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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY,DOCKET.NO	TOT CLAIMS	IND CLAIMS
62/753,579	10/31/2018		280	CNV14535US01/106693000180		

CONFIRMATION NO. 1062

FILING RECEIPT



0000000103843747

23377
BAKER & HOSTETLER LLP
CIRA CENTRE 12TH FLOOR
2929 ARCH STREET
PHILADELPHIA, PA 19104-2891

Date Mailed: 11/07/2018

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Stephen E. Terry, Northport, NY;
Pascal M. Adjakple, Great Neck, NY;
Joseph M. Murray, Schwenksville, PA;
Qing Li, Princeton Junction, NJ;
Lakshmi R. Iyer, King of Prussia, PA;
Guodong Zhang, Woodbury, NY;

Applicant(s)

Convida Wireless, LLC, Wilmington, DE;

Power of Attorney:

Craig Cupid--61308

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 11/06/2018

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/753,579**

Projected Publication Date: None, application is not eligible for pre-grant publication

page 1 of 3

Non-Publication Request: No

Early Publication Request: No

Title

NR-U LBT MAC PROCEDURES

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where

page 2 of 3

the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit <http://www.SelectUSA.gov> or call +1-202-482-6800.

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Stephen

E.

Terry

Northport

NY

US

Inventor 2

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Pascal

M.

Adjakple

Great Neck

NY

US

Inventor 3

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Joseph

M.

Murray

Schwenksville

PA

US

Inventor 4

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Qing

Li

Princeton Junction

NJ

US

Inventor 5

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Lakshmi

R.

Iyer

King of Prussia

PA

US

Inventor 6

Remove

Given Name

Middle Name

Family Name

City

State

Country ;

Guodong

Zhang

Woodbury

NY

US

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the Add button.

Add

Title of Invention

NR-U LBT MAC PROCEDURES

Attorney Docket Number (if applicable)

CNV14535US01/106693000180

Correspondence Address

Direct all correspondence to (select one):

☒ The address corresponding to Customer Number

☐ Firm or Individual Name

Customer Number	23377
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.
No.
Yes, the invention was made by an agency of the United States Government. The U.S. Government agency name is:
Yes, the invention was under a contract with an agency of the United States Government. The name of the U.S. Government agency and Government contract number are:

Entity Status

Applicant asserts small entity status under 37 CFR 1.27 or applicant certifies micro entity status under 37 CFR 1.29

- ☐ Applicant asserts small entity status under 37 CFR 1.27
- ☐ Applicant certifies micro entity status under 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
- ☒ No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Craig L. Cupid/		Date (YYYY-MM-DD)	2018-10-31
First Name	Craig L.	Last Name	Cupid	Registration Number (If appropriate) 61308

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to a n other federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
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Inventor Information:

Inventor	1				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Stephen	E.	Terry		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Northport	State/Province	NY	Country of Residence	US

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway				
Address 2	Suite 300				
City	Wilmington	State/Province	DE		
Postal Code	19809-3727	Country	US		

Inventor	2				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Pascal	M.	Adjakple		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Great Neck	State/Province	NY	Country of Residence	US

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway				
Address 2	Suite 300				
City	Wilmington	State/Province	DE		
Postal Code	19809-3727	Country	US		

Inventor	3				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Joseph	M.	Murray		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

City	Schwenksville	State/Province	PA	Country of Residence	JS
------	---------------	----------------	----	----------------------	----

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway				
Address 2	Suite 300				
City	Wilmington	State/Province	DE		
Postal Code	19809-3727	Country	US		

Inventor	4	Remove
Legal Name		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Qing		.i	

Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service

City	Princeton Junction	State/Province	NJ	Country of Residence	JS
------	--------------------	----------------	----	----------------------	----

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway				
Address 2	Suite 300				
City	Wilmington	State/Province	DE		
Postal Code	19809-3727	Country	US		

Inventor	5	Remove
Legal Name		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Lakshmi	R.	yer	

Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service

City	King of Prussia	State/Province	PA	Country of Residence	JS
------	-----------------	----------------	----	----------------------	----

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway				
Address 2	Suite 300				
City	Wilmington	State/Province	DE		
Postal Code	19809-3727	Country	US		

Inventor	6	Remove
Legal Name		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Guodong		Zhang	

Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service

City	Woodbury	State/Province	NY	Country of Residence	JS
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Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Mailing Address of Inventor:

Address 1	200 Bellevue Parkway		
Address 2	Suite 300		
City	Wilmington	State/Province	DE
Postal Code	19809-3727	Country i	US
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button. Add			

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence Information of this application.			
Customer Number	23377		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	NR-U LBT MAC PROCEDURES		
Attorney Docket Number	CNV14535US01/106693000180	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	13	Suggested Figure for Publication (if any)	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	23377		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Remove
			Access Code ^j (if applicable)
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			Add

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. ☐ NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.	
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant	1	Remove
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. Clear		
☒ Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.		Person who shows sufficient proprietary interest
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:		
Name of the Deceased or Legally Incapacitated Inventor:		
If the Applicant is an Organization check here. ☒		
Organization Name	Convida Wireless, LLC	
Mailing Address Information For Applicant:		
Address 1	200 Bellevue Parkway	
Address 2	Suite 300	
City	Wilmington	State/Province DE
Country	US	Postal Code 19809-3727
Phone Number		Fax Number
Email Address		
Additional Applicant Data may be generated within this form by selecting the Add button. Add		

Assignee Information including Non-Applicant Assignee Information:

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

Assignee	1			
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Signature	/Craig L. Cupid/		Date (YYYY-MM-DD)	2018-10-31
First Name	Craig L.	Last Name	Cupid	Registration Number
				61,308
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CNV14535US01/106693000180
		Application Number	
Title of Invention	NR-U LBT MAC PROCEDURES		

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ABSTRACT

Methods, apparatuses, and systems associated with existing MAC procedures that help maintain proper operation and performance of MAC procedures when operating in unlicensed spectrum. In NR-U when LBT failures occur existing MAC procedures may take inappropriate actions resulting in unintended consequences.

What is Claimed:

1. A device comprising:
a processor; and
a memory coupled with the processor, the memory comprising executable instructions stored thereon that when executed by the processor cause the processor to effectuate operations comprising:
determining that preamble transmission counter is greater than one, the notification of a suspending power ramping counter has not been received from lower layers, and SSB selected is not changed, and LBT Failure has not been detected; and
based on the determining step, providing instructions to increment preamble power ramping counter by 1.
2. A device comprising:
a processor; and
a memory coupled with the processor, the memory comprising executable instructions stored thereon that when executed by the processor cause the processor to effectuate operations comprising:
the steps of FIG. 1, 2, 3, 4, 5, 6, or 7.

NR-U LBT MAC PROCEDURES

BACKGROUND

LTE Licensed Assisted Access

[0001] 3GPP release 16 NR will support unlicensed operation without a licensed assisted connection which was available in previous releases. Since in previous releases there was always a licensed connection, it was not necessary to ensure a high level of QoS on the unlicensed connection.

[0002] Operation in unlicensed requires Listen Before Talk (LBT) procedures to not interfere with existing traffic and gain access to the channel.

[0003] Carrier aggregation with at least one SCell operating in the unlicensed spectrum is referred to as Licensed-Assisted Access (LAA). In LAA, the configured set of serving cells for a UE therefore always includes at least one SCell operating in the unlicensed spectrum according to frame structure Type 3, also called LAA SCell. Unless otherwise specified, LAA SCells act as regular SCells.

[0004] LAA eNB and UE apply Listen-Before-Talk (LBT) before performing a transmission on LAA SCell. When LBT is applied, the transmitter listens to/senses the channel to determine whether the channel is free or busy. If the channel is determined to be free, the transmitter may perform the transmission; otherwise, it does not perform the transmission. If an LAA eNB uses channel access signals of other technologies for the purpose of LAA channel access, it shall continue to meet the LAA maximum energy detection threshold requirement in 3GPP TS 36.321, (E-UTRA), Medium Access Control (MAC) protocol specification, V15.2.0 [1]. Further context may be included in 3GPP TS 36.321, (E-UTRA), Medium Access Control (MAC) protocol specification, V15.2.0.

SUMMARY

[0005] Disclosed herein are methods, apparatuses, and systems associated with existing MAC procedures that help maintain proper operation and performance of MAC procedures, such as when operating in unlicensed spectrum. In NR-U when LBT failures occur existing MAC procedures may take inappropriate actions resulting in unintended consequences.

[0006] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is

not constrained to limitations that solve any or all disadvantages noted in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

[0008] FIG. 1 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0009] FIG. 2 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0010] FIG. 3 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0011] FIG. 4 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0012] FIG. 5 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0013] FIG. 6 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0014] FIG. 7 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0015] FIG. 8 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0016] FIG. 9 illustrates an exemplary method associated with NR-U LBT MAC procedures;

[0017] FIG. 10 illustrates an exemplary display (e.g., graphical user interface) that may be generated based on the methods, systems, and devices of NR-U LBT MAC procedures;

[0018] FIG. 11A illustrates an example communications system;

[0019] FIG. 11B is a block diagram of an example apparatus or device configured for wireless communications such as, for example, a wireless transmit/receive unit (WTRU);

[0020] FIG. 11C is a system diagram of a first example radio access network (RAN) and core network;

[0021] FIG. 11D is a system diagram of a second example radio access network (RAN) and core network;

[0022] FIG. 11E is a system diagram of a third example radio access network (RAN) and core network;

[0023] FIG. 11F is a block diagram of an exemplary computing system in which one or more apparatuses of communications networks may be embodied, such as certain nodes or functional entities in the RAN, core network, public switched telephone network (PSTN), Internet, or other networks; and

[0024] FIG. 11G illustrates one example communications system in which the systems and methods described and claimed herein may be embodied.

DETAILED DESCRIPTION

[0025] Disclosed herein are methods, apparatuses, and systems associated with existing MAC procedures that help maintain proper operation and performance of MAC procedures when operating in unlicensed spectrum. In NR-U when LBT failures occur existing MAC procedures may take inappropriate actions resulting in unintended consequences.

[0026] Specific issues related to MAC procedures addressed herein may include issues associated with BWP operation procedure, random access procedure, PHR procedure, SCell activation or deactivation procedure, discontinuous reception procedure, scheduling procedure, buffer status reporting procedure, logical channel prioritization procedure, or coordination of UE and NB MAC procedures, among other things.

[0027] The Bandwidth Part Operation Procedure Issue -When LBT Failures occur: The Bandwidth Part Inactivity Timer may expire resulting in switching to the Initial or Default or default BWP even when there is UL or DL data to be scheduled.

[0028] The Random Access Procedure Issue - When LBT failures occur: 1) The Random Access Response Window may expire without allowing a sufficient number of transmission opportunities for the Random Access Response; 2) The Preamble Transmission Counter may reach the maximum number of transmissions without allowing for a sufficient number preamble transmissions needed for successful preamble transmission; 3) The Contention Resolution Timer may expire without allowing for a sufficient number of PDCCH transmission opportunities in response to MSG3 transmission; or 4) The power ramping may be increased even when there is no preamble transmission resulting in incorrect power setting.

[0029] The Power Headroom Reporting (PHR) Procedure Issue - When LBT failures occur: 1) The NB may not be able to determine when the PHR was calculated, and what was transmitted at that time, resulting in an incorrect power headroom determination; 2) PHR triggering due to the PHR Periodic Timer, reconfiguration, SCell Activation, PSCell Addition, or

Prohibit Timer expiration may occur inappropriately early; 3) PHR Calculation may incorrectly calculate power headroom assuming a real transmission; or 4) The PHR Prohibit timer may be set even when there was no PHR transmission.

[0030] The SCell Activation/Deactivation Procedure Issue - When LBT failure occur: The SCell Deactivation Timer may expire, deactivating the SCell when there is UL or DL data to be scheduled on the SCell.

[0031] The Discontinuous Reception Procedure Issue - When LBT failures occur: The On Duration or Inactivity Timers may expire, stopping PDCCH reception, when there is UL or DL data to be scheduled.

[0032] The Scheduling Request Procedure Issue - When LBT failures occur: 1) Failed SR transmissions will not initiate a Random Access procedure; 2) The SR Prohibit timer may be set even when there was no SR transmission; 3) The SR Transmission Counter may reach the maximum number of transmissions without allowing for a sufficient number SR transmissions needed for successful SR transmission; or 4) SR Pending may be cleared even when there is no SR transmission.

[0033] The Buffer Status Reporting Procedure Issue - When LBT failures occur: When there may be UL-SCH resources available, BSR may not be transmitted and an SR will not be triggered.

[0034] The Logical Channel Prioritization Procedure Issue - When LBT failures occur: A MAC PDU may not be able to be transmitted in a subsequent grant resulting in loss of user data and control signaling.

[0035] Coordination of UE and NB MAC Procedures Issue - When LBT failures occur: The UE may take actions effecting MAC procedures that need to be known to the NB for proper operation. Additionally, the NB may take actions independent of UE behavior.

[0036] In view of the aforementioned example issues, existing MAC procedures may be modified to take into account LBT failures so that inappropriate actions are not taken and unintended consequences are avoided. A summary of the how the issues may be addressed are disclosed below.

[0037] The Bandwidth Part Operation Procedure Summary - When LBT failures occur: The Bandwidth Part Inactivity Timer is extended so that switching to the Initial or Default or default BWP is avoided there may be UL or DL data to be scheduled.

[0038] The Random Access Procedure Summary - When LBT failures occur: 1) The Random Access Response Window may be extended to allow for a sufficient number of

transmission opportunities for the Random Access Response; 2) The Preamble Transmission Counter may not be incremented so that a sufficient number preamble transmissions are made to allow for successful preamble transmission; 3) The Contention Resolution Timer may be extended to allow for a sufficient number of PDCCH transmission opportunities in response to MSG3 transmission; or 4) The power ramping may not be increased in order to maintain proper power setting.

[0039] The Power Headroom Reporting Procedure Summary - When LBT failures occur: 1) The UE may indicate to the NB when the PHR was calculated; 2) The UE indicated to the NB what was transmitted at the time of PHR calculation; 3) The UE indicates to the NB when LBT failures have occurred; 4) The UE indicated to the NB that there has been a delay in PHR transmission; 5) PHR triggering due to the PHR Periodic Timer, reconfiguration, SCell Activation, PSCell Addition, or Prohibit Timer expiration is delayed; 6) PHR Calculation takes into account lost or delayed transmissions; or 7) The PHR Prohibit timer is not set or delayed.

[0040] The SCell Activation/Deactivation Procedure Summary - When LBT failure occur: The SCell Deactivation Timer may be extended to allow for additional UL or DL data scheduling opportunities on the SCell.

[0041] The Discontinuous Reception Procedure Summary - When LBT failures occur: The On Duration or Inactivity Timers may be extended to allow for additional UL or DL data scheduling opportunities.

[0042] The Scheduling Request Procedure Summary - When LBT failures occur: 1) A Random Access procedure may be initiated; 2) The SR Prohibit timer not set or setting of the prohibit timer may be delayed; 3) The SR Transmission Counter may not be incremented to allow for a sufficient number SR transmissions needed for successful SR transmission; or 4) SR Pending may not be cleared or clearing of SR Pending may be delayed.

[0043] The Buffer Status Reporting Procedure Summary - When LBT failures occur: Even though there may be UL-SCH resources available, an SR may be triggered.

[0044] The Logical Channel Prioritization Procedure Summary - When LBT failures occur: 1) A MAC PDU may not be built; or 2) The MAC PDU may be reformatted to allow for transmission in a subsequent grant.

[0045] Coordination of UE and NB MAC Procedures Summary - When LBT failures occur: The UE reports LBT failures or what procedures are affected and how.

[0046] FIG. 1 – FIG. 9 illustrate exemplary methods associated with NR-U LBT MAC procedures, which are described in more detail herein.

NR-U LBT Operation Effect on MAC

[0047] The disclosed subject matter applies to the overall MAC operation and numerous specific MAC procedures. These MAC procedures include Bandwidth Part Operation (BWP), Random Access (RA), Power Headroom Reporting (PHR), SCell Activation and deactivation, Logical Channel Prioritization (LCP), Discontinuous Reception (DRX), Scheduling Request (SR), Buffer Status Report (BSR), and potentially a new LBT MAC procedure and others.

[0048] LBT Failures can result in unnecessary and unintended effects on these MAC procedures. With knowledge of LBT Failures or successes these MAC procedures may operate similarly and with similar performance to operation in licensed spectrum where LBT is not required.

General Considerations for Both UL and DL LBT Failures

[0049] With respect to the effect on MAC procedures LBT failures are considered in the UL or in the DL. Depending on the MAC procedure, and specific actions within the procedure, both UL and DL LBT failures maybe considered, or only UL or only DL LBT failures may be considered. Additionally, how LBT indications are provided to the MAC and what information is provided may be different for the UL and DL.

[0050] For UL LBT operation the PHY layer may indicate to the MAC, LBT success or failure. The UL LBT success or failure indication may be associated with an UL transmission or the UL LBT procedure may be performed independently of an UL transmission. Each UL LBT success or failure indication may be associated with one or more MAC procedures.

[0051] For DL LBT operation the NB can signal to the UE DL LBT success or failures. The DL LBT success or failure indication may be associated with an DL transmission or the DL LBT procedure may be performed independently of an DL transmission. Each DL LBT success or failure indication may be associated with one or more MAC procedures.

[0052] Depending on the MAC procedure, and specific actions within the procedure it is necessary to perform LBT even when there is no associated transmission. This is necessary since currently MAC procedures assume there is always access to the channel and there is no halting or blocking of transmissions. For example, if the UE detects no downlink assignments or uplink grants MAC procedures assume there is no data to be scheduled for transmission in the downlink or uplink. But there may be data to be scheduled for transmission which has been

blocked or delayed by LBT failures. In this case MAC procedures may take inappropriate actions which may result in unintended consequences.

[0053] When LBT Failure or Success is referred to in this document for overall MAC operation or specific MAC procedures, both uplink LBT or downlink LBT may be considered. Depending on the MAC procedure, and specific actions within the procedure, either both UL and DL LBT failures are considered, or just UL or just DL LBT failures are considered.

[0054] It should be noted it is not necessary to signal or indicate to the MAC both LBT Failures and Successes. Lack of a LBT Failure indication can be interpreted as a Success, and lack of a Success indication can be interpreted as a Failure. UL LBT indications from the PHY layer may only indicate LBT Failures, and DL LBT indications from the NB may only indicate LBT Successes.

[0055] LBT success or failure indication may be provided periodically on known occasions or may be triggered by specific actions taken by a MAC procedure. DL LBT successes or failures may be periodically signaled by the NB, and UL LBT successes or failures may be indicated by the PHY layer depending on operation of specific MAC procedures. It is also considered periodic indications may be augmented by on demand indications driven by MAC procedures and vice versa.

[0056] LBT success or failure indications may be for a specific LBT procedure operation or the indications may provide information on more than one LBT procedure operation over a known period of time. The period of time may be the period since the last report. UL LBT indications may result from a specific LBT procedure operation, and DL LBT indications may provide information on a number of LBT operations over a period of time.

[0057] LBT success or failure indications may provide information on the carrier and BWP(s), where the LBT is performed. In addition to uplink or downlink LBT success, failure, indications further LBT procedure information may be provided to MAC procedures. MAC procedures take into account transmission opportunities in the downlink and uplink. For proper operation of these MAC procedures it is necessary to know the time periods transmissions can or can't be made in the uplink and downlink. To accomplish this, it is disclosed herein an addition to, or included with the LBT success or failure indication, the period of Clear Channel Assessment (CCA), the selected Maximum Channel Occupancy Time (MCOT), the selected Contention Window Size (CWS), and other timing information is provided to the MAC to allow for proper determination of downlink and uplink transmission opportunities. The MCOT, CWS and other may be identified by the Channel Access Priority Class (CAPC) or another index representing the selected timing.

Downlink LBT Success/Failure Indications

[0058] It has been discussed that a DL LBT Success indication may be signaled from the NB to the UEs during the UEs' DRX On Duration to effect DRX cycles. This should be extended to include the period the DRX Inactivity Timer is running, and potentially all periods that comprise DRX Active Time. For example, when a Random Access or Scheduling Request procedure is initiated while the UE is not within the DRX On Duration, knowledge of LBT failures is necessary for proper operation and performance similar to operation when LBT is not required.

[0059] Further, as a more comprehensive way to address this problem we consider DL LBT Success indications are continuously transmitted in a periodic manner known to the UE to allow MAC procedures which run outside of the DRX Active Time to benefit from the knowledge of DL LBT Success and Failures.

[0060] The DL LBT Success indication may be a new explicit signal or implicitly detected. For example, DL LBT Success may be implicitly detected by reception of SSB or DRS, and the new explicit signal may be a new DCI format (e.g., addressed to individual UE or a group of UEs or broadcast to all UEs).

[0061] Signaling DL LBT Success indications continuously in a periodic manner does not necessarily add complexity or require greater use of resources because DRX On Durations are in general staggered in time for different UE's. Depending on the periodicity signaling overhead may even be reduced.

[0062] It should also be noted that signaling DL LBT indications is effectively UE specific, or specific to groups of UE's that share DRX On Durations. Cell specific DL LBT indications can result in a more efficient use of resources and more consistent MAC procedure operation and performance.

[0063] It is also considered the LBT Success indication may not be a single indication. The information signaled may also provide information for the period since the last LBT Success indication. The information signaled may also provide information for how long the NB has access of the DL channel, for example to a specific channel or BWP. In this case, MAC procedures may have continuous knowledge over time of DL LBT Success or Failure which may result in more accurate effect on MAC procedures due to DL LBT Failure.

