

IEEE 802
Local and Metropolitan Area Network Standards Committee



Paul Nikolich
Chair, IEEE 802 LMSC
3 Barberry Way
Essex Fells, NJ 07021
cell: 857.205.0050

To: Dino Flore, 3GPP TSG RAN Chair, oflore@qti.qualcomm.com , Satoshi Nagata, 3GPP TSG WG RAN1 Chair, nagatas@nttdocomo.com

CC: Joern Krause, 3GPP TSG RAN RAN Secretary, Joern.Krause@ETSI.ORG, Susanna Kooistra, 3GPP Liaison Coordinator, susanna.kooistra@3gpp.org, John D'Ambrosia, IEEE 802 Recording Secretary, JAmbrosia@gmail.com, Steve Shellhammer, IEEE 802.19 Coexistence WG Chair, shellhammer@ieee.org

SUBJECT: Liaison Statement to 3GPP from IEEE 802 LMSC

DATE: 18 March 2016

Dear Dino and Satoshi

Thank you for the spirit of cooperation the ongoing liaison communications have built between IEEE 802 LMSC and 3GPP TSG RAN and RAN1.

At the IEEE 802 plenary session completed on 18 March 2016, a liaison statement containing comments related to the LAA specification was prepared by the 802.19 Coexistence Working Group and approved by the IEEE 802 LMSC Sponsor Executive Committee. The liaison statement is attached. Please distribute it for consideration at the next RAN1 meeting in Busan, Korea on 11-15 April 2016, and we look forward to a response to the comments.

We look forward to continued productive interchange between our organizations.

Regards,

/s/ Paul Nikolich

Paul Nikolich
Chair, IEEE 802 LAN/MAN Standards Committee
p.nikolich@ieee.org

IEEE 802 thanks 3GPP RAN for the opportunity to comment on LAA

During the 3GPP LAA Workshop in Beijing, China in August 2015, the RAN Chair committed to sending the LAA CRs to IEEE 802, Wi-Fi Alliance and other appropriate organizations for comment once they were approved by 3GPP RAN. The RAN Chair asked that any suggestions for substantive changes to the LAA CRs be made by April 2016, but noted that suggestions for parameter value changes could probably be made after April 2016. The RAN Chair further committed to 3GPP RAN seriously considering and responding to all IEEE 802 and Wi-Fi Alliance comments.

3GPP RAN subsequently approved the LAA CRs in December 2015, and fulfilled the RAN Chair's first commitment by sending the following liaison in December 2015.

3GPP TSG RAN would like to inform IEEE 802 LMSC and the Wi-Fi Alliance that it has approved the baseline CRs implementing the LAA feature in the 3GPP specs.

The CRs are provided in the attachment.

3GPP TSG RAN welcomes any further feedback from IEEE 802 LMSC and the Wi-Fi Alliance on LAA.

Potential corrections should be proposed directly to the relevant WGs (preferably with accompanying documents clearly articulating the motivation for the change).

IEEE 802 thanks 3GPP RAN for allowing the participants of IEEE 802 the opportunity to comment on the LAA CRs, and more generally for 3GPP's engagement with IEEE 802 on 802.11/LAA coexistence issues. IEEE 802 looks forward to reviewing the responses to our comments and the resulting changes to the LAA specification.

IEEE 802 believes this process of collaboration between IEEE 802 and 3GPP RAN will result in an LAA specification that better supports fair sharing of unlicensed spectrum by both 802.11 and LAA equipment. Further, it will also result in a better LAA specification that leverages the long experience of IEEE 802 in defining effective and fair sharing protocols in unlicensed spectrum.

This document contains comments by participants in IEEE 802, particularly focused on CR_R1_157922 (*Introduction of LAA (eNB Channel Access Procedures)*) [1] and CR_RP_152258 (*Introduction of LAA*) [2]. These comments are offered in the interest of improving the performance of all systems, including LAA, in unlicensed spectrum.

