

Nokia

LTE for unlicensed spectrum

White Paper

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Introduction

LTE networks carry a huge amount of data, driven by a growing number of LTE subscribers that reached almost 300 million by mid 2014. Radio capabilities have also been evolving rapidly with the development of LTE-Advanced, enabling a commercially available peak data rate, with carrier aggregation, of 300 Mbps during 2014. As part of 3GPP Release 13, a new activity has been started using unlicensed spectrum with LTE alongside licensed spectrum. This is known in 3GPP as License Assisted Access (LAA). This would allow operators to benefit from the additional capacity available from the unlicensed spectrum, particularly in hotspots and corporate environments. With LAA, the extra spectrum resource, especially on the 5 GHz frequency band, can complement licensed band LTE operation.

Unlicensed spectrum

The frequency band of most interest for 3GPP is the 5 GHz band, which has a lot of unlicensed spectrum available globally, much more than the 2.4 GHz frequency band. Most markets offer a large amount of spectrum in the 5 GHz band, for example in Europe there is 455 MHz of spectrum available in the band, as shown in Figure 1. There are also allocations available in the 5 GHz band in countries such as Korea and Japan.

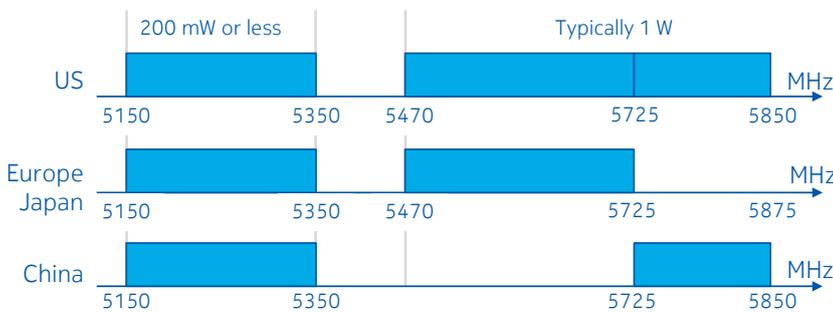


Figure 1. Unlicensed spectrum availability in different regions.

The use of unlicensed spectrum usually carries some regulatory requirements, such as being able to detect if a radar system is using the band or being able to co-exist with other users of the band. This is often referred to as Clear Channel Assessment (CCA) or as Listen-Before-Talk (LBT) and means it is not always possible to transmit immediately if the intended channel is occupied. The transmission power allowed also varies depending on the part of the band. Typically, the lower portion is often restricted to indoor use, with a transmit power of 200 mW or less, while the upper part of the spectrum allows higher transmission power, typically 1 W. In some cases, such as the US 5.725 GHz to 5.850 GHz, there are no specific requirements other than the transmission power limitation.

Operational Environment

The use of LTE on unlicensed bands has been considered for public indoor cells or outdoor hot spots, generally places where there is coverage from licensed band LTE operation but where additional capacity would be beneficial. The intention in the 3GPP work is not to define a standalone system that could be used for example, in residential/home environments, since there are existing solutions such as femto cell or Wi-Fi for that case. Another typical use case would be the corporate environment, which would benefit from the use of high capacity LTE radio technology.

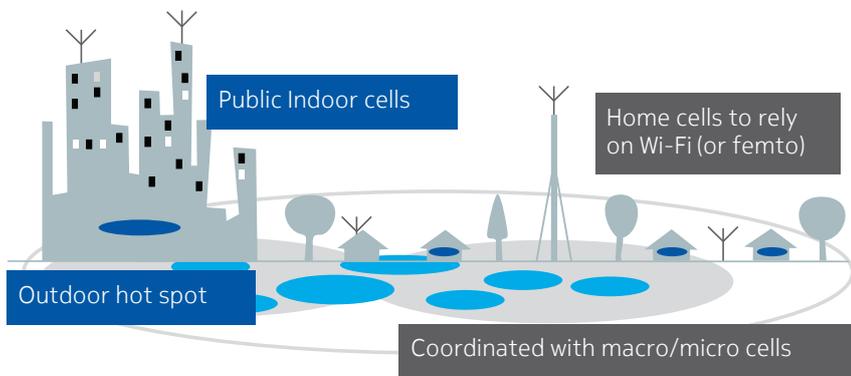


Figure 2. LTE-Unlicensed environment

Reasons for using unlicensed spectrum with LTE

The need to use LTE with unlicensed spectrum is the increase in traffic volumes and the number of mobile broadband users globally. As mentioned previously, the 5 GHz spectrum offers a large amount of bandwidth. With LTE technology, a number of the following could be achieved:

- Better spectrum efficiency than the current technologies in use with the 5 GHz band. Since LTE radio technology is based on state of the art technology, it can achieve both **high data rates and at the same time high spectral efficiency**, also in the unlicensed band. As well as higher capacity, LTE technology offers better coverage, especially when combined with the use of licensed band operation.
- From the network management point of view, using the unlicensed band with LTE instead of an alternative radio technology, provides a solution that is **well integrated to the operator's existing radio network setup**, avoiding multiple solutions for network management, security or authentication. Having only a single technology simplifies the overall network maintenance. Finally, the use of LAA is fully transparent to the LTE core network, avoiding the need to upgrade any of the Evolved Packet Core (EPC) elements.

- The use of both licensed and unlicensed spectrum offers end users higher data rates and overall better performance when the unlicensed band operation is available. The use of carrier aggregation means the licensed spectrum can quickly take over to **ensure service quality** should the unlicensed spectrum become unusable for any reason, such as reduced coverage, interference from another system or avoidance of, for example, a radar operating in the band.
- Based on the studies conducted, the LTE technology can meet the regulatory requirements for the unlicensed band **and allow co-existence with the other LTE systems as well as other technologies**, such as Wi-Fi, operating on the same frequency band.

LTE principle on unlicensed band

LTE operation on the unlicensed band is built on top of LTE-Advanced carrier aggregation, which has been deployed commercially since 2013. The simplest form of LTE-Unlicensed would be to use the unlicensed band with downlink only carrier aggregation, while the uplink would be in line with 3GPP carrier aggregation principles, as illustrated in Figure 3. This is similar to the first phase LTE-Advanced carrier aggregation in commercial networks which have started with downlink only aggregation. The primary cell, which ensures the connection is maintained, is always located on the licensed band carrier.

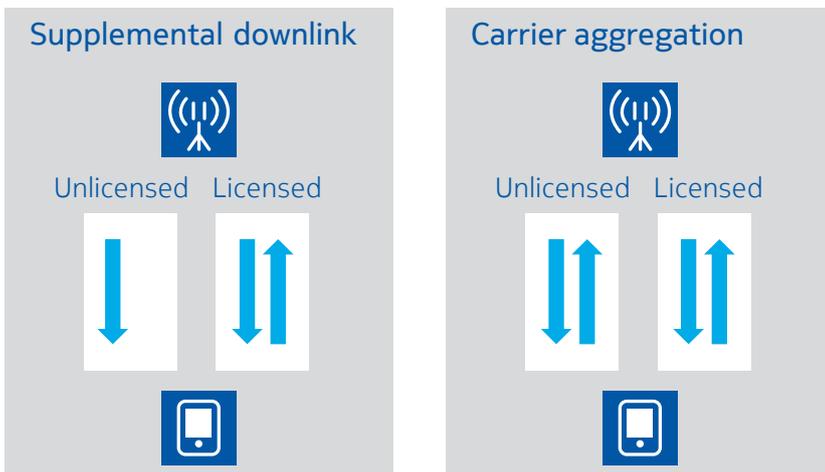


Figure 3. LTE-Unlicensed operation modes.

When operating with downlink only on the unlicensed band (supplemental downlink), the LTE eNodeB can perform most of the necessary operations to ensure reliable communications, including checking whether the intended unlicensed channel is free from other use.

The LTE eNodeB should aim to select a channel that does not have another network operating on it with a high interference level, but rather select a channel that is either free or only slightly loaded. Having selected the channel, the LBT operation must be performed before transmission is possible, as well as the other necessary procedures in-line with the unlicensed band regulation.

The LTE terminal capable of operating on the unlicensed band needs to be able to make the necessary measurements to support unlicensed band operation, including providing feedback when the terminal is in the coverage area of a LTE eNodeB transmitting with the unlicensed spectrum. Once the connection is activated to allow use on the unlicensed band, the existing Channel Quality Information (CQI) feedback will allow the eNodeB to determine what kind of quality could be achieved on the unlicensed band compared to the licensed band. The downlink only mode is particularly suited for situations where data volumes are dominated by downlink traffic.

The uplink transmission (full TDD operation) from a terminal operating on the unlicensed band requires more features, both in the terminal as well as in the LTE eNodeB, compared to the existing licensed band operation. These extra features are needed to meet the specific requirements of transmission on the unlicensed band, including enabling the LBT feature and radar detection in the terminal side. While in the downlink only mode, these features are needed only on the eNodeB side. Depending on the progress of the 3GPP work, the specification support for LAA may be phased in such a way that only downlink aggregation with 5 GHz band will supported in Release 13, with Release 14 supporting the full TDD operation. However, the current study in 3GPP is addressing both downlink only and full TDD operation.

