license-assisted access study

How Actix Analyzer accelerates LAA assurance

amdocs

table of contents

executive summary

For mobile communications, the emergence of 5G is ushering in an era in which data usage continues to explode, new applications and services demand unprecedented speeds, all while the global base of consumer and business customers continues to grow. At the same time, problems of low throughput and poor indoor coverage are set to threaten user experience and even connectivity to services. For Cellular Service Providers (CSPs), the solution lies in deploying better radio technology, improved spectral efficiency, and increased radio spectrum.

"Scarcity of spectrum" arises when there is a lack of sufficient radio resources to service the growing number of mobile users and a market flooded with smart phones. With spectrum an increasingly scarce resource, LTE (long-term evolution), a spectrally-efficient cellular technology, has emerged as a profitable option for increasing capacity without additional spectrum licensing costs. Using this technology over the unlicensed spectrum (i.e. LTE-unlicensed or LTE-U) is a potential solution to this problem.

LTE-U has been an important topic of discussion when it comes to standardization and deployment of 3GPP (Third-Generation Partnership Project) networks. It propagates the benefits of LTE and LTE-Advanced to unlicensed spectrum and enables CSPs to offload mobile data to unlicensed frequencies more effectively and efficiently. Recent standardization efforts on flexible and forward-looking technologies such as License-Assisted Access (LAA) and Carrier Aggregation (CA) enable CSPs, network equipment providers (NEPs), service providers and the rest of the mobile ecosystem to fulfil this ever-growing data demand.

LAA is a key feature of LTE-A that enables operators to create larger "virtual" carrier bandwidths for LTE services by combining separate unlicensed spectrum allocations. Carrier aggregation is currently the primary feature deployed by operators with commercial LTE-Advanced service. The LAA feature in LTE-Advanced-Pro enables service providers, facing scarcity of spectrum, to support bandwidths greater than those currently supported in LTE (up to 20MHz), while at the same time ensuring backward compatibility with LTE. The benefits of this aggregation include higher peak data rates and increased average data rates.

3GPP standards for LWIP, LWA, LAA, eLAA using unlicensed spectrum were formally issued as part of Release 13 and Release 14 (2017). While the 5GHz band is the primary target, shared spectrum bands (specifically the US CBRS band at 3.5GHz) are also areas of interest. This is defined as Band 46 (5150 to 5925MHz) and is TDD mode.

introduction

Licensed-Assisted Access (LAA) is meant to enable CSPs to offload traffic to LTE small cells or femtocells, without having to implement WLAN. Its initial focus is the 5GHz ISM band, which is used for WLAN. LAA triggers a modified form of LTE air interface, to enable co-existence with WLAN in the unlicensed band, thereby boosting downlink speeds, by aggregating with an existing standard LTE connection. This is achieved with the assistance of Dynamic Channel Selection (DCS), which identifies the least-used sub-band; and with the assistance of Listen-Before-Talk (LBT), which is used to avoid causing conflict with transmissions of other users.

LBT requires LTE base stations with which to "listen", and determine channel availability by means of energy detection, before "talking" or transmitting data. Various LBT approaches exist, but the one recommended by 3GPP is called LBT-Load Based Equipment Category 4. This adds a similar random-access protocol that Wi-Fi devices currently use, to ensure not only LTE/Wi-Fi coexistence, but also a standardized method to ensure LTE/LTE-U coexistence.

- Increased bandwidth to serve more number of users
- Low CAPEX cost for operator as no license fee charged for its use
- Improved user experience with rich quality of service
- No need to upgrade any of the evolved packet core
- Dynamic carrier selection
- Maximum power density per MHz

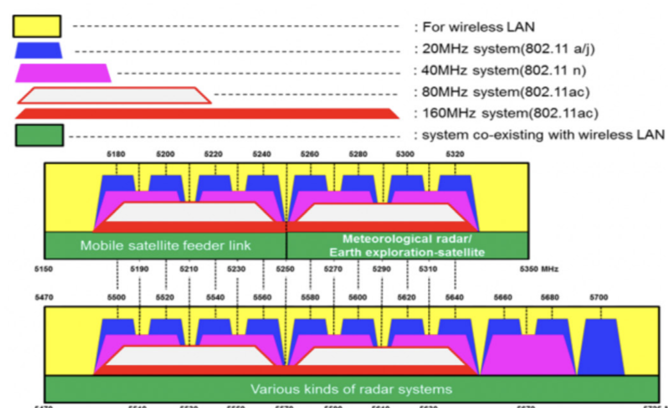
Many countries have regulations pertaining to appropriate behavior when using unlicensed spectrum. European countries have published some requirements specifying maximum permitted RF power and LBT procedures. By complying with these and several other region-specific rules, it is possible to develop global products that can work anywhere, legally.

spectrum and design regulations

Unlicensed Spectrum

Spectrum bands utilized with unlicensed LTE technology include the ISM bands operating at 2.4GHz and 5GHz. Most interest is in the 5GHz band, where in many regions, broad bandwidths are available. Historically, the fastest growing use of these bands has been for short-range low-power communication systems. The rules to access these bands vary between regions. In the US, FCC defines these rules, whereas in Europe, ETSI is the governing body. In 1985, the US FCC opened the ISM band and Effective Isotropic Radiated Power (EIRP) for radio communication and wireless LANs.

ITU Region	5250-5350MHz	5470-5725MHz	5725-5825MHz
EUROPE – ITU Region 1	TPC/DFS/ LBT	TPC/DFS/ LBT	-
USA – ITU Region 2	TPC/DFS	TPC/DFS	-
CHINA – ITU Region 3	TPC/DFS	-	TPC/DFS



Dynamic Frequency Selection Detection Requirements

Dynamic Frequency Selection (DFS), a mechanism for automatically selecting the most appropriate channel to reduce interference, can detect interference signals above a minimum DFS detection threshold of -62 dBm for devices with a maximum EIRP of <200 mW and -64 dBm for devices with a maximum EIRP of 200 mW to 1W (averaged over 1s). This is defined as the received signal strength (RSS) (dBm), normalized to the output of a 0 dBi receive antenna that is required to be detected within service channel bandwidth. This may not be necessary for each device to implement full DFS functionality, provided that such devices are only able to transmit under the control of a device that ensures that all DFS requirements are fulfilled.

The candidate band should allow for both indoor and outdoor deployment, and transmit power should be high enough for DFS procedures to operate, as adequate coverage level is the primary target scenario for LTE-U.

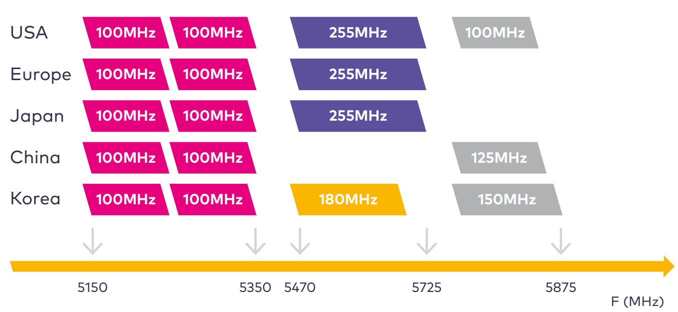
Sub-bands	5150-5250MHz	5250-5350MHz	5470-5725MHz	5725-5825MHz
EIRP	17dBm/23dBm	23dBm/30dBm	23dBm/30dBm	23dBm/30dBm/36dBm
US/Canada	Indoor	Indoor/Outdoor	Indoor/Outdoor	Indoor/Outdoor
EU	Indoor	Indoor	Indoor/Outdoor	NA
Korea	Indoor	Indoor/Outdoor	Indoor/Outdoor	Indoor/Outdoor
Japan	Indoor	Indoor	Indoor/Outdoor	NA
China	Indoor	Indoor	NA	Indoor/Outdoor
Australia	Indoor	Indoor/Outdoor	Indoor/Outdoor	Indoor/Outdoor
India	Indoor	Indoor	NA	Indoor/Outdoor

The 2.4GHz band is already crowded with residential and even public deployments; therefore, the 5GHz band is the main candidate, because of its relatively large amount of unlicensed spectrum with globally harmonized availability, as well as relatively good channel propagation performance. In contrast, within the 5GHz band, the 5150-5250MHz and 5250-5350MHz blocks are also widely used by residential WLAN in indoor/outdoor scenarios, making it less viable.