[0064] Downlink success indications may also provide timing information identifying periods when transmissions can and cannot be made in order for MAC procedures to be able to able to determine transmission opportunities accurately. To accomplish this, it is disclosed herein

may be an addition to, or included with the LBT success indication, the period of Clear Channel Assessment (CCA), the selected Maximum Channel Occupancy Time (MCOT), the selected Contention Window Size (CWS), or other timing information is provided to the MAC to allow for proper determination of downlink transmission opportunities. The MCOT, CWS and other may be identified by the Channel Access Priority Class (CAPC) or another index representing the selected timing.

Uplink LBT Success/Failure Indications

[0065] In addition to the NB indicating LBT Failure or Success status to the UE, we also disclose the UE provides UL LBT Failure or Success information to the NB.

[0066] As discussed in this invention there are multiple potential effects on UE MAC procedures. There are a number of cases where it is necessary for the NB to know how LBT Failure or Success have affected certain MAC procedures. For example, if DRX Active Time or DRX Cycles have been affected the NB must know for the UE to be properly scheduled.

[0067] The LBT procedure may do more than indicate UL LBT failures to the NB. After a significant amount of UL LBT failures, other actions may be taken. As discussed herein, operation of existing MAC procedures may be affected by LBT failures. The new LBT procedure has the possibility to take new actions to help resolve LBT failures. For example, the channel Access Priority may be adjusted to increase the chance of successful LBT.

[0068] Total number of LBT failures may be counted, which may be within a specified or configured period of time. Alternatively, LBT Failure Counters (FC) may count consecutive LBT failures, and upon a LBT success the LBT FC is reset to zero. The period in which LBT failures may be counted may be a sliding window in time. When the LBT failure counter exceeds a specified or configured threshold, the LBT State is considered failed. If a specified or configured number of LBT failures have not been exceeded or a specified or configured number of LBT success indications are received, the LBT State is considered successful. MAC procedures may check the LBT State rather than counting individual LBT failures associated with associated with the MAC procedure. MAC procedures may adjust counters and timers according to the LBT State. For example, MAC procedures may extend counters and timers, or consider timers and counters to have reached the maximum thresholds depending on the LBT State. The LBT State may also be indicated to higher layers. For example, to affect RRC procedures.

[0069] A new MAC LBT Report (LBTR) procedure may be defined to provide UL LBT success or failure information. A LBTR MAC CE may provide historical information on

previous UL LBT results. This may be over a certain period relative to when the report was generated. For example, it may be the period since the last LBTR MAC CE was transmitted. The MAC CE may provide information relative to which MAC procedure(s) was affected or when the LBT failure occurred so that the NB may attempt correlate which procedure(s) were affected. The LBTR MAC CE may also include BWP information in the LBT results for e.g., on which BWP LBT fails and on which BWP LBT was successful. RRC may configure into the UE, the LBTR reporting period.

[0070] Alternatively UL physical control signaling may provide UL LBT Failure or Success indication. This may be carried on PUCCH or piggybacked on PUSCH if scheduled or new UL signaling. Lack of reception of an periodic UL signaling may be interpreted as UE LBT Failure. This may be the PUCCH or new UL signaling. New UL signaling may have to be configured so that NB reception occurs at a known physical resource and at a known time.

[0071] Uplink LBT success or failure indications may also provide timing information identifying periods when transmissions can and cannot be made in order for MAC procedures to be able to determine transmission opportunities accurately. To accomplish this, it is proposed in addition to, or included with the LBT success or failure indication, the period of Clear Channel Assessment (CCA), the selected Maximum Channel Occupancy Time (MCOT), the selected Contention Window Size (CWS), and/or other timing information is provided to the MAC to allow for proper determination of uplink transmission opportunities. The MCOT, CWS and other may be identified by the Channel Access Priority Class (CAPC) or another index representing the selected timing.

LBT Effect on MAC Timers and Counters

[0072] LBT failures result in lost transmission opportunities. Loss of transmission opportunities also result in a greater period of time to achieve successful transmissions. MAC procedures consider an amount of transmission opportunities and period of time to complete before declaring failure of the procedure. To properly perform MAC procedures when LBT is required the count of transmission opportunities and possibly the period allowed for the procedure to complete successfully need to consider LBT failures.

[0073] Existing MAC procedures assume when a MAC PDU is given to the PHY layer or an instruction is given to the PHY to transmit PHY uplink control information (e.g. SR), the PDU or the PHY uplink control information is transmitted. When a MAC CE associated with a particular MAC procedure is built and multiplexed into a MAC PDU it may be assumed this MAC CE is transmitted. To limit the frequency a MAC CE or PHY uplink control information

associated with particular MAC procedures may be transmitted, prohibit timer may be set when the MAC CE is built and the MAC PDU may be given to the PHY layer, or when instruction is given to the PHY to transmit PHY uplink control information. To properly control the frequency a MAC CE or PHY uplink control information may be transmitted and ensure it is transmitted when needed setting of these prohibit timers also may consider LBT failures.

[0074] The sequence of processing MAC procedures also may be considered. Existing procedures increment counters and timers run when the MAC procedure executes before LBT is performed by the PHY layer. We consider several overall methods to affect the existing MAC procedures, which may be related to the following: 1) When the MAC receives an indication of LBT failure from the PHY layer counters and timers are adjusted to take the transmission failure into account; 2) When LBT succeeds timers and counters are acted upon; or 3) LBT failure are recorded during the period between when the initial MAC procedure was performed or between when they were initially set to the point counter(s) or timer(s) reach their maximum threshold.

[0075] When the MAC receives an indication of LBT failure from the PHY layer counters and timers are adjusted to take the transmission failure into account. Counters that were incremented when the MAC procedure was performed may be decremented so that they are unchanged from what they were set to before the procedure was performed. This may be somewhat more complex for the timers. Optimally the maximum time for the procedure should not consider the period of LBT failure. There are multiple options for effecting MAC timers when LBT failures occur depending on how the timers are used for different MAC procedures: a). The period from when the MAC procedure associated with the LBT failure was performed to the next opportunity to perform the MAC procedure is subtracted from the timers or is added to the maximum time threshold (when the timer expires); b). The timer is stopped upon reception of the LBT failure indication and restarted upon the next opportunity to perform the MAC procedure; c). The timer is restarted upon the LBT failure indication; or d). The period from when the timer in the MAC procedure associated with the LBT failure was set (start or restart) to the next opportunity to set the timer in the MAC procedure is subtracted from the timers or is added to the maximum time threshold (when the timer expires).

[0076] One concern with this approach is what happens when between the time when the MAC procedure was performed and reception of an LBT failure indication counter(s) or timer(s) associated with the MAC procedure reaches the maximum value. One way to address this issue would be when either a timer or counter reaches its maximum value the MAC checks if

it is awaiting an LBT indication for the previous transmission and only invokes the actions associated with the timer or counter expiration after a successful LBT indication is determined.

[0077] When LBT succeeds timers and counters are acted upon. In this method when the MAC procedure is performed counter(s) and timers(s) are not acted on. Upon indication of LBT success, the counters are incremented and timers are checked or adjusted. One issue with this approach is if upon the LBT success indication the timers or counters have reached their maximum threshold, which in cases mean the MAC procedure would have been performed differently. There are a few options to deal with this situation: When performing the MAC procedure timers and counters are checked to see if upon performing the procedure the timers or counters would have reached their maximum thresholds if they had been adjusted according to the procedure, and in this case the MAC procedure will take actions as if the counters or timers had reached their maximum thresholds.

[0078] LBT failures are recorded during the period between when the initial MAC procedure was performed or between when they were initially set to the point counter(s) or timers(s) reach their maximum threshold. When timers or counters reach their maximum threshold the LBT failure record is checked, and if LBT failures have occurred the procedures adjust the timers and counters to take the LBT failures into account. There are several options to accomplish this as the following (a) or (b): (a) The maximum timer and counter thresholds are adjusted according to the number of LBT failures and/or the time period of LBT failures so that actions taken upon reaching maximum thresholds are not taken at this time; or (b) The timers and counters are restarted according to the number of failures and the time period of the LBT failures so that actions taken upon reaching maximum thresholds are not taken at this time.

[0079] LBT failures affecting timers and counters may result in an unacceptable delay or even endlessly stalling of a MAC procedure. MAC procedure counters and timers may never reach their maximum thresholds. The disclosed changes to the MAC procedures therefore may take into account the possibility of continuous or a significant amount of LBT failures. In this case, the MAC procedures may take into account a maximum extension in time or maximum extension of counters so each MAC procedure is properly performed. For example, limiting extensions in MAC procedure counters (MAC PC) and timers (MAC PT) could be addressed by the following methods: 1) MAC procedure LBT Failure Counters (LBT FC); MAC PC and MAC PT Extension Counters (EC); or MAC PC and MAC PT Extended Maximum Thresholds (EMT).

[0080] MAC procedure LBT Failure Counters (LBT FC): LBT FC's may count total LBT failures, which maybe within a specified or configured period of time. Alternatively, LBT

FC's may count consecutive LBT failures, and upon a LBT success the LBT FC is reset to zero. LBT FC periods maybe the time allowed for a MAC procedure to complete, or maybe sliding windows in time. A specific MAC procedure may have more than one LBT FC. When a MAC procedure performs independent actions in parallel each may have an LBT FC. LBT FC's may have specified or configured maximums. When an LBT FC reaches a maximum count, the MAC PC and/or MAC PT are no longer extended upon LBT failure for the MAC procedure. Alternatively, when an LBT FC reaches a maximum count the MAC procedure takes actions as if the MAC PC and/or MAC PT have reached their maximum values. In cases this results in the MAC procedure to be considered to have failed.

[0081] MAC PC and MAC PT Extension Counters (EC): LBT failures cause MAC PC and/or MAC PT maximum thresholds to be extended. The criteria for extending maybe a specified or configured number of LBT failures within a specified or configured period of time. For example, it could be the MAC PT maximum threshold. EC's may count total MAC PC and/or MAC PT extensions, which maybe within a specified or configured period of time. Alternatively, EC's may count consecutive MAC PC and/or MAC PT extensions. EC periods maybe the time allowed for a MAC procedure to complete, or maybe sliding windows in time. A specific MAC procedure may have more than one EC. When a MAC procedure performs independent actions in parallel each may have an EC. EC's may have specified or configured maximums. When an EC reaches a maximum count the MAC PC or MAC PT are no longer extended upon LBT failure for the MAC procedure. Alternatively, when an EC reaches a maximum count the MAC procedure takes actions as if MAC PC's or MAC PT's have reached their maximum values. In cases this results in the MAC procedure to be considered to have failed.

[0082] MAC PC and MAC PT Extended Maximum Thresholds (EMT): LBT failures cause MAC PC and/or MAC PT maximum thresholds to be extended. The MAC PC and/or MAC PT maximum thresholds maybe extended upon each LBT failure or upon a specified or configured number of LBT failures within a specified or configured period of time. For example, the period of time could be the current MAC PT maximum threshold. The MAC PC or MAC PT maximum thresholds maybe extended upon a specified or configured consecutive number of LBT failures. When MAC PC and/or MAC PT reach a specified or configured EMT, the MAC PC and/or MAC PT maximum thresholds may no longer be extended. In cases this results in the MAC procedure to be considered to have failed.

[0083]

[0084] MAC procedures may also have timers that may be used to control the frequency the procedure is performed. These timers may be known as prohibit timers. When some MAC procedures are performed prohibit timers set the earliest time the procedure is allowed to be performed again. MAC procedures currently set these timers when the procedure is performed. Multiple methods or systems may be used to address this, such as 1) Prohibit timers may be no longer set when the procedures are performed and may be now set or not depending on LBT success or failure. Only upon LBT Success for the transmission associated with the MAC procedure should prohibit timers be set. The LBT procedure may take some time to succeed. In this case starting of the prohibit timer may be delayed relative to when the MAC procedure was performed. This is necessary to ensure the frequency the MAC procedure is performed is properly restricted; or 2) Prohibit timers which may be set upon performing the MAC procedure are cleared if an LBT Failure indication is received for the transmission associated with the MAC procedure. If the LBT procedure results in a delayed transmission the prohibit timer may be extended to take the time from when the MAC procedure was performed to the time when LBT success was determined into account.

Lost Scheduling and Transmission Opportunities

[0085] MAC procedures also take into account downlink assignments and uplink grants. LBT Failures may result in loss of downlink assignments and uplink grants. When the NB determines LBT Failure PDCCH scheduling opportunities may be lost. Also, when the UE determines LBT Failure even though PDCCH scheduling is received the uplink transmission opportunity is lost.

[0086] Several MAC procedures take actions when downlink assignments or uplink grants may not be received within a configured monitoring time period. We disclose LBT Failures or LBT Successes may be taken into account in MAC procedure criteria for not receiving downlink assignments and uplink grants. In addition to uplink and/or downlink LBT success, failure, indications further LBT procedure information may be provided to MAC procedures. In addition to, or included with the LBT success or failure indication, the period of Clear Channel Assessment (CCA), the selected Maximum Channel Occupancy Time (MCOT), the selected Contention Window Size (CWS), and other timing information is provided to the MAC to allow for proper determination of downlink and uplink transmission opportunities. The MCOT, CWS and other may be identified by the Channel Access Priority Class (CAPC) or another index representing the selected timing.

[0087] We consider several options if during the configured monitoring period when no downlink assignments or uplink grants may be received, LBT Failure is detected or LBT Success is not detected:

- If no LBT Success has been detected during the monitoring time period no actions may be taken by the MAC procedure.
- If a configured minimum threshold of LBT Success or continuous LBT success detections is not reached within the monitoring time period no actions may be taken by the MAC procedure.
- If an LBT Failure has been detected during the monitoring time period no actions may be taken by the MAC procedure.
- If a configured maximum threshold of LBT Failure or continuous LBT Failure detections is reached within the monitoring time period no actions may be taken by the MAC procedure.
- The number of or the time period of uplink or downlink transmission opportunities may be more accurately determined from CCA, MCOT, CWS and other timing information.

[0088] Actions that are not taken by the MAC procedure are actions that may have been taken by the currently specified MAC procedure when no downlink assignments or uplink grants are received during the configured monitoring period. For example:

- If during the time the BWP Inactivity timer is running LBT Failures are detected or LBT Successes are not detected BWP switching to the Initial or Default BWP will not be performed even though no downlink assignments or uplink grants were received during this period.
- If during the time the DRX Active Time LBT Failures are detected or LBT Successes are not detected the DRX Inactivity may be reset even though no downlink assignments or uplink grants were received during this period.

[0089] MAC procedures also need to take into account when an uplink transmission cannot be made due to LBT Failure. The effect on MAC procedures is the same as when LBT Failures result in lost PDCCH scheduling opportunities. MAC procedures may consider UL transmission failures due to LBT the same as is currently performed currently when no uplink grant is received or when the uplink grant is not acceptable for data available for transmission (i.e. LCP restriction). For e.g., during back-off periods following LBT failure, the MAC procedures may behave as it currently behaves when no uplink grant is received or when the uplink grant is not acceptable for data available for transmission (i.e. LCP restriction).

[0090] Currently MAC procedures assume when a MAC PDU is provided to the PHY layer it is transmitted. When LBT is performed this will not always be the case. Therefore, MAC procedures that refer to MAC PDU transmission need to clarify transmission considers LBT Success or Failure. This may be accomplished by referring to LBT Success within the MAC procedures or clarifying MAC PDU transmission criteria includes LBT Success.

[0091] MAC CE's may be recovered and stored or the events that triggered these MAC CE's are restored so when multiplexing and assembly of the MAC PDU is reperformed, triggering is reevaluated and reported values recalculated.

NR-U LBT Effect on Specific MAC Procedures

The LBT Operation Procedure

[0092] We disclose a new LBT MAC Procedure is introduced. This procedure is used to inform the NB of LBT Failures or successes. As described herein, there may be multiple possible effects on UE MAC procedures. In many cases it is necessary for the NB to know the effect on these MAC procedures for proper operation.

[0093] It is possible that each UE MAC procedure affected by LBT Failures signals the effect to the NB to maintain coordination between the UE and NB for the respective MAC procedure. But this may require additional logic and complexity is introduced to many MAC procedures.

[0094] A more efficient way is to define a new separate MAC procedure which indicates LBT Successes and Failures to the NB so that the NB can take the LBT information into account and adjust its behavior relative to other MAC procedures by realizing the altered behavior of these procedures by LBT operation.

[0095] Therefore, we disclose UE PHY layer LBT Success or Failure indications may be provided to the MAC. It is possible the PHY layer does some pre-processing to limit the amount of primitives signaled between the MAC and PHY layers. The new LBT MAC procedure consolidates these LBT indications and generates a Listen Before Talk Report (LBTR) MAC CE which provides information on LBT Failures or Successes over a period of time. In addition to LBT Success or Failure indications, we propose the UE PHY layer provided LBT timing information to the MAC layer. For example, LBT timing information could include CCA time periods, select MCOT or CWS periods.

[0096] The LBTR may provide UL and DL LBT failures separately. UL LBT failures may be unknown to the NB and need to be signaled to maintain MAC procedure coordination. But also DL LBT failures the UE is aware of may be useful to the NB since the NB may not be

able to assume what DL LBT failures, either signaled to the UE or otherwise detected by the UE, were realized by the UE. The UE may have missed or failed to receive NB DL LBT failure or success indications.

[0097] The LBTR procedure will require several triggers to initiate the procedure resulting in cases of transmitting the LBTR. At least the following triggers should be considered:

- LBT Failures reaching a threshold. There may be an RRC configured LBT Failure threshold. This threshold may either be a number of LBT Failures over a known time period or a number of consecutive LBT Failures. These parameters may need to be configurable since the reporting urgency may be dependent of the type of traffic supported.
- When certain effects on other MAC procedures results in a change of operation of that procedure which needs to be known by the NB for proper operation. For example, any change in DRX operation that effects Active Time or the DRX cycle. In this case the MAC DRX procedure triggers the LBTR.
- RRC configured periodic LBTRs.
- An LBTR Prohibit timer should also be introduced to limit LBTR frequency

[0098] The LBTR procedure may count LBT Failures or Successes over a configured LBTR Monitoring Period. For example:

- If LBT Failure Count is greater than a configured LBT Failure Count within a LBTR Monitoring Period an LBTR is triggered.
- If LBT Success Count is less than a configured LBT Success Minimum within a LBTR Monitoring Period an LBTR is triggered.

[0099] The LBTR procedure may count consecutive LBT Failures or Successes over a configured LBTR Monitoring Period.

- If consecutive LBT Failure Count is greater than a configured consecutive LBT Failure Count within a LBTR Monitoring Period, an LBTR is triggered.
- If consecutive LBT Success Count is less than a configured consecutive LBT Success Minimum within a LBTR Monitoring Period, an LBTR is triggered.

[00100] When other MAC Procedures trigger an LBTR this may be by setting an LBTR Pending indication. The LBTR Pending indication is later checked during MAC PDU multiplexing assembly to see an LBTR MAC CE is to be built.

[00101] The LBTR may include the following information:

- Count of LBT Failures or Successes since the last LBTR
- Number of times LBT Failures or consecutive LBT Failures have exceeded a maximum configured LBT Failure threshold since the last LBTR
- Number of time LBT Success Count or consecutive LBT Success Count is less than a configured consecutive LBT Success Minimum since last LBTR
- In addition to UL LBT failures DL LBT failures which have been either detected by the UE may also be reported
- The MAC procedure that triggered the LBTR
- Time stamp related to when the LBTR PDU is built.
- CCA, MCOT or CWS information

[00102] It should be noted that similar operations may be provided by the PHY layer or RRC layer, and PHY layer or RRC layer signaling may be used to convey similar information to the NB.

[00103] RRC may configured into the UE, the priority of the channel access priority class mapped to the logical channel specified for LBTR MAC CE. Alternatively, the access priority class may be specified as the channel access priority class with the highest priority. The LBTR procedure may also comprise a general LBT State determination procedure, or an independent LBT State procedure could be utilized by the LBTR and other MAC procedures. This method would minimize complexity introduced to each MAC procedure. For example, rather than each MAC procedure counting LBT failures affecting the procedure an LBT State would just be checked.

[00104]

[00105] Total number of LBT failures may be counted, which may be within a specified or configured period of time. Alternatively, LBT FC's may count consecutive LBT failures, and upon a LBT success the LBT FC is reset to zero. The period in which LBT failures may be counted may be sliding windows in time. When the LBT failure counter exceeds a specified or configured threshold the LBT State is considered failed. If a specified or configured number of LBT failures have not been received or a specified or configured number of LBT success indications are received the LBT State is considered successful. MAC procedures may check the LBT State rather than counting individual LBT failures associated with associated with the MAC procedure. MAC procedures may adjust counters and timers according to the LBT State. For

example, MAC procedures may extend counters and timers, or consider timers and counters to have reached the maximum thresholds depending on the LBT State. The LBT State may also be indicated to higher layers. For example, to effect RRC procedures.

BWP Operation Procedure

[00106] We disclose the following modifications to the BWP Operation procedure to take into account the effect of LBT operation in NR-U:

[00107] It is possible that LBT Failures results in blocking downlink assignments and uplink grants during a period of the BWP Inactivity Timer. In this case it may be inappropriate to perform BWP switching to the Default or Initial BWP(s).

