Channel Sensing Based Dynamic Adjustment of Contention Window in LAA-LTE Networks

Anand M. Baswade and Bheemarjuna Reddy Tamma
Department of Computer Science and Engineering
Indian Institute of Technology Hyderabad, India
Email: [cs14resch11002, tbr]@iith.ac.in

***Abstract*—3GPP is introducing Licensed Assisted Access (LAA) in Release 13 [1], for LTE operation in unlicensed bands, to provide high data rate and to reduce the load on licensed spectrum. One of the mandatory functionalities of LAA is Listen Before Talk (LBT) to co-exist fairly with other technologies in unlicensed bands like Wi-Fi. Contention Window (CW) adjustment is one of the important issues in LAA LBT. Hence in this paper, we propose a dynamic CW adjustment algorithm for LAA based on channel sensing and then evaluated the performance of Wi-Fi in Wi-Fi - Wi-Fi and LAA - Wi-Fi scenarios. Our simulation results show that LAA with proposed CW adjustment algorithm can fairly co-exist with Wi-Fi.**

I. Motivation

Due to the surge in usage of smart phones and tablets, there is an ever increasing demand for spectrum. A potential solution is using unlicensed spectrum to meet the user demand in last hop of wireless communication. The unlicensed spectrum can be utilized in two ways. One way is to use Wi-Fi for LTE traffic offloading and other is to use LTE itself in unlicensed spectrum. Use of LTE in unlicensed spectrum is a better option because of unified network, efficient spectrum utilization and easier management of the network with same technology. Though there are benefits of using LTE in unlicensed bands, due to its *always on* nature of operation, it is not fair to use LTE in unlicensed spectrum as there are many other technologies like Wi-Fi which operates on Carrier Sense Multiple Access (CSMA) principle and follows Listen-Before-Talk (LBT) procedure. To use an unlicensed spectrum, LTE needs to fairly co-exist with Wi-Fi and other technologies. Hence, the new challenge in LTE/LTE-Advanced is to make better use of unlicensed spectrum without affecting incumbent technologies of unlicensed spectrum.

II. Related Work

LTE in unlicensed can be achieved with LBT or without LBT procedure. In some geographical regions like India, USA and China LBT is not mandatory. Hence in such regions, one can use Carrier Sensing Adaptive Transmission (CSAT) [2]. But in some other regions like Europe and Japan LBT is mandatory. ETSI proposed [3] Frame Based Equipment (FBE) and Load Based Equipment (LBE) LBT procedure for LTE operation in unlicensed spectrum. For Release 13 [1] 3GPP is considering LBT category 4 as channel access scheme in LAA where the Contention Window (CW) adjustment can be done based on feedback report of UE(s) (e.g., HARQ ACK / NACK) or based on eNB's assessment (e.g., sensing based adjustment).

In this paper, we propose a dynamic CW adjustment algorithm based on channel sensing for LBT category 4 and then we analyze the performance of Wi-Fi in Wi-Fi - Wi-Fi and LAA - Wi-Fi scenarios.

III. LBT Category 4 with Dynamic CW Adjustment

LBT category 4 [1] has mainly two parameters: Defer period and Extended Clear Channel Assessment (ECCA). Defer period is the minimum time a device has to wait after the channel becomes idle before its transmission. The minimum value of defer period is at least 20 μs to avoid collision with Wi-Fi ACKs. If the channel is busy, a device also has to sense channel idle for random ECCA drawn from [0, CW] before transmission of data. The value of ECCA slot is smaller than 20 μs. If ECCA countdown is interrupted, a defer period is applied after the channel becomes idle as shown in Fig. 1.

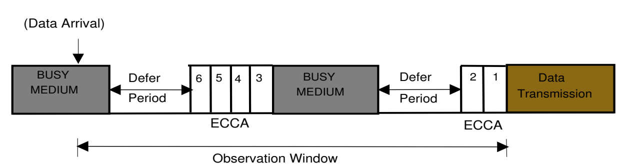

Fig. 1. Downlink LAA LBT category 4 scheme

In LBT category 4, the CW is of variable length. The selection of CW should be in such a way that, it should improve the overall channel utilization, reduce the collision rate and fairly co-exist with Wi-Fi. In case of Wi-Fi, CW adjustment is based on ACKs but LTE has delayed ACKs. Hence in this paper, we consider the CW adjustment based on channel sensing [4] and we propose a dynamic CW adjustment algorithm (Refer Algorithm 1). The algorithm considers load on a channel and adjust CW dynamically.
The important parameters of the algorithm are listed below.

- **Observation Window (OW) :** Time elapsed since a device wants to transmit on the channel to it actually starts its transmission after ECCA counter reaches zero as shown in Fig. 1.
- **Waiting Threshold (WT) :** It is the threshold used to adjust current CW. WT_{min} is initial value of WT.

The algorithm updates current CW & WT values for every transmission based on OW of the last transmitted packet.