Other band allocations include:

- 5150-5350 and 5470-5725MHz: Allocated on a co-primary basis to the mobile service for the implementation of "wireless access systems (WAS), including radio local area networks (RLANs)
- 5725-5850MHz: Allocated for Industrial Scientific Medical band; DFS is required
- 5850-5925MHz: For dedicated short-range communications operating Intelligent Transport Systems

Regulatory spectrum assignment differs in step with country allocations:



deployment scenarios: license-assisted access

LAA targets the carrier aggregation operation, whereby one or more low-power secondary cells (SCells) operate in unlicensed spectrum. LAA deployment scenarios encompass those with and without macro coverage, outdoor and indoor small cell deployments, as well as co-location and non-co-location (with ideal backhaul) between licensed and unlicensed carriers. For scenarios where carrier aggregation is operated within the small cell with carriers in both the licensed and unlicensed bands, the backhaul between macro cell and small cell can be ideal or non-ideal. Figure 1:, outlined in 3GPP 36.889, provides details on LAA deployment scenarios.

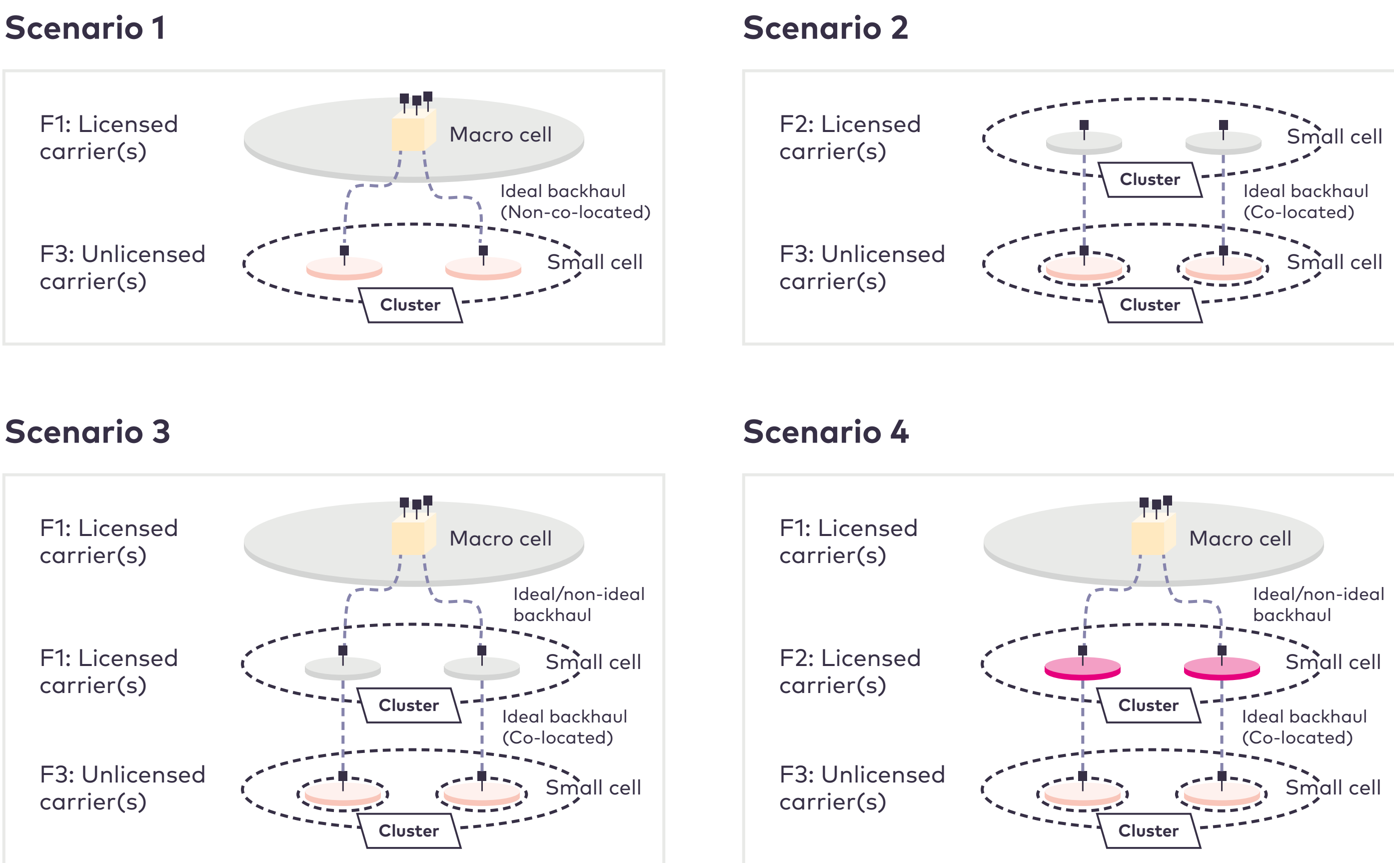


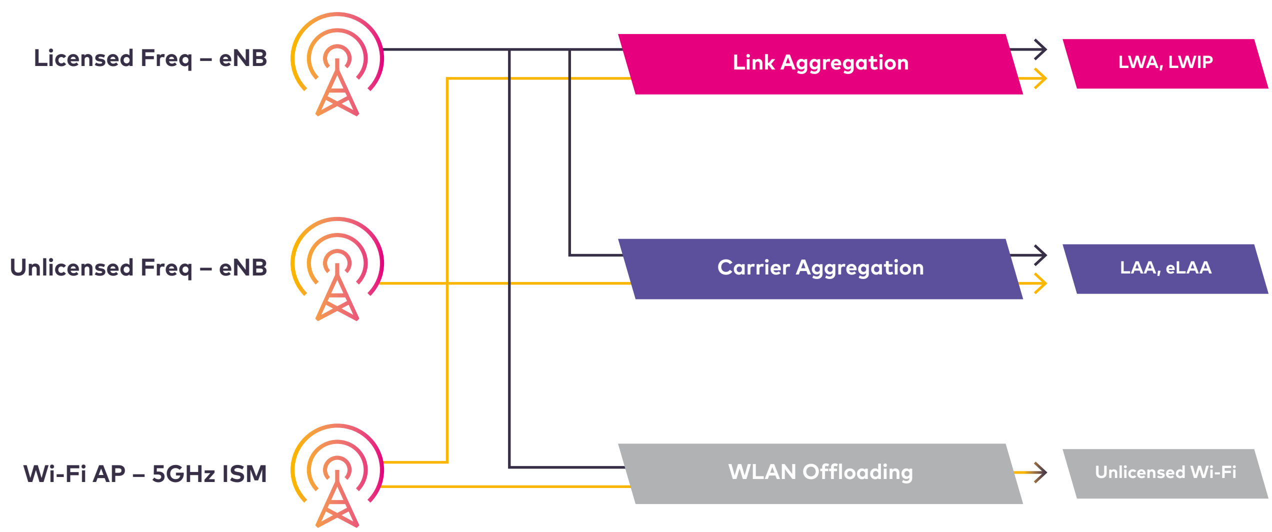
Figure 4: 1 LAA Deployment Scenarios from 3GPP TR 36.889

Co-existence with Wi-Fi Bands

LAA/eLAA is the dominant method for accessing the unlicensed 5GHz ISM band. It is also favored by most CSPs worldwide; therefore, it also represents an opportunity to provide greater bandwidth to operators who have existing WLAN deployments.

However, most supporters of LAA are CSPs, who are represented by standardization body 3GPP, and this has led to concerns in the industry that LAA is closer aligned to LTE than to Wi-Fi. To address these concerns, 3GPP defined a solution for co-existence, where LAA does not levy a detrimental impact over Wi-Fi. This has been handled by the Discovery Reference Signal (DRS) mechanism, by which a low power signal is transmitted even if the cell is in a dormant state, to allow it to still be discovered by a device.

The following diagram highlights three different methods for adding capacity with LTE and Wi-Fi:



Enhancements of CA Mechanism: Unlicensed Channel

As required by LBT rules, the transmission of both traffic data and the common channels of LTE-U should be based on the knowledge of channel vacancy by instantaneous channel sensing. In an integrated LTE framework, unlicensed carriers should be operated as secondary carriers associated to a licensed LTE primary carrier through carrier aggregation (CA). The activation and deactivation of SCell, as defined in CA, can already enable the opportunistic use of unlicensed spectrum, which is based on the always-on common channel transmission, continuous channel measurement and corresponding reports in LTE, and as mentioned in Rel-11 and earlier. Such a restriction will be resolved to some extent, by the standardization of small cell on/off in LTE Rel-12, where quick on-off switching of a cell will be supported, and during a cell off period, UE would quit legacy channel measurement.

These are the required further enhancements, to ensure more flexibility in terms of opportunistic synchronization/measurement/scheduling of SCell.

