The Recent Progress of 3GPP Licensed-Accessed Access to Unlicensed Spectrum

Shao-Yu Lien (連紹宇)
Department of Electronic Engineering, National Formosa University
Email: sylien@nfu.edu.tw

Outlines

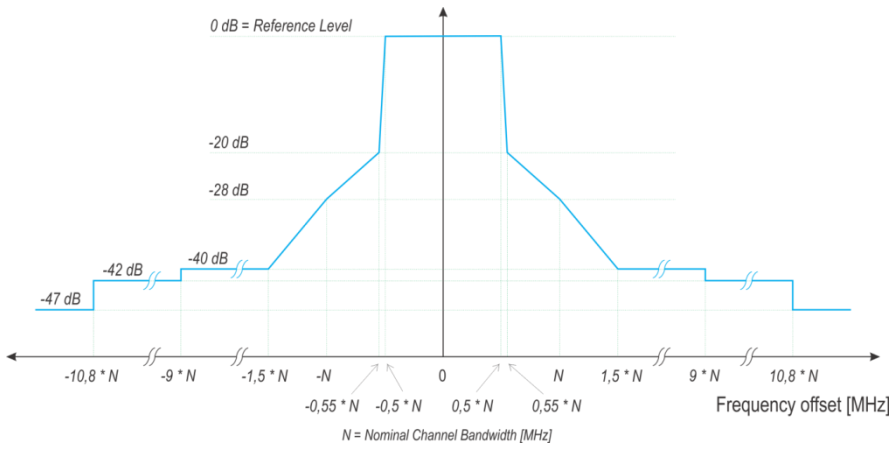
- Introduction to Licensed-Assisted Access
- Radio Access to Unlicensed Spectrum
- Carrier Aggregation for LAA
- Deployment Scenarios of LAA
- Design Targets of LAA
- Listen-Before-Talk (LBT) for LAA
- Scheduling in LAA
- Other Design Considerations for LAA
- Summary

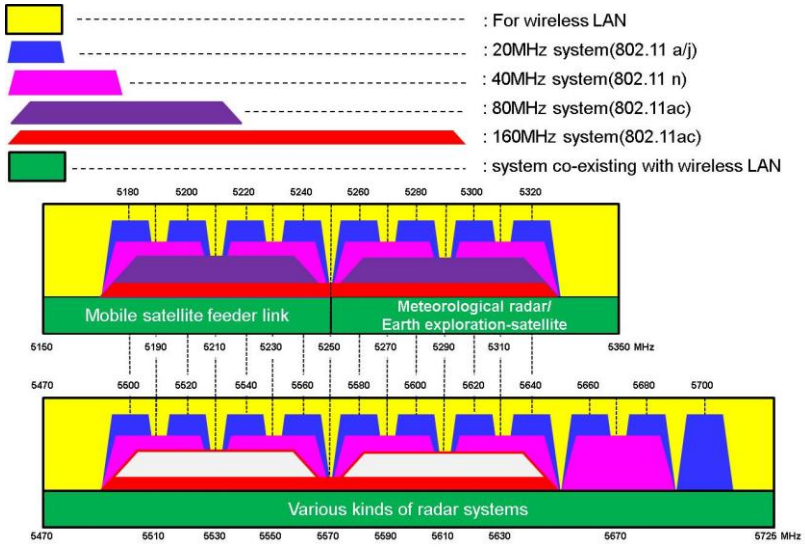
Introduction to Licensed-Assisted Access

- Licensed-Assisted Access is abbreviated as LAA
- LAA supports LTE deployment on 5GHz unlicensed spectrum to share the increasing traffic load on licensed bands
  - Europe: 5150-5350 MHz (indoor), 5470-5725 MHz, 5725-5855 MHz
  - USA: 5150-5925 MHz
  - China: 5150-5350 MHz (indoor)
  - Japan: 5150-5250 MHz (indoor), 5250-5350 MHz, 5470-5725 MHz
  - Taiwan: 5250-5350 MHz, 5470-5590 MHz, 5650-5850 MHz
  - Etc.
- Different from communications on licensed bands without strict regulations, several limits are imposed to communications on unlicensed spectrum
  - To provide a fair channel occupancy among multiple coexisting systems

Radio Access to Unlicensed Spectrum

- Documented regulations include
  - Maximum transmission power, power spectrum density, Out-of-band emission
  - Channel sensing (Listen-before-talk, LBT)
  - Maximum channel occupation time
  - Channel bandwidth





