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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
62/501,681	05/04/2017		260	030284.14639/ 173996P1		

CONFIRMATION NO. 2200

FILING RECEIPT

15142

Arent Fox, LLP and Qualcomm, Incorporated
1717 K Street, NW
Washington, DC 20006-5344



0000000091308472

Date Mailed: 05/12/2017

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)

Yi HUANG, San Diego, CA;
Renqiu WANG, San Diego, CA;
Hao XU, San Diego, CA;
Seyong PARK, San Diego, CA;

Applicant(s)

QUALCOMM Incorporated, San Diego, CA;

Power of Attorney: The patent practitioners associated with Customer Number 15142

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: 05/11/2017

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/501,681**

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

Non-Publication Request: No

Early Publication Request: No

Title

CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK
CONTROL CHANNEL

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 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.

TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA/82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	To be assigned
Filing Date	Filed concurrently herewith
First Named Inventor	Yi HUANG
Title	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL
Art Unit	To be assigned
Examiner Name	To be assigned
Attorney Docket Number	030284.14639/ 173996P1

SIGNATURE of Applicant or Patent Practitioner

Signature	/Lester J. Anderson, Reg. No. 45,833/	Date (Optional)	2017-05-04
Name	Lester J. Anderson	Registration Number	45833
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.



*Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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 3 minutes 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. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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

POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in the attached transmittal letter.

- ☒ I hereby appoint Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A or equivalent):

15142

OR

- ☐ I hereby appoint Practitioner(s) named below as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A or equivalent):

Name Registration	Number	Name Registration	Number

Please recognize or change the correspondence address for the above-identified patent to:

- ☒ The address associated with the above-mentioned Customer Number.

OR

- ☐ The address associated with Customer Number:

OR

☐ Firm or
Individual Name

Address

City

State

Zip

Country

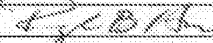
Telephone

Email

I am the Applicant:

- ☐ Inventor or Joint Inventor
- ☐ Legal Representative of a Deceased or Legally Incapacitated Inventor
- ☒ Assignee or Person to Whom the Inventor is Under an Obligation to Assign
- ☐ Person Who Otherwise Shows Sufficient *Proprietary* Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document)

SIGNATURE of Applicant for Patent

Signature		Date	11 SEP 2012
Name	Raymond B. Horn	Telephone	858-651-3679
Title and Company	Vice President, Patent Counsel and QUALCOMM Incorporated		

NOTE: Signature - This form must be signed by the applicant or applicant's representative in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms for more than one signature, see below *.

- ☒ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. 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 3 minutes 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. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		
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.)

Inventor Information:

Inventor	1				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Yi		HUANG			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	San Diego	State/Province	CA	Country of Residence	US	
Mailing Address of Inventor:						
Address 1	c/o QUALCOMM Incorporated					
Address 2	5775 Morehouse Drive					
City	San Diego	State/Province	CA			
Postal Code	92121-1714	Country	US			
Inventor	2				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Renqiu		WANG			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	San Diego	State/Province	CA	Country of Residence	US	
Mailing Address of Inventor:						
Address 1	c/o QUALCOMM Incorporated					
Address 2	5775 Morehouse Drive					
City	San Diego	State/Province	CA			
Postal Code	92121-1714	Country	US			
Inventor	3				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Hao		XU			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

City	San Diego	State/Province	CA	Country of Residence	US
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Mailing Address of Inventor:

Address 1	c/o QUALCOMM Incorporated				
Address 2	5775 Morehouse Drive				
City	San Diego	State/Province	CA		
Postal Code	92121-1714	Country i	US		
Inventor	4				Remove
Legal Name					

Prefix	Given Name	Middle Name	Family Name	Suffix
	Seyong		PARK	

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

City	San Diego	State/Province	CA	Country of Residence	US
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Mailing Address of Inventor:

Address 1	c/o QUALCOMM Incorporated				
Address 2	5775 Morehouse Drive				
City	San Diego	State/Province	CA		
Postal Code	92121-1714	Country i	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.					

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	15142		
Email Address	patentdocket@arentfox.com	Add Email	Remove Email

Application Information:

Title of the Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		
Attorney Docket Number	030284.14639/ 173996P1	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	8	Suggested Figure for Publication (if any)	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

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.

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	15142		

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.			

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

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)	Access Code ⁱ (if applicable)	Remove

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

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	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

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	QUALCOMM Incorporated		
Mailing Address Information For Applicant:			
Address 1	5775 Morehouse Drive		
Address 2			
City	San Diego	State/Province	CA
Country	US	Postal Code	92121-1714
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:

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

Assignee 1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
Remove				
If the Assignee or Non-Applicant Assignee is an Organization check here. ☐				
Prefix	Given Name	Middle Name	Family Name	Suffix
Mailing Address Information For Assignee including Non-Applicant Assignee:				
Address 1				
Address 2				
City		State/Province		
Country i		Postal Code		
Phone Number		Fax Number		
Email Address				
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add				

Signature:

Remove

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Lester J. Anderson, Reg. No. 45,833/		Date (YYYY-MM-DD)	2017-05-04	
First Name	Lester J.	Last Name	Anderson	Registration Number	45833
Additional Signature may be generated within this form by selecting the Add button. Add					

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	030284.14639/ 173996P1
		Application Number	
Title of Invention	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		

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CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL

BACKGROUND

Field

[0001] The present disclosure relates generally to communication systems, and more particularly, to an uplink control channels in a communication system.

Background

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources. Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example telecommunication standard is 5G New Radio (NR). 5G NR is part of a continuous mobile broadband evolution promulgated by Third Generation Partnership Project (3GPP) to meet new requirements associated with latency, reliability, security, scalability (e.g., with Internet of Things (IoT)), and other requirements. Some aspects of 5G NR may be based on the 4G Long Term Evolution (LTE) standard. There exists a need for further improvements in 5G NR technology. These improvements may also be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

[0004] 5G NR includes short physical uplink control channel (PUCCH) and long PUCCH. In some aspects, the duration of long PUCCH, e.g., in the number of symbols, may vary over a wide range. Demodulation reference signal (DMRS)

overhead may take up a larger percentage of the symbols for shorter durations of the long PUCCH as compared to longer durations of the long PUCCH. Accordingly, disabling intra-slot hopping may be beneficial to decrease DMRS overhead, particularly for shorter durations of the long PUCCH.

SUMMARY

[0005] The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

[0006] Variable length uplink control channels such as PUCCH may vary in length over a wide range, e.g., variable length uplink control channels may have a variable number of symbols. Overhead may use a number of symbols, e.g., 2 symbols, per variable length uplink control channel. Accordingly, variable length uplink control channels having 4 symbols may only have 2 symbols (e.g., 50%) available for data while a long PUCCH having 14 symbols may have 12 symbols (e.g., approximately 86%) available for a data. Accordingly, disabling intra-slot hopping may be beneficial to decrease overhead, particularly for shorter variable length uplink control channels. For shorter variable length uplink control channels, the benefits of intra-slot frequency hopping may be not outweigh the low percentage of symbols available for data. Conversely, longer variable length uplink control channels, with higher percentages of symbols available for data may use intra-slot frequency hopping to, for example, increase the reliability of the PUCCH transmissions.

[0007] For example, as discussed above, 5G NR includes short PUCCH and long PUCCH. In some aspects, the duration of long PUCCH, e.g., in the number of symbols, may vary over a wide range. For example, the duration of a long PUCCH in the number of symbols, may be: 4 symbols, 5 symbols, 6 symbols, 7 symbols, 8 symbols, 9 symbols, 10 symbols, 11 symbols, 12 symbols, 13 symbols, 14 symbols, or some other number of symbols. DMRS overhead may take up a larger percentage of symbols for the shorter durations of the long PUCCH, e.g., as compared to the longer durations of the long PUCCH. For example, DMRS overhead may use 2

symbols per long PUCCH. Accordingly, a long PUCCH having 4 symbols may only have 2 symbols (e.g., 50%) available for data intended to be transmitted over the PUCCH, while a long PUCCH having 14 symbols may have 12 symbols (e.g., approximately 86%) available for data intended to be transmitted over the PUCCH. Disabling intra-slot hopping may be beneficial to decrease DMRS overhead as a percentage of the number of symbols.

[0008] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be an apparatus for wireless communication. The apparatus may include a transmitter and a processing system. The processing system may be configured to determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and communicate information to the transmitter for transmission over the variable length uplink control channel, the information transmitted by the transmitter based on the determination of whether or not to use intra-slot frequency hopping.

[0009] In an aspect of the disclosure, a method, a computer-readable medium, and an apparatus are provided. The apparatus may be an apparatus for wireless communication. The apparatus may include a receiver and a processing system. The processing system may be configured to determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and receive information from the receiver, the information received by the receiver over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping.

[0010] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network.

- [0012] FIGs. 2A, 2B, 2C, and 2D are diagrams illustrating examples of a DL frame structure, DL channels within the DL frame structure, an UL frame structure, and UL channels within the UL frame structure, respectively.
- [0013] FIG. 3 is a diagram illustrating an example of a base station and user equipment (UE) in an access network.
- [0014] FIG. 4 is a diagram illustrating intra-slot hopping in LTE communications system.
- [0015] FIG. 5 is a diagram illustrating long PUCCH and short PUCCH in 5G NR.
- [0016] FIG. 6 is a diagram illustrating frequency hopping in slot aggregation.
- [0017] FIG. 7 is a flowchart of a method of wireless communication.
- [0018] FIG. 8 is a flowchart of a method of wireless communication.

