

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Ko-Chiang Lin; Li-Chih Tseng; Meng-Hui Ou and Yu-Hsuan Guo
Title: METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION
USING A CONFIGURED RESOURCE IN A WIRELESS
COMMUNICATION SYSTEM
Serial No.: TBD Filed: Herewith
Examiner: TBD Group Art Unit: TBD
Attorney Docket No.: 1426-113.001 (1050051-US-1)

**CERTIFICATE OF EFS-WEB TRANSMISSION
UNDER 37 CFR § 1.8**

I hereby certify that the enclosed 2 Page Provisional Application Cover Sheet; 8 Page
WebADS; 52 Page Specification; and 5 Page Drawings; are being transmitted to the United
States Patent and Trademark Office via EFS-Web on April 1, 2016.

Date: April 1, 2016 /Sandy Kim/
Sandy Kim

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Electronic Patent Application Fee Transmittal					
Application Number:					
Filing Date:					
Title of Invention:		METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM			
First Named Inventor/Applicant Name:		Ko-Chiang Lin			
Filer:		Sang N. Dang			
Attorney Docket Number:		1426-113.001			
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:	25371235
Application Number:	62316799
International Application Number:	
Confirmation Number:	1085
Title of Invention:	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM
First Named Inventor/Applicant Name:	Ko-Chiang Lin
Customer Number:	106622
Filer:	Sang N. Dang
Filer Authorized By:	
Attorney Docket Number:	1426-113.001
Receipt Date:	01-APR-2016
Filing Date:	
Time Stamp:	13:49:10
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	\$260
RAM confirmation Number	75
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	144704	no	8
			2f43fa591dcf53018efe2b4fa7a31d7abcb0fe1193		
Warnings:					
Information:					
2		1426-113-001--Package.pdf	794976	yes	60
			0172183bbcc6a4ee8b64565b33f7800c028e1193		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Provisional Cover Sheet (SB16)		1	2	
	Specification		3	50	
	Drawings-only black and white line drawings		51	51	
	Specification		52	56	
	Drawings-only black and white line drawings		57	59	
	Miscellaneous Incoming Letter		60	60	
	Warnings:				
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	29918	no	2
			c3950d3ed002ae621d0c55f5f943380b6b9c1e43		
Warnings:					
Information:					
Total Files Size (in bytes):			969598		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

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

Inventor 1				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Ko-Chiang		Lin	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
City	Taipei City	Country of Residence ⁱ	TW	
Mailing Address of Inventor:				
Address 1	No. 15, Lite Rd., Peitou District			
Address 2				
City	Taipei City 112	State/Province	OT	
Postal Code		Country ⁱ	TW	
Inventor 2				
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Li-Chih		Tseng	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
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Mailing Address of Inventor:				
Address 1	No. 15, Lite Rd., Peitou District			
Address 2				
City	Taipei City 112	State/Province	OT	
Postal Code		Country ⁱ	TW	
Inventor 3				
Legal Name				

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Meng-Hui		Ou	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				

City	Taipei City	Country of Residence ⁱ	TW
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Mailing Address of Inventor:

Address 1	No. 15, Lite Rd., Peitou District		
Address 2			
City	Taipei City 112	State/Province	OT
Postal Code		Country ⁱ	TW

Inventor 4

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Yu-Hsuan		Guo	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				

City	Taipei City	Country of Residence ⁱ	TW
-------------	-------------	--	----

Mailing Address of Inventor:

Address 1	No. 15, Lite Rd., Peitou District		
Address 2			
City	Taipei City 112	State/Province	OT
Postal Code		Country ⁱ	TW

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

Add**Correspondence Information:**

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence Information of this application.

Customer Number	106622		
Email Address		Add Email	Remove Email

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

Application Information:

Title of the Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		
Attorney Docket Number	1426-113.001	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	5	Suggested Figure for Publication (if any)	

Filing By Reference:

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

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

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

Publication Information:

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

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	106622				
Prefix	Given Name	Middle Name	Family Name	Suffix	Remove
Registration Number					

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	1426-113.001	
		Application Number		
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM			
Prefix	Given Name	Middle Name	Family Name	Suffix
Remove				
Registration Number				
Additional Representative Information blocks may be generated within this form by selecting the Add button.				

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 this 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 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.			

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) 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 ^l (if applicable)
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	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

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.

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	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

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			
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	ASUSTeK Computer Inc.		
Mailing Address Information For Applicant:			
Address 1	No. 15, Lite Rd., Peitou District		
Address 2			
City	Taipei City 112	State/Province	OT
Country ¹	TW	Postal Code	
Phone Number		Fax Number	
Email Address			
Additional Applicant Data may be generated within this form by selecting the Add button.			

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

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.

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.				
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.				

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1426-113.001
		Application Number	
Title of Invention	METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		

Signature:

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	/Sang N. Dang/			Date (YYYY-MM-DD)	
First Name	Sang N.	Last Name	Dang	Registration Number	51186
Additional Signature may be generated within this form by selecting the Add button.					

PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

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

Express Mail Label No. _____

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Ko-Chiang	Lin	Taipei City, Taiwan
Li-Chih	Tseng	Taipei City, Taiwan
Meng-Hui	Ou	Taipei City, Taiwan
Yu-Hsuan	Guo	Taipei City, Taiwan
Additional inventors are being named on the _____ separately numbered sheets attached hereto.		
TITLE OF THE INVENTION (500 characters max):		
METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED RESOURCE IN A WIRELESS COMMUNICATION SYSTEM		
Direct all correspondence to: CORRESPONDENCE ADDRESS		
☒ The address corresponding to Customer Number: 106622		
OR		
☐ Firm or Individual Name		
Address		
City	State	Zip
Country	Telephone	Email
ENCLOSED APPLICATION PARTS (check all that apply)		
☒ Application Data Sheet. See 37 CFR 1.76.		
☐ CD(s), Number of CDs _____		
☒ Drawing(s) Number of Sheets <u>5</u>		
☐ Other (specify) _____		
☒ Specification (e.g., description of the invention) Number of Pages <u>52</u>		
Fees Due: Filing Fee of \$260 (\$130 for small entity) (\$65 for micro entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is \$400 (\$200 for small entity) (\$100 for micro entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).		
METHOD OF PAYMENT OF THE FILING FEE AND APPLICATION SIZE FEE FOR THIS PROVISIONAL APPLICATION FOR PATENT		
☐ Applicant asserts small entity status. See 37 CFR 1.27.		
☐ Applicant certifies micro entity status. See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.		
☐ A check or money order made payable to the <i>Director of the United States Patent and Trademark Office</i> is enclosed to cover the filing fee and application size fee (if applicable).		
☒ Payment by credit card. Form PTO-2038 is attached.		
☐ The Director is hereby authorized to charge the filing fee and application size fee (if applicable) or credit any overpayment to Deposit Account Number: _____		
260.00 TOTAL FEE AMOUNT (\$)		

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 10 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **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.

PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 2 of 2

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.☐ Yes, the invention was made by an agency of the U.S. Government. The U.S. Government agency name is: _____☐ Yes, the invention was made under a contract with an agency of the U.S. Government. The name of the U.S. Government agency and Government contract number are: _____**WARNING:**

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

SIGNATURE /Sang N.Dang/ DATE April 1, 2016TYPED OR PRINTED NAME Sang N. Dang REGISTRATION NO. 51,186
(if appropriate)TELEPHONE (714) 839-3800 DOCKET NUMBER 1426-113.001

Method and apparatus for improving a transmission using a configured resource in a wireless communication system

Background

Table of abbreviations:

Abbreviation	Full name
3GPP	3 rd Generation Partnership Project
ACK	acknowledgement
BSR	buffer status report
C-RNTI	Cell Radio Network Temporary Identifier
CQI	channel quality indicator
eIMTA	Enhanced Interference Mitigation and Traffic Adaptation
eNB	Evolved Node B
E-UTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic Repeat Request
L1	Layer 1
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MAC	Medium Access Control
NACK	negative acknowledgement
NDI	New data indicator
OFDM	Orthogonal Frequency Division Multiplexing
PDCCH	Physical Downlink Control Channel
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RN	Relay Node
RRC	Radio Resource Control
SDU	Service Data Unit
SFN	System Frame Number
SpCell	Special Cell
SPS	Semi-Persistent Scheduling
SR	Scheduling Request
SRS	Sounding Reference Signal
TAG	Timing Advance Group
TDD	Time Division Duplex
TS	Technical Specification
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel

Packet data latency is one of the important metrics for performance evaluation. Reducing packet data

latency improves the system performance. In RP-150465 [1], the study item “study on latency reduction techniques for LTE” aims to investigate and standardize some techniques of latency reduction.

According to RP-150465 [1], the objective of the study item is to study enhancements to the E-UTRAN radio system in order to significantly reduce the packet data latency over the LTE Uu air interface for an active UE and significantly reduce the packet data transport round trip latency for UEs that have been inactive for a longer period (in connected state). The study area includes resource efficiency, including air interface capacity, battery lifetime, control channel resources, specification impact and technical feasibility. Both FDD and TDD duplex modes are considered.

According to RP-150465 [1], two areas should be studied and documented:

- Fast uplink access solutions
for active UEs and UEs that have been inactive a longer time, but are kept in RRC Connected, focus should be on reducing user plane latency for the scheduled UL transmission and getting a more resource efficient solution with protocol and signaling enhancements, compared to the pre-scheduling solutions allowed by the standard today, both with and without preserving the current TTI length and processing times
- TTI shortening and reduced processing times
Assess specification impact and study feasibility and performance of TTI lengths between 0.5ms and one OFDM symbol, taking into account impact on reference signals and physical layer control signaling

Figure 1 is quoted from RP-150310 [2]. It illustrates the improvement corresponding to the areas.

In RP-150310 [2], a candidate of fast uplink access solutions was raised:

- Pre-grant → fast uplink access but with limited throughput
Resources can be allocated with (modified) SPS
- Remove the requirement to send padding when no data is in buffer → saves battery resources when inactive
Good throughput per watt statistics
- Switch to dynamic scheduling when entering active phase → optimizing throughput when having lot of data in send buffer

Detailed result of the study can be found in [6] as quoted below, which confirmed that it is beneficial to skip the configured grant if there is no data or regular MAC CE to be sent:

8.1 Semi-Persistent Scheduling

With current Semi-Persistent Scheduling (SPS), the eNodeB may configure SPS periodicity via dedicated RRC signalling. Current minimum SPS periodicity is 10ms. Supporting a SPS periodicity of 1TTI is beneficial as this may reduce the latency of initial UL transmissions. This would allow UL transmission in consecutive subframes.

8.2 UL Grant reception

In current specifications, the UE sends a MAC PDU containing a MAC CE for padding BSR and optionally padding bits in response to an allocated UL dynamic or configured grant even if no data is available for transmission in the UE buffer and no other regular MAC CE is needed to be sent. It is beneficial to allow UEs to skip (most) dynamic and configured uplink grants if no data is available for transmission. With frequent UL grants, allowing skipping UL grants may decrease UL interference and improve UE battery efficiency. The UE will continue to send one or more regular MAC CE(s), if any. The eNB may enable skipping UL grants by RRC dedicated signalling.

8.2.1 Configured SPS activation and deactivation

The SPS resources are UE specific and may be reserved (configured and active) for a longer period in time. As such, it is in some cases considered useful for the eNB to be timely aligned with the UE state on activated or deactivated SPS resource(s), and if UL transmissions might occur in the granted SPS resource allocation instances.

An acknowledgement in response to a PDCCH grant indication activation could for example consist of an UE transmitted new MAC PDU containing zero MAC SDUs on the first SPS granted resource to indicate successful activation when the UE buffer is empty.

If the PDCCH grant indicating activation is not received, and UE has UL data to be transmitted, it is assumed that the UE would initiate a SR procedure if no other action is performed by the eNB.

For Deactivation, the eNB can indicate release of SPS resources on PDCCH. Also in these cases the eNB would in some cases benefit from being timely aligned with the UE state on activate or deactivated SPS resource(s).

Similarly to activation, a single transmission could be used also as deactivation acknowledgement as in instances of skipped transmissions as the absence of a UL transmission cannot be used as an implicit deactivation/release acknowledgement mechanism. Other means may thus be beneficial to specify.

Acknowledgment based Pro's

- 1 With an acknowledgment on the PDCCH grant activating or deactivating the SPS allocation, the eNB may be able to distinguish from cases where the PDCCH is missed by the UE.
- 2 With a higher degree of robustness of the activation/deactivation mechanism, the eNB may not have to repeat unnecessarily the SPS grant.
- 3 A activation and deactivation acknowledgement mechanism may allow for less conservative use of preconfigured SPS resources and may allow decreased PDCCH load as lower aggregation level can be used.
- 4 An acknowledged activation/deactivation of the SPS grant resources may reduce DRX misalignment.

Acknowledgement based Con's

- 1 Unnecessary UE battery consumption in instances of empty UE buffer at activation/deactivation;
- 2 DRX impacted by the additional UL transmission including the HARQ wait time (handling of inactivity timer /short cycle timer)
- 3 Increased uplink interference in instances where the SPS allocation is changed due to e.g. PDCCH activation/deactivation and where the UE buffer is empty.
- 4 New UE behaviour needed for deactivation/release acknowledgment.
- 5 DRX misalignment probability may be increased due to loss of ACK compared to if ACK is received correctly

- 6 SPS resources may be unused for a duration as a result of a missing ACK after successful PDCCH reception.

Acknowledgement free Pro's

- 1 Relies on the legacy behaviour that the UE in the rare cases of PDCCH loss (e.g. 1%) and non-empty buffer may initiate a SR procedure (alt. RACH procedure). The eNB may then re-initialise SPS or allocate a dynamic grant for the UE to compensate the PDCCH loss.
- 2 No additional UL transmissions that may cause interference in instances where the SPS allocation is changed due to e.g. PDCCH activation/deactivation and the UE buffer is empty.
- 3 UE may go earlier to DRX
- 4 UE behaviour simplified and no new behaviour at deactivation is needed.

Acknowledgement free Con's

- 1 Increased PDCCH aggregation level may need to be used which increases the PDCCH resource usage
- 2 SPS resources may be unused until a SR procedure has been initiated by the UE missing the PDCCH
- 3 SPS deactivation on PDCCH may need repetition to have robust SPS resource release
- 4 SPS resources are not released after release indication and are only detected at first periodic grant allocation opportunity after the release signalling time instance.

In the current 3GPP E-UTRA MAC specification [3], semi-persistent scheduling operates as below:

5.10 Semi-Persistent Scheduling

When Semi-Persistent Scheduling is enabled by RRC, the following information is provided [8]:

- Semi-Persistent Scheduling C-RNTI;
- Uplink Semi-Persistent Scheduling interval *semiPersistSchedIntervalUL* and number of empty transmissions before implicit release *implicitReleaseAfter*, if Semi-Persistent Scheduling is enabled for the uplink;
- Whether *twoIntervalsConfig* is enabled or disabled for uplink, only for TDD;
- Downlink Semi-Persistent Scheduling interval *semiPersistSchedIntervalDL* and number of configured HARQ processes for Semi-Persistent Scheduling *numberOfConfSPS-Processes*, if Semi-Persistent Scheduling is enabled for the downlink;

When Semi-Persistent Scheduling for uplink or downlink is disabled by RRC, the corresponding configured grant or configured assignment shall be discarded.

Semi-Persistent Scheduling is supported on the SpCell only.

Semi-Persistent Scheduling is not supported for RN communication with the E-UTRAN in combination with an RN subframe configuration.

- NOTE: When eIMTA is configured for the SpCell, if a configured uplink grant or a configured downlink assignment occurs on a subframe that can be reconfigured through eIMTA L1 signalling, then the UE behaviour is left unspecified.

