Cisco Cooperative Project

Start Recording

Channel Access for LAA

Student: Li Li
Advisors: Len Cimini, Chien-Chung Shen

May 18, 2016

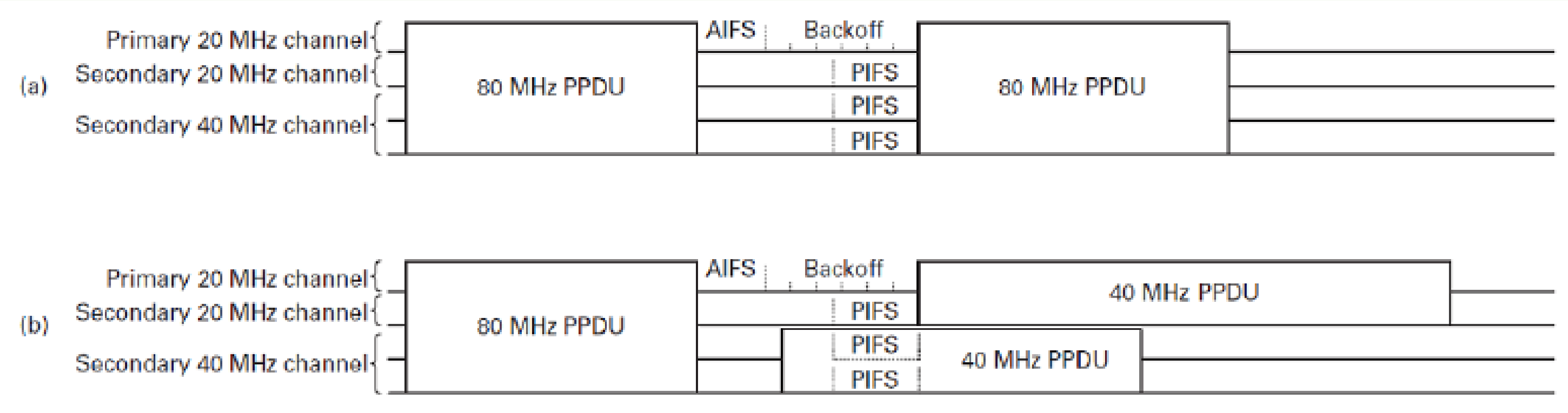
Outline

- Multi-carrier LBT

- Channel selection

Multi-carrier LBT

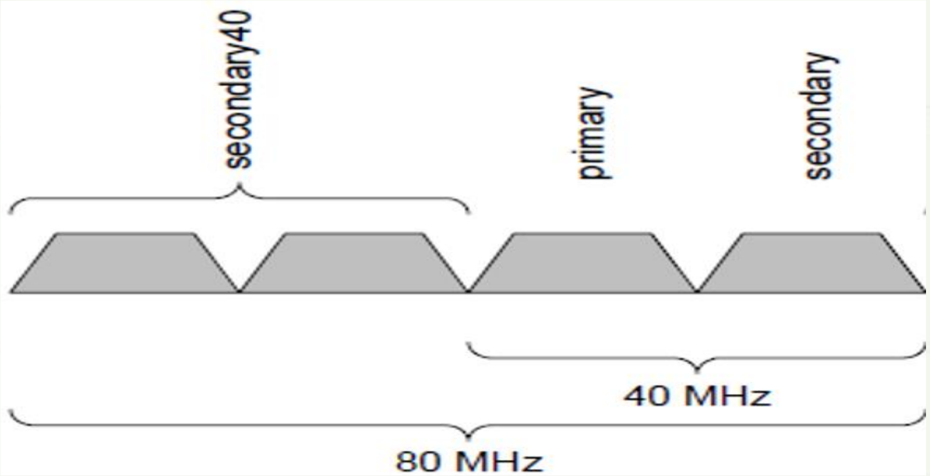
❖ 802.11ac's channel bonding



- The backoffprocedure is only performed on the primary channel, secondary channel(s) perform a one-shot CCA.
- Only certain channel bonding configurations are allowed.
- The designated primary channel should always be part of the channel bonding configurations.