References

- [1] R1-157922 Change Request for 36.213 "Introduction of LAA (eNB Channel Access Procedures)"
- [2] RP-152258 Change Request for 36.211 "Introduction of LAA"
- [3] R1-155310, "Energy detection threshold for LAA", Intel Corporation
- [4] R1-152936, "Coexistence Evaluation Results Using LBT Category 4 for Wi-Fi DL and LAA DL only Scenario", Broadcom Corporation
- [5] R1-152937, "Coexistence Evaluation Results Using LBT Category 4 for Wi-Fi DL+UL and LAA DL only Scenario", Broadcom Corporation

IEEE 802 has numerous comments in relation to CR_R1_157922 (*Channel Access Procedures for LAA*)

The following pages contain a variety of comments related to the LAA specification, focusing on CR_R1_157922 (*Introduction of LAA (eNB Channel Access Procedures)*) [1] and CR_RP_152258 (*Introduction of LAA*) [2], that have been highlighted by IEEE 802 participants:

1. Radio equipment in unlicensed spectrum should not transmit energy for the primary purpose of blocking access to the channel to others
2. Transmission of Discovery Reference Signals should be clearly bounded to avoid excess airtime overhead on unlicensed spectrum
3. Radio equipment in unlicensed spectrum should detect neighboring networks with sufficient sensitivity to ensure fair coexistence
4. LAA and IEEE 802.11 slot boundaries should align as accurately as possible to preserve spectral efficiency in unlicensed spectrum
5. LAA and 802.11 multi-channel aggregation schemes should align
6. Radio equipment in unlicensed spectrum should stop transmission as soon as transmission of useful data is complete
7. Channel access that is obtained using special access mechanisms for high priority data should not be used to transmit lower priority data
8. The maximum continuous transmission time should be limited to avoid blocking latency sensitive traffic on coexisting networks
9. Adjustment of channel access contention window should be based on comparable indicators of congestion to ensure fairness between technologies
10. Adjustment of channel access contention window should be clearly defined
11. The channel access state machine during channel sensing should be clearly defined
12. The use of the back off mechanism should be clearly defined

A common theme in these comments is that LAA has been underspecified and ambiguously specified. This approach is acceptable when there is a mechanism to resolve these issues after the specification stage. The Wi-Fi industry has traditionally resolved many such problems with the 802.11 specification at the plugfesting stage undertaken by the Wi-Fi Alliance. It is likely that the major operators have led equivalent processes in relation to licensed operation.

However, there are no directly equivalent processes in an environment with both LAA and Wi-Fi equipment. This highlights the importance of doing a very good job ensuring that 3GPP LAA (and IEEE 802.11 from now on) are fully specified and unambiguous.

1. Radio equipment in unlicensed spectrum should not transmit energy for the primary purpose of blocking access to the channel to others

1.1. Situation: LAA needs to maintain control of medium between gaining access and transmitting synchronized data bursts by sending energy

In LAA, there is normally a delay of 0-1 ms between gaining access to the channel and the start of the sub-frame, which is a result of LAA sub-frames always being aligned to 1 ms boundaries. The delay is 0-0.5 ms if partial sub-frames are used.

The only way for the LAA system to stop another system from accessing the channel during this delay is to transmit energy of some sort in the channel. This energy represents a form of interference because its primary purpose is to stop other systems from accessing the channel.

1.2. Problem: Transmitting energy for sole purpose of blocking others is contrary to best practice everywhere and possibly regulations in some domains

As noted during the IEEE 802 submission to the 3GPP LAA Workshop in August 2015, such interference is contrary to the well accepted principle in unlicensed spectrum to not cause unnecessary interference to others.

Such interference may also be against the regulations in some regulatory domains. For example, it is possible that a device transmitting unnecessary energy would not qualify as a 'Radio Equipment' under the RE-Directive (2014/53/EU) in Europe, which states, "*radio equipment shall only have intentional transmissions for the purpose of radio communications*". Transmitting energy for the sole purpose of stopping another derives from transmitting is unlikely to be classified as "*radio communications*".

1.3. Solution: LAA should be modified to avoid sending energy for the primary purpose of blocking access to the channel to others

IEEE 802 requests that LAA specification be modified so that it never needs to transmit energy for the primary purpose of stopping another device (LAA or 802.11) from using the channel. Options to satisfy this request include:

- Allowing (partial) sub-frames to start immediately after channel access is obtained
- Deferring sending energy in a channel until the LAA device is ready to transmit

2. Transmission of Discovery Reference Signals should be clearly bounded to avoid excess airtime overhead on unlicensed spectrum

2.1. Situation: LAA allows regularly transmitted DRS special access to the medium

LAA specifies that a Discovery Reference Signal (without PDSCH) may be transmitted after sensing the medium is free for 25 μ s (short LBT), using an ED Threshold of 5 dB less than normal. This approach recognizes the high importance of DRS signals in LTE and LAA.

