Cisco Cooperative Project

LAA with Multi-carrier LBT: Option 2

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Outline

- Multi-carrier LBT
  - Option 1 & Option 2
  - Results

- Simulation Results

- Discussion & Future Work
Multi-carrier LBT

Option 1 (Wi-Fi like) [1]-[3]

LAA eNB performs LBT on only one unlicensed carrier (LBT carrier, “primary” channel)

- LBT carrier determination: 1) pre-selection; 2) dynamic selection: the one finished LBT procedure first
- Carrier aggregation: 1) Wi-Fi channel bonding rule; 2) LTE carrier aggregation rule

Multicarrier LBT

Option 2

LAA eNB performs LBT Cat 4 on more than one unlicensed carriers

- Two variations\textsuperscript{[1]}:
  1. LBT scheme exit the self-defer stage if the number of the available channels is equal or larger than the pre-set threshold (early determination);
  2. LBT scheme do the final one-shot check at the end of the self-defer stage

\textsuperscript{[1]} Braodcom, “R1-157009: Further Discussion on LAA DL Multi-channel LBT,” Nov. 16, 2015
Multicarrier LBT

Results\cite{1}-\cite{2}

- Class A (Option 1): dynamic selection, CA
- Class B (Option 2): self-defer period: 15 CCA slots
- 4 carriers
- LAA ED: -72 dBm

An LAA network using multi-channel transmissions can coexist well with Wi-Fi networks
Class A is a bit better than Class B (Option 1 with dynamic selection is similar to Option 2)
Different companies with different simulation settings may have different conclusions

\cite{1} Ericsson, “R1-154624: Discussion on Wi-Fi and DL-only LAA Coexistence for Multi-Channel Transmission,” Aug. 24, 2015
\cite{2} Ericsson, “R1-157258: On Channel Access Solutions for LAA Multi-Carrier Transmission,” Nov. 16, 2015
Simulation Results

Simulation Setting

- 4 APs + 4 eNBs: each AP/eNB has five users, and each UE uniformly and randomly distributed around its associated transmitter
- 8 carriers in total (U-NII 1 and U-NII 3)
- FTP file size: 0.5 Mbytes, Poisson process: lambda = 25
- Transmit power: 200 mW (23 dBm) for all transmitters
- Multi-carrier LBT: Option 2.2 (no early determination): one carrier reaches to the defer period, and other carriers are chosen by channel index if idle
- LAA can aggregate at most 4 carriers
Simulation Results

- LAA-ED: -65 dBm, Wi-Fi’s primary channel: 1,5,1,5

- With a larger self-deferral waiting time, the probability that multiple carriers complete the LBT procedure is greatly enhanced: LAA improves, WiFi degrades

- However, if the waiting time is too long, the system’s performance will decrease
Simulation Results

- **LAA-ED: -70/-75 dBm**

- Decreasing LAA-ED is beneficial to WiFi; the overall performance also decreases.
- Choosing a defer between 10 and 20 slots may be a good choice in this case. (In Ericsson’s simulations, it is 15; in Broadcom’s simulations, it is 10)
Simulation Results

- Option 1 (LBT carrier is pre-selected)

  ✓ PC: 1, 4, 5, 8, 1, 4, 5, 8

  ![Simulation Diagram]

<table>
<thead>
<tr>
<th></th>
<th>WiFi #1</th>
<th>WiFi #3</th>
<th>WiFi #5</th>
<th>WiFi #7</th>
<th>Op. A</th>
<th>LAA #2</th>
<th>LAA #4</th>
<th>LAA #6</th>
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- The overall performance is better than that of pure WiFi networks (947.01): 1) higher physical rate for LAA; 2) CCA-CS is the only sensing threshold in pure WiFi networks

- Adapting LAA-ED can help to achieve fairness
Simulation Results

❖ Option 2 (Self-deferral: 15 CCA slots)

✓ PC: 1, ?, 5, ?, 1, ?, 5, ?

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• In this case, the performance of Option 2 is better than that of Option 1. However, if dynamic selection for LBT carrier is chosen for Option 1, its performance can be improved (Option 1 may even outperform Option 2).

• Generally, Option 1 and Option 2 have similar performance, and they can coexist well with Wi-Fi networks by choosing suitable LAA-ED.
Discussion & Future Work

✓ Improve simulations
  ▪ There should be a limitation on the total transmit power
  ▪ Wi-Fi can have 160 MHz or 80+80 MHz, LAA can aggregate 5 carriers
  ▪ Simulate LAA with channel bonding to see the performance difference

✓ Adapting the LAA-ED to improve the system performance and fairness?

✓ How to choose the “other” carriers in Option 1 and 2.