Listen Before Talk (LBT) Requirements

The LBT procedure provides a rational coexistence of LAA with other technologies that are operating in unlicensed spectrum. The procedure for a node attempting to transmit on a carrier in unlicensed spectrum requires a check for a clear channel assessment, to determine whether the channel is free to use. An LBT procedure applied at different nodes belonging to the same CSP might result in these nodes not transmitting on the channel simultaneously.

Two types of LBT schemes are defined by regulation and they are named as FBE (Frame Based Equipment) and LBE (Load Based Equipment). The differences between FBE and LBE include whether a strict frame structure should be followed, an interference avoidance mechanism, and channel occupancy time. For both schemes, some efforts are necessary, to ensure the consistency between the strict frame structure defined in the existing licensed LTE layer, and the opportunistic occupancy of unlicensed bandwidth, and at the same time allow for flexible channel sensing and occupancy, to offer a potentially good channel contention capability.

Transmit power control

A regulatory requirement in few regions for transmitting device should be able to reduce the transmit power.

Listen before talk procedure

The listen-before-talk (LBT) procedure is defined as a mechanism by which an equipment make use of clear channel assessment (CCA) process by utilizing least energy detection to determine the presence or absence of other signals on a channel.

Discovery reference signal, frequency/ time estimation and RRM measurements

RRM and CSI measurements including measurements of channel and interference are necessary for performing RRM measurements and for successful reception of information on the unlicensed band.

Bandwidth support

Support for at least 20MHz system BW option in the 5GHz band.

System bandwidths < 5MHz are not considered for PHY layer options in LAA.

Dynamic frequency selection

Dynamic frequency selection (DFS) is a regulatory requirement for some frequency bands to detect and avoid interference from radar systems.

Discontinuous transmission

To respect duty cycle in unlicensed spectrum, as channel availability cannot always be guaranteed.

Put simply, LBT represents a transmitter sensing mechanism, by which each device decides its transmission opportunities based on self-detection of channel availability. However, in LTE the UL transmission grant and channel-availability sensing are determined by the eNB and UE respectively. Therefore, it could be even more difficult to support UL transmission if an eNB were permitted to schedule a UE UL grant, but then this UE fails to gain access to the channel within the scheduled time because of contention. These problems must be addressed, to ensure that UL transmission can be supported without changing the basic centric-scheduling mechanism in LTE.

LBT: Listen Before Talk

Need to sense before transmission – the mechanism an equipment applies CCA before using the channel.

Thresholds for energy detection can be adaptive.

CCA: Clear Channel Assessment

The evaluation of presence/absence of other signals.

Using at least energy detection.

4 categories of LBT were considered

Cat-1: No LBT

Cat-2: LBT without random back-off

Cat-3: LBT with random back-off and fixed CW

Cat-4: LBT with random back-off and variable CW

Potential failure of LBT impacts LTE operation

Especially for standalone operation

Sensing-based channel occupancy provides a preliminary mechanism, with which to achieve interference coordination between co-existing nodes. Further coordination and handshake mechanisms over the air interface between inter-operator LTE-U nodes can allow efficient use of unlicensed spectrum, even in high load scenarios, in which the simple channel sensing and avoidance might not work well.

Summary	LWA	LAA/LTE-U	LTE CA
Standardization	3GPP	LTE-U Forum/3GPP	3GPP
3GPP Release	Release 13	Release 13	Release 10
Protocol Layer	L2-PDCP	L2-MAC	L2-MAC
LTE Spectrum	No Additional Cost	No Additional Cost	Additional Spectrum Cost
Access Network Cost	Medium – Additional AP	High – Small Cell/HetNet	High – New Feature Cost
Network Element	Technology Aware Access Point	Small Cells	-
LTE-Wi-Fi Coexistence	-	Contention Problem/Frame Structure	-
Aggregation	LTE LTE LTE	LTE LTE LTE	LTE LTE 802.11
Regulation	-	Required	-

Comparison – Unlicensed Technologies

LBT-U Forum

- LTE-U is based on the 3GPP Release 12 concept where LTE technology to be used in the unlicensed spectrum
- The fundamental concept of LTE-U is to extend LTE radio frequency to a frequency band which is not specified by 3GPP (Not-licensed)
- Supplemental downlink (SDL) to boost downlink data rates
- Duty cycle only (using DRS) to fairly coexist with Wi-Fi
- Frame Type 1 (FDD) to be used
- PCell to be FDD
- Carrier Sense Adaptive Transmission (CSAT) for dynamic channel selection to avoid Wi-Fi transmission collision

LWA (eLWA) – 3GPP

- LWA is developed as part of Release 13, which enables the simultaneous LTE and WLAN connectivity via dual connectivity
- LTE always serves as the MeNB, and for 3GPP Release 13, only LTE carries the UL. WAN is used as an additional downlink resource in an SeNB, which in LWA is called the WLAN termination node (WT)
- Xw interface, considered as non-ideal connection between the eNB and the WT
- With the 3GPP Release 14 eLWA enhancements of LWA (eLWA), uplink data transmission on WLAN including bearer switch and bearer split
- Avoidance of bearer switching during MeNB handover (eLWA)

LAA (eLAA) – 3GPP

- Licensed Assisted Access is a standardized version of LTE-U as governed by 3GPP Release 13A
- Collision control mechanism to make sure the "fair" co-existence with
- LAA require LBT to comply
- Minimum channel occupation bandwidth per device, discontinuous transmission & radar detection
- PCell could be TDD or FDD
- Secondary Cell in B46
- Frame Type 3 to be used
  - Same as TDD/FDD
  - DL only (for Release 13)
- (eLAA) is part of 3GPP Release 14, includes uplink Aggregation and Complexity Reduction

MulteFire

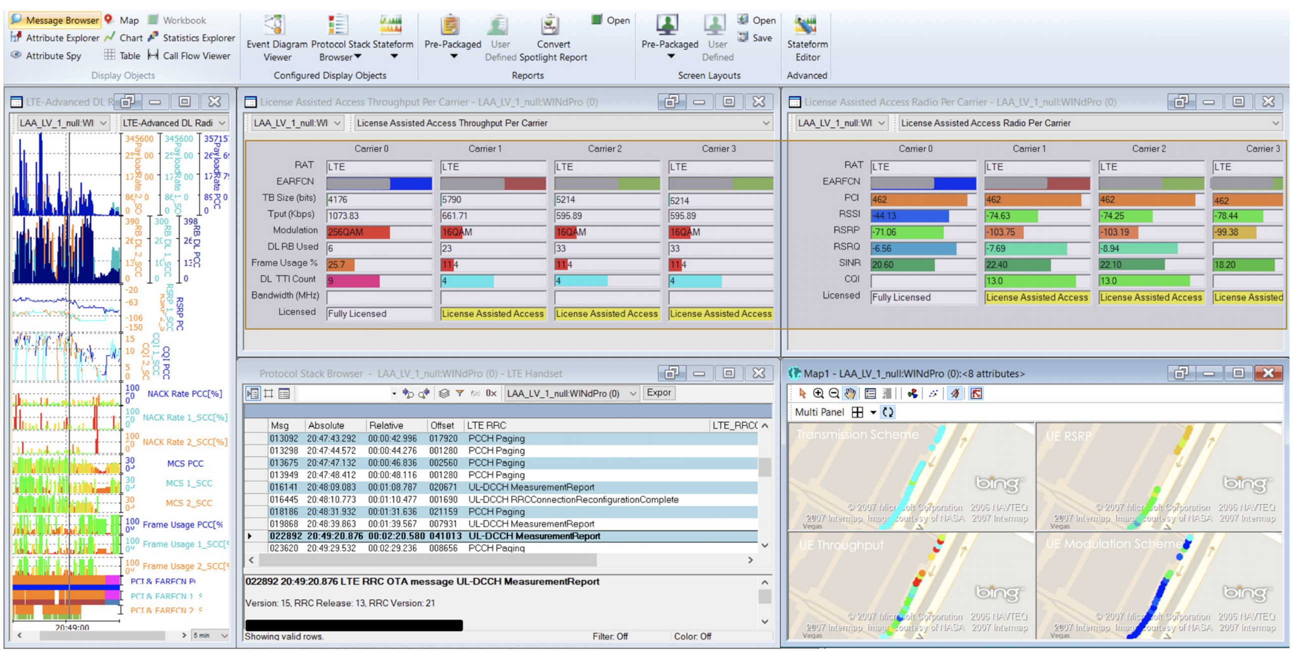
- MulteFire technology differs from LTE-U/LAA and LWA as it operates as standalone use of LTE in unlicensed band
- It was started by Qualcomm and Nokia and is now being spearheaded by a multi-company MulteFire Alliance that includes Intel and Ericsson
- It aims to merge the performance of LTE with Wi-Fi
- End users install MulteFire access points in lieu of Wi-Fi gateways to provide LTE coverage
- The underlying protocol is similar to LAA and conforms to the LBT protocol
- Strong LTE Roadmap – Can use existing LTE features such as VoLTE and Broadcast