5.10.1 Downlink

After a Semi-Persistent downlink assignment is configured, the MAC entity shall consider sequentially that the N^{th} assignment occurs in the subframe for which:

- $(10 * \text{SFN} + \text{subframe}) = [(10 * \text{SFN}_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * \text{semiPersistSchedIntervalDL}] \text{ modulo } 10240.$

Where $\text{SFN}_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ are the SFN and subframe, respectively, at the time the configured downlink assignment were (re-)initialised.

5.10.2 Uplink

After a Semi-Persistent Scheduling uplink grant is configured, the MAC entity shall:

- if *twoIntervalsConfig* is enabled by upper layer:
 - set the *Subframe_Offset* according to Table 7.4-1.
- else:
 - set *Subframe_Offset* to 0.
- consider sequentially that the N^{th} grant occurs in the subframe for which:
 - $(10 * \text{SFN} + \text{subframe}) = [(10 * \text{SFN}_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * \text{semiPersistSchedIntervalUL} + \text{Subframe_Offset} * (N \text{ modulo } 2)] \text{ modulo } 10240.$

Where $\text{SFN}_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ are the SFN and subframe, respectively, at the time the configured uplink grant were (re-)initialised.

The MAC entity shall clear the configured uplink grant immediately after *implicitReleaseAfter* [8] number of consecutive new MAC PDUs each containing zero MAC SDUs have been provided by the Multiplexing and Assembly entity, on the Semi-Persistent Scheduling resource.

NOTE: Retransmissions for Semi-Persistent Scheduling can continue after clearing the configured uplink grant.

5.4.1 UL Grant reception

In order to transmit on the UL-SCH the MAC entity must have a valid uplink grant (except for non-adaptive HARQ retransmissions) which it may receive dynamically on the PDCCH or in a Random Access Response or which may be configured semi-persistently. To perform requested transmissions, the MAC layer receives HARQ information from lower layers. When the physical layer is configured for uplink spatial multiplexing, the MAC layer can receive up to two grants (one per HARQ process) for the same TTI from lower layers.

If the MAC entity has a C-RNTI, a Semi-Persistent Scheduling C-RNTI, or a Temporary C-RNTI, the MAC entity shall for each TTI and for each Serving Cell belonging to a TAG that has a running *timeAlignmentTimer* and for each grant received for this TTI:

- if an uplink grant for this TTI and this Serving Cell has been received on the PDCCH for the MAC entity's C-RNTI or Temporary C-RNTI; or
- if an uplink grant for this TTI has been received in a Random Access Response:

- if the uplink grant is for MAC entity's C-RNTI and if the previous uplink grant delivered to the HARQ entity for the same HARQ process was either an uplink grant received for the MAC entity's Semi-Persistent Scheduling C-RNTI or a configured uplink grant:
 - consider the NDI to have been toggled for the corresponding HARQ process regardless of the value of the NDI.
- deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if this Serving Cell is the SpCell and if an uplink grant for this TTI has been received for the SpCell on the PDCCH of the SpCell for the MAC entity's Semi-Persistent Scheduling C-RNTI:
 - if the NDI in the received HARQ information is 1:
 - consider the NDI for the corresponding HARQ process not to have been toggled;
 - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
 - else if the NDI in the received HARQ information is 0:
 - if PDCCH contents indicate SPS release:
 - clear the configured uplink grant (if any).
 - else:
 - store the uplink grant and the associated HARQ information as configured uplink grant;
 - initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI and to recur according to rules in subclause 5.10.2;
 - consider the NDI bit for the corresponding HARQ process to have been toggled;
 - deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if this Serving Cell is the SpCell and an uplink grant for this TTI has been configured for the SpCell:
 - consider the NDI bit for the corresponding HARQ process to have been toggled;
 - deliver the configured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

NOTE: The period of configured uplink grants is expressed in TTIs.

NOTE: If the MAC entity receives both a grant in a Random Access Response and a grant for its C-RNTI or Semi persistent scheduling C-RNTI requiring transmissions on the SpCell in the same UL subframe, the MAC entity may choose to continue with either the grant for its RA-RNTI or the grant for its C-RNTI or Semi persistent scheduling C-RNTI.

NOTE: When a configured uplink grant is indicated during a measurement gap and indicates an UL-SCH transmission during a measurement gap, the MAC entity processes the grant but does not transmit on UL-SCH.

Details of UL HARQ operation can be found below:

5.4.2 HARQ operation

5.4.2.1 HARQ entity

There is one HARQ entity at the MAC entity for each Serving Cell with configured uplink, which maintains a number of parallel HARQ processes allowing transmissions to take place continuously while waiting for the HARQ feedback on the successful or unsuccessful reception of previous transmissions.

The number of parallel HARQ processes per HARQ entity is specified in [2], clause 8.

When the physical layer is configured for uplink spatial multiplexing [2], there are two HARQ processes associated with a given TTI. Otherwise there is one HARQ process associated with a given TTI.

At a given TTI, if an uplink grant is indicated for the TTI, the HARQ entity identifies the HARQ process(es) for which a transmission should take place. It also routes the received HARQ feedback (ACK/NACK information), MCS and resource, relayed by the physical layer, to the appropriate HARQ process(es).

When TTI bundling is configured, the parameter TTI_BUNDLE_SIZE provides the number of TTIs of a TTI bundle. TTI bundling operation relies on the HARQ entity for invoking the same HARQ process for each transmission that is part of the same bundle. Within a bundle HARQ retransmissions are non-adaptive and triggered without waiting for feedback from previous transmissions according to TTI_BUNDLE_SIZE. The HARQ feedback of a bundle is only received for the last TTI of the bundle (i.e the TTI corresponding to TTI_BUNDLE_SIZE), regardless of whether a transmission in that TTI takes place or not (e.g. when a measurement gap occurs). A retransmission of a TTI bundle is also a TTI bundle. TTI bundling is not supported when the MAC entity is configured with one or more SCells with configured uplink.

TTI bundling is not supported for RN communication with the E-UTRAN in combination with an RN subframe configuration.

For transmission of Msg3 during Random Access (see subclause 5.1.5) TTI bundling does not apply.

For each TTI, the HARQ entity shall:

- identify the HARQ process(es) associated with this TTI, and for each identified HARQ process:
 - if an uplink grant has been indicated for this process and this TTI:
 - if the received grant was not addressed to a Temporary C-RNTI on PDCCH and if the NDI provided in the associated HARQ information has been toggled compared to the value in the previous transmission of this HARQ process; or
 - if the uplink grant was received on PDCCH for the C-RNTI and the HARQ buffer of the identified process is empty; or
 - if the uplink grant was received in a Random Access Response:
 - if there is a MAC PDU in the Msg3 buffer and the uplink grant was received in a Random Access Response:
 - obtain the MAC PDU to transmit from the Msg3 buffer.
 - else:
 - obtain the MAC PDU to transmit from the "Multiplexing and assembly" entity;
 - deliver the MAC PDU and the uplink grant and the HARQ information to the identified HARQ process;
 - instruct the identified HARQ process to trigger a new transmission.

- else:
 - deliver the uplink grant and the HARQ information (redundancy version) to the identified HARQ process;
 - instruct the identified HARQ process to generate an adaptive retransmission.
- else, if the HARQ buffer of this HARQ process is not empty:
 - instruct the identified HARQ process to generate a non-adaptive retransmission.

When determining if NDI has been toggled compared to the value in the previous transmission the MAC entity shall ignore NDI received in all uplink grants on PDCCH for its Temporary C-RNTI.

5.4.2.2 HARQ process

Each HARQ process is associated with a HARQ buffer.

Each HARQ process shall maintain a state variable *CURRENT_TX_NB*, which indicates the number of transmissions that have taken place for the MAC PDU currently in the buffer, and a state variable *HARQ_FEEDBACK*, which indicates the HARQ feedback for the MAC PDU currently in the buffer. When the HARQ process is established, *CURRENT_TX_NB* shall be initialized to 0.

The sequence of redundancy versions is 0, 2, 3, 1. The variable *CURRENT_IRV* is an index into the sequence of redundancy versions. This variable is up-dated modulo 4.

New transmissions are performed on the resource and with the MCS indicated on PDCCH or Random Access Response. Adaptive retransmissions are performed on the resource and, if provided, with the MCS indicated on PDCCH. Non-adaptive retransmission is performed on the same resource and with the same MCS as was used for the last made transmission attempt.

The MAC entity is configured with a Maximum number of HARQ transmissions and a Maximum number of Msg3 HARQ transmissions by RRC: *maxHARQ-Tx* and *maxHARQ-Msg3Tx* respectively. For transmissions on all HARQ processes and all logical channels except for transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions shall be set to *maxHARQ-Tx*. For transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions shall be set to *maxHARQ-Msg3Tx*.

When the HARQ feedback is received for this TB, the HARQ process shall:

- set *HARQ_FEEDBACK* to the received value.

If the HARQ entity requests a new transmission, the HARQ process shall:

- set *CURRENT_TX_NB* to 0;
- set *CURRENT_IRV* to 0;
- store the MAC PDU in the associated HARQ buffer;
- store the uplink grant received from the HARQ entity;
- set *HARQ_FEEDBACK* to NACK;
- generate a transmission as described below.

If the HARQ entity requests a retransmission, the HARQ process shall:

- increment CURRENT_TX_NB by 1;
- if the HARQ entity requests an adaptive retransmission:
 - store the uplink grant received from the HARQ entity;
 - set CURRENT_IRV to the index corresponding to the redundancy version value provided in the HARQ information;
 - set HARQ_FEEDBACK to NACK;
 - generate a transmission as described below.
- else if the HARQ entity requests a non-adaptive retransmission:
 - if HARQ_FEEDBACK = NACK:
 - generate a transmission as described below.
- NOTE: When receiving a HARQ ACK alone, the MAC entity keeps the data in the HARQ buffer.
- NOTE: When no UL-SCH transmission can be made due to the occurrence of a measurement gap, no HARQ feedback can be received and a non-adaptive retransmission follows.

To generate a transmission, the HARQ process shall:

- if the MAC PDU was obtained from the Msg3 buffer; or
- if Sidelink Discovery Gaps for Transmission are not configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer in this TTI; or
- if Sidelink Discovery Gaps for Transmission are configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is no Sidelink Discovery Gap for Transmission in this TTI; or
- if Sidelink Discovery Gaps for Transmission are configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is a Sidelink Discovery Gap for Transmission, and there is no configured grant for transmission on SL-DCH in this TTI:
 - instruct the physical layer to generate a transmission according to the stored uplink grant with the redundancy version corresponding to the CURRENT_IRV value;
- increment CURRENT_IRV by 1;
- if there is a measurement gap or Sidelink Discovery Gap for Reception at the time of the HARQ feedback reception for this transmission and if the MAC PDU was not obtained from the Msg3 buffer:
 - set HARQ_FEEDBACK to ACK at the time of the HARQ feedback reception for this transmission.

After performing above actions, the HARQ process then shall:

- if CURRENT_TX_NB = maximum number of transmissions – 1:
- flush the HARQ buffer;

In the current 3GPP E-UTRA RRC specification [4], semi-persistent scheduling is configured as below:

– *SPS-Config*

The IE *SPS-Config* is used to specify the semi-persistent scheduling configuration.

***SPS-Config* information element**

```
-- ASN1START
SPS-Config ::= SEQUENCE {
    semiPersistSchedC-RNTI          C-RNTI          OPTIONAL,      -- Need OR
    sps-ConfigDL                    SPS-ConfigDL      OPTIONAL,      -- Need ON
    sps-ConfigUL                    SPS-ConfigUL      OPTIONAL      -- Need ON
}

SPS-ConfigDL ::= CHOICE {
    release          NULL,
    setup            SEQUENCE {
        semiPersistSchedIntervalDL  ENUMERATED {
            sf10, sf20, sf32, sf40, sf64, sf80,
            sf128, sf160, sf320, sf640, spare6,
            spare5, spare4, spare3, spare2,
            spare1},
        numberOfConfSPS-Processes    INTEGER (1..8),
        niPUCCH-AN-PersistentList    NI-PUCCH-AN-PersistentList,
        ...,
        [{ twoAntennaPortActivated-r10 CHOICE {
            release          NULL,
            setup            SEQUENCE {
                niPUCCH-AN-PersistentListP1-r10 NI-PUCCH-AN-PersistentList
            }
        }
    }
}
Need ON
}

SPS-ConfigUL ::= CHOICE {
    release          NULL,
    setup            SEQUENCE {
        semiPersistSchedIntervalUL  ENUMERATED {
            sf10, sf20, sf32, sf40, sf64, sf80,
            sf128, sf160, sf320, sf640, spare6,
            spare5, spare4, spare3, spare2,
            spare1},
        implicitReleaseAfter         ENUMERATED {e2, e3, e4, e8},
        p0-Persistent                SEQUENCE {
            p0-NominalPUSCH-Persistent    INTEGER (-126..24),
            p0-UE-PUSCH-Persistent        INTEGER (-8..7)
        } OPTIONAL,
        twoIntervalsConfig            ENUMERATED {true}      OPTIONAL,      -- Cond TDD
        ...,
        [{ p0-PersistentSubframeSet2-r12 CHOICE {
            release          NULL,
            setup            SEQUENCE {
                p0-NominalPUSCH-PersistentSubframeSet2-r12    INTEGER (-126..24),
                p0-UE-PUSCH-PersistentSubframeSet2-r12        INTEGER (-8..7)
            }
        }
    }
}
Need ON
}

NI-PUCCH-AN-PersistentList ::= SEQUENCE (SIZE (1..4)) OF INTEGER (0..2047)
```

