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Low complexity cell search scheme for LTE and LTE-advanced mobile technologies ☆

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ABSTRACT

In this paper, we propose a novel method to accomplish the cell search procedure in Long Term Evolution (LTE) and LTE-Advanced (LTE-A) mobile systems. By means of detecting the cyclic prefix (CP) configuration in the time domain, it is possible to reduce both the inter symbolic interference (ISI) and the inter carrier interference (ICI) prior to the detection of dedicated synchronization signals (SS) involved in cell search procedure. Thus, the SS detection is efficiently performed in the frequency domain while the implementation complexity is reduced, since the proposed architecture minimizes the necessity of matched filters. Results show that cell search procedure is successfully accomplished while keeping the cell search time in the range of 3–5 radio frames.

1. Introduction

In the recent years, mobile and wireless communications are evolving towards a common objective: providing broadband capabilities to mobile users. On the roadmap to the convergence of wireless networks that is expected for the 4th generation (4G) of mobile communications, a promising family of technologies is being developed by the 3rd Generation Partnership Project (3GPP): the 3GPP Long Term Evolution (LTE), and its evolution LTE-Advanced.

LTE technology [1–3], is targeted to provide 100 Mbps in the downlink (DL) using orthogonal frequency division multiple access (OFDMA), and 50 Mbps in the uplink (UL) using single-carrier frequency division multiple access (SC-FDMA), low delays in both the user and control planes, bandwidth scalability from 1.4 up to 20 MHz, and supported terminal mobility up to 350 km/h. LTE specification was frozen by the end of 2008, and the first commercial LTE devices have recently been presented at CES 2011.

The evolution of LTE, referred to as LTE-advanced (LTE-A), is expected to allow enhanced peak data rates up to 1 Gbps for advanced services and applications. In LTE-A, the system capacity is increased through different techniques such as carrier aggregation, coordinated transmission, relaying and advanced multi-antenna configurations [4].

In a cellular system, the first step for a mobile user equipment (UE) is to perform cell search procedure, prior to any UL initial transmission. In the case of LTE and LTE-A [1], there exist dedicated physical signals in the DL frame to facilitate this process: Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS). The detection of PSS is crucial for the acquisition of initial radio frame timing. Once this step is managed, SSS identification is easily carried out, thus solving the radio timing for the DL transmission.

During the development of LTE specification, many authors tackled the design of synchronization signals (SS) from different points of view: In [5], it was illustrated the design of synchronization sequences for LTE DL with the aim of optimizing the cell search time. In this line, in [6] general aspects about synchronization channel design as well as the evaluation of

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different solutions for cell search were considered. Moreover, [7] proposed a cell search scheme base on frequency-domain sequence hopping of synchronization channel symbols. Some mechanisms for the improvement of detection performance in neighboring cell search were introduced in [8,9].

Less references are available when considering the definitive SS structure, according to the final LTE specification: In [10], an overview of synchronization aspects and cell search in LTE is provided. Recently, [11] makes use of additional information apart from the synchronization signals (i.e. the cyclic prefix (CP) an cell-specific reference signals) to improve the cell search detection performance. However, it is assumed that the CP size is known by the UE and performance in terms of cell search time is neglected.

In this paper, a low complexity method for the cell search procedure in LTE downlink is presented. Two main contributions are proposed: First, we perform a blind detection of the CP size prior to the SS detection, which facilitates a coarse time and frequency synchronization of the received signal. Thus, the effect of inter symbolic interference (ISI) and inter carrier interference (ICI) is reduced. Secondly, the SS detection is efficiently performed in the frequency domain: only dot-products are required instead of matched filters for PSS detection, and 1-bit processing and two matched filters are used for SSS detection. This approach allows for a complexity reduction while achieving a good detection probability and cell search time.

