

# Licensed-Assisted Access to Unlicensed Spectrum – An Overview

Havish Koorapaty  
Study and Work Item Rapporteur  
(Ericsson Inc.)

# Outline



## Introduction

## 3GPP LAA study and work item overview

- Listen-before-talk and channel access schemes
- Coexistence evaluation methodology
- Study item conclusions
- Work item overview

## Conclusions

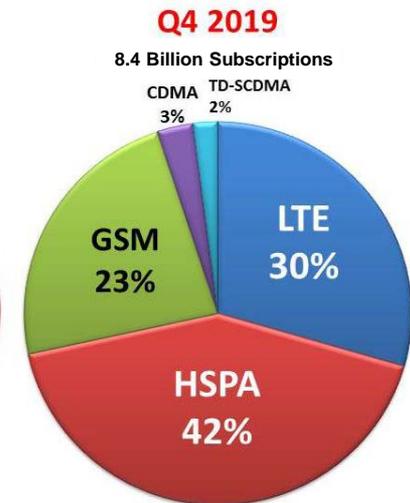
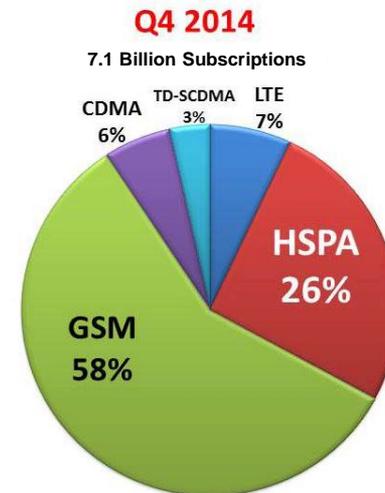
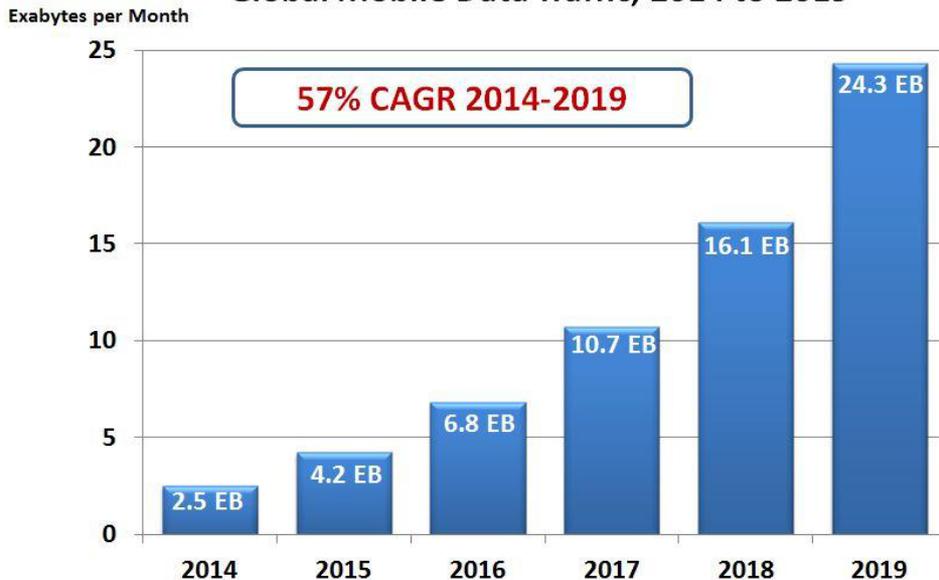
## Introduction – 3GPP

- 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group (TSG) level.
- Approval of Technical Specifications and Technical reports by a TSG shall normally be by consensus.
- Further information on 3GPP and its ways of working may be found at <http://www.3gpp.org/>.

# Introduction – LTE

- 📶 LTE (Long Term Evolution) is the most advanced 3GPP access technology
- 📶 LTE will play a key role in meeting global mobile data traffic demand

Global Mobile Data Traffic, 2014 to 2019



\* Figures from "Mobile Broadband Evolution Towards 5G: Rel-12 & Rel-13 and Beyond", 4G Americas, June 2015.