--- ASN1STOP

SPS-Config field descriptions	
implicitReleaseAfter	Number of empty transmissions before implicit release, see TS 36.321 [6, 5.10.2]. Value e2 corresponds to 2 transmissions, e3 corresponds to 3 transmissions and so on.
n1PUCCH-AN-PersistentList, n1PUCCH-AN-PersistentListP1	List of parameter: $n_{\text{PUCCH}}^{(1,p)}$ for antenna port P0 and for antenna port P1 respectively, see TS 36.213 [23, 10.1]. Field <i>n1-PUCCH-AN-PersistentListP1</i> is applicable only if the <i>twoAntennaPortActivatedPUCCH-Format1a1b</i> in <i>PUCCH-ConfigDedicated-v1020</i> is set to <i>true</i> . Otherwise the field is not configured.
numberOfConfSPS-Processes	The number of configured HARQ processes for Semi-Persistent Scheduling, see TS 36.321 [6].
p0-NominalPUSCH-Persistent	Parameter: $P_{\text{O_NOMINAL_PUSCH}}(0)$. See TS 36.213 [23, 5.1.1.1], unit dBm step 1. This field is applicable for persistent scheduling, only. If choice setup is used and <i>p0-Persistent</i> is absent, apply the value of <i>p0-NominalPUSCH</i> for <i>p0-NominalPUSCH-Persistent</i> . If uplink power control subframe sets are configured by <i>tpc-SubframeSet</i> , this field applies for uplink power control subframe set 1.
p0-NominalPUSCH-PersistentSubframeSet2	Parameter: $P_{\text{O_NOMINAL_PUSCH}}(0)$. See TS 36.213 [23, 5.1.1.1], unit dBm step 1. This field is applicable for persistent scheduling, only. If <i>p0-PersistentSubframeSet2-r12</i> is not configured, apply the value of <i>p0-NominalPUSCH-SubframeSet2-r12</i> for <i>p0-NominalPUSCH-PersistentSubframeSet2</i> . E-UTRAN configures this field only if uplink power control subframe sets are configured by <i>tpc-SubframeSet</i> , in which case this field applies for uplink power control subframe set 2.
p0-UE-PUSCH-Persistent	Parameter: $P_{\text{O_UE_PUSCH}}(0)$. See TS 36.213 [23, 5.1.1.1], unit dB. This field is applicable for persistent scheduling, only. If choice setup is used and <i>p0-Persistent</i> is absent, apply the value of <i>p0-UE-PUSCH</i> for <i>p0-UE-PUSCH-Persistent</i> . If uplink power control subframe sets are configured by <i>tpc-SubframeSet</i> , this field applies for uplink power control subframe set 1.
p0-UE-PUSCH-PersistentSubframeSet2	Parameter: $P_{\text{O_UE_PUSCH}}(0)$. See TS 36.213 [23, 5.1.1.1], unit dB. This field is applicable for persistent scheduling, only. If <i>p0-PersistentSubframeSet2-r12</i> is not configured, apply the value of <i>p0-UE-PUSCH-SubframeSet2</i> for <i>p0-UE-PUSCH-PersistentSubframeSet2</i> . E-UTRAN configures this field only if uplink power control subframe sets are configured by <i>tpc-SubframeSet</i> , in which case this field applies for uplink power control subframe set 2.
semiPersistSchedC-RNTI	Semi-persistent Scheduling C-RNTI, see TS 36.321 [6].
semiPersistSchedIntervalDL	Semi-persistent scheduling interval in downlink, see TS 36.321 [6]. Value in number of sub-frames. Value sf10 corresponds to 10 sub-frames, sf20 corresponds to 20 sub-frames and so on. For TDD, the UE shall round this parameter down to the nearest integer (of 10 sub-frames), e.g. sf10 corresponds to 10 sub-frames, sf32 corresponds to 30 sub-frames, sf128 corresponds to 120 sub-frames.
semiPersistSchedIntervalUL	Semi-persistent scheduling interval in uplink, see TS 36.321 [6]. Value in number of sub-frames. Value sf10 corresponds to 10 sub-frames, sf20 corresponds to 20 sub-frames and so on. For TDD, the UE shall round this parameter down to the nearest integer (of 10 sub-frames), e.g. sf10 corresponds to 10 sub-frames, sf32 corresponds to 30 sub-frames, sf128 corresponds to 120 sub-frames.
twoIntervalsConfig	Trigger of two-intervals-Semi-Persistent Scheduling in uplink. See TS 36.321 [6, 5.10]. If this field is present, two-intervals-SPS is enabled for uplink. Otherwise, two-intervals-SPS is disabled.

Conditional presence	Explanation
TDD	This field is optional present for TDD, need OR; it is not present for FDD and the UE shall delete any existing value for this field.

Some UEs are capable of transmitting PUSCH and PUCCH simultaneously, and some UEs are not capable of transmitting PUSCH and PUCCH simultaneously. Such capability would be reported to

eNB so that eNB can decide whether to configure this functionality or not. Even if UE support this feature, eNB may decide not to configure this function if the channel condition of this UE is poor, as to transmit both channel simultaneously is more power consuming and in such case UE maximum transmission power may not guarantee proper power level for each channel. UE may decide which channel to transmit UCI with depending on whether PUSCH and PUCCH simultaneously is configured or not.

10.1 UE procedure for determining physical uplink control channel assignment

If the UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe n uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting PUSCH
- on PUSCH if the UE is transmitting PUSCH in subframe n unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- on PUCCH using format 2/2a/2b/3 if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and periodic/aperiodic CSI and if the UE is transmitting PUSCH in subframe n , in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the periodic/aperiodic CSI transmitted on PUSCH unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, in which case periodic/aperiodic CSI is not transmitted

For a UE with poor channel condition, e.g. in cell edge, it is possible to configure HARQ-ACK repetition to improve the HARQ-ACK feedback reliability by repeating the transmission of ACK/NACK multiple times. Under such situation, the HARQ-ACK would be transmitted on PUCCH without multiplexed onto other channel, e.g. PUSCH, to enjoy the combining gain of repetition across subframes, as some of the repetitions would occur on the same resource and joint demodulation/channel estimation is possible.

10.2 Uplink HARQ-ACK timing

For TDD or for FDD-TDD and primary cell frame structure type 2 or for FDD-TDD and primary cell frame structure type 1, if a UE configured with *EIMTA-MainConfigServCell-r12* for a serving cell, "UL/DL

configuration” of the serving cell in subclause 10.2 refers to the UL/DL configuration given by the parameter *eimta-HARQ-ReferenceConfig-r12* for the serving cell unless specified otherwise.

For FDD or for FDD-TDD and primary cell frame structure type 1, the UE shall upon detection of a PDSCH transmission in subframe $n-4$ intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe n . If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe $n-4$ intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in subframes $n - N_{\text{ANRep}} - 3, \dots, n - 5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes $n, n+1, \dots, n + N_{\text{ANRep}} - 1$;
- shall not transmit any other signal/channel in subframes $n, n+1, \dots, n + N_{\text{ANRep}} - 1$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3, \dots, n + N_{\text{ANRep}} - 5$.

<...>

For TDD, if HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in a downlink or special subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$) on PUCCH in UL subframe n and the next $N_{\text{ANRep}} - 1$ UL subframes denoted as $n_1, \dots, n_{N_{\text{ANRep}} - 1}$;
- shall not transmit any other signal/channel in UL subframe $n, n_1, \dots, n_{N_{\text{ANRep}} - 1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n_i - k$, where $k \in K_i$, K_i is the set defined in Table 10.1.3.1-1 corresponding to UL subframe n_i , and $1 \leq i \leq N_{\text{ANRep}} - 1$.

How physical layer process a transport block from MAC layer and how to multiplex uplink control information can be found in below:

Uplink transport channels and control information

If the UE is configured with a Master Cell Group (MCG) and Secondary Cell Group (SCG) [6], the procedures described in this clause are applied to the MCG and SCG, respectively. When the procedures are applied to a SCG, the term primary cell refers to the primary SCell (PSCell) of the SCG.

If the UE is configured with a PUCCH SCell [6], the procedures described in this clause are applied to the group of DL cells associated with the primary cell and the group of DL cells associated with the PUCCH SCell, respectively. When the procedures are applied to the group of DL cells associated with the PUCCH SCell, the term primary cell refers to the PUCCH SCell.

If the UE is configured with a LAA SCell, the procedures described in this clause are applied assuming the LAA SCell is an FDD SCell.

5.2.1 Random access channel

The sequence index for the random access channel is received from higher layers and is processed according to [2].

5.2.2 Uplink shared channel

Figure 5.2.2-1 shows the processing structure for the UL-SCH transport channel on one UL cell. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per UL cell. The following coding steps can be identified for each transport block of an UL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding of data and control information
- Rate matching
- Code block concatenation
- Multiplexing of data and control information
- Channel interleaver

The coding steps for one UL-SCH transport block are shown in the figure below. The same general processing applies for each UL-SCH transport block on each UL cell with restrictions as specified in [3].

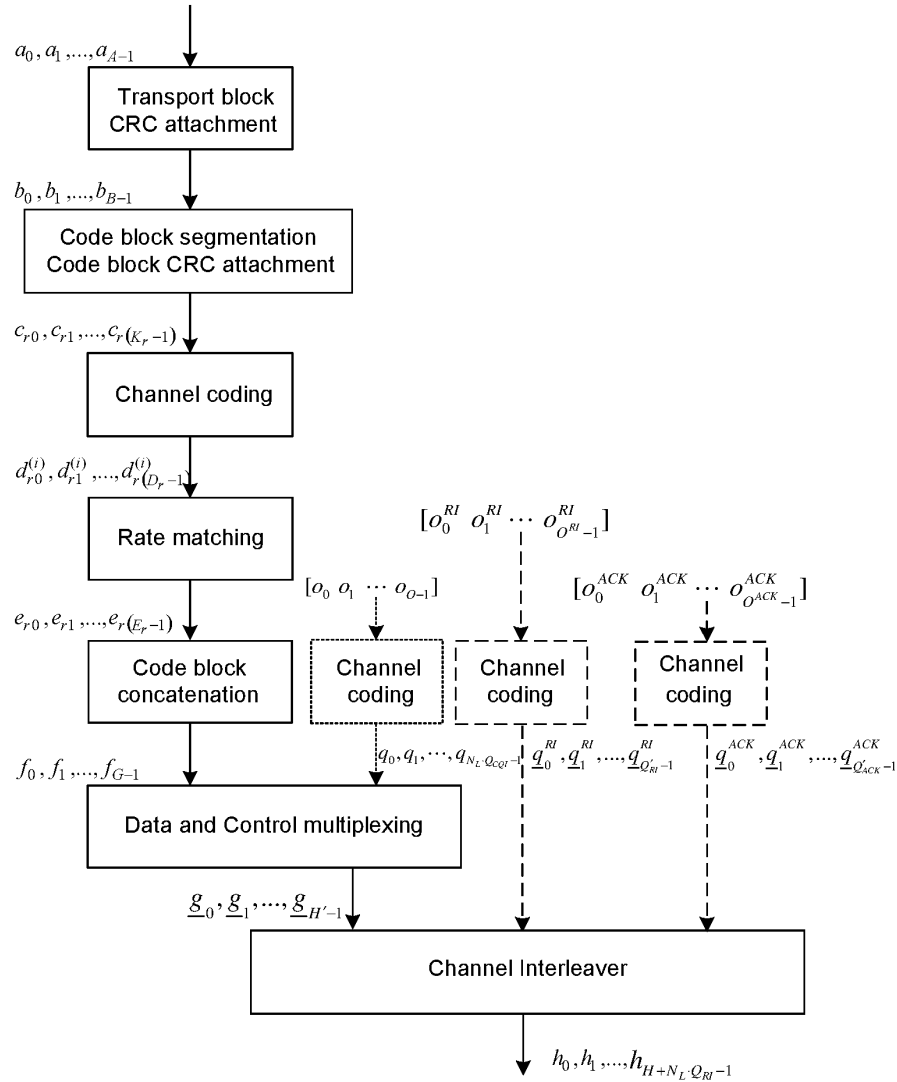


Figure 5.2.2-1: Transport block processing for UL-SCH.

5.2.2.1 Transport block CRC attachment

Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, \dots, a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, \dots, p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the UL-SCH transport block according to section 5.1.1 setting L to 24 bits and using the generator polynomial $g_{CRC24A}(D)$.

5.2.2.2 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, \dots, b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to section 5.1.2.

The bits after code block segmentation are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$, where r is the code block number and K_r is the number of bits for code block number r .

5.2.2.3 Channel coding of UL-SCH

Code blocks are delivered to the channel coding block. The bits in a code block are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, \dots, c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits in code block number r . The total number of code blocks is denoted by C and each code block is individually turbo encoded according to section 5.1.3.2.

After encoding the bits are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, \dots, d_{r(D_r-1)}^{(i)}$, with $i = 0, 1$, and 2 and where D_r is the number of bits on the i -th coded stream for code block number r , i.e. $D_r = K_r + 4$.

5.2.2.4 Rate matching

Turbo coded blocks are delivered to the rate matching block. They are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, \dots, d_{r(D_r-1)}^{(i)}$, with $i = 0, 1$, and 2 , and where r is the code block number, i is the coded stream index, and D_r is the number of bits in each coded stream of code block number r . The total number of code blocks is denoted by C and each coded block is individually rate matched according to section 5.1.4.1.

After rate matching, the bits are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, \dots, e_{r(E_r-1)}$, where r is the coded block number, and where E_r is the number of rate matched bits for code block number r .

5.2.2.5 Code block concatenation

The bits input to the code block concatenation block are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, \dots, e_{r(E_r-1)}$ for $r = 0, \dots, C-1$ and where E_r is the number of rate matched bits for the r -th code block.

Code block concatenation is performed according to section 5.1.5.

The bits after code block concatenation are denoted by $f_0, f_1, f_2, f_3, \dots, f_{G-1}$, where G is the total number of coded bits for transmission of the given transport block over N_L transmission layers excluding the bits used for control transmission, when control information is multiplexed with the UL-SCH transmission.

5.2.2.6 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication, and CSI-RS resource indication (CRI). Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When control data are transmitted in the PUSCH, the channel coding for HARQ-ACK, rank indication, CRI and channel quality information $o_0, o_1, o_2, \dots, o_{O-1}$ is done independently.

For the cases with TDD primary cell, the number of HARQ-ACK bits is determined as described in section 7.3 of [3].

When the UE transmits HARQ-ACK bits, rank indicator bits or CRI bits, it shall determine the number of coded modulation symbols per layer Q' for HARQ-ACK, rank indicator or CRI bits as follows.

For the case when only one transport block is transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \min \left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, 4 \cdot M_{sc}^{PUSCH} \right)$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, expressed as a number of subcarriers in [2], and
- $N_{symb}^{PUSCH-initial}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block, respectively, given by $N_{symb}^{PUSCH-initial} = \left(2 \cdot (N_{symb}^{UL} - 1) - N_{SRS} \right)$, where
 - N_{SRS} is equal to 1
 - - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
 - - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission, or
 - - if the PUSCH resource allocation for initial transmission even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
 - - if the subframe for initial transmission in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
 - - if the subframe for initial transmission in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
 - Otherwise N_{SRS} is equal to 0.

- $M_{sc}^{PUSCH-initial}$, C , and K_r are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial}$, C , and K_r shall be determined from:
 - the most recent semi-persistent scheduling assignment PDCCH or EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
 - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

For the case when two transport blocks are transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \max \left[\min(Q'_{temp}, 4 \cdot M_{sc}^{PUSCH}), Q'_{min} \right] \text{ with}$$

$$Q'_{temp} = \left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(1)}-1} K_r^{(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} + \sum_{r=0}^{C^{(2)}-1} K_r^{(2)} \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)}} \right\rceil$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- $Q'_{min} = O$ if $O \leq 2$, $Q'_{min} = \lceil 2O / Q'_m \rceil$ if $3 \leq O \leq 11$ with $Q'_m = \min(Q_m^1, Q_m^2)$ where $Q_m^x, x = \{1, 2\}$ is the modulation order of transport block “x”, and $Q'_{min} = \lceil 2O_1 / Q'_m \rceil + \lceil 2O_2 / Q'_m \rceil$ if $O > 11$ with $O_1 = \lceil O/2 \rceil$ and $O_2 = O - \lceil O/2 \rceil$.
- $M_{sc}^{PUSCH-initial(x)}, x = \{1, 2\}$ are the scheduled bandwidths for PUSCH transmission in the initial sub-frame for the first and second transport block, respectively, expressed as a number of subcarriers in [2], and
- $N_{symb}^{PUSCH-initial(x)}, x = \{1, 2\}$ are the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the first and second transport block given by $N_{symb}^{PUSCH-initial(x)} = \left(2 \cdot (N_{symb}^{UL} - 1) - N_{SRS}^{(x)} \right), x = \{1, 2\}$, where
 - $N_{SRS}^{(x)}, x = \{1, 2\}$ is equal to 1
 - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
 - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission of transport block “x”, or
 - if the PUSCH resource allocation for initial transmission of transport block “x” even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
 - if the subframe for initial transmission of transport block “x” in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
 - if the subframe for initial transmission of transport block “x” in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.

- Otherwise $N_{SRS}^{(x)}, x = \{1,2\}$ is equal to 0.
- $M_{sc}^{PUSCH-initial(x)}, x = \{1,2\}$, $C^{(x)}, x = \{1,2\}$, and $K_r^{(x)}, x = \{1,2\}$ are obtained from the initial PDCCH or EPDCCH for the corresponding transport block.