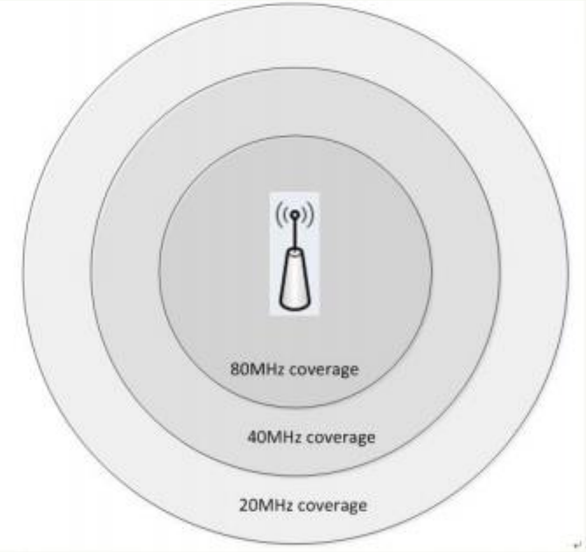
Multi-carrier LBT

❖ Channel bonding patterns



20/40/80 MHz contiguous channel widths

❖ Coverage



❖ Detection threshold

Channel Width	CCA-CS (primary)	CCA-CS (secondary)	CCA-ED
20 MHz	-82	-72	-62
40 MHz	-79	-72	-59
80 MHz	-76	-69	-56

Multi-carrier LBT

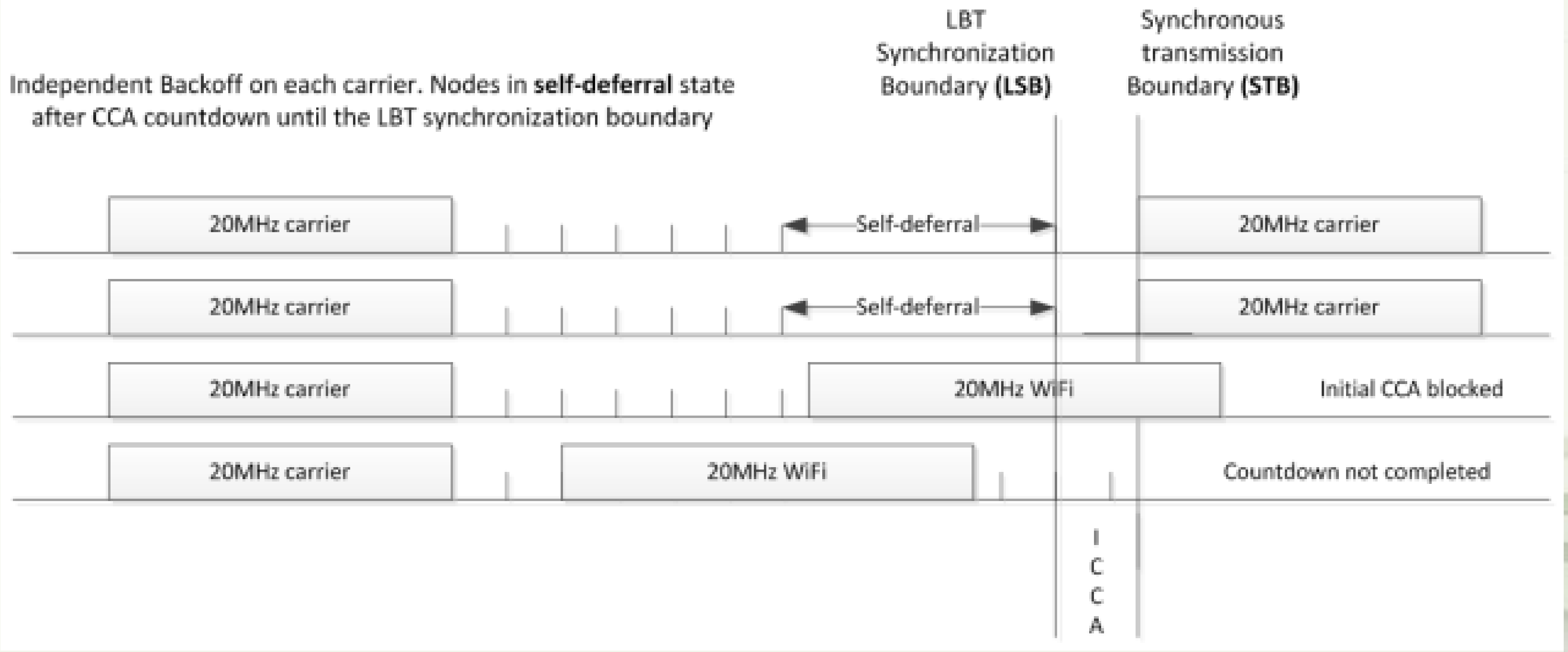
- Multi-carrier LBT, Alt 1: eNB performs LBT Cat 4 on only one unlicensed carrier (Wi-Fi like) [1]

  - The eNB shall choose the carrier requiring LBT uniformly randomly before each transmission burst or fix the carrier at least for 1 sec
  - The energy detection threshold used on channels not performing LBT is same as the one used on channel performing LBT
  - A single backoff counter should be used for the carrier on which LBT is performed.