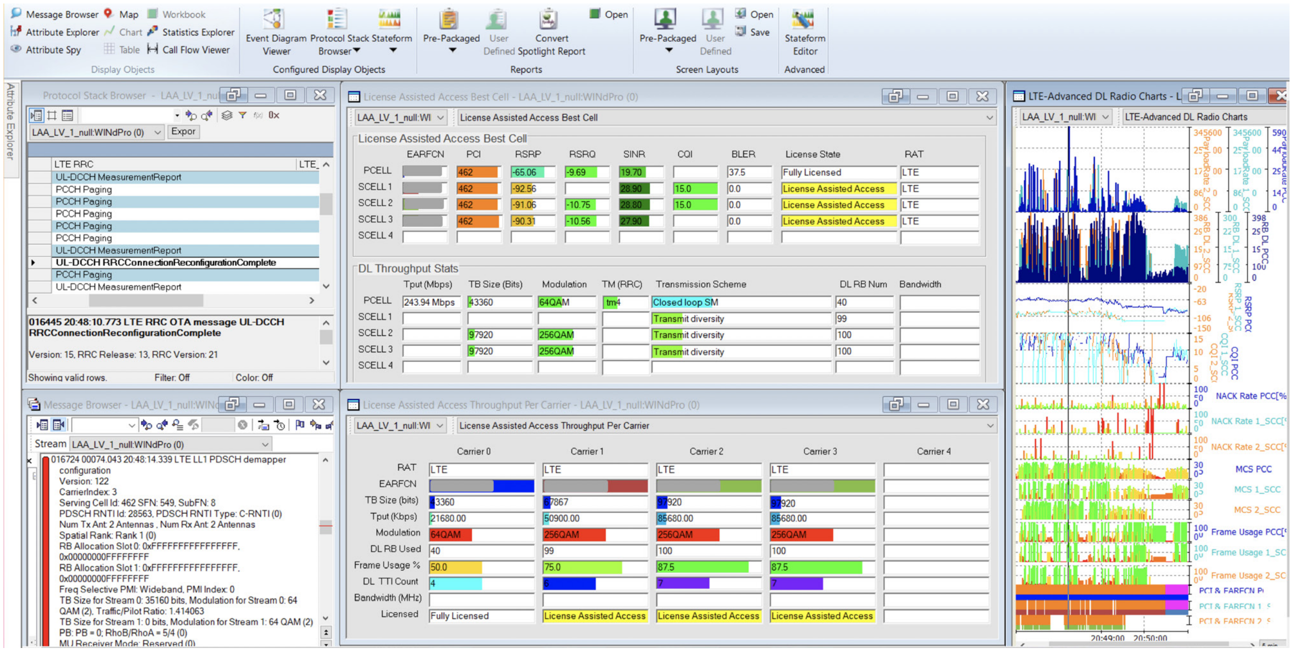
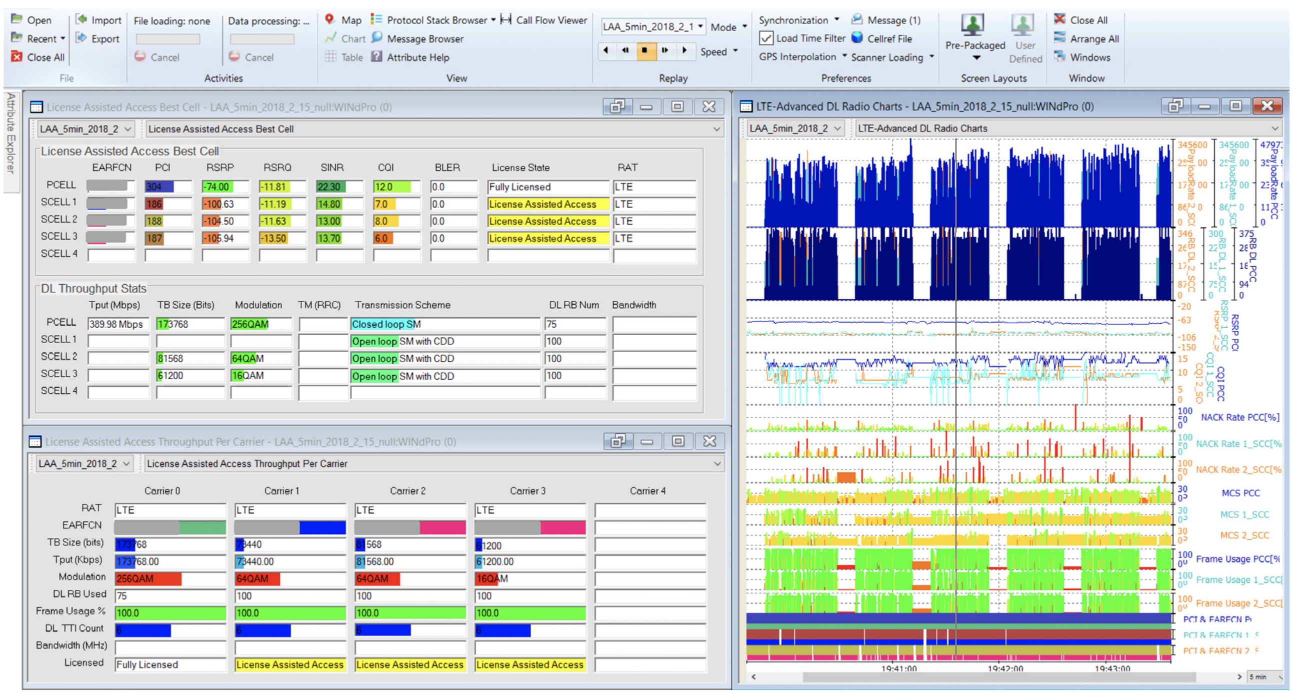
license-assisted access: performance study in actix analyzer

User Experience Study

A user-experience study is the key to ROI (Return on Investment) for a CSP when launching a new feature such as LAA. This triggers a requirement to go through per carrier performance statistical data, whether the carrier is licensed or unlicensed, to provide optimized services while having optimum resource utilization. The band is unlicensed; therefore, CSPs might want to do competitive benchmarking on the deployed band with respect to data volume and throughput comparison for LAA as opposed to the licensed spectrum. On the other hand, LAA coverage must also be validated for a strong presence.

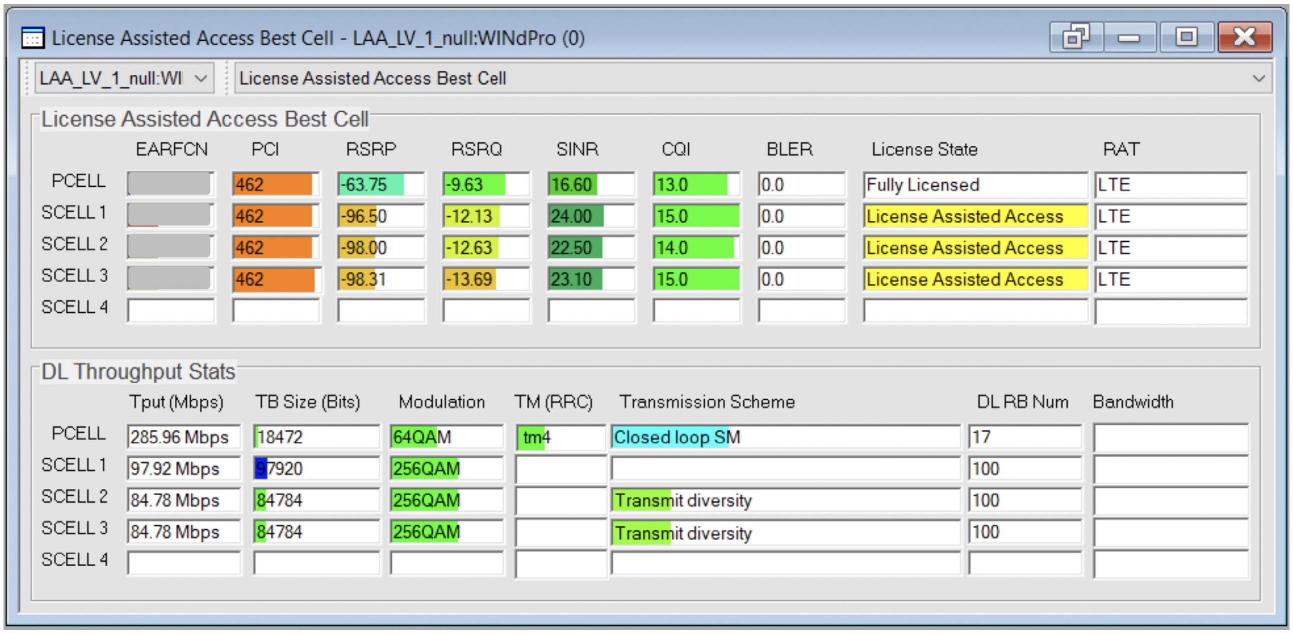
Actix Analyzer's support of License-Assisted Access, which is one of the key eMBB-specific enhancements to LTE-Advanced-Pro, provides distributed network statistics based on drive survey measurement logs. These statistics can also be correlated with vendor-based Performance Management counters and Subscriber Call Trace measurements in ActixOne. The measurement data can be viewed and bifurcated for each carrier level as shown in the following figures:




Message Browser
Map
Workbook
Attribute Explorer
Chart
Statistics Explorer
Attribute Spy
Table
Call Flow Viewer
Display Objects
Event Diagram Viewer
Protocol Stack Browser
Stateform
Configured Display Objects
Pre-Packaged
User Defined
Convert Spotlight Report
Open
Reports
Save
Screen Layouts
Stateform Editor
Advanced
License Assisted Access Best Cell
PCELL
SCELL 1
SCELL 2
SCELL 3
SCELL 4
EARFCN
PCI
RSRP
RSRQ
SINR
CQI
BLER
License State
RAT
Fully Licensed
License Assisted Access
LTE
DL Throughput Stats
Tput (Mbps)
TB Size (Bits)
Modulation
TM (RRC)
Transmission Scheme
DL RB Num
Bandwidth
Closed loop SM
Transmit diversity
License Assisted Access Throughput Per Carrier
Carrier 0
Carrier 1
Carrier 2
Carrier 3
Carrier 4
Frame Usage %
DL TTI Count
Licensed
LTE-Advanced DL Radio Charts

Open
Recent
Close All
File
Import
Export
File loading: none
Data processing:
Cancel
Activities
Map
Chart
Table
Protocol Stack Browser
Message Browser
Attribute Help
Call Flow Viewer
View
Replay
Synchronization
Load Time Filter
GPS Interpolation
Message (1)
Cellref File
Scanner Loading
Preferences
Pre-Packaged
User Defined
Screen Layouts
Close All
Arrange All
Windows
Window
License Assisted Access Best Cell - LAA_5min_2018_2_15_null:WINdPro (0)
License Assisted Access Best Cell
DL Throughput Stats
Open loop SM with CDD
License Assisted Access Throughput Per Carrier - LAA_5min_2018_2_15_null:WINdPro (0)
LTE-Advanced DL Radio Charts - LAA_5min_2018_2_15_null:WINdPro (0)

Best Cell Measurement: License-Assisted Access

Aggregated Throughput, Best Server RF Parameters



License Assisted Access Best Cell - LAA_LV_1_null:WINdPro (0)

LAA_LV_1_null:WI | License Assisted Access Best Cell

License Assisted Access Best Cell

	EARFCN	PCI	RSRP	RSRQ	SINR	CQI	BLER	License State	RAT
PCELL		462	-63.75	-9.63	16.60	13.0	0.0	Fully Licensed	LTE
SCELL 1		462	-96.50	-12.13	24.00	15.0	0.0	License Assisted Access	LTE
SCELL 2		462	-98.00	-12.63	22.50	14.0	0.0	License Assisted Access	LTE
SCELL 3		462	-98.31	-13.69	23.10	15.0	0.0	License Assisted Access	LTE
SCELL 4									

DL Throughput Stats

	Tput (Mbps)	TB Size (Bits)	Modulation	TM (RRC)	Transmission Scheme	DL RB Num	Bandwidth
PCELL	285.96 Mbps	18472	64QAM	tm4	Closed loop SM	17	
SCELL 1	97.92 Mbps	97920	256QAM			100	
SCELL 2	84.78 Mbps	84784	256QAM		Transmit diversity	100	
SCELL 3	84.78 Mbps	84784	256QAM		Transmit diversity	100	
SCELL 4							

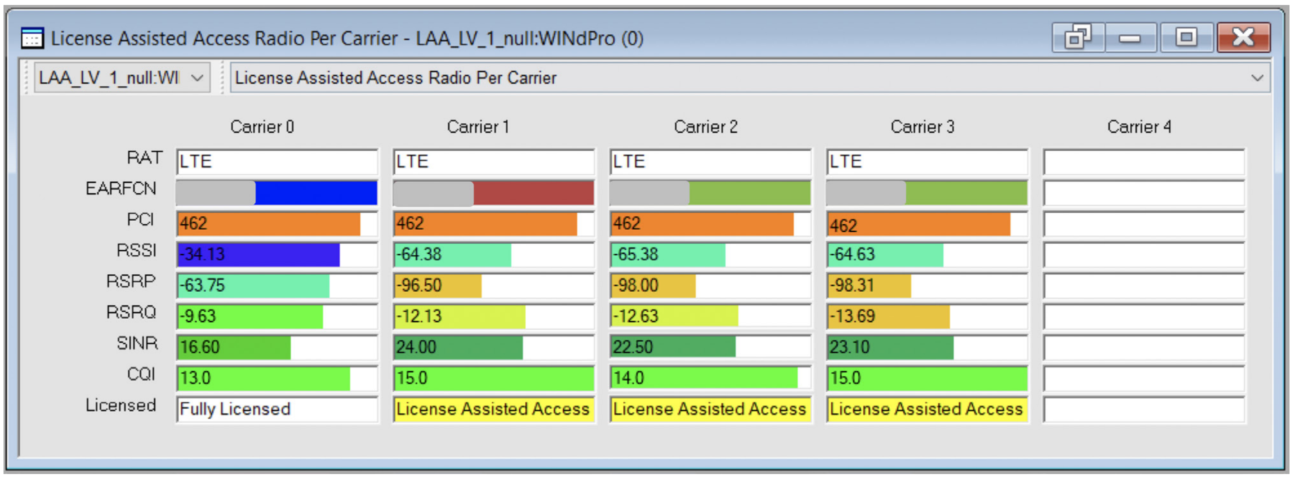
Actix Analyzer includes a comprehensive stateform view, which is designed to provide user-experienced radio conditions aggregated within a bin, either at Time, Distance or Location level. The values measured for each carrier allow CSPs to understand the performance of licensed versus unlicensed carriers deployed.

Per-carrier Stats: LAA – Licensed & Unlicensed

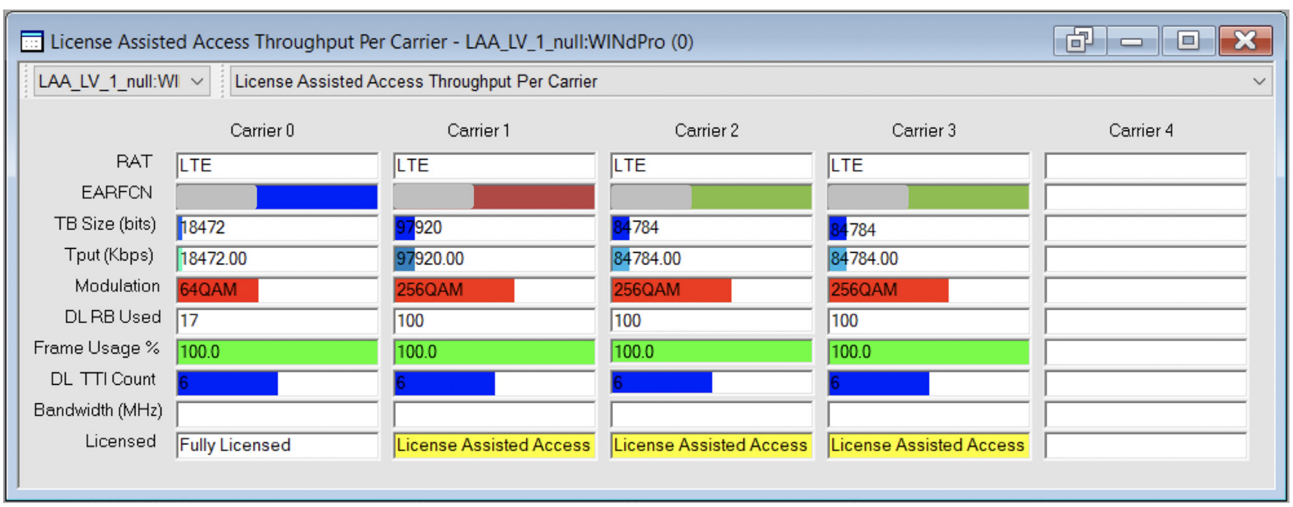
The Actix Analyzer LTE-Advanced-Pro platform solution provides the required radio parameter (bin level) for all aggregated carriers (Licensed + Unlicensed), enabling engineers to correlate processed data more prominently resulting in improved network experience.