For HARQ-ACK, $Q_{ACK} = Q_m \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{HARQ-ACK}$, where Q_m is the modulation order of a given transport block. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH and the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI} = Q_m \cdot Q'$, $Q_{CRI} = Q_m \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{RI}$, where Q_m is the modulation order of a given transport block, and β_{offset}^{RI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.

For HARQ-ACK

Each positive acknowledgement (ACK) is encoded as a binary '1' and each negative acknowledgement (NACK) is encoded as a binary '0'

If HARQ-ACK feedback consists of 1-bit of information, i.e., $[o_0^{ACK}]$, it is first encoded according to Table 5.2.2.6-1.

If HARQ-ACK feedback consists of 2-bits of information, i.e., $[o_0^{ACK} o_1^{ACK}]$ with o_0^{ACK} corresponding to HARQ-ACK bit for codeword 0 and o_1^{ACK} corresponding to that for codeword 1, or if HARQ-ACK feedback consists of 2-bits of information as a result of the aggregation of HARQ-ACK bits corresponding to two DL cells with which the UE is configured by higher layers, or if HARQ-ACK feedback consists of 2-bits of information corresponding to two subframes for TDD, it is first encoded according to Table 5.2.2.6-2 where $o_2^{ACK} = (o_0^{ACK} + o_1^{ACK}) \bmod 2$.

Table 5.2.2.6-1: Encoding of 1-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK} y]$
4	$[o_0^{ACK} y x x]$
6	$[o_0^{ACK} y x x x x]$

Table 5.2.2.6-2: Encoding of 2-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK} o_1^{ACK} o_2^{ACK} o_0^{ACK} o_1^{ACK} o_2^{ACK}]$
4	$[o_0^{ACK} o_1^{ACK} x x o_2^{ACK} o_0^{ACK} x x o_1^{ACK} o_2^{ACK} x x]$
6	$[o_0^{ACK} o_1^{ACK} x x x x o_2^{ACK} o_0^{ACK} x x x x o_1^{ACK} o_2^{ACK} x x x x]$

If HARQ-ACK feedback consists of $3 \leq O^{ACK} \leq 11$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK} o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$, then a coded bit sequence $\tilde{q}_0^{ACK} \tilde{q}_1^{ACK}, \dots, \tilde{q}_{31}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK} o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.4. In turn, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{ACK} \tilde{q}_1^{ACK}, \dots, \tilde{q}_{31}^{ACK}$ so that the total bit sequence length is equal to Q_{ACK} .

If HARQ-ACK feedback consists of $11 < O^{ACK} \leq 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK} o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$, then the coded bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK} o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.5.

If HARQ-ACK feedback consists of $O^{ACK} > 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, the coded bit sequence is denoted by $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0^{ACK} o_1^{ACK}, \dots, o_{O^{ACK}-1}^{ACK}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The “x” and “y” in Table 5.2.2.6-1 and 5.2.2.6-2 are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying HARQ-ACK information.

For FDD or TDD HARQ-ACK multiplexing or the aggregation of more than one DL cell including at least one cell using FDD and at least one cell using TDD when HARQ-ACK consists of one or two bits of information, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK} .

For UEs configured by higher layers with *codebooksizeDetermination-r13* = 0, the bit sequence

$\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined according to the Downlink Assignment Index (DAI) as in Table

5.3.3.1.1-2 and as defined in [3]. Otherwise, the bit sequence $\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined as below.

For FDD when HARQ ACK consists of 2 or more bits of information as a result of the aggregation of more than one DL cell, the bit sequence $\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the multiple DL cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1, 2, 5, 6, 7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK} =$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the bit sequence $\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for one or multiple DL cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the c -th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HARQ-ReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe $n-4$ in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

The bit sequence $\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL} = 1$

if transmission mode configured in cell $c \in \{1, 2, 5, 6, 7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK} =$
HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK} =$ binary AND operation of the HARQ-ACK bits corresponding to the first and second
codewords of this cell

$j = j + 1$

end if

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of one or more DL cells and the UE is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 [3], the bit sequence

$\tilde{o}_0^{ACK} \tilde{o}_1^{ACK}, \dots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the one or more DL cells configured by higher layers and the multiple subframes as defined in [3].

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits as defined in Section 7.3 of [3].

The number of HARQ-ACK bits for the UE to convey if it is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 is computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set $c=0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

```

while  $c < N_{cells}^{DL}$ 
    set  $l = 0$ ;
    while  $l < B_c^{DL}$ 
        if transmission mode configured in cell  $c \in \{1,2,5,6,7\}$  -- 1 bit HARQ-ACK feedback for this cell
             $k = k + 1$ 
        else
             $k = k + 2$ 
        end if
         $l = l + 1$ 
    end while
     $c = c + 1$ 
end while

```

When PUCCH format 3 is configured, if $k \leq 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k \leq 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is not configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

```

while  $c < N_{cells}^{DL}$ 
    set  $l = 0$ ;
    while  $l < B_c^{DL}$ 
        if transmission mode configured in cell  $c \in \{1,2,5,6,7\}$  -- 1 bit HARQ-ACK feedback for this cell
             $\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$  HARQ-ACK bit of this cell as defined in Section 7.3 of [3]
             $j = j + 1$ 
        else
             $[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$  HARQ-ACK bits of this cell as defined in Section 7.3 of [3]
             $j = j + 2$ 
        end if
         $l = l + 1$ 
    end while
     $c = c + 1$ 
end while

```

$c = c + 1$

end while

When PUCCH format 3 is configured, if $k > 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k > 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell, spatial bundling is applied to all subframes in all cells; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

set $l = 0$;

while $l < B_c^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l + 1$

end while

$c = c + 1$

end while

For $o^{ACK} \leq 11$ or $o^{ACK} > 22$, the bit sequence $o_0^{ACK}, o_1^{ACK}, \dots, o_{o^{ACK}-1}^{ACK}$ is obtained by setting $o_i^{ACK} = \tilde{o}_i^{ACK}$.

For $11 < o^{ACK} \leq 22$, the bit sequence $o_0^{ACK}, o_1^{ACK}, \dots, o_{o^{ACK}-1}^{ACK}$ is obtained by setting $o_{i/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is even and $o_{\lceil o^{ACK}/2 \rceil + (i-1)/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is odd.

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of two DL cells and the UE is configured with PUCCH format 1b with channel selection, the bit sequence $o_0^{ACK}, o_1^{ACK}, \dots, o_{o^{ACK}-1}^{ACK}$ is obtained as described in section 7.3 of [3].

For TDD HARQ-ACK bundling, a bit sequence $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, \dots, \tilde{q}_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total

bit sequence length is equal to Q_{ACK} . A scrambling sequence $[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}]$ is then selected from Table 5.2.2.6-A with index $i = (N_{bundled} - 1) \bmod 4$, where $N_{bundled}$ is determined as described in section 7.3 of [3]. The bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ is then generated by setting $m = 1$ if HARQ-ACK consists of 1-bit and $m = 3$ if HARQ-ACK consists of 2-bits and then scrambling $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, \dots, \tilde{q}_{Q_{ACK}-1}^{ACK}$ as follows

Set i, k to 0

while $i < Q_{ACK}$

if $\tilde{q}_i^{ACK} = y$ // place-holder repetition bit

$$q_i^{ACK} = (\tilde{q}_{i-1}^{ACK} + w_{[k/m]}^{ACK}) \bmod 2$$

$$k = (k + 1) \bmod 4m$$

else

if $\tilde{q}_i^{ACK} = x$ // a place-holder bit

$$q_i^{ACK} = \tilde{q}_i^{ACK}$$

else

// coded bit

$$q_i^{ACK} = (\tilde{q}_i^{ACK} + w_{[k/m]}^{ACK}) \bmod 2$$

$$k = (k + 1) \bmod 4m$$

end if

$$i = i + 1$$

end while

Table 5.2.2.6-A: Scrambling sequence selection for TDD HARQ-ACK bundling.

i	$[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}]$
0	[1 1 1 1]
1	[1 0 1 0]
2	[1 1 0 0]
3	[1 0 0 1]

When HARQ-ACK information is to be multiplexed with UL-SCH at a given PUSCH, the HARQ-ACK information is multiplexed in all layers of all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for HARQ-ACK information is denoted by

$q_0^{ACK}, q_1^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$, where q_i^{ACK} , $i = 0, \dots, Q_{ACK} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q_{ACK}' = Q_{ACK} / Q_m$ is obtained as follows:

Set i, k to 0

while $i < Q_{ACK}$

$\hat{q}_k^{ACK} = [q_i^{ACK} \dots q_{i+Q_m-1}^{ACK}]$ -- temporary row vector

$\underline{q}_k^{ACK} = \overbrace{[\hat{q}_k^{ACK} \dots \hat{q}_k^{ACK}]}^{N_L}{}^T$ -- replicating the row vector $\hat{q}_k^{ACK}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

For rank indication (RI) (RI only, joint report of RI and i1, joint report of CRI and RI, joint report of CRI,RI and i1, joint report of CRI,RI, and PTI, and joint report of RI and PTI) or CRI

- The corresponding bit widths for CRI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-3A, 5.2.2.6.2-3A, 5.2.2.6.3-3A, 5.2.3.3.1-3D,
- The corresponding bit widths for RI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-2, 5.2.2.6.2-3, 5.2.2.6.2-3B, 5.2.2.6.3-3, 5.2.2.6.3-3B, 5.2.3.3.1-3, 5.2.3.3.1-3A, 5.2.3.3.1-3B, 5.2.3.3.1-3C, 5.2.3.3.1-3D, 5.2.3.3.2-4, and 5.2.3.3.2-4A, 5.2.3.3.2-4B, 5.2.3.3.2-4C, 5.2.3.3.2-4D which are determined assuming the maximum number of layers as follows:
 - If the *maxLayersMIMO-r10* is configured for the DL cell, the maximum number of layers is determined according to *maxLayersMIMO-r10* for the DL cell
 - Else,
 - - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
 - - If the UE is configured with transmission mode 9 and Class B CSI reporting with $K > 1$ and RI and CRI are transmitted in the same reporting instance, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination,.
 - - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and *ue-Category* (without suffix).
 - - If the UE is configured with transmission mode 9 and Class B CSI reporting with $K > 1$ and RI and CRI are transmitted in the same reporting instance, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and *ue-Category* (without suffix).
 - - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum

number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.

- - If the UE is configured with transmission mode 10 and Class B CSI reporting with $K>1$ and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
- - If the UE is configured with transmission mode 10, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and ue-Category (without suffix).
- - If the UE is configured with transmission mode 10 and Class B CSI reporting with $K>1$ and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and ue-Category (without suffix).
- - Otherwise the maximum number of layers is determined according to the minimum of the number of PBCH antenna ports and ue-Category (without suffix).
- If RI feedback consists of 1-bit of information, i.e., $[o_0^{RI}]$, it is first encoded according to Table 5.2.2.6-3. The $[o_0^{RI}]$ to RI mapping is given by Table 5.2.2.6-5.
- If RI feedback consists of 2-bits of information, i.e., $[o_0^{RI} o_1^{RI}]$ with o_0^{RI} corresponding to MSB of 2-bit input and o_1^{RI} corresponding to LSB, it is first encoded according to Table 5.2.2.6-4 where $o_2^{RI} = (o_0^{RI} + o_1^{RI}) \bmod 2$. The $[o_0^{RI} o_1^{RI}]$ to RI mapping is given by Table 5.2.2.6-6.

Table 5.2.2.6-3: Encoding of 1-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI} y]$
4	$[o_0^{RI} y x x]$
6	$[o_0^{RI} y x x x x]$

Table 5.2.2.6-4: Encoding of 2-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI} o_1^{RI} o_2^{RI} o_0^{RI} o_1^{RI} o_2^{RI}]$
4	$[o_0^{RI} o_1^{RI} x x o_2^{RI} o_0^{RI} x x o_1^{RI} o_2^{RI} x x]$
6	$[o_0^{RI} o_1^{RI} x x x x o_2^{RI} o_0^{RI} x x x x o_1^{RI} o_2^{RI} x x x x]$

Table 5.2.2.6-5: O_0^{RI} to RI mapping.

O_0^{RI}	RI
0	1
1	2

Table 5.2.2.6-6: O_0^{RI}, O_1^{RI} to RI mapping.

O_0^{RI}, O_1^{RI}	RI
0, 0	1
0, 1	2
1, 0	3
1, 1	4

Table 5.2.2.6-7: $O_0^{RI}, O_1^{RI}, O_2^{RI}$ to RI mapping.

$O_0^{RI}, O_1^{RI}, O_2^{RI}$	RI
0, 0, 0	1
0, 0, 1	2
0, 1, 0	3
0, 1, 1	4
1, 0, 0	5
1, 0, 1	6
1, 1, 0	7
1, 1, 1	8

If RI feedback for a given DL cell consists of 3-bits of information, i.e., $[O_0^{RI} O_1^{RI} O_2^{RI}]$ with O_0^{RI} corresponding to MSB of 3-bit input and O_2^{RI} corresponding to LSB. The $[O_0^{RI} O_1^{RI} O_2^{RI}]$ to RI mapping is given by Table 5.2.2.6-7.

If RI feedback consists of $3 \leq O^{RI} \leq 11$ bits of information, i.e., $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$, then a coded bit sequence $[\tilde{q}_0^{RI}, \tilde{q}_1^{RI}, \dots, \tilde{q}_{31}^{RI}]$ is obtained by using the bit sequence $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.4.

If RI feedback consists of $11 < O^{RI} \leq 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$, then the coded bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI}, \dots, q_{Q_{RI}-1}^{RI}$ is obtained by using the bit sequence $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.5.

If RI feedback consists of $O^{RI} > 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$, then the coded bit sequence is denoted by $q_0^{RI}, q_1^{RI}, q_2^{RI}, \dots, q_{Q_{RI}-1}^{RI}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $[O_0^{RI} O_1^{RI}, \dots, O_{O^{RI}-1}^{RI}]$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The “x” and “y” in Table 5.2.2.6-3 and 5.2.2.6-4 are placeholders for [2] to scramble the RI bits in a way that maximizes the Euclidean distance of the modulation symbols carrying rank information.

For the case where RI feedback for more than one DL cell is to be reported, the RI report for each DL cell is concatenated prior to coding in increasing order of cell index.

For the case where RI feedback for more than one CSI process is to be reported, the RI reports are concatenated prior to coding first in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

For the case where RI feedback consists of one or two bits of information the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI}, \dots, q_{Q_{RI}-1}^{RI}$ is obtained by concatenation of multiple encoded RI blocks where Q_{RI} is the total number of coded bits for all the encoded RI blocks. The last concatenation of the encoded RI block may be partial so that the total bit sequence length is equal to Q_{RI} .

For the case where RI feedback consists of $3 \leq O^{RI} \leq 11$ bits of information, the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI}, \dots, q_{Q_{RI}-1}^{RI}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{RI}, \tilde{q}_1^{RI}, \dots, \tilde{q}_{31}^{RI}$ so that the total bit sequence length is equal to Q_{RI} .

When rank information is to be multiplexed with UL-SCH at a given PUSCH, the rank information is multiplexed in all layers of all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for rank information is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \dots, \underline{q}_{Q'_{RI}-1}^{RI}$, where $\underline{q}_i^{RI}$, $i = 0, \dots, Q'_{RI} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{RI} = Q_{RI} / Q_m$. The vector sequence is obtained as follows:

Set i, j, k to 0

while $i < Q_{RI}$

$\hat{\underline{q}}_k^{RI} = [q_i^{RI} \dots q_{i+Q_m-1}^{RI}]$ -- temporary row vector

$\underline{q}_k^{RI} = [\hat{\underline{q}}_k^{RI} \dots \hat{\underline{q}}_k^{RI}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{RI}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

The same procedures for encoding of RI and RI multiplexing with UL-SCH at a given PUSCH are applied for CRI, using CRI instead of RI in the equations.

