

### **Declaration of Translation**

I, SooJin Namgung, hereby declare:

I possess advanced knowledge of the Korean and English languages and am qualified to translate documents from Korean to English;

I translated U.S. Application Number 62/501,048 from Korean into English and to the best of my knowledge and belief, the attached Document is a true and accurate translation from Korean into English;

I also declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

Dated: May 14, 2024

\_\_\_\_\_남궁수진\_\_\_\_\_

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Filing date: 03 May 2017 (03.05.2017)

Application number: 62501048

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# THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

*March 20, 2018*

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: 62/501,048  
FILING DATE: *May 03, 2017*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/501,048*



Certified by

*Anders Iversen*

Under Secretary of Commerce  
for Intellectual Property  
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|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   |                        |              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                   | Application Number     |              |
| Title of Invention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO 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.)

**Inventor Information:**

|                                                                                                                                    |                                    |                                   |             |        |        |
|------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-----------------------------------|-------------|--------|--------|
| Inventor                                                                                                                           | 1                                  |                                   |             |        | Remove |
| Legal Name                                                                                                                         |                                    |                                   |             |        |        |
| Prefix                                                                                                                             | Given Name                         | Middle Name                       | Family Name | Suffix |        |
|                                                                                                                                    | Suckchel                           |                                   | YANG        |        |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |                                    |                                   |             |        |        |
| City                                                                                                                               | Seoul                              | Country of Residence <sup>i</sup> | KR          |        |        |
| Mailing Address of Inventor:                                                                                                       |                                    |                                   |             |        |        |
| Address 1                                                                                                                          | 19, Yangjae-daero 11gil, Seocho-gu |                                   |             |        |        |
| Address 2                                                                                                                          |                                    |                                   |             |        |        |
| City                                                                                                                               | Seoul                              | State/Province                    |             |        |        |
| Postal Code                                                                                                                        | 06772                              | Country <sup>i</sup>              | KR          |        |        |
| Inventor                                                                                                                           | 2                                  |                                   |             |        | Remove |
| Legal Name                                                                                                                         |                                    |                                   |             |        |        |
| Prefix                                                                                                                             | Given Name                         | Middle Name                       | Family Name | Suffix |        |
|                                                                                                                                    | Joonskui                           |                                   | AHN         |        |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |                                    |                                   |             |        |        |
| City                                                                                                                               | Seoul                              | Country of Residence <sup>i</sup> | KR          |        |        |
| Mailing Address of Inventor:                                                                                                       |                                    |                                   |             |        |        |
| Address 1                                                                                                                          | 19, Yangjae-daero 11gil, Seocho-gu |                                   |             |        |        |
| Address 2                                                                                                                          |                                    |                                   |             |        |        |
| City                                                                                                                               | Seoul                              | State/Province                    |             |        |        |
| Postal Code                                                                                                                        | 06772                              | Country <sup>i</sup>              | KR          |        |        |
| Inventor                                                                                                                           | 3                                  |                                   |             |        | Remove |
| Legal Name                                                                                                                         |                                    |                                   |             |        |        |

|                                           |                                                                   |                        |              |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                        |              |

|                                                                                                                                    |            |                                   |             |        |
|------------------------------------------------------------------------------------------------------------------------------------|------------|-----------------------------------|-------------|--------|
| Prefix                                                                                                                             | Given Name | Middle Name                       | Family Name | Suffix |
|                                                                                                                                    | Hanjun     |                                   | PARK        |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |            |                                   |             |        |
| City                                                                                                                               | Seoul      | Country of Residence <sup>i</sup> | KR          |        |

## Mailing Address of Inventor:

|             |                                    |                        |    |  |
|-------------|------------------------------------|------------------------|----|--|
| Address 1   | 19, Yangjae-daero 11gil, Seocho-gu |                        |    |  |
| Address 2   |                                    |                        |    |  |
| City        | Seoul                              | State/Province         |    |  |
| Postal Code | 06772                              | Country <sup>i</sup>   | KR |  |
| Inventor    | 4                                  | <a href="#">Remove</a> |    |  |
| Legal Name  |                                    |                        |    |  |

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| Prefix                                                                                                                             | Given Name | Middle Name                       | Family Name | Suffix |
|                                                                                                                                    | Seonwook   |                                   | KIM         |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |            |                                   |             |        |
| City                                                                                                                               | Seoul      | Country of Residence <sup>i</sup> | KR          |        |

## Mailing Address of Inventor:

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|-------------|------------------------------------|------------------------|----|--|
| Address 1   | 19, Yangjae-daero 11gil, Seocho-gu |                        |    |  |
| Address 2   |                                    |                        |    |  |
| City        | Seoul                              | State/Province         |    |  |
| Postal Code | 06772                              | Country <sup>i</sup>   | KR |  |
| Inventor    | 5                                  | <a href="#">Remove</a> |    |  |
| Legal Name  |                                    |                        |    |  |

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| Prefix                                                                                                                             | Given Name | Middle Name                       | Family Name | Suffix |
|                                                                                                                                    | Changhwan  |                                   | PARK        |        |
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| City                                                                                                                               | Seoul      | Country of Residence <sup>i</sup> | KR          |        |