Radio Access to Unlicensed Spectrum

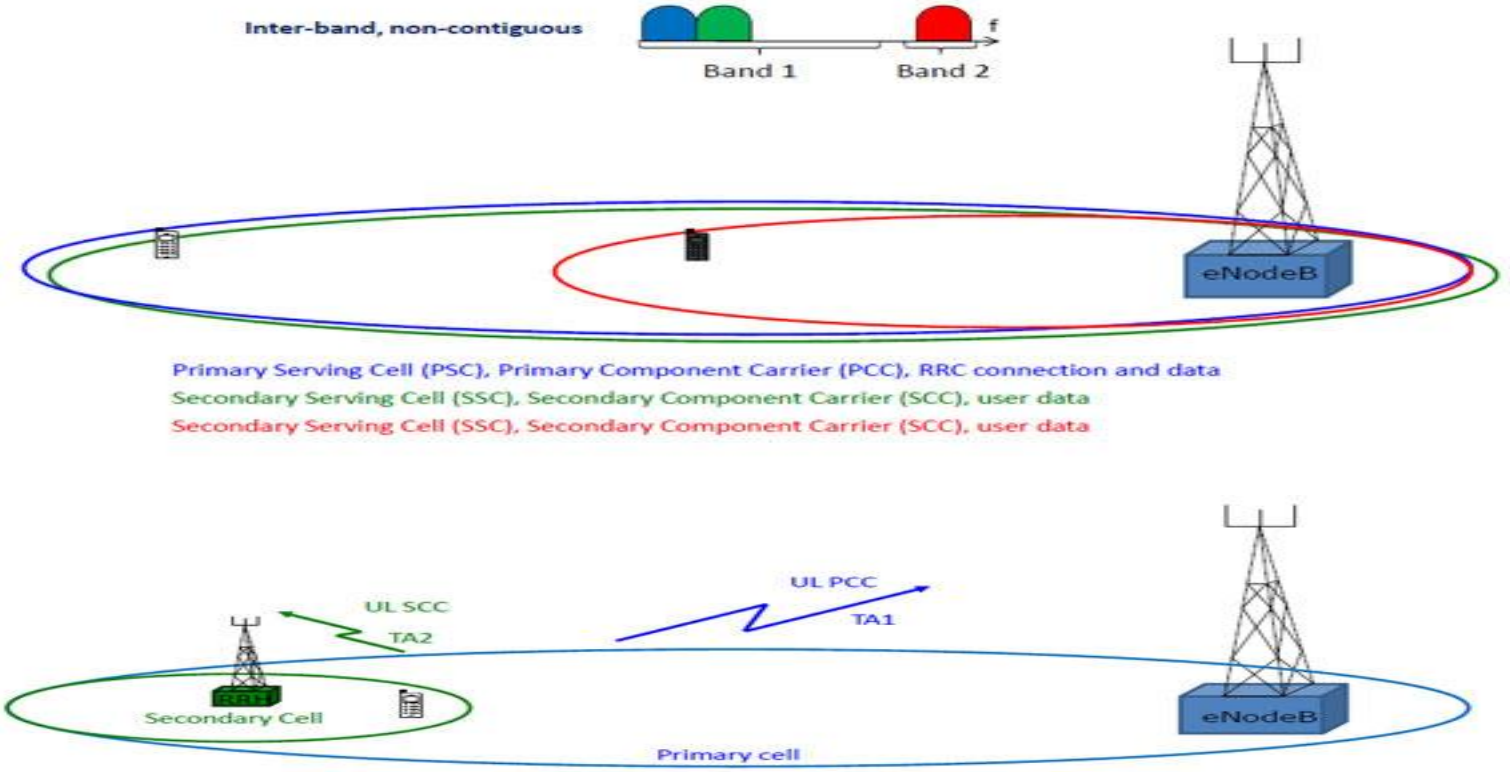
- Potential interference sources in 5G unlicensed bands
  - IEEE 802.11 (a, ac, ax)
  - Weather radar
- Concerns of deploying LTE on unlicensed spectrum
  - Communication range is reduced
    - Suitable for small cell
    - Dense deployment
    - May increase the number of handovers
  - Uncontrollable interference
    - Reliability and QoS guarantee are challenging issues

Carrier Aggregation for LAA

- Carrier aggregation (CA)
  - Flexible bandwidth is supported by LTE since Release 8
    - 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, 20MHz
  - To further enhance the data rate needing a wider bandwidth, CA technology in Release 11 allow to aggregate multiple component carriers
    - Both UL and DL can be supported
    - CCs can be of different bandwidth
    - Backward compactable to Release 8/9 UE to be supported by one CC
  - One CC shall be operated as primary serving cell (Pcell) for RRC connection
  - With potentially one or multiple secondary serving cell (Scell) for data communications

