Demystifying the Unlicensed LTE Conundrum and Understanding LTE-Wi-Fi Coexistence

Aricent®

The enormous growth in data traffic on both wireline and mobile networks, accompanied by the phenomenal rise of smartphone users and other connected devices, continue to demand higher capacity from network operators, who in turn still struggle with depleting spectrum bandwidth. The licensed spectrum, especially the low-frequency bands, is limited, and is rapidly getting congested by a growing subscriber base. This has compelled network operators to explore new opportunities based on wireless voice and data. Among the many interesting options proposed, is the proposal to aggregate the licensed LTE spectrum with the unlicensed 5 GHz band being used primarily for Wi-Fi today. The 5 GHz spectrum has by far emerged as the most viable spectrum with huge bandwidth availability. Operators are excited about the opportunity to leverage the performance characteristics of LTE and take advantage of this spectrum to address the imminent capacity crunch.

Key players have put forth a set of proposals to the 3GPP standards body to enable LTE in unlicensed spectrum bands to aggregate licensed and unlicensed spectrum under a single radio technology called LTE Unlicensed. However, regardless of industry readiness, the need for regulations, and the feasibility to retail this spectrum for users and commercial devices, one key issue is the ability of LTE to co-exist with Wi-Fi and other technologies. This paper explores the need for LTE-U and possible deployment scenarios, and also highlights any challenges that lie ahead.

Introduction

Recent surveys by leading equipment vendors have revealed that people spend more than 85 percent of their time indoors and only about 45 percent are highly satisfied with their indoor experience while browsing the Internet or accessing apps like social networks. This drops down further to 40 percent for more data heavy apps like watching videos online on a mobile network. The ever-increasing mobile broadband system (MBB) traffic load leads to a pressing need for additional spectral resources of cellular systems, which are deployed in the spectrum mainly from 700MHz to 2.6GHz. More operators are now facing the challenge of soaring traffic with an ever-increasing number of people using mobile broadband services, as well as the bandwidth and speed demand per person. While MBB in the licensed spectrum is highly efficient due to its exclusive occupancy of the spectrum, the amount of available licensed spectrum can be limited and expensive. On the other hand, the amount of unlicensed spectrum that can be assigned is comparable to or even more than the amount of licensed spectrum.

While Wi-Fi accounts for more than half of traffic from mobile devices, mobile operators, until recently, used Wi-Fi primarily as a cellular data offload for residential, enterprise and hotspot solutions. In fact, cellular offload was the first incident of mobile operators using the unlicensed band spectrum. The past few years have, however, seen a growing desire among operators to expand their usage of the unlicensed spectrum by aggregating it natively with the existing licensed band , with the aim to increase data bandwidth and speed and improve subscriber experience. This native integration is possible in LTE due to its inherent carrier aggregation capability. In a 3GPP Radio Access Network (RAN) plenary standards meeting in December 2013, Qualcomm, Ericsson, Verizon, China Mobile, Huawei, and others, formally proposed LTE-Unlicensed (LTE- U) to utilize unlicensed spectrum to carry data traffic for mobile services with the initial focus on the 5725-5850 MHz band for this purpose.

So what makes LTE in the unlicensed spectrum so attractive to network operators? The main reason is that LTE-U increases the spectral efficiency and capacity of 5GHz band and can efficiently address the growth in data traffic. Though there is a deep concern among Wi-Fi vendors and service providers that LTE-U will unfairly impact Wi-Fi networks, mobile operators are certain that LTE-U integration with licensed bands will in no way undermine existing Wi-Fi networks. A fair co-existence scheme is required in the unlicensed band for multiple technologies that can ultimately enhance the end user experience without unfairly impacting the performance of other technologies.

The addition of LTE-U in the 5GHz band will unquestionably increase the traffic load in the band, even though the 5 GHZ band has hundreds of MHz spectrum, and is mostly not heavily congested today. But utilization of the band is growing quickly and it is only a matter of time before different Wi-Fi networks and different technologies will have to compete to transmit on this band. Regulations such as Listen Before Talk (LBT) in LTE-U will ensure fair usage as LBT mechanisms are the basis of fairness in existing Wi-Fi networks.