LTE-Advanced carrier aggregation allows aggregating between FDD bands as well as between TDD bands from Release 10 onwards. With the Release 12 version of LTE-Advanced specifications, aggregation between FDD and TDD bands is also possible as shown in Figure 4, thus providing further flexibility in selecting the band to be used with the unlicensed band with LAA operation.

FDD/TDD Aggregation

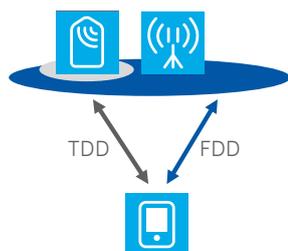


Figure 4. LTE-Advanced aggregation between FDD and TDD bands.

LTE performance on the unlicensed band

The first phase LTE networks provide up to 150 Mbps data rate, while the latest chip using LTE-Advanced supports up to 300 Mbps downlink peak data rate. Although LTE capabilities are evolving continuously and will ultimately enable higher data rates of up to 1 Gbps or even more, the next steps after 300 Mbps are support of 450 Mbps and 600 Mbps downlink peak rates. These rates will be achieved when devices supporting more than two aggregated LTE downlink carriers become available. The LTE performance study done in an office environment, with the layout as shown in Figure 5, was found to be roughly twice the data rate of a comparable Wi-Fi network (802.11ac).

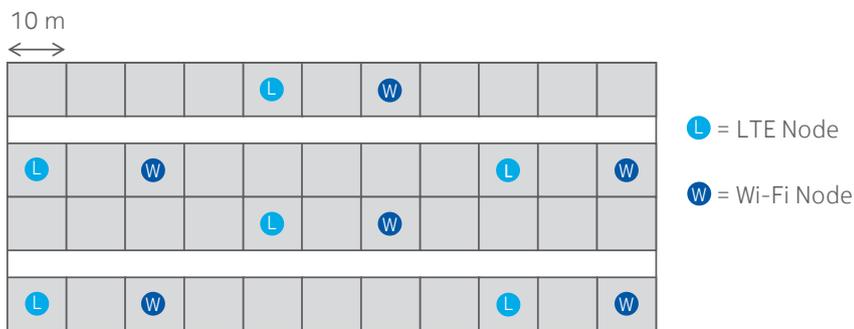


Figure 5. The example office layout with two corridors.

The results presented in Figure 6 indicate the extra performance achievable with a single 20 MHz carrier on unlicensed spectrum when there were no other interfering networks present and with 30 Mbps offered load per access node. The results do not contain the licensed band LTE capacity available. The office environment contained both LTE and Wi-Fi network 6 access nodes each operating on the same 20 MHz carrier without interference from other networks i.e. the channel was used only by a single network. The capacity was compared always

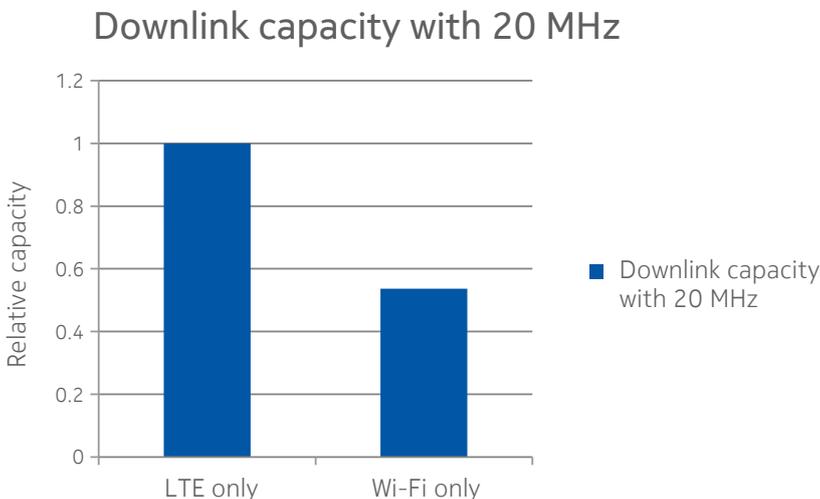


Figure 6. LTE capacity compared to the Wi-Fi capacity in the office environment.

relative to the achievable LTE capacity when operated on the unlicensed band using a channel without other networks. The relative capacity of the LTE network would be even higher when the offered load and number of users is further increased, as Wi-Fi capacity will not increase further or will even go down, while the LTE network can still reach a higher throughput. The traffic model assumed a 2 MB file download with FTP. In all cases, all the nodes are operating on their own schedule, with no coordination between them.