2.2. Problem: It is not clear how often the special access for DRS will be used in practice

This specification should have limited adverse effect on 802.11/LAA coexistence if the DRS are transmitted by an eNB, as expected by many, every 40/80/160ms. However, it is also possible for an eNB to configure different DRS offsets for different UEs. Hence, while each UE may be receiving the DRS at a suitably low rate, the eNB may, in reality, be transmitting DRS much more often than once every 40 ms/80ms/160ms. In this case, 802.11 operations are likely to be adversely affected.

In addition, the LAA specification [2] opens the possibility of a given eNB sending multiple DRS transmissions to a single UE within a given DMTC period (as opposed to Rel 12 where a UE is configured with a single offset). This may give rise to an even greater number of DRS transmissions and further adverse impact on 802.11.

Further, in a typical LAA frequency reuse scenario, it is likely that neighboring eNBs will transmit DRS with different offsets on the same channel. Therefore, the total DRS "load" as seen by an 802.11 system on a channel may be further increased.

Given that DRS are relatively long (1 ms) and are transmitted by eNBs even if there is no traffic load, they represent a significant and persistent load on unlicensed channels which should be carefully optimized.

2.3. Solution: Clarify the limitations on the use of special access for DRS

IEEE 802 requests responses from 3GPP RAN to the following questions:

- Are all served UEs expected to be configured with an identical DRS offset?
- How often is an eNB expected to transmit a DRS?
- How can it be ensured that the DRS transmitted by multiple neighboring eNBs in a network avoid causing excess impact on coexisting 802.11 systems?

IEEE 802 also requests that the LAA specification be modified to include reasonable limits on how often the channel may be accessed using the DRS mechanism, based on acceptable criteria for fair coexistence. It is noted that, while some regulatory domains specify limits for Short Control Signaling (SCS) such as DRS, others do not. Further, it is noted that the typical airtime overhead of 802.11 Beacon frames (which serve a similar role to DRS in Wi-Fi systems) is substantially less than 1% per AP (BSS) in 5 GHz band. IEEE 802 would be happy to discuss appropriate limits with 3GPP RAN.

3. Radio equipment in unlicensed spectrum should detect neighboring networks with sufficient sensitivity to ensure fair coexistence

3.1. Situation: LAA neighbor detection threshold of -72 dBm is relatively high

The LAA specification ([1], clauses 15.1.1 and 5.1.4) only requires LAA eNBs to perform energy detection for clear channel assessment (CCA) at a lowest ED threshold of -72dBm (20 MHz). In addition, the ED threshold can increase up to -62dBm if the LAA configured maximum transmission power is lower than 23dBm. In contrast, IEEE 802.11 requires neighbor detection at -82 dBm (CCA-CS threshold using preamble detection). Therefore LAA can be 20 dB less sensitive than 802.11 to neighboring networks.

3.2. Problem: -72 dBm neighbor detection does not ensure fair coexistence

3GPP simulation studies [3-5] have shown that if LAA only uses ED and the ED threshold is -72dBm, fair coexistence with IEEE 802.11 cannot be ensured.

In addition, simulation studies [3-4] have shown that incorporating both transmission and detection of IEEE 802.11 PHY preamble in LAA LBT is not only the best way to ensure fair coexistence with IEEE 802.11, but also achieves the best coexistence performance for both technologies.

Unfair coexistence with IEEE 802.11 is particularly acute in scenarios where the full coverage of each IEEE 802.11 AP is utilized (which are under-represented in 3GPP studies), since devices with weaker link strengths are especially sensitive to interference.

3.3. Solution: Improve detection sensitivity of neighboring networks

IEEE 802 requests that LAA specification be modified such that:

- LAA LBT procedure requires an eNB to detect 802.11 networks with a similar level of sensitivity to that with which current 802.11 devices can detect each other, in order to ensure fair coexistence with 802.11 and to improve both LAA and 802.11 performance. It is noted that one means to do so is to detect (and preferably also transmit) the 802.11 PHY preamble.
- Alternatively, in the case of LAA LBT that is capable only of energy detection, LAA LBT procedure requires a base energy detection threshold of $TH = -77\text{dBm}$ (20MHz), or preferably lower

4. LAA and IEEE 802.11 slot boundaries should align as accurately as possible to preserve spectral efficiency in unlicensed spectrum

4.1. Situation: LAA specification does not ensure time alignment of its slot boundary with IEEE 802.11 slot boundary

Both LAA and IEEE 802.11 try to determine the time reference for their slot boundary from the ending position of an on-going transmission.

