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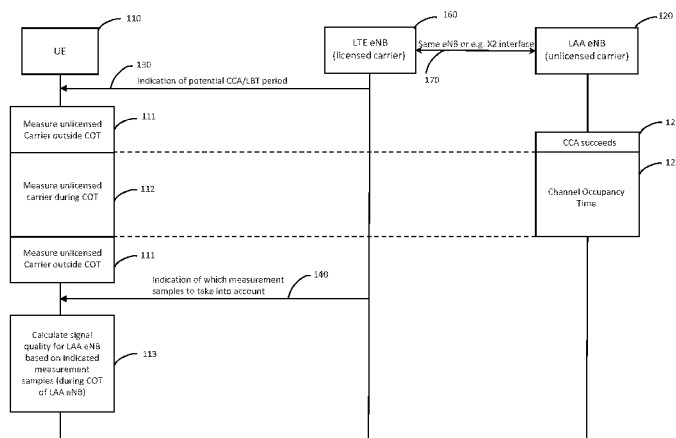


Figure 1

(57) Abstract: Various communication systems may benefit from measurement techniques. For example, wireless communication systems associated with licensed-assisted access may benefit from appropriate measurements, such as quality measurements, of the signals of transmitting network elements. A method can include measuring at least one licensed-assisted access reference signal. The method can also include measuring interference when licensed-assisted access has successfully done clear channel assessment. The method can further include forming a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference. The method can additionally include initiating transmission of the reference signal received quality measurement to a network element.

MEASUREMENTS IN LICENSED-ASSISTED ACCESS SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from U.S. Provisional Patent Application No.
5 62/116126 filed February 13, 2015.

TECHNICAL FIELD

[0002] The present application relates generally to configuration and performing of
appropriate quality measurements on, potentially licensed-assisted, unlicensed bands of the
10 signals of transmitting network elements.

BACKGROUND:

[0003] Long term evolution (LTE) licensed-assisted access may need options, solutions and
enhancements to the LTE radio access network (RAN) protocols to support deployment in
15 unlicensed spectrum for various scenarios.

[0004] A goal of the licensed-assisted access (LAA), also known as LTE on unlicensed band
(LTE-U), is that LTE would be deployed to the unlicensed bands in addition to the licensed
bands. LTE on unlicensed bands could be a stand-alone operation in some cells or some
transmission points. However, LTE could alternatively operate on the unlicensed band as a
20 component carrier, in addition to its licensed band carriers. This kind of component carrier may
be called a secondary component carrier and it may provide resources of a Secondary cell
(Scell). The Scell may be transmitted from a co-located or non-co-located transmission point
with the primary licensed carrier, or a primary cell (Pcell). In any of these schemes, the aim is
to co-exist by LTE carriers with Wi-Fi on the unlicensed band and create a constructive
25 communication environment. The benefits LAA brings may include that LTE can provide
quality of service (QoS) and seem to be strong where Wi-Fi throughputs, or quality of
experience (QoE), start to decrease due to too high load. For example, when the users are dense
in a deployment, Wi-Fi may struggle to provide an efficient scheme of operation.

[0005] The LTE operation in unlicensed band may take use of any unlicensed band where
30 feasible and for example at 5GHz band is widely available. The 5 GHz band has potentially up
to 500 MHz of available spectrum. This is a lot compared to the band available for licensed
LTE use in the 2GHz band. The licensed band carrier can be used for control, such as mobility
and signaling, and uplink. The unlicensed band can be used for data rate boost.

[0006] Licensed-assisted access can for example be a 2DL-1UL scheme, where the primary
35 cell (PCell) is in the licensed band, and the secondary cells (SCells) are in the unlicensed bands.

Therefore LAA may be used as a supplemental downlink (SDL) scheme, for example as a supplemental downlink carrier. Alternatively, LAA may contain uplink (UL) and downlink (DL) in an LTE carrier aggregation (CA) configuration. LTE-U may be also become available as a stand-alone technology, where the assistance from licensed carrier is not needed. Some of the embodiments of the present invention may be applicable to stand-alone LTE-U as well.

[0007] Obtaining a good measure of signal quality is not straightforward in LAA. Due to listen before talk/transmit (LBT), there is no guarantee that the LAA eNB can transmit at predetermined timing. Thus configuring a user equipment (UE) for, for example, periodic measurements may be challenging. Event-based measurements may be used instead.

[0008] Short control signaling (SCS) could potentially be used in some regions to transmit some periodic reference signal, occupying at most 5% of the time, without needing successful clear channel assessment (CCA) or LBT. This use of SCS may allow measuring reference signal received power (RSRP), but would prevent proper measuring of reference signal received quality (RSRQ). RSRQ is basically formed as a ratio of RSRP and interference measurement. However, interference measurement done without considering CCA/LBT may be misleading as it can contain interference from transmitters that would not be transmitting simultaneously with LAA eNB, due to LBT rules. As it is not known beforehand whether the CCA succeeds, it is not known when the eNB transmits, except SCS, and thus the UE cannot be configured with a measurement pattern in advance.

[0009] In addition, knowing whether there are hidden nodes and how strong interference those cause may change how the network operates. As an example, an eNB serving both licensed and unlicensed band cells can decide where it schedules the UE depending on such information. Furthermore, this can affect which LAA cell the UE should connect to, or whether any SCell should be even configured on unlicensed band. Consider a situation where different carriers have different hidden node interferers. Then based on a new RSRQ or channel quality indicator (CQI) measurement, distinguishing the level of interference from those hidden nodes can help to select the channel where the hidden node interference is the least harmful.

[00010] LTE and Wi-Fi deployed in a dense scenario could use, for example, carrier sense adaptive transmission (CSAT). In most countries, except US, China and Korea, regulatory requirements for listen-before-talk or listen-before-transmitting may need to be fulfilled. LTE-U should co-exist as well with dynamic frequency selection (DFS) for radar avoidance. Wireless local area network (WLAN) applies a solution based on sending two messages to reserve the spectrum around the transmitter and receiver, called request-to-send (RTS) and clear-to-send (CTS) messages.

SUMMARY OF THE INVENTION

[00011] Various aspects of examples of the invention are set out in the claims.

5 [00012] According to a first aspect of the present invention, an apparatus, method or code for measuring at least one licensed-assisted access reference signal received from a licensed-assisted access node; measuring interference when the licensed-assisted access node has successfully performed a clear channel assessment; forming a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and initiating transmission of the reference signal received quality measurement to a network element.

10 [00013] According to a second aspect of the present invention, an apparatus, method or code for receiving an indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period of a licensed-assisted access node transmitting the indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period to a user equipment; and transmitting an indication to the user equipment whether
15 the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

[00014] According to a third aspect of the present invention, an apparatus, method or code for measuring at least one reference signal received from an access node on an unlicensed carrier; measuring interference when the access node has successfully performed a clear
20 channel assessment; forming a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and initiating transmission of the reference signal received quality measurement to a network element.

[00015] According to a fourth aspect of the present invention, an apparatus, method or code for determining an indication of a potential clear channel assessment/listen-before-talk
25 period on an unlicensed carrier of an access node; transmitting the indication of a potential clear channel assessment/listen-before-talk period to a user equipment; and transmitting an indication to the user equipment whether the clear channel assessment/listen-before-talk period was successful.

[00016] According to a fifth aspect of the present invention, an apparatus, method or code
30 for determining attempting a clear channel assessment/listen-before-talk period on an unlicensed channel; and transmitting a signal to a user equipment on the unlicensed channel, the signal indicating whether the clear channel assessment/listen-before-talk period attempt was successful.

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BRIEF DESCRIPTION OF THE DRAWINGS:

[0016] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

[0017] Figure 1 illustrates an example signaling flow and licensed-assisted access (LAA) measurement in time and frequency, according to certain embodiments.

[0018] Figure 2 illustrates an example of CCA, COT and LAA transmission including CRS, according to certain embodiments.

[0019] Figure 3 illustrates a method according to certain embodiments.

[0020] Figure 4 illustrates a system according to certain embodiments.

[0021] Figure 5 illustrates various types of interference in a wireless communication system.

[0022] Figure 6 illustrates an example signaling flow and unlicensed measurement according to certain embodiments.

DETAILED DESCRIPTION

[0023] In certain embodiments, a user equipment (UE) can measure a signal when licensed-assisted access (LAA) is transmitting a reference signal. This could be for example the Reference Signal Received Power (RSRP) measurement. Moreover, the UE can measure interference when LAA has successfully done clear channel assessment (CCA). A new kind of Reference Signal Received Quality (RSRQ) measurement can then be formed out of the RS signal power measurements and from interference measurements. In some embodiments, in addition to or instead of forming and reporting a new RSRQ measurement the UE could report separately the RSRP and the interference measurement (e.g. received interference power), or report just the interference measurement – for this measurement reporting could be configured to trigger a report when interference exceeds a certain threshold or interference goes below a certain threshold (absolute threshold e.g. corresponding to high or low interference conditions, or a relative threshold compared to e.g. serving cell). The reporting could be also triggered by e.g. the new RSRQ exceeding a certain level (absolute or relative to e.g. serving cell), but the report may contain separately the RSRP and interference measurement.