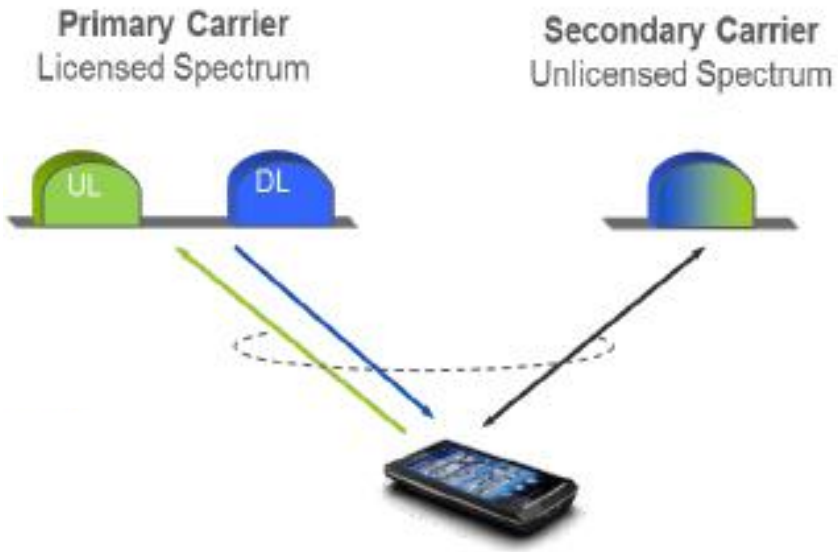
Carrier Aggregation for LAA

- Pcell and Scell can be collocated in one eNB, or separated in different eNBs

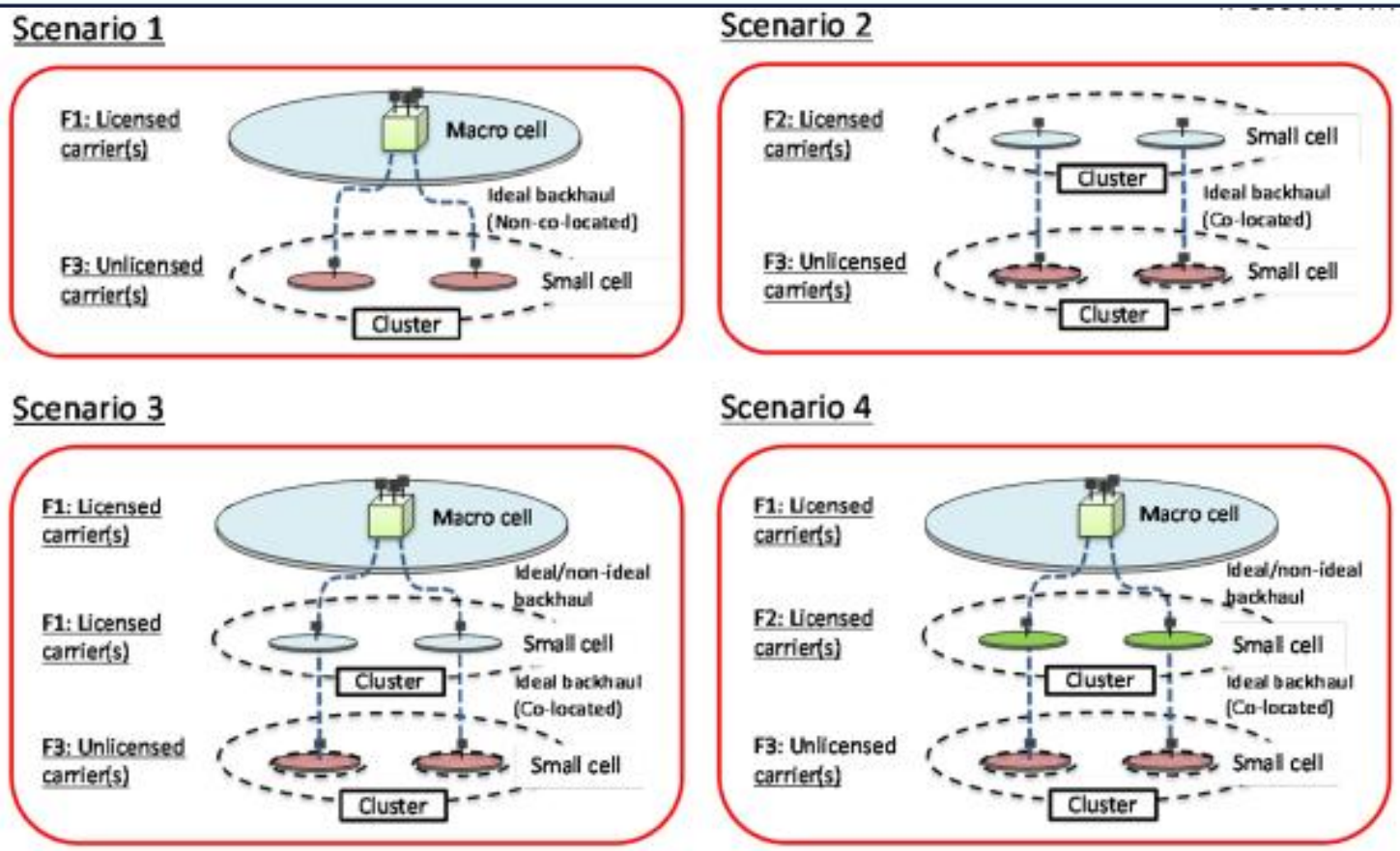


Carrier Aggregation for LAA

- Carrier aggregation is mandatory for LAA
  - Licensed band Pcell
    - Reliable control signaling
    - Better mobility management (handover)
    - Better real-time and QoS supports
  - Unlicensed band Scell
    - Best effort support for data transmissions



Deployment Scenarios of LAA



- LAA may not operate on unlicensed carrier standalone, a licensed carrier shall always exist

Design Targets of LAA

- Three design targets have been agreed
  - A single global solution framework allowing compliance with any regional regulatory requirements
    - Provide sufficient configurability to enable efficient operation in different geographical regions.
  - Effective and fair coexistence with Wi-Fi
  - Effective and fair coexistence among LAA networks deployed by different operators
    - With respect to throughput and latency

Design Targets of LAA

- Based on these design targets, it has been agreed that at least the following functionalities shall be supported by LAA
  - Listen-before-talk (LBT)
    - An equipment applies a clear channel assessment (CCA) check before using the channel
    - CCA utilizes at least energy detection to determine the presence or absence of other signals on a channel
  - Discontinuous transmission on a carrier with limited maximum transmission duration
    - In Japan, the maximum duration of a transmission burst is 4 ms
  - Dynamic frequency selection (DFS)
    - To detect interference from radar systems
    - Change different carriers on a relatively slow time scale

Design Targets of LAA

- Carrier selection
  - There is a large available bandwidth of unlicensed spectrum
  - To select the carriers with low interference
- Transmit Power Control (TPC)
  - A device should be able to reduce the transmit power in a proportion of 3dB or 6dB compared to the maximum nominal transmit power

Design Targets of LAA

- Other LAA functions include
  - Synchronization
  - Automatic gain control (AGC)
  - Channel reservation
  - Channel state information (CSI) measurement and report
  - Multi-carrier power allocation
  - DL and UL scheduling and HARQ
  - Channel access scheme (Listen-before-talk)
  - UL transmissions