## Mailing Address of Inventor:

|             |                                    |                      |    |  |
|-------------|------------------------------------|----------------------|----|--|
| Address 1   | 19, Yangjae-daero 11gil, Seocho-gu |                      |    |  |
| Address 2   |                                    |                      |    |  |
| City        | Seoul                              | State/Province       |    |  |
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|                                           |                                                                   |                        |              |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                        |              |

|                                                                                                                                    |            |                                   |             |        |        |
|------------------------------------------------------------------------------------------------------------------------------------|------------|-----------------------------------|-------------|--------|--------|
| Inventor                                                                                                                           | 6          |                                   |             |        | Remove |
| Legal Name                                                                                                                         |            |                                   |             |        |        |
| Prefix                                                                                                                             | Given Name | Middle Name                       | Family Name | Suffix |        |
|                                                                                                                                    | Seunggye   |                                   | HWANG       |        |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |            |                                   |             |        |        |
| City                                                                                                                               | Seoul      | Country of Residence <sup>i</sup> | KR          |        |        |

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|             |                                    |                      |    |  |  |
|-------------|------------------------------------|----------------------|----|--|--|
| Address 1   | 19, Yangjae-daero 11gil, Seocho-gu |                      |    |  |  |
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| City        | Seoul                              | State/Province       |    |  |  |
| Postal Code | 06772                              | Country <sup>i</sup> | KR |  |  |

|                                                                                                                                    |            |                                   |             |        |        |
|------------------------------------------------------------------------------------------------------------------------------------|------------|-----------------------------------|-------------|--------|--------|
| Inventor                                                                                                                           | 7          |                                   |             |        | Remove |
| Legal Name                                                                                                                         |            |                                   |             |        |        |
| Prefix                                                                                                                             | Given Name | Middle Name                       | Family Name | Suffix |        |
|                                                                                                                                    | Kijun      |                                   | KIM         |        |        |
| Residence Information (Select One)    US Residency <input checked="" type="radio"/> Non US Residency    Active US Military Service |            |                                   |             |        |        |
| City                                                                                                                               | Seoul      | Country of Residence <sup>i</sup> | KR          |        |        |

**Mailing Address of Inventor:**

|             |                                    |                      |    |  |  |
|-------------|------------------------------------|----------------------|----|--|--|
| Address 1   | 19, Yangjae-daero 11gil, Seocho-gu |                      |    |  |  |
| Address 2   |                                    |                      |    |  |  |
| City        | Seoul                              | State/Province       |    |  |  |
| Postal Code | 06772                              | Country <sup>i</sup> | KR |  |  |

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 | 67487             |           |              |
| Email Address   | info@kpatent.com  | Add Email | Remove Email |
| Email Address   | uspto@kpatent.com | Add Email | Remove Email |

|                                           |                                                                   |                        |              |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                        |              |

### Application Information:

|                                         |                                                                   |                                           |                          |
|-----------------------------------------|-------------------------------------------------------------------|-------------------------------------------|--------------------------|
| Title of the Invention                  | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                                           |                          |
| Attorney Docket Number                  | UT17-0756-US                                                      | Small Entity Status Claimed               | <input type="checkbox"/> |
| Application Type                        | Provisional                                                       |                                           |                          |
| Subject Matter                          | Utility                                                           |                                           |                          |
| Total Number of Drawing Sheets (if any) |                                                                   | 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:

|                                                                                                                                                                                                                                                                                                                                                                                                                        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Request Early Publication (Fee required at time of Request 37 CFR 1.219)                                                                                                                                                                                                                                                                                                                      |
| <input type="checkbox"/> <b>Request Not to Publish.</b> 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 <b>has not and will not be</b> 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: | <input checked="" type="radio"/> Customer Number | US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) |
| Customer Number    | 67487                                            |                        |                                                         |

|                                           |                                                                   |                        |              |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                        |              |

### Domestic Benefit/National Stage Information:

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

|                                                                                                                       |                      |                                       |                                    |
|-----------------------------------------------------------------------------------------------------------------------|----------------------|---------------------------------------|------------------------------------|
| Prior Application Status                                                                                              | <input type="text"/> | <input type="button" value="Remove"/> |                                    |
| Application Number                                                                                                    | Continuity Type      | Prior Application Number              | Filing or 371(c) Date (YYYY-MM-DD) |
| <input type="text"/>                                                                                                  | <input type="text"/> |                                       |                                    |
| Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the <b>Add</b> 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)<sup>i</sup> 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 <sup>i</sup> | Filing Date (YYYY-MM-DD) | <input type="button" value="Remove"/>    |
| <input type="text"/>                                                                                   | <input type="text"/> | <input type="text"/>     | Access Code <sup>j</sup> (if applicable) |
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### Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> | 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.<br>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. |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                           |                                                                   |                        |              |
|-------------------------------------------|-------------------------------------------------------------------|------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO 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.

|                                           |                                                                   |              |
|-------------------------------------------|-------------------------------------------------------------------|--------------|
| <b>Application Data Sheet 37 CFR 1.76</b> | Attorney Docket Number                                            | UT17-0756-US |
|                                           | Application Number                                                |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO 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.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                          |                                                  |                |                                       |
| <b>Applicant</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 1                                        |                                                  |                | <input type="button" value="Remove"/> |
| If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. |                                          |                                                  |                |                                       |
| <input type="button" value="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:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                          |                                                  |                |                                       |
| <div></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                          |                                                  |                |                                       |
| Name of the Deceased or Legally Incapacitated Inventor: <div></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                          |                                                  |                |                                       |
| If the Applicant is an Organization check here. <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                          |                                                  |                |                                       |
| Prefix                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Given Name                               | Middle Name                                      | Family Name    | Suffix                                |
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| <b>Mailing Address Information For Applicant:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                          |                                                  |                |                                       |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                          | <div></div>                                      |                |                                       |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                          | <div></div>                                      |                |                                       |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          | State/Province                                   | <div></div>    |                                       |
| Country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <div></div>                              | Postal Code                                      | <div></div>    |                                       |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <div></div>                              | Fax Number                                       | <div></div>    |                                       |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                          | <div></div>                                      |                |                                       |
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**Assignee Information including Non-Applicant Assignee Information:**

