Evaluating Unlicensed LTE technologies: LAA vs LTE-U

Biljana Bojovic, Lorenza Giupponi, Zoraze Ali
Mobile Networks Department, Communication Networks Division, CTTC

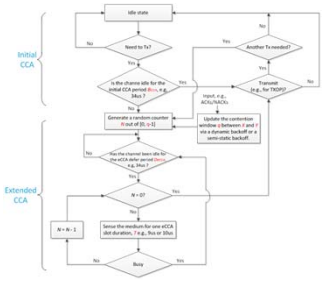
- The use of unlicensed spectrum for future LTE systems raises concerns about its impact on co-located Wi-Fi.
- LTE physical channels are designed on the basis of uninterrupted and synchronous operation.
- Existing systems in unlicensed spectrum operate in decentralized, asynchronous manner.
- Wi-Fi exploits interference avoidance principles
- Critical design issue: LTE has to coexist with other technologies, in a “fair” and “friendly” basis.
- 3GPP has defined fairness in technical report TR36.889 as follows:

  Fairness is the capability of an LAA network not to impact Wi-Fi networks active on a carrier more than an additional Wi-Fi network operating on the same carrier, in terms of both throughput and latency.

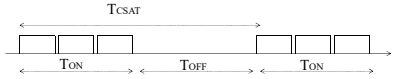
- In some markets such as Europe and Japan, a “sense and avoid” (or "listen before talk") approach is mandated before transmitting.
- Transmitters must first detect whether the channel is free before initiating a transmission.
- This requires modifications to the LTE air interface.
- Other markets, such as North America, Korea and China, such requirements do not exist.
- To meet ETSI’s requirements, 3GPP is producing a standardized version of LTE in unlicensed: Licensed Assisted Access (LAA)
- LTE-U Forum is specifying and developing a proprietary solution for access in unlicenced bands without Listen Before Talk (LBT) requirements.
- There is common thinking that LAA must be better than LTE-U because it incorporates LBT.
- We show that the reality is not so straight forward
- Coexistence performance are not only affect by the access mechanism, but also the traffic pattern, and the scenario set-up play a role.

Licensed Assisted Access (LAA) and LTE-U

- 3GPP is standardizing a solution that can be deployed under all regulatory requirements.
- Release 13 focuses on Supplemental Downlink (SDL) in 5 GHz band.
- Release 14 focuses on eLAA, which includes UL. Release 15 focuses on further enhanced LAA (feLAA)
- Other initiatives, MuLTEfire, rely on Rel. 13 and 14 to provide a complete solution not anchored to the licensed band



- LTE-U Forum is an industry consortium specifying a solution referred to as LTE-U
- This is based on LTE duty-cycling its transmission, i.e. alternating ON and OFF periods, by estimating the most appropriate channel share that it should occupy.
- The most representative algorithm for LTE-U to share the channel is Qualcomm’s CSAT.
- Qualcomm provided demonstrations at MWC16, and products are in the market (e.g. Spidercloud, Samsung small cells) with such Qualcomm chips.



- TON/TOFF is adaptive based on the Wi-Fi measured medium
- The medium utilization is measured during TOFF
- There is a maximum number of consecutive subframes for transmission of LTE-U, then LTE-U has to switch OFF during a punctuing period of 1 or 2 ms, to allow for low latency Wi-Fi traffic to go through.
- LTE-U nodes need beacon detection and preamble detection capabilities

$$\text{MU(n)} = \frac{1}{MonitoringTime}\sum_{i=1}^{K} D_i$$

$$T_{ON}(n+1) = \min(T_{ON}(n) + \Delta T_{UP}, T_{ON,\max}) \quad \text{if } \overline{MU(n)} < MU_{Thr1}$$

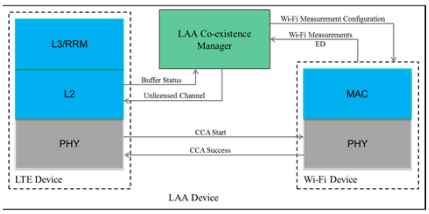
$$T_{ON}(n+1) = T_{ON}(n) \quad \text{if } MU_{Thr1} \le \overline{MU(n)} \le MU_{Thr2}$$

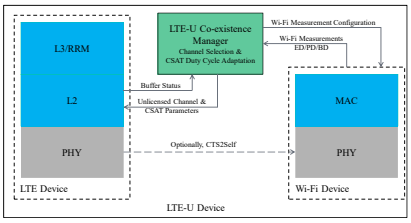
$$T_{ON}(n+1) = \min(T_{ON}(n) - \Delta T_{DOWN}, T_{ON,\min}) \quad \text{if } \overline{MU(n)} > MU_{Thr2}$$

ns-3 models

- Despite the large body of simulation results by industry and in the literature, the simulators are not publicly available.
- The two technologies have been evaluated in standalone fashion, they have not been compared over the same scenarios and the same simulation or test platforms.
- The obtained results are nor reproducible, neither comparable, and system performance metrics are presented without much details revealed about the underlying models and assumptions.