If we consider a single access node with a large amount of traffic (a hot spot), the LTE design allows the system to stay robust while serving a very large number of users, while the Wi-Fi access capacity would start to drop sharply with increased traffic. The advanced features for handling the load in LTE can also be applied when operating in the unlicensed band, ensuring high capacity when faced with a large number of users.

From the coverage point of view, the link budget of LTE is clearly better, due to a number of factors including more efficient air interface design. This allows fewer nodes for a given area to reach the same capacity as a Wi-Fi network. This enables a trade-off in deployment between the total network capacity and the number of LTE nodes being deployed for the unlicensed band.

Co-existence

An important part of the deployment is co-existence with Wi-Fi and other LTE networks on the unlicensed bands. When running LTE and Wi-Fi on the same 20 MHz carrier, both networks should use an LBT solution to ensure they co-exist smoothly. There is always an effect when interference is created by additional transmitters, regardless of whether those additional transmitters are using LTE or Wi-Fi or some other technology. Thanks to advanced radio features, sharing of channels by LTE networks results in a smaller overall capacity loss than would be the case with two Wi-Fi networks. This is illustrated in Figure 7 with two

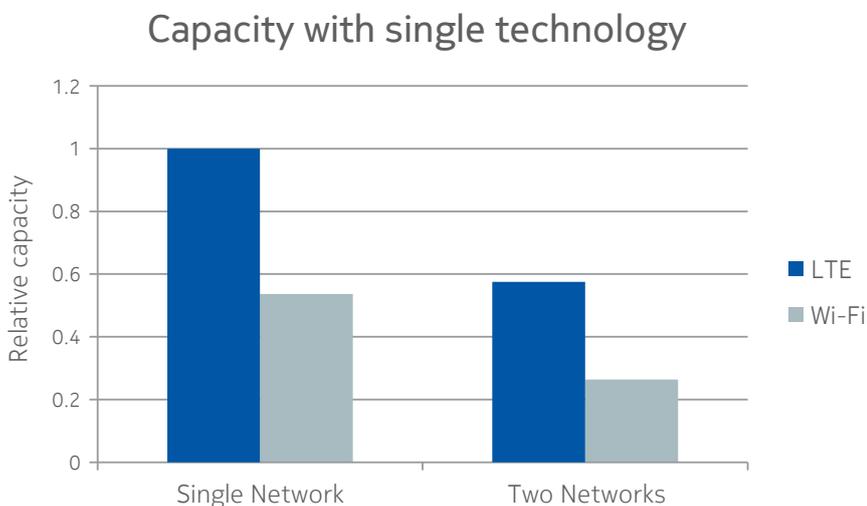


Figure 7. Performance per access node with two LTE or two Wi-Fi networks on the same channel

different networks operating on the same 20 MHz channel. In the first case, the two networks are using LTE technology, while in the other, the two networks are using Wi-Fi. The relative performance is dependent on the load. With smaller loads than shown in Figure 7, both networks are likely to be able to carry all or most of the offered traffic, in which case the difference would be smaller. Respectively, with higher loads, the LTE network performance would be even higher, resulting in a higher capacity than Wi-Fi.

Particularly for the first phase LTE deployments on unlicensed bands, it is important to have good performance when the other network on the same channel is a Wi-Fi network. In Figure 8, the downlink performance is shown with two independent networks of different technology sharing the same 20 MHz channel. As shown in Figure 8, when placed on the same 20 MHz channel without specific considerations other than the regulatory requirements, Wi-Fi suffers more as LTE is more resistant to co-channel interference. Both networks experience degradation due to increased interference, but the LTE network can still maintain good performance. When adding an additional fairness algorithm on the LTE side, it is possible to reduce the effects on the Wi-Fi network such that the degradation it experiences is similar to that caused by another Wi-Fi network. This means it does not really matter if the network causing interference is another Wi-Fi or LTE network. This shows that LTE technology can also be implemented to not only meet the requirements of the unlicensed band operation, but to provide extra fairness to compensate for the lower interference tolerance of Wi-Fi networks. The higher capacity of LTE technology will also reduce the number of nodes needed compared to a Wi-Fi network serving the same traffic.