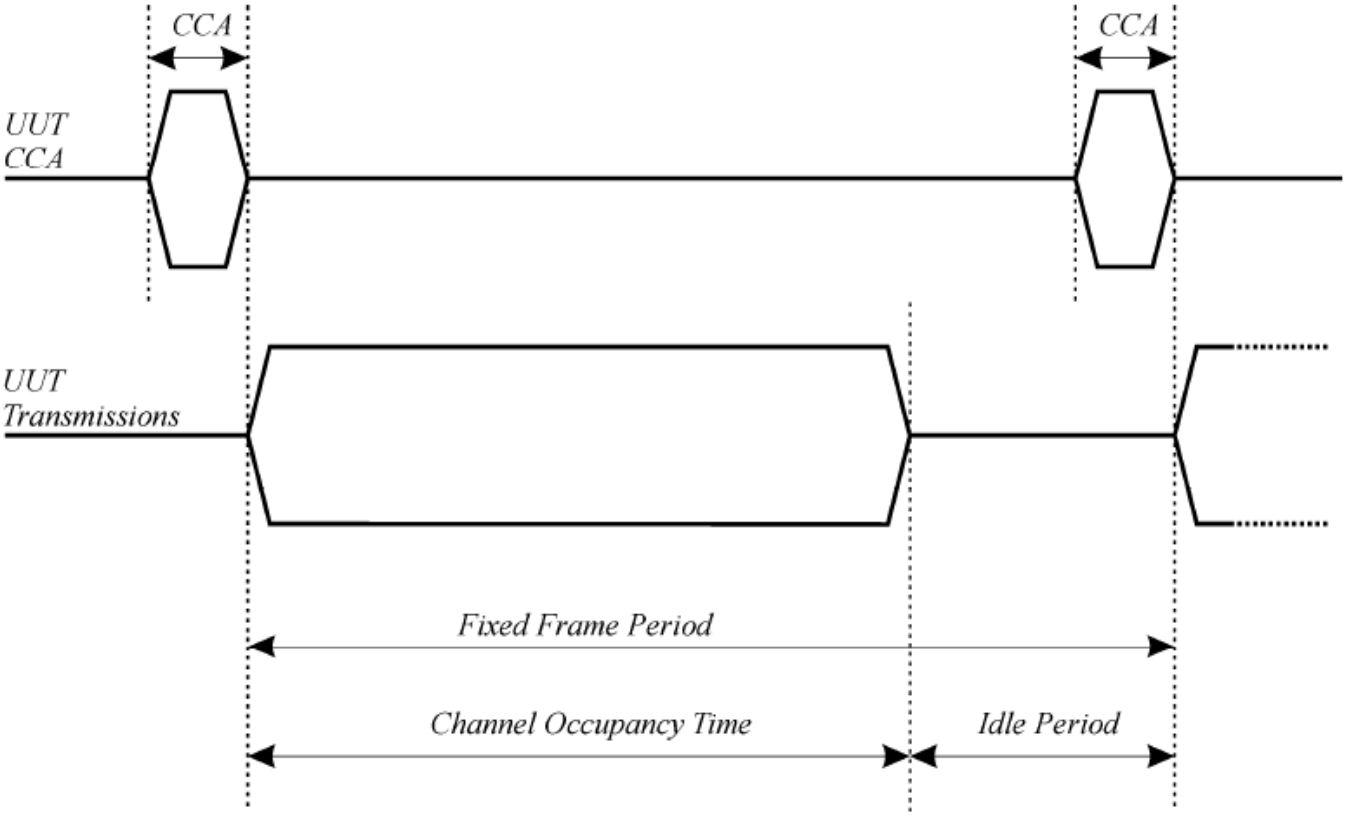
Listen-Before-Talk (LBT) for LAA

- In ETSI 301 893 V1.8.0, two types of LBT are defined
  - Frame based equipment (FBE)
  - Load based equipment (LBE)

- Frame based equipment (FBE)
  - Before starting transmissions on an Operating Channel, the equipment shall perform a CCA check using "energy detect".
    - Observe the channel for at least 20 μs
  - If the equipment finds the operating channel(s) to be clear, it may transmit immediately for a channel occupation time (1-10 ms)
  - If the equipment finds an operating channel to be occupied, it shall not transmit on that channel during the next Fixed Frame Period.
  - Upon correct reception of a packet intended for this equipment, can skip CCA and immediately proceed with the transmission of management and control frames (e.g. ACK and Block ACK frames).

Listen-Before-Talk (LBT) for LAA

- The operation of FBT

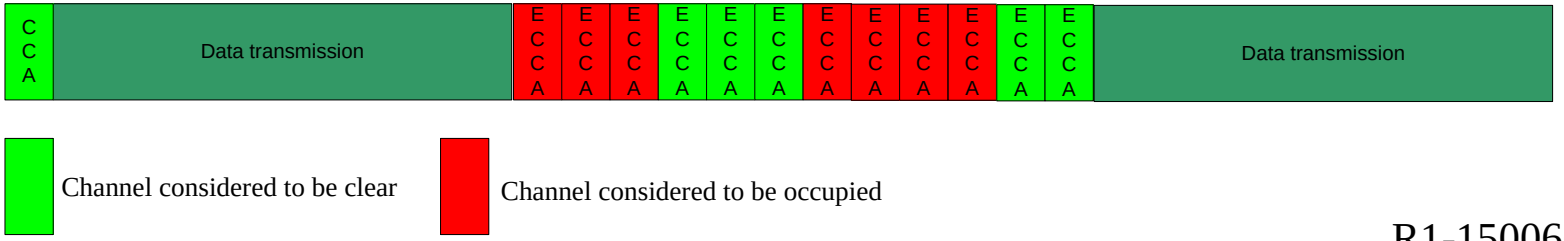


Listen-Before-Talk (LBT) for LAA

- Load based equipment (LBE)
  - Before starting transmissions on an operating channel, the equipment shall perform a CCA check using "energy detect".
    - Observe the channel for at least 20 μs
  - If the equipment finds the operating channel(s) to be clear, it may transmit immediately for a channel occupation
  - If the equipment finds an Operating Channel occupied, it shall not transmit on that channel and perform extended CCA check
    - Operating Channel is observed for the duration of a random factor N multiplied by the CCA observation time.
    - N ranges within [1, q], q is selected within [4, 32] and the value of N is stored in a counter
    - The counter is decremented every time a CCA slot is considered to be "unoccupied". When the counter reaches zero, the equipment may transmit.