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| <b>Application Data Sheet 37 CFR 1.76</b> |                                                                   | Attorney Docket Number | UT17-0756-US |
|                                           |                                                                   | Application Number     |              |
| Title of Invention                        | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |                        |              |

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PROVISIONAL APPLICATION FOR UNITED STATES PATENT  
IN THE NAMES OF

**Suckchel YANG, Joonkui AHN, Hanjun PARK, Seonwook KIM,  
Changhwan PARK, Seunggye HWANG and Kijun KIM**

for

**METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR  
NEW RADIO SYSTEM**

Customer Number: 67487

Attorney Docket Number: UT17-0756-US

Total Number of pages: 88 (including cover)

|                                       |
|---------------------------------------|
| <b>INVENTION DESCRIPTION DOCUMENT</b> |
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|                                         |                                                                                                  |                      |
|-----------------------------------------|--------------------------------------------------------------------------------------------------|----------------------|
| CTO) Mobile communication lab. ACS team | Date: 2017.04.30                                                                                 | TEL : 82-31-450-4074 |
| Inventor                                | Suckchel Yang, Joonkui Ahn, Hanjun Park, Seonwook Kim, Changhwan Park, Seunggye Hwang, Kijun Kim |                      |
| Title of Invention                      | Method of data scheduling and HARQ operation for new radio system                                |                      |

|                          |               |  |  |
|--------------------------|---------------|--|--|
| Specification Groups     | 3GPP TSG RAN1 |  |  |
| Related Technology field |               |  |  |
| Related Specification    | LTE-Advanced  |  |  |

## 1. Purpose of Invention

The present invention proposes a code block (CB) or a CB group (CBG) based data scheduling method and an HARQ operation method.

## 2. Prior Arts in the same field of the invention

Techniques, apparatus and systems described herein can be used in various wireless access technologies such as code division multiple access (CDMA), frequency division multiple access (FDMA), time division multiple access (TDMA), orthogonal frequency division multiple access (OFDMA), single carrier frequency division multiple access (SC-FDMA), etc. The CDMA may be implemented with a radio technology such as Universal Terrestrial Radio Access (UTRA) or CDMA2000. The TDMA may be implemented with a radio technology such as Global System for Mobile communications (GSM)/ General Packet Radio Service (GPRS)/ Enhanced Data Rates for GSM Evolution (EDGE). The OFDMA may be implemented with a radio technology such as institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802-20, evolved-UTRA (E-UTRA) etc. The UTRA is a part of a universal mobile telecommunication system (UMTS). 3rd generation partnership project (3GPP) long term evolution (LTE) is a part of an evolved-UMTS (E-UMTS) using the E-UTRA. The 3GPP LTE employs the OFDMA in downlink and employs the SC-FDMA in uplink [1][2][3]. LTE-advanced (LTE-A) is an evolution of the 3GPP LTE. For clarity, this application focuses on the 3GPP LTE/LTE-A. However, technical features of the present invention are not limited thereto.

### 2-1. LTE system architecture

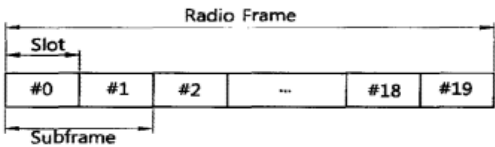


Figure 1. Structure of a radio frame of 3GPP LTE

In Figure 1, a radio frame includes 10 subframes. A subframe includes two slots in time domain. A time for transmitting one subframe is defined as a transmission time interval (TTI). For example, one subframe may have a length of 1 millisecond (ms), and one slot may have a length of 0.5 ms. One slot includes a plurality of orthogonal frequency division multiplexing (OFDM) symbols in time domain. Since the 3GPP LTE uses the OFDMA in the downlink, the OFDM symbol is for representing one symbol period. The OFDM symbol may also be referred to as an SC-FDMA symbol or a symbol period. A resource block (RB) is a resource allocation unit, and includes a plurality of contiguous subcarriers in one slot. The structure of the radio frame is shown for exemplary purposes only. Thus, the number of subframes included in the radio frame or the number of slots included in the subframe or the number of OFDM symbols included in the slot may be modified in various manners.