LAA devices are currently only able to rely on energy detection (ED) to find out when the on-going transmission ends since they are unable to detect 802.11 PHY preamble and MAC NAV field.

LAA specification ([1], clause 15.1.1) states *“A slot duration T_s is considered to be idle if the eNB senses the channel during the slot duration, and the power detected by the eNB for at least $4\mu\text{s}$ within the slot duration is less than energy detection threshold X_{Thresh} .”*

Since LAA requires ED to be performed during only $4\mu\text{s}$ of each channel access slot ($9\mu\text{s}$), the ED mechanism will sometimes fail to detect an end boundary within a given slot and will therefore not notice the transmission is complete until the next ED period within the subsequent slot. In addition, LAA does not specify the timing or granularity at which ED detection results are reported.

As a result, LAA specification does not require any mechanism by which an eNB time aligns its channel access slot boundaries with those of other coexisting devices – unlike IEEE 802.11 devices which accurately detect the end position of other 802.11 transmission bursts by PHY preamble and MAC NAV detection.

Hence, there is likely to be a significant slot time offset between LAA and coexisting IEEE 802.11 systems.

4.2. Problem: Large slot time offsets between LAA and 802.11 introduces more transmission collisions which reduce spectral efficiency and degrade both LAA and 802.11 performance

The large slot time offset between LAA and 802.11 systems converts a slotted-ALOHA like system into an ALOHA like system, which introduces more transmission collisions between the two systems and has an adverse effect on all users of the channel – including the performance of both LAA and 802.11 networks.

4.3. Solution: LAA should time align its slot boundary with 802.11 slot boundary as accurately as possible

IEEE 802 requests that LAA specification be modified such that:

- LAA requires a mechanism by which an LAA eNB accurately time aligns its channel access slots with those of coexisting IEEE 802.11 devices. It is noted that one means to do so is to detect and transmit the 802.11 PHY preamble.
- Alternatively, in the case of LAA LBT that is capable only of energy detection, LAA LBT procedure reduces the transmission burst ending position detection error by requiring a larger ED period $X\mu\text{s}$ ($X > 4$, e.g. $X=7$) in each channel access slot, and requires detection results to be reported every $1\mu\text{s}$ during each ED period.

5. LAA and 802.11 multi-channel aggregation schemes should align

5.1. Situation: LAA is not aligned with the multi-channel planning rules that are already widely in use by IEEE 802.11 devices

3GPP specification 36.300 section 5.7 recommends but does not require use of contiguous channels when aggregating up to 4 unlicensed channels, and does not specify the sets of channels that shall be used for aggregation. Therefore, LAA eNB may use any multi-channel combination within 5GHz band for channel access, which is not aligned with the channel planning rules already widely used by IEEE 802.11 devices for channel bandwidths greater than 20MHz.

5.2. Problem: Non-contiguous and/or differently aligned use of spectrum causes each LAA eNB to impact multiple 802.11 networks

Whereas IEEE 802.11 devices with up to 80MHz bandwidth operate on a contiguous group of channels, LAA allows multi-channel aggregation over such bandwidths on non-contiguous channels widely spread over the 5GHz unlicensed band (e.g. two clusters of 40MHz). Therefore, a single LAA eNB can impact the performance of multiple 802.11 networks, and the total coexistence impact is multiplied.

In addition, even when an LAA eNB is operating on contiguously aggregated channels, those channels are not in general aligned with the IEEE 802.11 channel rules, and therefore once again a single LAA eNB can impact multiple 802.11 networks even though all networks are operating on the same total bandwidth.

Simulation studies have shown that when the LAA eNB uses the multi-channel patterns that are not aligned with the 802.11 channel planning rules, both LAA Type A and Type B multi-channel access cannot ensure fair coexistence with 802.11ac devices.