[00108] If during the period the BWP Inactivity Timer is running LBT Failure(s) is determined the BWP Inactivity Timer associated with the active DL BWP should be extended. This, is necessary to ensure BWP switching to the Default or Initial BWP is not performed when downlink assignments and uplink grants may be lost due to LBT Failure. BWP switching to the Default or Initial BWP should only be performed when there is really no data to be transmitted while the BWP Inactivity Timer is running. The examples herein may refer to the MAC specification 3GPP TS 38.321, (NR), Medium Access Control (MAC) protocol specification, V15.2.0 (herein also referred as [2]). Many of the modifications are underlined herein. For example, the MAC specification may be modified as follows:

If the bwp-InactivityTimer is configured, the MAC entity shall for each activated Serving Cell:

- 1> if the defaultDownlinkBWP is configured, and the active DL BWP is not the BWP indicated by the defaultDownlinkBWP; or
 - 1> if the defaultDownlinkBWP is not configured, and the active DL BWP is not the initialDownlinkBWP:
 - 2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received on the active BWP; or
 - 2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received for the active BWP; or
 - 2> if a MAC PDU is transmitted in a configured uplink grant or received in a configured downlink assignment; or
 - 2> if LBT Failure has been detected on the active BWP:
 - 3> if there is no ongoing random access procedure associated with this Serving Cell;
- or

3> if the ongoing Random Access procedure associated with this Serving Cell is successfully completed upon reception of this PDCCH addressed to C-RNTI (e.g., as specified with regard to subclauses 5.1.4 and 5.1.5 of [2]):

4> start or restart the *bwp-InactivityTimer* associated with the active DL BWP.

[00109] The criteria may also be based on LBT Success detections while the BWP Inactivity is running. For example:

If the *bwp-InactivityTimer* is configured, the MAC entity shall for each activated Serving Cell:

1> if the *defaultDownlinkBWP* is configured, and the active DL BWP is not the BWP indicated by the *defaultDownlinkBWP*; or

1> if the *defaultDownlinkBWP* is not configured, and the active DL BWP is not the *initialDownlinkBWP*:

2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received on the active BWP; or

2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received for the active BWP; or

2> if a MAC PDU is transmitted in a configured uplink grant or received in a configured downlink assignment; or

2> if no LBT Success has been detected on the active BWP:

3> if there is no ongoing random access procedure associated with this Serving Cell; or

3> if the ongoing Random Access procedure associated with this Serving Cell is successfully completed upon reception of this PDCCH addressed to C-RNTI (e.g., as specified with regard to subclauses 5.1.4 and 5.1.5 of [2]):

4> start or restart the *bwp-InactivityTimer* associated with the active DL BWP.

[00110] The LBT Failure may not be a single instance. It may be a number of LBT Failure or Success detections while the BWP Inactivity Timer is running. Also, as indicated earlier in this document, LBT Failure or Success is refers to both uplink LBT or downlink LBT.

[00111] A procedure may be defined to count LBT Failures or LBT Successes over a period of time, or to count consecutive LBT Failures or consecutive LBT Successes over a period of time . Only if LBT Failures or consecutive LBT Failure exceeding a configured

Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success Threshold, is the BWP Inactivity Timer restarted. For example, the MAC specification may be modified as follows:

If the *bwp-InactivityTimer* is configured, the MAC entity shall for each activated Serving Cell:

- 1> if the *defaultDownlinkBWP* is configured, and the active DL BWP is not the BWP indicated by the *defaultDownlinkBWP*; or
- 1> if the *defaultDownlinkBWP* is not configured, and the active DL BWP is not the *initialDownlinkBWP*:
 - 2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received on the active BWP; or
 - 2> if a PDCCH addressed to C-RNTI or CS-RNTI indicating downlink assignment or uplink grant is received for the active BWP; or
 - 2> if a MAC PDU is transmitted in a configured uplink grant or received in a configured downlink assignment; or
 - 2> if LBT Failure Count has exceeded the LBT Failure Threshold on the active BWP:
- 3> if there is no ongoing random access procedure associated with this Serving Cell; or
- 3> if the ongoing Random Access procedure associated with this Serving Cell is successfully completed upon reception of this PDCCH addressed to C-RNTI (e.g., as specified with regard to subclauses 5.1.4 and 5.1.5 of [2]):
 - 4> start or restart the *bwp-InactivityTimer* associated with the active DL BWP;
 - 4> reset the LBT Failure Count.

[00112] In the above procedures it should be noted that LBT Failure has been detected applies to the period while the BWP Inactivity Timer is running, the period from when a PDCCH for BWP switching is received on the active DL BWP, or PDCCH reception of an uplink grant on or for the active BWP, or a MAC PDU is transmitted or received for a configured grant, to the moment the BWP Inactivity Timer expires.

[00113] The BWP Inactivity Timer may be extended by a period different from the initial configured value. The period the BWP Inactivity Timer is extended may be another configured value or a value depending on the amount of detected LBT failures or successes determined.

[00114] LBT failures may also trigger switching between configured BWPs. The LBT Failure may not be a single instance. It could be a number of LBT Failure or Success detections within a specified or configured period of time. Also, as indicated earlier in this document, LBT Failure or Success refers to uplink LBT or downlink LBT.

[00115] A procedure could be defined to count LBT Failures or LBT Successes over a period of time, or to count consecutive LBT Failures or consecutive LBT Successes over a period of time. Only if LBT Failures or consecutive LBT Failure exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes are less than a configured Minimum LBT Success Threshold, is the Active BWP switched to an alternate configured Active BWP.

[00116] It is also necessary to avoid significantly extending the BWP Inactivity timer or even indefinitely extending the Inactivity timer due to LBT failures so that the UE never returns to the Initial or Default BWP. Restarting of the BWP Inactivity Timer then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

- 1> if BWP-Inactivity-LBT-Failure-Count > BWP-Inactivity-LBT Failure Threshold on the active BWP; and
- 1> if LBT-BWP-InactivityRestartCount <= LBT-BWP-Inactivity-Restart-Threshold;
 - 2> set the BWP-Inactivity-LBT-Failure-Count to 0;
 - 2> increment LBT-BWP-InactivityRestartCount by 1;
 - 2> start or restart the bwp-InactivityTimer associated with the active DL BWP.
- 1> If LBT Failure has been detected;
 - 2> Increment BWP-Inactivity-LBT-Failure-Count.

When the LBT BWP Inactivity Restart Threshold is exceeded the following actions may be taken:

- 1> if LBT-BWP-InactivityRestartCount > LBT-BWP-Inactivity-Restart-Threshold;
 - 2> BWP switching to the Default or Initial BWP is performed;
 - 2> An indication identifying the BWP is sent to higher layers;
 - 2> The SCell is deactivated;

Random Access Procedures

Random Access Response Reception

[00117] We disclose the following modifications to the Random Access Response Reception procedure to take into account the effect of LBT in NR-U:

[00118] If the RA Response Window expires but LBT Failures have been detected since the preamble transmission the RA Response Window should be extended. This is necessary since the NB may have received the preamble transmission, but the Random Access Response is delayed due to LBT Failure. When the UE detects the NB has missed transmission opportunities the RA Response window is extended.

[00119] For example, the MAC specification may be modified as follows:

1> if *ra-ResponseWindow* configured in *RACH-ConfigCommon* expires, and if the Random Access Response containing Random Access Preamble identifiers that matches the transmitted *PREAMBLE_INDEX* has not been received; or

1> if *ra-ResponseWindow* configured in *BeamFailureRecoveryConfig* expires and if the PDCCH addressed to the C-RNTI has not been received:

2> If LBT Failure has been detected:

3> if the contention-free Random Access Preamble for beam failure recovery request was transmitted by the MAC entity:

4> restart the *ra-ResponseWindow* configured in

BeamFailureRecoveryConfig.

4> monitor the PDCCH of the SpCell for response to beam failure recovery request identified by the C-RNTI while *ra-ResponseWindow* is running.

3> else:

4> restart the *ra-ResponseWindow* configured in *RACH-ConfigCommon*.

4> monitor the PDCCH of the SpCell for Random Access Response(s) identified by the RA-RNTI while the *ra-ResponseWindow* is running.

2> else (LBT Failure not detected):

3> consider the Random Access Response reception not successful;

[00120] In the above procedure it should be noted that LBT Failure has been detected applies to the period while the RA Response Window is running, the period from preamble transmission to the moment the RA Response Window expires the first time after preamble

transmission, or the period from last time the RA Contention Resolution Timer was restarted upon expiry as a result of LBT detection to the following ra-ResponseWindow expiry.

[00121] Alternatively, a procedure may be defined to count LBT Failures or LBT Successes. Only if LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes may be less than a configured Minimum LBT Success Threshold, is the RA Response Window restarted.

[00122] Alternatively, the RA Response Window may be extended by a period different from the configured value in *BeamFailureRecoveryConfig* or in *RACH-ConfigCommon*. The period the RA Response window is extended may be another configured value or a value depending on the amount of detected LBT failures or successes determined. It is also necessary to avoid significantly extending the RA Response Window or even indefinitely extending the RA Response Window due to LBT failures so that the UE never determines the Random Access Response reception not successful. Restarting of the RA Response Window then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

1> if RA-ResponseWindow-LBT-Failure-Count > RA-ResponseWindow-LBT-FailureThreshold; and

1> if LBT-RA-ResponseWindowRestartCount <= LBT-RA-ResponseWindow-Restart-Threshold;

2> set the RA-ResponseWindow-LBT-Failure-Count to 0;

2> increment LBT-RA-ResponseWindowRestartCount by 1;

2> start or restart the ra-ResponseWindow.

1> If LBT Failure has been detected;

2> increment RA-ResponseWindow-LBT-Failure-Count.

When the RA-ResponseWindow-LBT-FailureThreshold is exceeded the following actions may be taken:

1> if LBT-RA-ResponseWindowRestartCount > LBT-RA-ResponseWindow-Restart-Threshold;

2> consider the Random Access Response reception not successful.

x x x x

[00123] Another embodiment below. It has been discussed the Preamble Transmission Counter should not be incremented if LBT fails. For example:

- 1> if *ra-ResponseWindow* configured in *RACH-ConfigCommon* expires, and if the Random Access Response containing Random Access Preamble identifiers that matches the transmitted *PREAMBLE_INDEX* has not been received; or
- 1> if *ra-ResponseWindow* configured in *BeamFailureRecoveryConfig* expires and if the PDCCH addressed to the C-RNTI has not been received:
 - 2> consider the Random Access Response reception not successful;
 - 2> If LBT Failure has not been detected:
 - 3> increment *PREAMBLE_TRANSMISSION_COUNTER* by 1;
 - 3> if *PREAMBLE_TRANSMISSION_COUNTER* = *preambleTransMax* + 1:
 - 4> if the Random Access Preamble is transmitted on the SpCell:
 - 5> indicate a Random Access problem to upper layer
 - 4> if this Random Access procedure was triggered for SI request:
 - 5> consider the Random Access procedure unsuccessfully completed.
 - 3> else if the Random Access Preamble is transmitted on a SCell:
 - 4> consider the Random Access procedure unsuccessfully completed.

[00124] We disclose the Preamble Transmission Counter should be decremented upon detection of LBT Failure. For example:

- 1> instruct the physical layer to transmit the Random Access Preamble using the selected PRACH, corresponding RA-RNTI (if available), *PREAMBLE_INDEX* and *PREAMBLE_RECEIVED_TARGET_POWER*.

- 1> If LBT Failure has been detected:
 - 2> decrement *PREAMBLE_TRANSMISSION_COUNTER* by 1.

[00125] In the above procedure it should be noted that LBT Failure applies to the preamble transmission. There should be an attempt to avoid significantly not incrementing the Preamble Transmission Counter or even indefinitely not incrementing the Preamble Transmission Counter due to LBT failures so that the UE does not determine the Random Access

Response reception not successful. Restarting of the RA Response Window then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

1> if *ra-ResponseWindow* configured in *RACH-ConfigCommon* expires, and if the Random Access Response containing Random Access Preamble identifiers that matches the transmitted *PREAMBLE_INDEX* has not been received; or

1> if *ra-ResponseWindow* configured in *BeamFailureRecoveryConfig* expires and if the PDCCH addressed to the C-RNTI has not been received:

2> consider the Random Access Response reception not successful;

2> if PreambleTransmission LBT Failure has not been detected; or

2> if RA-PreambleTransmission-LBT-Failure-Count > RA-PreambleTransmission-LBT-FailureThreshold;

3> increment *PREAMBLE_TRANSMISSION_COUNTER* by 1;

3> if *PREAMBLE_TRANSMISSION_COUNTER* = *preambleTransMax* + 1:

4> if the Random Access Preamble is transmitted on the SpCell:

5> indicate a Random Access problem to upper layer

4> if this Random Access procedure was triggered for SI request:

5> consider the Random Access procedure unsuccessfully completed.

3> else if the Random Access Preamble is transmitted on a SCell:

4> consider the Random Access procedure unsuccessfully completed.

1> If PreambleTransmission-LBT-Failure has been detected:

2> Increment RA-PreambleTransmission-LBT-Failure-Count.

[00126] When the RA-PreambleTransmission-LBT-FailureThreshold is exceeded the following actions may be taken:

- indicate a Random Access problem to upper layers;
- consider the Random Access procedure unsuccessfully completed.

Alternatively, the MAC specification could be modified as follows:

1> If PreambleTransmission-LBT-Failure has been detected:

2> Increment RA-PreambleTransmission-LBT-Failure-Count;

2> if RA-PreambleTransmission-LBT-Failure-Count > RA-PreambleTransmission-LBT-FailureThreshold;

- 3> if the Random Access Preamble is transmitted on the SpCell:
 - 4> indicate a Random Access problem to upper layer
- 3> if this Random Access procedure was triggered for SI request:
 - 4> consider the Random Access procedure unsuccessfully completed.
- 3> else if the Random Access Preamble is transmitted on a SCell:
 - 4> consider the Random Access procedure unsuccessfully completed.

Contention Resolution

[00127] We disclose the following modifications to the Random Access Contention Resolution procedure to take into account the effect of LBT in NR-U:

[00128] If the RA Contention Resolution Timer expires but LBT Failures have been detected since the preamble transmission the RA Contention Resolution Timer should be extended. This is necessary since the NB may have received the MSG3 transmission, but the PDCCH transmission is delayed due to LBT Failure. When the UE detects the NB has missed transmission opportunities due to LBT Failures the RA Contention Resolution Timer is extended.

[00129] For example, the MAC specification may be modified as follows:

1> if *ra-ContentionResolutionTimer* expires:

2> If LBT Failure has been detected:

3> start the *ra-ContentionResolutionTimer* and restart the *ra-ContentionResolutionTimer* at each HARQ retransmission;

3> monitor the PDCCH while the *ra-ContentionResolutionTimer* is running regardless of the possible occurrence of a measurement gap;

2> else:

3> discard the *TEMPORARY_C-RNTI*;

3> consider the Contention Resolution not successful.

[00130] In the above procedure it should be noted that LBT Failure has been detected applies to the period while the RA Contention Resolution Timer is running, the period from MSG3 transmission to the moment the RA Contention Resolution Timer expires the first time after MSG3 transmission, or the period from last time the RA Contention Resolution Timer was

started upon expiry as a result of LBT detection to the following RA Contention Resolution Timer expiry.

[00131] Alternatively, a procedure may be defined to count LBT Failures or LBT Successes. Only if LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes may be less than a configured Minimum LBT Success Threshold, is the RA Contention Resolution Timer restarted.

[00132] Alternatively, the RA Contention Resolution Timer may be extended by a period different from the configured RA Contention Resolution Timer. The period the RA Contention Resolution Timer is extended may be another configured value or a value depending on the amount of detected LBT failures or successes determined. It is also necessary to avoid significantly extending the RA Contention Resolution Timer or even indefinitely extending the RA Contention Resolution Timer due to LBT failures so that the UE never determines Contention Resolution is not successful.. Restarting of the RA Contention Resolution Timer then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

1> if RA-ContentionResolution-LBT-Failure-Count > RA-ContentionResolution-LBT-FailureThreshold; and

1> if LBT-RA-ContentionResolutionTimerRestartCount <= LBT-RAContentionResolutionRestart-Threshold;

2> set the RA-ContentionResolution-LBT-Failure-Count to 0;

2> increment LBT-RA-ContentionResolutionTimerRestartCount by 1;

2> start the *ra-ContentionResolutionTimer* and restart the *ra-ContentionResolutionTimer* at each HARQ retransmission;

2> monitor the PDCCH while the *ra-ContentionResolutionTimer* is running regardless of the possible occurrence of a measurement gap;

.

1> if LBT Failure has been detected;

2> increment RA-ContentionResolution-LBT-Failure-Count.

When the RA-ContentionResolution-LBTRestartThreshold is exceeded the following actions may be taken:

1> if LBT-RA-ContentionResolutionTimerRestartCount > LBT-RA-ContentionResolutionRestart-Threshold;

2> consider the Random Access Response reception not successful.

Random Access Preamble transmission

[00133] We disclose the following modifications to the Random Access Preamble Transmission procedure to take into account the effect of LBT in NR-U:

[00134] It has been discussed the Preamble Power Ramping Counter should not be incremented if LBT fails. For example:

The MAC entity shall, for each Random Access Preamble:

- 1> if *PREAMBLE_TRANSMISSION_COUNTER* is greater than one; and
- 1> if the notification of suspending power ramping counter has not been received from lower layers; and
- 1> if SSB selected is not changed (i.e. same as the previous Random Access Preamble transmission); and
- 1> If LBT Failure has not been detected:
 - 2> increment *PREAMBLE_POWER_RAMPING_COUNTER* by 1.

[00135] We disclose the preamble Power Ramping Counter should be decremented upon detection of LBT Failure. For example:

- 1> instruct the physical layer to transmit the Random Access Preamble using the selected PRACH, corresponding RA-RNTI (if available), *PREAMBLE_INDEX* and *PREAMBLE_RECEIVED_TARGET_POWER*.
- 2> If LBT Failure has been detected:
 - 2> decrement *PREAMBLE_POWER_RAMPING_COUNTER* by 1.

[00136] In the above procedure it should be noted that LBT Failure applies to the preamble transmission.

Power Headroom Reporting

[00137] We disclose the following modifications to the PHR procedure to take into account the effect of LBT in NR-U:

[00138] When PHR MAC CE transmission is blocked by LBT Failure, and retransmitted later in time additional signaling is introduced to either inform the NB when the PHR was calculated or informs the NB of the transmission conditions when the PHR was calculated.

[00139] In order for the NB to properly process PHR it is necessary for the NB to know under what conditions the PHR was calculated.

[00140] PHR calculates about the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission or SRS transmission per activated Serving Cell and also with information about the difference between the nominal UE maximum power and the estimated power for UL-SCH and PUCCH transmission on SpCell and PUCCH SCell.

[00141] Existing PHR signaling identifies if the UL-SCH transmission was based on a real transmission or a virtual transmission, and if a PUCCH was transmitted when the PHR was calculated. When the UL-SCH is a real transmission it is necessary for the NB to know what was transmitted at the time of PHR calculation.

[00142] When not operating in unlicensed spectrum and LBT is not used the NB can determine when the PHR calculation was made. Since the NB is aware of what scheduled and received it can interpret the PHR by knowing what was transmitted on the UL-SCH at this time. But when LBT Fails and the transmission is delayed until LBT Success it is not possible for the NB to determine what was transmitted in UL-SCH at the time of PHR calculation.

[00143] Below are multiple ways to address this problem:

- Provide an additional indication to the PHR that allows the NB to determine when the PHR calculation was made. This may be the delay caused by LBT relative to the time of the first LBT failure, or it may be an absolute time reference.
- Provide additional information with the PHR that informs the NB of what was transmitted on the UL-SCH. This may be an indexed value approximating what was transmitted on the UL-SCH, or it may be physical details of the transmission at the time of PHR calculation.
- LBT Failures or Successes may be independently indicated to the NB so that the NB may determine the effective delay incurred by LBT for the PHR.
- Provide additional information with the PHR that informs the NB of the grant (e.g. uplink grant) used when the PHR was calculated.

[00144] It is preferred but it is not absolute necessary for the NB to receive additional information which allows the NB to know how the PHR was calculated. Alternatively, the NB must at least know when a real PHR is providing inaccurate information. This may be accomplished by the UE indicating LBT Failure and Success to the NB, allowing the NB to determine there were LBT Failures which delayed the PHR.

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[00145] Another embodiment below. PHR Triggering conditions should consider LBT Failures. Available UL resources, PHR Periodic Timer expiration, PHR reconfiguration, SCell Activation, and PSCell addition, triggering criteria should only be considered when LBT succeeds. The addition of LBT criteria is mutually exclusive for each existing trigger, and may therefore only affect a subset of the existing criteria.

[00146] For example (where all triggers may be considered), the MAC specification may be modified as follows:

A Power Headroom Report (PHR) shall be triggered if any of the following events occur:

- *phr-ProhibitTimer* expires or has expired and the path loss has changed more than *phr-Tx-PowerFactorChange* dB for at least one activated Serving Cell of any MAC entity which is used as a pathloss reference since the last transmission of a PHR in this MAC entity when the MAC entity has UL resources for new transmission and this transmission is not blocked by LBT Failure;

NOTE 1: The path loss variation for one cell assessed above is between the pathloss measured at present time on the current pathloss reference and the pathloss measured at the transmission time of the last transmission of PHR on the pathloss reference in use at that time, irrespective of whether the pathloss reference has changed in between.

- *phr-PeriodicTimer* expires and LBT subsequently succeeds;
- upon configuration or reconfiguration of the power headroom reporting functionality by upper layers and LBT subsequently succeeds, which is not used to disable the function;
- activation of an SCell of any MAC entity with configured uplink and LBT subsequently succeeds;

- addition of the PSCell (i.e. PSCell is newly added or changed) and LBT subsequently succeeds;
- *phr-ProhibitTimer* expires or has expired, when the MAC entity has UL resources for new transmission transmission and this transmission is not blocked by LBT Failure, and the following is true for any of the activated Serving Cells of any MAC entity with configured uplink:
 - there are UL resources allocated for transmission or there is a PUCCH transmission on this cell, and the required power backoff due to power management (as allowed by P-MPR_c as specified in TS 38.101 [10]) for this cell has changed more than *phr-Tx-PowerFactorChange* dB since the last transmission of a PHR when the MAC entity had UL resources allocated for transmission or PUCCH transmission on this cell.