Listen-Before-Talk (LBT) for LAA

- An example of LBE when *N*=5



R1-150066

Listen-Before-Talk (LBT) for LAA

- In Release 13, DL-only LAA is primarily specified
- DL+UL LAA should be agreed, but not specified in Release 13
  - UL for LAA SCells can be added in future release without modifications to the DL design

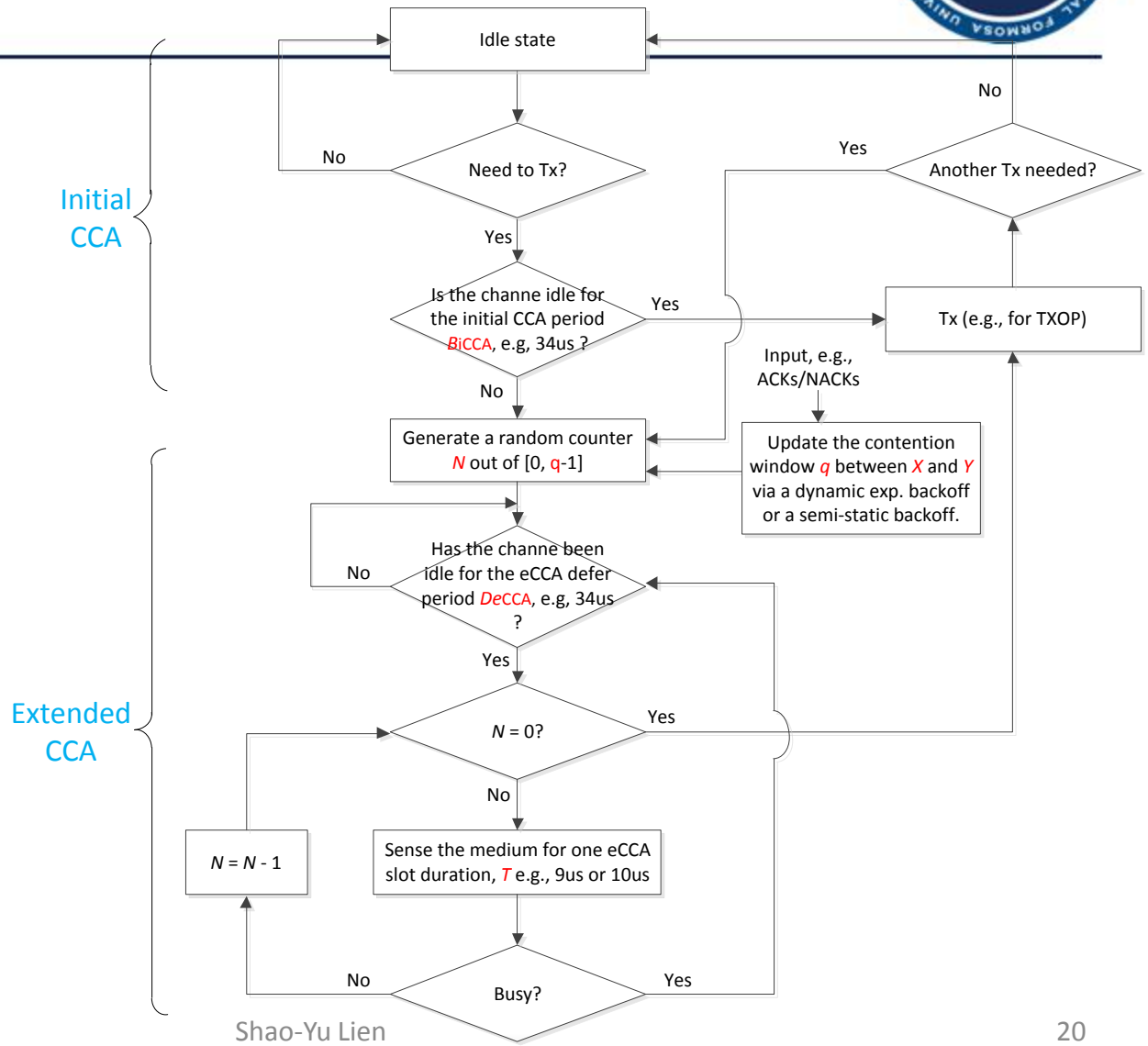
- For DL LAA, the performance of four categories of radio access schemes are evaluated
  - Category 1: No LBT.
  - Category 2: LBT without random back-off. (e.g. ETSI Frame Based Equipment)
    - The duration of time that the channel is sensed to be idle before the transmitting entity transmits is deterministic.

Listen-Before-Talk (LBT) for LAA

- Category 3: LBT with random back-off with a fixed contention window size. (e.g. ETSI Load Based Equipment)
  - The transmitting entity draws a random number N within a contention window. The size of the contention window is specified by the minimum and maximum value of N. The size of the contention window is fixed.
- Category 4: LBT with random back-off with a variable contention window size.
  - The transmitting entity draws a random number N within a contention window. The size of contention window is specified by the minimum and maximum value of N. The transmitting entity can vary the size of the contention window when drawing the random number N.

