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Editorial

Dynamic Spectrum Access: From the Concept to the Implementation

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We are today witnessing an explosive growth in the deployment of wireless communication services. At the same time, wireless system designers are facing the continuously increasing demand for capacity and mobility required by the new user applications. The scarcity of the radio spectrum, densely allocated by the regulators, is a major bottleneck in the development of new wireless communications systems.

However actual spectrum occupancy measurements show that the frequency band scarcity is not a result of the heavy usage of the spectrum but is rather due to the inefficient static frequency allocation pursued by the regulators.

Dynamic spectrum access, also generally referred to as cognitive radios, has been proposed as a new technology to resolve this paradox. Sparse assigned frequency bands are opened to secondary users, provided that interference generated on the primary licensee is negligible. Even if the concept constitutes a real paradigm shift, it is still unclear how the dynamic spectrum access can operate efficiently and how it can be implemented cost-effectively.

The goal of this special issue has been to solicit high-quality unpublished research papers on the spectrum sensing and access, the intelligence and learning capability, and implementation aspects of communication systems relying on dynamic spectrum access. Based on the 16 submitted manuscripts, six papers have been accepted, which will be summarized briefly in this paper.

Spectrum sensing techniques have been heavily discussed and treated in the literature. Their performance in a noisy environment is measured in terms of the probability of false alarm and the probability of miss detection.

A radiometer (also called energy detector) can be used to detect completely unknown signals in a frequency band. Unfortunately when the primary user bandwidth is much smaller than the cognitive radio spectrum sensing frequency range, scanning a wide range of frequencies can be time consuming. In their paper, S. Kandeepan et al. propose to make use of the primary user time-domain spectral occupancy statistics to enhance the performance of the wideband energy detector. They assume that the primary user spectral occupancy can be modeled with a Poisson law and derive analytically the minimum required sensing time for the cognitive radio to detect the primary user.

The energy detector is historically the oldest and simplest detector, and it achieves good performance when the signal-to-noise ratio is strong enough. Unfortunately, since it is based on the estimation of the in-band noise power spectral density, it is affected by the noise level uncertainty due to measurement errors or a changing environment, especially at low signal-to-noise ratio. Cyclic feature detectors rely on the hidden periodicities such as the carrier frequency, the symbol rate, or the chip rate hidden in man-made communications signals, that can be extracted based on nonlinear operations of the nth order (order equal to or larger than 2). Cyclostationarity detectors perform better than energy detectors in low signal-to-noise ratio environments.

In their paper, D. Noguet et al. analyze the architectural trade-offs that the cognitive radio system designer has to face when implementing a second-order cyclostationarity detector in two dedicated scenarios: the secondary ISM band usage assuming that the primary system is an IEEE 802.11a/g wireless local area network, the secondary TV band usage assuming that the primary system is a DVB-T broadcast system. In the first case, low-latency detection is required, while low-signal-to-noise-ratio detection is required in the second case.

Higher-order (order larger than 2) cyclostationarity detectors are generally more complex, and since the variance of the estimators increases when the order rises, most research results concern second-order detectors. Nevertheless, J. Renard et al. demonstrate in their paper that it is possible to derive a fourth-order detector that bears comparable performances to second-order ones to detect linearly modulated signals.

Conventionally the physical resources are defined in the time/frequency plan. However when antenna arrays are deployed on the communicating terminals, the definition of the physical resources can be extended to the spatial dimension.

J.-M. Dricot et al. propose to further exploit the polarimetric dimension to discriminate the primary and secondary communications. They establish a theoretical model of the interference in dual-polarized networks and derive a closed-form expression of the primary link probability of outage due to interference. They theoretically prove that polarimetric diversity can increase the transmission rates for secondary terminals while, at the same time, can significantly reduce the primary exclusive region.

Once the knowledge about the spectrum availability has been acquired through spectrum sensing techniques, the access to the frequency resources must be managed. The main issue comes from the dynamism in the resource availability which cannot ensure the viability of the secondary network communication.

Blocking the request of a new secondary user session can be employed as a strategy to reduce the number of forcedly terminated secondary user sessions and the interference caused to primary users. J. Martinez-Bauset et al. evaluate how the fractional guard channel reservation scheme, proposed initially for cellular networks, can be used to give priority to spectrum hand-overs over new arrivals. They propose an adaptive admission control scheme able to limit simultaneously the forced termination probability of secondary users and the probability of interference on the primary network.

Resource allocation among different communication links is finally another important issue. In their paper, G. He et al. investigate the power allocation in the downlink of small-cell networks, recognized as an effective and low-cost architecture to provide wireless data access to mobile users. Since the base stations of small-cell networks may belong to different service providers eventually organized in coalitions to maximize their own revenues, there is a critical trade-off between cooperation and competition among the providers. The paper proposes to rely on the game theory as an efficient framework to develop decentralized and/or distributed algorithms for resource allocation. They model the small cells of different operators as players who adaptively and rationally choose their power levels.

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