For channel quality control information (CQI and/or PMI denoted as CQI/PMI);

When the UE transmits channel quality control information bits, it shall determine the number of modulation coded symbols per layer Q' for channel quality information as

$$Q' = \min \left(\left\lceil \frac{(O+L) \cdot M_{sc}^{PUSCH-initial(x)} \cdot N_{symb}^{PUSCH-initial(x)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(x)}-1} K_r^{(x)}} \right\rceil, M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} - \frac{Q_{RI}^{(x)}}{Q_m^{(x)}} \right)$$

where

- O is the number of CQI/PMI bits, and
- L is the number of CRC bits given by $L = \begin{cases} 0 & O \leq 11 \\ 8 & \text{otherwise} \end{cases}$, and
- $Q_{CQI} = Q_m^{(x)} \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$, where β_{offset}^{CQI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.
- If RI or CRI is not transmitted then $Q_{RI}^{(x)} = 0$.

The variable “ x ” in $K_r^{(x)}$ represents the transport block index corresponding to the highest I_{MCS} value indicated by the initial UL grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, “ $x=1$ ”, which corresponds to the first transport block. $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ are obtained from the initial PDCCH or EPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 for the same transport block, $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ shall be determined from:

- the most recent semi-persistent scheduling assignment PDCCH or EPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

$N_{symb}^{PUSCH-initial(x)}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block.

For UL-SCH data information $G = N_L^{(x)} \cdot (N_{symb}^{PUSCH} \cdot M_{sc}^{PUSCH} \cdot Q_m^{(x)} - Q_{CQI} - Q_{RI}^{(x)})$, where

- $N_L^{(x)}$ is the number of layers the corresponding UL-SCH transport block is mapped onto, and
- M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, and
- N_{symb}^{PUSCH} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{symb}^{PUSCH} = (2 \cdot (N_{symb}^{UL} - 1) - N_{SRS})$, where
 - N_{SRS} is equal to 1
 - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
 - if UE transmits PUSCH and SRS in the same subframe for the current subframe in the same serving cell, or

- - if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
- - if the current subframe in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
- - if the current subframe in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
- Otherwise N_{SRS} is equal to 0.

In case of CQI/PMI report for more than one DL cell, $o_0, o_1, o_2, \dots, o_{O-1}$ is the result of concatenating the CQI/PMI report for each DL cell in increasing order of cell index. For the case where CQI/PMI feedback for more than one CSI process is to be reported, $o_0, o_1, o_2, \dots, o_{O-1}$ is the result of concatenating the CQI/PMI reports in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

- If the payload size is less than or equal to 11 bits, the channel coding of the channel quality information is performed according to section 5.2.2.6.4 with input sequence $o_0, o_1, o_2, \dots, o_{O-1}$.
- For payload sizes greater than 11 bits, the CRC attachment, channel coding and rate matching of the channel quality information is performed according to sections 5.1.1, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0, o_1, o_2, \dots, o_{O-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The output sequence for the channel coding of channel quality information is denoted by $q_0, q_1, q_2, q_3, \dots, q_{N_L \cdot Q_{CQI} - 1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

5.2.2.7 Data and control multiplexing

The control and data multiplexing is performed such that HARQ-ACK information is present on both slots and is mapped to resources around the demodulation reference signals. In addition, the multiplexing ensures that control and data information are mapped to different modulation symbols.

The inputs to the data and control multiplexing are the coded bits of the control information denoted by $q_0, q_1, q_2, q_3, \dots, q_{N_L \cdot Q_{CQI} - 1}$ and the coded bits of the UL-SCH denoted by $f_0, f_1, f_2, f_3, \dots, f_{G-1}$. The output of the data and control multiplexing operation is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3, \dots, \underline{g}_{H'-1}$, where $H = (G + N_L \cdot Q_{CQI})$ and $H' = H / (N_L \cdot Q_m)$, and where $\underline{g}_i$, $i = 0, \dots, H'-1$ are column vectors of length $(Q_m \cdot N_L)$. H is the total number of coded bits allocated for UL-SCH data and CQI/PMI information across the N_L transmission layers of the transport block.

In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the CQI/PMI information is multiplexed with data only on the UL-SCH transport block with highest I_{MCS} value on the initial grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, the CQI/PMI information is multiplexed with data only on the first transport block. For that UL-SCH transport block or in the case of single transport block transmission, and assuming that N_L is the number of layers onto which the UL-SCH transport block is mapped, the control information and the data shall be multiplexed as follows:

Set i, j, k to 0

while $j < N_L \cdot Q_{CQI}$ -- first place the control information

$$\underline{g}_k = [q_j \dots q_{j+N_L \cdot Q_m - 1}]^T$$

```

j = j + NL · Qm

k = k + 1

end while

while i < G -- then place the data

    gk = [fi ... fi+Qm·NL-1]T

    i = i + Qm · NL

    k = k + 1

end while

```

5.2.2.8 Channel interleaver

The channel interleaver described in this section in conjunction with the resource element mapping for PUSCH in [2] implements a time-first mapping of modulation symbols onto the transmit waveform while ensuring that the HARQ-ACK and RI information are present on both slots in the subframe. HARQ-ACK information is mapped to resources around the uplink demodulation reference signals while RI information is mapped to resources around those used by HARQ-ACK.

The input to the channel interleaver are denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \dots, \underline{g}_{H'-1}, \underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \dots, \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \dots, \underline{q}_{Q_{ACK}-1}^{ACK}$. In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the HARQ-ACK and RI information are multiplexed with data on both UL-SCH transport blocks.

The number of modulation symbols per layer in the subframe is given by $H'_{total} = H' + Q'_{RI}$. The output bit sequence from the channel interleaver is derived as follows:

(1) Assign $C_{mux} = N_{\text{symb}}^{\text{PUSCH}}$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2, ..., $C_{mux} - 1$ from left to right. $N_{\text{symb}}^{\text{PUSCH}}$ is determined according to section 5.2.2.6.

(2) The number of rows of the matrix is $R_{mux} = (H'_{total} \cdot Q_m \cdot N_L) / C_{mux}$ and we define $R'_{mux} = R_{mux} / (Q_m \cdot N_L)$.

The rows of the rectangular matrix are numbered 0, 1, 2, ..., $R_{mux} - 1$ from top to bottom.

(3) If rank information is transmitted in this subframe, the vector sequence $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \dots, \underline{q}_{Q'_{RI}-1}^{RI}$ is written onto the columns indicated by Table 5.2.2.8-1, and by sets of $(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code.

Set i, j to 0.

Set r to $R'_{mux} - 1$

while $i < Q'_{RI}$

$c_{RI} = \text{ColumnSet}(j)$

$$\underline{y}_{r \times C_{max} + c_{RI}} = \underline{q}_i^{RI}$$

$$i = i + 1$$

$$r = R'_{max} - 1 - \lfloor i/4 \rfloor$$

$$j = (j + 3) \bmod 4$$

end while

Where ColumnSet is given in Table 5.2.2.8-1 and indexed left to right from 0 to 3.

- (4) Write the input vector sequence, for $k = 0, 1, \dots, H' - 1$, into the $(R_{max} \times C_{max})$ matrix by sets of $(Q_m \cdot N_L)$ rows starting with the vector $\underline{y}_0$ in column 0 and rows 0 to $(Q_m \cdot N_L - 1)$ and skipping the matrix entries that are already occupied:

$$\begin{bmatrix} \underline{y}_0 & \underline{y}_1 & \underline{y}_2 & \cdots & \underline{y}_{C_{max}-1} \\ \underline{y}_{C_{max}} & \underline{y}_{C_{max}+1} & \underline{y}_{C_{max}+2} & \cdots & \underline{y}_{2C_{max}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \underline{y}_{(R'_{max}-1) \times C_{max}} & \underline{y}_{(R'_{max}-1) \times C_{max}+1} & \underline{y}_{(R'_{max}-1) \times C_{max}+2} & \cdots & \underline{y}_{(R'_{max}-1) \times C_{max}-1} \end{bmatrix}$$

The pseudocode is as follows:

Set i, k to 0.

while $k < H'$,

if $\underline{y}_i$ is not assigned to RI symbols

$$\underline{y}_i = \underline{g}_k$$

$$k = k + 1$$

end if

$$i = i + 1$$

end while

- (5) If HARQ-ACK information is transmitted in this subframe, the vector sequence

$\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \dots, \underline{q}_{Q'_{ACK}-1}^{ACK}$ is written onto the columns indicated by Table 5.2.2.8-2, and by sets of

$(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code.

Note that this operation overwrites some of the channel interleaver entries obtained in step (4).

Set i, j to 0.

Set r to $R'_{max} - 1$

while $i < Q'_{ACK}$

$$c_{ACK} = \text{ColumnSet}(j)$$

$$\underline{y}_{r \times C_{max} + c_{ACK}} = \underline{q}_i^{ACK}$$

$$i = i + 1$$

$$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$$

$$j = (j + 3) \bmod 4$$

end while

Where ColumnSet is given in Table 5.2.2.8-2 and indexed left to right from 0 to 3.

- (6) The output of the block interleaver is the bit sequence read out column by column from the $(R_{mux} \times C_{mux})$ matrix. The bits after channel interleaving are denoted by $h_0, h_1, h_2, \dots, h_{H+N_L \cdot Q_{RI}-1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

Table 5.2.2.8-1: Column set for Insertion of rank information.

CP configuration	Column Set
Normal	{1, 4, 7, 10}
Extended	{0, 3, 5, 8}

Table 5.2.2.8-2: Column set for Insertion of HARQ-ACK information.

CP configuration	Column Set
Normal	{2, 3, 8, 9}
Extended	{1, 2, 6, 7}

The same channel interleaver procedures for RI are applied for CRI, using CRI instead of RI in the equations.

5.2.4 Uplink control information on PUSCH without UL-SCH data

When control data are sent via PUSCH without UL-SCH data, the following coding steps can be identified:

- Channel coding of control information
- Control information mapping
- Channel interleaver

5.2.4.1 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded symbols Q' for HARQ-ACK or rank indicator as

$$Q' = \min \left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} \cdot \beta_{offset}^{PUSCH}}{O_{CQI-MIN}} \right\rceil, 4 \cdot M_{sc}^{PUSCH} \right)$$

where O is the number of HARQ-ACK bits as defined in section 5.2.2.6, or rank indicator bits, $O_{CQI-MIN}$ is the number of CQI bits including CRC bits assuming rank equals to 1 for all serving cells for which an aperiodic CSI report is triggered [3], M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current subframe expressed as a number of subcarriers in [2], and N_{symb}^{PUSCH} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{symb}^{PUSCH} = (2 \cdot (N_{symb}^{UL} - 1) - N_{SRS})$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for the current subframe, or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the current subframe is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the current subframe is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise N_{SRS} is equal to 0.

For HARQ-ACK information $Q_{ACK} = Q_m \cdot Q'$ and $[\beta_{offset}^{PUSCH} = \beta_{offset}^{HARQ-ACK} / \beta_{offset}^{CQI}]$. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3]. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI} = Q_m \cdot Q'$, $Q_{CRI} = Q_m \cdot Q'$ and $[\beta_{offset}^{PUSCH} = \beta_{offset}^{RI} / \beta_{offset}^{CQI}]$, where β_{offset}^{RI} shall be determined according to [3].

For CQI and/or PMI information $Q_{CQI} = N_{symb}^{PUSCH} \cdot M_{sc}^{PUSCH} \cdot Q_m - Q_{RI}$.

The channel coding and rate matching of the control data is performed according to section 5.2.2.6. The coded output sequence for channel quality information is denoted by $q_0, q_1, q_2, q_3, \dots, q_{Q_{CQI}-1}$, the coded vector sequence output for HARQ-ACK is denoted by $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, \dots, q_{Q_{ACK}-1}^{ACK}$ and the coded vector sequence output for rank indication or CRI, is denoted by $q_0^{RI}, q_1^{RI}, q_2^{RI}, \dots, q_{Q_{RI}-1}^{RI}$.

5.2.4.2 Control information mapping

The input are the coded bits of the channel quality information denoted by $q_0, q_1, q_2, q_3, \dots, q_{Q_{CQI}-1}$. The output is denoted by $g_0, g_1, g_2, g_3, \dots, g_{H'-1}$, where $H = Q_{CQI}$ and $H' = H / Q_m$, and where g_i , $i = 0, \dots, H'-1$ are column vectors of length Q_m . H is the total number of coded bits allocated for CQI/PMI information.

The control information shall be mapped as follows:

Set j, k to 0

while $j < Q_{CQI}$

$$g_k = [q_j \dots q_{j+Q_m-1}]^T$$

$$j = j + Q_m$$

$$k = k + 1$$

end while

5.2.4.3 Channel interleaver

The vector sequences $\underline{g}_0, \underline{g}_1, \underline{g}_2, \dots, \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \dots, \underline{q}_{Q_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \dots, \underline{q}_{Q_{ACK}-1}^{ACK}$ are channel interleaved according section 5.2.2.8. The bits after channel interleaving are denoted by $h_0, h_1, h_2, \dots, h_{H+Q_{RI}-1}$.

Description of the inventions

Any two or more than two of the following paragraphs, (sub)-bullets, points, actions, or claims described in each invention may be combined logically, reasonably, and properly to form a specific method.

Any sentence, paragraph, (sub)-bullet, point, action, or claim described in each of the following invention(s) may be implemented independently and separately to form a specific method. Dependency, e.g. “based on”, “more specifically”, or etc., in the following invention(s) is just one possible embodiment which would not restrict the specific method.

Issue:

Semi-persistent scheduling enables a UE to consider a configured uplink grant occurs periodically after it is initiated. It may be initiated by receiving a network signaling to initiate SPS. No network signaling is needed to allocate the following configured uplink grant after SPS is initiated. Based on RP-150310 [2], fast uplink access may be achieved by a specific type of SPS (semi-persistent scheduling). The specific type of SPS is assumed to be with small size and short interval, e.g. less than 10ms. Further, the specific type of SPS is assumed to be pre-allocated. An eNB may allocate this kind of SPS resource to a UE without receiving any scheduling request or buffer status information. When the UE has data available for transmission [3], it can use resource configured by the SPS for uplink transmission. Compared with requesting uplink resource via scheduling request [3], the latency can then be reduced if the interval of the resource configured by the SPS is short enough. Figure 2 quoted from RP-150310 [2] shows how pre-allocated uplink grant (e.g. allocated by SPS) improves latency reduction compared with scheduling request procedure specified in [3]. The resource configured by the specific type of SPS may be separated from resource configured by the legacy SPS (with longer interval) or jointly used.

In addition, it is also mentioned in RP-150310 [2] that the requirement of sending padding when there is UL resource but no data is in buffer can be removed. The intention of removing the requirement is to save battery power.

Based on current E-UTRA specification [5], when a physical control information (e.g. CQI, PMI, RI, and/or HARQ feedback) needs to be transmitted in a TTI, a UE should transmit the physical control information via either PUSCH or PUCCH. Traditionally, if an uplink grant for PUSCH is not available or the UE is allowed to perform transmission on PUCCH and PUSCH simultaneously, the physical control information is transmitted on PUCCH. If HARQ-ACK repetition is not configured and if an uplink grant for PUSCH is available and the UE is not allowed to perform transmission on PUCCH and PUSCH simultaneously, e.g. due to UE capability, UE power limitation, or eNB configuration, the physical control information is transmitted on PUSCH multiplexed with upper

layer data, e.g. MAC PDU. If HARQ-ACK repetition is not configured and if an uplink grant for PUSCH is available, the physical control information is transmitted on PUCCH and data is not transmitted, irrespective of whether UE is allowed to perform transmission on PUCCH and PUSCH simultaneously or not. Note that UE which is configured with HARQ-ACK repetition is reasonably not allowed to perform transmission on PUCCH and PUSCH simultaneously, given transmitting PUCCH and PUSCH simultaneously requires proper channel quality and is usually configured for cell center UEs.