[1] Nokia, Alcatel-Lucent, "R1-160915: Discussion on Multi-Carrier LBT for LAA DL," Feb. 15, 2016

Multi-carrier LBT

- Multi-carrier LBT, Alt 2: eNB performs LBT Cat 4 on more than one unlicensed carriers
  - The eNB can transmit on the carriers that has completed LBT with potential self-deferral to align transmission over multiple carriers.



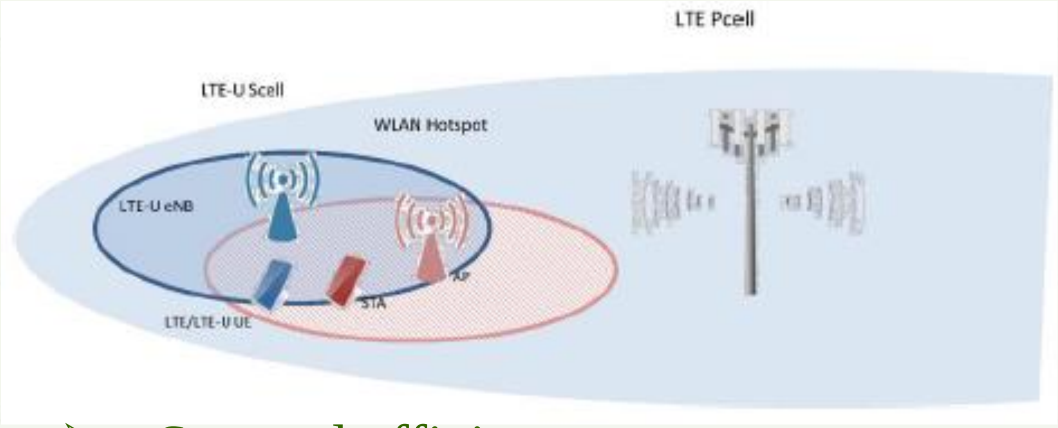
[1] Nokia, Alcatel-Lucent, "R1-160915: Discussion on Multi-Carrier LBT for LAA DL," Feb. 15, 2016

Multi-carrier LBT

- Work to do
  - Evaluate the performance for LAA with Alt 1 and Alt 2
    - ✓ LAA with carrier aggregation for any idle channels
    - ✓ LAA with channel bonding as Wi-Fi does
    - ✓ LAA with carrier aggregation for every four contiguous channels

Channel Selection

❖ Maximize area spectral efficiency[2]



➢ Spectral efficiency

$$S_e(\mathbf{x}, c) = \log_2 \left(1 + \frac{P_L l(\mathbf{x}_n^a, \mathbf{x})}{\sum_{i \in S_c^A,\ i \neq n} P_L l(\mathbf{x}_i^a, \mathbf{x}) + \sum_{m \in S_c^W} P_W l(\mathbf{x}_m^w, \mathbf{x}) + N} \right)$$

[2] C. Ibars, A. Bhorkar, A. Papathanassiou, P. P. Zong, (Intel), “Channel Selection for Licensed Assisted Access in LTE Based on UE Measurements”, 2015 VTC Fall