DETAILED DESCRIPTION

- [0019] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well known structures and components are shown in block diagram form in order to avoid obscuring such concepts.
- [0020] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, components, circuits, processes, algorithms, etc. (collectively referred to as “elements”). These elements may be implemented using electronic hardware, computer software, or any combination thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.
- [0021] By way of example, an element, or any portion of an element, or any combination of elements may be implemented as a “processing system” that includes one or more processors. Examples of processors include microprocessors, microcontrollers, graphics processing units (GPUs), central processing units

(CPUs), application processors, digital signal processors (DSPs), reduced instruction set computing (RISC) processors, systems on a chip (SoC), baseband processors, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software components, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise.

[0022] Accordingly, in one or more example embodiments, the functions described may be implemented in hardware, software, or any combination thereof. If implemented in software, the functions may be stored on or encoded as one or more instructions or code on a computer-readable medium. Computer-readable media includes computer storage media. Storage media may be any available media that can be accessed by a computer. By way of example, and not limitation, such computer-readable media can comprise a random-access memory (RAM), a read-only memory (ROM), an electrically erasable programmable ROM (EEPROM), optical disk storage, magnetic disk storage, other magnetic storage devices, combinations of the aforementioned types of computer-readable media, or any other medium that can be used to store computer executable code in the form of instructions or data structures that can be accessed by a computer.

[0023] FIG. 1 is a diagram illustrating an example of a wireless communications system and an access network 100. The wireless communications system (also referred to as a wireless wide area network (WWAN)) includes base stations 102, UEs 104, and an Evolved Packet Core (EPC) 160. The base stations 102 may include macro cells (high power cellular base station) and/or small cells (low power cellular base station). The macro cells include base stations. The small cells include femtocells, picocells, and microcells.

[0024] The base stations 102 (collectively referred to as Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN)) interface with the EPC 160 through backhaul links 132 (e.g., S1

interface). In addition to other functions, the base stations 102 may perform one or more of the following functions: transfer of user data, radio channel ciphering and deciphering, integrity protection, header compression, mobility control functions (e.g., handover, dual connectivity), inter-cell interference coordination, connection setup and release, load balancing, distribution for non-access stratum (NAS) messages, NAS node selection, synchronization, radio access network (RAN) sharing, multimedia broadcast multicast service (MBMS), subscriber and equipment trace, RAN information management (RIM), paging, positioning, and delivery of warning messages. The base stations 102 may communicate directly or indirectly (e.g., through the EPC 160) with each other over backhaul links 134 (e.g., X2 interface). The backhaul links 134 may be wired or wireless.

[0025] The base stations 102 may wirelessly communicate with the UEs 104. Each of the base stations 102 may provide communication coverage for a respective geographic coverage area 110. There may be overlapping geographic coverage areas 110. For example, the small cell 102' may have a coverage area 110' that overlaps the coverage area 110 of one or more macro base stations 102. A network that includes both small cell and macro cells may be known as a heterogeneous network. A heterogeneous network may also include Home Evolved Node Bs (eNBs) (HeNBs), which may provide service to a restricted group known as a closed subscriber group (CSG). The communication links 120 between the base stations 102 and the UEs 104 may include uplink (UL) (also referred to as reverse link) transmissions from a UE 104 to a base station 102 and/or downlink (DL) (also referred to as forward link) transmissions from a base station 102 to a UE 104. The communication links 120 may use multiple-input and multiple-output (MIMO) antenna technology, including spatial multiplexing, beamforming, and/or transmit diversity. The communication links may be through one or more carriers. The base stations 102 / UEs 104 may use spectrum up to Y MHz (e.g., 5, 10, 15, 20, 100 MHz) bandwidth per carrier allocated in a carrier aggregation of up to a total of Yx MHz (x component carriers) used for transmission in each direction. The carriers may or may not be adjacent to each other. Allocation of carriers may be asymmetric with respect to DL and UL (e.g., more or less carriers may be allocated for DL than for UL). The component carriers may include a primary component carrier and one or more secondary component carriers. A primary component carrier may be

referred to as a primary cell (PCell) and a secondary component carrier may be referred to as a secondary cell (SCell).

[0026] Certain UEs 104 may communicate with each other using device-to-device (D2D) communication link 192. The D2D communication link 192 may use the DL/UL WWAN spectrum. The D2D communication link 192 may use one or more sidelink channels, such as a physical sidelink broadcast channel (PSBCH), a physical sidelink discovery channel (PSDCH), a physical sidelink shared channel (PSSCH), and a physical sidelink control channel (PSCCH). D2D communication may be through a variety of wireless D2D communications systems, such as for example, FlashLinQ, WiMedia, Bluetooth, ZigBee, Wi-Fi based on the IEEE 802.11 standard, LTE, or NR.

[0027] The wireless communications system may further include a Wi-Fi access point (AP) 150 in communication with Wi-Fi stations (STAs) 152 via communication links 154 in a 5 GHz unlicensed frequency spectrum. When communicating in an unlicensed frequency spectrum, the STAs 152 / AP 150 may perform a clear channel assessment (CCA) prior to communicating in order to determine whether the channel is available.

[0028] The small cell 102' may operate in a licensed and/or an unlicensed frequency spectrum. When operating in an unlicensed frequency spectrum, the small cell 102' may employ NR and use the same 5 GHz unlicensed frequency spectrum as used by the Wi-Fi AP 150. The small cell 102', employing NR in an unlicensed frequency spectrum, may boost coverage to and/or increase capacity of the access network.

[0029] The gNodeB (gNB) 180 may operate in millimeter wave (mmW) frequencies and/or near mmW frequencies in communication with the UE 104. When the gNB 180 operates in mmW or near mmW frequencies, the gNB 180 may be referred to as an mmW base station. Extremely high frequency (EHF) is part of the RF in the electromagnetic spectrum. EHF has a range of 30 GHz to 300 GHz and a wavelength between 1 millimeter and 10 millimeters. Radio waves in the band may be referred to as a millimeter wave. Near mmW may extend down to a frequency of 3 GHz with a wavelength of 100 millimeters. The super high frequency (SHF) band extends between 3 GHz and 30 GHz, also referred to as centimeter wave. Communications using the mmW / near mmW radio frequency band has extremely high path loss and a short range. The mmW base station 180 may utilize

beamforming 184 with the UE 104 to compensate for the extremely high path loss and short range.

[0030] The EPC 160 may include a Mobility Management Entity (MME) 162, other MMEs 164, a Serving Gateway 166, a Multimedia Broadcast Multicast Service (MBMS) Gateway 168, a Broadcast Multicast Service Center (BM-SC) 170, and a Packet Data Network (PDN) Gateway 172. The MME 162 may be in communication with a Home Subscriber Server (HSS) 174. The MME 162 is the control node that processes the signaling between the UEs 104 and the EPC 160. Generally, the MME 162 provides bearer and connection management. All user Internet protocol (IP) packets are transferred through the Serving Gateway 166, which itself is connected to the PDN Gateway 172. The PDN Gateway 172 provides UE IP address allocation as well as other functions. The PDN Gateway 172 and the BM-SC 170 are connected to the IP Services 176. The IP Services 176 may include the Internet, an intranet, an IP Multimedia Subsystem (IMS), a PS Streaming Service, and/or other IP services. The BM-SC 170 may provide functions for MBMS user service provisioning and delivery. The BM-SC 170 may serve as an entry point for content provider MBMS transmission, may be used to authorize and initiate MBMS Bearer Services within a public land mobile network (PLMN), and may be used to schedule MBMS transmissions. The MBMS Gateway 168 may be used to distribute MBMS traffic to the base stations 102 belonging to a Multicast Broadcast Single Frequency Network (MBSFN) area broadcasting a particular service, and may be responsible for session management (start/stop) and for collecting eMBMS related charging information.

[0031] The base station may also be referred to as a gNB, Node B, evolved Node B (eNB), an access point, a base transceiver station, a radio base station, a radio transceiver, a transceiver function, a basic service set (BSS), an extended service set (ESS), or some other suitable terminology. The base station 102 provides an access point to the EPC 160 for a UE 104. Examples of UEs 104 include a cellular phone, a smart phone, a session initiation protocol (SIP) phone, a laptop, a personal digital assistant (PDA), a satellite radio, a global positioning system, a multimedia device, a video device, a digital audio player (e.g., MP3 player), a camera, a game console, a tablet, a smart device, a wearable device, a vehicle, an electric meter, a gas pump, a toaster, or any other similar functioning device. Some of the UEs 104 may be referred to as IoT devices (e.g., parking meter, gas pump, toaster, vehicles, etc.).

The UE 104 may also be referred to as a station, a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a mobile client, a client, or some other suitable terminology.