Three scenarios are considered in the following:

[Scenario 1]

When a physical control information needs to be transmitted in a TTI, if a UE is unable to perform transmission on PUCCH and PUSCH simultaneously and the UE has data available for transmission, traditionally the UE multiplexes the physical control information with data and transmits them on PUSCH jointly. However, if the assigned UL resource for PUSCH is small, e.g. a pre-allocated configured uplink resource is assumed to be small, multiplexing the physical control information into PUSCH may jeopardize the data delivery because coding rate of data may be worse than normal so that data transmission is likely to fail. In addition, since network (e.g. eNB) may not know whether the UE transmits the physical control information on PUCCH or PUSCH which may depend on whether the UE has data available for transmission or not, complexity of decoding the UE transmission is increased.

[Scenario 2]

When a physical control information needs to be transmitted in a TTI, if a UE has data available for transmission and simultaneous transmission on PUCCH and PUSCH is enabled but the UE is not able to perform both transmissions on the control channel and the data channel with sufficient power, traditionally the UE prioritizes PUCCH transmission over PUSCH transmission. However, it means that data on PUSCH may not be transmitted in this TTI, or less power is used on PUSCH so that the PUSCH transmission is likely to fail.

[Scenario 3]

If a UE does not have data available for transmission in a TTI, the UE would skip configured UL grant or dynamic uplink grant in that TTI. And thus if the UE needs to transmit UCI in the TTI, UE would transmit UCI on the PUCCH. However, if there is more than one UCI to be transmitted in a TTI, PUCCH may not be a good candidate to carry UCI as it has limited capacity and UE may require to drop some of the UCI mentioned in the background. Also, the available resource on PUCCH is limited and thus transmit UCI on PUCCH may not be very robust.

Solution:

In general, a configured uplink grant is available periodically after it is initiated. The configured uplink grant is initiated by a network signaling. No network signaling is needed to allocate the following configured uplink grant after it is initiated.

Unless specified otherwise, a UE may not use a configured uplink grant if no data is available for transmission. Unless specified otherwise, the UE may not transmit padding using the configured

uplink grant. The period of the configured uplink grant may be less than a specified value. The specified value may be 10ms or 10 TTIs. The period of the configured uplink grant may be 1ms or 1 TTI. The period of the configured uplink grant may be 2ms or 2 TTIs. The period of the configured uplink grant may be 5ms or 5 TTIs.

TTI length may be 1ms, 0.5 ms, or several OFDM(or SC-FDMA) symbol(s), e.g. 1,2,3,4,5,6 symbols.

Throughout the application, the method may be applied for the case HARQ-ACK repetition is not configured, unless otherwise specified.

Throughout the application, "UE has data available for transmission" may mean UE has UL data in the buffer. "UE has data available for transmission" may mean UE has regular MAC control element for transmission. Throughout the application, "UE has data available for transmission" may mean UE has UL data in the buffer and regular MAC control element for transmission.

The configured uplink grant may be pre-allocated. A UE may be allocated the configured uplink grant when no data is available for transmission. The UE may be allocated the configured uplink grant before the UE transmits a scheduling request or a buffer status report.

To deal with scenario 1, a solution is that when a configured uplink grant is available and a physical control information needs to be transmitted in a TTI, if a UE is unable to perform transmission on a control channel and a data channel simultaneously and the UE has data available for transmission, the UE transmits the physical control information on the control channel. Moreover, The UE doesn't use the configured uplink grant for transmission on the data channel. Examples are listed in table 1 and table 2.

To deal with scenario 1, a second solution is that when a configured uplink grant is available and a physical control information needs to be transmitted in a TTI, if HARQ-ACK repetition is not configured, if a UE is unable to perform transmission on a control channel and a data channel simultaneously and the UE has data available for transmission, the UE transmits the physical control information on the control channel, and if HARQ-ACK repetition is configured, and the UE has data available for transmission the UE transmits the physical control information on the control channel. Moreover, The UE doesn't use the configured uplink grant for transmission on the data channel. To deal with scenario 1, a third solution is to determine which channel to transmit physical control information in a TTI according to an uplink grant on data channel in the TTI. Preferably, determine which channel to transmit physical control information is to determine to transmit physical control information on a data channel or on a control channel. Preferably, the determination may be different for different types of UCI, e.g. HARQ-ACK, CQI/PMI/RI,SR(scheduling request). Preferably, determination is according to a type of the uplink grant. In one example, uplink grant type can be an uplink grant periodically available or an uplink grant for a specific TTI. More specifically, determining based on uplink grant type means if the uplink grant is periodically available, transmit physical control information on the control channel and if the uplink grant is for the specific TTI, transmit physical control information on the data channel. Preferably, determination is based on the purpose of the uplink grant. One example of purpose is whether the uplink grant is for latency reduction or not. The purpose of the uplink grant may be known according to , e.g.an indication, a configuration, a periodicity of the uplink grant or an identifier to address the uplink grant. For the example, if the uplink grant is addressed by one RNTI, transmit physical control information on the control channel and if the uplink grant is addressed by another RNTI, transmit physical control

information on the data channel. Preferably, determination is based on the available resource of the uplink grant. More specifically, the available resource of the uplink grant is a TTI length of the uplink grant. Alternatively, the available resource of the uplink grant is a number of PRB (pairs) of the uplink grant. Alternatively, the available resource of the uplink grant is a TTI length of the uplink grant and a number of PRB (pairs) of the uplink grant. In one example, if the available resource of the uplink grant is less than a specific value, transmit physical control information on the control channel and if the available resource of the uplink grant is more than a specific value, transmit physical control information on the data channel. More specifically, the specific value is fixed or configured for a UE. Alternatively, the specific value is derived according to the payload size or amount of physical control information. Alternatively, the specific value is derived according to a type of physical control information, e.g. HARQ-ACK/CQI/PMI/RI/SR(scheduling request). Alternatively, the specific value is derived according to a modulation and coding scheme of the uplink grant. Furthermore, the specific value is set to guarantee the code rate of physical control information if it is carried on the data channel.

If UE behavior can be consistent no matter a UE has data available or not, e.g. physical control information is transmitted on the control channel as listed in table 2, network decoding can be simplified because network doesn't need to assume different UE behaviors.

To deal with scenario 2, a solution is that when a configured uplink grant is available and a physical control information needs to be transmitted in a TTI, if a UE has data available for transmission and simultaneous transmission on the control channel and the data channel is enabled but the UE is not able to perform both transmissions on the control channel and the data channel with sufficient power, the UE transmits the physical control information on the data channel. The power-insufficient case may be due to the sum of the computed power for the data channel and the computed power for the control channel exceed the maximum power of the UE. More specifically, the UE multiplexes the physical control information with data on the data channel. The UE uses the configured uplink to transmit data on the data channel. Moreover, when a configured uplink grant is available and no data is available for transmission, if no physical control information needs to be transmitted in a TTI, the UE doesn't use the configured uplink grant for transmission on the data channel, e.g. transmit padding. Examples are listed in table 1 and table 3. If the UE transmits the physical control information on the data channel and not transmits on the control channel, more power can be used on the data channel transmission and the data channel transmission may be more likely to succeed. On the other hand, if more than one physical control information needs to be transmitted in a TTI, some of the physical control information may be dropped due to the control channel configuration if the UE prioritizes the control channel transmission. Transmitting the physical control information on the data channel allows all physical control information to be transmitted.

To deal with scenario 3, a solution is that UE determine whether to skip a configured uplink grant or to skip a dynamic grant in a TTI according to whether a physical control information needs to be transmitted in the TTI or not. For example, when a configured uplink grant is available and if a UE does not have data available for transmission, if a physical control information needs to be transmitted in a TTI, the UE transmits the physical control information on a data channel and if no physical control information needs to be transmitted in a TTI, the UE skip the configured uplink grant. Preferably, the UE skip the configured uplink grant means UE does not perform transmission on the

data channel. Preferably, the UE transmits the physical control information on the data channel with a transport block comprise padding (or padding MAC control element). More specifically, physical layer in a UE would indicate whether a physical control information needs to be transmitted in the TTI or not to MAC layer, so that MAC layer could decide whether to skip the grant. Alternatively, the UE transmits the physical control information on the data channel without padding (or without padding MAC control element). More specifically, MAC layer may indicate a configured uplink grant or a dynamic grant available for a TTI and indicate there is no data to be transmitted in the TTI so that physical layer in the UE could decide whether to use the grant to transmit physical control information or to skip the UL grant and how to use the grant to transmit physical control information. Several example of how the UE transmits the physical control information on the data channel without padding (or without padding MAC control element). In one example, UE treat all the physical control information as a regular transport block from MAC layer and perform regular encoding, such as CRC attachment, interleaving, channel coding, for the all the physical control information. In another example, UE would perform the data channel transmission like perform PUSCH transmission without UL-SCH data. More specifically, UE treat a first physical control information, e.g. CQI and/or PMI as a regular transport block from MAC layer and perform regular encoding, such as CRC attachment, interleaving, channel coding, for the first physical control information, and multiplex a second type of physical control information, e.g. HARQ-ACK and/or RI on some resource of the data channel. Preferably for the above example(s), UE would indicate the payload size of physical control information on the data channel. More specifically, indication of the payload size is carried on some specific resource on the data channel. Alternatively, indication of the payload size is done by masking a CRC of the data channel. Preferably for the above example(s) UE would assume a specific payload size to carry the physical control information on the data channel. Preferably for the above example(s), UE would indicate whether UE have data available for transmission or not on the data channel. More specifically, indication of whether UE have data available for transmission or not is carried on some specific resource on the data channel. Alternatively, indication of whether UE have data available for transmission or not is done by masking a CRC of the data channel. Preferably for the above example(s), eNB would assume both hypotheses of UE have data available for transmission and UE does not have data available for transmission to perform decoding.

In the above example, indicating information by masking a CRC of the data channel may mean after CRC is generated, different sequence is utilized to mask the CRC. To indicate a one bit information, two sequence may be required. Note that a sequence with all 1 is a special case and may mean no masking is done. Mask may mean to perform exclusive or (XOR) operation or some other operation to CRC with a sequence. From a receiver perspective, an reverse operation would be performed with different sequences and only one of them would pass the CRC check, so as to realize the indication according to which sequence could be used to pass the CRC check.

The physical control information may be CQI. The physical control information may be PMI, RI, and/or HARQ feedback. The UE may not be able to transmit the data channel and the control channel simultaneously, e.g. due to UE capability or power restriction. The data channel may be PUSCH. The control channel may be PUCCH.

Details of the invention are described below:

1. A method of a user equipment (UE), comprising:

receiving a signalling to configure an uplink grant, wherein the configured uplink grant is periodically available for UL transmission on a data channel;

preparing a physical control information transmission in a TTI where the configured uplink grant is available; and

transmitting the physical control information on a control channel in the TTI,

wherein the UE has data available for transmission;

wherein the UE is not allowed to perform transmission on the control channel and the data channel simultaneously.

2. A method of a user equipment (UE), comprising:

receiving a signalling to configure an uplink grant, wherein the configured uplink grant is periodically available for UL transmission on a data channel;

preparing a physical control information transmission in a TTI where the configured uplink grant is available; and

if HARQ-ACK repetition is not configured,

transmitting the physical control information on a control channel in the TTI,

if HARQ-ACK repetition is configured,

transmitting the physical control information on a control channel in the TTI,

wherein the UE has data available for transmission;

wherein the UE is not allowed to perform transmission on the control channel and the data channel simultaneously.
3. Based on bullet 1 or 2, the UE doesn't use the configured uplink grant for a transmission on the data channel.
4. Based on bullet 1 or 2, the UE doesn't transmit the available data.
5. A method of a user equipment (UE), comprising:

receiving a signalling to configure an uplink grant, wherein the configured uplink grant is periodically available for UL transmission on a data channel;

preparing a physical control information transmission in a TTI where the configured uplink grant is available; and

uses the configured uplink grant to transmit the physical control information on the data channel,

wherein the UE has data available for transmission;

wherein simultaneous transmission on the control channel and the data channel is allowed but the UE is not able to perform both transmissions on the control channel and the data channel with sufficient power.
6. Based on bullet 5, the UE multiplexes the physical control information with data on the data channel.
7. Based on any of bullets 5 to 6, the UE uses the configured uplink grant to transmit the physical control information on the data channel if no data is available for transmission.
8. Based on any of bullets 5 to 6, the UE doesn't use the configured uplink grant to transmit padding on the data channel if no physical control information needs to be transmitted in a TTI.
9. Based on any of bullets 1 to 8, the physical control information is CQI.

10. Based on any of bullets 1 to 8, the physical control information is HARQ feedback.
11. Based on any of bullets 1 to 10, no network signalling is needed to allocate the configured uplink grant after it is initiated.
12. Based on any of bullets 1 to 11, the configured uplink grant is initiated by a network signalling.
13. Based on bullet 10, the network signalling is SPS (re)initiation.
14. Based on any of bullets 1 to 12, the configured uplink grant is pre-allocated.
15. Based on any of bullets 1 to 13, the UE receives the signalling before transmitting a scheduling request [3].
16. Based on any of bullets 1 to 15, the UE receives the signalling before transmitting a BSR control element [3].
17. Based on any of bullets 1 to 16, the UE receives the signalling when no data is available for transmission.
18. Based on any of bullets 1 to 17, the UE does not transmit a MAC PDU with padding only via the configured uplink grant.
19. Based on any of bullets 1 to 18, the padding includes padding bit(s).
20. Based on any of bullets 1 to 19, the padding includes at least one subheader associated with padding bit(s).
21. Based on any of bullets 1 to 20, the padding includes a MAC control element corresponding to a Padding BSR [3].
22. Based on any of bullets 1 to 21, the padding includes a subheader associated with a MAC control element corresponding to a Padding BSR.
23. Based on any of bullets 1 to 22, the padding includes a MAC control element corresponding to a Padding Sidelink BSR [3].
24. Based on any of bullets 1 to 23, the padding includes a subheader associated with a MAC control element corresponding to a Padding Sidelink BSR.
25. Based on any of bullets 1 to 24, periodicity, where the configured uplink grant is available, is shorter than a specified value.
26. Based on any of bullets 1 to 25, periodicity, where the configured uplink grant is available, is 1ms, 2ms or 5ms.
27. Based on bullet 26, the specified value is 10ms.
28. Based on any of bullets 1 to 27, the signalling is transmitted on PDCCH [3].
29. Based on any of bullets 1 to 28, the signalling is addressed to Semi-Persistent Scheduling C-RNTI [3].
30. Based on any of bullets 1 to 29, the signalling is a RRC message.
31. Based on any of bullets 1 to 30, the uplink grant is on the data channel [4].
32. Based on any of bullets 1 to 31, the uplink grant is on UL-SCH [3].
33. Based on any of bullets 1 to 32, the data available for transmission means that the data belonging to a logical channel that can utilize the configured uplink grant is available for transmission.
34. Based on any of bullets 1 to 33, the UE is not allowed to perform transmission on the control channel and the data channel based on network configuration.