# Introduction – Licensed Assisted Access

- 📶 Licensed spectrum remains 3GPP operators' top priority to deliver advanced services and user experience
- 📶 Opportunistic use of unlicensed spectrum has become an important complement for operators to meet growing traffic demands
- 📶 Technology options for operators to choose and combine:
  - Wi-Fi (via LTE/Wi-Fi integration and interworking)
  - LTE (via Licensed-Assisted Access)

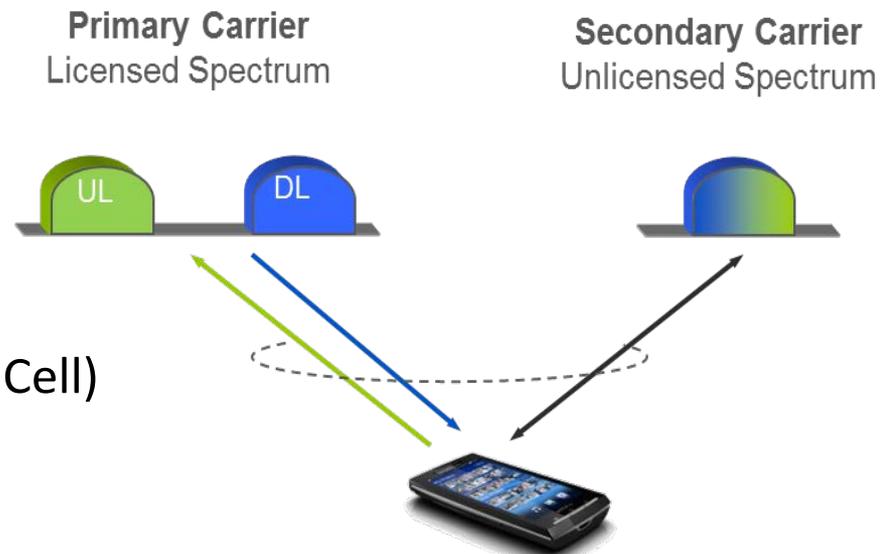
# Licensed Assisted Access

Unlicensed spectrum as performance booster managed by a licensed carrier

- Small cells planned and deployed by operators

Carrier aggregation framework

- Licensed band PCell (Primary Cell)
  - Reliable control signaling
  - Mobility (handover)
  - Carrier grade real-time services with LTE QoS
- Unlicensed band SCell (Secondary Cell)
  - Primarily best effort data



# 3GPP Rel-13 LAA

- 📶 The feature is targeting completion in Rel-13, which is scheduled to freeze in Mar. 2016
- 📶 Study Item started in Sept. 2014 and completed in June 2015, work item started in June 2015
  - Focus on 5 GHz
  - Single global solution framework
  - Fair LTE - Wi-Fi & LTE – LTE coexistence
    - LAA should not impact Wi-Fi services more than an additional Wi-Fi network on the same carrier
  - Study item considered both DL-only LAA operation and DL+UL LAA operation
  - Work item focus is on DL-only LAA operation

# Liaison Statements Exchanged with ETSI BRAN, IEEE and Wi-Fi Alliance



## Incoming

- RP-141747, LS on Coexistence Lessons Learned, IEEE 802 LMSC
- RP-150024, LS regarding coexistence of Licensed Assisted Access (LAA) and IEEE 802, IEEE 802 LMSC
- RP-150543, LS regarding clarification of LBT Categories and LAA/802.11 Coexistence (IEEE802\_LMSC\_LS\_150318; to: RAN, RAN1; cc: IEEE 802.19 Coexistence WG; contact: Chairman IEEE 802 LMSC)
- RP-150566, LS as follow-up regarding LAA (IEEE802\_LMSC\_LS\_150518; to: RAN, RAN1; cc: IEEE 802, IEEE 802.19 Coexistence WG; contact: Chairman IEEE 802 LMSC)
- RP-150545, Reply LS to RP-150505 on Licensed-Assisted Access (BRAN(15)000015r2)
- RP-151137, Reply LS to RP-151098 on Progress of work on Adaptivity in EN 301 893 (ETSI\_BRAN(15)000105r1)

