Research on Irregular Carrier Aggregation in Complex Electromagnetic Environment

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Abstract. In order to take full advantage of the discontinuous and irregular frequency in complex electromagnetic environment, an irregular carrier aggregation method is proposed. In the proposed method, several frequency bands from 1 MHz to 20 MHz can be combined to a wideband channel, witch can transmit HD image etc. The process and the key technologies are introduced, including channelized spectrum, resource allocation, synchronization and channel estimation. Analysis shows that the proposed carrier aggregation method has effective anti-jamming ability and the spectrum resources can be utilized efficiently.

Keywords: Complex electromagnetic environment
Irregular carrier aggregation · Channelized spectrum · Resource allocation

1 Introduction

Carrier Aggregation (CA) is one of the key technologies of Long Term Evolution Advanced (LTE-A) systems, consists of distributing the information over several frequency bands to achieve a very large bandwidth. According to the CA approach, the User Equipments (UEs) can access a wider transmission bandwidth by using CA to aggregate a number of individual Component Carriers (CCs) shaping heterogeneous contiguous and non-contiguous frequency bands. In LTE-A, at most 5×20 MHz carrier aggregation is adopted.

There are three methods of frequency aggregation; the first method is contiguous intraband frequency aggregation in which the information is transmitted over frequency subbands placed next to each other, within one frequency band. The second method consists of transmitting information over separated subbands within a frequency band, which is called noncontiguous intraband frequency aggregation. In the last method, the information is transmitted over different subbands placed at different bands [1, 2].

In complex electromagnetic environment, there are not 20 MHz or 5 MHz frequency spectrum without interference. The available frequency spectrum in frequency band is discontinuous and irregular. The CA methods for several regular frequency band in LTE-A are not applicable. Cognitive Radio (CR) and Non-Contiguous Orthogonal Frequency

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Divison Mutilplex (NC-OFDM) are effective solution for this scene. NC-OFDM is a highly efficient multi-carrier modulation technology which has a good anti-jamming performance by selecting the sub-band without interference to transmit data in interference environment [3, 4]. But the frequency band of NC-OFDM is limited, such as 20 MHz or 40 MHz, and the available frequency spectrum band is distributed in one or several hundred MHz.

In order to apply the discontinuous and irregular frequency resource in wide frequency band, a new carrier aggregation method is proposed, which can combine several irregular frequency band distributing in 100 MHz or more.

The rest of the manuscript is organized as follows. In Sect. 2, the system model description and parameter setting are given. In Sect. 3, the proposed CA method and the research points are introduced. And Sect. 4 concludes the work.

2 Parameter Setting and Flow

The LTE is consulted in this paper, such as the sub-carrier bandwidth, synchronization and resource allocation. The sub-carrier bandwidth is 15 kHz and one resource block (RB) contains 12 sub-carrier (180 kHz). The primary synchronization signal (PSS) and the secondary synchronization signal (SSS) need to occupy 6 RBs (1.08 MHz). UEs receive the PSS and SSS to get time and frequency synchronization, and obtain the UE physical layer cell ID, the length of the Cyclic Prefix (CP) (Fig. 1).

Spectrum sensing is the first step, frequency occupancy is obtained. The available frequency spectrum distributes in 100 MHz discretely. A threshold is set and the frequency spectrum with interference lower than the given threshold is available. There are 4 available frequency band in Fig. 2.

The spectrum is periodic and the available frequency spectrum is dynamic changing. The operating bandwidth is 100 MHz, and at least 2 carriers can be converged and at least 5 MHz frequency can be used. The bandwidth of one band is at most 20 MHz.

Resource allocation is the second step, the available frequency spectrum is allocated to multi-user. The spectral efficiency and energy efficiency should be considered in this step.