Algorithm 1 Dynamic CW Adjustment in LAA

```
Inputs: CW, WT, OW        /* current values */
Outputs: CW, WT        /* updated values */
Initialization: CW ← CW_min, WT ← WT_min
if OW ≥ WT then
    CW ← 2 * CW        /* increase CW for next packet */
    WT ← 2 * WT        /* increase WT for next packet */
    if CW > CW_max then
        CW ← CW_max
    end if
else
    CW ← CW_min        /* reset CW for next packet */
    WT ← WT_min        /* reset WT for next packet */
end if
```

IV. Simulation Setup and Results

For simulation, we considered an indoor scenario according to 3GPP [1] in which two operators (A & B) deployed 4 small cells in a single floor building with rooms on both sides of the corridor as shown in Fig. 2. Each operator has deployed 10 users in each cell and positions of the users are same for both Wi-Fi - Wi-Fi and LAA - Wi-Fi case. Simulations are performed in MATLAB simulator by considering LAA and Wi-Fi parameters as described in Table I.

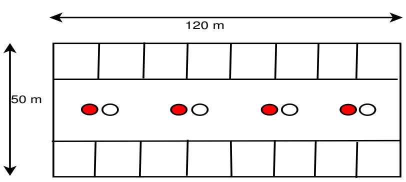

Fig. 2. Indoor Layout considered for evaluation

TABLE I
LAA & Wi-Fi Simulation Parameters

Parameter	LAA	Wi-Fi
Bandwidth	20 MHz	20 MHz
Tx Power	18 dBm	18 dBm
Path Loss Model [5]	Indoor Hotspot	Indoor Hotspot
CW (Min, Max)	(15, 1023)	(15, 1023)
Transmission opportunity	1 ms	1 ms
Energy detection threshold	-62 dBm	-62 dBm
Antenna	SISO	SISO

We assumed the values of defer period and ECCA as 34 μs and 9 μs, respectively. The MCS table used for Wi-Fi is 802.11ac excluding 256 QAM. 3GPP FTP traffic model 1 [5] is used by varying user arrival rate from 0.5 to 2.5 users/s. Each user downloads file size of 0.5 MB. The considered value of WT_{min} is equal to transmission opportunity. The simulation ran with 10 different seed values. User Perceived Throughput (UPT) and delay are calculated for performance evaluation. UPT is defined as the ratio of total file size to the time taken for successful transmission of file. Delay is defined as total time, file lived in buffer before its successful transmission. Performance of Wi-Fi is measured in Wi-Fi - Wi-Fi and LAA - Wi-Fi scenarios.

A. Case 1 : Wi-Fi - Wi-Fi Scenario

Both the operators deployed Wi-Fi. In Fig. 3 & 4 solid lines shows the performance for Case 1. Solid lines are close to each other as both the operators are using Wi-Fi.

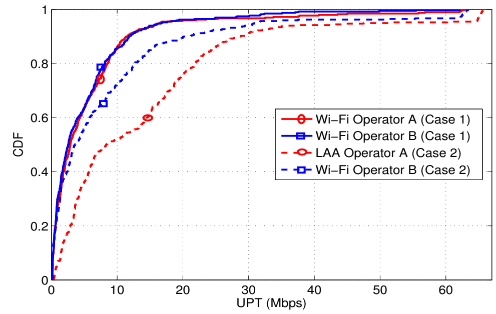

Fig. 3. UPT CDF

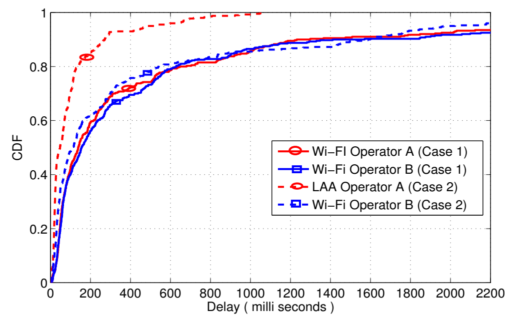

Fig. 4. Delay CDF

B. Case 2 : LAA - Wi-Fi Scenario

In this case, Wi-Fi of operator A is replaced with LAA and the above simulations are repeated. In Fig. 3 & 4, dotted lines shows the performance of LAA and Wi-Fi in LAA - Wi-Fi scenario. The performance of Wi-Fi (operator B) in Case 2 is better than Case 1 because LAA utilize spectrum efficiently and gives more channel access opportunity to Wi-Fi.

V. Conclusions

LAA with proposed dynamic CW adjustment algorithm can fairly co-exist with Wi-Fi and the performance of Wi-Fi in LAA - Wi-Fi scenario is better than Wi-Fi - Wi-Fi scenario. Future work comprises of optimal WT value selection for CW adjustment as the lower WT value can lead to increase the backoff time and higher WT value can result in more number of collisions.

Acknowledgment

This work was supported by the Deity, Govt of India (Grant No. 13(6)/2010CC&BT).

References

[1] 3GPP, "TSGRAN; Study on Licensed-Assisted Access to Unlicensed Spectrum," Tech. Rep. TR 36.889 V13.0.0, June 2015.

[2] "LTE in Unlicensed Spectrum : Harmonious Coexistence with Wi-Fi." Qualcomm white paper, June 2014.

[3] ETSI, "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive," in *ETSI EN 301 893 V1.8.1*, 2015.

[4] 3GPP, "WF on CW adjustment based on eNB sensing," in *TSG RAN WG1 R1-154975*, August 2015.

[5] 3GPP, "E-UTRA; Further advancements for E-UTRA physical layer aspects," Tech. Rep. TS 36.814 Release 9.