[00147] These changes may be necessary so that PHR is calculated or transmitted when LBT Succeeds and the UE has access to the channel.

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[00148] Another embodiment below. PHR calculation and transmission should only be considered when LBT succeeds.

[00149] Calculation of the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission or SRS transmission per activated Serving Cell and also with information about the difference between the nominal UE maximum power and the estimated power for UL-SCH and PUCCH transmission on SpCell and PUCCH SCell should only be considered when LBT Succeeds.

[00150] When checking if UL resources can accommodate a PHR MAC CE it is also necessary to determine LBT Success. Having available UL resources does not matter of the PHR MAC CE transmission is blocked due to LBT.

[00151] For example, the MAC specification may be modified as follows:

If the MAC entity has UL resources allocated for a new transmission and LBT Success is determined the MAC entity shall:

- 1> if it is the first UL resource allocated for a new transmission since the last MAC reset:
- 2> start *phr-PeriodicTimer*;

- 1> if the Power Headroom reporting procedure determines that at least one PHR has been triggered and not cancelled, and;
- 1> if the allocated UL resources can accommodate the MAC CE for PHR which the MAC entity is configured to transmit, plus its subheader, as a result of logical channel prioritization, and;
- 1> LBT Success is determined:
 - 2> if *multiplePHR* is configured:
 - 3> for each activated Serving Cell with configured uplink associated with any MAC entity:
 - 4> obtain the value of the Type 1 or Type 3 power headroom for the corresponding uplink carrier;
 - 4> if this MAC entity has UL resources allocated for transmission on this Serving Cell and LBT Success is determined; or
 - 4> if the other MAC entity, if configured, has UL resources allocated for transmission and LBT Success is determined on this Serving Cell and *phr-ModeOtherCG* is set to real by upper layers:
 - 5> obtain the value for the corresponding $P_{\text{CMAX},f,c}$ field from the physical layer.
 - 3> if *phr-Type2SpCell* is configured:
 - 4> obtain the value of the Type 2 power headroom for the SpCell of this MAC entity;
 - 4> obtain the value for the corresponding $P_{\text{CMAX},f,c}$ field from the physical layer.
 - 3> if *phr-Type2OtherCell* is configured:
 - 4> if other CG is configured:
 - 5> obtain the value of the Type 2 power headroom for the SpCell of the other MAC entity;
 - 5> if *phr-ModeOtherCG* is set to real by upper layers:
 - 6> obtain the value for the corresponding $P_{\text{CMAX},f,c}$ field for the SpCell of the other MAC entity from the physical layer.
 - 4> else if PUCCH SCell is configured and activated:
 - 5> obtain the value of the Type 2 power headroom for the PUCCH SCell;
 - 5> obtain the value for the corresponding $P_{\text{CMAX},f,c}$ field from the physical layer.

- 3> when LBT Success is determined instruct the Multiplexing and Assembly procedure to generate and transmit a PHR MAC CE according to configured *ServCellIndex* and the PUCCH(s) for the MAC entity as defined in subclause 6.1.3.9 of [2] based on the values reported by the physical layer.
- 2> else (i.e. Single Entry PHR format is used):
 - 3> obtain the value of the Type 1 power headroom from the physical layer for the corresponding uplink carrier of the PCell;
 - 3> obtain the value for the corresponding $P_{\text{CMAX},f,c}$ field from the physical layer;
 - 3> when LBT Success is determined instruct the Multiplexing and Assembly procedure to generate and transmit a PHR MAC CE as defined in subclause 6.1.3.8 of [2] based on the value reported by the physical layer.
- 2> start or restart *phr-PeriodicTimer*;
- 2> start or restart *phr-ProhibitTimer*;
- 2> cancel all triggered PHR(s).

[00152] While the exemplary MAC specific change above is described in terms of LBT success, the example may also be equally expressed in terms of no LBT Failure. In this example it should be noted the changes are mutually exclusive. Only a subset of the disclosed changes may be necessary.

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[00153] Another embodiment below. Additionally, it is disclosed that upon detection of LBT Failure of a transmission including a MAC PHR CE, the PHR Prohibit timer should not be set or it should be cleared if it was set.

[00154] When the physical layer is instructed to transmit a MAC PDU including a MAC PHR CE, the PHR prohibit timer should only be started or restarted upon determination of LBT success for the MAC PDU transmission. For example, the MAC specification may be modified as follows:

- 1> If LBT Success is determined:
 - 2> start or restart *phr-PeriodicTimer*;
 - 2> start or restart *phr-ProhibitTimer*;

2> cancel all triggered PHR(s).

[00155] While the exemplary MAC specific change above is described in terms of LBT success, the example may also be equally expressed in terms of no LBT Failure.

[00156] Alternatively, the PHR Prohibit Timer or the PHR Periodic Timer may be started as it is done in the existing procedure, but if LBT Failure is determined the PHR Prohibit timer is cleared or the PHR Periodic Timer is reset to the remaining value before the last reset because of LBT failure, or to a different time value for e.g. a configured time value.

[00157] This modification is necessary to ensure the PHR Prohibit Timer is not set so that subsequent PHR transmissions may be not delayed, or the PHR Periodic Timer is not reset so that periodic PHR are not delayed when an PHR transmission is blocked by LBT Failure.

Activation/Deactivation of SCells

[00158] We disclose the following modifications to the Activation/Deactivation of SCells procedure to take into account the effect of LBT in NR-U:

[00159] We disclose if LBT Failure has been detected while the SCell Deactivation Timer was running, the SCell Deactivation Timer is extended. This is necessary to avoid unintended SCell Deactivations.

[00160] When the UE detects the NB has missed DL transmission opportunities (downlink assignment(s) may be lost), or UL transmissions may be blocked (a MAC PDU is not transmitted) due to LBT Failures the SCell Deactivation Timer is extended.

[00161] There may be multiple options how this may be accomplished:

- Upon LBT Failure detection the SCell Deactivation Timer is extended or restarted
- Upon SCell Deactivation Timer expiration if LBT Failure is detected the SCell Deactivation Timer is extended or restarted.

[00162] It should be noted when we refer to LBT failure, it may also mean lack of LBT success. For example, the UE PHY layer may indicate LBT failure to UE MAC or the NB may indicate LBT success to UE MAC.

[00163] For example, the MAC specification may be modified as follows:

1> else if an SCell Activation/Deactivation MAC CE is received deactivating the SCell; or

1> if the *sCellDeactivationTimer* associated with the activated SCell expires and LBT Failure has not been detected:

- 2> deactivate the SCell according to the timing defined in TS 38.213;
- 2> stop the *sCellDeactivationTimer* associated with the SCell;
- 2> stop the *bwp-InactivityTimer* associated with the SCell;
- 2> clear any configured downlink assignment and any configured uplink grant Type 2 associated with the SCell respectively;
- 2> suspend any configured uplink grant Type 1 associated with the SCell;
- 2> flush all HARQ buffers associated with the SCell.

1> if the *sCellDeactivationTimer* associated with the activated SCell expires and LBT Failure has been detected:

2> restart the *sCellDeactivationTimer* associated with the SCell.

[00164] In the above procedure(s) it should be noted that LBT Failure has been detected applies to the period while the SCell Deactivation Timer is running, the period from SCell Activation, or from when the last MAC PDU is transmitted in a configured uplink grant or from the last time the UE received in a configured downlink assignment to the moment the SCell Deactivation Timer expires the first time after it has been set, or the period from last time the SCell Deactivation Timer was started upon expiry as a result of LBT detection to the following SCell Deactivation Timer expiry.

[00165] Alternatively upon LBT Failure detection on the SCell:

1> If LBT Failure has been detected:

2> restart the *sCellDeactivationTimer* associated with the SCell.

[00166] Alternatively, a procedure may be defined to count LBT Failures or LBT Successes, or to consecutive LBT Failures or consecutive LBT success. Only if LBT Failures or consecutive LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success

Threshold, is the SCell Deactivation Timer restarted. For example the MAC specification could be modified as follows:

- 1> If ScellDeactLBT-Failure-Count > ScellDeactLBT-Failure-Threshold:
 - 2> restart the *sCellDeactivationTimer* associated with the SCell;
 - 2> set the ScellDeactLBT-Failure-Count to 0;

- 1> If an LBT failure has occurred:
 - 2> increment the ScellDeactLBT-Failure-Count;

[00167] Alternatively, the SCell Deactivation Timer may be extended by a period different from the configured SCell Deactivation Timer. The period the SCell Deactivation Timer is extended may be another configured value or a value depending on the amount of detected LBT failures or successes determined. It is also necessary to avoid significantly extending the SCell Deactivation Timer or even indefinitely extending the SCell Deactivation Timer due to LBT failures so that the UE never deactivates. Restarting of the SCell Deactivation Timer then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

- 1> if ScellDeact-LBT-Failure-Count > ScellDeact-LBT-FailureThreshold; and
- 1> if LBT-ScellDeactTimerRestartCount <= LBT-ScellDeact-Restart-Threshold;
 - 2> set the ScellDeact-LBT-Failure-Count to 0;
 - 2> increment LBT-ScellDeactTimerRestartCount by 1;
 - 2> restart the *sCellDeactivationTimer* associated with the SCell;
- 1> if LBT Failure has been detected;
 - 2> increment ScellDeact-LBT-Failure-Count.

[00168] When the ScellDeact-LBT-FailureThreshold is exceeded the following actions may be taken:

- 1> if LBT-ScellDeactTimerRestartCount <= LBT-ScellDeact-Restart-Threshold:
 - 2> deactivate the SCell according to the timing defined in TS 38.213 [6];
 - 2> stop the *sCellDeactivationTimer* associated with the SCell;
 - 2> stop the *bwp-InactivityTimer* associated with the SCell;

- 2> clear any configured downlink assignment and any configured uplink grant Type 2 associated with the SCell respectively;
- 2> suspend any configured uplink grant Type 1 associated with the SCell;
- 2> flush all HARQ buffers associated with the SCell.

Discontinuous Reception (DRX)

[00169] We disclose the following modifications to the DRX procedure to take into account the effect of LBT in NR-U:

[00170] It has been disclosed that transition from the Short DRX cycle to the Long DRX cycle when the short cycle timer expires should only be performed when LBT Success has been detected or LBT Failure has not been detected. For example:

- 1> if *drx-ShortCycleTimer* expires and LBT Success has been detected:
 - 1> use the Long DRX cycle.
- 1> else
 - 2> Start or restart the *drx-ShortCycleTimer*

[00171] Disclosed herein is a Maximum LBT Failure or Minimum LBT Success threshold is configured. And only if the count of LBT Failures or LBT Successes exceeds the threshold should the UE remain using the DRX Short cycle. For example:

- 1> if *drx-ShortCycleTimer* expires and the LBT Success Counter exceeds the Minimum LBT Success Threshold:
 - 2> use the Long DRX cycle.
- 2> else
 - 2> Start or restart the *drx-ShortCycleTimer*

[00172] Alternatively, we disclose if LBT Failure is detected or LBT Success is not detected to extend DRX Active Time. This may be accomplished by starting or restarting the DRX Inactivity Timer. This also results in continuing to use the DRX Short cycle since upon expiration of the DRX Inactivity timer the DRX Short Cycle timer is started or restarted. Additionally, this allows for further PDCCH UL & DL scheduling opportunities, which is

necessary due to the scheduling opportunities that were lost due to LBT Failure. For example, the MAC specification could be modified as follows:

- 3> if the PDCCH indicates a new transmission (DL or UL);
 - 4> start or restart *drx-InactivityTimer* in the first symbol after the end of the PDCCH reception.
- 3> if LBT Failure has been detected:
 - 4> start or restart *drx-InactivityTimer*.

[00173] Preferably starting or restarting the DRX Inactivity timer is dependent on multiple occurrences of detecting LBT Failure or not detecting LBT Success during a period of time. The period of time may be the period of On Duration or the period of the Inactivity Timer, the combination of the On Duration and the time the Inactivity Timer is running. For example:

- 1> When the *drx-onDurationTimer* expires if LBT Success has not been detected:
 - 2> start or restart *drx-InactivityTimer*
- 1> When the *drx-InactivityTimer* expires if LBT Success has not been detected:
 - 2> start or restart *drx-InactivityTimer*

[00174] The LBT Failure may not be a single instance. It may be a number of LBT Failure or Success detections. The RA procedure may be initiated only after a series of LBT Failures affecting UE reception of PDDCH.

[00175] A procedure may be defined to count LBT Failures or LBT Successes, ir to count consecutive LBT Failures or consecutive LBT Successes . Only if LBT Failures or consecutive LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success Threshold, is the DRX Inactivity Timer restarted. For example:

- 1> When the OnDuration Timer expires if LBT Success Count is less than the LBT Minimum Success Threshold:
 - 2> start or restart *drx-InactivityTimer*

It is also necessary to avoid significantly extending the DRX Inactivity Timer or even indefinitely extending the DRX Inactivity Timer Timer due to LBT failures, so that the UE never

enters DRX. Restarting of the DRX Inactivity Timer then could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

- 1> if DRX-Inactivity-LBT-Failure-Count > DRX-Inactivity-LBT-FailureThreshold; and
- 1> if DRX-Inactivity-TimerRestartCount <=DRX-Inactivity-Restart-Threshold;
 - 2> set the DRX-Inactivity-LBT-Failure-Count to 0;
 - 2> increment DRX-Inactivity-TimerRestartCount by 1;
 - 2> start or restart *drx-InactivityTimer*;
- 1> if LBT Failure has been detected;
 - 2> increment DRX-Inactivity-LBT-Failure-Count.

When the DRX-Inactivity-LBTRestartThreshold is exceeded the following actions may be taken:

- 1> if DRX-Inactivity-TimerRestartCount > DRX-Inactivity-Restart-Threshold
 - 2>if the Short DRX cycle is configured;
 - 3>start or restart *drx-ShortCycleTimer* in the first symbol after the expiry of *drx-InactivityTimer* or in the first symbol after the end of DRX Command MAC CE reception;
 - 3>use the Short DRX Cycle.
 - 2>else;
 - 3>use the Long DRX cycle.

[00176] Extending DRX Active Time when LBT Failures occur by starting or restarting the Inactivity Time should be a configurable option or dependent on what services may be currently active. For example when URLLC services may be supported it is much more important to maintain scheduling opportunities when LBT Failures occur.

[00177] Alternatively, the amount of time DRX Active Time is extended may be different from the period of the configured DRX In Activity Timer. It may be another configured value, or preferably it may be a period relative the amount of LBT Failures detected during the current DRX Active Time period.

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[00178] In another embodiment. We propose a method to address the DRX inefficiencies caused by LBT operation by dynamically adapting DRX procedures. When the UE wakes each DRX cycle the DRX configuration may be dynamically adjusted according to LBT operation. For example, the DRX On Duration, In Activity and/or DRX cycles may be periodically adjusted. This may be each DRX cycle.

[00179] Before transmission the NB determines Clear Channel Assessment (CCA) and selects a Channel Access Priority Class (CAPC). For the CAPC a Maximum Channel Occupancy Time (MCOT) and Contention Window Size (CWS) is selected. Transmissions can occur during the MCOT period, while during the CCA and CWS periods transmission cannot occur. Since transmission timing is dynamically adjusted we propose the UE DRX operation is dynamically adjusted to better match transmission opportunities determined by the NB.

[00180] To accomplish this, it is proposed in addition to, or included with downlink LBT success indications signaled from the NB each DRX cycle, the CCA period, the selected MCOT and CWS, and other timing information is provided to the MAC to allow for more accurate determination of downlink and uplink transmission opportunities. The MCOT, CWS and other may be identified by the Channel Access Priority Class (CAPC) or another index representing the selected timing.

[00181] Based on reception of LBT timing information the UE DRX procedure dynamically adjusts Active Time to align with MCOT time periods and apply DRX during CWS and potentially CCA time periods.

[00182] For example, at the start of each DRX cycle the On Duration may be set to the MCOT selected by the NB. Similarly, the Inactivity timer may be set to align with the selected MCOT.

[00183] Alternatively, the UE may enter DRX during CWS and potentially CCA time periods. For example, Active Time would only include On Duration and Inactivity time periods that are overlapped with MCOT periods, or that are not overlapped by CWS and potentially CCA time periods. For example, the MAC specification could be modified as follows:

- [00184]** When a DRX cycle is configured, the Active Time includes the time while:
- *drx-onDurationTimer* or *drx-InactivityTimer* or *drx-RetransmissionTimerDL* or *drx-RetransmissionTimerUL* or *ra-ContentionResolutionTimer* (as described in subclause 5.1.5) is running; and
 - *drx-MCOT-Timer* is running.

[00185] Or alternatively:

- [00186]** When a DRX cycle is configured, the Active Time includes the time while:
- *drx-onDurationTimer* or *drx-InactivityTimer* or *drx-RetransmissionTimerDL* or *drx-RetransmissionTimerUL* or *ra-ContentionResolutionTimer* (as described in subclause 5.1.5) is running; and
 - *drx-CWS-Timer* is not running.

Scheduling Request

[00187] We disclose the following modifications to the SR procedure to take into account the effect of LBT in NR-U:

[00188] If there is an SR pending and LBT Failure has been determined, potentially over a period of time, a Random Access procedure should be initiated and the pending SR cancelled. This is necessary in case PUCCH resources become unusable due to LBT Failure. In this case the RA procedure will be attempted, and if this procedure fails Radio Link Failure will be declared to resolve the problem. For example, the MAC specification may be modified as follows:

As long as at least one SR is pending, the MAC entity shall for each pending SR:

- 1> if the MAC entity has no valid PUCCH resource configured for the pending SR: or
- 1> if LBT Failure has been determined:
 - 2> initiate a Random Access procedure (e.g., see subclause 5.1 of [2]) on the SpCell and cancel the pending SR.

[00189] The validity of PUCCH resources may also be defined relative to LBT Successes or LBT Failures. For example, the MAC specification may be modified as follow:

[00190] Only PUCCH resources on a BWP which is active at the time of SR transmission occasion where no LBT Failure has been determined, are considered valid.

[00191] As long as at least one SR is pending, the MAC entity shall for each pending SR:

- 1> if the MAC entity has no valid PUCCH resource configured for the pending SR:
 - 2> initiate a Random Access procedure (e.g., see subclause 5.1 of [2]) on the SpCell and cancel the pending SR.

[00192] While the examples above may be expressed in terms of “no LBT Failure” detection, they may also be expressed in terms of “LBT success” detection. The LBT Failure or

LBT success may not be a single instance. It may be a number of LBT Failure or Success detections. The RA procedure may initiated only after a series of LBT Failures affecting SR transmission on PUCCH.

[00193] A procedure may be defined to count LBT Failures or LBT Successes, or to count consecutive LBT Failures or consecutive LBT Successes. Only if LBT Failures or consecutive LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success Threshold, is the Random Access procedure initiated.

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[00194] Another embodiment below. When the physical layer is instructed to transmit an SR, the SR prohibit timer should only be started and the SR Counter incremented upon determination of LBT success for the SR transmission. For example, the MAC specification may be modified as follows:

- 2> when the MAC entity has an SR transmission occasion on the valid PUCCH resource for SR configured; and
- 2> if *sr-ProhibitTimer* is not running at the time of the SR transmission occasion; and
- 2> if the PUCCH resource for the SR transmission occasion does not overlap with a measurement gap; and
- 2> if the PUCCH resource for the SR transmission occasion does not overlap with a UL-SCH resource:
- 3> if *SR_COUNTER* < *sr-TransMax*:
- 4> instruct the physical layer to signal the SR on one valid PUCCH resource for SR;

If LBT Success is determined:

5> start the *sr-ProhibitTimer*.

5> increment *SR_COUNTER* by 1;

[00195] Alternatively, the SR Prohibit Timer may be started and the SR Counter incremented as it is done in the existing procedure, but if LBT Failure is determined the Prohibit timer is stopped and the SR Counter is decremented.

[00196] This modification is necessary to ensure the SR Prohibit Timer, delaying subsequent SR transmissions is not set and so that the SR Counter does not reach SR Trans Max,

resulting in releasing physical resources and initiating RA procedure when an SR transmission is blocked by LBT Failure.

X X X X

[00197] It is also necessary to avoid significantly not incrementing the SR Transmission Counter or even indefinitely not incrementing the SR Transmission Counter due to LBT failures so that the UE never determines the SR transmission procedure not successful. Not incrementing the SR transmission count could be limited to a specified or configured maximum. For example, the MAC specification could be modified as follows:

- 2> if SR LBT Failure has not been detected; or
- 2> if SR-Transmission-LBT-Failure-Count > SR-Transmission-LBT-FailureThreshold:
 - 3> increment *SR_COUNTER* by 1;
 - 3>
- 2> If SRTransmission-LBT-Failure has been detected:
 - 2> Increment SRTransmission-LBT-Failure-Count.

[00198] When the RA-PreambleTransmission-LBT-FailureThreshold is exceeded the following actions may be taken:

- XXXXXX

Alternatively, the MAC specification could be modified as follows:

- 2> If SR-Transmission-LBT-Failure has been detected:
 - 2> Increment SR-Transmission-LBT-Failure-Count;
 - 2> If SR-Transmission-LBT-Failure-Count > STransmission-LBT-FailureThreshold:

X X X X

[00199] Another embodiment below. Pending SR(s) should only be cancelled and SR Prohibit Timer should only be stopped when LBT success is determined for BSR transmission. This is necessary to ensure the Prohibit Timer, delaying subsequent SR transmissions is not set when the current SR is not transmitted due to LBT Failure. For example:

[00200] All pending SR(s) triggered prior to MAC PDU assembly shall be cancelled and each respective sr-ProhibitTimer shall be stopped when LBT success is determined for MAC PDU transmission and this PDU includes a BSR MAC CE which contains buffer status up to (and including) the last event that triggered a BSR (see subclause 5.4.5 of [2]) prior to MAC PDU assembly.