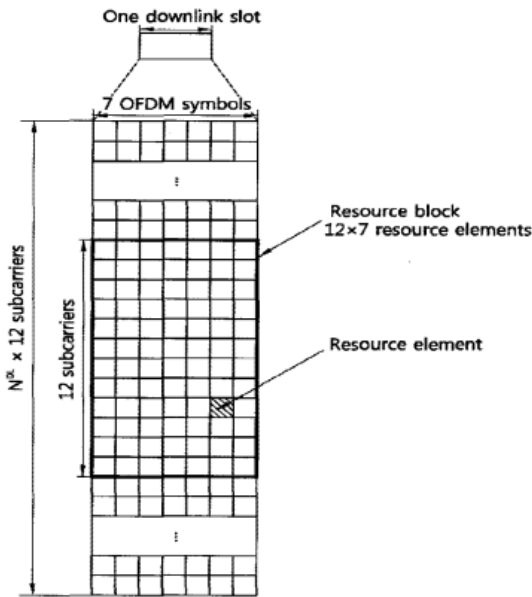


Figure 2. Resource grid for one downlink slot

In Figure 2, a downlink slot includes a plurality of OFDM symbols in time domain. It is described herein that one downlink slot includes 7 OFDM symbols, and one resource block (RB) includes 12 subcarriers in frequency domain as an example. However, the present invention is not limited thereto. Each element on the resource grid is referred to as a resource element (RE). One RB includes 12x7 REs. The number  $N^{DL}$  of RBs included in the downlink slot

## Section 1

depends on a downlink transmit bandwidth. The structure of an uplink slot may be same as that of the downlink slot.

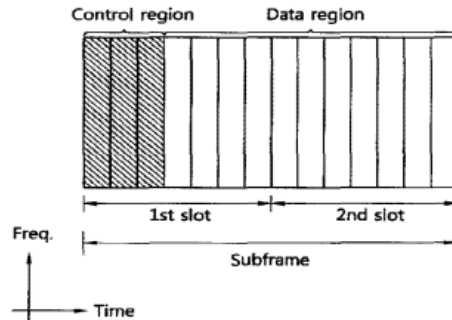


Figure 3. Structure of downlink subframe

In Figure 3, a maximum of three OFDM symbols located in a front portion of a first slot within a subframe correspond to a control region to be assigned with a control channel. The remaining OFDM symbols correspond to a data region to be assigned with a physical downlink shared channel (PDSCH). Examples of downlink control channels used in the 3GPP LTE includes a physical control format indicator channel (PCFICH), a physical downlink control channel (PDCCH), a physical hybrid ARQ indicator channel (PHICH), etc. The PCFICH is transmitted at a first OFDM symbol of a subframe and carries information regarding the number of OFDM symbols used for transmission of control channels within the subframe. The PHICH is a response of uplink transmission and carries an HARQ acknowledgment (ACK)/not-acknowledgment (NACK) signal. Control information transmitted through the PDCCH is referred to as downlink control information (DCI). The DCI includes uplink or downlink scheduling information or includes an uplink transmit (Tx) power control command for arbitrary UE groups.

The PDCCH may carry a transport format and a resource allocation of a downlink shared channel (DL-SCH), resource allocation information of an uplink shared channel (UL-SCH), paging information on a paging channel (PCH), system information on the DL-SCH, a resource allocation of an upper-layer control message such as a random access response transmitted on the PDSCH, a set of Tx power control commands on individual UEs within an arbitrary UE group, a Tx power control command, activation of a voice over IP (VoIP), etc. A plurality of PDCCHs can be transmitted within a control region. The UE can monitor the plurality of PDCCHs. The PDCCH is transmitted on an aggregation of one or several consecutive control channel elements (CCEs). The CCE is a logical allocation unit used to provide the PDCCH with a coding rate based on a state of a radio channel. The CCE corresponds to a plurality of resource element groups (REGs). A format of the PDCCH and the number of bits of the available PDCCH are determined according to a correlation between the number of CCEs and the coding rate provided by the CCEs. The BS determines a PDCCH format according to a DCI to be transmitted to the UE, and attaches a cyclic redundancy check (CRC) to control information. The CRC is masked with a unique identifier (referred to as a radio network temporary identifier (RNTI)) according to an owner or usage of the PDCCH. If the PDCCH is for a specific UE, a unique identifier (e.g., cell-RNTI (C-RNTI)) of the UE may be masked to the CRC. Alternatively, if the

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PDCCH is for a paging message, a paging indicator identifier (e.g., paging-RNTI (P-RNTI)) may be masked to the CRC. If the PDCCH is for system information (more specifically, a system information block (SIB) to be described below), a system information identifier and a system information RNTI (SI-RNTI) may be masked to the CRC. To indicate a random access response that is a response for transmission of a random access preamble of the UE, a random access-RNTI (RA-RNTI) may be masked to the CRC.

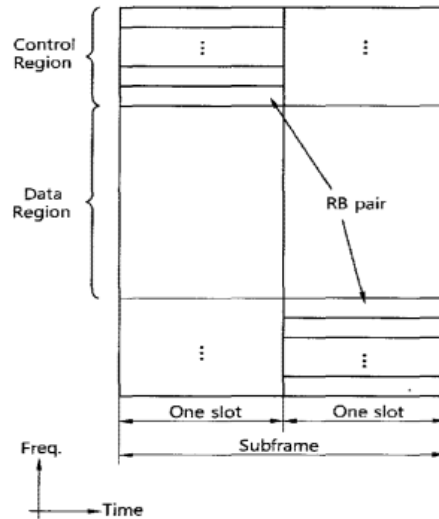


Figure 4. Structure of uplink subframe

In Figure 4, an uplink subframe can be divided in a frequency domain into a control region and a data region. The control region is allocated with a physical uplink control channel (PUCCH) for carrying uplink control information. The data region is allocated with a physical uplink shared channel (PUSCH) for carrying user data. To maintain a single carrier property, one UE does not simultaneously transmit the PUCCH and the PUSCH. The PUCCH for one UE is allocated to an RB pair in a subframe. RBs belonging to the RB pair occupy different subcarriers in respective two slots. This is called that the RB pair allocated to the PUCCH is frequency-hopped in a slot boundary.