[0024] The UE may not know in advance whether CCA will be successful at a particular time. Thus, the UE may measure over a broader period of time and then the measurements later determined to correspond to a suitable period for measurement may be retained and used. Thus, CCA may not be needed for measurement to occur, but the UE may be aiming to obtain measurement of the interference that is present after successful CCA. This is the interference that the UE could expect to observe when LAA is actually transmitting. The

UE can also measure interference at other times.

[0025] Thus, for example, in certain embodiments a UE can receive an indication of an LAA CCA/LBT period from an evolved Node B (eNB) and can collect measurement samples during the period. Subsequent to the collecting, the UE can receive an indication of
5 a transmission period during the period. The UE can compute a signal quality based on the collected samples corresponding to the transmission period. Other options, such as continuous measurement are also possible in certain embodiments, as discussed below.

[0026] More particularly, in certain embodiments a user equipment can measure the signal from the cell-specific reference signals (CRS). In some embodiments, UE can measure the
10 signal from Dedicated Reference Signals (DRS), from channel state Reference Signals (CSI-RS) or from discovery reference signals. Some of these signals can be transmitted without CCA/LBT as short control signaling (SCS) in subframes which are transmitted only occasionally meeting the SCS requirement (e.g. not exceeding 5% of channel time in an observation period). The user equipment may measure interference only when the eNB has
15 done CCA/LBT and is transmitting user data. As noted above, the user equipment may actually measure interference over a broader period of time, but in certain embodiments only those measurements may be used, which correspond to the time when the eNB has done CCA/LBT and is transmitting user data.

[0027] The UE can decode control signaling, for example physical downlink control
20 channel (PDCCH). Based on whether there was a transmission (to the UE, or to some other UE, or e.g. a transmission that could be received by any of the served UEs), the UE can either discard the stored interference measurement sample(s) or calculate a signal quality measure based on those.

[0028] For example, in certain embodiments, a user equipment can measure a plurality of
25 interference samples on resources protected by LAA CCA/LBT. This limitation on measurement can permit the user equipment to avoid measuring the strongest interferers that are using the same channel, but are so close to the eNB that due to LBT they are not simultaneously transmitting. The LAA eNB, due to LBT, may not assess the channel free and thus may not start transmitting simultaneously with these interferers. Further away
30 interferers as well as hidden node interferers may still be present.

[0029] Also, in certain embodiments, a user equipment can decode licensed band control signaling, such as PDCCH or enhanced PDCCH (E-PDCCH), to determine a portion of the resources protected by LAA CCA/LBT on which the serving eNB was transmitting. Thus,
35 the licensed band control signaling can indicate what was transmitted rather than what will be transmitted on LAA. Indicating transmission before-hand may not be feasible. Due to

LBT, the timing of transmission may not be known for sure before-hand, as CCA may fail.

[0030] Furthermore, in certain embodiments, a user equipment may discard, from a plurality of already collected interference samples, all samples not corresponding to the portion of the resources protected by LAA CCA/LBT on which the serving eNB was transmitting data.

[0031] Additionally, in certain embodiments, a user equipment may calculate a signal quality of the serving eNB from a portion of the plurality of interference samples corresponding to the portion of the resources protected by LAA CCA/LBT on which the serving eNB was transmitting data. In certain embodiments, the above-discarding may not involve actively deleting or removing measurements, but may simply involve the selective disuse of those measurements in the calculation of the signal quality.

[0032] Figure 1 illustrates an example signaling flow and licensed-assisted access (LAA) measurement in time and frequency, according to certain embodiments. As shown in Figure 1, measurement samples to be taken into account may be the ones during channel occupancy time (COT), including possibly during a clear channel assessment (CCA) period as well.

[0033] In addition, the UE can measure for each of a plurality of LAA eNBs the signal strength of the LAA eNB's cell-specific reference signal (CRS) (other reference signals may be used instead or in addition) at the known resources of the LAA eNB's CRS. These may be measured also when LAA eNB doesn't have successful CCA. Information distinguishing these two cases may be transmitted as SCS. This information may also be included in the transmission of reference signal (e.g. as selection between two different sequences or selection between set of radio resources where the signal is transmitted). In some embodiments this information may be otherwise included in the LAA transmission, e.g. as part of the control information transmitted on PDCCH or other control channel. The CCA, COT and LAA transmission including RS are illustrated in Figure 2.

[0034] As shown in Figure 1, an LTE eNB (160) can communicate with a UE (110) on a licensed carrier to provide the indication (130) of a potential CCA/LBT period. The UE may then measure during this entire potential period (111,112). Meanwhile, an LAA eNB (120), operating on an unlicensed carrier, may perform LBT/CCA and may succeed at CCA during the window (121). The LAA eNB can be the eNB or can be connected with the licensed eNB over an interface, such as an X2 interface (170). The LAA may also be transmitted by a remote radio head (RRH), which is part of the same eNB as the licensed eNB.

[0035] After the end of the potential CCA/LBT period, the LTE eNB can communicate (140) to the UE regarding which measurement samples should be taken into account. For

example, the LTE eNB may inform the UE regarding when CCA was successful. The communication may be readable by any UE, or it could be dedicated signaling to a specific UE. The indication of which measurement samples to take into account may be signaled in a variety of ways, for example in dependence of additional information a UE may be able to establish, for example because such additional information may be predetermined. In one embodiment, it may take the form of an indication that a CCA was successful, allowing a UE to determine from the observation of the CCA which samples to use and discard based on a predetermined time offset between the observed CCA and a minimum channel occupancy time over which the LAA eNB may be expected to have transmitted after the observed CCA. In another embodiment, in addition or instead, one or both of the start time (either relative to the CCA or in an absolute manner) and the stop time (for example in the form of a duration relative to the start time or in the form of a stop time relative to the observed CCA or a stop time in an absolute manner) may be used to indicate which of the stored samples are to be used. In yet another embodiment, it may in a similar manner be indicated which of the stored samples are to be discarded instead of or in addition to which of the stored samples are to be used. In yet another embodiment, the indication of which measurement samples to take into account may comprise an indication of a time-frequency pattern.

[0036] Based on the measurements and the information from the eNB, the UE can calculate a signal quality for the LAA eNB. This calculation may be based on the indicated measurement samples, namely those taken during channel occupancy time of the LAA eNB.

[0037] More particularly, Figure 2 illustrates an example of CCA, COT and LAA transmission including CRS, according to certain embodiments. Antenna port 0 is shown in Figure 2. As shown in Figure 2, there may be a CCA period, prior to a channel occupancy time, in which the eNB may listen before transmitting. Then, once channel occupancy for a fixed frame period is complete, the eNB may have an idle time until a later CCA success. Cell specific reference symbols may exist at various times/frequencies within the channel occupancy time (as well as outside such time), and there may be multiple such CRSs within a given subframe.

[0038] Figure 5 illustrates various types of interference in a wireless communication system. As shown in Figure 5, there may be a variety of interferences. For example, Type 1 interference may be present typically and may come from a distant source. This interference type may be below the CCA detection thresholds.

[0039] Type 2 and Type 3 interference may be un-coordinated and may be generated by close-by interfering transmissions, for example due to network transmissions or due to device

transmissions. These interferences may be detectable by the CCA or may not be detectable by the CCA.

[0040] Interference as such can be handled as anything sampled or correlated from any arbitrary symbols to result in a measurement sample over all interferers. Moreover, the system can act based on that measurement. If there are a plurality of interferers present, the interference measurement over the sum of interferers from different distances may be good or may be very inaccurate.

[0041] When assuming LAA Scell and typically a smaller cell size, the interferers present may be few and may present very different contribution to the summed interference. For example, own LAA network neighbor interference may always be distant, whereas the other LAA transmission or any hidden node can be close. However, as the cell sizes are rather small, the number of such close by alien transmissions may be fairly small and may be severe. Furthermore, measurement samples for LAA transmissions (whether signals or interference) can be estimated. Other, alien signals may not be able to be estimated.

[0042] Interference handling can be based on such principles. In certain embodiments, for example, the receiver may not just blindly form an interference measurement sample from the sum of interferers. On the contrary, the receiver could recognize the three different types of interferers and handle them differently. Estimating the interference, even if processing intensive, may result a good estimate of each and every interferer separately. The number of these interferers present in a small cell may be fairly small. Thus, categorizing the interferers to three types may allow the network to act on the interference per UE receiver beneficially, as opposed to the network acting only according to the sum interference.