[00201] The example above may also be expressed in terms of LBT failure detection instead of LBT success detection as follows. All pending SR(s) triggered prior to MAC PDU assembly shall be cancelled and each respective sr-ProhibitTimer shall be stopped when no LBT failure is determined for MAC PDU transmission and this PDU includes a BSR MAC CE which contains buffer status up to (and including) the last event that triggered a BSR (see subclause 5.4.5 of [2]) prior to MAC PDU assembly.

[00202] Alternatively, Pending SR(s) may be cancelled and Prohibit Timers may be stopped when the MAC PDU including the BSR is provided to the PHY layer as it is done in the existing procedure, but if LBT failure (or equivalently no LBT success) is determined the Pending SR(s) may be restored and the Prohibit Timer restarted.

Buffer Status Reporting

[00203] We disclose the following modifications to the BSR procedure to take into account the effect of LBT in NR-U:

[00204] If a Regular BSR has been triggered and there may be UL-SCH resources available for transmission, but the transmission is blocked by LBT Failure an SR should be triggered. This is necessary since if the available grant is lost due to LBT Failure a new SR is needed to help ensure a subsequent grant is made available for transmission of the BSR. For example, the MAC specification may be modified as follows:

- 2> if a Regular BSR has been triggered and *logicalChannelSR-DelayTimer* is not running:
 - 3> if there is no UL-SCH resource available for a new transmission; or
 - 3> if the MAC entity is configured with configured uplink grant(s) and the Regular BSR was not triggered for a logical channel for which logical channel SR masking (*logicalChannelSR-Mask*) is setup by upper layers; or
 - 3> if the UL-SCH resources available for a new transmission do not meet the LCP mapping restrictions (see subclause 5.4.3.1 of [2]) configured for the logical channel(s) that triggered the BSR(s); or

3> if there are UL-SCH resources available for transmission and LBT Failure has been detected for this transmission:

4> trigger a Scheduling Request.

[00205] While the modified text above is described in terms of LBT Failure, it may have been also expressed in terms of no LBT Success.

[00206] The LBT Failure or LBT Success may not be a single instance. It may be a number of LBT Failure or Success detections. An SR may be triggered only after a series of LBT Failures affecting MAC BSR CE transmission.

[00207] A procedure may also be defined to count LBT Failures or LBT Successes, or to count consecutive LBT Failures or consecutive LBT Successes. Only if LBT Failures or consecutive LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success Threshold, is an SR triggered.

[00208] When BSR MAC CE transmission is blocked by LBT Failure, and retransmitted later in time additional signaling is introduced to either inform the NB when the BSR was calculated or informs the NB of the transmission conditions when the PHR was calculated.

[00209] In order for the NB to properly process BSR it is necessary for the NB to know when the BSR was calculated.

[00210] When not operating in unlicensed spectrum and LBT is not used the NB can roughly know when the content of the BSR was determined. Since the NB is aware of what scheduled and received and the rules for BSR, it can adequately interpret the BSR. But when LBT Fails and the transmission is delayed until LBT Success, the NB may receive an out dated BSR or inaccurate BSR leading potentially to more resource assignment than required by the UE, or less resources than needed by UE or transmission delay and QoS assurance penalty.

Below are multiple ways to address this problem:

- Provide an additional indication to the BSR that allows the NB to determine when the BSR was built. This may be the delay caused by LBT relative to the time of the first LBT failure, or it may be an absolute time reference.
- LBT Failures or Successes may be independently indicated to the NB so that the NB may determine the effective delay incurred by LBT for the BSR.
- Provide additional information with the PHR that informs the NB of the grant (e.g. uplink grant) used when the PHR was calculated.

[00211] It is preferred but it is not absolute necessary for the NB to receive additional information which allows the NB to know when the BSR was built. Alternatively, the NB must at least know when a BSR is providing inaccurate information. This may be accomplished by the UE indicating LBT Failure and Success to the NB, allowing the NB to determine there were LBT Failures which delayed the BSR.

X X X X

[00212] Another embodiment below. BSR Triggering conditions should consider LBT Failures. New data becoming available and fulfilling the currently specified regular BSR triggering criteria, padding BSR triggering condition, BSR Retransmission Timer expiration, BSR Periodic Timer expiration, triggering criteria should only be considered when LBT succeeds. The addition of LBT criteria is mutually exclusive for each existing trigger, and may therefore only affect a subset of the existing criteria.

[00213] For example (where all triggers may be considered), the MAC specification may be modified as follows:

A BSR shall be triggered if any of the following events occur:

- the MAC entity has new UL data available for a logical channel which belongs to an LCG; and either
 - the new UL data belongs to a logical channel with higher priority than the priority of any logical channel containing available UL data which belong to any LCG and LBT subsequently succeeds; or
 - none of the logical channels which belong to an LCG contains any available UL data and LBT subsequently succeeds.

in which case the BSR is referred below to as 'Regular BSR';

- UL resources are allocated and number of padding bits is equal to or larger than the size of the Buffer Status Report MAC CE plus its subheader and LBT subsequently succeeds, in which case the BSR is referred below to as 'Padding BSR';
- retxBSR-Timer expires, and at least one of the logical channels which belong to an LCG contains UL data and LBT subsequently succeeds, in which case the BSR is referred below to as 'Regular BSR';
- periodicBSR-Timer expires and LBT subsequently succeeds, in which case the BSR is referred below to as 'Periodic BSR'.

The MAC entity shall:

- 1> if the Buffer Status reporting procedure determines that at least one BSR has been triggered and not cancelled:
- 2> if UL-SCH resources are available for a new transmission and LBT Success is determined:
- 3> instruct the Multiplexing and Assembly procedure to generate the BSR MAC CE(s);
- 3> start or restart *periodicBSR-Timer* except when all the generated BSRs are long or short Truncated BSRs;
- 3> start or restart *retxBSR-Timer*.

[00214] A MAC PDU shall contain at most one BSR MAC CE, even when multiple events have triggered a BSR. The Regular BSR and the Periodic BSR shall have precedence over the padding BSR.

[00215] The MAC entity shall restart *retxBSR-Timer* upon reception of a grant for transmission of new data on any UL-SCH.

[00216] All triggered BSRs may be cancelled when the UL grant(s) can accommodate all pending data available for transmission and LBT Success is determined but is not sufficient to additionally accommodate the BSR MAC CE plus its subheader. All BSRs triggered prior to MAC PDU assembly shall be cancelled when LBT Success is determined and a MAC PDU which includes a BSR MAC CE is transmitted and .

[00217] While the modified text above is described in terms of LBT Success, it may have been also expressed in terms of no LBT Failure.

[00218] The LBT Failure or LBT Success may not be a single instance. It may be a number of LBT Failure or Success detections. An SR may be triggered only after a series of LBT Failures affecting MAC BSR CE transmission.

[00219] A procedure may also be defined to count LBT Failures or LBT Successes, or to count consecutive LBT Failures or consecutive LBT Successes. Only if LBT Failures or consecutive LBT Failures exceeding a configured Maximum LBT Failure Threshold or if LBT Successes or consecutive LBT Successes may be less than a configured Minimum LBT Success Threshold, is an SR triggered.

[00220] While the exemplary MAC specific change above is described in terms of LBT success, the example may also be equally expressed in terms of no LBT Failure.

[00221] Alternatively, the BSR Periodic Timer and the BSR Retransmission Timer may be started or restarted as it is done in the existing procedure, but if LBT Failure is determined the BSR Periodic Timer and BSR Retransmission Timer is reset to the remaining

value before the last reset because of LBT failure, or to a different time value for e.g. a configured time value.

[00222] This modification is necessary to ensure the BSR Periodic Timer or BSR Retransmission Timer may be not reset so that periodic BSR or retransmission of BSR may not be delayed when an BSR transmission is blocked by LBT Failure.

Logical Channel Prioritization (LCP) Procedure

[00223] We disclose the following modifications to the LCP procedure to take into account the effect of LBT in NR-U:

[00224] In the case of LBT Failure being detected in advance of transmission a MAC PDU should not be generated.

[00225] For example, the MAC specification may be modified as follows:

[00226] The MAC entity shall not generate a MAC PDU for the HARQ entity if the following conditions are satisfied:

- the MAC entity is configured with *skipUplinkTxDynamic* and the grant indicated to the HARQ entity was addressed to a C-RNTI, or the grant indicated to the HARQ entity is a configured uplink grant; and
- there is no aperiodic CSI requested for this PUSCH transmission as specified in TS 38.212 and
- the MAC PDU includes zero MAC SDUs; and
- the MAC PDU includes only the periodic BSR and there is no data available for any LCG, or the MAC PDU includes only the padding BSR; or
- LBT Failure has not been detected.

[00227] Alternatively, the criteria may be LBT Success is detected.

[00228] This modification is necessary since this MAC PDU may not be acceptable for a subsequent grant (i.e. due to size of the UL grant), and MAC CE(s) generated may provide incorrect information at the time of MAC PDU transmission (e.g., PHR, BSR...).

X X X X

[00229] Another embodiment below. Alternatively the MAC PDU may be generated and provided to the physical layer, but upon LBT Failure detection for this MAC PDU the LCP procedure is restarted to generate a new MAC PDU.

[00230] To accomplish this MAC SDU's that were incorporated within this MAC PDU may be preserved until LBT success is determined. These MAC SDUs may then be reprocessed rather than having to recreate these MAC SDUs from the already built MAC PDU.

[00231] The simpler case is if the grant is larger, UE removes padding and multiplex additional data according to LCP in the remaining space or does the UE back out the sub-PDUs (MAC SDU's and CE's) and reperform LCP as if the data was never processed for the previous grant.

[00232] But even in this case you may have already built MAC CE's which were determined earlier. In LAA they allow the old PHR CE. The network may then not know how the PHR was calculated, based on what transmissions.

[00233] Rebuilding the CE's is complex since the timers and counters of the MAC procedures (BSR, PHR...) have already been affected by the previous (failed) transmission.

[00234] MAC CE's may be recovered and stored or the events that triggered these MAC CE's may be restored so when multiplexing and assembly of the MAC PDU is reperformed, triggering is reevaluated and reported values recalculated.

[00235] The more complex case is what to do when the grant is smaller. First determine what may be sent from the previous PDU according to LCP. Then recover MAC SDUs that may not be transmitted and reset MAC procedure timers and counters associated with a MAC CE transmission so that the timers and counters may be set to values before the MAC CE was built.

[00236] New higher priority data or other MAC CE triggering events may be received since the previous transmission. To handle this possibility the multiplexing and assembly procedure may not prioritize MAC SDUs associated with the failed MAC PDU transmission.

[00237] We have the similar problems with the MAC CE's, they are now old and backing out the MAC procedures is complex.

[00238] The NB should be informed MAC CE's transmission have been delayed or when transmission was originally scheduled...

[00239] Another problem is segmentation is performed in the RLC and there is a possibility the MAC SDU is too large. Having the MAC request RLC back out the previous RLC PDU is enormously complex. One way to address this is to fake an RLC negative acknowledgement for the RLC PDU's that correspond to this MAC SDU and other SDU's that may not be multiplexed into the new MAC PDU transmission.

Beam Failure Detection and Recovery

[00240] We disclose the following modifications to the Beam Failure and Detection procedure to take into account the effect of LBT in NR-U: If the Beam Failure Recovery Timer expires but LBT Failures have been detected since the initiation of Random Access procedure for beam failure recovery, the Beam Failure Recovery Timer should be extended. This is necessary to avoid premature expiration of Beam Failure Recovery Timer and potentially cell reselection or RRC (re) establishment.

[00241] It is understood that the entities performing the steps illustrated herein, such as FIG. 1, may be performed by logical entities. The steps may be stored in a memory of, and executing on a processor of, a device, server, or computer system such as those illustrated in FIG. 11C or FIG. 11D. Skipping steps, combining steps, or adding steps between exemplary methods disclosed herein is contemplated.

[00242] Table 1 provides exemplary abbreviations or definitions.

Table 1 - Abbreviations and Definitions

Abbreviations	Definitions
3GPP	3rd Generation Partnership Project (3GPP)
BSR	Buffer Status Report
BWP	Bandwidth Part
CE	Control Element
CG	Cell Group
C-RNTI	Cell RNTI
CS-RNTI	Configured Scheduling RNTI
DL	Downlink
DRX	Discontinuous Reception
eNB	Evolved Node B
gNB	g NB, A RAN node which supports the NR as well as connectivity to NGC
HARQ	Hybrid Automatic Repeat Request
LBT	Listen Before Talk
LCP	Logical Channel Prioritization
MAC	Medium Access Control
MSG3	Message 3

NB	Node B
NGC	Next Generation Core network
NR	New Radio
NR-U	NR Unlicensed
PDCCH	Physical Downlink Control Channel
PDU	Protocol Data Unit
PHR	Power Headroom Reporting
PHY	Physical Layer
P-MPR	Power Management Maximum Power Reduction
PRACH	Physical Random Access Channel
PSCell	Primary Secondary Cell
PUCCH	Physical Uplink Control Channel
QoS	Quality of Service
RLC	Radio Link Control
RRC	Radio Resource Control
RA	Random Access
RAN	Radio Access Network
RA-RNTI	Random Access RNTI
RNTI	Radio Network Temporary Identifier
SCell	Secondary Cell
SDU	Service Data Unit
SpCell	Special Cell
SR	Scheduling Request
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
3GPP	3rd Generation Partnership Project (3GPP)
BSR	Buffer Status Report
BWP	Bandwidth Part
CE	Control Element
CG	Cell Group
C-RNTI	Cell RNTI

CS-RNTI	Configured Scheduling RNTI
DL	Downlink
DRX	Discontinuous Reception
eNB	Evolved Node B
gNB	g NB, A RAN node which supports the NR as well as connectivity to NGC
HARQ	Hybrid Automatic Repeat Request
LBT	Listen Before Talk
LCP	Logical Channel Prioritization
MAC	Medium Access Control
MSG3	Message 3
NB	Node B
NGC	Next Generation Core network
NR	New Radio
NR-U	NR Unlicensed
PDCCH	Physical Downlink Control Channel
PDU	Protocol Data Unit
PHR	Power Headroom Reporting
PHY	Physical Layer
P-MPR	Power Management Maximum Power Reduction
PRACH	Physical Random Access Channel
PSCell	Primary Secondary Cell
PUCCH	Physical Uplink Control Channel
QoS	Quality of Service

[00243] FIG. 10 illustrates an exemplary display (e.g., graphical user interface) that may be generated based on the methods, systems, and devices of NR-U LBT MAC procedures, as discussed herein. Display interface 901 (e.g., touch screen display) may provide text in block 902 associated with NR-U LBT MAC procedures, such as PHR related parameters and method flow, among other things. Progress of any of the steps (e.g., sent messages or success of steps) discussed herein may be displayed in block 902. In addition, graphical output 902 may be displayed on display interface 901. Graphical output may be the topology of the devices

implementing the methods, systems, and devices of NR-U LBT MAC procedures, a graphical output of the progress of any method or systems discussed herein, or the like.

[00244] The 3rd Generation Partnership Project (3GPP) develops technical standards for cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities - including work on codecs, security, and quality of service. Recent radio access technology (RAT) standards include WCDMA (commonly referred as 3G), LTE (commonly referred as 4G), and LTE-Advanced standards. 3GPP has begun working on the standardization of next generation cellular technology, called New Radio (NR), which is also referred to as “5G”. 3GPP NR standards development is expected to include the definition of next generation radio access technology (new RAT), which is expected to include the provision of new flexible radio access below 6 GHz, and the provision of new ultra-mobile broadband radio access above 6 GHz. The flexible radio access is expected to consist of a new, non-backwards compatible radio access in new spectrum below 6 GHz, and it is expected to include different operating modes that may be multiplexed together in the same spectrum to address a broad set of 3GPP NR use cases with diverging requirements. The ultra-mobile broadband is expected to include cmWave and mmWave spectrum that will provide the opportunity for ultra-mobile broadband access for, e.g., indoor applications and hotspots. In particular, the ultra-mobile broadband is expected to share a common design framework with the flexible radio access below 6 GHz, with cmWave and mmWave specific design optimizations.

[00245] 3GPP has identified a variety of use cases that NR is expected to support, resulting in a wide variety of user experience requirements for data rate, latency, and mobility. The use cases include the following general categories: enhanced mobile broadband (e.g., broadband access in dense areas, indoor ultra-high broadband access, broadband access in a crowd, 50+ Mbps everywhere, ultra-low cost broadband access, mobile broadband in vehicles), critical communications, massive machine type communications, network operation (e.g., network slicing, routing, migration and interworking, energy savings), and enhanced vehicle-to-everything (eV2X) communications, which may include any of Vehicle-to-Vehicle Communication (V2V), Vehicle-to-Infrastructure Communication (V2I), Vehicle-to-Network Communication (V2N), Vehicle-to-Pedestrian Communication (V2P), and vehicle communications with other entities. Specific services and applications in these categories include, e.g., monitoring and sensor networks, device remote controlling, bi-directional remote controlling, personal cloud computing, video streaming, wireless cloud-based office, first responder connectivity, automotive ecall, disaster alerts, real-time gaming, multi-person video

calls, autonomous driving, augmented reality, tactile internet, and virtual reality to name a few. All of these use cases and others are contemplated herein.

[00246] FIG. 11A illustrates an example communications system 100 in which the methods and apparatuses of NR-U LBT MAC procedures. As shown, the example communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, or 102d (which generally or collectively may be referred to as WTRU 102), a radio access network (RAN) 103/104/105/103b/104b/105b, a core network 106/107/109, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed examples contemplate any number of WTRUs, base stations, networks, or network elements. Each of the WTRUs 102a, 102b, 102c, 102d, 102e may be any type of apparatus or device configured to operate or communicate in a wireless environment. Although each WTRU 102a, 102b, 102c, 102d, 102e is depicted in FIG. 11A, FIG. 11B, FIG. 11C, FIG. 11D, and FIG. 11E as a hand-held wireless communications apparatus, it is understood that with the wide variety of use cases contemplated for 5G wireless communications, each WTRU may comprise or be embodied in any type of apparatus or device configured to transmit or receive wireless signals, including, by way of example only, user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a tablet, a netbook, a notebook computer, a personal computer, a wireless sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, truck, train, or airplane, and the like.

[00247] The communications system 100 may also include a base station 114a and a base station 114b. Base stations 114a may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c to facilitate access to one or more communication networks, such as the core network 106/107/109, the Internet 110, or the other networks 112. Base stations 114b may be any type of device configured to wiredly or wirelessly interface with at least one of the RRHs (Remote Radio Heads) 118a, 118b or TRPs (Transmission and Reception Points) 119a, 119b to facilitate access to one or more communication networks, such as the core network 106/107/109, the Internet 110, or the other networks 112. RRHs 118a, 118b may be any type of device configured to wirelessly interface with at least one of the WTRU 102c, to facilitate access to one or more communication networks, such as the core network 106/107/109, the Internet 110, or the other networks 112. TRPs 119a, 119b may be any type of device configured to wirelessly interface with at least one of the WTRU 102d, to facilitate access to one or more communication networks, such as the core

network 106/107/109, the Internet 110, or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations or network elements.

[00248] The base station 114a may be part of the RAN 103/104/105, which may also include other base stations or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114b may be part of the RAN 103b/104b/105b, which may also include other base stations or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a may be configured to transmit or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown) for methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. The base station 114b may be configured to transmit or receive wired or wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in an example, the base station 114a may include three transceivers, e.g., one for each sector of the cell. In an example, the base station 114a may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[00249] The base stations 114a may communicate with one or more of the WTRUs 102a, 102b, 102c over an air interface 115/116/117, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface 115/116/117 may be established using any suitable radio access technology (RAT).

[00250] The base stations 114b may communicate with one or more of the RRHs 118a, 118b or TRPs 119a, 119b over a wired or air interface 115b/116b/117b, which may be any suitable wired (e.g., cable, optical fiber, etc.) or wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface 115b/116b/117b may be established using any suitable radio access technology (RAT).

[00251] The RRHs 118a, 118b or TRPs 119a, 119b may communicate with one or more of the WTRUs 102c, 102d over an air interface 115c/116c/117c, which may be any suitable

wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, cmWave, mmWave, etc.). The air interface 115c/116c/117c may be established using any suitable radio access technology (RAT).

[00252] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 103/104/105 and the WTRUs 102a, 102b, 102c, or RRHs 118a, 118b and TRPs 119a, 119b in the RAN 103b/104b/105b and the WTRUs 102c, 102d, may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 115/116/117 or 115c/116c/117c respectively using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) or High-Speed Uplink Packet Access (HSUPA).

[00253] In an example, the base station 114a and the WTRUs 102a, 102b, 102c, or RRHs 118a, 118b and TRPs 119a, 119b in the RAN 103b/104b/105b and the WTRUs 102c, 102d, may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 115/116/117 or 115c/116c/117c respectively using Long Term Evolution (LTE) or LTE-Advanced (LTE-A). In the future, the air interface 115/116/117 may implement 3GPP NR technology.

[00254] In an example, the base station 114a in the RAN 103/104/105 and the WTRUs 102a, 102b, 102c, or RRHs 118a, 118b and TRPs 119a, 119b in the RAN 103b/104b/105b and the WTRUs 102c, 102d, may implement radio technologies such as IEEE 802.16 (e.g., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[00255] The base station 114c in FIG. 11A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like, for implementing the methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. In an example, the base station 114c and the WTRUs 102e, may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an example, the base station 114c and the WTRUs 102d, may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet

another example, the base station 114c and the WTRUs 102e, may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, etc.) to establish a picocell or femtocell. As shown in FIG. 11A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114c may not be required to access the Internet 110 via the core network 106/107/109.