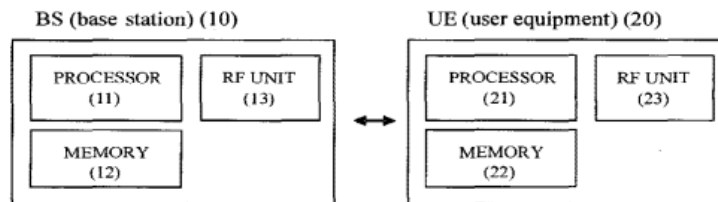


Figure 5. System for implementing present invention

In Figure 5, a wireless communication system includes a BS 10 and one or more UE 20. In downlink, a transmitter may be a part of the BS 10, and a receiver may be a part of the UE 20. In uplink, a transmitter may be a

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part of the UE 20, and a receiver may be a part of the BS 10. A BS 10 may include a processor 11, a memory 12, and a radio frequency (RF) unit 13. The processor 11 may be configured to implement proposed procedures and/or methods described in this application. The memory 12 is coupled with the processor 11 and stores a variety of information to operate the processor 11. The RF unit 13 is coupled with the processor 11 and transmits and/or receives a radio signal. A UE 20 may include a processor 21, a memory 22, and a RF unit 23. The processor 21 may be configured to implement proposed procedures and/or methods described in this application. The memory 22 is coupled with the processor 21 and stores a variety of information to operate the processor 21. The RF unit 23 is coupled with the processor 21 and transmits and/or receives a radio signal. The BS 10 and/or the UE 20 may have single antenna and multiple antennas. When at least one of the BS 10 and the UE 20 has multiple antennas, the wireless communication system may be called as multiple input multiple output (MIMO) system.

## 2-2. Frame structure in LTE

Throughout LTE specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units  $T_s = 1/(15000 \times 2048)$  seconds.

Downlink and uplink transmissions are organized into radio frames with  $T_f = 307200 \times T_s = 10$  ms duration.

Two radio frame structures are supported:

- Type 1, applicable to FDD,
- Type 2, applicable to TDD.

### (1). Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is  $T_f = 307200 \times T_s = 10$  ms long and consists of 20 slots of length  $T_{slot} = 15360 \times T_s = 0.5$  ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe  $i$  consists of slots  $2i$  and  $2i+1$ .

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

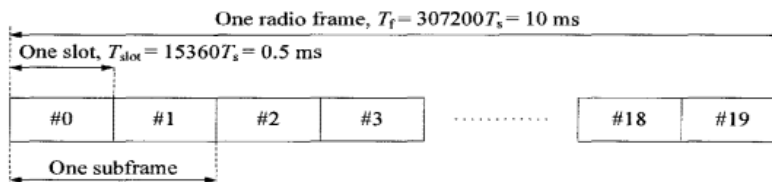


Figure 6: Frame structure type 1.

### (2). Frame structure type 2

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Frame structure type 2 is applicable to TDD. Each radio frame of length  $T_f = 307200 \cdot T_s = 10 \text{ ms}$  consists of two half-frames of length  $153600 \cdot T_s = 5 \text{ ms}$  each. Each half-frame consists of five subframes of length  $30720 \cdot T_s = 1 \text{ ms}$ . The supported uplink-downlink configurations are listed in Table 2 where, for each subframe in a radio frame, "D" denotes the subframe is reserved for downlink transmissions, "U" denotes the subframe is reserved for uplink transmissions and "S" denotes a special subframe with the three fields DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is given by Table 1 subject to the total length of DwPTS, GP and UpPTS being equal to  $30720 \cdot T_s = 1 \text{ ms}$ . Each subframe  $i$  is defined as two slots,  $2i$  and  $2i+1$  of length  $T_{\text{slot}} = 15360 \cdot T_s = 0.5 \text{ ms}$  in each subframe.

Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported. In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames. In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

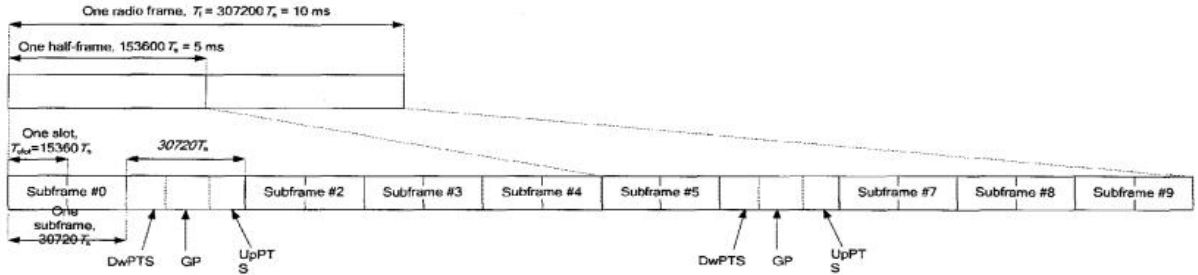


Figure 7: Frame structure type 2 (for 5 ms switch-point periodicity).

