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

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Introduction

- The phenomenal growth in mobile data demand.
- Limited and costly licensed spectrum.
- One solution is to use unlicensed spectrum.
- 23 non-overlapping channels in 5GHz.

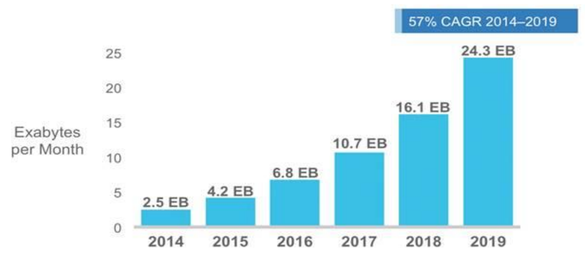

Fig. 1. Global Mobile Data Traffic Source: Cisco VNI Mobile, 2015

LTE in Unlicensed Spectrum

- LTE can utilize unlicensed spectrum in two ways.
  1. Use Wi-Fi for LTE traffic offloading.
  2. 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.

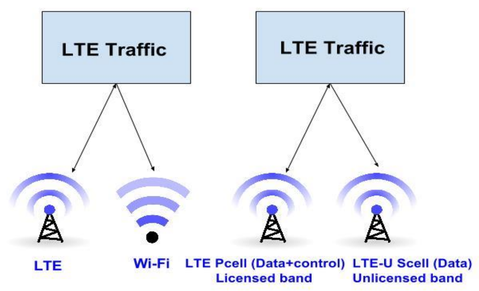

Fig. 2. LTE Traffic in Unlicensed Spectrum

- But due to its always on nature of operation, it is not fair to use LTE in unlicensed spectrum as it will be difficult for Wi-Fi to grab the channel from LTE.
- To use an unlicensed spectrum, LTE needs to fairly coexist with Wi-Fi and other technologies.

Motivation

- To provide high data rate and to reduce the load on licensed spectrum, 3GPP is introducing Licensed Assisted Access (LAA) in Release 13 for LTE operation in unlicensed spectrum.
- One of the mandatory functionalities of LAA is Listen Before Talk (LBT) to coexist fairly with other technologies in unlicensed spectrum like Wi-Fi.
- Contention Window (CW) adjustment is one of the important issues in LAA LBT.

LBT Category 4 with Dynamic CW Adjustment

- LBT category 4 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. Defer period ≥ 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. ECCA slot < 20 µs.
- If ECCA countdown is interrupted, a defer period is applied after the channel becomes idle as shown in Fig 3.

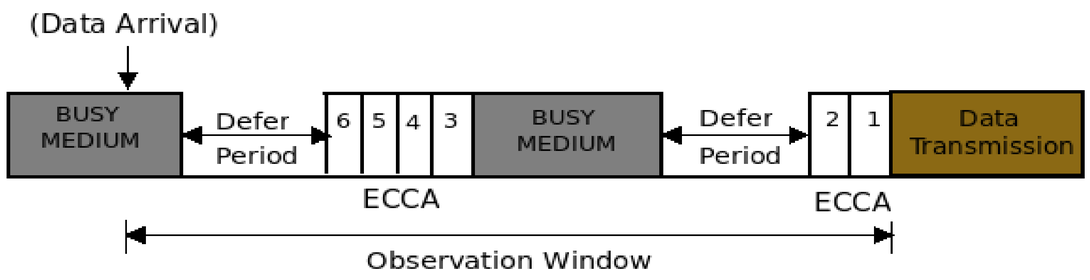

Fig. 3. Downlink LAA -LBT category 4 scheme.

- According to 3GPP, 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).
- We consider the CW adjustment based on channel sensing and we propose dynamic CW adjustment algorithm (Refer Algorithm 1).