## Outgoing

- RP-150454 Response LS to IEEE\_802\_LMSC\_150202 = RP-150024 regarding Coexistence of Licensed Assisted Access (LAA) and IEEE 802 (to: IEEE 802 LMSC)
- RP-150505 LS on Licensed-Assisted Access (to: ETSI BRAN)
- RP-151098 LS on Licensed-Assisted Access (to: ETSI BRAN)
- RP-150551, Response LS to IEEE802\_LMSC\_LS\_150318 = RP-150543 on Clarification of LBT Categories (R1-152182)
- RP-150553, Response LS to IEEE802\_LMSC\_LS\_150318 = RP-150543 on LAA-802.11 Coexistence (R1-152183)
- RP-150570, Response LS to IEEE802\_LMSC\_LS\_150518 = RP-150566 related to LAA-802.11 Coexistence (R1-153659)

# External Presentations on LAA



- 📶 RP-150055 RAN chair's presentation on "3GPP & unlicensed spectrum" at IEEE 802 Interim Session, 11-16.01.2015, Atlanta, USA, RAN chairman (Qualcomm)
- 📶 RP-150054 RAN chair's presentation on "3GPP & unlicensed spectrum" at WFA Board of Directors, Feb. 23, 2015, RAN chairman (Qualcomm)
- 📶 RP-150564 Report about Study on Licensed-Assisted Access to Unlicensed Spectrum provided by SI rapporteur to IEEE 802 Interim Session in Vancouver, Canada on 12.05.2015, Ericsson (rapporteur)
- 📶 RP-150565 Report about Study on Licensed-Assisted Access to Unlicensed Spectrum provided by SI rapporteur in a phone conference of the Wi-Fi Alliance (WFA) CoX TG (coexistence task group) on 19.05.2015, Ericsson (rapporteur)

# LAA Study Item

 Addressed the following:

- Regulatory requirements
- Deployment scenarios
- Design targets, functionalities and solutions for LAA
- Coexistence methodology and evaluations

 3GPP Technical Report 36.889

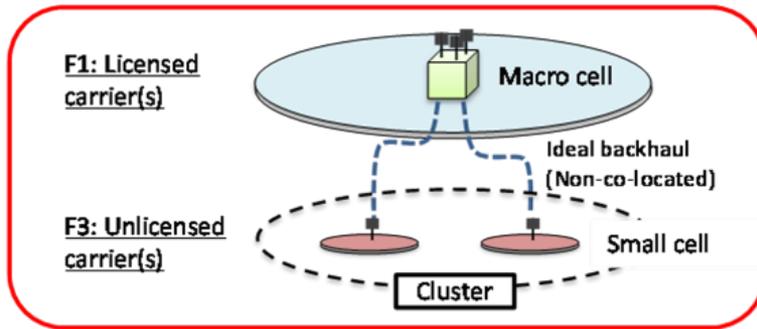
- Approved report at  
<http://www.3gpp.org/dynareport/36889.htm>

## Regulatory Aspects

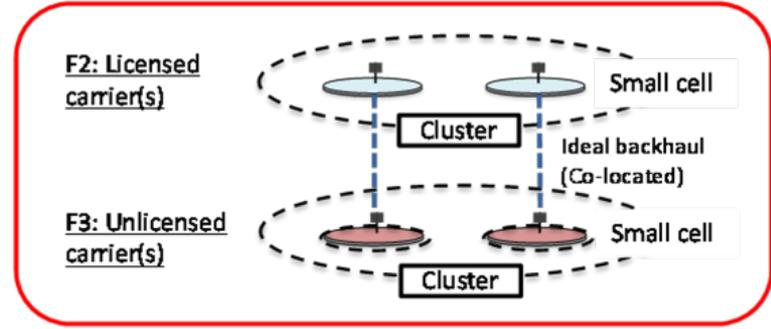
- Produced an overview of the regulatory requirements for unlicensed operation in 5 GHz
  - Covering USA, Canada, Mexico, Europe, Israel, Russia, South Africa, Turkey, China, Japan, Korea, India, Taiwan, Singapore, Australia
- Documented requirements in terms of
  - Power and power spectral density levels
  - Maximum channel occupancy
  - Channel sensing
  - Channel bandwidth
  - etc

