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Wireless distributed computing for cyclostationary feature detection

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Abstract
Recently, wireless distributed computing (WDC) concept has emerged promising manifolds improvements to current wireless technologies. Despite the various expected benefits of this concept, significant drawbacks were addressed in the open literature. One of WDC key challenges is the impact of wireless channel quality on the load of distributed computations. Therefore, this research investigates the wireless channel impact on WDC performance when the latter is applied to spectrum sensing in cognitive radio (CR) technology. However, a trade-off is found between accuracy and computational complexity in spectrum sensing approaches. Increasing these approaches accuracy is accompanied by an increase in computational complexity. This results in greater power consumption and processing time. A novel WDC scheme for cyclostationary feature detection spectrum sensing approach is proposed in this paper and thoroughly investigated. The benefits of the proposed scheme are firstly presented. Then, the impact of the wireless channel of the proposed scheme is addressed considering two scenarios. In the first scenario, workload matrices are distributed over the wireless channel. Then, a fusion center combines these matrices in order to make a decision. Meanwhile, in the

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second scenario, local decisions are made by CRs, then, only a binary flag is sent to the fusion center.

1. Introduction

In the future wireless technology standard, local computing, where a single node performs all workload computations, is expected to face challenges in satisfying the required quality of service (QoS) levels such as power consumption or latency. Furthermore, the required high speed for computations, arrives at the saturation point of CPUs. In addition to the ability of new communication devices to collect and analyze data are the main reasons to turn to distributed computing [1-4].

According to [4], *"Distributed computing studies the models architectures and algorithms used for building and managing distributed systems."* Distributed system can be defined as the system where cooperating nodes communicate and coordinate their actions by passing messages [5]. The medium to communicate or coordinate actions is either wired or wireless links. Many research works in the open literature have explored wired distributed computing. However, wireless distributed computing (WDC) is a new concept that still faces enormous challenges. These WDC challenges are discussed in [3] and categorized mainly into three groups. Firstly, communication subsystem design which considers the challenge of channel robustness. This uncertainty of the wireless channel leads to a high bit error rate and random delay [6]. Thus, efficient methods to gather, relay or broadcast and buffer the distributed tasks between the cooperating nodes maybe required to overcome data loss and delay. Secondly, WDC networks are expected to face synchronization challenge. Synchronization is essential for heterogeneous applications in order to synchronize processing and communication operations between the cooperating cognitive radios (CR). Thirdly, network control challenges such as leaders election, topology control, i.e. the selection of the processing nodes based on the link quality, and workload allocation or tasks allocation that ensures efficient distribution of tasks among cooperating nodes.

Herein, the concept of WDC is employed to overcome the increasing computational complexity of an accurate spectrum sensing approach. Moreover, this research is motivated to investigate WDC with spectrum sensing due to the various benefits of WDC. This includes energy savings by reducing the consumed processing power per cooperating CR as well as distributing the workload efficiently to fit the requirements of the cooperating CRs by segmenting the main task to subtasks and allocating the tasks onto the best suitable processor. Furthermore, WDC reduces the processing time per cooperating CR and enable computing complex tasks that cannot be completed by local computing.

Amongst the common spectrum sensing approaches, i.e. matched filtering, cyclostationary feature detector and energy detection, WDC concept is applied to cyclostationary feature detector due to it's high level of accuracy but at the cost of computational complexity as well as it has been recommended by IEEE 802.22 standard [7]. WDC, however, is not a benefit in case of the energy detector spectrum sensing technique due to it's design simplicity and low computational complexity. In addition, WDC cannot be applied to match filtering spectrum sensing approach due to the demand for perfect knowledge of PU signals [8]. New research work for cyclostationary feature detector claimed that it is possible to detect the PU's signal without the relevant information of the signal attributes [9]. Another research has proposed detection and classification method for cyclostationarity detector without any prior knowledge of the transmitting signal except rough information on signal bandwidth [10]. Moreover, in order to facilitate obtaining the information to detect and analyze the signal cyclostationarity, signatures might be intentionally embedded in the PU signal as proposed in [11,12].

To the best of our knowledge, the first research that investigated applying WDC within spectrum sensing is [13] where the mathematical viability of applying WDC with strip spectral correlation algorithm (SSCA) is presented. In addition, the channel impact is highlighted using only one scenario where the workload of SSCA is distributed wirelessly between processing CRs.

The contributions of this research are:

a. Extension of the novel mathematical model to verify the viability of applying WDC with FFT time smoothing algorithms, i.e. FFT accumulation method (FAM) and SSCA.
b. Highlights the benefits of applying WDC with FFT time smoothing algorithms.
c. Investigates the channel impact on the proposed WDC with FFT time smoothing algorithms in case of transmitting workload matrices through the wireless channel. Even though, in the first scenario, the channel effect is highlighted in [13], it did not propose any solutions to reduce the channel degradation. Herein, the channel limitation is reduced by utilizing more realistic wireless links employing channel encoders.
d. Proposes novel scheme which transmits a binary flag instead of payload matrices.
e. Evaluates the performance of the proposed novel schemes by computing probability of detection P_D, probability of error P_E and ROC.

The rest of this research paper is organized as follows. Section 2 presents the proposed scheme of WDC with FFT time smoothing algorithms. Then, Section 3 justifies the proposed scheme mathematically. Later, Section 4 tests the performance of the proposed schemes against the conventional algorithms. Finally, the conclusion and recommendations for future work are drawn in Section 5.