[0032] Referring again to FIG. 1, in certain aspects, the UE 104 and/or base station 180 may each be configured to determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and communicate information to the transmitter for transmission over the variable length uplink control channel (e.g., UE 104) or receive information received by the receiver over the variable length uplink control channel (e.g., base station 180), the information transmitted by the transmitter (e.g., in the UE 104) or received by the receiver (e.g., in base station 180) based on the determination of whether or not to use intra-slot frequency hopping (198).

[0033] FIG. 2A is a diagram 200 illustrating an example of a DL frame structure. FIG. 2B is a diagram 230 illustrating an example of channels within the DL frame structure. FIG. 2C is a diagram 250 illustrating an example of an UL frame structure. FIG. 2D is a diagram 280 illustrating an example of channels within the UL frame structure. Other wireless communication technologies may have a different frame structure and/or different channels. A frame (10 ms) may be divided into 10 equally sized subframes. Each subframe may include two consecutive time slots. A resource grid may be used to represent the two time slots, each time slot including one or more time concurrent resource blocks (RBs) (also referred to as physical RBs (PRBs)). The resource grid is divided into multiple resource elements (REs). For a normal cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and 7 consecutive symbols (for DL, OFDM symbols; for UL, SC-FDMA symbols) in the time domain, for a total of 84 REs. For an extended cyclic prefix, an RB may contain 12 consecutive subcarriers in the frequency domain and 6 consecutive symbols in the time domain, for a total of 72 REs. The number of bits carried by each RE depends on the modulation scheme.

[0034] As illustrated in FIG. 2A, some of the REs carry DL reference (pilot) signals (DL-RS) for channel estimation at the UE. The DL-RS may include cell-specific reference signals (CRS) (also sometimes called common RS), UE-specific reference

signals (UE-RS), and channel state information reference signals (CSI-RS). FIG. 2A illustrates CRS for antenna ports 0, 1, 2, and 3 (indicated as R_0 , R_1 , R_2 , and R_3 , respectively), UE-RS for antenna port 5 (indicated as R_5), and CSI-RS for antenna port 15 (indicated as R).

[0035] FIG. 2B illustrates an example of various channels within a DL subframe of a frame. The physical control format indicator channel (PCFICH) is within symbol 0 of slot 0, and carries a control format indicator (CFI) that indicates whether the physical downlink control channel (PDCCH) occupies 1, 2, or 3 symbols (FIG. 2B illustrates a PDCCH that occupies 3 symbols). The PDCCH carries downlink control information (DCI) within one or more control channel elements (CCEs), each CCE including nine RE groups (REGs), each REG including four consecutive REs in an OFDM symbol. A UE may be configured with a UE-specific enhanced PDCCH (ePDCCH) that also carries DCI. The ePDCCH may have 2, 4, or 8 RB pairs (FIG. 2B shows two RB pairs, each subset including one RB pair). The physical hybrid automatic repeat request (ARQ) (HARQ) indicator channel (PHICH) is also within symbol 0 of slot 0 and carries the HARQ indicator (HI) that indicates HARQ acknowledgement (ACK) / negative ACK (NACK) feedback based on the physical uplink shared channel (PUSCH). The primary synchronization channel (PSCH) may be within symbol 6 of slot 0 within subframes 0 and 5 of a frame. The PSCH carries a primary synchronization signal (PSS) that is used by a UE 104 to determine subframe/symbol timing and a physical layer identity. The secondary synchronization channel (SSCH) may be within symbol 5 of slot 0 within subframes 0 and 5 of a frame. The SSCH carries a secondary synchronization signal (SSS) that is used by a UE to determine a physical layer cell identity group number and radio frame timing. Based on the physical layer identity and the physical layer cell identity group number, the UE can determine a physical cell identifier (PCI). Based on the PCI, the UE can determine the locations of the aforementioned DL-RS. The physical broadcast channel (PBCH), which carries a master information block (MIB), may be logically grouped with the PSCH and SSCH to form a synchronization signal (SS) block. The MIB provides a number of RBs in the DL system bandwidth, a PHICH configuration, and a system frame number (SFN). The physical downlink shared channel (PDSCH) carries user data, broadcast system information not transmitted through the PBCH such as system information blocks (SIBs), and paging messages.

[0036] As illustrated in FIG. 2C, some of the REs carry demodulation reference signals (DM-RS) for channel estimation at the base station. The UE may additionally transmit sounding reference signals (SRS) in the last symbol of a subframe. The SRS may have a comb structure, and a UE may transmit SRS on one of the combs. The SRS may be used by a base station for channel quality estimation to enable frequency-dependent scheduling on the UL.

[0037] FIG. 2D illustrates an example of various channels within an UL subframe of a frame. A physical random access channel (PRACH) may be within one or more subframes within a frame based on the PRACH configuration. The PRACH may include six consecutive RB pairs within a subframe. The PRACH allows the UE to perform initial system access and achieve UL synchronization. A physical uplink control channel (PUCCH) may be located on edges of the UL system bandwidth. The PUCCH carries uplink control information (UCI), such as scheduling requests, a channel quality indicator (CQI), a precoding matrix indicator (PMI), a rank indicator (RI), and HARQ ACK/NACK feedback. The PUSCH carries data, and may additionally be used to carry a buffer status report (BSR), a power headroom report (PHR), and/or UCI.

[0038] FIG. 3 is a block diagram of a base station 310 in communication with a UE 350 in an access network. In the DL, IP packets from the EPC 160 may be provided to a controller/processor 375. The controller/processor 375 implements layer 3 and layer 2 functionality. Layer 3 includes a radio resource control (RRC) layer, and layer 2 includes a packet data convergence protocol (PDCP) layer, a radio link control (RLC) layer, and a medium access control (MAC) layer. The controller/processor 375 provides RRC layer functionality associated with broadcasting of system information (e.g., MIB, SIBs), RRC connection control (e.g., RRC connection paging, RRC connection establishment, RRC connection modification, and RRC connection release), inter radio access technology (RAT) mobility, and measurement configuration for UE measurement reporting; PDCP layer functionality associated with header compression / decompression, security (ciphering, deciphering, integrity protection, integrity verification), and handover support functions; RLC layer functionality associated with the transfer of upper layer packet data units (PDUs), error correction through ARQ, concatenation, segmentation, and reassembly of RLC service data units (SDUs), re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between

logical channels and transport channels, multiplexing of MAC SDUs onto transport blocks (TBs), demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0039] The transmit (TX) processor 316 and the receive (RX) processor 370 implement layer 1 functionality associated with various signal processing functions. Layer 1, which includes a physical (PHY) layer, may include error detection on the transport channels, forward error correction (FEC) coding/decoding of the transport channels, interleaving, rate matching, mapping onto physical channels, modulation/demodulation of physical channels, and MIMO antenna processing. The TX processor 316 handles mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols may then be split into parallel streams. Each stream may then be mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 374 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 350. Each spatial stream may then be provided to a different antenna 320 via a separate transmitter 318TX. Each transmitter 318TX may modulate an RF carrier with a respective spatial stream for transmission.

[0040] At the UE 350, each receiver 354RX receives a signal through its respective antenna 352. Each receiver 354RX recovers information modulated onto an RF carrier and provides the information to the receive (RX) processor 356. The TX processor 368 and the RX processor 356 implement layer 1 functionality associated with various signal processing functions. The RX processor 356 may perform spatial processing on the information to recover any spatial streams destined for the UE 350. If multiple spatial streams are destined for the UE 350, they may be combined by the RX processor 356 into a single OFDM symbol stream. The RX processor 356 then converts the OFDM symbol stream from the time-domain to the

frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, are recovered and demodulated by determining the most likely signal constellation points transmitted by the base station 310. These soft decisions may be based on channel estimates computed by the channel estimator 358. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the base station 310 on the physical channel. The data and control signals are then provided to the controller/processor 359, which implements layer 3 and layer 2 functionality.

[0041] The controller/processor 359 can be associated with a memory 360 that stores program codes and data. The memory 360 may be referred to as a computer-readable medium. In the UL, the controller/processor 359 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, and control signal processing to recover IP packets from the EPC 160. The controller/processor 359 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0042] Similar to the functionality described in connection with the DL transmission by the base station 310, the controller/processor 359 provides RRC layer functionality associated with system information (e.g., MIB, SIBs) acquisition, RRC connections, and measurement reporting; PDCP layer functionality associated with header compression / decompression, and security (ciphering, deciphering, integrity protection, integrity verification); RLC layer functionality associated with the transfer of upper layer PDUs, error correction through ARQ, concatenation, segmentation, and reassembly of RLC SDUs, re-segmentation of RLC data PDUs, and reordering of RLC data PDUs; and MAC layer functionality associated with mapping between logical channels and transport channels, multiplexing of MAC SDUs onto TBs, demultiplexing of MAC SDUs from TBs, scheduling information reporting, error correction through HARQ, priority handling, and logical channel prioritization.

[0043] Channel estimates derived by a channel estimator 358 from a reference signal or feedback transmitted by the base station 310 may be used by the TX processor 368 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 368 may be

provided to different antenna 352 via separate transmitters 354TX. Each transmitter 354TX may modulate an RF carrier with a respective spatial stream for transmission.

[0044] The UL transmission is processed at the base station 310 in a manner similar to that described in connection with the receiver function at the UE 350. Each receiver 318RX receives a signal through its respective antenna 320. Each receiver 318RX recovers information modulated onto an RF carrier and provides the information to a RX processor 370.