# Deployment Scenarios

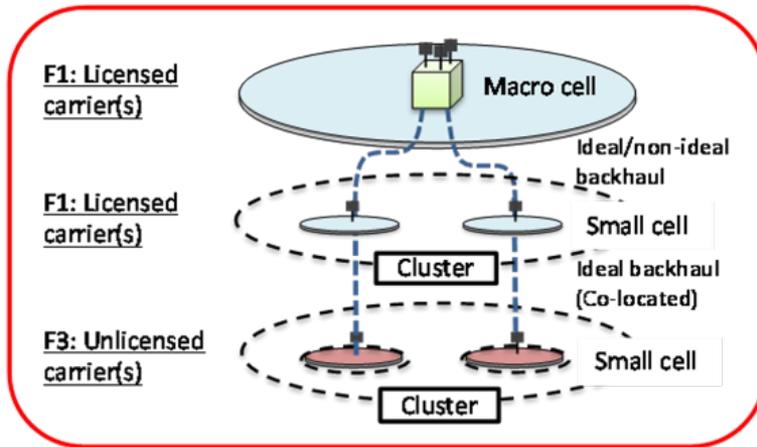
### Scenario 1



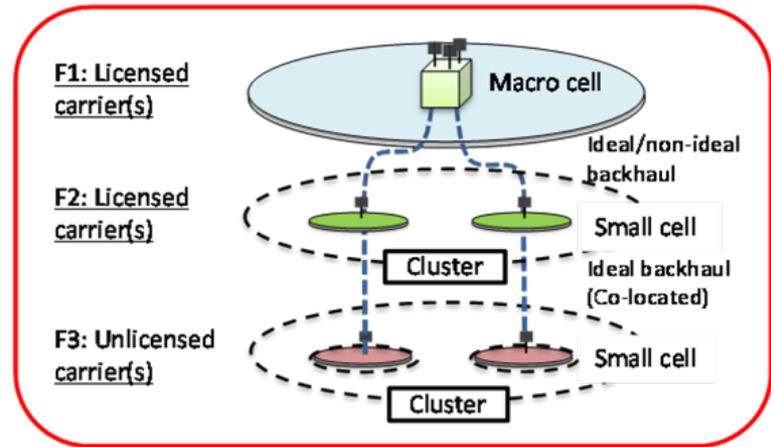
### Scenario 2



### Scenario 3



### Scenario 4



A LAA carrier is always operated together with a licensed band primary carrier.

# Design Targets & Functionalities

- 📶 Agreed design targets:
  - Single global solution framework allowing compliance with any regional regulatory requirements
  - Fair coexistence with Wi-Fi
  - Fair coexistence among LAA networks deployed by different operators
  
- 📶 Based on the above targets, it was agreed that at least the following functionalities are required for LAA:
  1. Listen-before-talk (Clear channel assessment)
  2. Discontinuous transmission on a carrier with limited maximum transmission duration
  3. Dynamic Frequency Selection for radar avoidance in certain bands/regions
  4. Carrier selection
  5. Transmit Power Control
  6. Others including Radio Resource Management (RRM), AGC, Synchronization and channel measurements

# LAA Solutions

 Aspects for which solutions were studied to support required functionalities include

- Synchronization, AGC, channel reservation
- Radio resource management (RRM) and reporting
- Channel state information measurements and reporting
- DL transmission modes and timing, multi-carrier power allocation
- DL and UL Scheduling and HARQ
- Channel access schemes (Listen-before-talk design)
- UL transmissions

 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

# Classification of Channel Access Schemes

## Category 1: No LBT

- No LBT procedure is performed by the transmitting entity.