Algorithm Parameters

- Important parameters of algorithm:
  - **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. 3.
  - **Waiting Threshold (WT) :** It is the threshold used to adjust current CW. WT_{min} is initial value of WT.
  - **CW_{min} and CW_{max}**: Minimum and maximum value of CW, respectively.
- The proposed algorithm considers load on the channel and adjust CW dynamically.
- 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}
1: **if** OW ≥ WT **then**
2: CW ← 2∗CW /* increase CW for next packet */
3: WT ← 2∗WT /* increase WT for next packet */
4: **if** CW > CW_{max} **then**
5: CW ← CW_{max}
6: **end if**
7: **else**
8: CW ← CW_{min} /* reset CW for next packet */
9: WT ← WT_{min} /* reset WT for next packet */
10: **end if**

Simulation Setup & Parameters

- For simulation, 3GPP indoor scenario is considered with two operators (A & B) deployed 4 small cells in a single floor building as shown in Fig. 4.
- Each operator deployed 10 users in each cell and positions of the users are same for both Wi-Fi - Wi-Fi and LAA - Wi-Fi case.

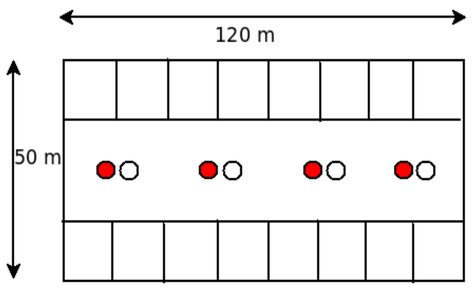

Fig. 4. Indoor Layout considered for evaluation

TABLE 1: LAA & WI-FI SIMULATION PARAMETERS

Parameters	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

Results & Analysis

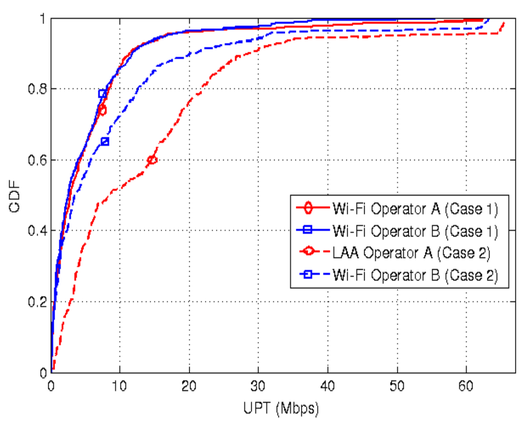

Fig. 5. UPT CDF

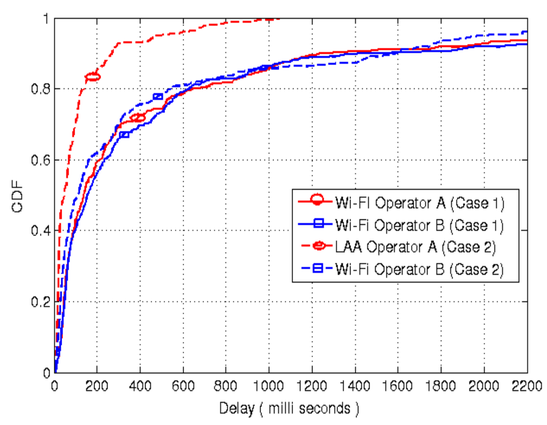

Fig. 6. Delay CDF

Case 1 : Wi-Fi - Wi-Fi Scenario

- Both the operators deployed Wi-Fi. In Fig. 5 & 6 solid lines shows the performance for Case 1. Solid lines are close to each other as both the operators are using Wi-Fi.

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. 5 & 6, dotted lines shows the performance of LAA and Wi-Fi in LAA - Wi- Fi scenario.
- The performance of Wi-Fi in Case 2 is better than Case 1 because LAA utilize spectrum efficiently and gives more channel access opportunity to Wi-Fi.

Conclusions

- LAA with proposed dynamic CW adjustment algorithm can fairly coexist 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.

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