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Study on Licensed-Assisted Access to Unlicensed Spectrum

Havish Koorapaty

Study Item Rapporteur

(Ericsson Inc.)

Outline

- Introduction to Licensed-Assisted Access
- 3GPP study item status and technical report
- Listen-before-talk and channel access schemes
- Coexistence evaluation methodology
- Conclusions

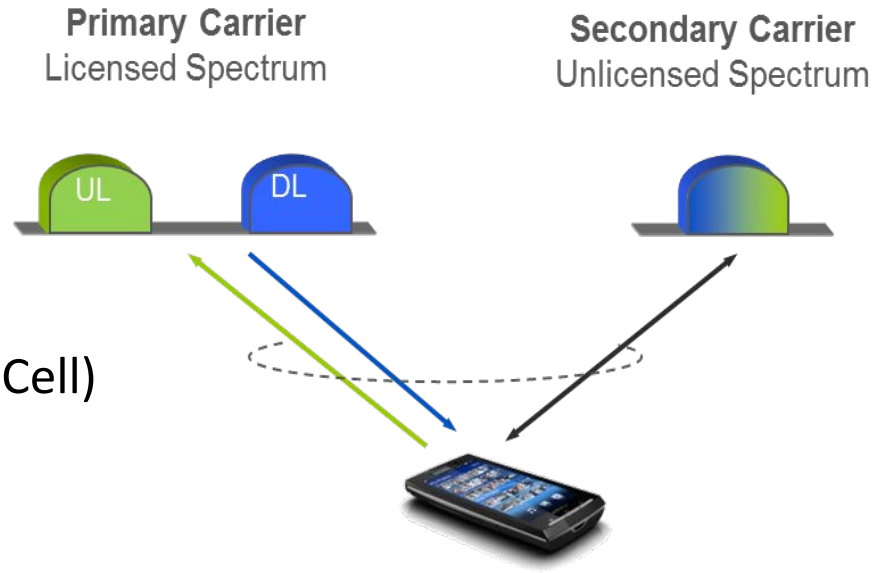
Introduction

- 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
    - Robust/real-time user data with LTE QoS
  - Unlicensed band SCell (Secondary Cell)
    - Primarily best effort data
    - Can be DL-only or DL+UL



3GPP Rel-13 LAA

- The feature is targeting completion in Rel-13, which is scheduled to freeze in Mar. 2016

- Study Item scheduled to complete by 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
  - Consider DL-only LAA operation and DL+UL LAA operation

LAA Study Item

- Started in RAN1 in Q4-14, addressing the following:
  - Regulatory requirements
  - Deployment scenarios
  - Design targets, functionalities and solutions for LAA
  - Coexistence methodology and evaluations

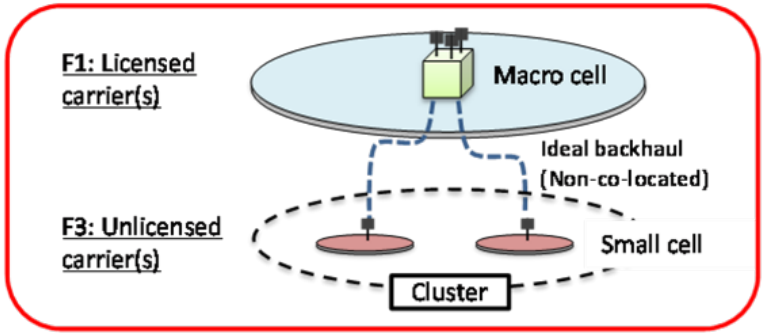
- 3GPP Technical Report 36.889
  - Latest approved revision at http://www.3gpp.org/dynareport/36889.htm
  - Latest draft available in R1-152241

Regulatory Aspects

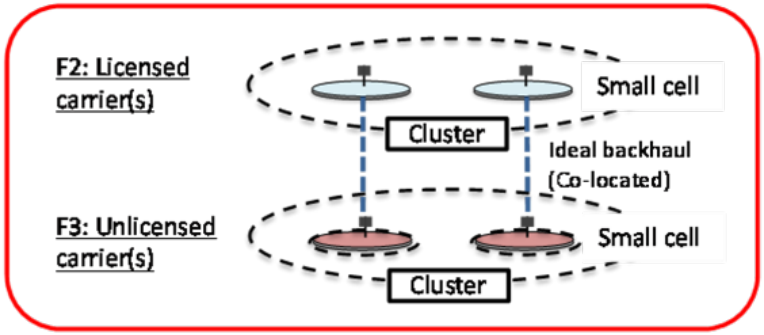
- Produced an overview of the regulatory requirements for unlicensed operation in 5 GHz
  - Covering USA, Canada, Mexico, Europe, Israel, Russia, South Africa, Turkey, China, Japan, Korea, India, Taiwan, Singapore, Australia
- Documented requirements in terms of
  - Power and power spectral density levels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