[0045] The controller/processor 375 can be associated with a memory 376 that stores program codes and data. The memory 376 may be referred to as a computer-readable medium. In the UL, the controller/processor 375 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover IP packets from the UE 350. IP packets from the controller/processor 375 may be provided to the EPC 160. The controller/processor 375 is also responsible for error detection using an ACK and/or NACK protocol to support HARQ operations.

[0046] FIG. 4 is a diagram 400 illustrating intra-slot hopping in LTE communications system. The diagram 400 includes an example radio frame 402. The example radio frame 402 includes 10 sub-frames numbered 0 to 9. Each of the sub-frames may be 1 ms in length. Furthermore, the radio frame may be broken into two 5 ms portions, e.g., 5 sub-frames each.

[0047] As illustrated in FIG. 4, a subframe may be broken into a series of time/frequency blocks (e.g., resource blocks) that may be used for transmission of information. A PUCCH may be assigned to one or more time/frequency blocks (resource blocks) and may be used to transmit Physical Uplink Control Channel information. Other time/frequency blocks (resource blocks) may be used to transmit user data. For example, the resource blocks that are not used to transmit a PUCCH may be used to transmit user data or other types of data, such as other control information in other control channels.

[0048] As indicated by the arrows between different time/frequency blocks (resource blocks), intra-slot frequency hopping may be used in LTE to provide frequency diversity. Accordingly, a PUCCH may be moved from one frequency to another frequency, e.g., hopping. In the illustrated example, multiple PUCCH may be transmitted. Each of the multiple PUCCH may change frequency every 0.5 ms.

[0049] FIG. 5 is a diagram 500 illustrating uplink centric slot 502 and downlink centric slot 504 in 5G NR. The example of FIG. 5 is specific to PUCCH, however, the systems and methods described herein may be applied to any variable length uplink control channel where frequency hopping may be allowed. In such an example, the frequency hopping may be turned on and off based on various circumstances such as those described herein, e.g., number of symbols available, channel conditions, need for efficiency in the use of symbols or lack thereof, or other factors that may impact the utility of frequency hopping. As illustrated in FIG. 5, a downlink centric slot 504 may include a PDCCH, a GAP, and an uplink short PUCCH and a PUSCH region. An uplink centric slot 502 may also include a PDCCH, a GAP, an uplink short PUCCH and a PUSCH region.

[0050] In the downlink centric slot 504, an area between the PDCCU and GAP may include the PDSCH. In the uplink centric slot 502, an area between the GAP and the uplink short PUCCH and a PUSCH region may include a uplink long PUCCH and PUSCH region 506. In an example, the PUSCH region 506 may include time/frequency resources that may be used to transmit or receive symbols used for the PUCCH. The time/frequency resources in the PUSCH region 506 may include, for example, a long PUCCH that may be 4 to 14 symbols wide. The long PUCCH may be located anywhere within the time/frequency resources of the PUSCH region 506.

[0051] In an aspect, variable length uplink control channel intra-slot frequency hopping, such as long PUCCH intra-slot hopping, may be disabled. For example, in 5G NR, there are long PUCCH and short PUCCH. In 5G NR, because the duration of long PUCCH, e.g., in number of symbols, may have a wide range, such as, 4 to 14 symbols wide, it may be advantageous to disable intra-slot hopping for some long PUCCH. Factors such as number of symbols available for each PUCCH, channel conditions, a need for efficiency in the use of symbols, a lack of a need for efficiency in the use of symbols, or other factors may be used to determine when hopping should be used or not used.

[0052] As discussed above, for certain scenarios, it may be beneficial to disable intra-slot hopping. For example, when a long PUCCH duration is only 4 symbols, a system may disable hopping to reduce DMRS overhead. Some systems may disable or enable intra-slot long PUCCH hopping based on channel conditions. For example, when one or more frequencies include a large amount of noise, enabling

frequency hopping may be more advantageous. Accordingly, the factors of number of symbols available for each PUCCH, channel conditions, a need for efficiency in the use of symbols, a lack of a need for efficiency in the use of symbols, or other factors may be used to determine when to use and when not to use frequency hopping. For example, when a total number of symbols available for PUCCH is used to determine when to use or not to use frequency hopping, the threshold of total number of symbols available for PUCCH may be adjusted up or down based on one or more of the other factors.

[0053] In an aspect, a UE or a base station may implicitly disable or enable intra-slot long PUCCH hopping based on PUCCH duration and/or the other factors described herein. For example, a number of symbols, e.g., 4 to 14 symbols, may be selected to indicate enabling or disabling variable length uplink control channel intra-slot frequency hopping. When a variable length uplink control channel is greater than or equal to a predetermined number of symbols (e.g., one of 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, or 14 symbols wide) variable length uplink control channel intra-slot frequency hopping may be used, while when the variable length uplink control channel is less than the predetermined number of symbols, may not be used. Thus, it may be advantageous to use hopping only for cases when a higher percentage of symbols are available for data transmission or data reception. (The example used 4 to 14 symbols, however, some other number of symbols may be used for communications systems having a different number of symbols in a variable length uplink control channel such as a PUCCH.) The number of symbols selected may be variable, e.g., based on other factors.

[0054] As discussed above, the duration of a long PUCCH (or other variable length uplink control channel) in the number of symbols, may be: 4 to 14 symbols, or some other number of symbols. Overhead may take up a larger percentage of symbols for the shorter durations of the long PUCCH, e.g., as compared to the longer durations of the long PUCCH. For example, overhead may use 2 symbols per long PUCCH. Accordingly, a long PUCCH (or other variable length uplink control channel) having 4 symbols may only have 2 symbols (e.g., 50%) available for a data intended to be transmitted over the PUCCH while a long PUCCH having 14 symbols may have 12 symbols (e.g., approximately 86%) available for a data intended to be transmitted over the PUCCH. The selected number of symbols may correspond to having between 50% and 86% available for the transmission of data over a PUCCH

(variable length uplink control channel). Disabling intra-slot hopping may be beneficial to decrease overhead, such as DMRS overhead (e.g., overhead as a percentage of the number of symbols in the PUCCH or variable length uplink control channel). Table 1, below, provides percentages of symbols available for data transmission over a variable length uplink control channel assuming two symbols are used for overhead.

Total number of symbols for PUCCH	Percentage of symbols available for data transmission
4	50%
5	60%
6	67.7%
7	71.4%
8	75%
9	77.8%
10	80%
11	81.8
12	83.3%
13	84.6%
14	85.7%

TABLE 1

[0055] The percentage of symbols available for data transmission that is acceptable may vary from implementation to implementation. The total number of symbols selected as a threshold for enabling and disabling, for example, intra-slot PUCCH frequency hopping, may vary from, for example, 4 to 14. Furthermore, the threshold selected may be variable based on other factors, as described herein. In other examples, the number of symbols selected may be fixed for a particular implementation. For example, in one implementation the threshold may be equal to 4. In another example, the threshold may be equal to 7. The number of symbols for the threshold may be selected to attain a desired percentage of symbols available for data transmission in, for example a PUCCH. Thus, for example, when a percentage such as 80% is selected, for any number of slots in a PUCCH less than 10, intra-slot PUCCH frequency hopping should not be used. For PUCCH having 10 or more symbols, intra-slot PUCCH frequency hopping may be used.

[0056] In a first aspect, a threshold may be predetermined. Accordingly, each device in such a system may use a known threshold. Thus, no signaling is needed to transmit the threshold because the threshold is already known to each device in the system. For example, when an available number of symbols for a long PUCCH is less than a

value, X , where X is known to each device, both a UE and a base station may disable long PUCCH intra-slot hopping. When an available number of symbols for long PUCCH is greater than or equal to a value, X , where X is known to each device, both the UE and the base station may enable long PUCCH intra-slot hopping.

[0057] In a second aspect, signaling may be used to enable or disable variable intra-slot control channel frequency hopping. For example, in the second aspect base station-signaling may be used to enable or disable intra-slot long PUCCH hopping. For example, RRC signaling may be used to enable or disable intra-slot long PUCCH hopping. Unlike the first aspect above, signaling is needed in the second aspect. However, the second aspect, may allow for changing the threshold used to determine whether to enable or disable intra-slot long PUCCH hopping, unlike the first aspect, which may have a fixed threshold.

[0058] In a third aspect, a dynamic signaling (signaling available with a greater frequency as compared to the signaling in the second aspect) may be used to disable or enable intra-slot control channel frequency hopping. For example, in the third aspect, a base station may use dynamic signaling to disable or enable intra-slot long PUCCH hopping. A base station may use DCI for signaling to disable or enable intra-slot long PUCCH hopping. Unlike the first aspect above, signaling is needed for the third aspect (e.g., similar to the second aspect). Accordingly, like the second aspect above, using the third aspect, it may be possible to change the threshold used to determine whether to enable or disable intra-slot long PUCCH hopping, unlike the first aspect which may have a fixed threshold. The third aspect may allow for more rapid changes to the threshold as compared to the second aspect discussed above. The second aspect discussed above, however, may devote fewer bits to transmitting threshold information because the threshold information may be transmitted less often in the second aspect as compared to the third aspect.