[0043] The presence of devices or network nodes acting as hidden nodes close-by may be limited. Certain embodiments allow detection of the presence of a hidden node on the same channel. The bursty actions of a hidden-node may not cause serious re-scheduling needs, because the bursty transmitter may still be a single actor in the spectrum. If there is a serious hidden node close-by, this node can be avoided by configuring the Scell to another frequency channel at least for that served UE that is suffering from the hidden node.

[0044] When there is no close-by other actor on that newly changed frequency channel, the hidden node problem may be avoided. On the other hand, if the same hidden node is active in many frequency channels, avoiding the hidden node may be more difficult. For these reasons, scheduling to another channel may be only one tool of avoiding the hidden node. Other tools can include, for example, issuing a temporary signal to reserve the channel, which would target at reserving the channel so that both the own LAA network communications and the hidden node could act on the same channel in alternating turns. If

the hidden node in this co-channel situation is rarely active or bursty, coordinating in this way and doing proper scheduling based on the short term interference measurement feedback, may allow avoidance of collisions of own LAA network transmissions to the victim UE at a time when the hidden node generates its interference. At that time, another

5 LAA UE which is not the victim of the same hidden node may be scheduled instead. When the short term indication reveals that the hidden node is not active, the UE can be scheduled.

[0045] Various modifications or alterations can be made with respect to the above-described embodiments. For example, a user equipment may also measure received signal strength also on reference signal(s) transmitted outside the LAA CCA/LBT. Nevertheless,

10 interference to form signal quality measure, as a ratio of received signal strength and the interference plus noise may be measured only when CCA/LBT succeeded.

[0046] If there was a collision, and some device interfered strongly even though CCA succeeded, the UE may be signaled not to take into account the measurement samples collected during the LAA transmission but instead discard those. Or alternatively UE may

15 not be signaled to take into account those measurement samples.

[0047] The UE may be required to store the measurement samples for a certain duration, such as, for example, 10 ms, or 50 ms or so. If the UE does not receive an indication to take those stored samples into account during that time, the UE may discard those measurements.

[0048] Instead of using licensed carrier to indicate which stored measurements should the

20 UE use in the signal quality measure, for example in a new RSRQ, the information can be included in the LAA transmission on unlicensed carrier information, which the UE can decode and determine that there was a transmission and can implicitly assume successful CCA/LBT. This information may be for example included in the transmission of reference signal (e.g. as selection between two different sequences or selection between set of radio

25 resources where the signal is transmitted). In some embodiments this information may be otherwise included in the LAA transmission, e.g. as part of the control information transmitted on PDCCH or other control channel. The information may be readable by any UE, or it could be dedicated signaling to a specific UE.

[0049] Certain embodiments may omit the UE receiving an indication of an LAA

30 CCA/LBT period from an eNB. Instead, the UE may measure interference on carrier/resources used by LAA eNB either continuously or according to a configured pattern. The configured pattern may be, for example, a pattern of reference signal transmissions by LAA eNB, or a discontinuous reception (DRX) pattern. The UE may use in calculating the interference only those stored interference samples that were measured when there was an

35 LAA transmission. As noted above, the indication can be on a licensed carrier or can be on

an unlicensed carrier as part of LAA transmission.

- [0050] The indication regarding which measurements to use in the calculation may be an indication that CCA/LBT succeeded during a period of time, for example for certain indicated subframes. Alternatively, or in addition, the indication may be an indication that there was a transmission during indicated subframes (if indicated as part of LAA transmission, this could be for example some control information or control channel always present in the transmission). Also, or alternatively, the indication may be an indication to take into account the measurements of indicated subframes, or specifically to take into account only the measurements of the indicated subframes.
- 10 [0051] The indication can be provided as a separate indication for each subframe. Alternatively, the indication can indicate a longer period with one signaling. For example, the indication may indicate a start of a channel occupancy time, and the UE may be able to determine the length of the channel occupancy time based on a previous configuration or based on other information.
- 15 [0052] The above-described new measurement can be used also for detecting hidden node interference. The UE can compare RSRQ measurement formed from only those interference samples that were taken when LAA was transmitting, namely when CCA/LBT succeeded, to those samples that were taken outside this time.
- [0053] High correlation between the two measurements may indicate that there is a substantial interference that is not affected by the CCA/LBT. Thus, there may be a hidden node. Low correlation may indicate that the interference can be controlled by CCA/LBT. In addition to looking at the correlation, also the absolute level of interference may be considered when determining whether there is an interference or hidden node problem: If there is low amount of interference, high correlation is not a problem.
- 20 [0054] When having a choice of several carriers or cells, of otherwise similar quality level, the selection and/or scheduling could favor the one with lower correlation. This selection may be done as it may then be less likely that there is unpredictable interference component from hidden nodes. Similarly as for scheduling decisions, the network could favor serving those UEs at LAA that have low correlation.
- 25 [0055] Besides RSRQ, or in general signal to interference plus noise ratio or such measure, interference measures could be directly compared/correlated. Other manners of interference comparison are also permitted.
- [0056] Due to the burstiness of the interference, inherently due to bursty interferer activity, these measures can be averaged or filtered over some number of samples or some period of time. For example, the measures can be averaged or filtered potentially over several
- 35

CCA/LBT periods.

[0057] The network could configure UE with a measurement event and associated reporting at certain correlation level(s). Other such modifications and variations are also permitted. There could be also a combined measurement event triggering a report when both
5 the interference level exceeds a threshold (or signal to noise plus interference ratio is below a threshold) and the correlation is below another threshold.

[0058] Even if in short-term the network based on CSI can manage scheduling the UE when the hidden node interferer is not active, cell selection can be based on longer term quality metric. The longer term measurements may still be useful for selecting on which carrier the
10 network is to schedule the UE, as it may depend on the number, and average activity, of the hidden node interferers.

[0059] SINR/RSRQ can be low for other reasons besides a hidden node. For example, a signal may be weak without substantial interference. Therefore, besides the above-mentioned correlation, one alternative is to determine correlation between RSRP and RSRQ,
15 or similar but shorter-term measurements, and to setup a measurement event triggering and reporting for that secondary correlation.

[0060] The UE can measure the received signal quality, for example RSRQ, and received signal strength, for example RSRP, of the UE's serving cell on the unlicensed band carrier. An event can be triggered when there is high variance in the received signal quality but the
20 signal strength, for example RSRP, is stable.

[0061] In certain embodiments, the UE can measure the correlation between RSRP and RSRQ, or other signal strength and quality metrics, such as CSI/CQI. A measurement event can be defined for correlation, with, for example, a configured threshold value for triggering a report by UE to serving eNB.

[0062] The event definition may include thresholds for both signal level and quality. There could be a secondary threshold that determines how much of hidden node interference there needs to be to trigger a report. The threshold may relate to received interference power and/or % of time. For example, the event definition may include to trigger report only if interference occurs more than 20% of the time when the serving eNB is transmitting.

[0063] Using currently specified, for example LTE Rel-12, measurements and reporting, and doing at the network side similar processing to the embodiments described here is also possible. For example, there may be a periodic CSI reporting. Moreover, radio resource management (RRM) measurements such as RSRP/RSRQ measurements may be reported
30 on an event basis. For both shorter-term (CQI/CSI type of measurements) and RRM measurements the timing of the measurement would may be configured to match the LAA
35

eNB transmission when CCA has succeeded.

[0064] Certain embodiments may have various benefits and/or advantages. For example, certain embodiments may provide a better measure of channel quality in LTE-LAA that reflects the received signal quality more accurately. Thus, certain embodiments may allow
5 a more informed decision of which cell/carrier to use as well as where and when to schedule a UE.

[0065] Figure 3 illustrates a method according to certain embodiments. As shown in Figure 3, a method can include, at 310, measuring at least one licensed-assisted access reference signal. The method can also include, at 320, measuring interference when licensed-assisted
10 access has successfully done clear channel assessment. This interference measurement may take place during the measurement of the reference signal. Certain embodiments may address using measurements corresponding to cases where LAA had successful CCA and cases where a network element, such as an eNB, is transmitting something needing CCA, for example something other than SCS.

[0066] The method can also include, at 330, forming a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference. The method can further include, at 340, transmitting or initiating transmission of the reference signal received quality measurement to a network element. This may be a transmission back to the network element that is transmitting the reference signal, or may
15 be a transmission to another network element.

[0067] The method can also include, at 312, receiving an indication of a licensed-assisted access clear channel assessment/listen-before-talk period from a base station. The base station here can be any access point or evolved Node B and can be the network element mentioned above. The measurement of the reference signal can be taken within the clear
25 channel assessment/listen-before-talk period. This can be an indication of the potential transmission period, as described above.