Some operators have already deployed a large amount of Wi-Fi access points (APs) to offload some cellular traffic to unlicensed spectrums. However, such efforts have not always led to desired results in terms of network performance improvement or cost reduction. Among the many reasons that contributes to such unexpected results, is the lack of good coordination between International Mobile Telecommunications (IMT) and Wi-Fi systems, which enforces manual switch between systems and results in low-efficient use of spectrum and poor user experience.

The Need for LTE Unlicensed

There has been a remarkable increase in both mobile traffic as well as wireless traffic over the last decade. In fact, wireless traffic accounts for more than half of IP traffic, and most of that is not mobile but Wi-Fi, and transported over unlicensed spectrum, mostly still in the 2.4 GHz band. It is thus not possible to overstate the relevance and value of the unlicensed spectrum. Initially allocated for niche applications, it has become a key enabler of wireless consumption worldwide, driven by the success of Wi-Fi.

Given more and more operators have already deployed LTE systems, it is in the interests of the operators to expand LTE capacity to meet the traffic demands by integrating unlicensed carrier into the overall LTE system by adapting LTE air interface to operate in the unlicensed spectrum. This will expand LTE capacity to meet constantly growing traffic demands. LTE, as an IMT-Advanced system, is currently the most advanced mobile communication technology. Many operators are today upgrading their networks to LTE and creating a roadmap towards an LTE-Advanced system.

According to Qualcomm, LTE-U provides better coverage and offload as compared to Wi-Fi, and requires fewer nodes at the same capacity when compared with Wi-Fi. It also states that stand-alone Wi-Fi requires 5x more APs to provide the same capacity as LTE-U. A seprate Nokia research shows that for a given system bandwidth and transmission power, the average throughput on LTE is 4x higher than Wi-Fi varied scenarios. LTE thus provides a better performance over Wi- Fi due to its coordinated and managed nature, which is thus more reliable and predictable performance vs. Wi-Fi.

How Will It All Work

The unlicensed spectrum will operate as a secondary carrier aggregated with a primary licensed carrier, to offer flexible and efficient traffic offloading in a mobile public operator network, while relying on existing LTE CN and RAN architectures for access authority, security, mobility and Quality of Service. With respect to the availability of large bandwidth and co-existence issues, 5.8G and 5.4G Hz bands are preferred for the first-wave of LTE-U deployments. Several vendor studies on LTE-U performance relative to Wi-Fi show a 3x-5x improvement of LTE over Wi-Fi in the unlicensed spectrum.

Regulations Critical for Optimal Performance

In addition to necessary telecom regulations aside, the industry is faced with a very evident and unavoidable situation. Data transmissions sent out by Wi-Fi and LTE-U will interfere with each other if transmitted simultaneously. On the one hand, Wi-Fi comes with coexistence procedures that allow multiple Wi-Fi systems to co-exist, while on the other LTE's natural design assumes that only one operator controls a given spectrum exclusively. LTE traffic channels have been designed to continuously transmit when delivering traffic. LTE also transmits control and synchronization signaling even when no traffic is being actively delivered. In such a scenario, Wi-Fi will not be able to sense the channel unoccupied and suitable for transmission.

Multiple technologies will co-exist for best use of all spectrum

LTE Advanced

Licensed spectrum foundation, augmented with unlicensed spectrum solutions

Mobile broadband services for best performance and quality-of-experience

LTE Unlicensed

LTE-based technologies in unlicensed spectrum, LTE-U, LAA, MuLTEfire™

Broadens LTE ecosystem to enhanced and new deployment opportunities

Wi-Fi ac/ad/ax

802.11-based technology solely operation in unlicensed spectrum

Also evolving for enhanced performance and expanding to new usage models

LTE-U traffic channels will have to be redesigned differently than LTE channels in the licensed spectrum, if we are to avoid LTE-U being the primary controller of the unlicensed spectrum at the expense of Wi-Fi devices and technology. Regulations will be needed to maintain coexistence between LTE and Wi-Fi without impacting the data throughput efficiency of either.