The remainder of this paper is organized as follows: in Section 2, synchronization signals in 3GPP LTE DL frame are presented. Section 3 is dedicated to describe the proposed mechanism for performing the cell search procedure in LTE. An statistical analysis of the average cell search time is performed in Section 4. Finally, Section 5 presents the performance results in terms of cell search time and detection probability, whereas main conclusions are exposed in Section 6.

2. Synchronization signals in 3GPP-LTE DL

Fig. 1 shows the structure of the LTE DL frame, for the case of frequency domain duplex (FDD). The radio frame length is T_{frame} = 10 ms long, and consists of 10 subframes of length $T_{subframe}$ = 1 ms. A subframe consists of two consecutive time slots, each of 0.5 ms duration. One slot can be seen as a time-frequency resource grid, composed by a set of OFDM subcarriers along several OFDM symbol intervals. The number of OFDM symbols per slot may be seven or six, depending on the cyclic prefix length (normal or extended).

Prior to an UL initial transmission or a handover procedure, cell search process is needed to be performed by the UE. As aforementioned, there exist dedicated physical signals to facilitate this process. This physical signals are allocated in two physical channels: primary synchronization channel (P-SCH) for the PSS, and secondary synchronization channel (S-SCH) for the SSS, which are time division multiplexed twice in a frame. Particularly, the P-SCH is transmitted in the last OFDM symbol in slots 0 and 10, whereas the S-SCH is mapped onto the second last OFDM symbol in slots 0 and 10. Fig. 2 shows the location of synchronization channels in the LTE DL frame, for the normal mode CP configuration.

According to [1], there exist 504 unique physical layer cell-identities in LTE, namely N_{ID}^{cell}. This set of N_{ID}^{cell} is grouped into 168 unique physical layer cell-identity groups $\left(N_{ID}^{(1)}\right)$, where each group contains three unique identities $\left(N_{ID}^{(2)}\right)$. Thus, physical layer cell-identity is univocally defined by a $N_{ID}^{(1)}$ value in the range of 0–167, and a $N_{ID}^{(2)}$ value in the range of 0–2, representing the physical layer identity within the physical layer cell-identity group. From these definitions, the physical layer cell identity is given by

$$N_{ID}^{cell} = 3N_{ID}^{(1)} + N_{ID}^{(2)}. \tag{1}$$

As defined in [1] PSS is formed from a Zadoff–Chu (ZC) polyphase sequence [12,13] $d_u[n]$ generated as:

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{N_{ZC}}} & n = 0,1,\ldots,30, \\ e^{-j\frac{\pi u(n+1)(n+2)}{N_{ZC}}} & n = 31,32,\ldots,61, \end{cases} \quad \mathrm{N_{ZC}} = 63 \tag{2}$$

where the ZC root sequence index u is within the subset {25,29,34}. This sequence is mapped onto the 72 central subcarriers (62 plus 10 guard subcarriers) around the DC carrier. Thus, they can be detected independently of the bandwidth configu-

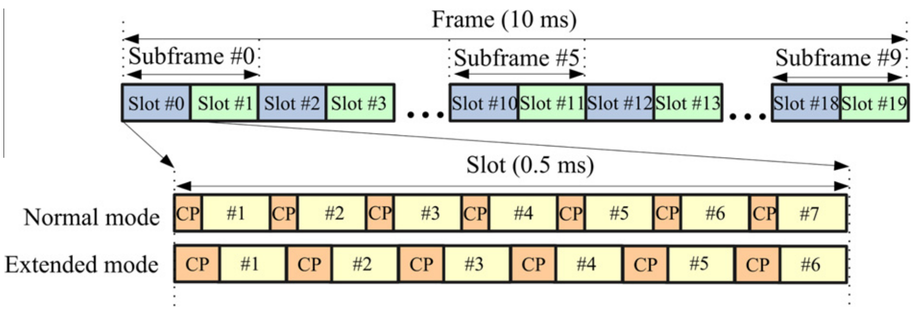

Fig. 1. Structure of LTE downlink frame.