5.3. Solution: LAA should align its multi-channel aggregation scheme with 802.11

IEEE 802 requests that LAA be modified so that:

- in the case of operation using up to four 20 MHz channels in unlicensed band, those channels shall reside in a single specified 80 MHz channel group aligned with IEEE 802.11
- the channels selected for operation shall be the least utilized channels

6. Radio equipment in unlicensed spectrum should stop transmission as soon as transmission of useful data is complete

6.1. Situation: Use of LAA sub-frames is sometime inefficient

LAA transmits data in 1ms sub-frames, or 0.5ms partial sub-frames. In some cases, the sub-frames may only contain a very small amount of data compared to the capacity of the sub-frame. This represents a potential structural inefficiency.

6.2. Problem: There is no obvious upside to this structural inefficiency

It is a well-accepted principle in unlicensed spectrum that systems should attempt to make efficient use of the spectrum. Regulations also often highlight efficiency as an important goal. For example in Europe article 3.2 of RE-Directive (2014/53/EU) states, *“Radio equipment shall be so constructed that it both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference”*.

It is acknowledged that common network management principles require a trade-off between raw spectral efficiency and other goals such as coverage maximization (transmission at low data rates reduces spectral efficiency) and distributed spectrum sharing among multiple unrelated networks (channel access contention and resolution). However, in this case there is no justifiable reason for such inefficient use of airtime other than the desire to reuse an existing transmission protocol and framework that was designed for a TDMA system but now operates in unlicensed spectrum.

Both Wi-Fi and LAA would have greater access to the medium for data transmission if LAA systems stopped transmission as soon as they had no more data to transmit.

6.3. Solution: LAA should be modified to avoid inefficiencies caused by use of fixed length sub-frames

IEEE 802 suggests that LAA be modified so that it avoids the inefficiencies that result from transmitting unfilled sub-frames. We understand from some 3GPP RAN1 participants that there is some possibility of such a feature in a future release of LAA. It is noted that partial subframes (3/6/9/10/11/12 OFDM symbols) are already defined in the underlying LTE framework and could be used as the basis for this feature. We suggest that this feature be brought forward to R13.

Another alternative is to specify in LAA that sub-frames must be filled above a certain threshold with same or higher priority data. This approach ensures at least some minimum level of efficiency. It is noted that LAA can always use licensed spectrum to transmit data bursts if they cannot be efficiently transmitted over unlicensed spectrum.

7. Channel access that is obtained using special access mechanisms for high priority data should not be used to transmit lower priority data

7.1. Situation: The LAA spec defines the transmission of data of only one priority

LAA specification ([1], clause 15.1.1) specifies that, " m_p , $CW_{min,p}$ and $CW_{max,p}$ are based on channel access priority class associated with the eNB transmission". This suggests that each transmission of one or more contiguous sub-frames contains data of a single priority.

7.2. Problem: It seems that the intent is to allow the transmission of both higher and lower priority data in a single sub-frame

3GPP RAN1 participants in ETSI BRAN have noted that a single transmission (of one or more sub-frames) can actually contain data of multiple priorities. Specifically, it is asserted that it can contain data of any higher priority. It can also contain low priority traffic if there is spare space in the sub-frames (however, per the previous comment, sub-frame length should adapt as much as possible to the data available). This perspective is contrary to what is actually written in clause 15.1.1.

The transmission of higher priority data in a sub-frame seems reasonable and is also allowed in 802.11. The transmission of lower priority traffic might also be reasonable if the transmission of such traffic does not increase the time the medium is used. This is what happens in 802.11.

Unfortunately, the transmission of lower priority traffic by LAA interacts adversely (from an 802.11 perspective) with the use by LAA of fixed length sub-frames. It appears from descriptions of LAA provided to ETSI BRAN that a single bit of high priority data in a LAA sub-frame allows the rest of sub-frame to be filled with low priority data. In contrast, 802.11 systems only allow the transmission of lower priority data only if the transmission of such data does not increase the length of the TXOP.

7.3. Solution: The LAA specification needs to be clarified to explain what data may be sent in a sub-frame accessing the channel at a particular priority

IEEE 802 requests that:

- The LAA specification is clarified to make it clear that a transmission of one or more sub-frames using a particular access priority may contain data of that priority and higher priorities.
- The LAA specification is clarified to make it clear that a transmission of one or more sub-frames using a particular access priority may contain lower priority data as long as that lower priority data does not increase the duration of the transmission
- Per the previous comment, the LAA specification is modified to require the use of partial subframes, which are then used to implement the existing requirement of "*minimum possible duration needed to transmit all available buffered traffic corresponding to LBT priority classes $\leq X$* "

8. The maximum continuous transmission time should be limited to avoid blocking latency sensitive traffic on coexisting networks

8.1. Situation: LAA uses $T_{\text{mcot}} = 8$ ms for priority 3, 4

Table 15.1.1-1 specifies values of $T_{\text{mcot},p}$ for each priority level. The values for $p = 3, 4$ are 8ms in any band in which 802.11 can operate.

