Channel Switching Operation of LTE-LAA in Unlicensed Spectrum

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Abstract—Recently, the 3rd Generation Partnership Project (3GPP) has standardized LTE-licensed assisted access (LTE-LAA) supporting LTE downlink carrier aggregation (CA) in the 5 GHz unlicensed spectrum. LTE-LAA technology allows LTE operators to freely use additional frequency resources in the 5 GHz unlicensed spectrum. Therefore, the problem of coexistence with other existing communication technologies in unlicensed spectrum has become an important issue. With listen-before-talk (LBT) mechanism, a resource sharing scheme defined in LTE-LAA, performance degradation cannot be avoided when the LTE-LAA operates on heavily interfered channels. Thus, an operation to avoid such crowded channels is required for LTE-LAA. In this paper, we consider the channel switching operation of LTE-LAA and present the experiment results of the coexistence of Wi-Fi and LTE-LAA with channel switching, based on the prototype implementation with National Instruments (NI) USRP.

I. INTRODUCTION

Over the past few decades, advances in wireless networks have had a great impact on mobile communications, and everyday things also have come into wireless networks. From small watches to automobiles, almost everything is now turning into a communication device. Accordingly, telecommunication firms and organizations are eager to seek solutions that can meet the ever-increasing demand for wireless traffic. As part of the 3rd Generation Partnership Project (3GPP) Release 13, LTE-licensed assisted access (LTE-LAA) has been standardized to support carrier aggregation (CA) of licensed spectrum and 5 GHz unlicensed spectrum [1].

With LTE-LAA technology, LTE operators are free to use additional frequency resources in the 5 GHz unlicensed spectrum. However, unlike licensed bands, where LTE operators can use frequency resources exclusively, LTE-LAA must coexist with other communication technologies that use the 5 GHz unlicensed spectrum (e.g., Wi-Fi). Therefore, how LTE-LAA coexists with other communication technologies in unlicensed spectrum is becoming increasingly important.

Basically, listen-before-talk (LBT) mechanism is defined to share frequency resources when Wi-Fi and LTE-LAA use the same frequency band [1]. In [2], Yoon et al. propose a channel occupancy time (COT) adaptation algorithm for LTE-LAA to be a more friendly neighbor to Wi-Fi in the same unlicensed band. However, even with LBT, LTE-LAA can achieve degraded performance on extremely crowded and heavily interfered channels. Thus, LTE-LAA requires an action to avoid such channels. In this paper, we consider the channel switching operation of LTE-LAA and prototype the LTE-LAA channel switching using National Instruments (NI) USRP [3].

The rest of this paper is organized as follows. Section II introduces the background of channel switching of LTE-LAA. Then in Section III, we evaluate the coexistence performance of Wi-Fi and LTE-LAA with channel switching function. Finally, we conclude the paper with future work in Section IV.

II. BACKGROUND

A. Secondary cell activation/deactivation mechanism

For the channel switching operation of LTE-LAA, LTE-LAA should be able to activate and deactivate the secondary cell (SCell). CA technology defined in the 3GPP supports the activation/deactivation mechanism of the SCell in order to reduce the UE energy consumption [4]. When an SCell is active, the UE should receive physical downlink control channel (PDCCH) and physical downlink shared channel
(PDSCH) and be able to perform channel quality indicator (CQI) measurements. On the other hand, when an SCell is deactivated, it is not necessary to receive PDCCH or PDSCH corresponding to the UE and perform CQI measurements.

The activation/deactivation mechanism consists of the LTE medium access control (MAC) control element (CE) and the deactivation timer operation as shown in Fig. 1. UE can deactivate the activated SCell either by using MAC CE or by the expiration of the deactivation timer called sCellDeactivationTimer. The sCellDeactivationTimer represents the amount of time (in units of radio frames) during UE has not received any data on the SCell, where its expiration time is configured to be from 20 ms to 1280 ms by RRC [5]. Unlike the deactivation mechanism through the sCellDeactivationTimer and MAC CE signaling, SCell activation is achieved only through the MAC CE. The MAC CE is identified by a MAC protocol data unit (PDU) subheader [6]. As shown in Fig. 2, it consists of 8 bits containing seven C-fields and one R-field which is a reserved bit set to 0. C-fields, consisted of 7 bits, represent a group of SCells which is configured for CA. A bitmap carried by the MAC CE is used to activate and deactivate SCells. A bit in the bitmap indicates activation and deactivation of the corresponding SCell when it is set to 1 and 0, respectively.