[0059] FIG. 6 is a diagram 600 illustrating frequency hopping in slot aggregation. For example, a long PUCCH 602 in a first uplink centric slot 604 may be located at a first frequency. A long PUCCH 606 in a second uplink centric slot 608 may be located at a second frequency.

[0060] Intra-slot hopping may include individual PUCCHs hopping between frequencies within a set of frequencies used for the PUCCHs. Inter-slot hopping may include changing sets of frequencies used for PUCCHs hopping, e.g., changing

from one set of frequencies to another set of frequencies. A change in a set of frequencies may include changing as few as a single frequency in a set of frequencies to a new frequency used for the PUCCHs up to changing as many as all the frequencies in a set of frequencies to new frequencies used for the PUCCHs. In the illustrated example of FIG. 6, all of the frequencies in a set of frequencies used for the PUCCHs are moved to a new set of frequencies used for PUCCHs.

[0061] In the case of slot aggregation, regardless of whether intra-slot hopping may be turned on or off, inter-slot hopping may be turned on or off independently by a base station. For example, inter-slot hopping may be turned on or off independently by a base station. Inter-slot hopping may be turned on or off via RRC signaling or DCI dynamic signaling. For example, in an aspect, a long PUCCH may only have four symbols per slot. In an example with a long PUCCH that only has four symbols per slot, intra-slot hopping may be turned off. When intra-slot hopping is turned off, inter-slot hopping may still be turned on (or off). Inter-slot hopping may be turned on (or off) via RRC signaling or DCI dynamic signaling. For example, inter-slot hopping may be turned on (or off) to achieve frequency diversity.

[0062] The frequency used to transmit the longer PUCCH may vary. For example, the x-axis in FIG. 6 may be time and the y-axis in FIG. 6 may be frequency. Frequency may increase along the y-axis. For example, the long PUCCH 602 may be at a higher frequency as compared to the long PUCCH 606. For intra-slot hopping, different PUCCHs may change frequency within each long PUCCH 602 and/or a long PUCCH 606. For inter-slot hopping, a set of PUCCH may change frequency. For example, for inter-slot hopping, the long PUCCH may change frequency from the frequencies for the long PUCCH 602 to the frequencies for the long PUCCH 606.

[0063] FIG. 7 is a flowchart 700 of a method of wireless communication. The method may be performed by a UE (e.g., the UE 104, 350). At 702, the UE determines whether or not to use intra-slot frequency hopping for a variable length uplink control channel. For example, the UE (e.g., UE 104, 350) determines whether or not to use intra-slot frequency hopping for a variable length uplink control channel (e.g., Rx Processor 356, Controller/Processor 359, Tx Processor 368).

[0064] At 704, the UE communicates information to the transmitter for transmission over the variable length uplink control channel, the information transmitted by the transmitter based on the determination of whether or not to use intra-slot frequency

hopping. For example, the UE (e.g., the UE 104, 350) communicates information to the transmitter (e.g., transmitter 354TX) for transmission over the variable length uplink control channel, the information transmitted by the transmitter (e.g., transmitter 354TX) based on the determination of whether or not to use intra-slot frequency hopping.

- [0065] In an aspect, the variable length uplink control channel includes a long PUCCH.
- [0066] In an aspect, the transmitter may be configured to transmit the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.
- [0067] In an aspect, determining whether or not to use intra-slot frequency hopping may include determining whether or not to use intra-slot frequency hopping for transmitting data on the variable length uplink control channel based on a duration of the variable length uplink control channel.
- [0068] In an aspect, the variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping may be predetermined.
- [0069] In an aspect, determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel may be based on signaling to enable or disable the variable length uplink control channel hopping.
- [0070] In an aspect, the signaling may include RRC signaling to enable or disable the variable length uplink control channel hopping.
- [0071] In an aspect, the signaling may include DCI signaling to enable or disable the variable length uplink control channel hopping.
- [0072] An aspect may further include using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.
- [0073] FIG. 8 is a flowchart 800 of a method of wireless communication. The method may be performed by a base station (e.g., the base station 102, 180, 310). At 802, the base station determines whether or not to use intra-slot frequency hopping for a variable length uplink control channel. For example, the base station (e.g., base station 102, 180, 310) determines whether or not to use intra-slot frequency hopping for a variable length uplink control channel (e.g., Rx Processor 370, Controller/Processor 375, Tx Processor 316).

- [0074]** At 804, the base station receives information from the receiver, the information received by the receiver over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping. For example, the base station (e.g., base station 102, 180, 310) receives information from the receiver (e.g., receiver 318RX), the information received by the receiver (e.g., receiver 318RX) over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping.
- [0075]** In an aspect, the variable length uplink control channel comprises a long PUCCH.
- [0076]** In an aspect, the receiver may be configured to receive the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.
- [0077]** In an aspect, determining whether or not to use intra-slot frequency hopping may include determining whether or not to use intra-slot frequency hopping for receiving data on the variable length uplink control channel based on a duration of the variable length uplink control channel.
- [0078]** In an aspect, the variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping may be predetermined.
- [0079]** In an aspect, determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel may be based on signaling to enable or disable the variable length uplink control channel hopping.
- [0080]** In an aspect, the signaling may include RRC signaling to enable or disable the variable length uplink control channel hopping.
- [0081]** In an aspect, the signaling may include DCI signaling to enable or disable the variable length uplink control channel hopping.
- [0082]** An aspect may further include using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.
- [0083]** In a UE (e.g., UE 104, 350), the means for determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel may include Rx Processor 356, Controller/Processor 359, Tx Processor 368. The means for communicating information to the transmitter (e.g., transmitter 354TX) for

transmission over the variable length uplink control channel, the information transmitted by the transmitter (e.g., transmitter 354TX) based on the determination of whether or not to use intra-slot frequency hopping may include Rx Processor 356, Controller/Processor 359, Tx Processor 368. The transmitter 354TX and the antenna 352 may be used to transmit the communication information.

[0084] In a base station (e.g., base station 102, 180, 310), the means for determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel may include Rx Processor 370, Controller/Processor 375, Tx Processor 316. The means for receiving information from the receiver (e.g., receiver 318RX) may include Rx Processor 370, Controller/Processor 375, Tx Processor 316. The information may be received by the receiver (e.g., receiver 318RX) over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping. The information may be received by the receiver 318RX and the antenna 320.

[0085] It is understood that the specific order or hierarchy of blocks in the processes / flowcharts disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of blocks in the processes / flowcharts may be rearranged. Further, some blocks may be combined or omitted. The accompanying method claims present elements of the various blocks in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0086] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean “one and only one” unless specifically so stated, but rather “one or more.” The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects. Unless specifically stated otherwise, the term “some” refers to one or more. Combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination

thereof” include any combination of A, B, and/or C, and may include multiples of A, multiples of B, or multiples of C. Specifically, combinations such as “at least one of A, B, or C,” “one or more of A, B, or C,” “at least one of A, B, and C,” “one or more of A, B, and C,” and “A, B, C, or any combination thereof” may be A only, B only, C only, A and B, A and C, B and C, or A and B and C, where any such combinations may contain one or more member or members of A, B, or C. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. The words “module,” “mechanism,” “element,” “device,” and the like may not be a substitute for the word “means.” As such, no claim element is to be construed as a means plus function unless the element is expressly recited using the phrase “means for.”

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus for wireless communication, comprising:
a transmitter; and
a processing system configured to:
determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and
communicate information to the transmitter for transmission over the variable length uplink control channel, the information transmitted by the transmitter based on the determination of whether or not to use intra-slot frequency hopping.
2. The apparatus of claim 1, wherein the variable length uplink control channel comprises a long physical uplink control channel (PUCCH).
3. The apparatus of claim 1, wherein the transmitter is configured to transmit the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.
4. The apparatus of claim 3, wherein determining whether or not to use intra-slot frequency hopping comprises determining whether or not to use intra-slot frequency hopping for transmitting data on the variable length uplink control channel based on a duration of the variable length uplink control channel.
5. The apparatus of claim 4, wherein variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping are predetermined.

6. The apparatus of claim 3, wherein determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel is based on signaling to enable or disable the variable length uplink control channel hopping.
7. The apparatus of claim 6, wherein the signaling comprises Radio Resource Control (RRC) signaling to enable or disable the variable length uplink control channel hopping or the signaling comprises downlink control information (DCI) signaling to enable or disable the variable length uplink control channel hopping.
8. The apparatus of claim 1, further comprising using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.
9. An apparatus for wireless communication, comprising:
 - a receiver; and
 - a processing system configured to:
 - determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and
 - receive information from the receiver, the information received by the receiver over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping.
10. The apparatus of claim 9, wherein the variable length uplink control channel comprises a long physical uplink control channel (PUCCH).
11. The apparatus of claim 9, wherein the receiver is configured to receive the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.

12. The apparatus of claim 11, wherein determining whether or not to use intra-slot frequency hopping comprises determining whether or not to use intra-slot frequency hopping for receiving data on the variable length uplink control channel based on a duration of the variable length uplink control channel.

13. The apparatus of claim 12, wherein variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping are predetermined.

14. The apparatus of claim 12, wherein determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel is based on signaling to enable or disable the variable length uplink control channel hopping.