Capacity with LTE & Wi-Fi on the same 20 MHz channel

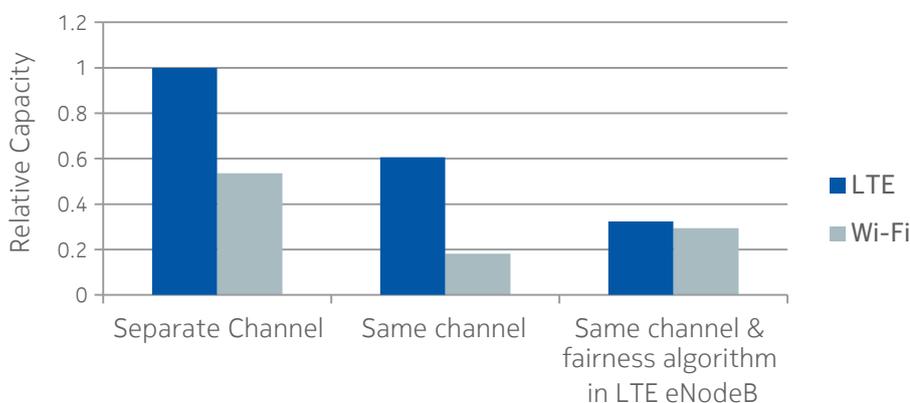


Figure 8. Co-existence performance between LTE and Wi-Fi.

The co-existence performance presented in Figure 7 is actually the worst case scenario. When considering on which channel to place the LAA transmission, one should at first set a priority to select a frequency not used by a high power and high activity Wi-Fi network. Selecting a channel which has either low activity or a low level of interference from other users of the channel will help achieve the performance equivalent to a single LTE network, while also minimizing the interference for any of the other networks on the 5 GHz band. Since LTE radio resource management is a dynamic process, it can avoid a static worst case interference situation by continuously monitoring the environment. LTE radio resource management should have as its first priority avoiding the use of channels overlapping with a nearby Wi-Fi or another LTE network on the unlicensed band.

LTE itself can tolerate more interference when sharing a channel case, thus, as seen from Figure 6, two LTE networks from different operators on the same channel cause a clearly smaller capacity loss compared to sharing with a Wi-Fi network, as both LTE networks have advanced features for handling co-channel interference.

Standardization

3GPP Release 13 is expected to include support for LTE operation on the unlicensed band once LAA is completed. 3GPP started the work with a workshop on LTE unlicensed in June 2014, with the formal study starting in September 2014. The ongoing study is scheduled to be completed in June 2015, as shown in Figure 9 and will cover the necessary mechanisms for co-existence. Once complete, the work item phase will finalize the detailed specification, including the necessary band combinations to enable LTE operation with 5 GHz band aggregated with another licensed frequency band.

The assumption with 3GPP work is that LTE is not operated as a standalone system on the unlicensed band but will be used in conjunction with a Primary Cell in the licensed band. The specification work for Release 13 LTE operation in unlicensed spectrum is expected to be ready by mid-2016. Once the basis is specified, 3GPP will define the necessary bands and band combinations to be used with the 5 GHz band, which can be done as Release independent on top of Release 13.



Figure 9. Expected 3GPP timeline for the work on LTE for unlicensed band.

Summary

A strong momentum with LTE evolution continues in Release 13. One of the new technology components in Release 13 is the deployment of LTE in the 5 GHz unlicensed band. The License Assisted Access (LAA) with LTE will allow co-existence with Wi-Fi without any specific coordination and will meet all the regulatory requirements for 5 GHz unlicensed band operation. This is an important feature of LAA which allows deployment in the same markets, such as shopping malls and corporate environment, as Wi-Fi networks. The interference effect on a Wi-Fi network from a LTE network is similar to the interference from another Wi-Fi network.

However, such an LTE network can reach higher capacity than a Wi-Fi network. Thus, installing unlicensed band capable LTE eNodeB to be operated in aggregation with an existing LTE eNodeB in licensed band is expected to require no more site permissions for installation than a Wi-Fi access point or any other system operating on the 5 GHz unlicensed band. Especially in an environment where the traffic density is high, LAA is an attractive solution to tap the unused potential of the 5 GHz spectrum. With the ability to control the kinds of systems installed, such as in a corporate environment, finding fully empty channels from the 5 GHz band will be relatively easy, allowing LTE to reach its full performance.

LTE for unlicensed band will rely on the existing LTE core network and will use the existing LTE security and authentication framework, meaning no changes in the core network domain will be required. The use of LTE unlicensed together with the licensed band operation brings a major capacity boost from the unlicensed band while still ensuring end user quality of service, regardless of the interference situation in the unlicensed band.

Further Reading

- [Nokia Technology Vision 2020](#)
- [LTE Release 12 and Beyond, Nokia White paper.](#)
- [LTE in Unlicensed Spectrum: European Regulation and Co-existence Considerations, Nokia 3GPP presentation](#)



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