LTE Connected – CA Active – Availability of per carrier stats at selected bin

- RSSI, RSRP, RSRQ, EARFCN, SINR
- Payload, TB Size, Throughput, Used Resource Block Count
- MIMO Usage, MCS Usage, Rank Indicator & Spatial Rank Usage
- CA Configuration and Activation events
  - SCell Activation – Licensed spectrum
  - SCell Activation – Un-Licensed spectrum



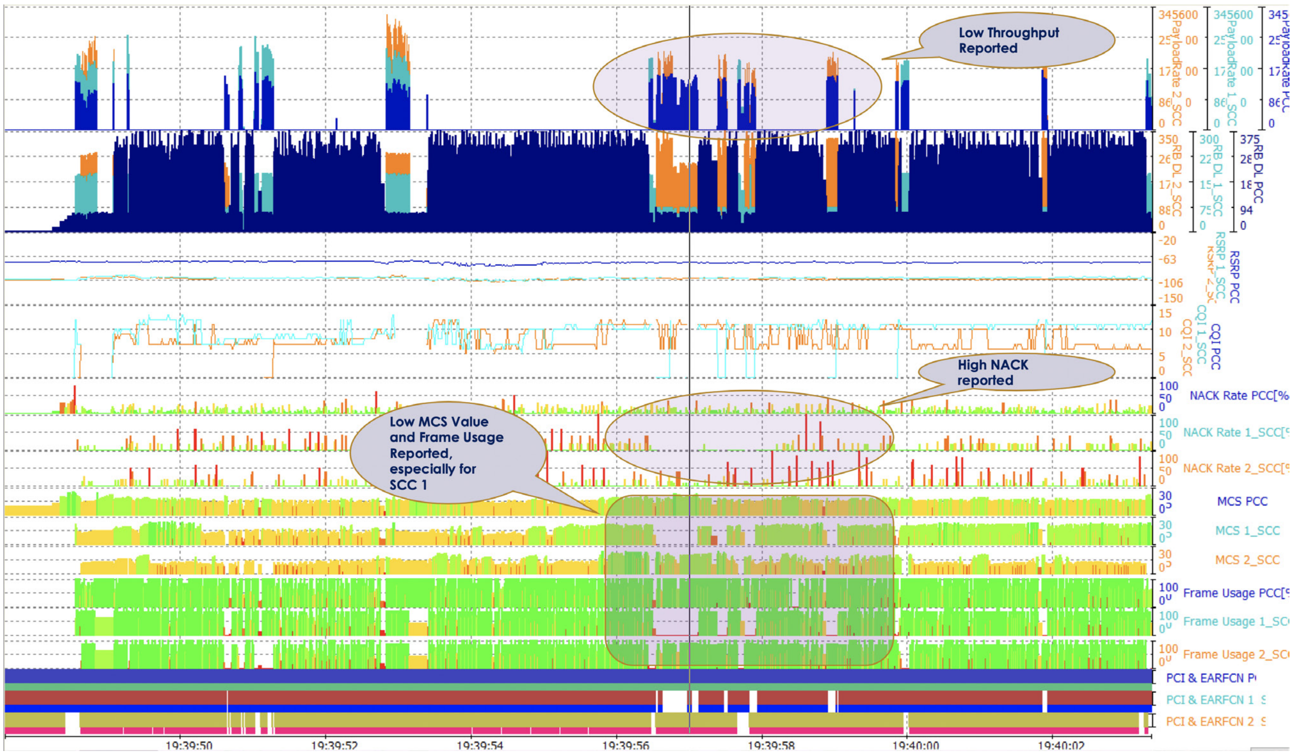
	Carrier 0	Carrier 1	Carrier 2	Carrier 3	Carrier 4
RAT	LTE	LTE	LTE	LTE	
EARFCN					
PCI	462	462	462	462	
RSSI	-34.13	-64.38	-65.38	-64.63	
RSRP	-63.75	-96.50	-98.00	-98.31	
RSRQ	-9.63	-12.13	-12.63	-13.69	
SINR	16.60	24.00	22.50	23.10	
CQI	13.0	15.0	14.0	15.0	
Licensed	Fully Licensed	License Assisted Access	License Assisted Access	License Assisted Access	



	Carrier 0	Carrier 1	Carrier 2	Carrier 3	Carrier 4
RAT	LTE	LTE	LTE	LTE	
EARFCN					
TB Size (bits)	18472	97920	84784	84784	
Tput (Kbps)	18472.00	97920.00	84784.00	84784.00	
Modulation	64QAM	256QAM	256QAM	256QAM	
DL RB Used	17	100	100	100	
Frame Usage %	100.0	100.0	100.0	100.0	
DL TTI Count	6	6	6	6	
Bandwidth (MHz)					
Licensed	Fully Licensed	License Assisted Access	License Assisted Access	License Assisted Access	

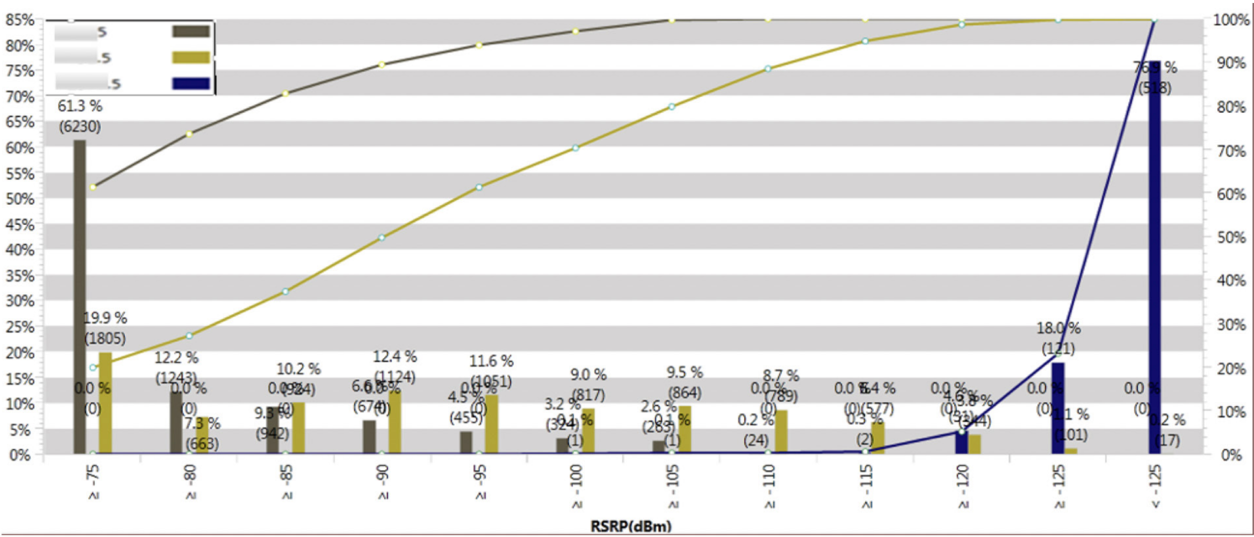
Actix Analyzer Stateform and Chart View: License-Assisted Access

The powerful stateform feature provides correlation and comparison between different user performance characteristics over complete data sets in one go and enables users to drill down into a single bin. Pre-defined combinations of measurements have been presented, to assist CSPs to identify poor network performance spots across the entire drive.