15. The apparatus of claim 14, wherein the signaling comprises Radio Resource Control (RRC) signaling to enable or disable the variable length uplink control channel hopping or the signaling comprises downlink control information (DCI) signaling to enable or disable the variable length uplink control channel hopping.

16. The apparatus of claim 12, further comprising using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.

17. A method of wireless communication, comprising:
determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and
communicating information to the transmitter for transmission over the variable length uplink control channel, the information transmitted by the transmitter based on the determination of whether or not to use intra-slot frequency hopping.

18. The method of claim 17, wherein the variable length uplink control channel comprises a long physical uplink control channel (PUCCH).

19. The method of claim 17, wherein the transmitter is configured to transmit the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.

20. The method of claim 19, wherein determining whether or not to use intra-slot frequency hopping comprises determining whether or not to use intra-slot frequency hopping for transmitting data on the variable length uplink control channel based on a duration of the variable length uplink control channel.

21. The method of claim 20, wherein variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping are predetermined.

22. The method of claim 19, wherein determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel is based on signaling to enable or disable the variable length uplink control channel hopping.

23. The method of claim 22, wherein the signaling comprises at least one of Radio Resource Control (RRC) signaling to enable or disable the variable length uplink control channel hopping or downlink control information (DCI) signaling to enable or disable the variable length uplink control channel hopping.

24. The method of claim 17, further comprising using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.

25. A method of wireless communication, comprising:
determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and

receiving information from the receiver, the information received by the receiver over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping.

26. The method of claim 25, wherein the variable length uplink control channel comprises a long physical uplink control channel (PUCCH).

27. The method of claim 25, wherein the receiver is configured to receive the information in a slot on the variable length uplink control channel using a single frequency or intra-slot frequency hopping based on the determination of whether or not to use intra-slot frequency hopping.

28. The method of claim 27, wherein determining whether or not to use intra-slot frequency hopping comprises determining whether or not to use intra-slot frequency hopping for receiving data on the variable length uplink control channel based on a duration of the variable length uplink control channel.

29. The method of claim 28, wherein variable length uplink control channel durations using intra-slot frequency hopping and the variable length uplink control channel durations not using intra-slot frequency hopping are predetermined.

30. The method of claim 28, wherein determining whether or not to use intra-slot frequency hopping for the variable length uplink control channel is based on signaling to enable or disable the variable length uplink control channel hopping.

31. The method of claim 30, wherein the signaling comprises at least one of Radio Resource Control (RRC) signaling to enable or disable the variable length uplink control channel hopping or downlink control information (DCI) signaling to enable or disable the variable length uplink control channel hopping.

32. The method of claim 25, further comprising using one of Radio Resource Control (RRC) or downlink control information (DCI) signaling to change the state of inter-slot hopping.

33. An apparatus for wireless communication, comprising:

means for determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and

means for communicating information to the transmitter for transmission over the variable length uplink control channel, the information transmitted by the transmitter based on the determination of whether or not to use intra-slot frequency hopping.

25. An apparatus for wireless communication, comprising:

means for determining whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and

means for receiving information from the receiver, the information received by the receiver over the variable length uplink control channel based on the determination of whether or not to use intra-slot frequency hopping.

ABSTRACT

The duration of variable length uplink control channels may vary over a wide range. Transmissions related to overhead may take up a larger percentage of symbols for shorter durations of the variable length uplink control channel. Disabling intra-slot hopping may be beneficial to decrease overhead (as a percentage). The apparatus may be an apparatus for wireless communication. The apparatus may include a transmitter or receiver and a processing system. The processing system may be configured to determine whether or not to use intra-slot frequency hopping for a variable length uplink control channel, and communicate information to the transmitter for transmission over the variable length uplink control channel or receive information from the receiver received over the variable length uplink control channel, the information transmitted by the transmitter or received by the receiver based on the determination of whether or not to use intra-slot frequency hopping.