Table 1: Configuration of special subframe (lengths of DwPTS/GP/UpPTS).

| Special subframe configuration | Normal cyclic prefix in downlink |                                |                                  | Extended cyclic prefix in downlink |                                |                                  |
|--------------------------------|----------------------------------|--------------------------------|----------------------------------|------------------------------------|--------------------------------|----------------------------------|
|                                | DwPTS                            | UpPTS                          |                                  | DwPTS                              | UpPTS                          |                                  |
|                                |                                  | Normal cyclic prefix in uplink | Extended cyclic prefix in uplink |                                    | Normal cyclic prefix in uplink | Extended cyclic prefix in uplink |
| 0                              | $6592 \cdot T_s$                 | $2192 \cdot T_s$               | $2560 \cdot T_s$                 | $7680 \cdot T_s$                   | $2192 \cdot T_s$               | $2560 \cdot T_s$                 |
| 1                              | $19760 \cdot T_s$                |                                |                                  | $20480 \cdot T_s$                  |                                |                                  |
| 2                              | $21952 \cdot T_s$                |                                |                                  | $23040 \cdot T_s$                  |                                |                                  |
| 3                              | $24144 \cdot T_s$                |                                |                                  | $25600 \cdot T_s$                  |                                |                                  |
| 4                              | $26336 \cdot T_s$                | $4384 \cdot T_s$               | $5120 \cdot T_s$                 | $7680 \cdot T_s$                   | $4384 \cdot T_s$               | $5120 \cdot T_s$                 |
| 5                              | $6592 \cdot T_s$                 |                                |                                  | $20480 \cdot T_s$                  |                                |                                  |
| 6                              | $19760 \cdot T_s$                |                                |                                  | $23040 \cdot T_s$                  |                                |                                  |
| 7                              | $21952 \cdot T_s$                |                                |                                  | -                                  | -                              | -                                |
| 8                              | $24144 \cdot T_s$                |                                |                                  | -                                  | -                              | -                                |

Table 2: Uplink-downlink configurations.

| Uplink-downlink configuration | Downlink-to-Uplink Switch-point periodicity | Subframe number |   |   |   |   |   |   |   |   |   |
|-------------------------------|---------------------------------------------|-----------------|---|---|---|---|---|---|---|---|---|
|                               |                                             | 0               | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                             | 5 ms                                        | D               | S | U | U | U | D | S | U | U | U |
| 1                             | 5 ms                                        | D               | S | U | U | D | D | S | U | U | D |
| 2                             | 5 ms                                        | D               | S | U | D | D | D | S | U | D | D |
| 3                             | 10 ms                                       | D               | S | U | U | U | D | D | D | D | D |
| 4                             | 10 ms                                       | D               | S | U | U | D | D | D | D | D | D |
| 5                             | 10 ms                                       | D               | S | U | D | D | D | D | D | D | D |
| 6                             | 5 ms                                        | D               | S | U | U | U | D | S | U | U | D |

### 2-3. PUSCH related procedures in LTE

For FDD, there shall be 8 HARQ processes in the uplink for non-subframe bundling operation, i.e. normal HARQ operation, and 4 HARQ processes in the uplink for subframe bundling operation. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

In subframe bundling operation, a bundle of PUSCH transmissions consists of four consecutive uplink subframes in

both FDD and TDD.

For FDD and normal HARQ operation, the UE shall upon detection of a PDCCH with DCI format 0 and/or a PHICH transmission in subframe  $n$  intended for the UE, adjust the corresponding PUSCH transmission in subframe  $n+4$  according to the PDCCH and PHICH information.

For FDD and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe  $n$  intended for the UE, and/or a PHICH transmission in subframe  $n-5$  intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe  $n+4$  according to the PDCCH and PHICH information.

For FDD and TDD, the NDI as signalled on PDCCH, the RV, and the TBS shall be delivered to higher layers. For TDD, the number of HARQ processes shall be determined by the DL/UL configuration, as indicated in Table 3.

**Table 3: Number of synchronous UL HARQ processes for TDD**

| TDD UL/DL configuration | Number of HARQ processes for normal HARQ operation | Number of HARQ processes for subframe bundling operation |
|-------------------------|----------------------------------------------------|----------------------------------------------------------|
| 0                       | 7                                                  | 3                                                        |
| 1                       | 4                                                  | 2                                                        |
| 2                       | 2                                                  | N/A                                                      |
| 3                       | 3                                                  | N/A                                                      |
| 4                       | 2                                                  | N/A                                                      |
| 5                       | 1                                                  | N/A                                                      |
| 6                       | 6                                                  | 3                                                        |

For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH with DCI format 0 and/or a PHICH transmission in subframe  $n$  intended for the UE, adjust the corresponding PUSCH transmission in subframe  $n+k$ , with  $k$  given in Table 4, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH with DCI format 0 and/or a PHICH transmission in subframe  $n$  intended for the UE, adjust the corresponding PUSCH transmission in subframe  $n+k$  if the MSB of the UL index in the DCI format 0 is set to 1 or PHICH is received in subframe  $n=0$  or 5 in the resource corresponding to  $I_{PHICH}=0$ , with  $k$  given in Table 4. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0 is set to 1 in subframe  $n$  or a PHICH is received in subframe  $n=0$  or 5 in the resource corresponding to  $I_{PHICH}=1$ , or PHICH is received in subframe  $n=1$  or 6, the UE shall adjust the corresponding PUSCH transmission in subframe  $n+7$ . If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the DCI format 0 are set in subframe  $n$ , the UE shall adjust the corresponding PUSCH transmission in both subframes  $n+k$  and  $n+7$ , with  $k$  given in Table 4.