8.2. Problem: $T_{\text{mcot}} = 8$ ms has not been properly justified

the value of 8ms has not been properly justified

- The vast majority of simulations undertaken by 3GPP participants during the study period used a $T_{\text{mcot},3}$ of 4 ms, not 8ms. They mostly showed fair sharing was possible.
- While some simulations by 3GPP participants during the study period showed that a $T_{\text{mcot},3} > 10$ ms also led to fair sharing, other simulations within 3GPP showed that these values caused fairness issues, particularly for Wi-Fi based voice traffic. Some regulators in Europe have emphasized a view that LAA should not adversely Wi-Fi voice under any circumstances, for competition reasons.
- At least two recent simulations undertaken by ETSI BRAN participants appear to confirm that $T_{\text{mcot},3} = 10$ ms has an adverse effect on Wi-Fi voice. While other simulations did not show the same effect, it appears at least some of those simulations did not use realistic deployment scenarios with hidden stations.

8.3. Solution: LAA should use $T_{\text{mcot}} = 6$ ms for priority 3, 4 until justification for larger values is agreed

IEEE 802 requests that the LAA specification define $T_{\text{mcot},3} = 6$ ms and $T_{\text{mcot},4} = 6$ ms, until it is agreed by all parties that higher values do not cause problems.

Note this proposal represents a compromise on IEEE 802 behalf with respect to the values of $T_{\text{mcot},3} = 4$ ms and $T_{\text{mcot},4} = 4$ ms requested during the 3GPP LAA Workshop in August 2015.

9. Adjustment of channel access contention window should be based on comparable indicators of congestion to ensure fairness between technologies

9.1. Situation: LAA uses a NACK threshold (Z) to drive increase of CW_p

LAA specifies in clause 15.1.3 that CW_p values are increased when 80% of acknowledgements (Z) are NACKs

9.2. Problem: The justification of Z is unclear

A high percentage of NACKs means that collisions at many UEs will be ignored and thus those UEs and their neighbors will not benefit from the LAA back off mechanisms. This percentage intuitively seems to be very high, and the justification is unclear.

9.3. Solution: 3GPP is requested to justify the value of Z

IEEE 802 requests that 3GPP explain and justify the selection of the 80% threshold for Z, and particularly why this value does not have an adverse effect on neighboring 802.11 devices.

10. Adjustment of channel access contention window should be clearly defined

10.1. Situation: LAA defines how CW_p is adjusted

Clause 15.1.3 describes how CW_p is adjusted when accessing the channel with priority class p as follows:

1. For each priority class $p \in \{1,2,3,4\}$ set $CW_p = CW_{min,p}$
2. if at least $Z = 80\%$ of HARQ-ACK values corresponding to PDSCH transmission(s) in reference subframe k are determined as NACK, increase CW_p for each priority class $p \in \{1,2,3,4\}$ to the next higher allowed value; otherwise, go to step 1.

10.2. Problem: The adjustment of CW_p in LAA is ambiguous

One interpretation of this text is that all of CW_1 , CW_2 , CW_3 and CW_4 are increased in step 2. Another reasonable interpretation is that only the CW_p associated with the priority p of the transmission is increased. The two interpretations could lead to quite different results when combined with other parts of the LAA specification.

A similar issue arises at the end of clause 15.1.3 in the text that describes resetting CW_p after K uses of $CW_{p,max}$. Is only one CW_p reset or are all the CW_p values reset?

10.3. Solution: LAA should describe the adjustment of CW_p in an unambiguous manner

The LAA specification needs to more clearly define how CW_p is adjusted.