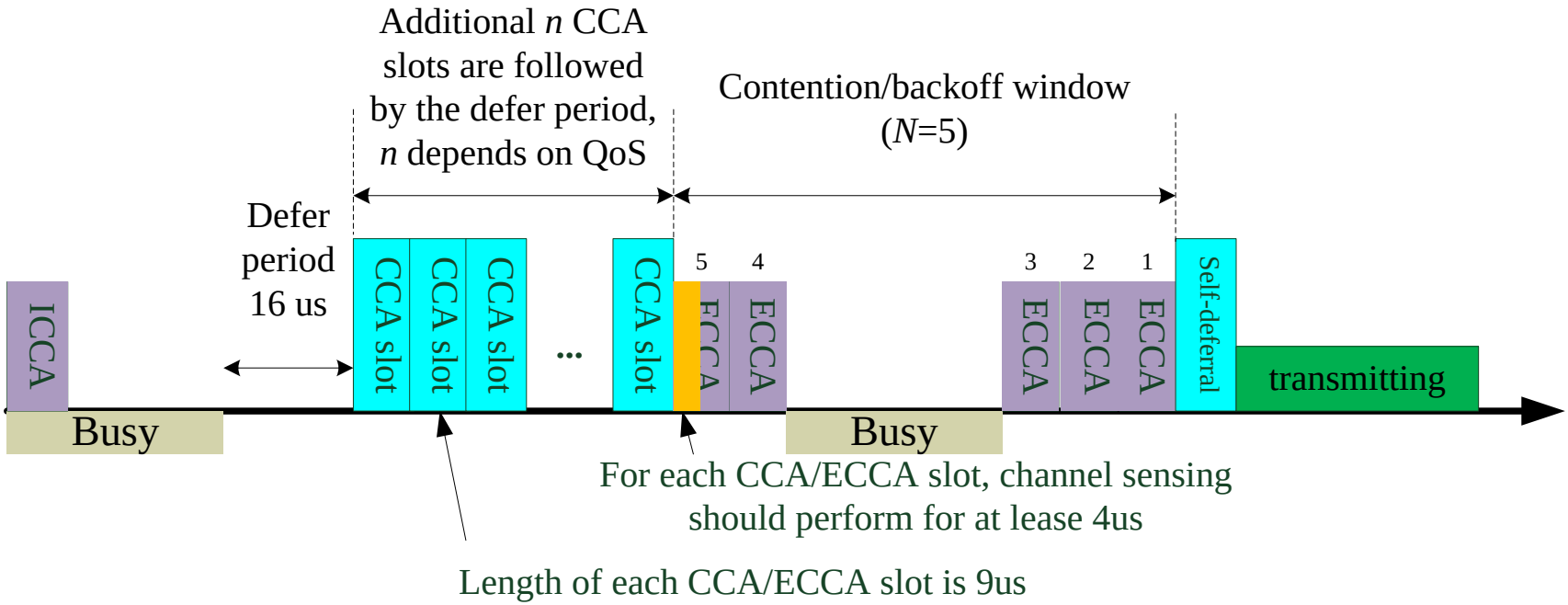
Listen-Before-Talk (LBT) for LAA

- For Category 4, the following LBT procedure is considered



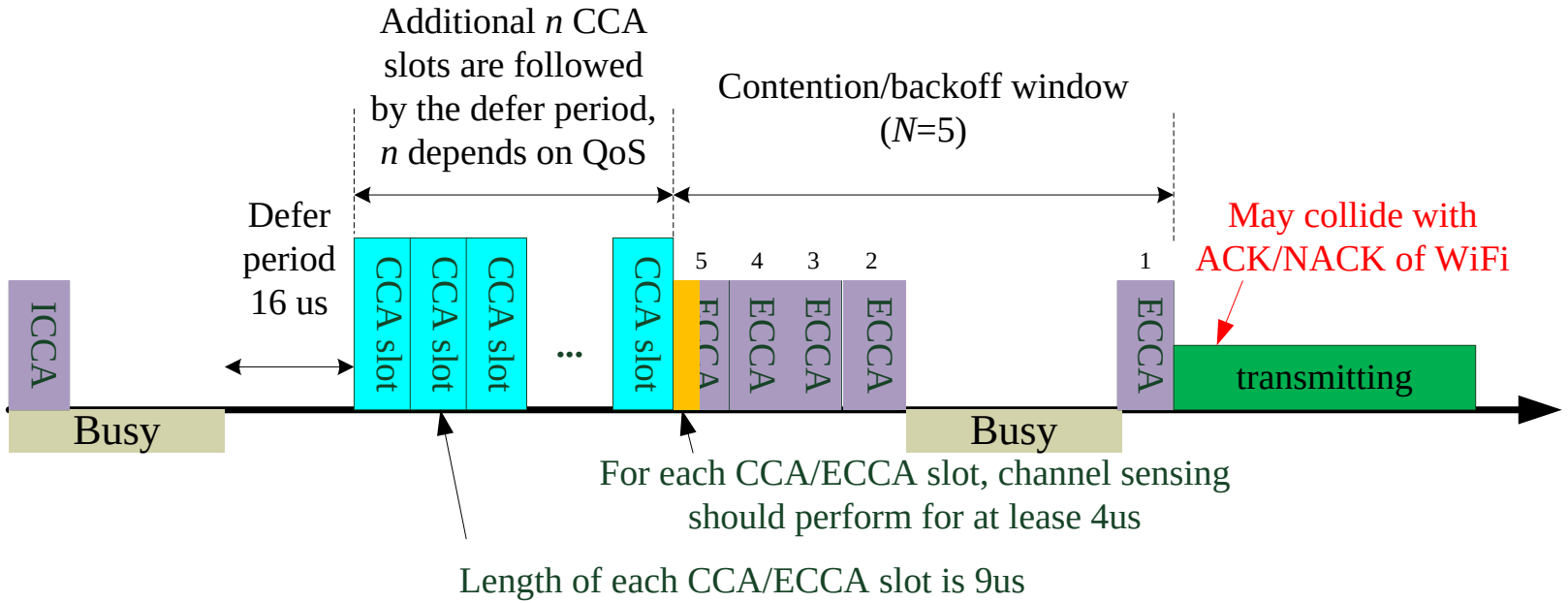
Listen-Before-Talk (LBT) for LAA

- After performance evaluation, for DL, the LBT operates as follows



Listen-Before-Talk (LBT) for LAA

- Self-deferral
  - When the counter reaches 0, CCA check is performed for at lease one more CCA slot
  - Why? SIF of IEEE 802.11a/n/ac is 16us (i.e., at least two CCA slots)