[0068] The method can further include, at 322, receiving an indication of a licensed-assisted access transmission period. The measurement of the interference can be taken within the transmission period. This can be the actual period during which CCA was
30 successful and transmission occurred as a result.

[0069] Receiving the indication can involve, at 323, decoding control signaling and determining whether to keep a measured interference value for use in forming the reference signal, based on whether there was a transmission.

[0070] The method can also include, at 325, discarding any sample not corresponding to a
35 portion of resources protected by clear channel assessment/listen-before-talk. Thus, the

measuring interference can include measuring a plurality of interference samples on resources protected by clear channel assessment/listen-before-talk. Additionally, the method can include, at 327, discarding a measurement of interference based on a collision despite licensed-assisted access transmission.

5 [0071] The above-described steps of Figure 3 may be performed by a device such as, for example, a user equipment. The remainder of the steps of Figure 3 may be performed by a network element such as, for example, an eNB or other base station or access point.

[0072] The method can also include, at 350, indicating an LAA CAA/LBT period. The method can further include, at 360, determining when licensed-assisted access has
10 successfully done clear channel assessment and transmitted.

[0073] The method can additionally include, at 370, providing an indication, in control information, of a period when the clear channel assessment was successful and transmission was performed.

[0074] The control information can be transmitted in a physical downlink control channel or enhanced physical downlink control channel. More particularly, in certain embodiments
15 the control information can be provided in short control signaling.

[0075] The method can also include, at 380, signaling that a collision occurred despite clear channel assessment being successful and transmission being performed.

[0076] Figure 4 illustrates a system according to certain embodiments of the invention. It
20 should be understood that each block of the flowchart of Figure 1 may be implemented by various means or their combinations, such as hardware, software, firmware, one or more processors and/or circuitry. In one embodiment, a system may include several devices, such as, for example, network element 410 and user equipment (UE) or user device 420. The system may include more than one UE 420 and more than one network element 410,
25 although only one of each is shown for the purposes of illustration. A network element can be an access point, a base station, an eNode B (eNB), or any other network element, such as an LAA eNB. Each of these devices may include at least one processor or control unit or module, respectively indicated as 414 and 424. At least one memory may be provided in each device, and indicated as 415 and 425, respectively. The memory may include computer
30 program instructions or computer code contained therein. One or more transceiver 416 and 426 may be provided, and each device may also include an antenna, respectively illustrated as 417 and 427. Although only one antenna each is shown, many antennas and multiple antenna elements may be provided to each of the devices. Other configurations of these devices, for example, may be provided. For example, network element 410 and UE 420
35 may be additionally configured for wired communication, in addition to wireless

communication, and in such a case antennas 417 and 427 may illustrate any form of communication hardware, without being limited to merely an antenna.

[0077] Transceivers 416 and 426 may each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception. The transmitter and/or receiver (as far as radio parts are concerned) may also be implemented as a remote radio head which is not located in the device itself, but in a mast, for example. It should also be appreciated that according to the “liquid” or flexible radio concept, the operations and functionalities may be performed in different entities, such as nodes, hosts or servers, in a flexible manner. In other words, division of labor may vary case by case. One possible use is to make a network element to deliver local content. One or more functionalities may also be implemented as a virtual application that is provided as software that can run on a server.

[0078] A user device or user equipment 420 may be a mobile station (MS) such as a mobile phone or smart phone or multimedia device, a computer, such as a tablet, provided with wireless communication capabilities, personal data or digital assistant (PDA) provided with wireless communication capabilities, portable media player, digital camera, pocket video camera, navigation unit provided with wireless communication capabilities or any combinations thereof. The user device or user equipment 420 may be a sensor or smart meter, or other device that may usually be configured for a single location.

[0079] In an exemplifying embodiment, an apparatus, such as a node or user device, may include means for carrying out embodiments described above in relation to any of Figures 1 through 3.

[0080] Processors 414 and 424 may be embodied by any computational or data processing device, such as a central processing unit (CPU), digital signal processor (DSP), application specific integrated circuit (ASIC), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), digitally enhanced circuits, or comparable device or a combination thereof. The processors may be implemented as a single controller, or a plurality of controllers or processors. Additionally, the processors may be implemented as a pool of processors in a local configuration, in a cloud configuration, or in a combination thereof.

[0081] For firmware or software, the implementation may include modules or unit of at least one chip set (e.g., procedures, functions, and so on). Memories 415 and 425 may independently be any suitable storage device, such as a non-transitory computer-readable medium. A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate therefrom. Furthermore, the computer program

instructions may be stored in the memory and which may be processed by the processors can be any suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language. The memory or data storage entity is typically internal but may also be external or a combination thereof, such as in the case when additional memory capacity is obtained from a service provider. The memory may be fixed or removable.

[0082] The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus such as network element 410 and/or UE 420, to perform any of the processes described above (see, for example, any of Figures 1 through 3). Therefore, in certain embodiments, a non-transitory computer-readable medium may be encoded with computer instructions or one or more computer program (such as added or updated software routine, applet or macro) that, when executed in hardware, may perform a process such as one of the processes described herein. Computer programs may be coded by a programming language, which may be a high-level programming language, such as objective-C, C, C++, C#, Java, etc., or a low-level programming language, such as a machine language, or assembler. Alternatively, certain embodiments of the invention may be performed entirely in hardware.

[0083] Furthermore, although Figure 4 illustrates a system including a network element 410 and a UE 420, embodiments of the invention may be applicable to other configurations, and configurations involving additional elements, as illustrated and discussed herein. For example, multiple user equipment devices and multiple network elements may be present, or other nodes providing similar functionality, such as nodes that combine the functionality of a user equipment and an access point, such as a relay node.

[0084] Figure 6 illustrates an example signaling flow and unlicensed measurement according to certain embodiments. As shown in Figure 6, an unlicensed access node (620) can communicate with a UE (610) to provide an indication (630) of a potential CCA/LBT period. The UE may then measure during this entire potential period (611,612). Meanwhile, the unlicensed access node, operating on the unlicensed carrier, may perform LBT/CCA and may succeed at CCA during the window (621). After the end of the potential CCA/LBT period, the unlicensed access node can communicate (640) to the UE regarding which measurement samples should be taken into account according to various embodiments as disclosed supra. The UE may use the indication which measurement samples should be taken into account to calculate a signal quality (613), which may be indicated to the unlicensed access node (650).

[0085] One having ordinary skill in the art will readily understand that the invention as

discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention.

[0086] According to a first embodiment, a method can include measuring at least one licensed-assisted access reference signal. The method can also include measuring interference when licensed-assisted access has successfully done clear channel assessment. The method can further include forming a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference. The method can additionally include initiating transmission of the reference signal received quality measurement to a network element.

[0087] In a variant, the method can be performed by a user equipment.

[0088] In a variant, the method can also include receiving an indication of a licensed-assisted access clear channel assessment/listen-before-talk period from a base station, wherein the measurement of the reference signal is taken within the clear channel assessment/listen-before-talk period.

[0089] In a variant, the method can further include receiving an indication of a licensed-assisted access transmission period, wherein the measurement of the interference is taken within the transmission period.

[0090] In a variant, the method can additionally include decoding control signaling and determining whether to keep a measured interference value for use in forming the reference signal, based on whether there was a transmission.

[0091] In a variant, the method can also include discarding any sample not corresponding to a portion of resources protected by clear channel assessment/listen-before-talk.

[0092] In a variant, the measuring interference can include measuring a plurality of interference samples on resources protected by clear channel assessment/listen-before-talk.

[0093] In a variant, the method can further include discarding a measurement of interference based on a collision despite licensed-assisted access transmission.

[0094] According to a second embodiment, a method can include determining when licensed-assisted access has successfully done clear channel assessment and transmitted. The method can also include providing an indication, in control information, of a period when the clear channel assessment was successful and transmission was performed.

[0095] In a variant, the method can be performed by an evolved Node B.

[0096] In a variant, the control information can be transmitted in a physical downlink control channel or enhanced physical downlink control channel.

[0097] In a variant, the control information can be provided in short control signaling.

- 5 [0098] In a variant, the method can further include signaling that a collision occurred despite clear channel assessment being successful and transmission being performed.

[0099] According to third and fourth embodiments, an apparatus can include means for performing the method according to the first and second embodiments respectively, in any of their variants.

- 10 [00100] According to fifth and sixth embodiments, an apparatus can include at least one processor and at least one memory and computer program code. The at least one memory and the computer program code can be configured to, with the at least one processor, cause the apparatus at least to perform the method according to the first and second embodiments respectively, in any of their variants.

- 15 [00101] According to seventh and eighth embodiments, a computer program product may encode instructions for performing a process including the method according to the first and second embodiments respectively, in any of their variants.