Regulations could limit unlicensed operations to a specified maximum transmit power so that LTE-U can be deployed as small cells. However, though LTE-U standard development is still underway, it is possible that some operators may be economically motivated to deploy pre-standard LTE-U small cells in 2016. To facilitate possible coexistence with Wi-Fi, the initial pre-standard LTE-U small cells might be integrated with Wi-Fi in countries that do not have explicit Listen Before Talk (LBT) policies, such as the United States, China, and Korea. Ideally, coexistence regulations should level the playing field for each network and technology while accounting for any local regulatory requirements.

How Will LTE-U Work

As the name implies, the goal of LTE-U is to extend LTE to unlicensed spectrum. LTE-U is the version of LTE unlicensed which relies on 3GPP Release 10-12 functionality with specifications defined by the LTE-U forum. Since it requires few modifications from licensed LTE, LTE-U will be the first version of unlicensed LTE to be available in commercial deployments.

LTE-U covers all implementations of LTE in the 5GHz unlicensed band that use a licensed channel – referred as a primary channel for signaling to co-ordinate transmission among different channels.

In LTE Licensed Assisted Access (LTE-LAA), a primary cell carries critical control signaling, mobility, and user data that demand high quality of service on licensed spectrum while less-demanding, best-effort traffic is carried on a secondary cell on unlicensed spectrum. It is the version of LTE unlicensed that 3GPP plans to standardize in Release 13 that supports LBT. LTE-LAA is set to become a global standard as it strives to meet regulatory requirements worldwide. In this scenario the use of unlicensed spectrum is always accompanied by a primary carrier on licensed spectrum. Operators and vendors worldwide could find it easier to adapt to LTE-LAA because it provides a globally harmonized solution that leads to better scalability and choice among equipment and device vendors.

The fair co-existence with Wi-Fi networks and support of LBT is essential for the success of LTE unlicensed. There is a growing consensus that LTE-LAA specifications have to go beyond regulatory requirements to meet the level of fairness the Wi-Fi stakeholders expect, i.e. the impact of an LTE-U small cell is not greater than that of a Wi-.Fi access point operating on the same channel. This is also why most operators want to introduce LBT across all markets, including those that do not require it.

LTE Unlicensed

– Deployed in the 5 GHz license- exempt band
– Uses a licensed LTE channel as a primary, anchor channel for signaling
– Designed to coexist alongside Wi-Fi

Two versions developed in parallel

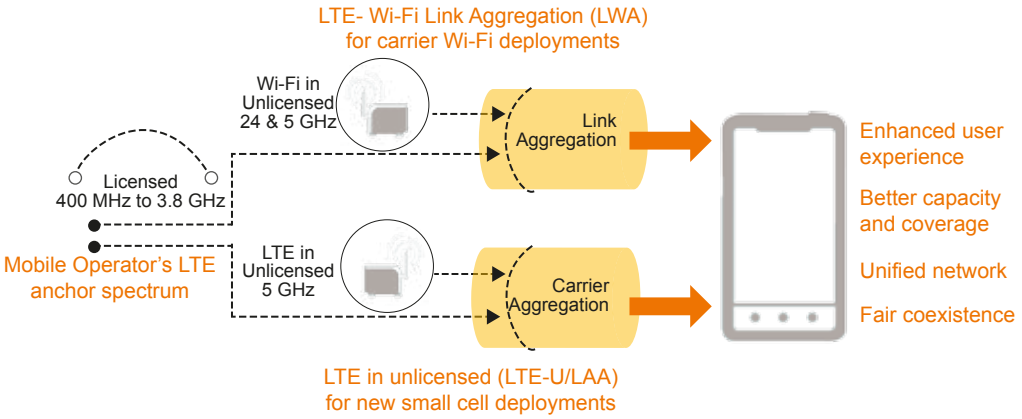
LTE - U

– Integration with licensed LTE supplemental downlink (CA with uplink no needed)
– Coexistence with Wi-Fi dynamic channel selection and CSAT (based on LTE Duty cycle)
– No support for listen before talk (LBT)
– Based on 3GPP Release 10-12
– Can be used in China, Korea, India, USA
– Fewer changes from licensed LTE
– Earlier Commercialization

LAA-LTE

– Integration with licensed LTE CA (uplink and downlink, using TDD in LAA-LTE)
– Coexistence with Wi-Fi dynamic channel selection, LBT
– Based on 3GPP Release 13
– Compliant with regulatory requirements of most countries
– More changes from licensed LTE
– Later commercialization