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe  $n$  intended for the UE, and/or a PHICH transmission intended for the UE in

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subframe  $n-l$  with  $l$  given in Table 5, adjust the corresponding first PUSCH transmission in the bundle in subframe  $n+k$ , with  $k$  given in Table 4, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe  $n$  intended for the UE, and/or a PHICH transmission intended for the UE in subframe  $n-l$  with  $l$  given in Table 5, adjust the corresponding first PUSCH transmission in the bundle in subframe  $n+k$ , if the MSB of the UL index in the DCI format 0 is set to 1 or if  $I_{PHICH} = 0$ , with  $k$  given in Table 4, according to the PDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the DCI format 0 is set to 1 in subframe  $n$  or if  $I_{PHICH} = 1$ , the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe  $n+7$ , according to the PDCCH and PHICH information.

Table 4:  $k$  for TDD configurations 0-6

| TDD UL/DL<br>Configuratio<br>n | DL subframe number $n$ |   |   |   |   |   |   |   |   |   |
|--------------------------------|------------------------|---|---|---|---|---|---|---|---|---|
|                                | 0                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                              | 4                      | 6 |   |   |   | 4 | 6 |   |   |   |
| 1                              |                        | 6 |   |   | 4 |   | 6 |   |   | 4 |
| 2                              |                        |   |   | 4 |   |   |   |   | 4 |   |
| 3                              | 4                      |   |   |   |   |   |   |   | 4 | 4 |
| 4                              |                        |   |   |   |   |   |   |   | 4 | 4 |
| 5                              |                        |   |   |   |   |   |   |   | 4 |   |
| 6                              | 7                      | 7 |   |   |   | 7 | 7 |   |   | 5 |

Table 5:  $l$  for TDD configurations 0, 1 and 6

| TDD UL/DL<br>Configuratio<br>n | DL subframe number $n$ |   |   |   |   |   |   |   |   |   |
|--------------------------------|------------------------|---|---|---|---|---|---|---|---|---|
|                                | 0                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                              | 9                      | 6 |   |   |   | 9 | 6 |   |   |   |
| 1                              |                        | 2 |   |   | 3 |   | 2 |   |   | 3 |
| 6                              | 5                      | 5 |   |   |   | 6 | 6 |   |   | 8 |

## 2-4. UE ACK/NACK procedure in LTE

For Frame Structure type 1, an ACK/NACK received on the PHICH assigned to a UE in subframe  $i$  is associated with the PUSCH transmission in subframe  $i-4$ .

For Frame Structure type 2 UL/DL configuration 1-6, an ACK/NACK received on the PHICH assigned to a UE in subframe  $i$  is associated with the PUSCH transmission in the subframe  $i-k$  as indicated by the following Table 6. For Frame Structure type 2 UL/DL configuration 0, an ACK/NACK received on the PHICH in the resource corresponding to  $I_{PHICH} = 0$ , assigned to a UE in subframe  $i$  is associated with the PUSCH transmission in the subframe  $i-k$  as indicated by the following Table 6. If, for Frame Structure type 2 UL/DL configuration 0, an ACK/NACK received on the PHICH in the resource corresponding to  $I_{PHICH} = 1$ , assigned to a UE in subframe  $i$  is associated with the PUSCH transmission in the subframe  $i-6$ .

Table 6:  $k$  for TDD configurations 0-6

| TDD UL/DL<br>Configuratio<br>n | DL subframe number $i$ |   |   |   |   |   |   |   |   |   |
|--------------------------------|------------------------|---|---|---|---|---|---|---|---|---|
|                                | 0                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                              | 7                      | 4 |   |   |   | 7 | 4 |   |   |   |
| 1                              |                        | 4 |   |   | 6 |   | 4 |   |   | 6 |
| 2                              |                        |   |   | 6 |   |   |   |   | 6 |   |
| 3                              | 6                      |   |   |   |   |   |   |   | 6 | 6 |
| 4                              |                        |   |   |   |   |   |   |   | 6 | 6 |
| 5                              |                        |   |   |   |   |   |   |   | 6 |   |
| 6                              | 6                      | 4 |   |   |   | 7 | 4 |   |   | 6 |

The physical layer in the UE shall deliver indications to the higher layers as follows:

For downlink subframe  $i$ , if a transport block was transmitted in the associated PUSCH subframe then:

- ① if ACK is decoded on the PHICH in subframe  $i$ , ACK shall be delivered to the higher layers;
- ② else NACK shall be delivered to the higher layers.

## 2-5. PHICH assignment procedure

For PUSCH transmissions scheduled from serving cell  $c$  in subframe  $n$ , a UE shall determine the corresponding PHICH resource of serving cell  $c$  in subframe  $n + k_{PHICH}$ , where  $k_{PHICH}$  is always 4 for FDD and is given in Table 7 for TDD. For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

Table 7:  $k_{PHICH}$  for TDD

| TDD UL/DL<br>Configuratio<br>n | subframe index $n$ |   |   |   |   |   |   |   |   |   |
|--------------------------------|--------------------|---|---|---|---|---|---|---|---|---|
|                                | 0                  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                              |                    |   | 4 | 7 | 6 |   |   | 4 | 7 | 6 |
| 1                              |                    |   | 4 | 6 |   |   |   | 4 | 6 |   |
| 2                              |                    |   | 6 |   |   |   |   | 6 |   |   |
| 3                              |                    |   | 6 | 6 | 6 |   |   |   |   |   |
| 4                              |                    |   | 6 | 6 |   |   |   |   |   |   |
| 5                              |                    |   | 6 |   |   |   |   |   |   |   |
| 6                              |                    |   | 4 | 6 | 6 |   |   | 4 | 7 |   |