The SCell activation/deactivation mechanism is configured according to the timing as follows [1], [7]. In subframe $n$, if a UE receives a deactivation MAC CE for a SCell or the expiration of the sCellDeactivationTimer associated with the SCell, the UE should deactivate the corresponding SCell no later than subframe $(n+8)$. On the other hand, in subframe $n$, if a UE receives an activation MAC CE for a secondary cell, the UE should activate the corresponding SCell no earlier than subframe $(n+8)$ and no later than subframe $(n+24)$.

### B. LTE-LAA Listen-Before-Talk (LBT) Mechanism

LTE technology, which exclusively uses the licensed spectrum, has no chance of being interfered by unexpected signals. LTE-LAA, on the other hand, should coexist with other communication technologies using 5 GHz unlicensed spectrum (e.g., Wi-Fi). Therefore, LBT mechanism of LTE-LAA needs to be defined in order for frequency resources to be shared with coexisting Wi-Fi and LTE-LAA in the same unlicensed band [1].

Before LTE-LAA eNodeB transmits data for downlink using unlicensed spectrum, it should be confirmed first that the channel is idle during defer duration. The defer duration is defined to be 43 $\mu$s for channel access priority class 3, i.e., the best effort traffic class, while it can be different for other classes. After it is sensed that the channel is idle during the defer duration, the value of backoff counter must reach zero in order for LTE-LAA eNodeB to start transmitting. The backoff duration is set to 9 $\mu$s slot duration multiplied by a backoff counter value which is chosen randomly from zero to the contention window size. After channel sensing, LTE-LAA gains the transmission opportunity and can transmit data for up to 8 ms channel occupancy time (COT).

### III. COEXISTENCE EVALUATION

To demonstrate the advantages of LTE-LAA channel switching, we conduct an experiment where Wi-Fi and LTE-LAA coexist. We design the channel switching operation into the LTE-LAA testbed [8] using NI USRP-2943R, which has Xilinx 7 FPGA, utilizing LabVIEW™ Communication System Design Suite (CSDS™). Basically, the LTE-LAA testbed system setup in the application framework involves a single eNodeB communicating with a single UE in the same NI USRP.

We have implemented a channel switching operation by considering the SCell activation/deactivation mechanism described in Section II. When LTE-LAA channel switching is operated, LTE-LAA eNodeB and UE should be deactivated before changing center frequency. The eNodeB and UE can then be activated and resume LTE-LAA communication. The total delay for the channel switching operation is measured to be 110 ms.

### A. Measurement Setup

Through hostAP [9] daemon program, we create an Wi-Fi AP on the Qualcomm Atheros AR9380 NIC, a commercial 802.11n [10] device driver ath9k [11] and generate UDP traffic using Iperf 2.0.5 [12]. Fig. 3 shows the topology of
our measurement experiments. We choose a 20 MHz channel (channel number 48 with 5.240 GHz center frequency) without interference. In channel 48, Wi-Fi AP generates full-pumping traffic while there is no uplink traffic. While Wi-Fi transmits data, the LTE-LAA operates on the same channel, where Wi-Fi is transmitting, and LTE-LAA triggers the channel switching operation after 5 s. When the channel switching action occurs, the channel, on which the LTE-LAA communicates, is changed to another vacant 20 MHz channel (channel number 44 with 5.22 GHz center frequency) after 110 ms delay. The detailed measurement settings are summarized in TABLE I.

**B. Measurement Results**

Fig. 4 shows the result of throughput performance with coexisting Wi-Fi and LTE-LAA supporting channel switching operation after 5 s. After channel switching operation, LTE-LAA avoids coexistence with Wi-Fi. As a result, both LTE-LAA and Wi-Fi operate on empty channels, and their throughput performance are improved as shown in Fig. 4(a) and Fig. 4(b).

Thus, using radio resources at unlicensed spectrum through LTE-LAA channel switching can achieve more effective coexistence by escaping spectrum sharing between signals in the same band.

**IV. CONCLUSION AND FUTURE WORK**

In this paper, we demonstrate that the coexistence performance of Wi-Fi and LTE-LAA can be improved by avoiding highly interfered spectrum using LTE-LAA channel switching. Also, feasibility of LTE-LAA channel switching is verified through a prototype implementation using NI USRP.

However, there is no specific algorithm to trigger the LTE-LAA channel switching operation yet. As future work, if the sensor-based cognitive radio technology [13] is additionally applied or a channel avoidance judgment algorithm is implemented in the LTE-LAA, we can expect to build a more effective LTE-LAA coexistence system with LBT in unlicensed spectrum.

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