## Category 2: LBT without random back-off

- The duration of time that the channel is sensed to be idle before the transmitting entity transmits is deterministic. (e.g. ETSI Frame Based Equipment)

## Category 3: LBT with random back-off with a fixed contention window size

- 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. The random number  $N$  is used in the LBT procedure to determine the duration of time that the channel is sensed to be idle before the transmitting entity transmits on the channel.

## 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  $N$ . The random number  $N$  is used in the LBT procedure to determine the duration of time that the channel is sensed to be idle before the transmitting entity transmits on the channel.

# Channel Access Schemes

## Illustrative examples for LBT categories

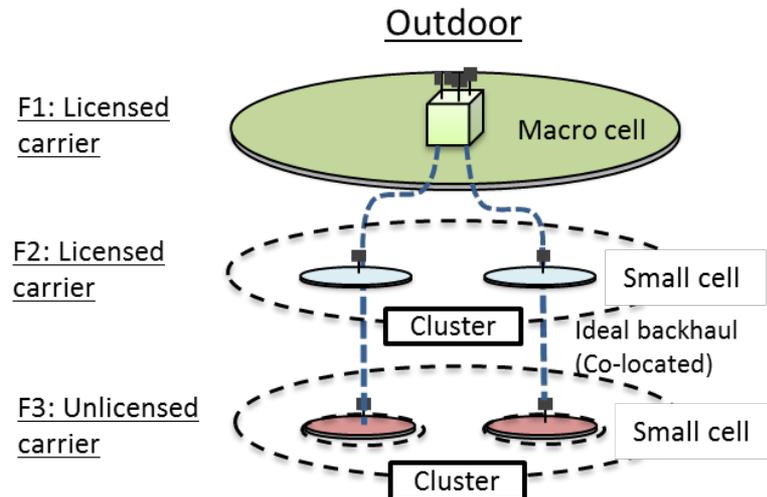
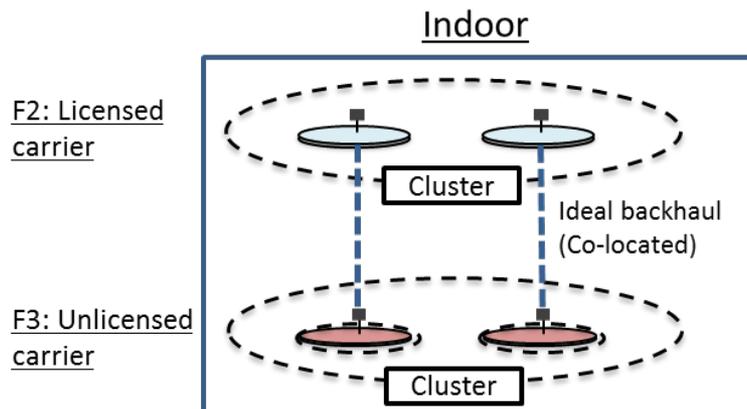
- Frame based equipment (FBE) procedure as defined in EN 301 893 V1.8.0 belongs to category 2
- Load based equipment (LBE) procedure Option B with a fixed contention window as defined in EN 301 893 V1.8.0 belongs to category 3
- A LBE procedure Option B extended with a contention window increase similar to Wi-Fi belongs to category 4

## Category 2, 3 and 4 schemes were evaluated

- Cat. 2 schemes mainly based on the ETSI FBE procedure
- Cat. 3 schemes mainly based on ETSI op. B with/without modifications
- Cat. 4 schemes based on a framework that includes a channel access scheme similar to that used by Wi-Fi

# Coexistence Evaluation Scenarios

- Indoor and Outdoor scenarios with co-located licensed and unlicensed carriers
  - Licensed carrier for small cell and macro cell are different in Outdoor scenario
  - One licensed carrier and one or four unlicensed carriers
  - Simulation methodology for Outdoor carriers assume an unmanaged Wi-Fi network