11. The channel access state machine during channel sensing should be clearly defined

11.1. Situation: LAA defines a basic access method for an eNB

LAA defines a basic access method (in 15.1.1 of CR_R1_157922) for an eNB to access the channel for downlink traffic with priority level of p

- 1) set $N = N_{init}$, where N_{int} is a random number uniformly distributed between 0 and CW_p ;
- 2) if $N > 0$ and the eNB chooses to decrement the counter, set $N = N - 1$;
- 3) sense the channel for an additional slot duration, and if the additional slot duration is idle, go to step 4; else, go to step 5;
- 4) if $N = 0$, stop; else, go to step 2.
- 5) sense the channel during the slot durations of an additional defer duration T_d ;
- 6) if the channel is sensed to be idle during the slot durations of the additional defer duration T_d , go to step 2; else, go to step 5;

11.2. Problem: The LAA access mechanism is more conservative than 802.11 accessing the medium by using T_d quanta

In LAA, if a countdown is interrupted by a transmission, the access algorithm samples the medium in quanta of T_d . This process is specified in step 5). In other words, if the medium is busy at any time during T_d , another complete sensing period of length T_d is required once the first T_d is completed.

In contrast, 802.11 starts the equivalent to T_d as soon as the medium is detected to be free. This means that LAA could take up to an extra 43 μs deferring (assuming, for example, that $p = 3$) compared to 802.11 before it resumes its countdown after an interruption.

This example demonstrates a problem in the LAA access mechanism. While this problem actually represents an advantage for 802.11 over LAA, it also highlights that the LAA access mechanism is generally underspecified. Other comments from IEEE 802 also emphasize this point

11.3. Solution: The LAA access mechanism should be better aligned with 802.11 EDCA

IEEE 802 suggests that the LAA access mechanism be defined so that it better aligned with the IEEE 802.11 EDCA access mechanism. The main advantage of doing so is that coexistence is more likely if both LAA and 802.11 use the same access mechanism. In this particular case, better alignment will result in LAA having earlier access to the medium.

12. The use of the back off mechanism should be clearly defined

12.1. Situation: LAA defines a back off mechanism but is ambiguous about when the mechanism is used

The LAA specification defines a back off mechanism in clause 15.1.1. However, the LAA specification does not clearly define when the back off procedure is used.

12.2. Problem: The back off ambiguity results in a variety of inefficiencies and unfair behavior

One interpretation is that a back off occurs every time a frame is queued for transmission. In this case, LAA will have a disadvantage compared to 802.11 because an 802.11 system can transmit on the next slot boundary as long as the medium is free after a previous post transmission back off.

It has been asserted by some LAA advocates that LAA also executes a post transmission back off like 802.11. While such an assertion might be true, it is not specified in an unambiguous manner. It also leads to a variety of additional problems:

- Assuming a post back off has completed, it appears that an LAA eNB can transmit after sensing the medium for T_d . In contrast, an 802.11 system is supposed to transmit on a slot boundary. The LAA mechanism essentially converts a slotted ALOHA style system into an ALOHA style system and has an adverse effect on all users of the channel – including the performance of both LAA and 802.11 networks.
- Assuming a post back off has completed, it appears an LAA eNB takes at least T_d (43 μ s) to access the medium. In contrast an 802.11 system can access the medium at the next slot boundary (in practice, after about 13 μ s). While this is a minor issue, and is a disadvantage for LAA compared to 802.11, it represents an unnecessary inefficiency.
- The LAA specification states that LAA can transmit after finding the channel to be free for a defer duration of T_d , and suggests that it can keep searching for a defer duration. Alignment with 802.11 requires a full back off if the channel is determined not to be free when a frame is queued, but this is not specified. The lack of specification appears to give LAA a significant and unfair advantage over 802.11.

These problems highlight that the LAA access mechanism is generally underspecified. Other comments from IEEE 802 also emphasize this point.

12.3. Solution: The LAA priority access mechanism should be better aligned with 802.11 EDCA

IEEE 802 suggests 3GPP modify LAA to define when the back off mechanism is used, probably by aligning the LAA access mechanism with 802.11 EDCA. Any revised LAA specification should:

- Make it clearer that that a post transmission back off is required after every transmission.
- Specify that an LAA system can transmit immediately on any slot boundary after the post transmission back off, unless the channel is not free or is in a defer period; in these latter cases, LAA should specify the execution of a new back off procedure. Note that this requires slot boundary alignment per previous comment.

IEEE 802 notes that the draft of ETSI BRAN's EN 301 893 currently under development provides a reasonable and unambiguous description of this behavior. It is also worth noting that the LAA specification must satisfy EN 301 893 to enable LAA operation in Europe and other parts of the world. At this time, it is unclear that the LAA specification can satisfy the requirements in the draft version of EN 301 893. This specification is likely to be the basis of regulations in Europe and other regulatory domains.