Aggregation with licensed spectrum provides best performance



Current Issues & Drivers

Mobile operators may rely on the unlicensed Wi-Fi spectrum for offload, but in most cases they do not own it or control it. LTE-U proposals have met with deep concern from Wi-Fi vendors and service providers that have been using the 5 GHz band for years and resent any possible unfair treatment due to the introduction of LTE. But the fact remains that the addition of LTE-U in the 5 GHz band will increase the traffic load in the band, leading to congestion. A fair coexistence of multiple technologies is essential to preserving equilibrium in the spectrum.

Wi-Fi's design allows it to support fair coexistence through LBT controls that stop AP transmission when a neighboring AP is transmitting. LTE uses a scheduled- transmission model designed to operate in licensed bands over which it has exclusive access. Extending this transmission approach to the 5 GHz band is sure to have an adverse impact on Wi-Fi. As of mid-2015, multiple proposals are under consideration and the 3GPP standardization process is ongoing. The standards specifications will determine whether LTE-U will provide guarantees of fair coexistence with Wi-Fi and high spectral efficiency sufficient to gather the support needed from both the Wi-Fi supporters and the LTE stakeholders.

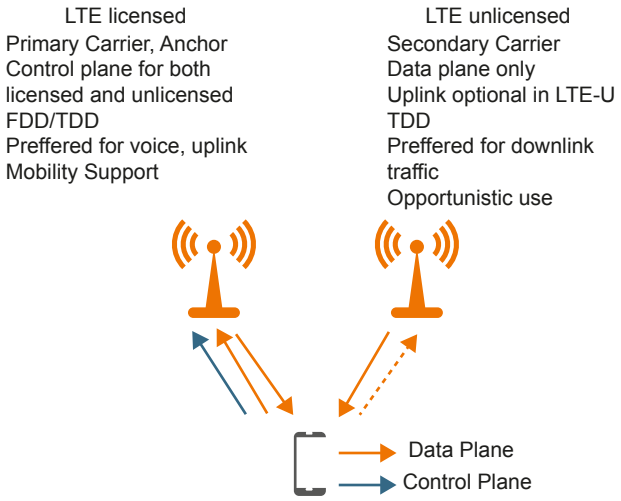
Deployment: LTE-U with LTE Licensed

LTE-U is fundamentally a special case of carrier aggregation in which the primary carrier uses licensed spectrum carrier and the secondary carrier uses 5GHz unlicensed spectrum carrier. The primary carrier manages the control plane for both carriers and hence is reliable for the resource allocation of traffic between carriers. The primary carrier is also used for data traffic in the uplink and downlink. The secondary carrier is limited to the data plane, with downlink required, but uplink optional. The secondary carrier uses TDD, while the primary carrier can use either FDD or TDD.

The primary carrier is preferred for voice and uplink traffic, while the secondary carrier is used to transport more downlink traffic. The usage of secondary channel is on an opportunistic basis –i.e. only when the primary carrier is at capacity or overloaded. This is the reason, sometimes, the secondary carrier is also called supplementary channel in LTE unlicensed. The primary carrier due its better reliability is suited for mobility support.

The secondary carrier operates on a high capacity wide channel but the capacity is not guaranteed because the channel may be shared with other LTE unlicensed cells or with Wi-Fi APs. LTE unlicensed will be deployed mostly in small cell topologies, often in indoor locations. In a small cell deployment, multiple scenarios are possible.