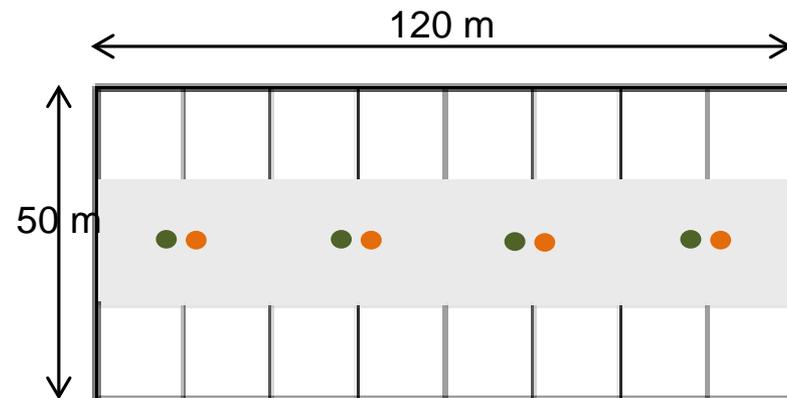


- Scenarios also used for adjacent channel coexistence evaluations

# Coexistence Evaluation Scenarios

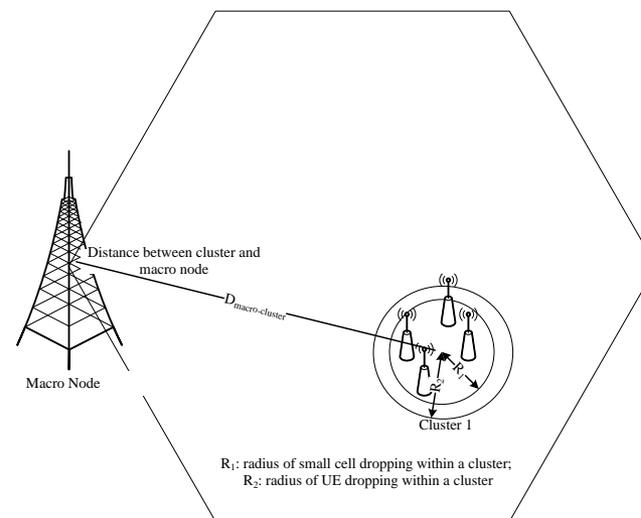
## Indoor scenario

- Two operators deploy 4 small cells each in the single-floor building.
- Regular spacing for each operator
- The distance between two closest nodes from two operators is random.
- The set of small cells for both operators is centered along the longer dimension of the building.



## Outdoor scenario

- Clusters uniformly random within macro geographical area
- Two operators with 4 small cells per operator, uniformly random dropping within cluster area.



## Methodology for Wi-Fi – LAA coexistence

- For each UE and eNB/AP drop
  - Step 1: Performance metrics for two Wi-Fi networks coexisting in a given evaluation scenario are evaluated and recorded.
  - Step 2: Wi-Fi is replaced with LAA for the group of eNBs and UEs served by one of the Wi-Fi operators. Performance metrics of the Wi-Fi network coexisting with the LAA network are evaluated and recorded.
- A comparison of the performance metrics between the two steps for the Wi-Fi network that was not replaced with LAA can be used to evaluate coexistence between LAA and Wi-Fi in an unlicensed band

## Methodology for LAA – LAA coexistence

- Performance metrics for two LAA operators coexisting in a given evaluation scenario are evaluated and recorded.
- A comparison of the performance metrics for the two LAA operators can be used to evaluate coexistence between two LAA operators in an unlicensed band.

# Coexistence Evaluations - Traffic Models and Performance Metrics

## Traffic models

- FTP model (model 3 or 1 as in TR 36.814)
  - 0.5 MB file size with variable Poisson arrival rate ( $\lambda$ ) to control traffic load
- Mixed traffic model (optional)
  - UEs with VoIP traffic in addition to UEs with FTP traffic

## Performance metrics reported include

- User-perceived throughput (UPT)
- Latency
- For VoIP, number of UEs with 98%ile latency > 50 ms
- Mean buffer occupancy (BO)
- Ratio of served to offered traffic ( $\rho_{DL}$  and  $\rho_{UL}$ )