35. Based on any of bullets 1 to 34, the control channel is PUCCH.
36. Based on any of bullets 1 to 35, the data channel is PUSCH.
37. Based on any of bullets 1 to 36, “the UE is not able to perform both transmissions on the control channel and the data channel with sufficient power” means the sum of computed power for the data channel and the computed power for the control channel exceeds the maximum power of the UE.
38. A method of a user equipment (UE), comprising:
 - receiving a first signalling to configure a first uplink grant, wherein the configured uplink grant is periodically available for UL transmission on a data channel;
 - preparing a physical control information transmission in a given TTI; and
 - if the configured uplink grant is available in the TTI, transmitting the physical control information on a control channel in the TTI,
 - if a second signalling is received to indicate a second uplink grant for the specific TTI,;
 - transmitting the physical control information on a data channel in the TTI,
39. Based on bullet 38, the UE doesn’t use the configured uplink grant for a transmission on the data channel if the physical control information is transmitted on a control channel.
40. Based on bullet 38, wherein the UE is not allowed to perform transmission on the control channel and the data channel simultaneously.
41. A method of a user equipment (UE), comprising:
 - receiving a first signalling to configure a first uplink grant, wherein the configured first uplink grant is periodically available for UL transmission on a data channel;
 - preparing a physical control information transmission in a given TTI; and
 - if the configured uplink grant is available in the TTI, uses the configured uplink grant to transmit the physical control information on the data channel,
 - if a second signalling is received to indicate an uplink grant for the specific TTI;
 - and
 - transmit the physical control information on the control channel;
 - wherein simultaneous transmission on the control channel and the data channel is allowed.
42. Based on bullet 41, the UE multiplexes the physical control information with data on the data channel if the physical control information is transmitted on the data channel
43. Based on any of bullets 41 to 42, the UE uses the configured first uplink grant to transmit the physical control information on the data channel if no data is available for transmission.
44. Based on any of bullets 41 to 43, the UE doesn’t use the configured first uplink grant to transmit padding on the data channel if no physical control information needs to be transmitted in a TTI.
45. Based on any of bullets 38 to 44, the UE use the second uplink grant for the specific TTI to transmit padding on the data channel if no physical control information needs to be transmitted in a TTI.
46. Based on any of bullets 38 to 45, the UE uses the second uplink grant for the specific TTI to transmit data if data is available for transmission.

47. Based on any of bullets 38 to 46, the physical control information is CQI.
48. Based on any of bullets 38 to 47, the physical control information is HARQ feedback.
49. Based on any of bullets 38 to 48, no network signalling is needed to allocate the configured first uplink grant after it is initiated.
50. Based on any of bullets 38 to 49, the configured first uplink grant is initiated by a network signalling.
51. Based on bullet 49, the network signalling is SPS (re)initiation.
52. Based on any of bullets 38 to 51, the configured first uplink grant is pre-allocated.
53. Based on any of bullets 38 to 52, the UE receives the first signalling before transmitting a scheduling request [3].
54. Based on any of bullets 38 to 53, the UE receives the first signalling before transmitting a BSR control element [3].
55. Based on any of bullets 38 to 54, the UE receives the first signalling when no data is available for transmission.
56. Based on any of bullets 38 to 55, the UE does not transmit a MAC PDU with padding only via the configured first uplink grant.
57. Based on any of bullets 38 to 56, the padding includes padding bit(s).
58. Based on any of bullets 38 to 57, the padding includes at least one subheader associated with padding bit(s).
59. Based on any of bullets 38 to 58, the padding includes a MAC control element corresponding to a Padding BSR [3].
60. Based on any of bullets 38 to 59, the padding includes a subheader associated with a MAC control element corresponding to a Padding BSR.
61. Based on any of bullets 38 to 60, the padding includes a MAC control element corresponding to a Padding Sidelink BSR [3].
62. Based on any of bullets 38 to 61, the padding includes a subheader associated with a MAC control element corresponding to a Padding Sidelink BSR.
63. Based on any of bullets 38 to 62, periodicity, where the configured first uplink grant is available, is shorter than a specified value.
64. Based on any of bullets 38 to 63, periodicity, where the configured first uplink grant is available, is 1ms, 2ms or 5ms.
65. Based on bullet 63, the specified value is 10ms.
66. Based on any of bullets 38 to 65, the first signalling is transmitted on PDCCH [3].
67. Based on any of bullets 38 to 66, the first signalling is addressed to Semi-Persistent Scheduling C-RNTI [3].
68. Based on any of bullets 38 to 67, the first signalling is a RRC message.
69. Based on any of bullets 38 to 68, the second signalling is transmitted on PDCCH [3].
70. Based on any of bullets 38 to 69, the second signalling is addressed to C-RNTI [3].
71. Based on any of bullets 38 to 70, the first uplink grant and the second uplink grant are on the

data channel [4].

72. Based on any of bullets 38 to 71, the first uplink grant and the second uplink grant are on UL-SCH [3].
73. Based on any of bullets 38 to 72, the data available for transmission means that the data belonging to a logical channel that can utilize the configured first uplink grant is available for transmission.
74. Based on any of bullets 38 to 73, the UE is not allowed to perform transmission on the control channel and the data channel based on network configuration.
75. Based on any of bullets 38 to 74, the control channel is PUCCH.
76. Based on any of bullets 38 to 75, the data channel is PUSCH.
77. A method of a user equipment (UE), comprising:
 - receiving a first signalling to configure a first uplink grant, wherein the configured uplink grant is periodically available for UL transmission on a data channel;
 - preparing a physical control information transmission in a given TTI; and
 - if the configured uplink grant is available in the TTI, transmitting the physical control information on a control channel in the TTI,
 - if a second signalling is received to indicate a second uplink grant for the specific TTI,;
 - transmitting the physical control information on a data channel in the TTI,
78. A method of a user equipment (UE), comprising:
 - an uplink grant is available for a TTI for transmission on a data channel,
 - preparing a physical control information transmission in the TTI; and
 - determine which channel to transmit the physical control information according to the available resource of the uplink grant.
79. Based on bullet 78, if the available resource of the uplink grant is less than a specific value, transmitting the physical control information on a control channel in the TTI.
80. Based on bullet 78 or 79, if the available resource of the uplink grant is more than a specific value, transmitting the physical control information on a data channel in the TTI.
81. Based on bullet 78 to 80, the available resource is TTI length of the uplink grant.
82. Based on bullet 78 to 80, the available resource is the number of PRB (pairs) of the uplink grant.
83. Based on bullet 78 to 82, the uplink grant is received on a downlink control for the specific TTI.
84. Based on bullet 78 to 82, the uplink grant is configured to be periodically available for UL transmission.
85. Based on bullet 78 to 84, the specific value is different for different amount/payload size of physical control information.
86. Based on bullet 78 to 85, the specific value is different for different modulation and coding scheme.
87. Based on bullet 78 to 86, the specific value guarantee code rate of the physical control information would above a threshold.
88. Based on bullet 78, determine which channel to transmit the physical control information according to the available resource of the uplink grant means if the available resource of the

uplink grant is less than a specific value, transmitting the physical control information on a control channel in the TTI and if the available resource of the uplink grant is more than a specific value, transmitting the physical control information on a data channel in the TTI.

89. Based on bullet 77 or 78, the UE doesn't use the configured uplink grant for a transmission on the data channel if the physical control information is transmitted on a control channel.
90. Based on bullet 77 or 78, wherein the UE is not allowed to perform transmission on the control channel and the data channel simultaneously.
91. A method of a user equipment (UE), comprising:
An uplink grant is available for the UE in a TTI;
wherein the UE does not have data available for transmission;
UE determine whether to skip the uplink grant in the TTI according to whether a physical control information needs to be transmitted in the TTI or not.
92. A method of a user equipment (UE), comprising:
An uplink grant is available for the UE in a TTI;
wherein the UE does not have data available for transmission;
if a physical control information needs to be transmitted in a TTI, the UE transmits the physical control information on a data channel according to the uplink grant; and
if no physical control information needs to be transmitted in a TTI, the UE skip the uplink grant.
93. Based on bullet 91 or 92, the uplink grant is a configured uplink grant which is periodically available.
94. Based on bullet 91 or 92, the uplink grant is a dynamic grant specific for the TTI.
95. Based on bullet 91 to 94, skip the uplink grant means UE does not perform transmission on the data channel.
96. Based on bullet 91 to 95, the UE transmits the physical control information on the data channel with a transport block comprise padding (or padding MAC control element)
97. Based on bullet 91 to 95, the UE transmits the physical control information on the data channel without padding (or without padding MAC control element)
98. Based on bullet 97, to perform the data channel transmission the UE treat all the physical control information as a regular transport block from MAC layer and perform regular encoding for the all the physical control information
99. Based on bullet 97, the UE would perform the data channel transmission like perform PUSCH transmission without UL-SCH data
100. Based on bullet 97 or 99, the UE treat a first physical control information, e.g. CQI and/or PMI as a regular transport block from MAC layer and perform regular encoding, such as CRC attachment, interleaving, channel coding, for the first physical control information

101. Based on bullet 97, 99, or 100, the UE multiplex a second type of physical control information, e.g. HARQ-ACK and/or RI on some resource of the data channel.
102. Based on bullet 97 to 101, the UE indicate the payload size of physical control information on the data channel.
103. Based on bullet 102, indication of the payload size is carried on some specific resource on the data channel.
104. Based on bullet 102, indication of the payload size is done by masking a CRC of the data channel.
105. Based on bullet 97 to 104, the UE indicate whether UE have data available for transmission or not on the data channel.
106. Based on bullet 105, indication of whether UE have data available for transmission or not is carried on some specific resource on the data channel.
107. Based on bullet 105, indication of whether UE have data available for transmission or not is done by masking a CRC of the data channel.
108. A UE comprising:
a control circuit;
a processor installed in the control circuit;
a memory installed in the control circuit and coupled to the processor;
wherein the processor is configured to execute a program code stored in the memory to perform the method steps as defined in anyone of the preceding bullets.

Advantage of the invention

A physical control information can be transmitted more efficiently.

Tables

Configured resource is available	Scenario 1	Scenario 2
PHY control info needs to be transmitted in a TTI	yes	yes
Data available for Tx	yes	yes
Simultaneous Tx on PUCCH	no	Yes but power is not enough

and PUSCH		to transmit on both
→ Prior Art	Transmit on PUSCH	Transmit on PUCCH
→ Idea	Transmit on PUCCH	Transmit on PUSCH

Table 1: An example of solution (scenario 1 & scenario 2)

When physical control information needs to be transmitted in a TTI:	Simultaneous transmission on PUCCH and PUSCH is enabled	Simultaneous transmission on PUCCH and PUSCH is disabled
The UE has data	Transmit on PUCCH	Transmit on PUSCH
The UE has no data	Transmit on PUCCH	Transmit on PUCCH

Table 2: prior art (scenario1)

When physical control information needs to be transmitted in a TTI :	Simultaneous transmission on PUCCH and PUSCH is enabled	Simultaneous transmission on PUCCH and PUSCH is disabled
The UE has data	Transmit on PUCCH	Transmit on PUCCH.
The UE has no data	Transmit on PUCCH	Transmit on PUCCH

Table 3: An example of solution (scenario 1)

When physical control information needs to be transmitted in a TTI:	Simultaneous transmission on PUCCH and PUSCH is enabled	
	Tx power is enough	Tx power is not enough
The UE has data	Transmit on PUCCH	Transmit on PUCCH
The UE has no data	Transmit on PUCCH	Transmit on PUCCH

Table 4: prior art (scenario 2)

When physical control information needs to be transmitted in a TTI:	Simultaneous transmission on PUCCH and PUSCH is enabled	
	Tx power is enough	Tx power is not enough
The UE has data	Transmit on PUCCH	Transmit on PUSCH
The UE has no data	Transmit on PUCCH	Transmit on PUSCH

Table 5: An example of solution (scenario 2)

Figures

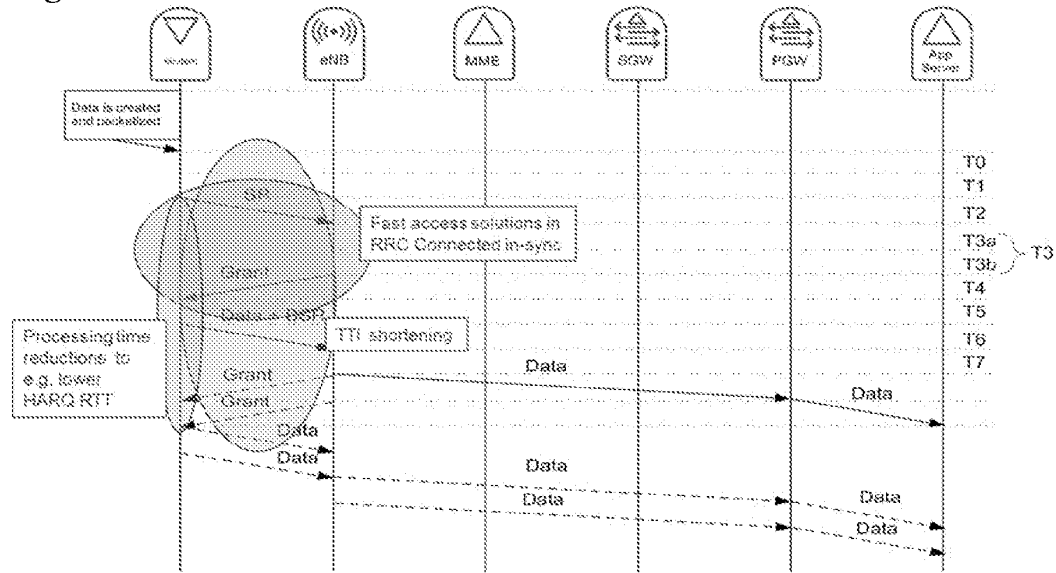
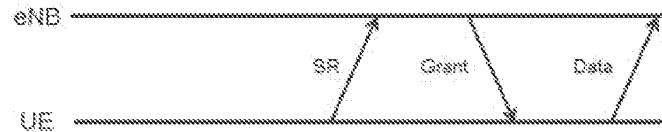


Fig.1: Scope of improvement

> Current uplink transmission procedure:



> Enabling instant uplink access

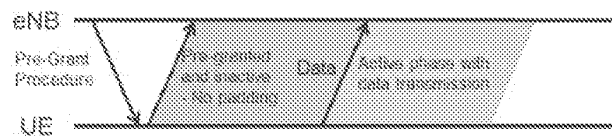


Fig.2: latency reduction by pre-allocated grant

References:

1. 3GPP RP-150465, "New SI proposal: Study on Latency reduction techniques for LTE", Ericsson, Huawei.
2. 3GPP RP-150310, "Study on Latency reduction techniques For LTE", Ericsson.
3. 3GPP TS 36.321 v12.5.0, "E-UTRA MAC protocol specification (Release 12)."
4. 3GPP TS 36.331 v12.5.0, "E-UTRA RRC protocol specification (Release 12)."
5. 3GPP TS 36.213 v12.5.0, "E-UTRA Physical layer procedures (Release 12)."
6. 3GPP TR 36.881 V0.6.0, "E-UTRA Study on latency reduction techniques for LTE (Release 13)."
7. 3GPP TS 36.212 V13.0.0, "E-UTRA Multiplexing and channel coding (Release 13)".

Application and Implementation in Wireless Communication Systems and Devices

The invention(s) described above can be applied to or implemented in exemplary wireless communication systems and devices described below. In addition, the invention(s) is described mainly in the context of the 3GPP architecture reference model. However, it is understood that with the disclosed information, one skilled in the art could easily adapt for use and implement aspects of the invention in a 3GPP2 network architecture as well as in other network architectures.