[00102] According to ninth and tenth embodiments, a non-transitory computer readable medium may encode instructions that, when executed in hardware, perform a process
20 including the method according to the first and second embodiments respectively, in any of their variants.

[00103] According to tenth and eleventh embodiments, a system may include at least one apparatus according to the third or fifth embodiments in communication with at least one apparatus according to the fourth or sixth embodiments, respectively in any of their variants.

WE CLAIM:

1. A method comprising:
 - measuring (112,612) at least one licensed-assisted access reference signal received from a licensed-assisted access node (120, 620);
 - measuring (111,611) interference when the licensed-assisted access node has successfully performed a clear channel assessment;
 - forming (113,330,613) a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and
 - initiating transmission (340,650) of the reference signal received quality measurement to a network element (120,160,620).
2. The method according to claim 1, wherein the licensed-assisted access reference signal is measured regardless of whether the licensed-assisted access node has successfully performed a clear channel assessment.
3. The method according to claim 1, further comprising:
 - receiving (130,630) from an access node (160, 620) an indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period, wherein the measurement of the interference is taken within the indicated clear channel assessment/listen-before-talk period.
4. The method according to claim 1, further comprising:
 - receiving (140, 640) from an access node (120,160,620) an indication that a licensed-assisted access clear channel assessment/listen-before-talk was successful; and
 - determining (113,613) in response to the indication a subset of samples of the measurement of interference; and
 - forming (113,613) the reference signal received quality measurement from the measurement of the reference signal and the subset of samples of the measurement of the interference.
5. The method according to claim 4, wherein the receiving from an access node comprises receiving from the access node (160) over a licensed carrier.
6. The method according to claim 4, wherein determining the subset of samples of the

measurement of interference comprises selecting the subset of samples of the measurement of interference based at least on determining a subset of samples corresponding to resources protected by the licensed-assisted access clear channel assessment/listen-before-talk.

7. The method according to claim 4, further comprising receiving (140,640) from an access node (120,160,620) an indication of a portion of resources of the licensed-assisted access clear channel assessment/listen-before-talk that was occupied by a transmission from the licensed-assisted access node.
8. The method according to claim 7, wherein determining the subset of samples of the measurement of interference comprises selecting the subset of samples of the measurement of interference based at least on determining a subset of samples corresponding to resources not occupied during resources protected by the licensed-assisted access clear channel assessment/listen-before-talk as indicated by the indication of the portion of resources of the licensed-assisted access clear channel assessment/listen-before-talk period that was occupied.
9. A method comprising:
 - receiving an indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period of a licensed-assisted access node;
 - transmitting (130,630) the indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period to a user equipment (110,610); and
 - transmitting (140,640) an indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.
10. The method according to claim 9, wherein transmitting an indication to the user equipment comprises transmitting a reference signal on the unlicensed carrier.
11. The method according to claim 9, wherein the indication of whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful further comprises an indication for identifying a subset of measurement samples during the licensed-assisted access clear channel assessment/listen-before-talk period for determining an interference measure.

12. The method according to claim 9, further comprising:
 - transmitting to the user equipment an indication of resources that were occupied during the licensed-assisted access clear channel assessment/listen-before-talk period.
13. The method according to claim 9, further comprising:
 - receiving from the user equipment an indication of a reference signal received quality measurement dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.
14. The method according to claim 13, wherein the value of the reference signal received quality measurement is dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.
15. A apparatus comprising:
 - at least one processor; and
 - at least one memory including computer program code
 - the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:
 - measure (112,612) at least one licensed-assisted access reference signal received from a licensed-assisted access node (120, 620);
 - measure (111,611) interference when the licensed-assisted access node has successfully performed a clear channel assessment;
 - form (113,330,613) a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and
 - initiate transmission (340,650) of the reference signal received quality measurement to a network element (120,160,620).
16. The apparatus according to claim 15, wherein the licensed-assisted access reference signal is measured regardless of whether the licensed-assisted access node has successfully performed a clear channel assessment.
17. The apparatus according to claim 15, wherein the at least one memory and the

computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive (130,630) from an access node (160, 620) an indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period, wherein the measurement of the interference is taken within the indicated clear channel assessment/listen-before-talk period.

18. The apparatus according to claim 15, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive (140, 640) from an access node (120,160,620) an indication that a licensed-assisted access clear channel assessment/listen-before-talk was successful; and

determine (113,613) in response to the indication a subset of samples of the measurement of interference; and

form (113,613) the reference signal received quality measurement from the measurement of the reference signal and the subset of samples of the measurement of the interference.

19. The apparatus according to claim 18, wherein receive from an access node comprises receive from the access node (160) over a licensed carrier.
20. The apparatus according to claim 18, wherein the determination of the subset of samples of the measurement of interference comprises a selection of the subset of samples of the measurement of interference based at least on a determination of a subset of samples corresponding to resources protected by the licensed-assisted access clear channel assessment/listen-before-talk.
21. The apparatus according to claim 18, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:
- receive (140,640) from an access node (120,160,620) an indication of a portion of resources of the licensed-assisted access clear channel assessment/listen-before-talk that was occupied by a transmission from the licensed-assisted access node.
22. The apparatus according to claim 21, wherein the determination of the subset of

samples of the measurement of interference comprises a selection of the subset of samples of the measurement of interference based at least on a determination of a subset of samples corresponding to resources not occupied during resources protected by the licensed-assisted access clear channel assessment/listen-before-talk as indicated by the indication of the portion of resources of the licensed-assisted access clear channel assessment/listen-before-talk period that was occupied.

23. An apparatus comprising:

at least one processor; and

at least one memory including computer program code

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive an indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period of a licensed-assisted access node;

transmit (130,630) the indication of a potential licensed-assisted access clear channel assessment/listen-before-talk period to a user equipment (110,610); and

transmit (140,640) an indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

24. The apparatus of claim 23, wherein transmitting an indication to the user equipment comprises transmitting a reference signal on the unlicensed carrier.

25. The apparatus of claim 23, wherein the indication of whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful further comprises an indication for identifying a subset of measurement samples during the licensed-assisted access clear channel assessment/listen-before-talk period for determining an interference measure.

26. The apparatus of claim 23, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:

transmit to the user equipment an indication of resources that were occupied during the licensed-assisted access clear channel assessment/listen-before-talk period.

27. The apparatus of claim 23, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to

perform at least the following:

receive from the user equipment an indication of a reference signal received quality measurement dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

28. The apparatus according to claim 27, wherein the value of the reference signal received quality measurement is dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

29. A computer program product, embodied on a non-transitory computer readable medium, wherein the computer program is configured to control a processor to perform a process, comprising the method according any of claims 1-14.

30. A method comprising:

measuring (112,612) at least one reference signal received from an access node (120,620) on an unlicensed carrier;

measuring (111,611) interference when the access node has successfully performed a clear channel assessment;

forming (113,330,613) a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and

initiating transmission (340,650) of the reference signal received quality measurement to a network element (120,160,620).

31. The method according to claim 30, wherein the reference signal is measured regardless of whether the access node has successfully performed a clear channel assessment.

32. The method according to claim 30, further comprising:

receiving (130,630) from a second access node (120,160,620) an indication of a potential clear channel assessment/listen-before-talk period, wherein the measurement of the interference is taken within the indicated clear channel assessment/listen-before-talk period.

33. The method according to claim 32, wherein the receiving from the second access node

comprises receiving from the access node (620) over the unlicensed carrier.

34. The method according to claim 30, further comprising:

receiving from a second access node (120,160,620) an indication that a clear channel assessment/listen-before-talk was successful; and

determining in response to the indication a subset of samples of the measurement of interference; and

forming the reference signal received quality measurement from the measurement of the reference signal and the subset of samples of the measurement of the interference.

35. The method according to claim 34, wherein determining the subset of samples of the measurement of interference comprises selecting the subset of samples of the measurement of interference based at least on determining a subset of samples corresponding to resources protected by the clear channel assessment/listen-before-talk.

36. The method according to claim 34, further comprising receiving from the access node an indication of a portion of resources of the clear channel assessment/listen-before-talk that was occupied by a transmission from the access node.

37. The method according to claim 36, wherein determining the subset of samples of the measurement of interference comprises selecting the subset of samples of the measurement of interference based at least on determining a subset of samples corresponding to resources not occupied during resources protected by the clear channel assessment/listen-before-talk as indicated by the indication of the portion of resources of the clear channel assessment/listen-before-talk period that was occupied.

38. A method comprising:

determining an indication of a potential clear channel assessment/listen-before-talk period on an unlicensed carrier of an access node (120,620);

transmitting (130,630) the indication of a potential clear channel assessment/listen-before-talk period to a user equipment (110,610); and

transmitting (140,640) an indication to the user equipment whether the clear channel assessment/listen-before-talk period was successful.