Integration of LTE licensed and LTE unlicensed

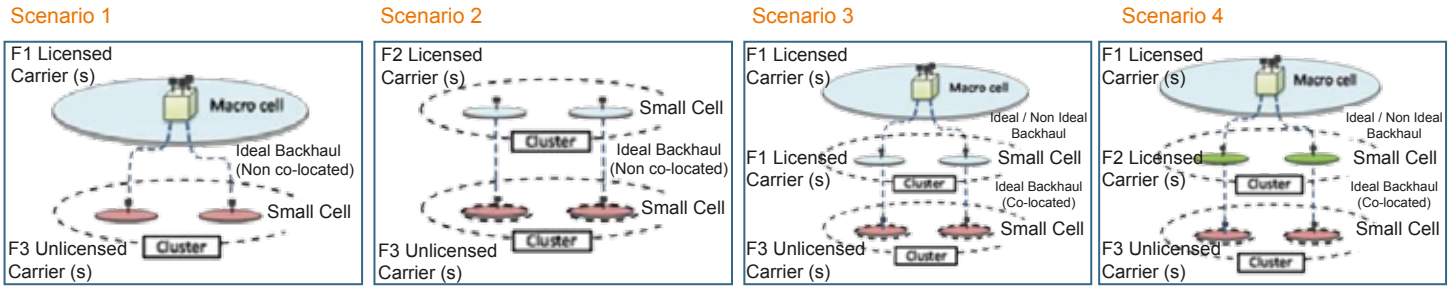


For the foreseeable future LTE-U will not be autonomous from the existing LTE networks in licensed spectrum. Instead, LTE-U will need to leverage the licensed spectrum for the anchor carrier since the licensed spectrum can always be used and it is more reliable than the unlicensed spectrum where LTE-U will reside. Even in this context there are still a few deployment options to consider, including the possibility for some pre-standard LTE-U deployments.

LTE-U can be thought of as a two-phase approach. Phase 1 is a pre-R13 solution that can be deployed in certain regulatory regions with a ready ecosystem. Phase 1 is possible because it leverages existing LTE Carrier Aggregation and radio resource management features to avoid interference with itself. Any wireless application or service can use this spectrum alongside Wi-Fi and other existing incumbents, as long as the new entrant supports technical features that enable fair usage of the spectrum. Phase 2 is the R-13- based solution that is necessary to make LTE-U a reality worldwide, including those countries that have more stringent regulatory requirements for the 5 GHz band.

The scenarios which 3GPP envisages are shown below, and all include an LTE-LAA small cell.

In the first scenario, the primary cell is the macro, and the LTE-LAA small cell is not co-located, but linked to the macro cell will ideal backhaul (most commonly fiber). In other three scenarios, the LTE unlicensed cell is always co-located with a licensed LTE small cell, with the licensed small cell or the macro cell acting as the primary carrier. The second scenario is most likely used in indoor environments. The 3GPP deployment scenarios are conceived to better meet the multiple operators need for small cell deployments as well as provide enough flexibility to operators in small cell deployments. It is becoming clear that small cell deployments will play a key role in 5 GHz as densification is required in deployments to meet the ever-growing demand for data.



3GPP LAA Deployment Scenarios

Scenario 1: CA between licensed macro cell (F1) and unlicensed small cell (F3)

Scenario 2: CA between licensed Small cell (F2) and unlicensed small cell (F3), no macro coverage (e.g., indoor deployement)

Scenario 3: CA between licensed Small cell (F1) and unlicensed small cell (F3), with macro coverage

Scenario 4: CA between licensed Small cell (F2) and unlicensed small cell (F3), with macro coverage (F1). With ideal backhaul between macro and small cell, CA among F1, F2 and F3 is possible. Dual connectivity between macro cell and small cell can be enabled.

Source 3GPP

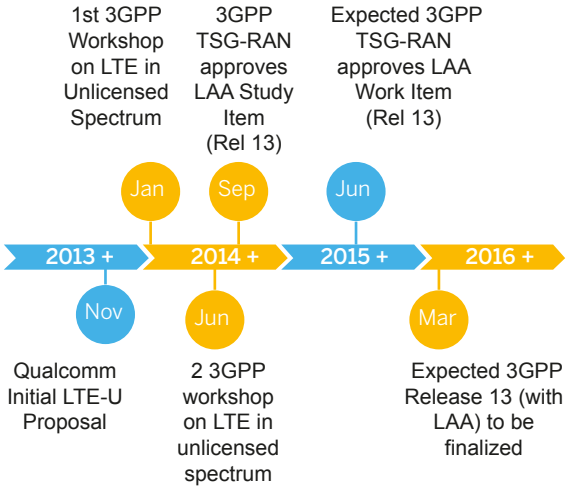
Although nothing is preventing mobile operators in most countries from deploying LTE-U today, they still need commercially- viable solutions, including devices/chipsets and infrastructure that support it with full interoperability. Given that the major infrastructure vendors are on board and Qualcomm was one of the initial proponents of LTE-U, it is certain that development work is underway on both chipsets and infrastructure from all of these companies. But there is no clear indication for when these solutions will be available.