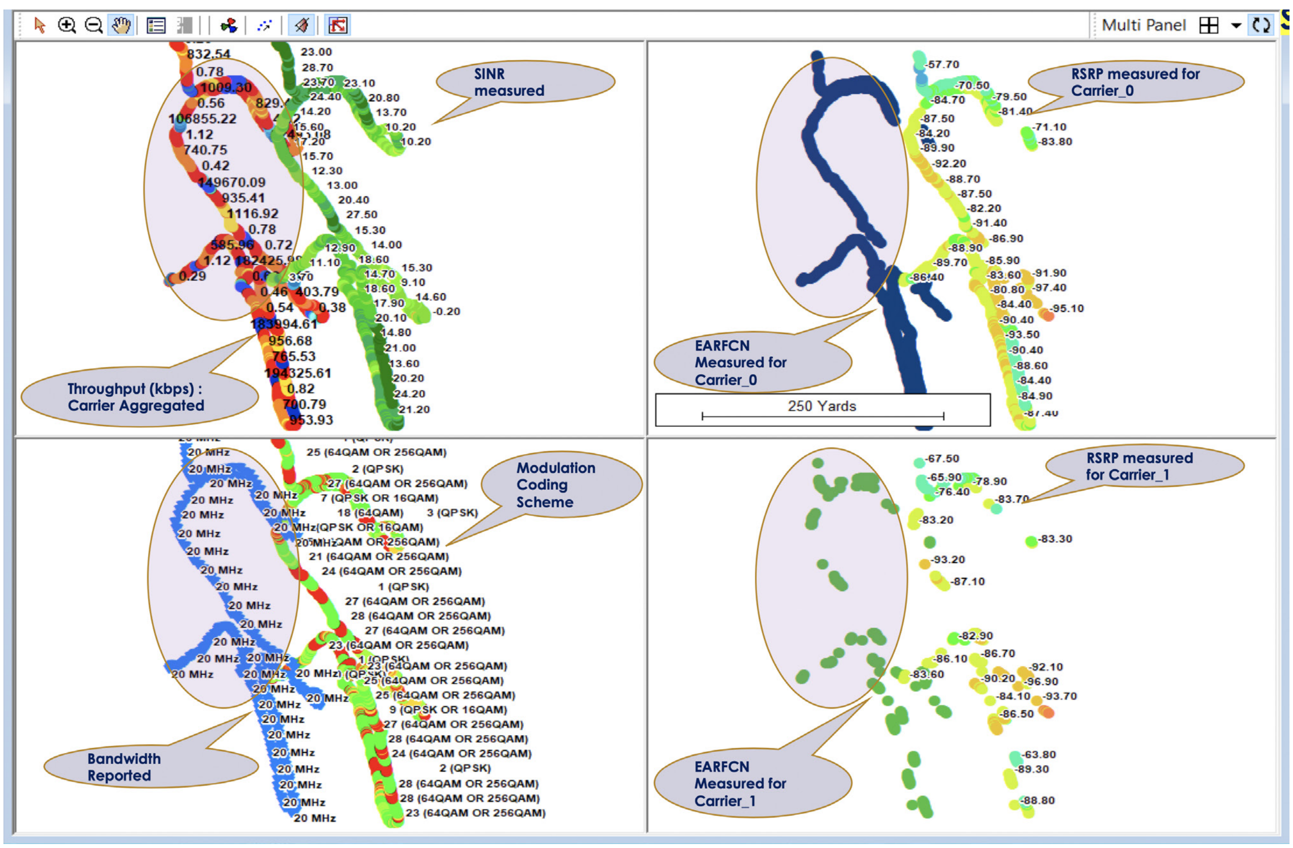


Viewing multiple attributes simultaneously enables CSPs to correlate efficiently for root cause analysis and pin down the areas most impacting the performance characteristics in terms of throughput, signal quality and overall user experience. The following screenshots show real time scenarios for per carrier RSRP, Transport Block Size, Allocated Modulation Coding Scheme and Resulting User Perceived Throughput, to easily create optimization equations.

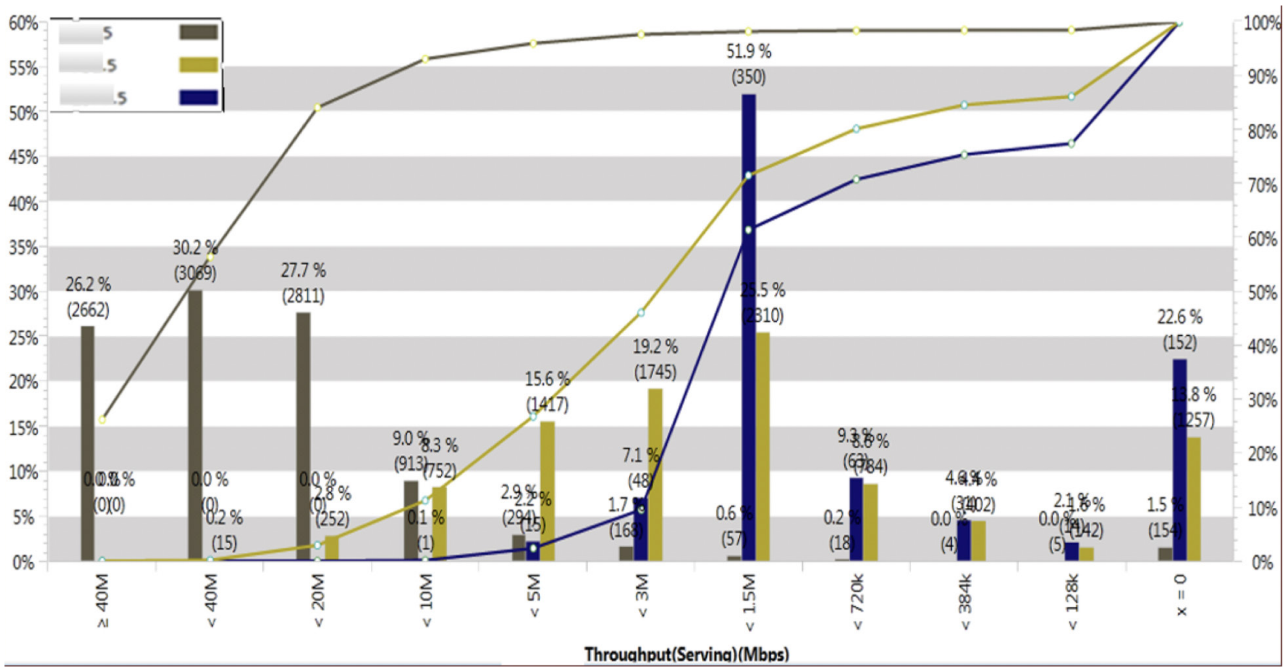
RSRP Usage: Best Layer – Sample Distributions per Carrier



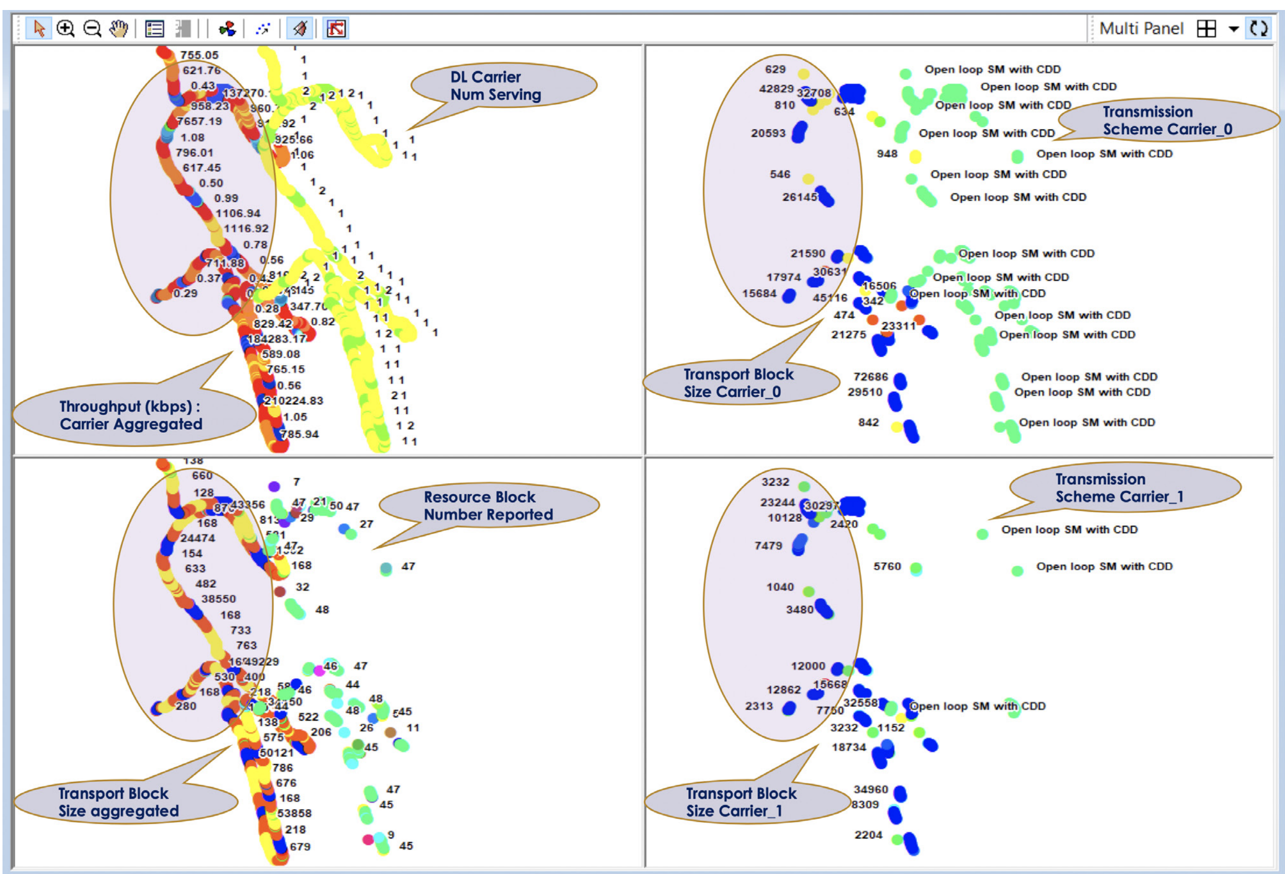
Throughput Analysis: RSRP, SINR and MCS Correlation – Distribution per Carrier



