using USB-SA44B and Microchip Explorer 16 modules [5], [6].

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II. Experimental Testbed and System model

We use radio modules based on the IEEE 802.11 standard with proprietary firmware of Signal Hound USB-SA44B spectrum analyzer [5] for sensing and sampling the broadband, and the Microchip Explorer 16 Development Board [6] with Wi-Fi module RN-171 Pictail [7] to simulate the dynamics between primary and secondary users. Then, two spectrum sharing strategies [3] were implemented in this testbed and their performance evaluated by means of system-level simulations.

We use the Monte Carlo approach to develop a system-level simulator and implement the aforesaid spectrum sensing and sharing strategies. Terminals are randomly scattered over the network area following a Poisson distribution and their received power incorporates path loss and shadowing effects. An arbitrary interferer disrupts the communication of the tagged receiver with a component given by $P_r(d) = P_t x$, where P_t yields this interferer transmitted power, d is the separation distance from its position to the tagged receiver, and x yields the corresponding shadowing. We evaluate the system performance using the signal to interference ratio (SIR) and the respective outage probability with respect to the primary user.

III. Spectrum Sensing and Sharing Strategies

Secondary users share the primary user spectrum throughout two strategies: (i) change to another carrier (CAC); and (ii) incremental power control (IPC).

In the former, after secondary users detect the primary they change to another carrier. As a result the secondary users inside detection region do not contribute to the aggregate interference. In the latter, secondary users inside the detection region continue to transmit on the same carrier, though at lower power level. We use a discrete power control, based on experimental testbed results, that decreases the transmission power with fixed steps.

IV. Performance Evaluation

In this section, we evaluate how the spectrum sharing strategies perform in terms of the outage probability of the user of interest. To do that, we carry system-level simulations so as to evaluate how the spectrum sharing strategies perform under distinct propagation conditions and network configuration which characterize our evaluation scenario. The main configuration parameters and their respectively values are: path loss exponent, α equal to 3, log-normal shadowing standard deviation σ of 6 dB (desired) and 8 dB (interferer), transmission power equal to 10 dBm and PC step equal to -6 dB.

A. *Numerical Results*

Fig. 1 shows the data collected from the spectrum analyzer for a particular case where primary and secondary users transmit simultaneously. Starting at 500 ms, the secondary user decreases its power level, by a predefined fixed step φ so as to avoid interfering with the licensed user, which maintains its transmit power.

Fig. 2 presents the SIR of the primary user for the aforesaid strategies, namely CAC and IPC. As it can be seen, CAC outperforms the IPC strategy: in the former, the secondary users change carrier, while in the latter, detecting secondary users continue to interfere with the primary transmission though with lower power (PC step). We observed a gain about 10 dB for the CAC strategy, whereas the IPC provides 8 dB only. It is worth mentioning that in the IPC the secondary users remain on the same carrier.

V. Conclusions and Perspectives

Based on cognitive radio concepts, we developed solutions, *i.e.* CAC and IPC as described in Section III, to improve the spectrum usage in M2M deployments scenarios. Two strategies were investigated using computational and hardware implementations. In the CAC scenario, after secondary users detect the primary, they change to another carrier. On the other hand, in the IPC, secondary users continue to transmit on the same carrier, though at lower power level. From these studies, we observed that the proposed cognitive strategies are indeed effective to share meager spectrum resources between primary and secondary users. Our testbed showed that it is even possible to exploit the underused frequency bands on a time bases (see Fig. 1) Furthermore, our simulations showed that there exist a trade off: in the CAC configuration, the primary user experiences the highest SIR levels, but secondary users need to switch to another carrier.

As perspectives, we intend to enhance our simulator by implementing more elaborated radio channel models (for example, Nakagami – m which allows LoS and NLoS scenarios). Currently, our testbed is under work so as to implement multi-hop communication, while considering the primary and secondary spectrum sharing problem. Cooperative strategies are also envisaged as promising alternative to further improve the performance of the scenarios under study.

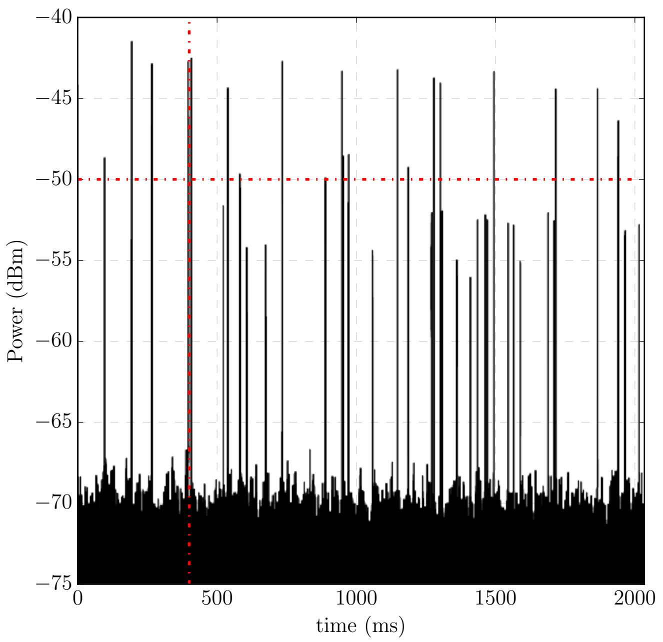

Fig. 1. Time evolution of primary and secondary transmission power levels.

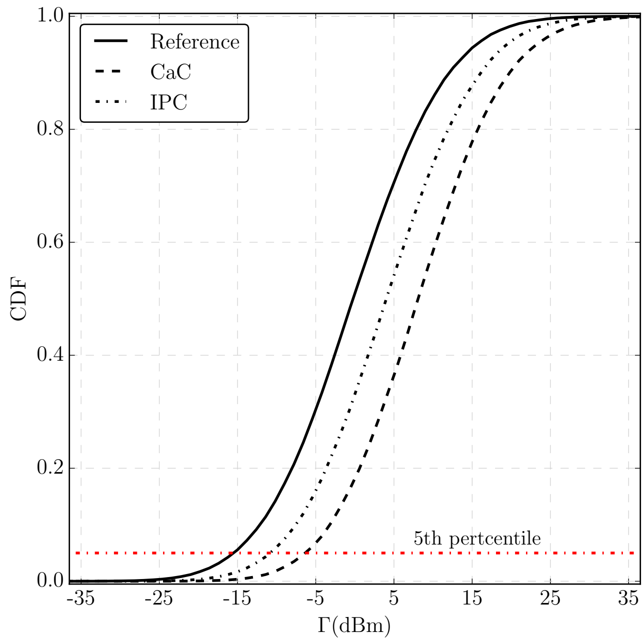

Fig. 2. SIR at the primary user for the spectrum sharing strategies.

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