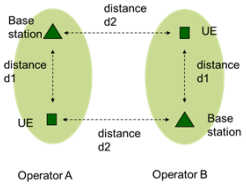
- In order to perform a coexistence study and comparison of LAA and LTE-U technologies, we have built a detailed simulation platform, strictly complying with LTE-U Forum and 3GPP specifications, in the popular open source network simulator ns-3
- WFA funded the LAA work and Spidercloud Wireless the LTE-U
- We can reproduce both 3GPP and WFA evaluation methodologies
- Full protocol stack and end-to-end evaluations





Parameter	Description	Default value
T_{CSAT}	ON+OFF interval. It takes values between 40 and 1280 ms	160 ms
$T_{ON,min}$	Bounds ON interval to be sure LTE receives a fair share	adaptable
$T_{ON,max}$	Bounds OFF interval to allow time to share Wi-Fi activity	$T_{CSAT} - T_{OFF,min}$
$T_{OFF,min}$	Minimum time to monitor Wi-Fi activity	20 msec
TONminPerTxOP	Based on LTE-U Forum specs is the minimum time the LTE-U cell can be ON, as long as it has data in buffer.	4 msec
Puncturing period	It defines the interval of puncturing.	20 msec
Puncturing length	It defines the length of puncturing.	1 msec
APscan period	It defines the periodicity of the APscan period.	16 T_{CSAT}
APscan duration	It defines the length of the period	160 msec
TONminInMillisec	controls the minimum duty cycle below threshold.	120 msec

Simulation scenarios and selected simulation results



Simple scenario

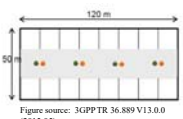
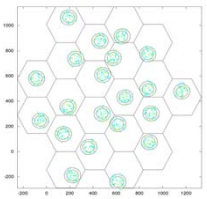
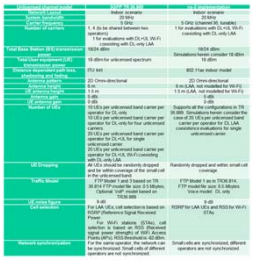


Figure source: 3GPP TR 36.889 V13.0.0 (2015-05)

Indoor scenario



Outdoor scenario



Traffic models:

- FTP Model 1: Poisson process with arrival rate lambda across the entire operator network.
- CBR (Constant Bit Rate) with varying bit rates till saturation

Performance metrics:

- The main performance metrics are ‘user perceived throughput’ and ‘latency’, plotted as CDFs, for a given scenario.
- built-in FlowMonitor tool that tracks per-flow statistics including throughput and latency, and we then post-process these results to obtain CDFs.

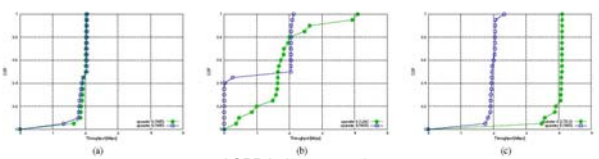
- ***CBR UDP traffic***

TABLE XI
LTE-U VS LAA THROUGHPUT COEXISTENCE COMPARISON IN SIMPLE SCENARIO WITH A FULL BUFFER TRAFFIC AS A FUNCTION OF $d2$.

Distance d2 (m)	Wi-Fi in Wi-Fi/Wi-Fi (Mbps)	Wi-Fi in Wi-Fi/LAA (Mbps)	LAA in Wi-Fi/LAA (Mbps)	Wi-Fi in Wi-Fi/LTE-U (Mbps)	LTE-U in Wi-Fi/LTE-U (Mbps)
10	54.70	13.99	188.37	57.58	209.44
30	55.14	2.09	208.76	77.87	201.79
50	60.81	113.48	279.85	114.35	226.68
1000	115.26	115.28	279.85	115.31	273.34

Simple scenario

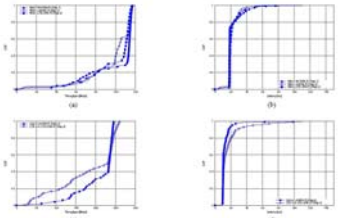
With a simple full buffer model, we can show that it can be true the claim that **LTE-U can be a better neighbor to Wi-i than LAA or WiFi itself**



3GPP Indoor scenario

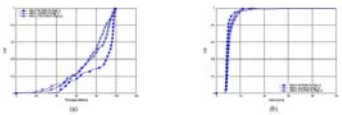
- With *CBR UDP traffic*, RLC queues receive a packet from application every 2 ms, so a MC PDU is ready to be transmitted every 2 ms.
- LAA eNB asks for the channel, accesses (with reservation), sends the packet, and then it gets out because it has no more data to transmit, so it cannot hold the channel.
- Still it occupies the channel with reservation and 1 msec. Extremely inefficient.
- 80,3% of channel occupancy vs. 52.1% of LTE-U and 32,9% of WiFi.
- LTE-U is again a better neighbor than LAA, when the traffic model is not bursty.

- ***FTP UDP traffic***



- With *FTP UDP traffic*, the pattern of packet arrivals is bursty and LAA efficiently fills the subframes of the transmission opportunities.
- LAA performs better than LTE-U
- Coexistence performance of LTE-U are more affected by collisions, as expected.
- With FTP UDP we reproduce the expected results, but FTP traffic never goes over UDP in reality…

- ***FTP TCP traffic***



3GPP Indoor scenario

- With *FTP TCP traffic*, the coexistence of TCP and RLC windows generates a flow control effect that can alter the data arrival pattern as compared to the bursty behavior shown with UDP.
- Channel occupancy of LAA is 16,4%, of LTE-U is 12,3%, while another WiFi occupies 8,3%
- LAA does not use properly the subframe resources again