LTE-LAA Standardization within 3GPP

The 3GPP decided early that it will only standardize that version of unlicensed LTE which can be deployed worldwide. The 3GPP is working on this, having created a study item in 2014, finalization is expected in Release 13, projected for March 2016.

The focus of current work within the standardization is to find an industry wide consensus as to what is required for fair co-existence. This is a difficult process, because fairness does not come for free: the price is reduced performance. When adding LBT to LTE unlicensed, there would be a negative impact on performance and that degradation will depend upon how LBT is supported in LTE-U.

The success of LTE-LAA will depend upon large-scale industry wide support by mobile device vendors to support the technology in new devices. These considerations are guiding the work being done in 3GPP. There is a growing commitment to finding a robust solution to co-existence in environments where Wi-Fi will continue to dominate for the foreseeable future.



Source: Ruckus Wireless

3GPP Standardization Timeline

Progress in LTE Unlicensed Standardization	
December 2013	Qualcomm and Ericsson presentation of the intitial proposal for LTE-U at 3GPP meeting in Busan, South Korea
January 2014	A 3GPP unofficial meeting in Paris with companies and operators presenting their perspectives on the use of LTE in unlicensed bands.
March 2014	Discussion at the 3GPP plenary meeting in Fukuoka, Japan
June 2014	Workshop in Sophia Antipolis, France.Outcomes included ▪ A plan to setup a study item in September 2014 ▪ Adoption of LAA-LTE designation ▪ Agreement to focus on the 5 GHz band ▪ Commitment to finding a global solution ▪ Establishment of fair coexistence with Wi-Fi and among LTE operators
September 2014	3GPP TSG-RAN approved LAA-LTE as a study item for Release 13. The main goal is to determine the changes needed for fair coexistence of LAA-LTE and Wi-Fi, Release 13 covers ▪ Regulatory requirements ▪ Deployement scenarios, including multiple operators, and coexistence with both Wi-Fi and other LAA-LTE networks ▪ Design targets and functionalities ▪ Coexistence evaluation and methodolgy Required functionalities include ▪ LBT, with maximum transmission duration ▪ Dynamic frequency selection for radar avoidance in certain bands and regions ▪ Carrier Selection ▪ Transmit power control ▪ The primary focus is on the downlink, although uplink is also under consideration
March 2016	3GPP work item specs to be finalized. They will define the LBT coexistence mechanisms to be implemented, and the pairing of unlicensed transmission with licensed bands. Release 13 will also include LTE and Wi-Fi aggregation (LWA) and new functionality to improve mobility management and eNB management in integrated LTE and Wi-Fi networks,

Performance Benefits of LTE-U

It is difficult to quantify the performance benefits of LTE-U versus Wi-Fi, based upon the simulation results, as 3GPP standardization is still underway. The high level driver for performance differences between the two technologies are however becoming established, even though results from individual trials and simulations are somewhat varied. The table below summarizes the high-level findings to date, but interested readers should consult the various published documents by 3GPP members in 3GPP repository.

There are multiple factors supporting the improved spectral efficiency of LTE-U over Wi-Fi, including:

- Robust FEC
- Hybrid ARQ
- Effective interference co-ordinance and avoidance
- Better mobility support and device scheduling
- Carrier aggregation to manage traffic over licensed and unlicensed channels
- RAN synchronization

In an environment where LTE –U has complete access to a channel because there is no competing network (either Wi-Fi or LTE unlicensed), operators reap all these benefits to the maximum. In the unlicensed spectrum, LTE uses the same scheduled transmission mechanisms that it uses in licensed bands, giving it a higher spectral efficiency than Wi-Fi. In contrast, when operating in a channel shared with Wi-Fi or another LTE-U network, LTE performance advantages are reduced somewhat due to interference as well as by fair co-existence mechanisms.