The exemplary wireless communication systems and devices described below employ a wireless communication system, supporting a broadcast service. Wireless communication systems are widely deployed to provide various types of communication such as voice, data, and so on. These systems may be based on code division multiple access (CDMA), time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA), 3GPP LTE (Long Term Evolution) wireless access, 3GPP LTE-A (Long Term Evolution Advanced) wireless access, 3GPP2 UMB (Ultra Mobile Broadband), WiMax, or some other modulation techniques.

Figure A1 shows a multiple access wireless communication system according to one embodiment of the invention. An access network 100 (AN) includes multiple antenna groups, one including 104 and 106, another including 108 and 110, and an additional including 112 and 114. In Figure A1, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Access terminal 116 (AT) is in communication with antennas 112 and 114, where antennas 112 and 114 transmit information to access terminal 116 over forward link 120 and receive information from access terminal 116 over reverse link 118. Access terminal (AT) 122 is in communication with antennas 106 and 108, where antennas 106 and 108 transmit information to access terminal (AT) 122 over forward link 126 and receive information from access terminal (AT) 122 over reverse link 124. In a FDD system, communication links 118, 120, 124 and 126 may use different frequency for communication. For example, forward link 120 may use a different frequency than that used by reverse link 118.

Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the access network. In the embodiment, antenna groups each are designed to communicate to access terminals in a sector of the areas covered by access network 100.

In communication over forward links 120 and 126, the transmitting antennas of access network 100 may utilize beamforming in order to improve the signal-to-noise ratio of forward links for the different access terminals 116 and 122. Also, an access network using beamforming to transmit to access terminals scattered randomly through its coverage normally causes less interference to access terminals in neighboring cells than an access network transmitting through a single antenna to all its access terminals.

An access network (AN) may be a fixed station or base station used for communicating with the terminals and may also be referred to as an access point, a Node B, a base station, an enhanced base station, an eNodeB, or some other terminology. An access terminal (AT) may also be called user equipment (UE), a wireless communication device, terminal, access terminal or some other terminology.

Figure A2 is a simplified block diagram of an embodiment of a transmitter system 210 (also known as the access network) and a receiver system 250 (also known as access terminal (AT) or user equipment (UE)) in a MIMO system 200. At the transmitter system 210, traffic data for a number of data streams is provided from a data source 212 to a transmit (TX) data processor 214.

In one embodiment, each data stream is transmitted over a respective transmit antenna. TX data processor 214 formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.

The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data is typically a known data pattern that is processed in a known manner and may be used at the receiver system to estimate the channel response. The multiplexed pilot and coded data for each data stream is then modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QPSK, M-PSK, or M-QAM) selected for that data stream to provide modulation symbols. The data rate, coding, and modulation for each data stream may be determined by instructions performed by processor 230.

The modulation symbols for all data streams are then provided to a TX MIMO processor 220, which may further process the modulation symbols (e.g., for OFDM). TX MIMO processor 220 then provides N_T modulation symbol streams to N_T transmitters (TMTR) 222a through 222t. In certain embodiments, TX MIMO processor 220 applies beamforming weights to the symbols of the data streams and to the antenna from which the symbol is being transmitted.

Each transmitter 222 receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and upconverts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. N_T modulated signals from transmitters 222a through 222t are then transmitted from N_T antennas 224a through 224t, respectively.

At receiver system 250, the transmitted modulated signals are received by N_R antennas 252a through 252r and the received signal from each antenna 252 is provided to a respective receiver (RCVR) 254a through 254r. Each receiver 254 conditions (e.g., filters, amplifies, and downconverts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding "received" symbol stream.

An RX data processor 260 then receives and processes the N_R received symbol streams from N_R receivers 254 based on a particular receiver processing technique to provide N_T "detected" symbol streams. The RX data processor 260 then demodulates, deinterleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by RX data processor 260 is complementary to that performed by TX MIMO processor 220 and TX data processor 214 at transmitter system 210.

A processor 270 periodically determines which pre-coding matrix to use (discussed below). Processor 270 formulates a reverse link message comprising a matrix index portion and a rank value portion.

The reverse link message may comprise various types of information regarding the communication link and/or the received data stream. The reverse link message is then processed by a TX data processor 238, which also receives traffic data for a number of data streams from a data source 236, modulated by a modulator 280, conditioned by transmitters 254a through 254r, and transmitted back to transmitter system 210.

At transmitter system 210, the modulated signals from receiver system 250 are received by antennas 224, conditioned by receivers 222, demodulated by a demodulator 240, and processed by a RX data processor 242 to extract the reserve link message transmitted by the receiver system 250. Processor 230 then determines which pre-coding matrix to use for determining the beamforming weights then processes the extracted message.

Memory 232 may be used to temporarily store some buffered/computational data from 240 or 242 through Processor 230, store some buffed data from 212, or store some specific program codes. And Memory 272 may be used to temporarily store some buffered/computational data from 260 through Processor 270, store some buffed data from 236, or store some specific program codes.

Turning to Figure A3, this figure shows an alternative simplified functional block diagram of a communication device according to one embodiment of the invention. As shown in Figure A3, the

communication device 300 in a wireless communication system can be utilized for realizing the UEs (or ATs) 116 and 122 in Figure A1, and the wireless communications system is preferably the LTE system. The communication device 300 may include an input device 302, an output device 304, a control circuit 306, a central processing unit (CPU) 308, a memory 310, a program code 312, and a transceiver 314. The control circuit 306 executes the program code 312 in the memory 310 through the CPU 308, thereby controlling an operation of the communications device 300. The communications device 300 can receive signals input by a user through the input device 302, such as a keyboard or keypad, and can output images and sounds through the output device 304, such as a monitor or speakers. The transceiver 314 is used to receive and transmit wireless signals, delivering received signals to the control circuit 306, and outputting signals generated by the control circuit 306 wirelessly.

Figure A4 is a simplified block diagram of the program code 312 shown in Figure A3 in accordance with one embodiment of the invention. In this embodiment, the program code 312 includes an application layer 400, a Layer 3 portion 402, and a Layer 2 portion 404, and is coupled to a Layer 1 portion 406. The Layer 3 portion 402 generally performs radio resource control. The Layer 2 portion 404 generally performs link control. The Layer 1 portion 406 generally performs physical connections.

For LTE or LTE-A system, the Layer 2 portion 404 may include a Radio Link Control (RLC) layer and a Medium Access Control (MAC) layer. The Layer 3 portion 402 may include a Radio Resource Control (RRC) layer.

Various aspects of the disclosure have been described above. It should be apparent that the teachings herein may be embodied in a wide variety of forms and that any specific structure, function, or both being disclosed herein is merely representative. Based on the teachings herein one skilled in the art should appreciate that an aspect disclosed herein may be implemented independently of any other aspects and that two or more of these aspects may be combined in various ways. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, such an apparatus may be implemented or such a method may be practiced using other structure, functionality, or structure and functionality in addition to or other than one or more of the aspects set forth herein. As an example of some of the above concepts, in some aspects concurrent channels may be established based on pulse repetition frequencies. In some aspects concurrent channels may be established based on pulse position or offsets. In some aspects concurrent channels may be established based on time hopping sequences. In some aspects concurrent channels may be established based on pulse repetition frequencies, pulse positions or offsets, and time hopping sequences.

Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

Those of skill would further appreciate that the various illustrative logical blocks, modules, processors, means, circuits, and algorithm steps described in connection with the aspects disclosed herein may be implemented as electronic hardware (e.g., a digital implementation, an analog implementation, or a combination of the two, which may be designed using source coding or some other technique), various forms of program or design code incorporating instructions (which may be referred to herein, for convenience, as “software” or a “software module”), or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may

implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

In addition, the various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented within or performed by an integrated circuit (“IC”), an access terminal, or an access point. The IC may comprise a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, electrical components, optical components, mechanical components, or any combination thereof designed to perform the functions described herein, and may execute codes or instructions that reside within the IC, outside of the IC, or both. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

It is understood that any specific order or hierarchy of steps in any disclosed process is an example of a sample approach. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

The steps of a method or algorithm described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module (e.g., including executable instructions and related data) and other data may reside in a data memory such as RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of computer-readable storage medium known in the art. A sample storage medium may be coupled to a machine such as, for example, a computer/processor (which may be referred to herein, for convenience, as a “processor”) such the processor can read information (e.g., code) from and write information to the storage medium. A sample storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in user equipment. In the alternative, the processor and the storage medium may reside as discrete components in user equipment. Moreover, in some aspects any suitable computer-program product may comprise a computer-readable medium comprising codes relating to one or more of the aspects of the disclosure. In some aspects a computer program product may comprise packaging materials.

While the invention has been described in connection with various aspects, it will be understood that the invention is capable of further modifications. This application is intended to cover any variations, uses or adaptation of the invention following, in general, the principles of the invention, and including such departures from the present disclosure as come within the known and customary practice within the art to which the invention pertains.

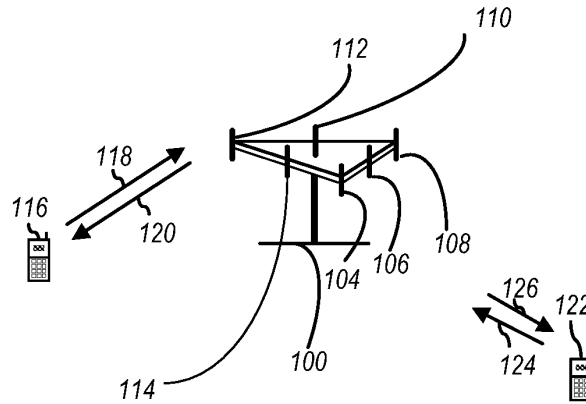


FIG. A1

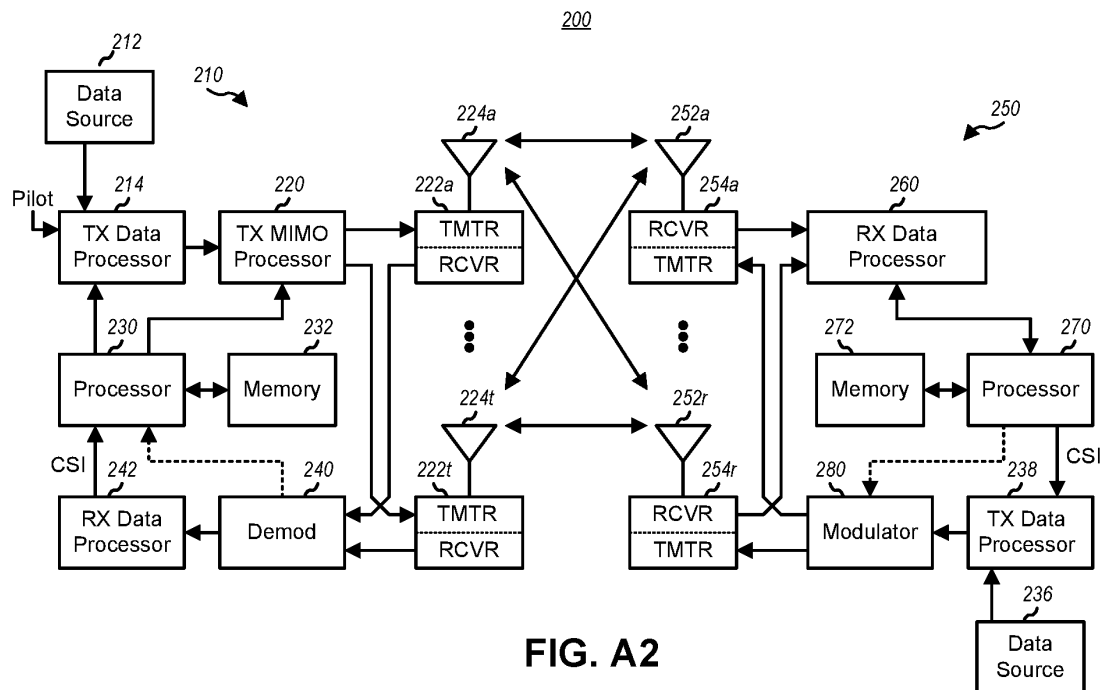


FIG. A2

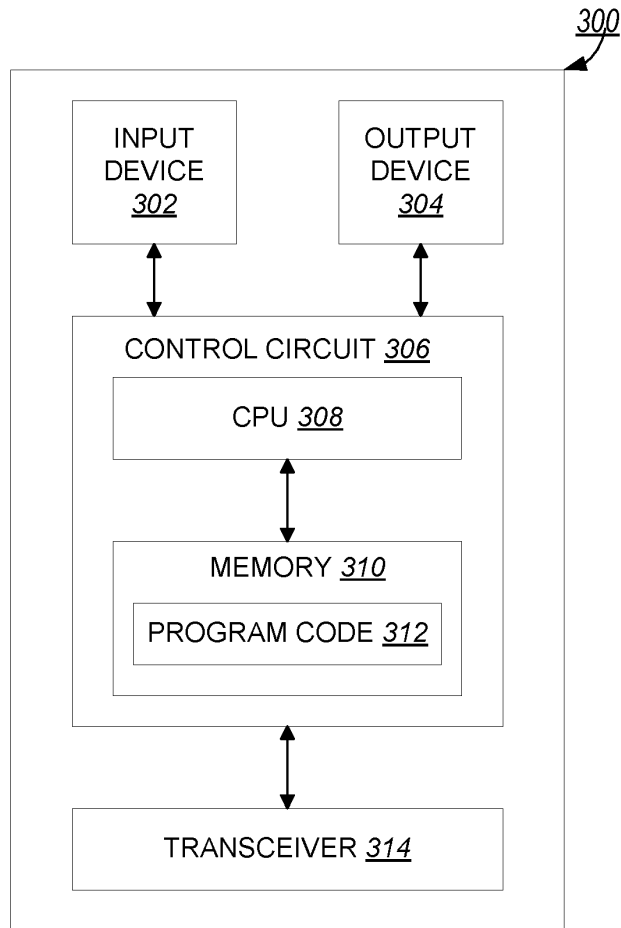


FIG. A3

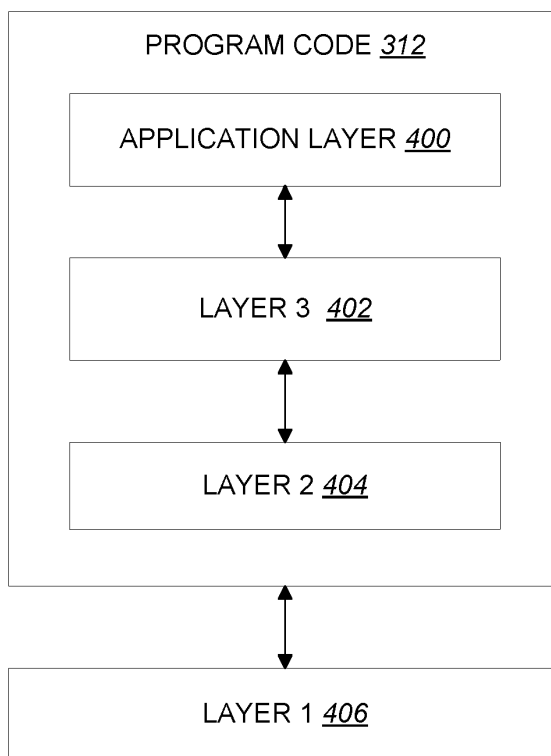


FIG. A4



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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
62/316,799	04/01/2016		260	1426-113.001		

106622
Blue Capital Law Firm, P.C.
611 Anton Blvd., Suite 1050
Costa Mesa, CA 92626

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Date Mailed: 04/20/2016

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

Non-Publication Request: No

Early Publication Request: No

Title

METHOD AND APPARATUS FOR IMPROVING A TRANSMISSION USING A CONFIGURED
RESOURCE IN A WIRELESS COMMUNICATION SYSTEM

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

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