# Coexistence Evaluation Cases



## Three cases for Wi-Fi – LAA coexistence

- DL-only LAA network coexisting with a Wi-Fi network having only DL traffic (Wi-Fi ACKs modeled)
  - 10 UEs per unlicensed band carrier per operator
- DL-only LAA network coexisting with a Wi-Fi network having DL and UL traffic
  - 20 UEs per unlicensed band carrier per operator (Up to 50 UEs evaluated by some sources)
  - 80-20 and 50-50 DL-UL traffic split
- LAA network coexisting with a Wi-Fi network where both networks have DL and UL traffic
  - 20 UEs per unlicensed band carrier per operator
  - 50-50 DL-UL traffic split

## More details on evaluation assumptions in TR

- Some cases added/modified based on input from incoming LSs (Category 4 LBT, increased number of users, 256 QAM, LDPC, RTS/CTS, DL+UL in non-replaced Wi-Fi network, TxBF, CL MCS/rank adaptation, short GI)

# Reported Results –Template for DL-only LAA with DL+UL Wi-Fi



A GLOBAL INITIATIVE

Reported parameters		Low load BO range for Wi-Fi Opt.1 in Step 1: 10%~25%				Medium load BO range for Wi-Fi Opt. 1 in Step 1: 35%~50%				High load BO range for Wi-Fi Opt.1 in Step 1: above 55%			
		Wi-Fi Opt.1 in step 1	Wi-Fi Opt.2 in step 1	Wi-Fi Opt. 1 in step 2	LAA Opt.2 in step 2	Wi-Fi Opt.1 in step 1	Wi-Fi Opt.2 in step 1	Wi-Fi Opt. 1 in step 2	LAA Opt.2 in step 2	Wi-Fi Opt.1 in step 1	Wi-Fi Opt.2 in step 1	Wi-Fi Opt. 1 in step 2	LAA Opt.2 in step 2
<b>DL:</b> UPT CDF [Mbps]	5%												
	50%												
	95%												
	Mean												
<b>DL:</b> Delay CDF [s]	5%												
	50%												
	95%												
	Mean												
<b>UL:</b> UPT CDF [Mbps]	5%		N/A		N/A		N/A		N/A		N/A		N/A
	50%		N/A		N/A		N/A		N/A		N/A		N/A
	95%		N/A		N/A		N/A		N/A		N/A		N/A
	Mean		N/A		N/A		N/A		N/A		N/A		N/A
<b>UL:</b> Delay CDF [s]	5%		N/A		N/A		N/A		N/A		N/A		N/A
	50%		N/A		N/A		N/A		N/A		N/A		N/A
	95%		N/A		N/A		N/A		N/A		N/A		N/A
	Mean		N/A		N/A		N/A		N/A		N/A		N/A
VoIP outage			N/A		N/A		N/A		N/A		N/A		N/A
VoIP outage (DL)			N/A		N/A		N/A		N/A		N/A		N/A
VoIP outage (UL)			N/A		N/A		N/A		N/A		N/A		N/A
$\rho_{DL}$													
$\rho_{UL}$			N/A		N/A		N/A		N/A		N/A		N/A
BO													
$\lambda$													
Company/tdoc, LBT category, Additional information													

# Reported Results



- 📶 Considering 5<sup>th</sup>, 50<sup>th</sup>, 95<sup>th</sup> percentile and mean UPT and delay metrics in addition to VoIP outage metrics at low, medium and high loads for both DL and UL, each evaluation report can contain up to more than 200 metrics with 50 metrics used for comparison to evaluate coexistence.
- 📶 Over 380 coexistence evaluation reports were submitted and included in the Technical Report. Detailed analysis of the evaluation reports can be found in Section 8.3 of the Technical Report..

# High Level Observations from Coexistence Evaluations



- A majority of sources showed at least one LBT scheme for LAA that does not impact Wi-Fi more than another Wi-Fi network (offering the same traffic to the same users). Within each LBT category, the LBT schemes and/or parameters shown by different sources to not impact Wi-Fi more than another Wi-Fi network may be different.