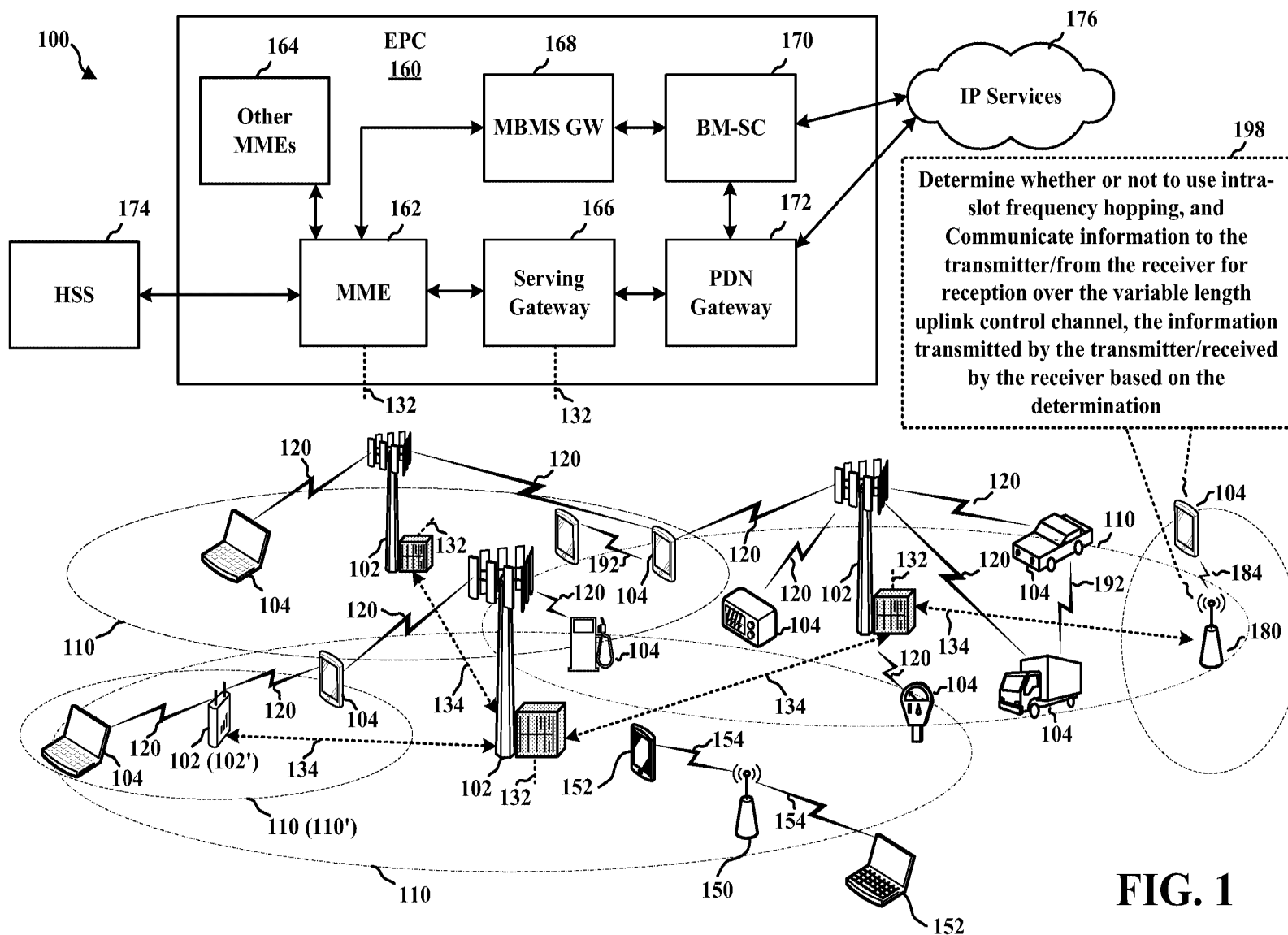


FIG. 1

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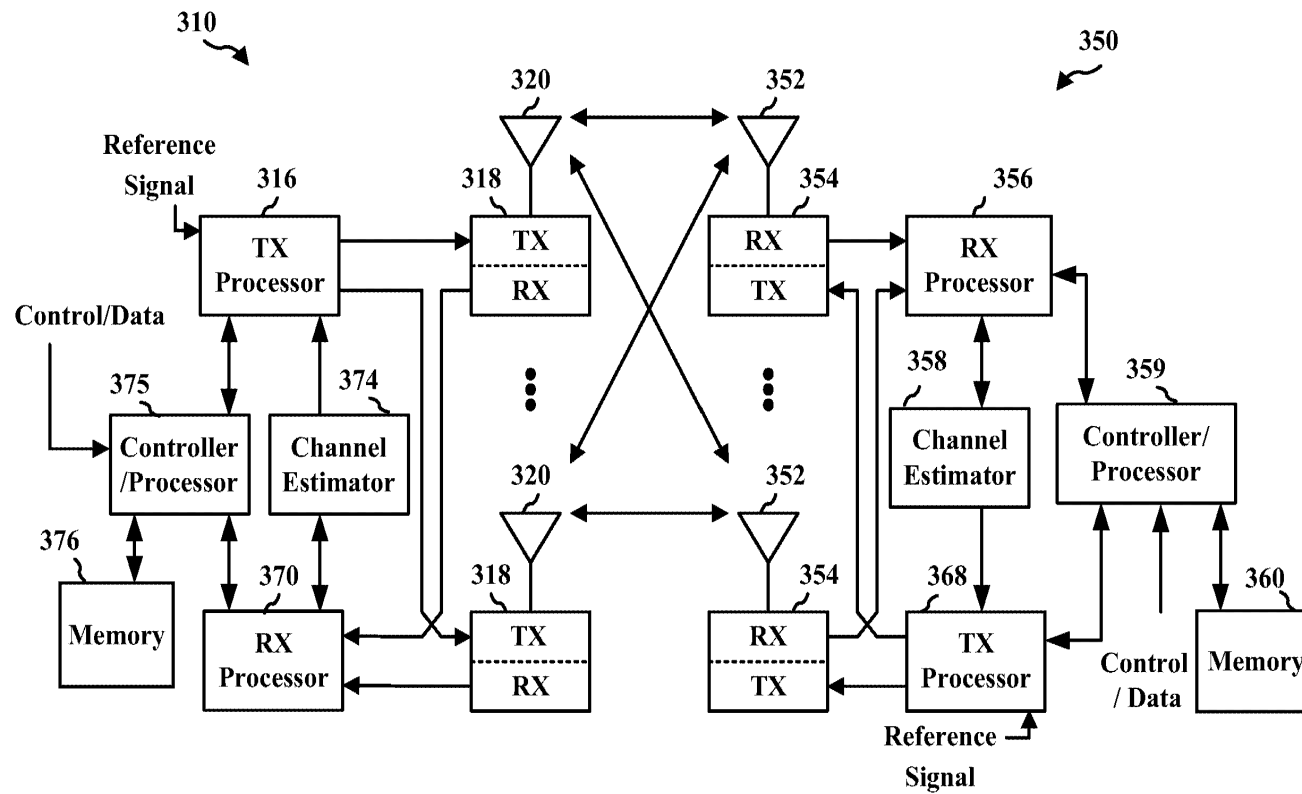


FIG. 3

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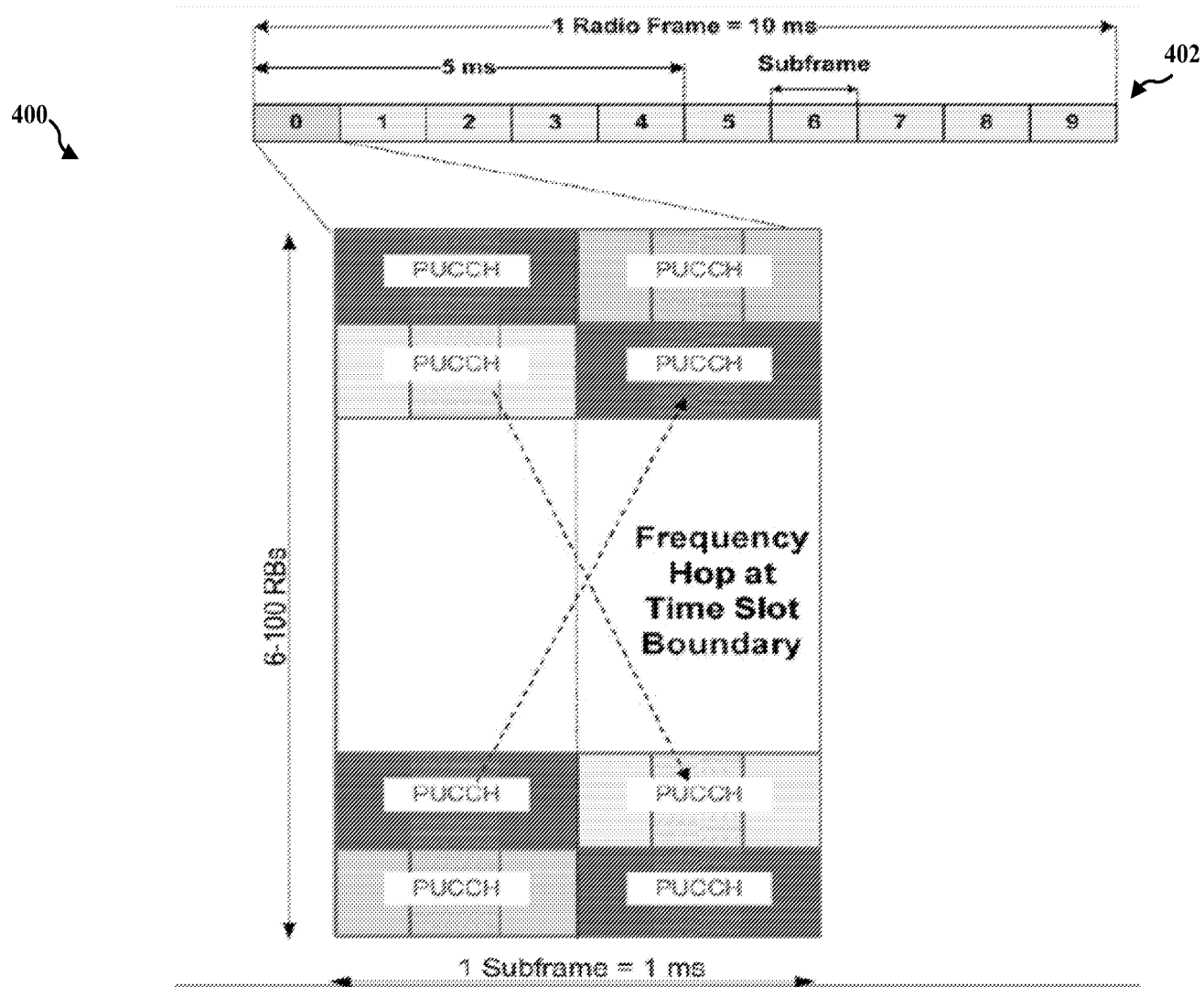


FIG. 4

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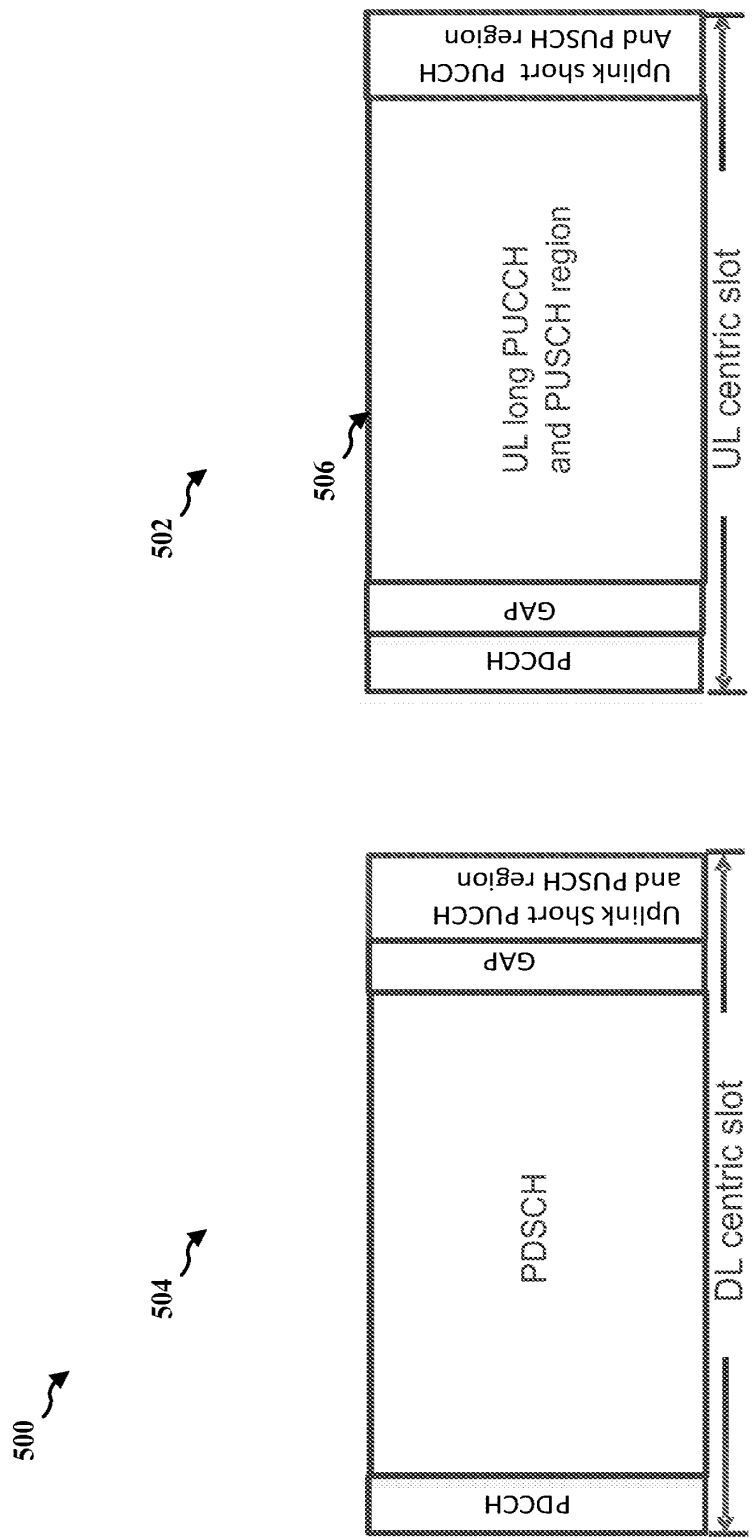