Deployment Scenarios

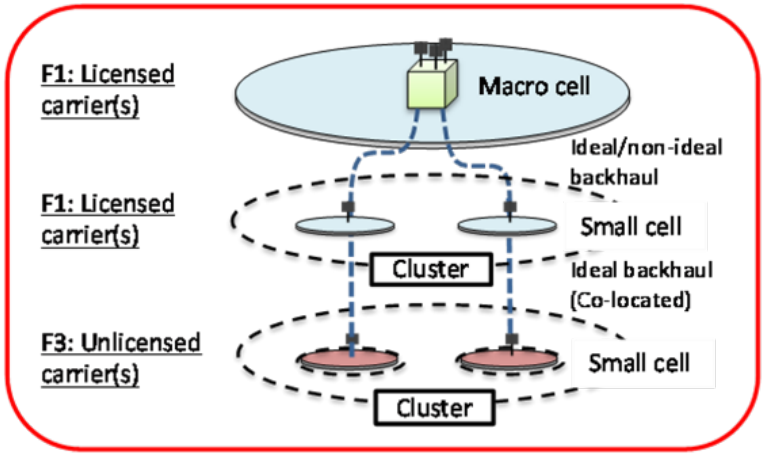
Scenario 1



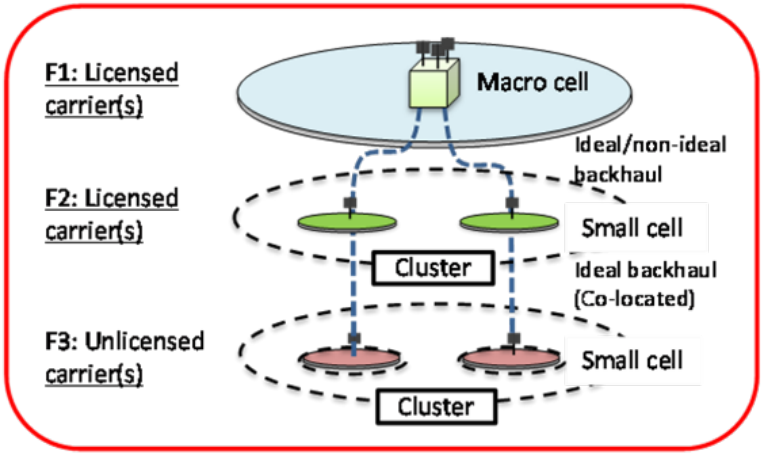
Scenario 2



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 are being studied to support required functionalities include
  - Synchronization, AGC, channel reservation
  - Radio resource management (RRM) and reporting
  - Channel state information measurements and reporting
  - 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

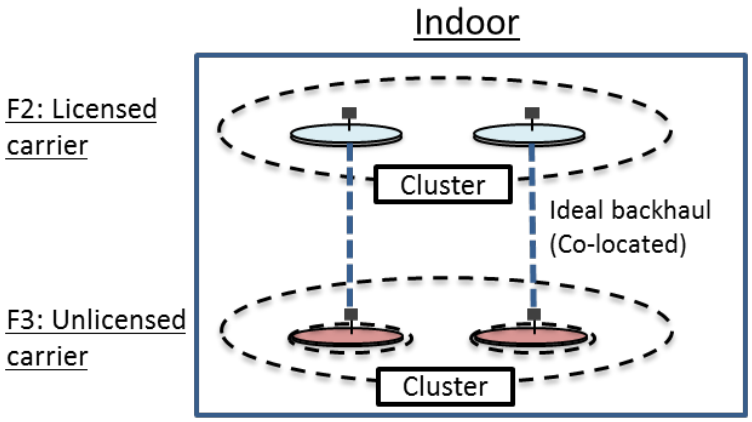
- Category 1: No LBT
  - No LBT procedure is performed by the transmitting entity.
- Category 2: LBT without random back-off
  - The duration of time that the channel is sensed to be idle before the transmitting entity transmits is deterministic. (e.g. ETSI Frame Based Equipment)
- Category 3: LBT with 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.