Channel Selection

- Maximize area spectral efficiency[2]
  - Area Spectral efficiency

$$S(A_n, c) = \frac{1}{A_n}\int_{A_n} S_e(\mathrm{x}, c)\,d\mathrm{x},$$

  - Optimization problem

$$\max_{I(n,c)} \sum_{n=1}^{N_A} S(A_n, c) I(n, c)$$

$$\sum_{c=1}^{C} I(n, c) \leq 1$$

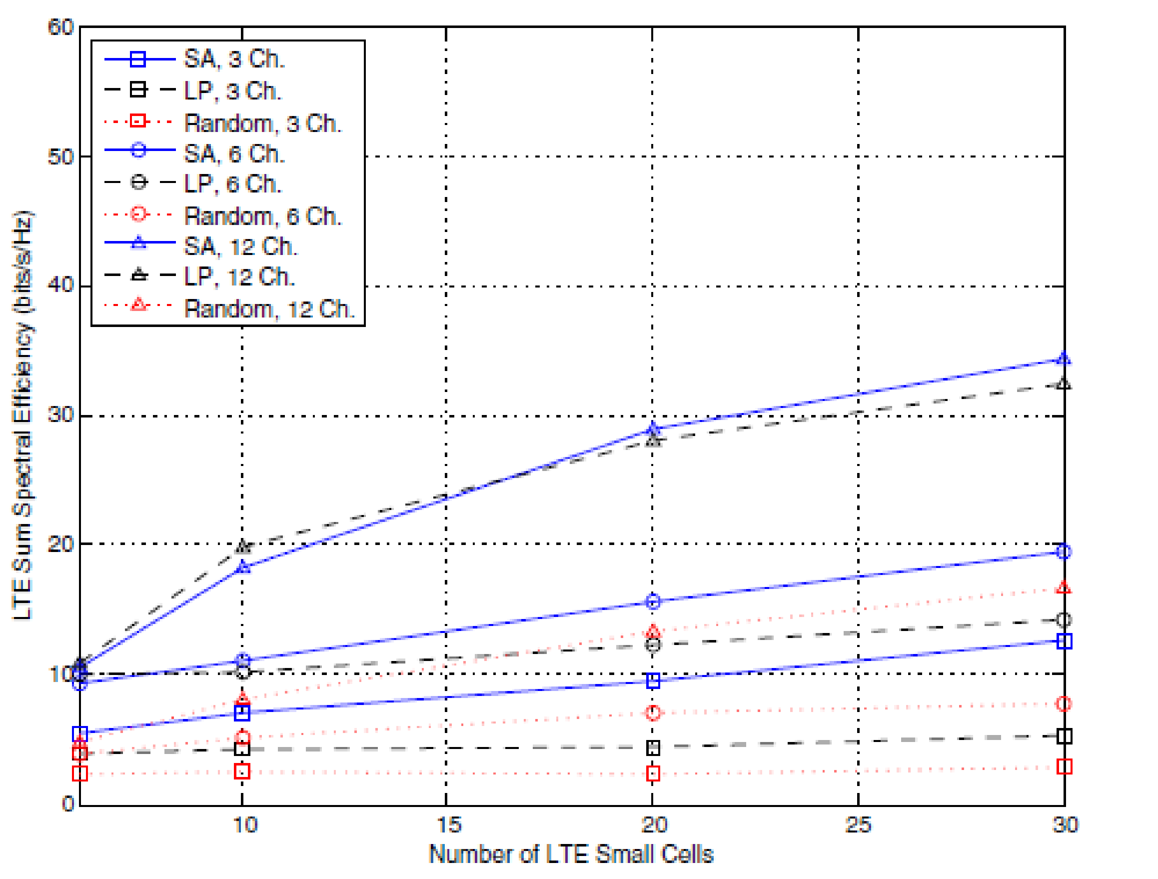
$$I \in 0, 1.$$

$I(n,c) = 1$, if eNB A_n transmit data on channel c;
$I(n,c) = 0$, otherwise.

  - Integer linear program (NP complete). Simulated annealing algorithm: check whether a neighbor solution is better or not in each iteration.

Channel Selection

❖ Maximize area spectral efficiency[2]



SA: simulated annealing
LP: least interference power channel selection

1) Both SA & LP outperform random selection
2) SA has advantage over LP in congested cases, for a lower number of channels

Channel Selection

❖ Maximize number of LAA-UEs sharing *M* channels

- For uplink transmissions, assuming the probability of interference energy from Wi-Fi sensed to exceed a threshold at each channel is *p*.
- Randomly choose the channel to transmit

$$\mathbf{I}_{m,i} = \begin{cases} 1, & i\text{th LAA-UE selects the } m\text{th resource batch,} \\ 0, & \text{otherwise,} \end{cases}$$

- The probability that the *m*-th channel is selected without collisions

$$\Pr\left\{\sum_{i=1}^{N} \mathbf{I}_{m,i} = 1\right\} = N\left(\frac{1-p^M}{M}\right)\left(1 - \frac{1-p^M}{M}\right)^{N-1}$$

[3] S. Y. Lien, J. Lee, and Y. C. Liang, "Random Access or Scheduling: Optimum LTE Licensed-Assisted Access to Unlicensed Spectrum," in IEEE Communication Letters, Mar. 2016.