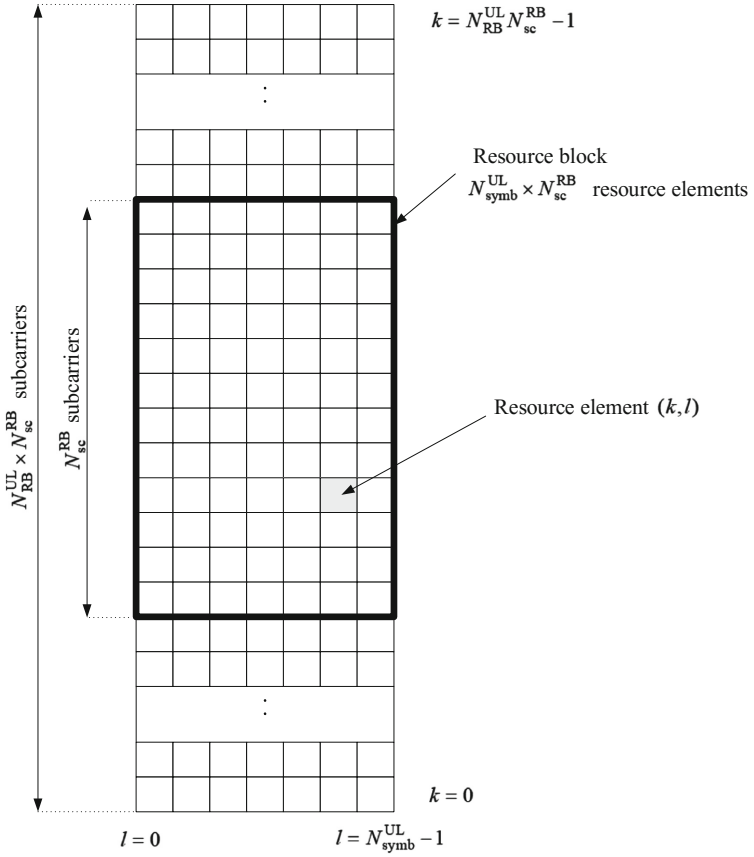

Fig. 1. The RB in LTE, which is consulted in this paper.

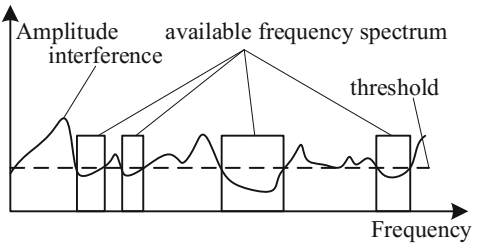

Fig. 2. There are 4 available bands where the interference is lower than the given threshold.

3 Key Technologies

3.1 Channelized Spectrum in Spectrum Sensing and Using

In spectrum sensing, the spectral resolution is related to complexity. Consult the LTE standard, 2048 points FFT is used and the spectral resolution is 15 kHz. The filter bandwidth is finite, so frequency sensing should be segmented to several 20 MHz for 100 MHz frequency band. The sensing result should be coupled together.

Because of the smallest distributable resource unit is RB in LTE, the sensing result is added up by 180 kHz (one RB). If there are more than 12 continuous RBs are usable, the spectrum is marked as usable, as in Fig. 3. The spectrum band is integer multiple for 180 kHz, which is consistent with LTE.

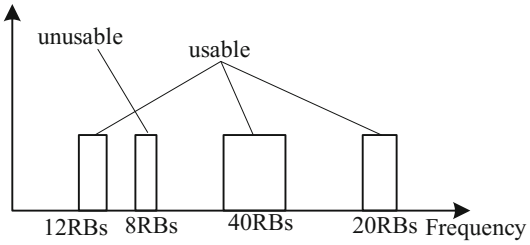

Fig. 3. Band more than 12 continuous RBs is usable.

If the available frequency spectrum is larger than 20 MHz, it should be split into several parts, and each part is at most 20 MHz.

3.2 Synchronization and Channel Estimation

Synchronization is important in communication systems and there are 2 synchronization symbols in LTE, which are PSS and SSS. The PSS, SSS and packet broadcast channel (PBCH) are all occupied 6 RBs, so the least usable band is 1.08 MHz.

The interference minimum channel is selected as the "main channel", and the PSS, SSS and the PBCH are arranged here, which is the "center frequency" such as LTE. See Fig. 4, the "center frequency" of irregular CA is in the center of the "best" channel. And in the PBCH, frequency bandwidth and center of the other channels are broadcast.