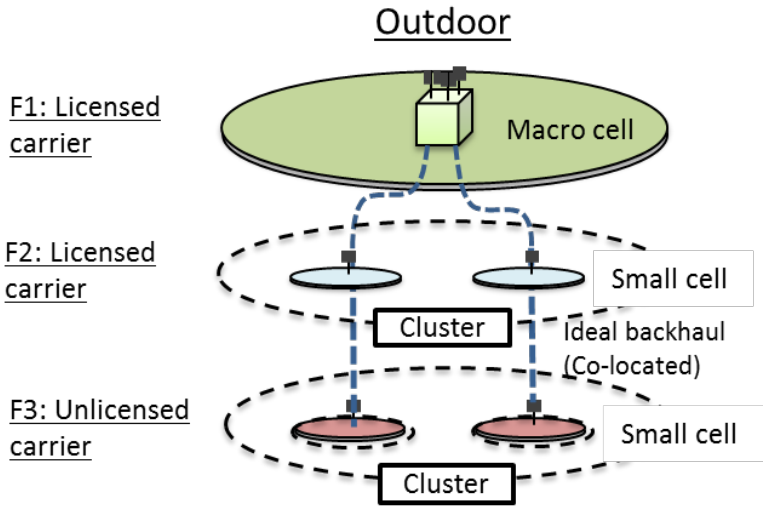
Channel Access Schemes

- 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 are being 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

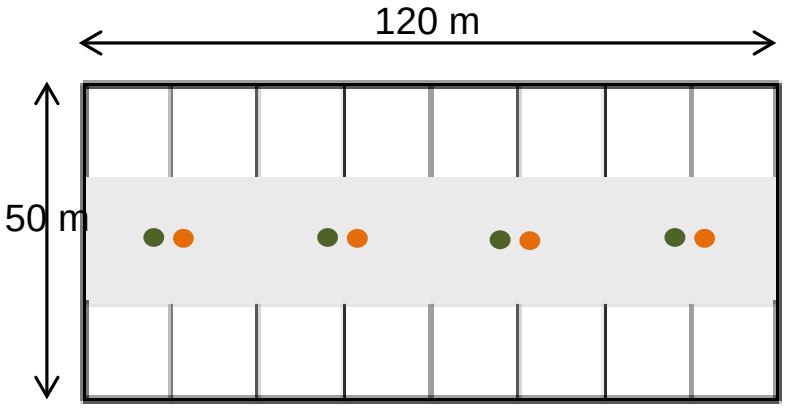




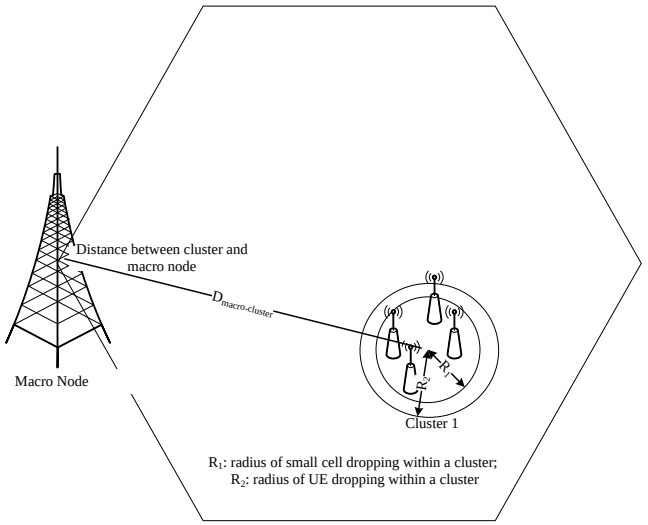
- Scenarios also used for adjacent channel coexistence evaluations

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.



Coexistence Evaluation Methodology

- 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 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
  - Ratio of served to offered traffic

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
    - 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 latest TR draft

Coexistence Evaluations Status

- Many contributions have already been submitted and discussed on coexistence evaluations for the cases with DL-only LAA

- Contributions on case where LAA has DL and UL traffic expected to be addressed in RAN1#81 (25-29 May, Fukuoka, Japan).

- Adjacent channel coexistence evaluations have been performed in RAN4 with the following preliminary conclusion
  - … because of better LAA RF performance, when looking at impact of LAA on Wi-Fi we can conclude that the amount of adjacent channel interference created by LAA UEs and BSs will be lower compared to the one created by Wi-Fi APs and STAs.

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

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
DL: UPT CDF [Mbps]	5%												
	50%												
	95%												
	Mean												
DL: Delay CDF [s]	5%												
	50%												
	95%												
	Mean												
UL: 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
UL: 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
ρ_{DL}													
ρ_{UL}			N/A		N/A		N/A		N/A		N/A		N/A
BO													
λ													
Company/tdoc, LBT category, Additional information													

Conclusions

- LAA study item investigating enhancements to LTE needed for operation in unlicensed bands

- Design options are being studied and evaluated
  - Study item does not generate any specifications
  - Some design options including promising channel access schemes can be recommended for further consideration

Thank You!