[00256] The RAN 103/104/105 or RAN 103b/104b/105b may be in communication with the core network 106/107/109, which may be any type of network configured to provide voice, data, applications, or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. For example, the core network 106/107/109 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., or perform high-level security functions, such as user authentication.

[00257] Although not shown in FIG. 11A, it will be appreciated that the RAN 103/104/105 or RAN 103b/104b/105b or the core network 106/107/109 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 103/104/105 or RAN 103b/104b/105b or a different RAT. For example, in addition to being connected to the RAN 103/104/105 or RAN 103b/104b/105b, which may be utilizing an E-UTRA radio technology, the core network 106/107/109 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[00258] The core network 106/107/109 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d, 102e to access the PSTN 108, the Internet 110, or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired or wireless communications networks owned or operated by other service providers. For example, the networks 112 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 103/104/105 or RAN 103b/104b/105b or a different RAT.

[00259] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities, e.g., the WTRUs 102a, 102b, 102c, 102d, and 102e may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU 102e shown in FIG. 11A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114c, which may employ an IEEE 802 radio technology.

[00260] FIG. 11B is a block diagram of an example apparatus or device configured for wireless communications in accordance with the examples illustrated herein, such as for example, a WTRU 102. As shown in FIG. 11B, the example WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad/indicators 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and other peripherals 138. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an example. Also, examples contemplate that the base stations 114a and 114b, or the nodes that base stations 114a and 114b may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B (eNodeB), a home evolved node-B (HeNB), a home evolved node-B gateway, and proxy nodes, among others, may include some or all of the elements depicted in FIG. 11B and described herein.

[00261] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 11B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[00262] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 115/116/117. For example, in an example, the transmit/receive element 122 may be an antenna configured to transmit or receive RF signals. Although not shown in FIG. 11A, it will be appreciated that the RAN 103/104/105 or the core network 106/107/109 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 103/104/105 or a different RAT. For example, in addition to being connected to the RAN 103/104/105, which may be utilizing an E-UTRA radio technology, the core network 106/107/109 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[00263] The core network 106/107/109 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired or wireless communications networks owned or operated by other service providers. For example, the networks 112 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 103/104/105 or a different RAT.

[00264] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities, e.g., the WTRUs 102a, 102b, 102c, and 102d may include multiple transceivers for communicating with different wireless networks over different wireless links for implementing methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. For example, the WTRU 102c shown in FIG. 11A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[00265] FIG. 11B is a block diagram of an example apparatus or device configured for wireless communications in accordance with NR-U LBT MAC procedures, as disclosed herein, such as a WTRU 102. As shown in FIG. 11B, the example WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad/indicators 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and other peripherals 138. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an example. Also, the examples herein contemplate that the base stations 114a and 114b, or the nodes that base stations 114a and 114b may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B (eNodeB), a home evolved node-B (HeNB), a home evolved node-B gateway, and proxy nodes, among others, may include some or all of the elements depicted in FIG. 11B and may be an exemplary implementation that performs the disclosed systems and methods for NR-U LBT MAC procedures described herein.

[00266] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a

microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 11B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[00267] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 115/116/117. For example, in an example, the transmit/receive element 122 may be an antenna configured to transmit or receive RF signals. In an example, the transmit/receive element 122 may be an emitter/detector configured to transmit or receive IR, UV, or visible light signals, for example. In yet another example, the transmit/receive element 122 may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit or receive any combination of wireless signals.

[00268] In addition, although the transmit/receive element 122 is depicted in FIG. 11B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in an example, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 115/116/117.

[00269] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

[00270] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, or the display/touchpad/indicators 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, or the display/touchpad/indicators 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of

memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other examples, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown). The processor 118 may be configured to control lighting patterns, images, or colors on the display or indicators 128 in response to whether the setup of the NR-U LBT MAC procedures in some of the examples described herein are successful or unsuccessful, or otherwise indicate a status of NR-U LBT MAC procedures and associated components. The control lighting patterns, images, or colors on the display or indicators 128 may be reflective of the status of any of the method flows or components in the FIG.'s illustrated or discussed herein. Disclosed herein are messages and procedures of NR-U LBT MAC procedures. The messages and procedures may be extended to provide interface/API for users to request resources via an input source (e.g., speaker/microphone 124, keypad 126, or display/touchpad/indicators 128) and request, configure, or query NR-U LBT MAC procedures, among other things that may be displayed on display 128.

[00271] The processor 118 may receive power from the power source 134, and may be configured to distribute or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries, solar cells, fuel cells, and the like.

[00272] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 115/116/117 from a base station (e.g., base stations 114a, 114b) or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an example.

[00273] The processor 118 may further be coupled to other peripherals 138, which may include one or more software or hardware modules that provide additional features, functionality or wired or wireless connectivity. For example, the peripherals 138 may include various sensors such as an accelerometer, biometrics (e.g., finger print) sensors, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port or other interconnect interfaces, a vibration device, a television transceiver, a hands free headset, a

Bluetooth module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

[00274] The WTRU 102 may be used for other apparatuses or devices, such as a sensor, consumer electronics, a wearable device such as a smart watch or smart clothing, a medical or eHealth device, a robot, industrial equipment, a drone, a vehicle such as a car, truck, train, or airplane. The WTRU 102 may connect to other components, modules, or systems of such apparatuses or devices via one or more interconnect interfaces, such as an interconnect interface that may comprise one of the peripherals 138.

[00275] FIG. 11C is a system diagram of the RAN 103 and the core network 106 that may implement the methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. As noted above, the RAN 103 may employ a UTRA radio technology to communicate with the WTRUs 102a, 102b, and 102c over the air interface 115. The RAN 103 may also be in communication with the core network 106. As shown in FIG. 11C, the RAN 103 may include Node-Bs 140a, 140b, 140c, which may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 115. The Node-Bs 140a, 140b, 140c may each be associated with a particular cell (not shown) within the RAN 103. The RAN 103 may also include RNCs 142a, 142b. It will be appreciated that the RAN 103 may include any number of Node-Bs and RNCs while remaining consistent with an example.

[00276] As shown in FIG. 11C, the Node-Bs 140a, 140b may be in communication with the RNC 142a. Additionally, the Node-B 140c may be in communication with the RNC 142b. The Node-Bs 140a, 140b, 140c may communicate with the respective RNCs 142a, 142b via an Iub interface. The RNCs 142a, 142b may be in communication with one another via an Iur interface. Each of the RNCs 142a, 142b may be configured to control the respective Node-Bs 140a, 140b, 140c to which it is connected. In addition, each of the RNCs 142a, 142b may be configured to carry out or support other functionality, such as outer loop power control, load control, admission control, packet scheduling, handover control, macro-diversity, security functions, data encryption, and the like.

[00277] The core network 106 shown in FIG. 11C may include a media gateway (MGW) 144, a mobile switching center (MSC) 146, a serving GPRS support node (SGSN) 148, or a gateway GPRS support node (GGSN) 150. While each of the foregoing elements are depicted as part of the core network 106, it will be appreciated that any one of these elements may be owned or operated by an entity other than the core network operator.

[00278] The RNC 142a in the RAN 103 may be connected to the MSC 146 in the core network 106 via an IuCS interface. The MSC 146 may be connected to the MGW 144. The

MSC 146 and the MGW 144 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices.

[00279] The RNC 142a in the RAN 103 may also be connected to the SGSN 148 in the core network 106 via an IuPS interface. The SGSN 148 may be connected to the GGSN 150. The SGSN 148 and the GGSN 150 may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between and the WTRUs 102a, 102b, 102c and IP-enabled devices.

[00280] As noted above, the core network 106 may also be connected to the networks 112, which may include other wired or wireless networks that are owned or operated by other service providers.

[00281] FIG. 11D is a system diagram of the RAN 104 and the core network 107 that may implement methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, and 102c over the air interface 116. The RAN 104 may also be in communication with the core network 107.

[00282] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an example. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In an example, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[00283] Each of the eNode-Bs 160a, 160b, and 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink or downlink, and the like. As shown in FIG. 11D, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[00284] The core network 107 shown in FIG. 11D may include a mobility management gateway (MME) 162, a serving gateway 164, and a packet data network (PDN) gateway 166. While each of the foregoing elements are depicted as part of the core network 107, it will be appreciated that any one of these elements may be owned or operated by an entity other than the core network operator.

[00285] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, and 160c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may also provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

[00286] The serving gateway 164 may be connected to each of the eNode-Bs 160a, 160b, and 160c in the RAN 104 via the S1 interface. The serving gateway 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The serving gateway 164 may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[00287] The serving gateway 164 may also be connected to the PDN gateway 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[00288] The core network 107 may facilitate communications with other networks. For example, the core network 107 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the core network 107 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network 107 and the PSTN 108. In addition, the core network 107 may provide the WTRUs 102a, 102b, 102c with access to the networks 112, which may include other wired or wireless networks that are owned or operated by other service providers.

[00289] FIG. 11E is a system diagram of the RAN 105 and the core network 109 that may implement methods, systems, and devices of NR-U LBT MAC procedures, as disclosed herein. The RAN 105 may be an access service network (ASN) that employs IEEE 802.16 radio technology to communicate with the WTRUs 102a, 102b, and 102c over the air interface 117. As will be further discussed below, the communication links between the different functional entities of the WTRUs 102a, 102b, 102c, the RAN 105, and the core network 109 may be defined as reference points.

[00290] As shown in FIG. 11E, the RAN 105 may include base stations 180a, 180b, 180c, and an ASN gateway 182, though it will be appreciated that the RAN 105 may include any number of base stations and ASN gateways while remaining consistent with an example. The base stations 180a, 180b, 180c may each be associated with a particular cell in the RAN 105 and may include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 117. In an example, the base stations 180a, 180b, 180c may implement MIMO technology. Thus, the base station 180a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a. The base stations 180a, 180b, 180c may also provide mobility management functions, such as handoff triggering, tunnel establishment, radio resource management, traffic classification, quality of service (QoS) policy enforcement, and the like. The ASN gateway 182 may serve as a traffic aggregation point and may be responsible for paging, caching of subscriber profiles, routing to the core network 109, and the like.

[00291] The air interface 117 between the WTRUs 102a, 102b, 102c and the RAN 105 may be defined as an R1 reference point that implements the IEEE 802.16 specification. In addition, each of the WTRUs 102a, 102b, and 102c may establish a logical interface (not shown) with the core network 109. The logical interface between the WTRUs 102a, 102b, 102c and the core network 109 may be defined as an R2 reference point, which may be used for authentication, authorization, IP host configuration management, or mobility management.

[00292] The communication link between each of the base stations 180a, 180b, and 180c may be defined as an R8 reference point that includes protocols for facilitating WTRU handovers and the transfer of data between base stations. The communication link between the base stations 180a, 180b, 180c and the ASN gateway 182 may be defined as an R6 reference point. The R6 reference point may include protocols for facilitating mobility management based on mobility events associated with each of the WTRUs 102a, 102b, 102c.

[00293] As shown in FIG. 11E, the RAN 105 may be connected to the core network 109. The communication link between the RAN 105 and the core network 109 may be defined as an R3 reference point that includes protocols for facilitating data transfer and mobility management capabilities, for example. The core network 109 may include a mobile IP home agent (MIP-HA) 184, an authentication, authorization, accounting (AAA) server 186, and a gateway 188. While each of the foregoing elements are depicted as part of the core network 109, it will be appreciated that any one of these elements may be owned or operated by an entity other than the core network operator.

[00294] The MIP-HA may be responsible for IP address management, and may enable the WTRUs 102a, 102b, and 102c to roam between different ASNs or different core networks. The MIP-HA 184 may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The AAA server 186 may be responsible for user authentication and for supporting user services. The gateway 188 may facilitate interworking with other networks. For example, the gateway 188 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. In addition, the gateway 188 may provide the WTRUs 102a, 102b, 102c with access to the networks 112, which may include other wired or wireless networks that are owned or operated by other service providers.

[00295] Although not shown in FIG. 11E, it will be appreciated that the RAN 105 may be connected to other ASNs and the core network 109 may be connected to other core networks. The communication link between the RAN 105 the other ASNs may be defined as an R4 reference point, which may include protocols for coordinating the mobility of the WTRUs 102a, 102b, 102c between the RAN 105 and the other ASNs. The communication link between the core network 109 and the other core networks may be defined as an R5 reference, which may include protocols for facilitating interworking between home core networks and visited core networks.

[00296] The core network entities described herein and illustrated in FIG. 11A, FIG. 11C, FIG. 11D, and FIG. 11E are identified by the names given to those entities in certain existing 3GPP specifications, but it is understood that in the future those entities and functionalities may be identified by other names and certain entities or functions may be combined in future specifications published by 3GPP, including future 3GPP NR specifications. Thus, the particular network entities and functionalities described and illustrated in FIG. 11A, FIG. 11B, FIG. 11C, FIG. 11D, and FIG. 11E are provided by way of example only, and it is understood that the subject matter disclosed and claimed herein may be implemented in any similar communication system, whether presently defined or defined in the future.

[00297] FIG. 11F is a block diagram of an exemplary computing system 90 in which one or more apparatuses of the communications networks illustrated in FIG. 11A, FIG. 11C, FIG. 11D, and FIG. 11E may be embodied, such as certain nodes or functional entities in the RAN 103/104/105, Core Network 106/107/109, PSTN 108, Internet 110, or Other Networks 112. Computing system 90 may comprise a computer or server and may be controlled primarily by

computer readable instructions, which may be in the form of software, wherever, or by whatever means such software is stored or accessed. Such computer readable instructions may be executed within a processor 91, to cause computing system 90 to do work. The processor 91 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 91 may perform signal coding, data processing, power control, input/output processing, or any other functionality that enables the computing system 90 to operate in a communications network. Coprocessor 81 is an optional processor, distinct from main processor 91, that may perform additional functions or assist processor 91. Processor 91 or coprocessor 81 may receive, generate, and process data related to the methods and apparatuses disclosed herein for NR-U LBT MAC procedures.

[00298] In operation, processor 91 fetches, decodes, and executes instructions, and transfers information to and from other resources via the computing system's main data-transfer path, system bus 80. Such a system bus connects the components in computing system 90 and defines the medium for data exchange. System bus 80 typically includes data lines for sending data, address lines for sending addresses, and control lines for sending interrupts and for operating the system bus. An example of such a system bus 80 is the PCI (Peripheral Component Interconnect) bus.

[00299] Memories coupled to system bus 80 include random access memory (RAM) 82 and read only memory (ROM) 93. Such memories include circuitry that allows information to be stored and retrieved. ROMs 93 generally contain stored data that cannot easily be modified. Data stored in RAM 82 may be read or changed by processor 91 or other hardware devices. Access to RAM 82 or ROM 93 may be controlled by memory controller 92. Memory controller 92 may provide an address translation function that translates virtual addresses into physical addresses as instructions are executed. Memory controller 92 may also provide a memory protection function that isolates processes within the system and isolates system processes from user processes. Thus, a program running in a first mode may access only memory mapped by its own process virtual address space; it cannot access memory within another process's virtual address space unless memory sharing between the processes has been set up.

[00300] In addition, computing system 90 may contain peripherals controller 83 responsible for communicating instructions from processor 91 to peripherals, such as printer 94, keyboard 84, mouse 95, and disk drive 85.

[00301] Display 86, which is controlled by display controller 96, is used to display visual output generated by computing system 90. Such visual output may include text, graphics, animated graphics, and video. The visual output may be provided in the form of a graphical user interface (GUI). Display 86 may be implemented with a CRT-based video display, an LCD-based flat-panel display, gas plasma-based flat-panel display, or a touch-panel. Display controller 96 includes electronic components required to generate a video signal that is sent to display 86.

[00302] Further, computing system 90 may contain communication circuitry, such as for example a network adapter 97, that may be used to connect computing system 90 to an external communications network, such as the RAN 103/104/105, Core Network 106/107/109, PSTN 108, Internet 110, or Other Networks 112 of FIG. 11A, FIG. 11B, FIG. 11C, FIG. 11D, and FIG. 11E, to enable the computing system 90 to communicate with other nodes or functional entities of those networks. The communication circuitry, alone or in combination with the processor 91, may be used to perform the transmitting and receiving steps of certain apparatuses, nodes, or functional entities described herein.

[00303] FIG. 11G illustrates one example communications system 99 in which the methods and apparatuses NR-U LBT MAC procedures, such as the parameters, systems, and methods illustrated in FIG. 1 through FIG. 7 described and claimed herein may be embodied. As shown, the example communications system 99 may include wireless transmit/receive units (WTRUs) A, B, C, D, E, F, a base station, a V2X server, and a RSUs A and B, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, or network elements. One or several or all WTRUs A, B, C, D, E can be out of range of the network (for example, in the figure out of the cell coverage boundary shown as the dash line). WTRUs A, B, C form a V2X group, among which WTRU A is the group lead and WTRUs B and C are group members. WTRUs A, B, C, D, E, F may communicate over Uu interface or Sidelink (PC5) interface.

[00304] It is understood that any or all of the apparatuses, systems, methods and processes described herein may be embodied in the form of computer executable instructions (e.g., program code) stored on a computer-readable storage medium which instructions, when executed by a processor, such as processors 118 or 91, cause the processor to perform or implement the systems, methods and processes described herein. Specifically, any of the steps, operations or functions described herein may be implemented in the form of such computer executable instructions, executing on the processor of an apparatus or computing system configured for wireless or wired network communications. Computer readable storage media

include volatile and nonvolatile, removable and non-removable media implemented in any non-transitory (e.g., tangible or physical) method or technology for storage of information, but such computer readable storage media do not include signals. Computer readable storage media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other tangible or physical medium which may be used to store the desired information and which may be accessed by a computing system.

[00305] In describing preferred methods, systems, or apparatuses of the subject matter of the present disclosure - NR-U LBT MAC procedures - as illustrated in the Figures, specific terminology is employed for the sake of clarity. The claimed subject matter, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish a similar purpose.

[00306] The various techniques described herein may be implemented in connection with hardware, firmware, software or, where appropriate, combinations thereof. Such hardware, firmware, and software may reside in apparatuses located at various nodes of a communication network. The apparatuses may operate singly or in combination with each other to effectuate the methods described herein. As used herein, the terms “apparatus,” “network apparatus,” “node,” “device,” “network node,” or the like may be used interchangeably. In addition, the use of the word “or” is generally used inclusively unless otherwise provided herein.

[00307] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art (e.g., skipping steps, combining steps, or adding steps between exemplary methods disclosed herein). Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