Listen-Before-Talk (LBT) for LAA

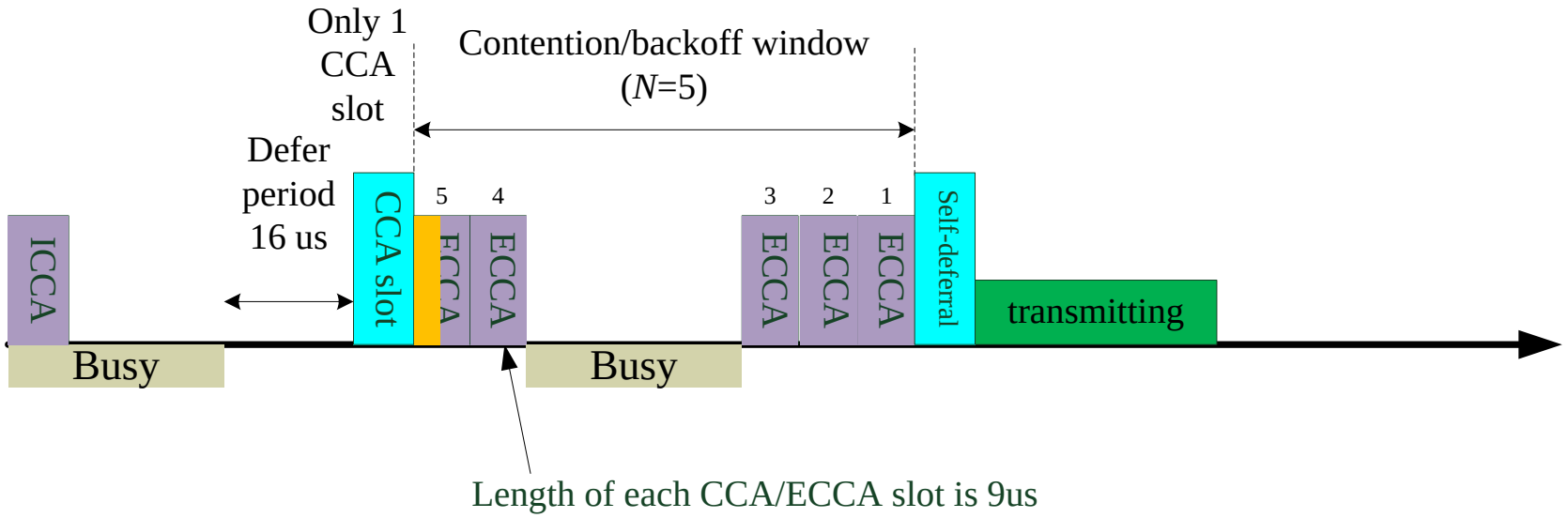
- For DL, the following two schemes are studied to dynamically adjust the contention window size
  - Based on HARQ ACK/NACK feedback
    - Contention window size adjustment of IEEE 802.11 is based on ACK/NACK feedback
    - Details of how to use HARQ ACK/NACK feedback are FFS
  - Based on eNB medium sensing based metrics
    - Option 1: Number of busy periods between transmissions
      - A busy period is the total time the channel is occupied between two idle CCA slots
    - Option 2: Number of idle slots (or) ratio of the number of idle to busy slots within a defined observation window

Listen-Before-Talk (LBT) for LAA

- In an LTE SCell, a UE does not transmit any signals unless explicitly scheduled by the eNB
  - UE channel access is coordinated by eNB to avoid collision and uncontrolled congestion
- LAA supports uplink LBT at the UE
  - In LAA systems, where the UE's uplink transmissions are controlled by the eNB, the uplink channel access scheme can be different from DL channel access for an LAA Scell

Listen-Before-Talk (LBT) for LAA

- For UL, the LBT operates as follows



- The backoff counter for UL is generated by eNB within the determined contention window size (CWmin=1, CWmax=X) and is informed to a UE

Scheduling in LAA

- There are two types of carriers for LAA
  - Licensed carriers
    - There can be one to multiple carriers in licensed spectrum supported by LAA
  - Unlicensed carriers
    - There can be one to multiple carriers in unlicensed spectrum supported by LAA
- For these two types of LAA, there are two categories of radio resource scheduling in LAA
  - Self-scheduling
    - DCI/UCI is announced using the same carrier of PDSCH/PUSCH
  - Cross-carrier scheduling
    - DCI/UCI is announced using different carriers of PDSCH/PUSCH