# High Level Observations from Coexistence Evaluations

## Observations on LBT schemes of different categories:

- All sources that submitted results with a category 1 DL LBT scheme, i.e., no coexistence mechanism implemented by the transmitting node, showed that it cannot operate without impacting Wi-Fi in at least some of the measured performance metrics.
- An LAA network operating a category 2 DL LBT scheme based on the ETSI FBE procedure [4] can operate without impacting Wi-Fi more than an equivalent Wi-Fi network. Further discussion may also be needed on the coexistence performance between two LAA networks, especially for the case where the LBT sensing periods of the two operators' networks are synchronized.
- A majority of sources that evaluated an LAA network operating a category 3 DL LBT scheme based on ETSI Option B [4] with modifications including at least a defer period showed that it can operate without impacting Wi-Fi more than another Wi-Fi network.
- A majority of sources that evaluated an LAA network operating a category 4 DL LBT scheme based on ETSI Option B with modifications including at least defer periods and variable (exponential) contention windows showed that it can operate without impacting Wi-Fi more than an equivalent Wi-Fi network.

# High Level Observations from Coexistence Evaluations

-  DL+UL operation: A majority of sources showed combinations of LAA DL and UL LBT schemes that do not impact Wi-Fi more than another Wi-Fi network (offering the same traffic to the same users) in any of the measured performance metrics. Category 3 and 4 were tested for the DL and Categories 1 through 4 were tested for the UL. Within each LBT category, the LBT schemes and/or parameters shown by different sources to not impact Wi-Fi more than another Wi-Fi network may be different.
-  Adjacent channel performance: Based on the simulation results provided in 8.3.3.4, it can be concluded that LAA and Wi-Fi can coexist in adjacent channels. According to the simulation results, LAA causes less adjacent channel interference to a Wi-Fi system compared to another Wi-Fi system. In other words, LAA is a better neighbour than another Wi-Fi system in terms of adjacent channel coexistence with a Wi-Fi system.

# Study Item Conclusions

- 📶 When an appropriate channel access scheme is used, it is feasible for LAA to achieve fair coexistence with Wi-Fi, and for LAA to coexist with itself based on the evaluated scenarios.
- 📶 A study of the major aspects of LTE radio interface architecture, protocol termination, radio interface protocols between UEs and RAN and RRM strategies to support Licensed Assisted Access to unlicensed spectrum was conducted and it was determined that it is feasible to support these aspects for LAA downlink and uplink operations.

# Study Item Conclusions

 Based on the evaluations and findings, the Technical Report recommends that

- The channel access framework defined in section 7.2.1.6 [1] be adopted for LAA. The channel access framework includes a category 4 LBT scheme including random backoff and variable contention windows at least for the downlink data transmissions.
  - The key parameters of the LBT scheme such as contention windows and defer periods should be configurable within limits to enable fair coexistence with other technologies operating in unlicensed spectrum.
- 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 the downlink channel access scheme for an LAA SCell

# Work Item

📶 Work item started in June 2015 with core work to be completed by Dec 2015. Available as [RP-151045](#).

## 📶 Key Objectives:

- Single global solution framework for LAA in 5 GHz unlicensed bands
  - Core technology should be band agnostic as much as possible
- Fair coexistence between Wi-Fi and LAA and between LAA systems
  - Shall be ensured by following the recommendations and conclusions from the TR on LAA and continuing to consider coexistence for the specification work
- Only specify support for DL-only LAA
- The following for the UL should be agreed (but not specified):
  - The principles of UL channel access and the necessary forward compatibility mechanism so that the UL for LAA SCells can be added in future release without modifications to the DL design.
- Define band/bands and a limited set of example band combinations
  - The 5 GHz band/bands definition should include DL only and UL/DL operations (without UL requirements being defined in Rel-13)

## Conclusions

-  LAA study item investigated enhancements to LTE needed for operation in unlicensed bands
  - Coexistence with Wi-Fi is feasible
  - Recommendations for LAA enhancements including adoption of a category 4 LBT mechanism
  
-  Work item to specify Licensed Assisted Access to unlicensed spectrum has commenced
  - Focus on DL-only operation

Thank You!