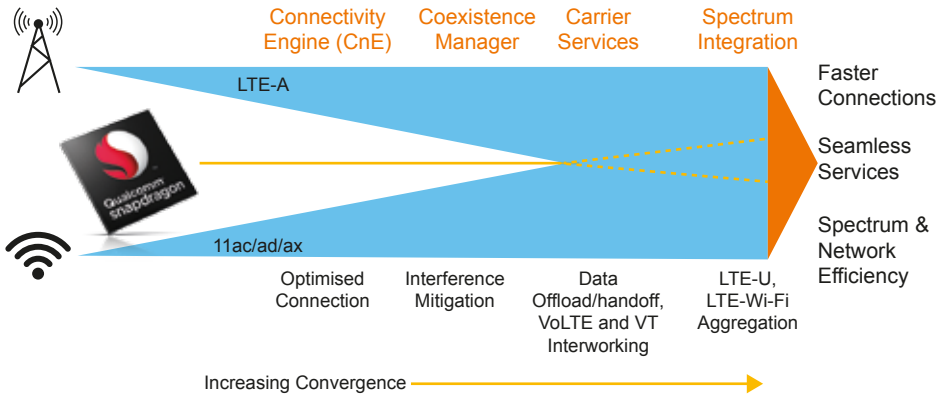
An implementation of LBT according to the 3GPP target – of not degrading Wi-Fi performance any more than another Wi-Fi access point would – is expected to degrade LTE-LAA performance significantly. However, simulations results indicate that the combined throughput of LTE-LAA and Wi-Fi is still better than two standalone Wi-Fi networks. The simulation results not only indicate combined increase in throughput but also increase in coverage due to better interference mitigation and avoidance in LTE-LAA.

Performance comparison:
LTE Unlicensed versus Wi-Fi, stand-alone configuration

- LTE has better spectral efficiency:
  – Transmission
  – Interference Management
  – Coverage
- LTE performance is more robust than Wi-Fi with:
  – Increased traffic load
  – Increased number of users

The impact on Wi-Fi will depend upon how LBT is standardized in LTE-LAA. 3GPP is considering the use of a fixed back-off period whereas Wi-Fi uses a variable back-off period. One way to address the concerns of Wi-Fi players is to replicate within the LTE-LAA a level of fairness which is closely in line with the one which is currently supported in Wi-Fi networks. This approach will make sense, because Wi-Fi is the prevalent technology using 5GHz spectrum, and LTE-LAA is the newcomer. It seems there is going to be a consensus among all players (Wi-Fi, LTE-LAA, both) which will ensure equal fairness for all without sacrificing unnecessary performance gains of one technology versus the other.

LTE - Wi-Fi convergence-going beyond interworking



Alternatives to LTE-U

A stand-alone version of LTE-U that does not require aggregation with a licensed band has also been proposed, but so far it has not gained enough support within the 3GPP. This version of LTE-U operates just like a Wi-Fi AP, carrying both control and traffic.

Another alternative is LTE and Wi-Fi aggregation (LWA), where the Wi-Fi access is used with Wi-Fi transmission in the unlicensed band along with LTE transmission in the licensed band. Licensed LTE provides the anchor for Wi-Fi and is responsible for signaling. Data traffic is transmitted through both LTE and Wi-Fi. The key advantage of LWA is that it requires very small changes in existing networks as well as in existing devices. However, LWA lacks the performance benefits offered by LTE-U. LWA delivers other important benefits over Wi-Fi offload and increases the attractiveness of carrier Wi-Fi when the two are combined. LWA is also being standardized within the 3GPP.