Scheduling in LAA

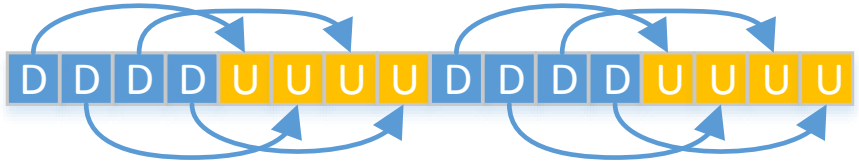
- The following possible scheduling combinations for a LAA CC are identified
  - Combination 1: DL/UL: self-scheduling
    - Using ePDCCH based grant for DL. TX power of ePDCCH is reduced by 9.2 dBm
    - For UL, if the DL buffer is not empty, then UL grant is multiplexed by DL transmissions
    - For UL, if the DL buffer is empty, then ePDCCH is also adopted to provide UL grants
  - Combination 2: DL: self-scheduling; UL: cross-carrier scheduling
    - Using ePDCCH based grant for DL. TX power of ePDCCH is reduced by 9.2 dBm
    - For UL, scheduling grant is provided on licensed spectrum

Scheduling in LAA

- ~~Combination 3: DL: cross-carrier scheduling; UL: self-scheduling~~
  - ~~For DL, scheduling grant is provided on licensed spectrum~~
  - ~~For UL, ePDCCH (or other schemes) is adopted to provide UL grants~~
- Combination 4: DL/UL: cross-carrier scheduling from a same scheduling CC
  - For both UL and DL, scheduling grant is provided on licensed spectrum
  - This combination is FFS

Scheduling in LAA

- Contention window size for UL should be smaller than that for DL to reduce latency and enhance throughput
  - For high traffic load in DL, UL has a larger opportunity to be scheduled and transmitted



  - For low traffic load in DL, additional overheads of DL are needed to provide UL grant
  - DL needs additional LBT

Scheduling in LAA

- LAA may also support multiple carrier transmission
- Two design alternatives are studied
  - Each carrier on unlicensed spectrum performs LBT individually
  - A single LBT is performed for all carriers on unlicensed spectrum
- To avoid wrong LBT from adjacent-carrier self-interference, the concept of self-deferral is also reused
  - During the eCCA procedure, the backoff counter does not have to be decremented when a slot is sensed to be idle.
- Self-deferral also applied
  - To limited number of starting points
  - To align TX start timing

Other Design Considerations for LAA

- Energy detection (ED) threshold for CCA
  - ED threshold of WiFi is -62dBm
  - Adjustable ED threshold within [-62dBm, -75dBm] is studied
  - RAN1 shall identify adaptation rules for LAA to adaptively lower the maximum energy detection threshold to ensure co-existence with other RATs including WiFi and good performance of LAA
- DRS/PSS/SSS transmissions
- CRS/DMRS transmissions
- RRM measurement and report
- Frame structure of LAA

Summary

- Release 13 work item started in June 2015 with core work to be completed by Dec 2015.
- Key Objectives
  - Single global solution framework for LAA in 5 GHz unlicensed
  - Fair coexistence between Wi-Fi and LAA and between LAA
  - Only specify support for DL-only LAA
  - The following for the UL should be agreed (but not specified)
  - The 5 GHz band/bands definition should include DL only and UL/DL operations (without UL requirements being defined in Rel-13)
- Operated based on LBT

Thank You

Appendix:

Comparison between 3GPP LAA and IEEE 802.11 (ac/ax)

Transmission Schemes

- Synchronous/asynchronous operations
  - In LAA, synchronous operations are adopted, by which, all UEs needs to align with the timing of an eNB all the time
  - In WiFi, asynchronous operations are adopted, by which, all receivers only capture the preamble of each transmission burst
- Radio access
  - In LAA, all resources are scheduled by eNBs
  - In WiFi, STAs randomly access (based on DCF) radio resources
    - IEEE 802.11ax has a certain scheduling capability
- Timing
  - In LAA, the time domain resources are divided into (ECCA/CCA) slots and the length of each slot is 9us
  - In WiFi, the same operation is adopted

Transmission Schemes

- Information for channel occupation
  - In WiFi, each STA is aware of the length of channel occupation by other STAs using NAV
  - In LAA, this information is held by an eNB and each UE is not aware of this information
- UL transmissions
  - In WiFi (IEEE 802.11ax), UL transmissions can immediately occur when a triffer_frame message from AP is received by a STA. A STA does not need to perform LBT
  - In LAA, avoiding LBT for UL may only be allowed when the time gap between DL and UL transmissions is less than 16 us (under discussion)

LBT Schemes

- "Clear" and "busy" slot
  - In LAA, energy detection needs to be performed at each ECCA/CCA slot for at least 4us
  - In WiFi, energy detection needs to be performed at each slot to provide a 90% confidence
- CCA
  - In LAA, energy detection threshold less than -77dBm is discussed
  - In WiFi, energy detection threshold is -62dBm, and preamble detection threshold is -82 dBm
- Defer period
  - In LAA, 16us+*n* slot is adopted, *n* depends on QoS level
  - In WiFi, AIFS, SIFS, DIFS, PIFS are adopted

LBT Schemes

- Contention/backoff window size
  - In LAA, the following contention window size is studied

Level	Priority	n	CW_{min}	CW_{max}	$TxOP_{max}$
Highest	Voice	2	3	7	1.5 ms
Next highest	Video	2	7	15	3.0 ms
Typical	Best effort	3	15	1023	4.0 ms
Lowest	Background	7	15	1023	4.0 ms

  - In WiFi, a similar contention window size is adopted

Acknowledgement and TX power

- ACK/NACK
  - In LAA, delayed ACK/NACK is adopted
  - In WiFi, immediate ACK/NACK is adopted
- DL transmission power for 20 MHz bandwidth
  - In LAA eNB, 23dBm TX power is evaluated
  - In WiFi, 13-17 dBm TX power is adopted due to cost down considerations

Length of Each Transmission Burst

- Transmission length
  - In LAA, a maximum transmission length between 4ms (regulation in Japan) and 10ms (regulation in ETSI) is discussed
  - In WiFi, each TXoP length is 3ms-5.5ms (max)