Channel estimation is different in LTE and irregular CA system, because the spectrum is discontinuous and irregular. The pilot arrangement scheme is not the same as the OFDM in LTE, see as Fig. 5. In irregular CA system, the pilot should consider the irregular band.

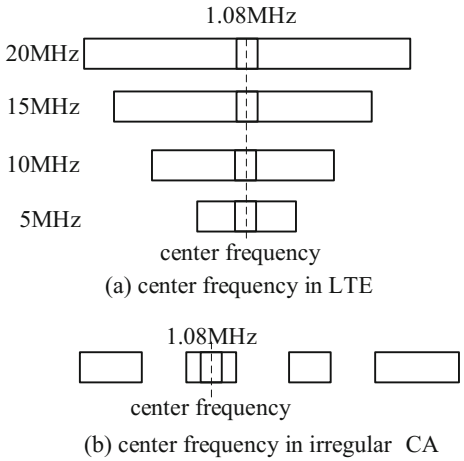

Fig. 4. The "center frequency" of irregular CA is in the center of the "best" channel.

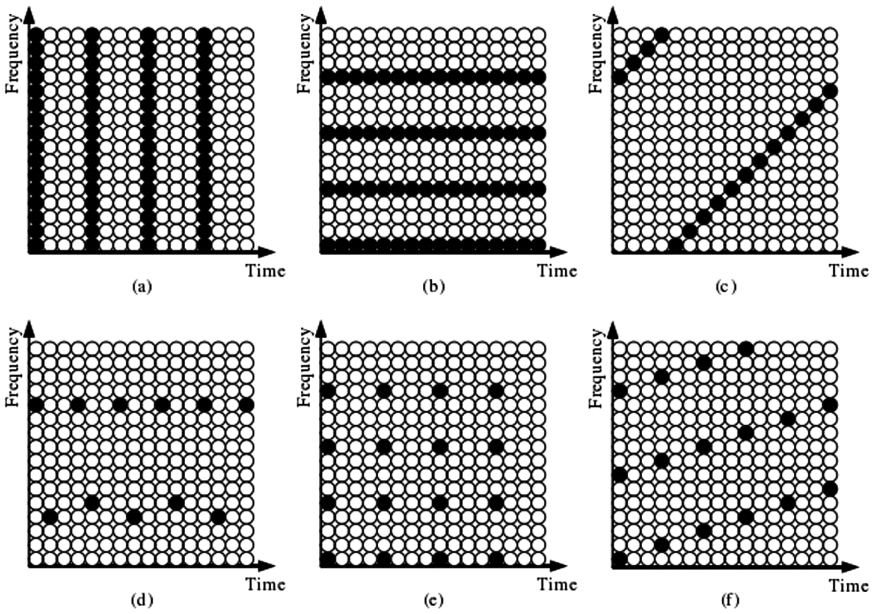

Fig. 5. The comb-type pilot, block-type pilot, equal interval pilot in OFDM

3.3 Resource Allocation

Under carrier aggregation, resource scheduling gets more complicated for the existence of multiple carriers. On the other hand, since a Quality-of-Service (QoS) protection mechanism has been adopted, the QoS-based resource scheduling has become a very important research direction [5].

Distinguish from the CA in LTE-A, in irregular CA, the resource allocation should consider UE's complexity. UE occupies as few as possible frequency band in addition to the band contains "center frequency". For each UE, it can work at least occupying 2 bands.

Fairness and throughput should be considered, each UE should retain minimum bandwidth to transmit high priority service.

Hybrid algorithm should be used and the amount of CA, Fairness and throughput are all should be considered. An evaluation function can be proposed, which is like that

$$F = a * N_{CA} + b * Throu + c * Fair. \quad (1)$$

Here, a, b and c are coefficient, N_{CA} is carrier number of one UE, Throu is throughput of the system, Fair is fairness factor.

4 Conclusion

In this paper, an irregular CA scheme is introduced in complex electromagnetic environment, when there is no continuous 5 MHz or 20 MHz spectrum. There are some differences between irregular CA and CA in LTE-A. In order to consistent with LTE, spectrum band more than 1.08 MHz can be used. NC-OFDM can be combined to irregular CA in the future, which can use narrower spectrum band, such as 180 kHz.

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