Per-Carrier Throughput Distribution



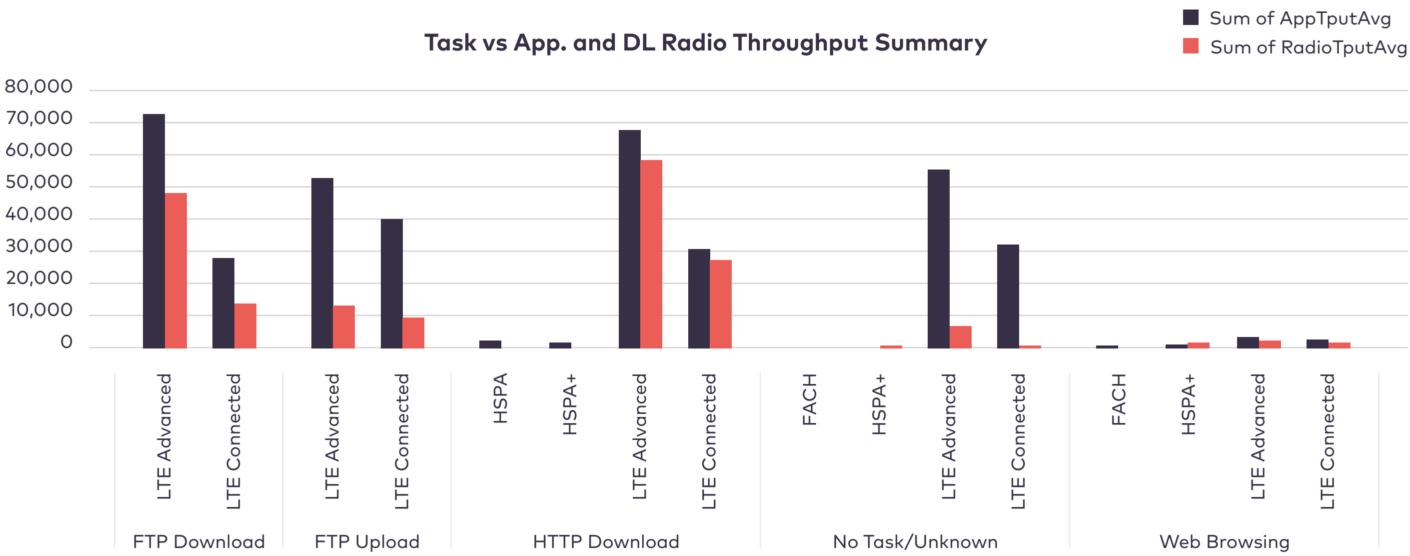
Throughput Analysis: Transmission Scheme, RB & TB Size – Distribution per Carrier



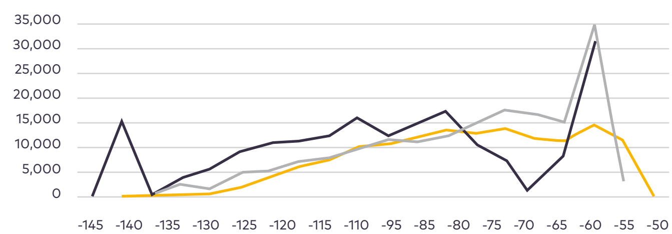
solution flow – reporting

Detailed reporting is included as standard, with graphical representation of data. This data includes carrier-level performance statistics that can be run across a whole cluster of drive survey measurements, from within the Spotlight dashboard. In turn, this helps CSPs to drill down to poor-performing network areas and highlight KPIs across per task, per carrier, or per number of active carrier component views.

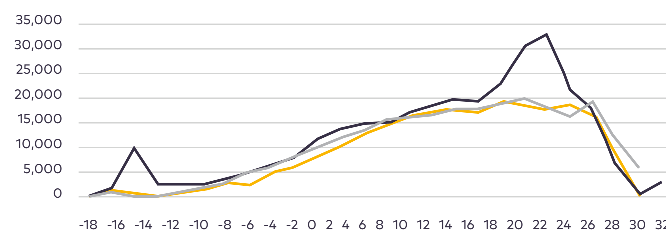
Task vs App. and DL Radio Throughput Summary



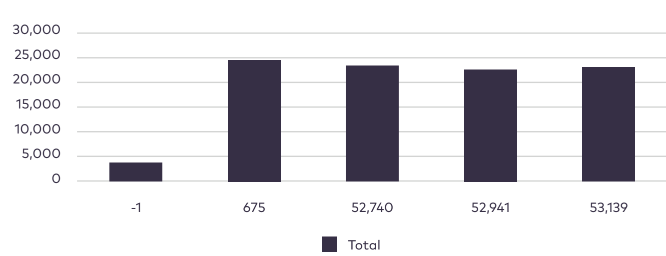
RSRP vs Radio Throughput per EARFCN



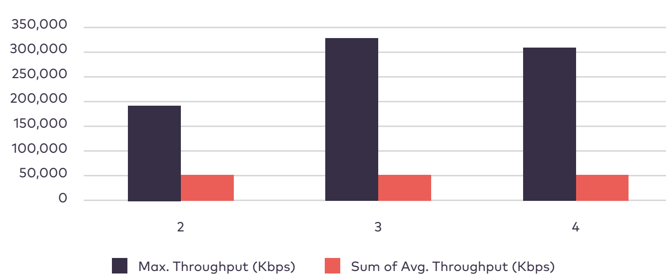
SINR vs Radio Throughput per EARFCN



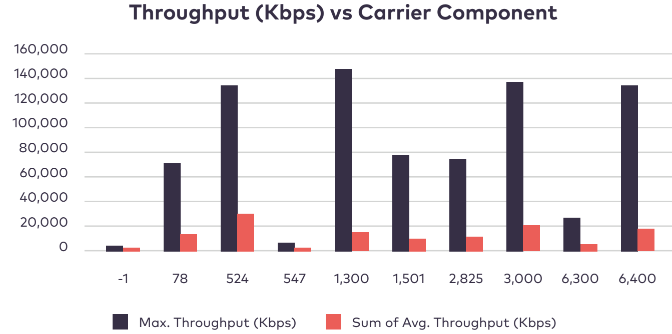
Distribution of Throughput Measurements vs Carrier Component



Throughput (Kbps) vs Number of Secondary Carrier Component



Throughput (Kbps) vs Carrier Component



conclusion

License-Assisted Access (LAA) is one of the eMBB-specific enhancements to LTE-Advance-Pro that evolved as part of 3GPP Releases 13 and 14. Its aim is to further increase peak data rate and capacity for broadband services, using unlicensed spectrum. Performance optimization of carrier aggregation support for higher numbers of LTE carriers, in combination with unlicensed spectrum, has been considered to be the most impactful in commercial networks.

Per-carrier level (licensed & unlicensed) radio network performance stats in Actix Analyzer provides an unparalleled level of detail, as well as ease in analyzing data, from which to compile recommendations on improving network performance. This enhances user experience in terms of faster broadband data speed, seamless indoor-outdoor mobility and service continuity, and enhanced performance for enterprise customers.

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