FIG. 5

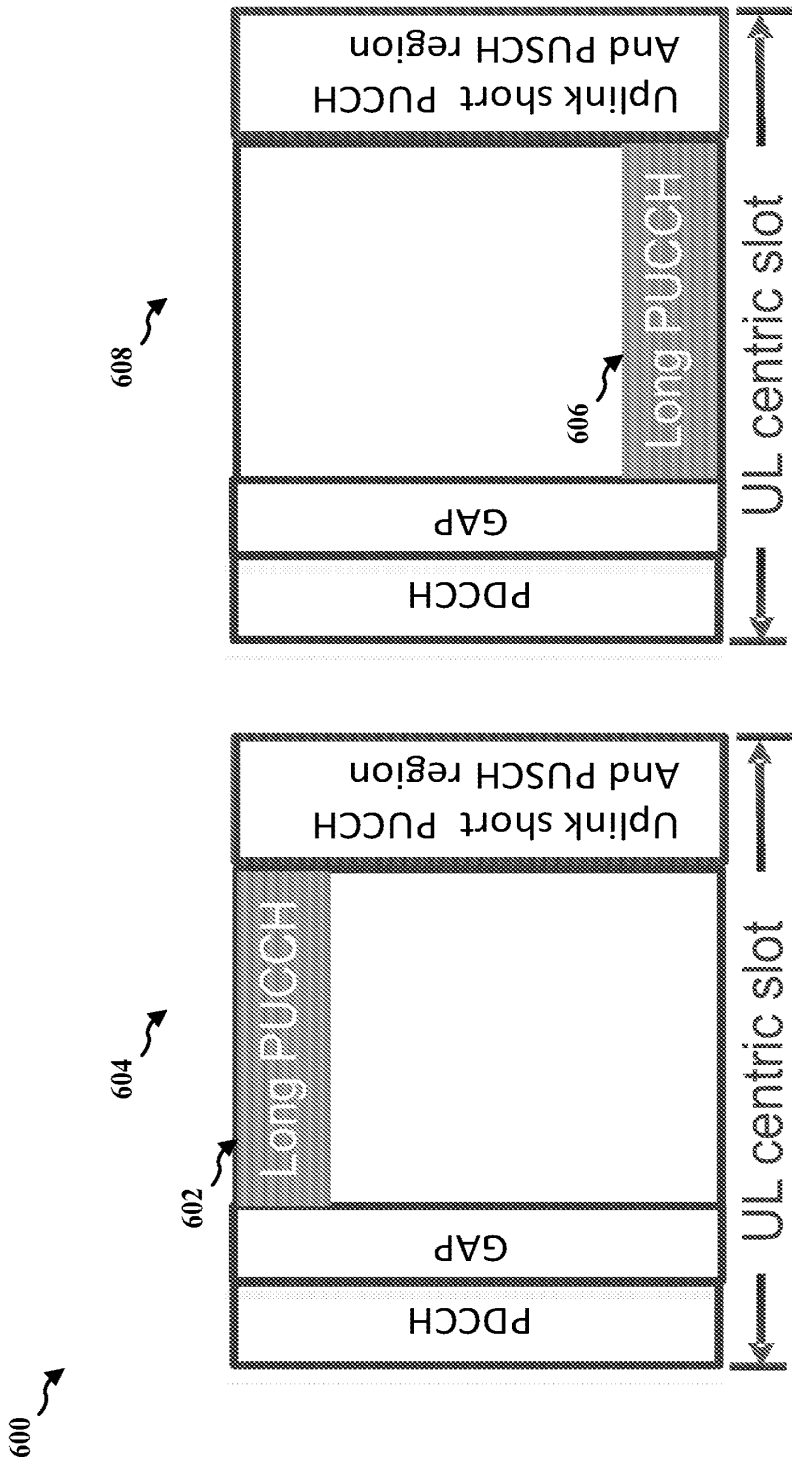


FIG. 6

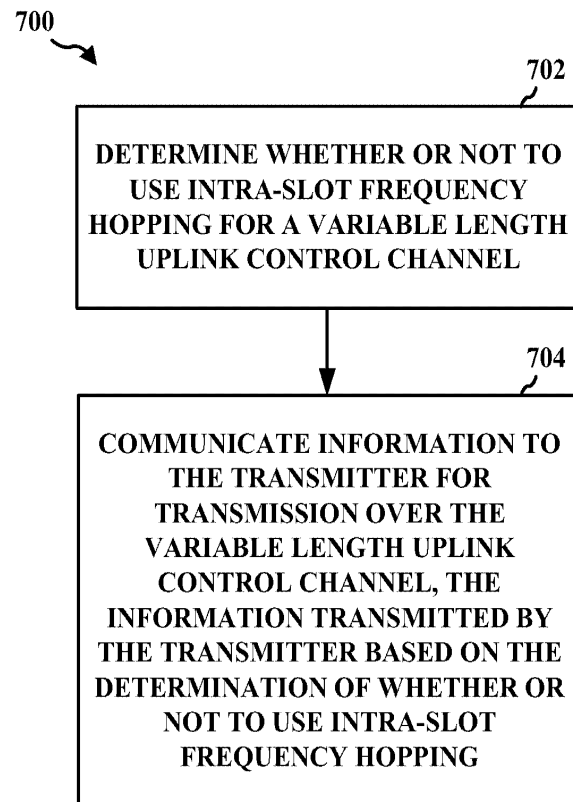


FIG. 7

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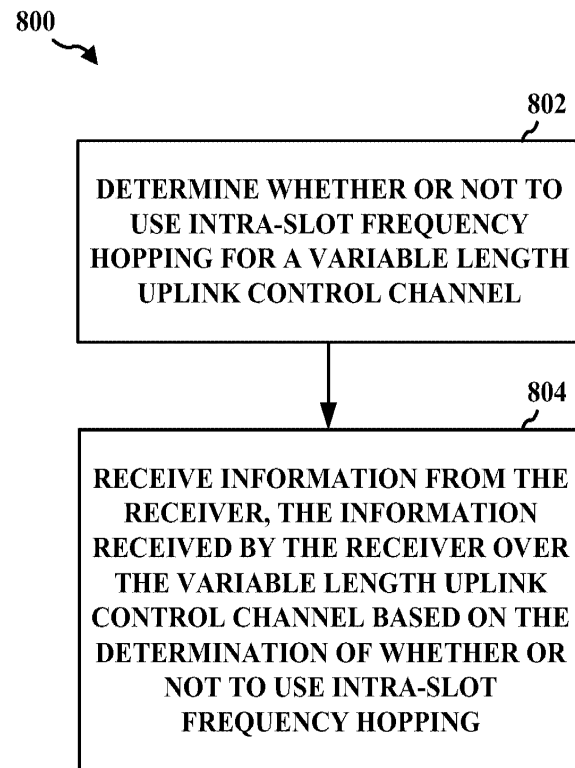


FIG. 8

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Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL		
First Named Inventor/Applicant Name:		YI HUANG		
Filer:		Jonas J. Hodges/Rebecca Golden		
Attorney Docket Number:		030284.14639/ 173996P1		
Filed as Large Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
PROVISIONAL APPLICATION FILING	1005	1	260	260
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 (\$)				260

Electronic Acknowledgement Receipt	
EFS ID:	29122556
Application Number:	62501681
International Application Number:	
Confirmation Number:	2200
Title of Invention:	CONFIGURABLE INTRA-SLOT FREQUENCY HOPPING FOR A VARIABLE LENGTH UPLINK CONTROL CHANNEL
First Named Inventor/Applicant Name:	Yi HUANG
Customer Number:	15142
Filer:	Jonas J. Hodges/Rebecca Golden
Filer Authorized By:	Jonas J. Hodges
Attorney Docket Number:	030284.14639/ 173996P1
Receipt Date:	04-MAY-2017
Filing Date:	
Time Stamp:	20:41:39
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$260
RAM confirmation Number	050517INTEFSW20422200
Deposit Account	012300
Authorized User	Rebecca Golden
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	173996P1_POA.pdf	1089479	no	2
			1dbf4ee85777b7cfa344cf4877502bba244d821c		
Warnings:					
Information:					
2	Application Data Sheet	173996P1_ADS.pdf	1814437	no	9
			d774157c63258a3caccd5ded6b98295a6cd667e7		
Warnings:					
Information:					
3		173996P1_Specification.pdf	265667	yes	30
			3e1e661673b1ebaa3183adc43898552a5973499		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	23	
	Claims		24	29	
	Abstract		30	30	
Warnings:					
Information:					
4	Drawings-other than black and white line drawings	173996P1_Drawings.pdf	1036349	no	8
			548add267b0c27821310d7f837d9493eb2a14c65		
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	30104	no	2
			581b397041cb4264c02ba2d3c8f1af1806bcb23		

Warnings:	
Information:	
Total Files Size (in bytes):	4236036
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Application Number: 62501681

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