39. The method according to claim 38, wherein transmitting an indication to the user equipment comprises transmitting a reference signal on the unlicensed carrier.
40. The method according to claim 38, wherein the indication of whether the clear channel assessment/listen-before-talk period was successful further comprises an indication for identifying a subset of measurement samples during the clear channel assessment/listen-before-talk period for determining an interference measure.
41. The method according to claim 38, further comprising:
transmitting to the user equipment an indication of resources that were occupied during the clear channel assessment/listen-before-talk period.
42. The method according to claim 38, further comprising:
receiving from the user equipment an indication of a reference signal received quality measurement dependent of the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.
43. The method according to claim 42, wherein the value of the reference signal received quality measurement is dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.
44. A apparatus comprising:
at least one processor; and
at least one memory including computer program code
the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:
measure (112,612) at least one reference signal received from an access node (120,620) on an unlicensed carrier;
measure (111,611) interference when the access node has successfully performed a clear channel assessment;
form (113,330,613) a reference signal received quality measurement from the measurement of the reference signal and the measurement of the interference; and
initiate transmission (340,650) of the reference signal received quality

measurement to a network element (120,160,620).

45. The apparatus according to claim 44, wherein the reference signal is measured regardless of whether the access node has successfully performed a clear channel assessment.
46. The apparatus according to claim 44, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:
 - receive (130,630) from a second access node (120,160,620) an indication of a potential clear channel assessment/listen-before-talk period, wherein the measurement of the interference is taken within the indicated clear channel assessment/listen-before-talk period.
47. The apparatus according to claim 46, wherein the reception from the second access node comprises reception from the access node (620) over the unlicensed carrier.
48. The apparatus according to claim 44, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:
 - receive from a second access node (120,160,620) an indication that a clear channel assessment/listen-before-talk was successful; and
 - determine in response to the indication a subset of samples of the measurement of interference; and
 - form the reference signal received quality measurement from the measurement of the reference signal and the subset of samples of the measurement of the interference.
49. The apparatus according to claim 46, wherein the determination of the subset of samples of the measurement of interference comprises a selection of the subset of samples of the measurement of interference based at least on a determination of a subset of samples corresponding to resources protected by the clear channel assessment/listen-before-talk.
50. The apparatus according to claim 44, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause

the apparatus to perform at least the following:

receive from the access node an indication of a portion of resources of the clear channel assessment/listen-before-talk that was occupied by a transmission from the access node.

51. The apparatus according to claim 50, wherein the determination of the subset of samples of the measurement of interference comprises a selection of the subset of samples of the measurement of interference based at least on a determination of a subset of samples corresponding to resources not occupied during resources protected by the clear channel assessment/listen-before-talk as indicated by the indication of the portion of resources of the clear channel assessment/listen-before-talk period that was occupied.
52. A apparatus comprising:
 - at least one processor; and
 - at least one memory including computer program codethe at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:
 - determine an indication of a potential clear channel assessment/listen-before-talk period on an unlicensed carrier of an access node (120,620);
 - transmit (130,630) the indication of a potential clear channel assessment/listen-before-talk period to a user equipment (110,610); and
 - transmit (140,640) an indication to the user equipment whether the clear channel assessment/listen-before-talk period was successful.
53. The apparatus of claim 52, wherein transmitting an indication to the user equipment comprises transmitting a reference signal on the unlicensed carrier.
54. The apparatus according to claim 52, wherein the indication of whether the clear channel assessment/listen-before-talk period was successful further comprises an indication for identifying a subset of measurement samples during the clear channel assessment/listen-before-talk period for determining an interference measure.
55. The apparatus according to claim 52, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:

transmit to the user equipment an indication of resources that were occupied during the clear channel assessment/listen-before-talk period.

56. The apparatus according to claim 52, wherein the at least one memory and the computer program code further configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive from the user equipment an indication of a reference signal received quality measurement dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

57. The apparatus according to claim 56, wherein the value of the reference signal received quality measurement is dependent on the indication to the user equipment whether the licensed-assisted access clear channel assessment/listen-before-talk period was successful.

58. A computer program product, embodied on a non-transitory computer readable medium, wherein the computer program is configured to control a processor to perform a process, comprising the method according any of claims 30-43.

59. A method comprising:

attempting a clear channel assessment/listen-before-talk period on an unlicensed channel; and

transmitting a signal to a user equipment on the unlicensed channel, the signal indicating whether the clear channel assessment/listen-before-talk period attempt was successful.

60. The method according to claim 59, wherein the indication whether the the clear channel assessment/listen-before-talk period attempt was successful is comprised in a reference signal.

61. A apparatus comprising:

at least one processor; and

at least one memory including computer program code

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

attempt a clear channel assessment/listen-before-talk period on an unlicensed channel; and

transmit a signal to a user equipment on the unlicensed channel, the signal indicating whether the clear channel assessment/listen-before-talk period attempt was successful.

62. The apparatus according to claim 61, wherein the indication whether the clear channel assessment/listen-before-talk period attempt was successful is comprised in a reference signal.
63. A computer program product, embodied on a non-transitory computer readable medium, wherein the computer program is configured to control a processor to perform a process, comprising the method according any of claims 59-60.