Channel Selection

- Maximize number of LAA-UEs sharing *M* channels[3]
  - Optimization problem

$$N^* = \arg\max_{N} \left\{ N \left(\frac{1-p^M}{M} \right) \left(1 - \frac{1-p^M}{M} \right)^{N-1} \right\}$$

  - Solution

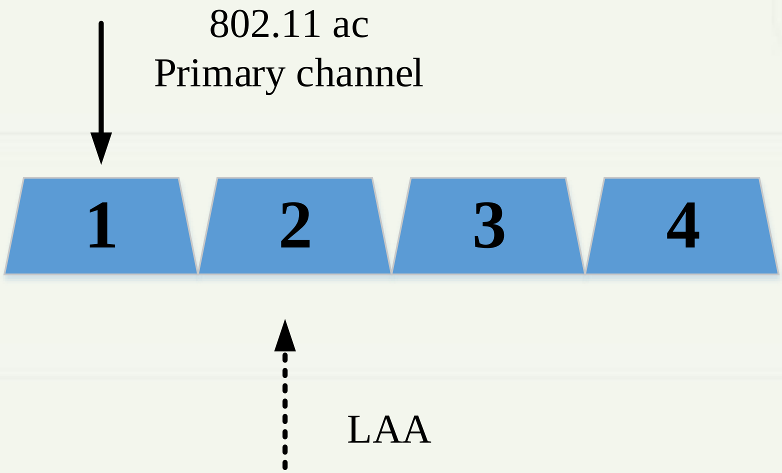
$$N^* = \begin{cases} \frac{M}{1-p^M}, & \text{if } \frac{M}{1-p^M} \text{ is an integer,} \\ \lfloor \frac{M}{1-p^M} \rfloor, & \text{otherwise,} \end{cases}$$

$$N^* = \left\lfloor \frac{M}{1-p^M} \right\rfloor \geq M.$$

Channel Selection

❖ Previous work

- ✓ 802.11ac with dynamic 80/40/20 MHz (primary channel requires to be included in any bandwidth)
- ✓ LAA works in 20 MHz bandwidth
- ✓ Channel selection depends on load rates (Ignore delay, from probability perspective)



Example 1: 2 pairs, $p_{AC} = p_{LAA} = 0.2$

To achieve the highest effective bandwidth (throughput), both 802.11ac and LAA will choose the same subchannel (e.g. #1).

$EB(1,1) = 0.2 * 80 + 0.2 * 20 = 20$

$EB(1,2) = 0.2 * (0.8 * 80 + 0.2 * 20) + 0.2 * 20 = 17.6$

$EB(1,3) = 0.2 * (0.8 * 80 + 0.2 * 40) + 0.2 * 20 = 18.4$

Example 2: 2 pairs, $p_{AC} = p_{LAA} = 1$

To achieve the highest effective bandwidth (throughput), 802.11ac chooses #1, and LAA choose #3 or #4.

$EB_{max} = EB(1,3) = 1 * 40 + 1 * 20 = 60$

Channel Selection

❖ Previous work

Let h_{ij} denote whether the j-th transmitter choose the i-th subchannel. To maximize the total effective bandwidth, one possible model is

Primary 20 MHz

Secondary 20 MHz

Secondary 40 MHz

$$\begin{aligned}
maximize \quad & \sum_{i\in C}\sum_{j\in S_{AC}} p_j h_{ij}\left(1+\prod_{i\in i_1}\sum_{j\in \bar{j}}(1-p_j h_{ij})\left(1+2\prod_{i\in i_2}\sum_{j\in \bar{j}}(1-p_j h_{ij})\right)\right)+\sum_{i\in C}\sum_{j\in S_{LAA}} p_j h_{ij} \\
s.t. \quad & \sum_{i}^{K} h_{ij}=1, \qquad \forall j\in S \\
& p_j h_{ij}=\min\{p_j h_{ij}, 1/\sum_{j\in S} h_{ij}\} \qquad \forall i\in C, \quad \forall j\in S \\
& j\cup\bar{j}=S \\
& h_{ij}\in\{0,1\}
\end{aligned}$$

One transmitter can only choose one subchannel (For AC, it is primary channel)

Multiple transmitters have the same opportunity to win the channel access

$$i_1=\begin{cases}2 & i=1\\ 1 & i=2\\ 4 & i=3\\ 3 & i=4\end{cases} \qquad i_2=\begin{cases}\{3,4\} & i=1\\ \{3,4\} & i=2\\ \{1,2\} & i=3\\ \{1,2\} & i=4\end{cases}$$

Channel Selection

- Work to do
  - To do optimization, a lot of assumptions are required: ignore the procedure of CSMA/LBT, using probability instead of traffic model, and so on
  - Simplify the model, sub-optimal solutions
  - For 3GPP scenario, work on selecting channel based on measurements