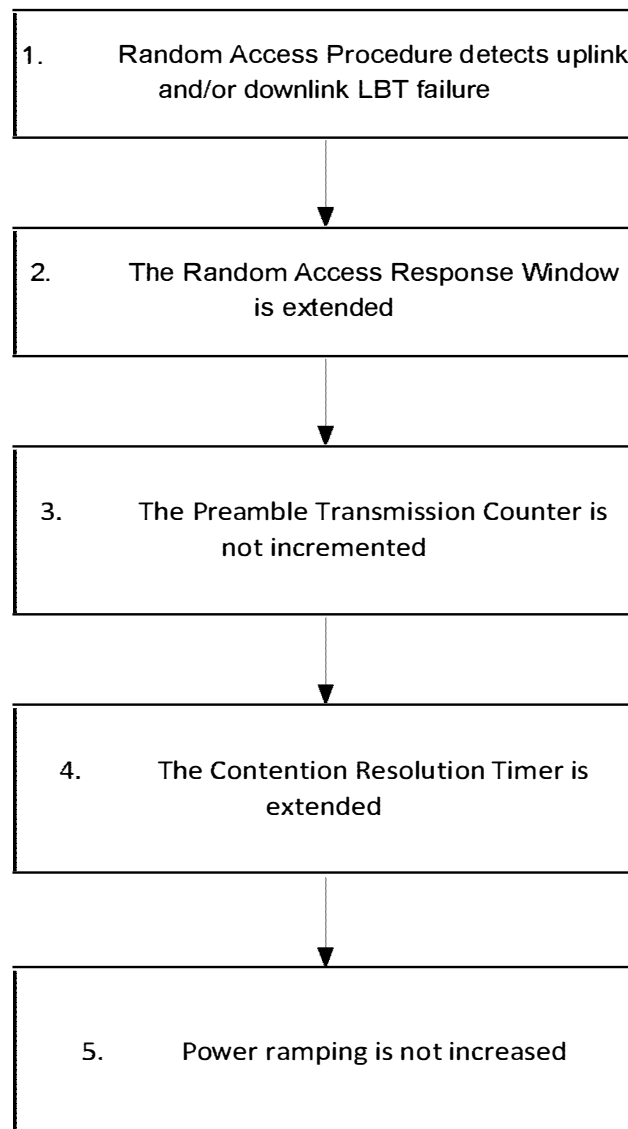


FIG. 1

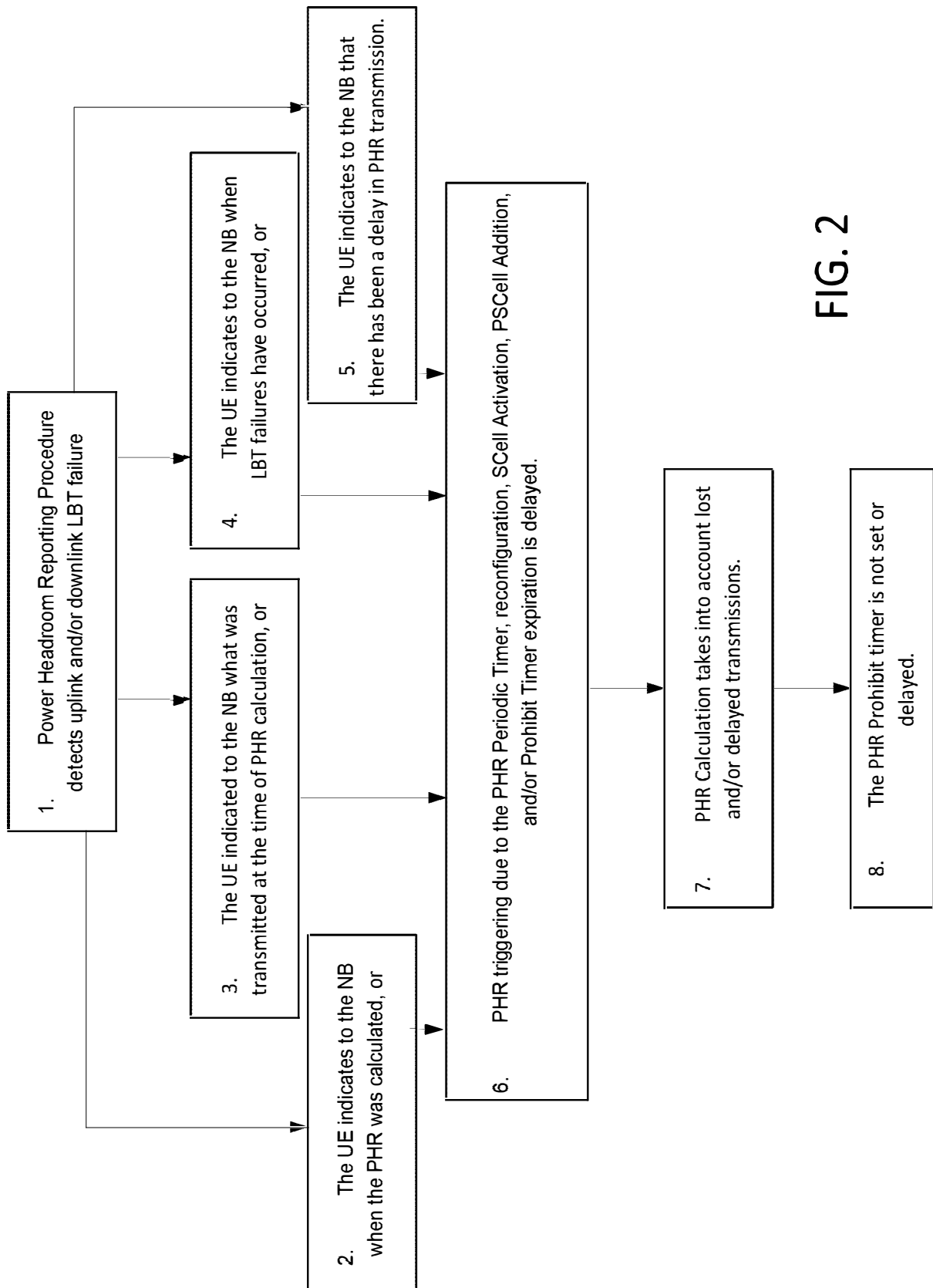


FIG. 2

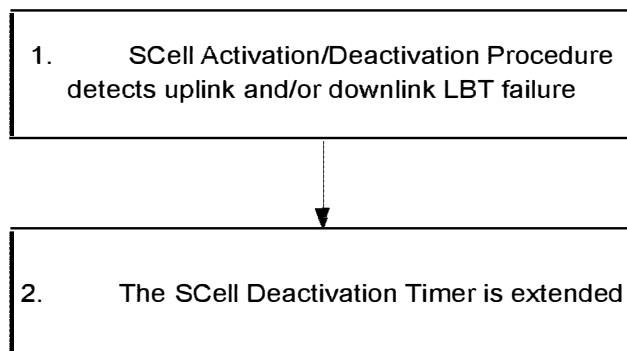


FIG. 3

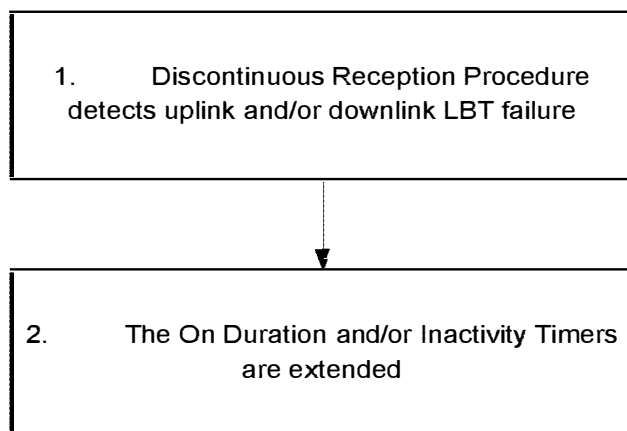


FIG. 4

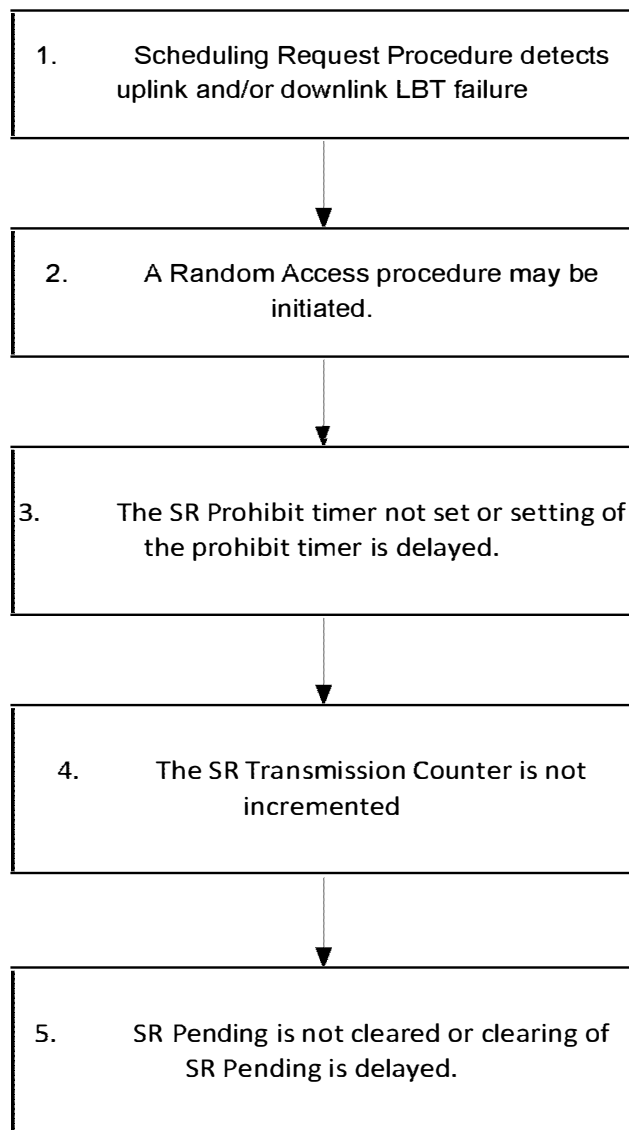


FIG. 5

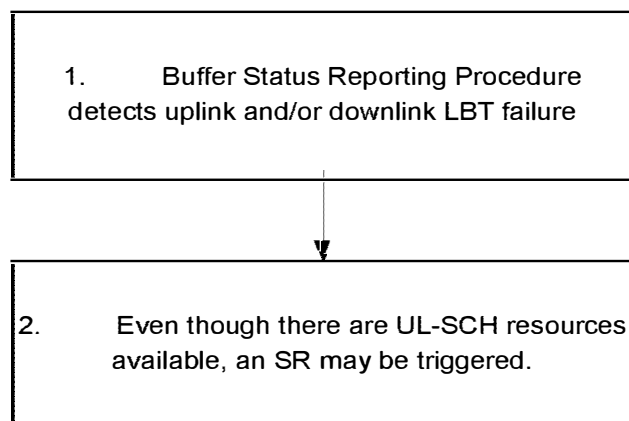


FIG. 6

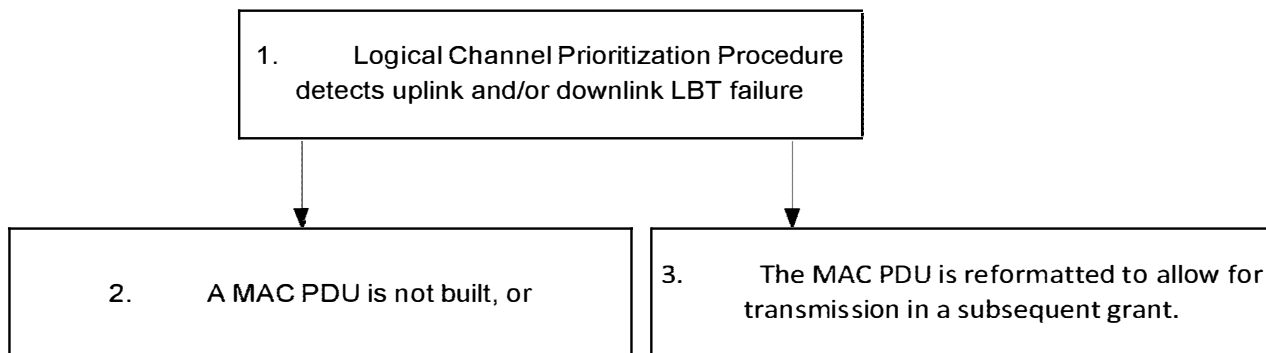


FIG. 7

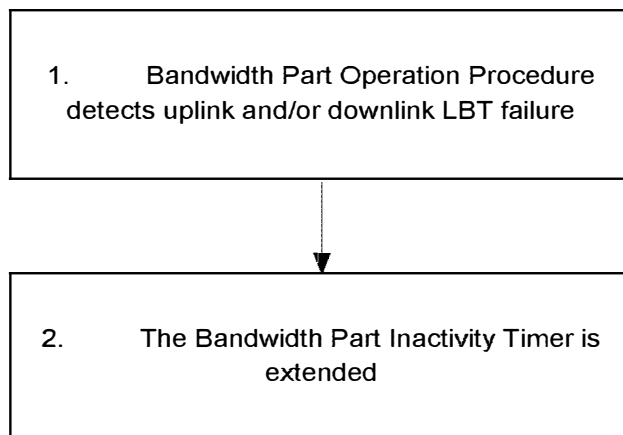


FIG. 8

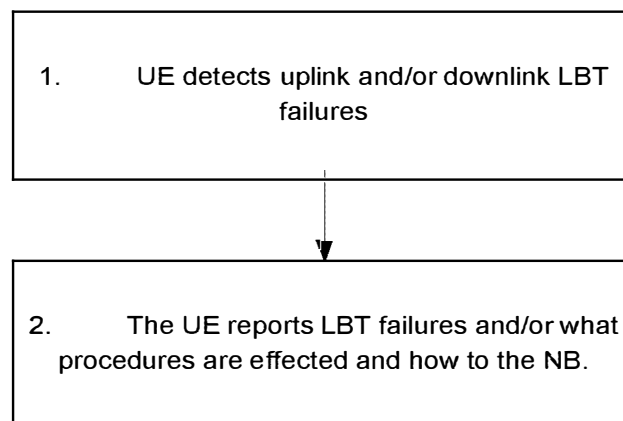


FIG. 9

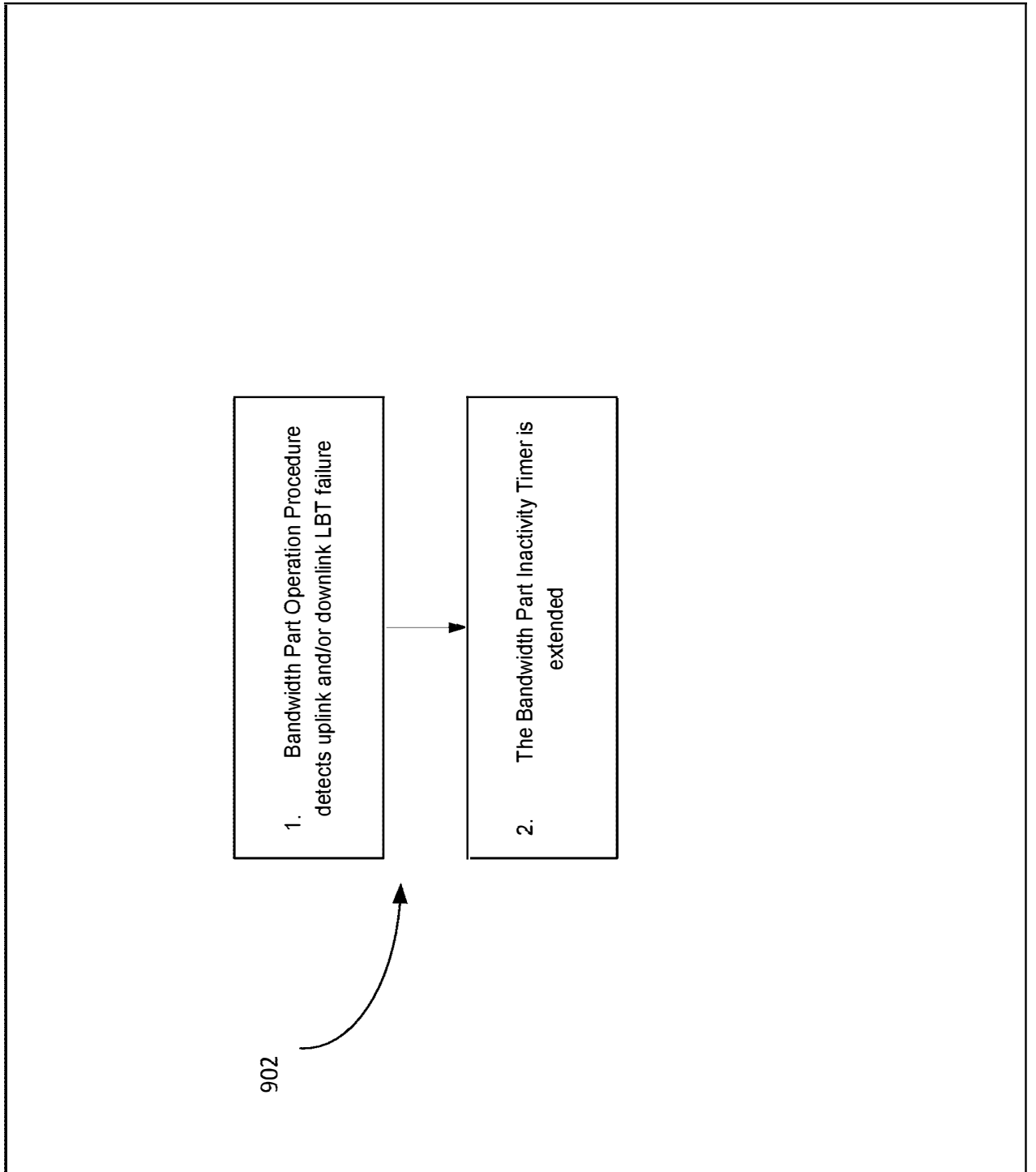


FIG. 10

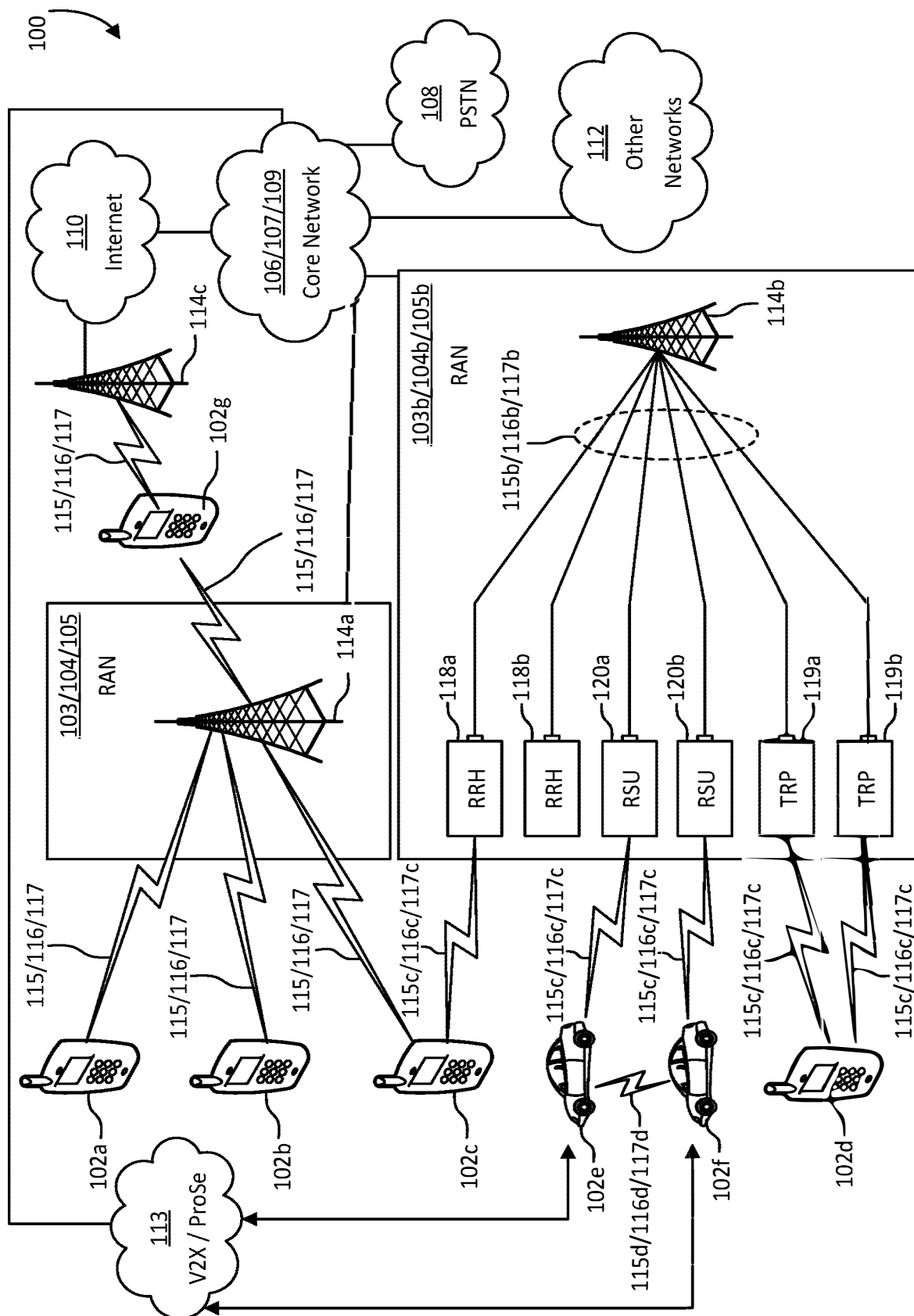


FIG. 11A

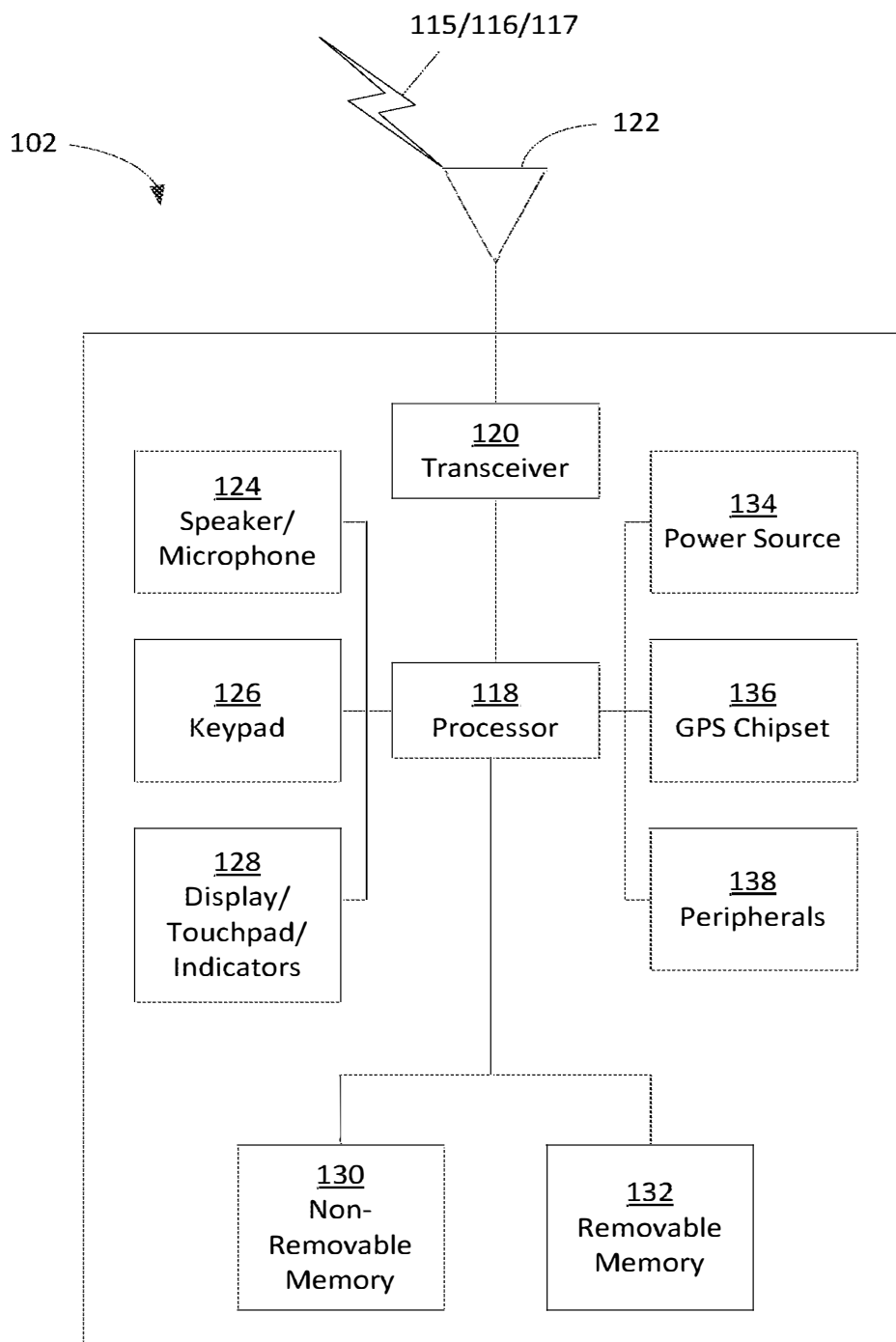


FIG. 11B

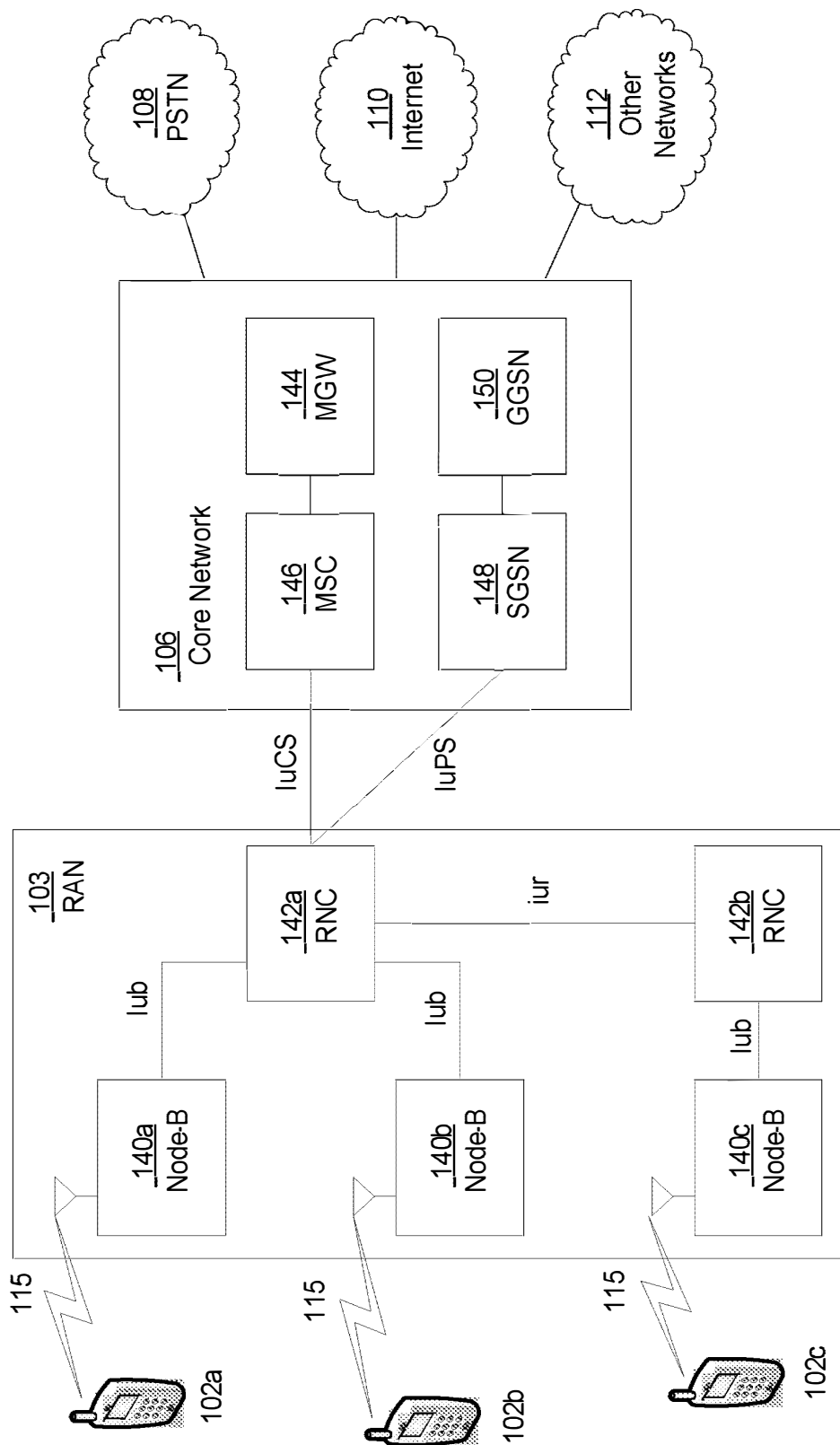


FIG. 11C

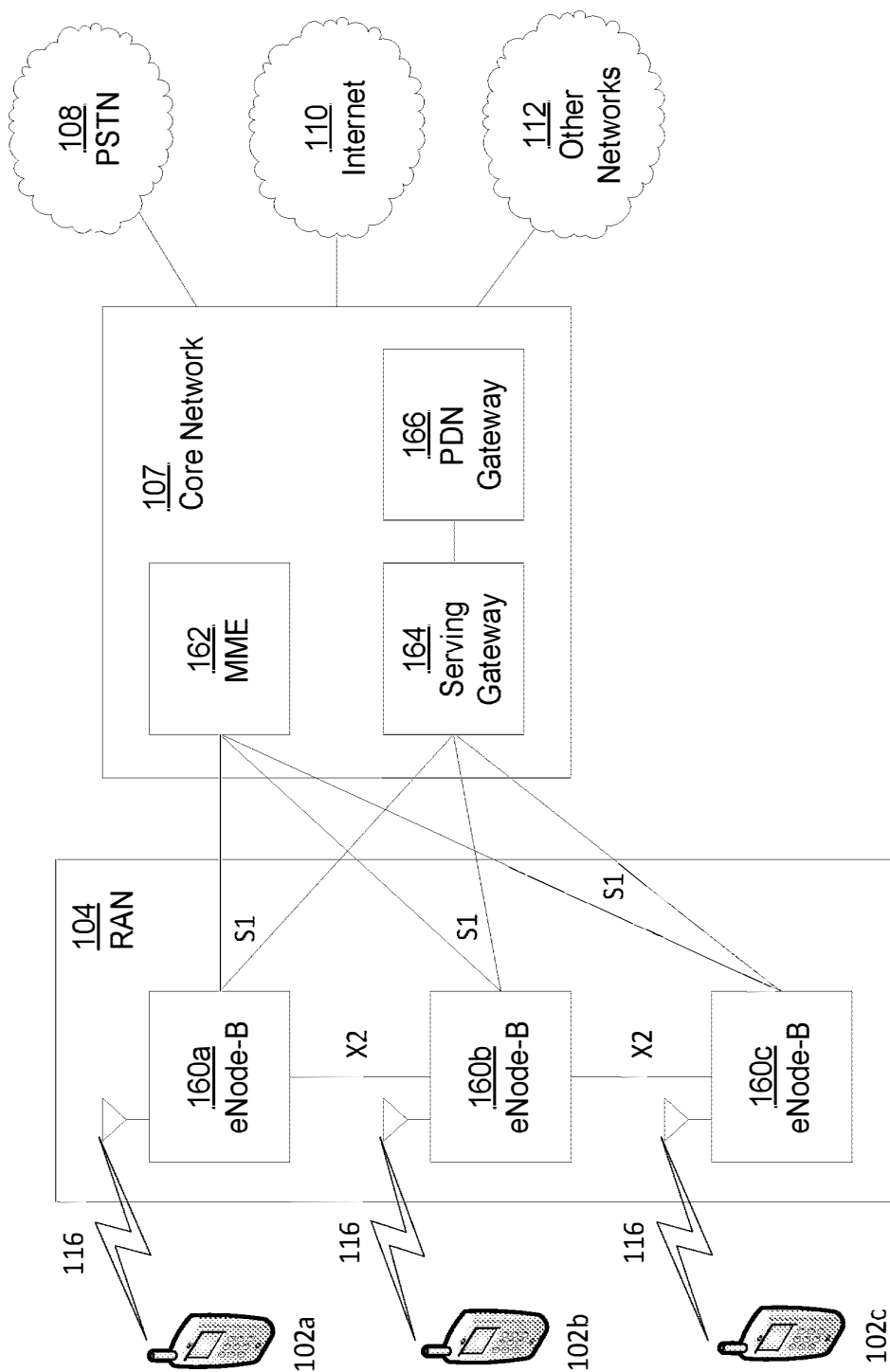


FIG. 11D

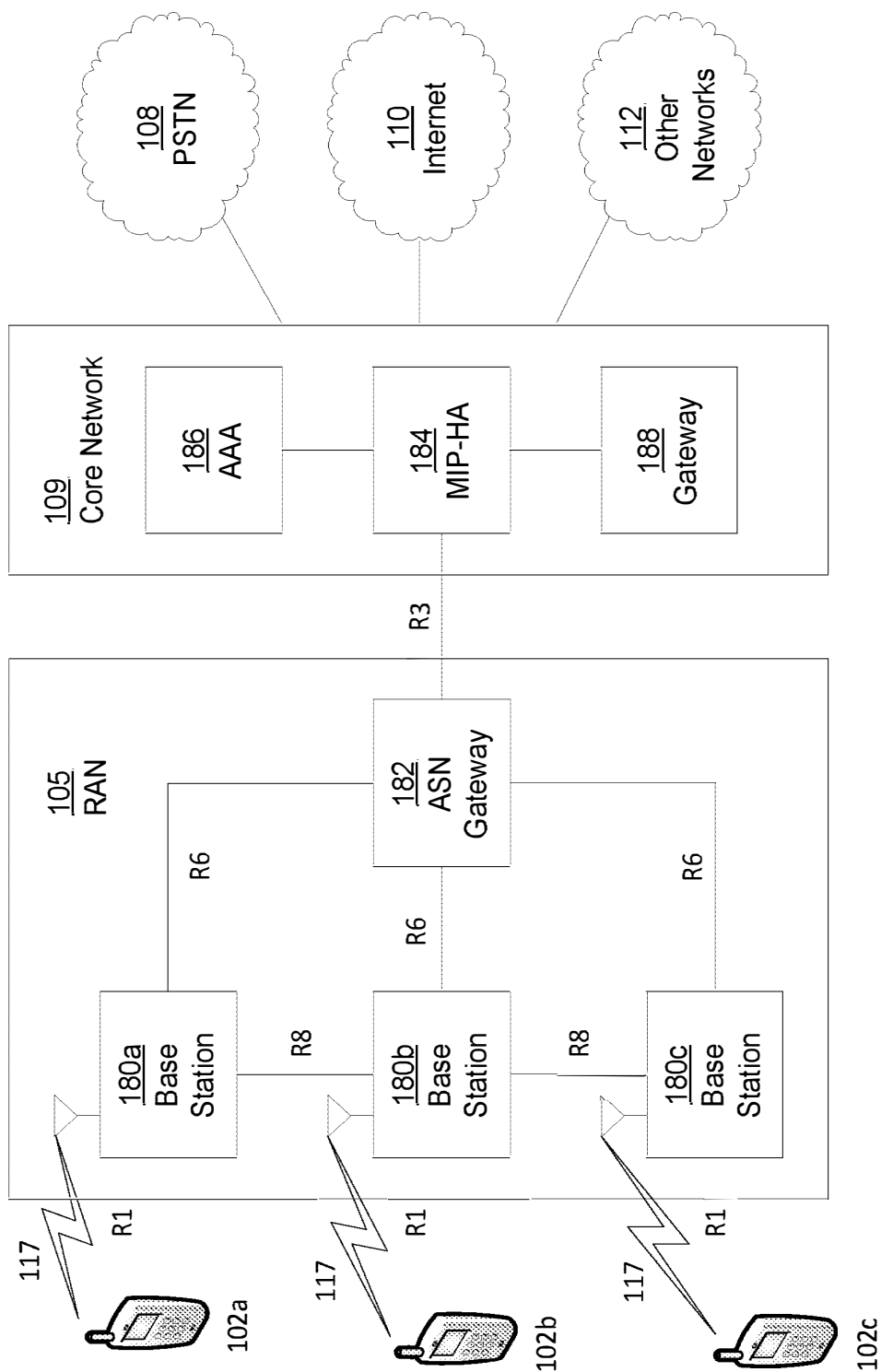


FIG. 11E

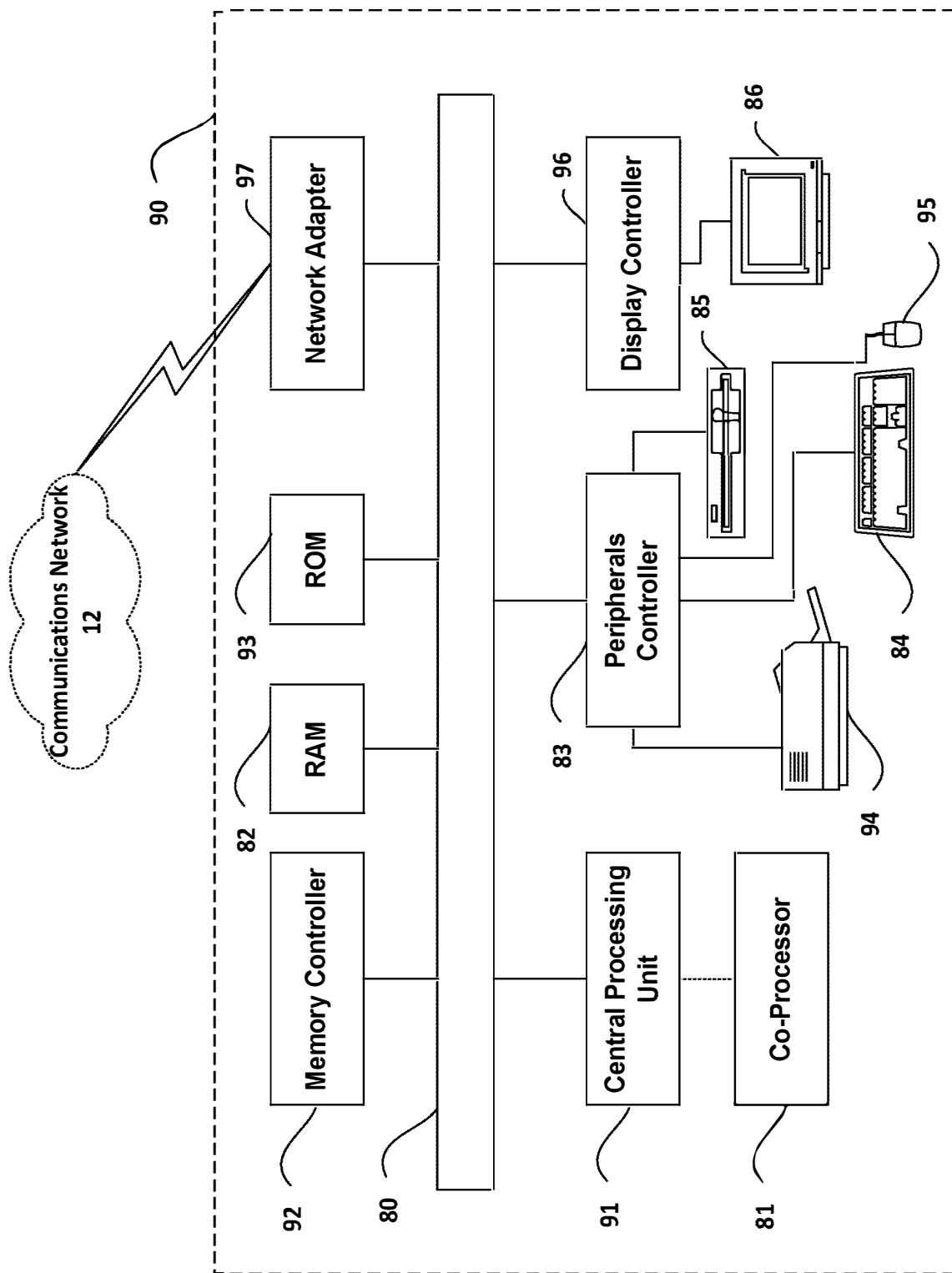
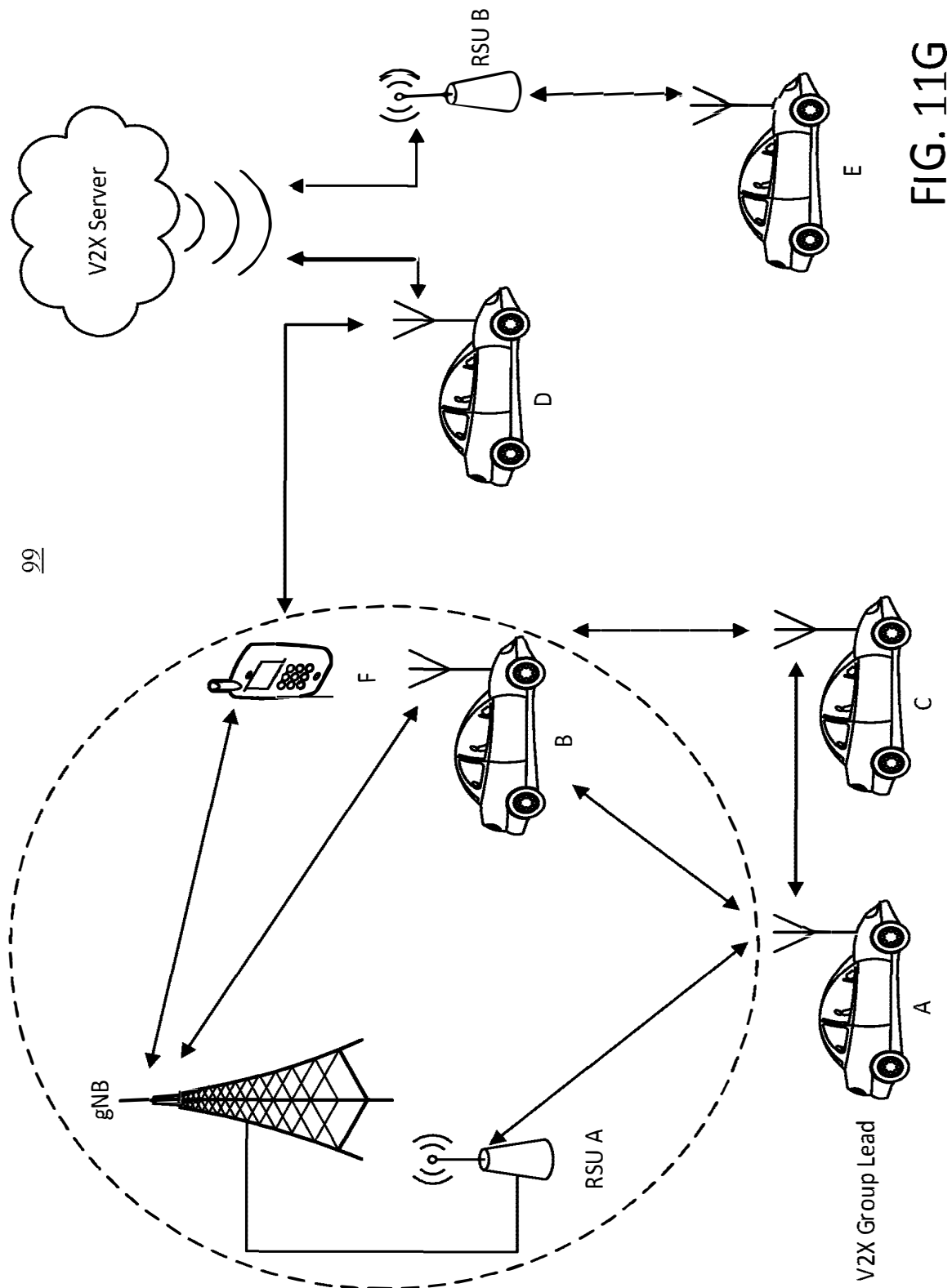


FIG. 11F



Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		NR-U LBT MAC PROCEDURES		
First Named Inventor/Applicant Name:		Stephen E. Terry		
Filer:		Craig L. Cupid/Ouida Howard		
Attorney Docket Number:		CV14535US01/106693000180		
Filed as Large Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
PROVISIONAL APPLICATION FILING	1005	1	280	280
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				280

Electronic Acknowledgement Receipt

EFS ID:	34177531
Application Number:	62753579
International Application Number:	
Confirmation Number:	1062
Title of Invention:	NR-U LBT MAC PROCEDURES