Summary

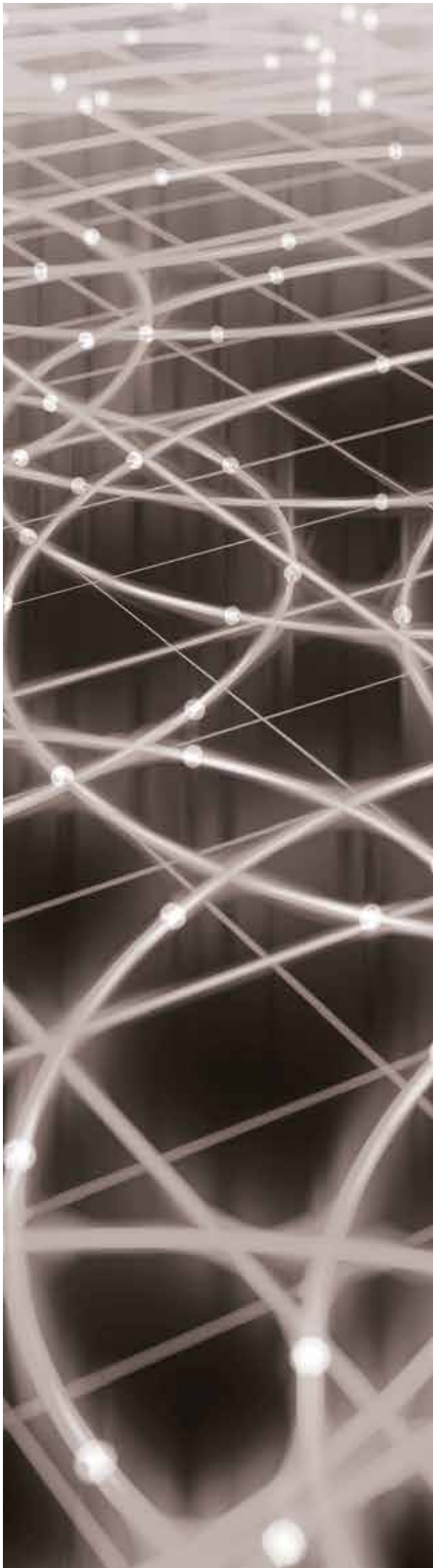
There are two variants of LTE unlicensed, i.e. LTE-U and LTE-LAA. LTE-U is specified by LTU forum, which does not support LBT and will not meet fairness co-existence with Wi-Fi APs. The LTE-LAA is being specified by 3GPP, which will support LBT and will support fair co-existence with incumbent players. The success of LTE-U will depend upon mutually agreed support for fair co-existence with all players as well as quick adoption by the mobile device players. In some countries, LTE-U could be deployed as a pre-standard solution and offer meaningful coverage and capacity gains over what is possible with Wi-Fi. However, some other countries have regulatory requirements that necessitate some important changes to the LTE standard in order to leverage the unlicensed spectrum. These changes will likely get incorporated into Release 13 of the LTE standard.

With both the pre-standard and standards-based implementations of LTE-U, LTE will be a good neighbor to the other occupants in the spectrum, thus ensuring that all applications and services that use the spectrum must grant others fair usage. The success of LTE and Wi-Fi integration will also depend upon the relative performance of both these technologies and how easily systems can be developed cost effectively.

Aricent's LTE Unlicensed Solution

Aricent along with its ecosystem partner has developed an LTE-Unlicensed solution which supports both flavors of LTE-Unlicensed (LTE-U and LTE-LAA). Currently Aricent's LTE-Unlicensed solution for LTE-LAA is somewhat proprietary as the 3GPP based standardized specifications are yet not available. The solution is currently at an advanced stage of integration and testing and will be available soon.

The key feature of Aricent's LTE-Unlicensed solution is that the same solution can be used for both flavors of LTE unlicensed. The solution is currently only supported for one our ecosystem partner platform and will be made available on other ecosystem partner platforms based upon clients and partner interest on those platforms.



References

1. 3GPP TR36.889
2. LTE-U forum: eNB Minimum Requirements for LTE-U SDL
3. LTE-U forum: LTE-U SDL Co-existence specifications
4. LTE-U forum: LTE-U Technical report
5. ETSI EN 301 893 V 1.7.1
6. 3GPP TSG RAN WG1 meeting#80 R1-150584
7. 3GPP TSG RAN WG1 meeting#80 R1-150701
8. 3GPP TSG RAN WG1 meeting#80 R1-150271
9. 3GPP Workshop on LTE in Unlicensed Spectrum, 13 June 2014, Sophia Antipolis, France.
10. LTE in unlicensed spectrum, Qualcomm and Ericsson. RP-131635.
11. Playing by the rules: The success of unlicensed spectrum: http://www.lightreading.com/mobile/carrier-wifi/playing-by-the-rules-the-success-of-unlicensed-spectrum/a/d-id/708088

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