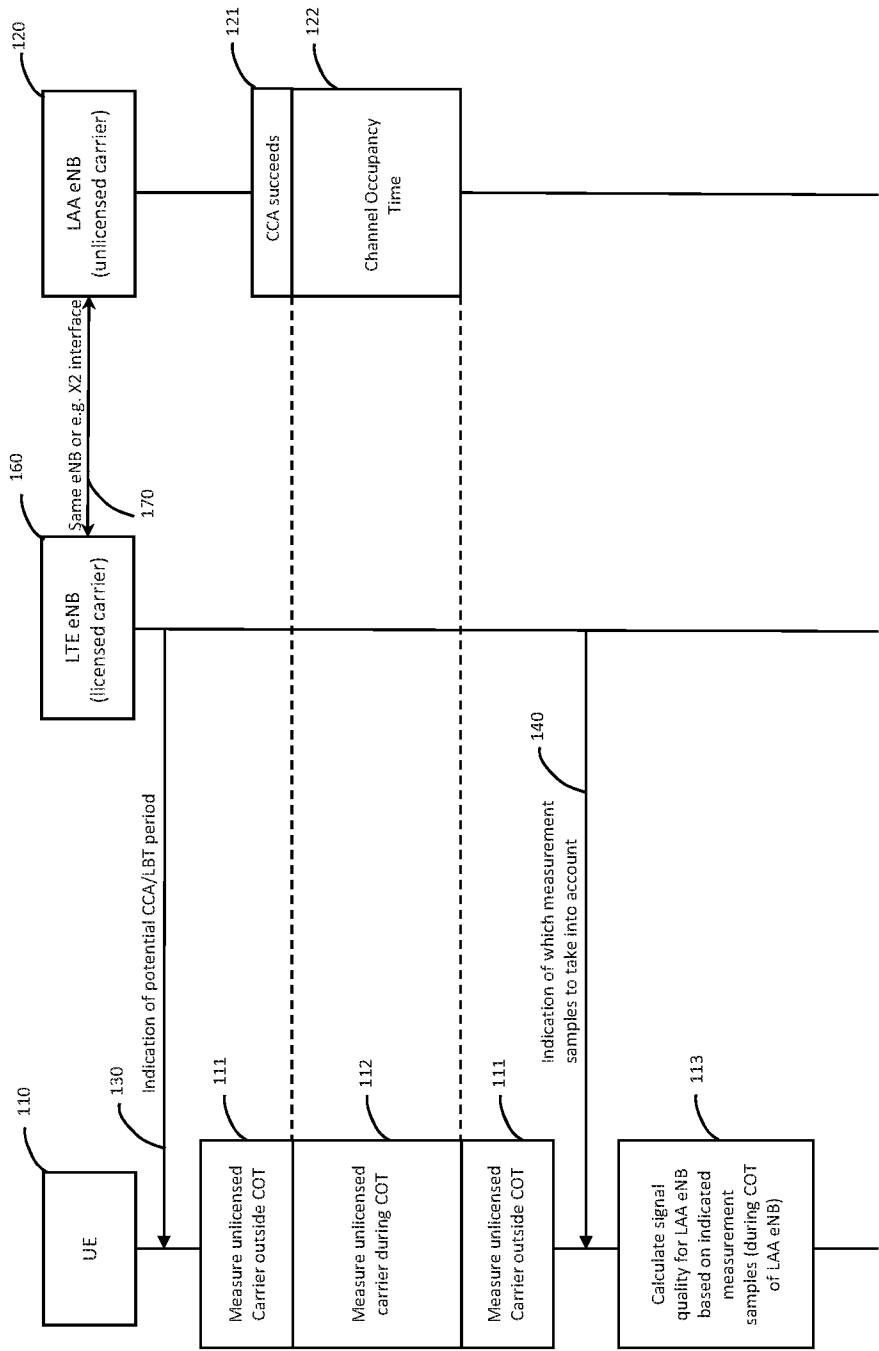


Figure 1

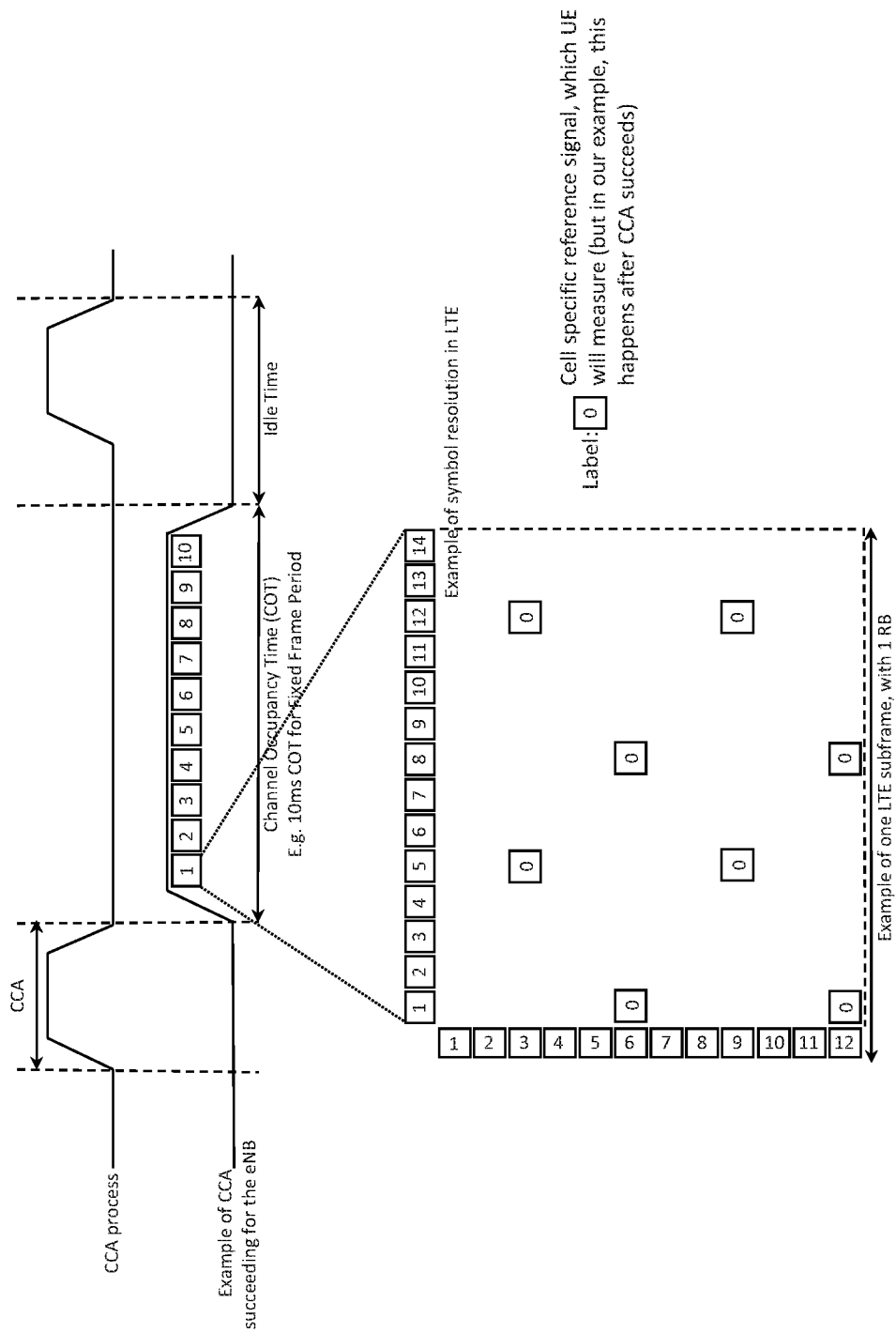


Figure 2

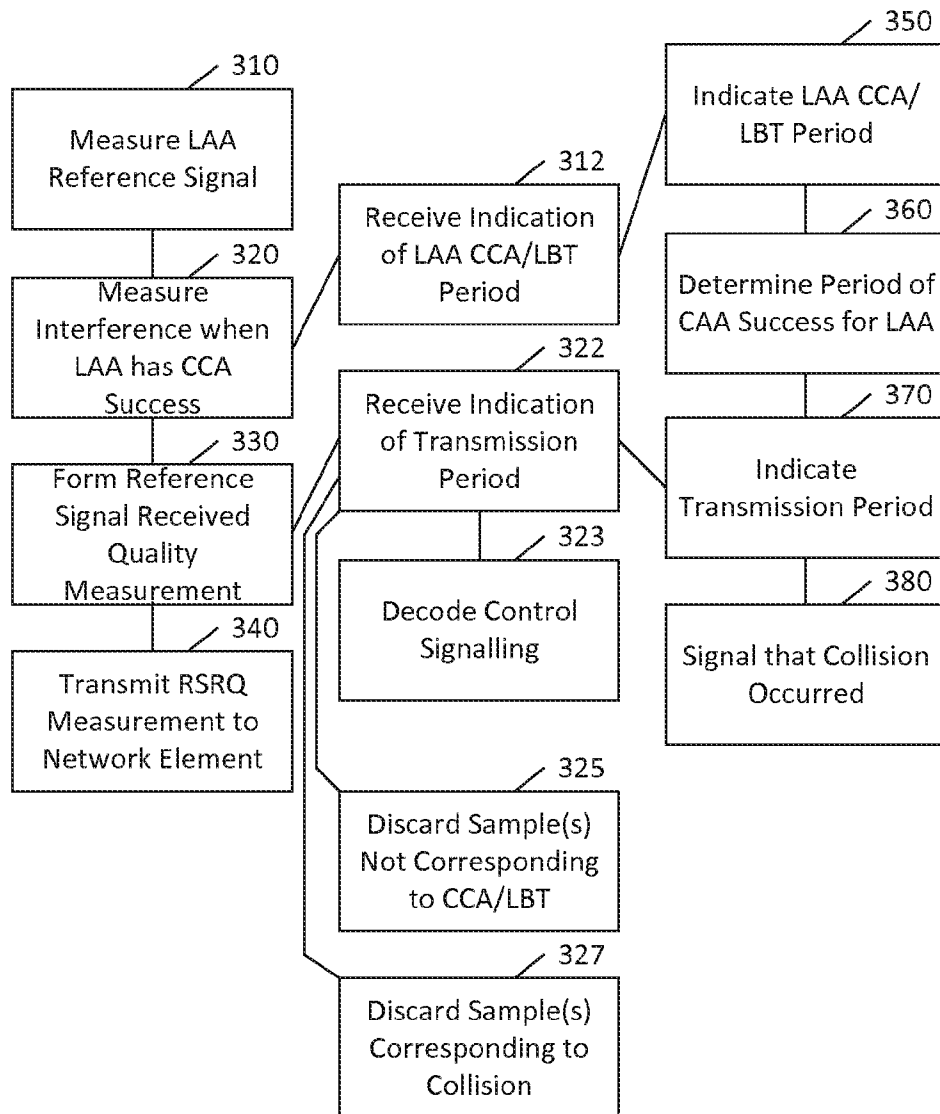


Figure 3

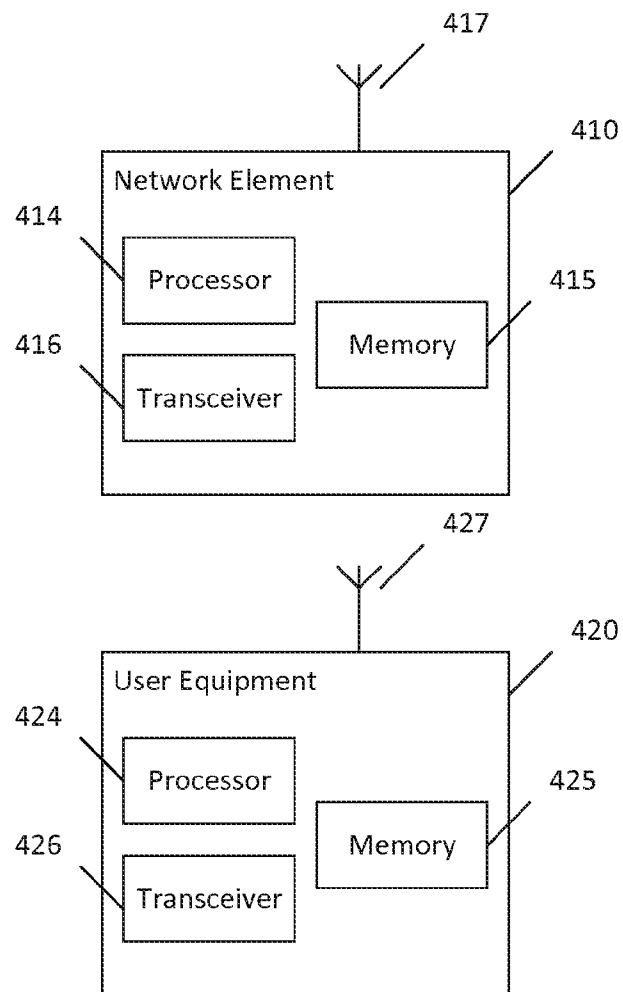


Figure 4

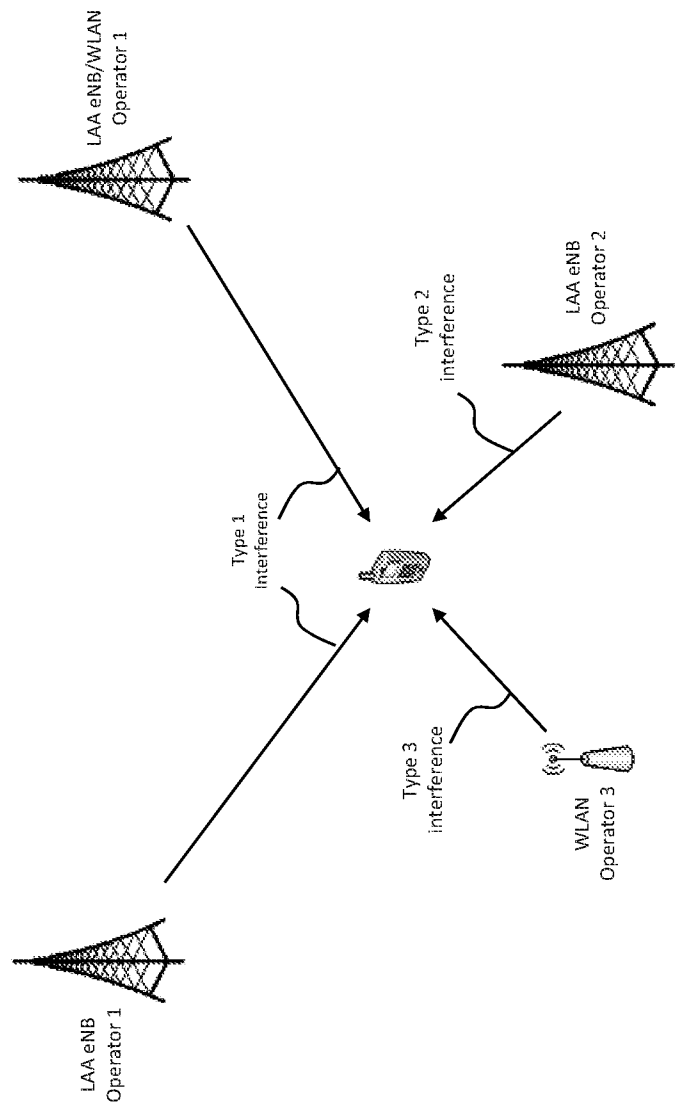


Figure 5

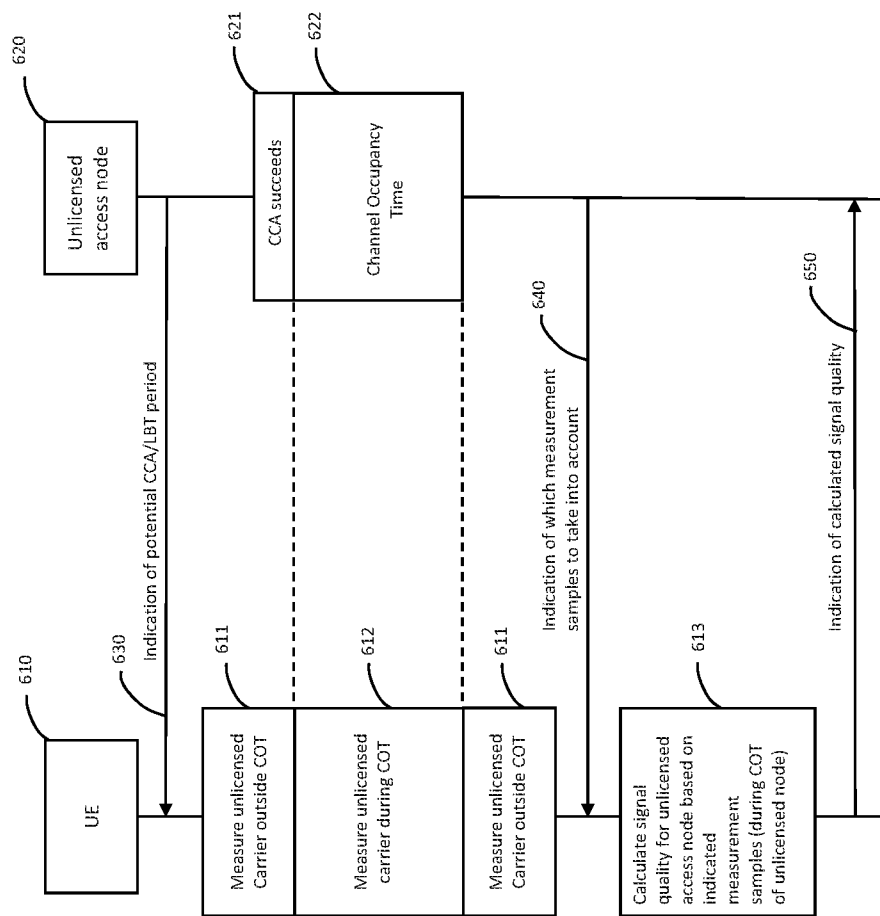


Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/050630

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04L, H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012116489 A1 (RENESAS MOBILE CORP ET AL), 7 September 2012 (2012-09-07); abstract; paragraphs [0001]-[0014], [0029], [0039]; figures 2-B	1-3, 15-17, 30-33, 44-47, 50
A	--	4-14, 18-29, 34-43, 48-49, 51-63



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/050630

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	--	4-14, 18-29, 34-43, 48-49, 51-63
X	3rd generation Partnership Project; 3GPP TSG RAN WG1 Meeting #79; R1-144743; San Francisco, USA, November 17 - 21, 2014; Samsung; Discussion on CSI measurement aspects for LAA; [retrieved on 2016-05-23]; Retrieved from the Internet: < http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_79/Docs/R1-144743.zip >; whole document	9-10, 12-14, 23-24, 26-28, 38-39, 41-43, 52-53, 55-57, 59-63
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A	Nokia Networks; LTE for unlicensed spectrum; White Paper; 2014; [retrieved on 2016-05-23]; Retrieved from the Internet: < https://docs.google.com/viewer?url=http%3A%2F%2Fnetworks.nokia.com%2Fsites%2Fdefault%2Ffiles%2Fdocument%2Fnokia_lte_unlicensed_white_paper.pdf >; whole document	1-63