First Named Inventor/Applicant Name:	Stephen E. Terry
Customer Number:	23377
Filer:	Craig L. Cupid/Ouida Howard
Filer Authorized By:	Craig L. Cupid
Attorney Docket Number:	CV14535US01/106693000180
Receipt Date:	31-OCT-2018
Filing Date:	
Time Stamp:	16:56:20
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$ 280
RAM confirmation Number	110118INTEFSW00003918233050
Deposit Account	233050
Authorized User	Ouida Howard

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37 CFR 1.19 (Document supply fees)
37 CFR 1.20 (Post Issuance fees)
37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Provisional Cover Sheet (SB16)	106693_000180_Provisional_Cover_Sheet.pdf	2032499	no	4
			a530799e0e0534adbfb2e6980d638e4b51e a47ba		
Warnings:					
Information:					
2	Application Data Sheet	106693_000180_Application_Data_Sheet.pdf	1256227	no	10
			cf5834a8ddb17f466d4e079ea4427c4bb39 aad52		
Warnings:					
Information:					
3		106693_000180_Specification.pdf	498011	yes	72
			c286eddbc2a7c839ab64eb5afe6bd4bcb11 793d1		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Abstract		72	72	
	Claims		71	71	
	Specification		1	70	
Warnings:					
Information:					
4	Drawings-only black and white line drawings	106693_000180_Drawings.pdf	964718	no	13
			733370efbc84e0011da27edae1178b8ba88 3bf19		
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	30143	no	2
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Warnings:	
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