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	LTE Unlicensed and Wi-Fi: Moving Beyond Coexistence; Monica Paolini, Senza Fili; 2015; [retrieved on 2016-05-23]; Retrieved from the Internet: < http://www.interdigital.com/white_papers/lte-unlicensed-and-wifi-moving-beyond-coexistence?r=y >; pages 1-27	1-63
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	US 20150098397 A1 (DAMNJANOVIC ALEKSANDAR ET AL), 9 April 2015 (2015-04-09); abstract; paragraphs [0128]-[0144]; figures 16-18	30-33, 38-39, 41-43, 52-53, 55-63
P, Y		1-3, 9-17, 23-24, 26-29
P, A		4-8, 18-22, 25, 34-37, 40, 44-51, 54
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P, X	US 20150289208 A1 (LIU JIALING ET AL), 8 October 2015 (2015-10-08); paragraphs [0091]-[0097], [0109]-[0115]; figures 9a-9b, 12a-12b	30-33, 38-39, 41-43, 52-53, 55-63
P, Y		1-3, 9-17, 23-24, 26-29
P, A		4-8, 18-22, 25, 34-37, 40, 44-51, 54
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E	US 20150327233 A1 (LIU JIALING ET AL), 12 November 2015 (2015-11-12); paragraphs [0112]-[0118]; figures 7-9	1-63
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International Patent Classification (IPC)

H04W 72/08 (2009.01)

H04L 12/413 (2006.01)

H04W 16/14 (2009.01)

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