The PHICH resource is identified by the index pair  $(n_{PHICH}^{group}, n_{PHICH}^{seq})$  where  $n_{PHICH}^{group}$  is the PHICH group number and  $n_{PHICH}^{seq}$  is the orthogonal sequence index within the group as defined by:

$$n_{PHICH}^{group} = (I_{PRB\_RA} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$

$$n_{PHICH}^{seq} = \left( \lfloor I_{PRB\_RA} / N_{PHICH}^{group} \rfloor + n_{DMRS} \right) \bmod 2N_{SF}^{PHICH}$$

where

- $n_{DMRS}$  is mapped from the cyclic shift for DMRS field (according to Table 8) in the most recent PDCCH with uplink DCI format [2] for the transport block(s) associated with the corresponding PUSCH transmission.  $n_{DMRS}$  shall be set to zero, if there is no PDCCH with uplink DCI format for the same transport block, and
  - if the initial PUSCH for the same transport block is semi-persistently scheduled, or
  - if the initial PUSCH for the same transport block is scheduled by the random access response grant.
- $N_{SF}^{PHICH}$  is the spreading factor size used for PHICH modulation as described in [1].

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$$I_{PRB\_RA} = \begin{cases} I_{PRB\_RA}^{lowest\_index} & \text{for the first TB of a PUSCH with associated PDCCH or for the case of} \\ & \text{no associated PDCCH when the number of negatively acknowledged} \\ & \text{TBs is not equal to the number of TBs indicated in the most recent} \\ & \text{PDCCH associated with the corresponding PUSCH} \\ I_{PRB\_RA}^{lowest\_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH} \end{cases}$$

where  $I_{PRB\_RA}^{lowest\_index}$  is the lowest PRB index in the first slot of the corresponding PUSCH transmission

- $N_{PHICH}^{group}$  is the number of PHICH groups configured by higher layers as described in [1],
- $I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$

Table 8: Mapping between  $n_{DMRS}$  and the cyclic shift for DMRS field in PDCCH with uplink DCI format [2]

| Cyclic Shift for DMRS Field in PDCCH with uplink DCI format in [2] | $n_{DMRS}$ |
|--------------------------------------------------------------------|------------|
| 000                                                                | 0          |
| 001                                                                | 1          |
| 010                                                                | 2          |
| 011                                                                | 3          |
| 100                                                                | 4          |
| 101                                                                | 5          |
| 110                                                                | 6          |
| 111                                                                | 7          |

## 2-6. UE procedure for reporting ACK/NACK in LTE

For FDD, when both ACK/NACK and SR are transmitted in the same sub-frame a UE shall transmit the ACK/NACK on its assigned ACK/NACK PUCCH resource for a negative SR transmission and transmit the ACK/NACK on its assigned SR PUCCH resource for a positive SR transmission.

For TDD and all UL-DL configurations except configuration 5, two ACK/NACK feedback modes are supported by higher layer configuration.

- ACK/NACK bundling, and
- ACK/NACK multiplexing

For TDD UL-DL configuration 5, only ACK/NACK bundling is supported.

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH indicating downlink SPS release within subframe(s)  $n-k$ , where  $k \in K$  and  $K$  is defined in Table 11 intended for the UE and for which

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ACK/NACK response shall be provided, transmit the ACK/NACK response in UL subframe  $n$ .

For TDD UL-DL configurations 1-6, the value of the Downlink Assignment Index (DAI) in DCI format 0,  $V_{DAI}^{UL}$ , detected by the UE according to Table 9 in subframe  $n - k'$ , where  $k'$  is defined in Table 10, represents the total number of subframes with PDSCH transmissions and with PDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s)  $n - k$ , where  $k \in K$ . The value  $V_{DAI}^{UL}$  includes all PDSCH transmission with and without corresponding PDCCH within all the subframe(s)  $n - k$ . In case neither PDSCH transmission, nor PDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0,  $V_{DAI}^{UL}$ , if transmitted, is set to 4.

For TDD UL-DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A denotes the accumulative number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release up to the present subframe within subframe(s)  $n - k$ , where  $k \in K$ , and shall be updated from subframe to subframe. Denote  $V_{DAI}^{DL}$  as the value of the DAI in PDCCH with DCI format 1/1A/1B/1D/2/2A detected by the UE according to Table 9 in subframe  $n - k_m$ , where  $k_m$  is the smallest value in the set  $K$  (defined in Table 11) such that the UE detects a DCI format 1/1A/1B/1D/2/2A. Denote  $U_{DAI}$  as the total number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release detected by the UE within the subframe(s)  $n - k$ , where  $k \in K$ . Denote  $N_{SPS}$ , which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH within the subframe(s)  $n - k$ , where  $k \in K$ .

Table 9: Value of Downlink Assignment Index

| DAI<br>MSB, LSB | $V_{DAI}^{UL}$ or $V_{DAI}^{DL}$ | Number of subframes with PDSCH<br>transmission |
|-----------------|----------------------------------|------------------------------------------------|
| 0,0             | 1                                | 1 or 5 or 9                                    |
| 0,1             | 2                                | 2 or 6                                         |
| 1,0             | 3                                | 3 or 7                                         |
| 1,1             | 4                                | 0 or 4 or 8                                    |

Table 10: Uplink association index  $k'$  for TDD

| TDD UL/DL<br>Configuration | DL subframe number $n$ |   |   |   |   |   |   |   |   |   |
|----------------------------|------------------------|---|---|---|---|---|---|---|---|---|
|                            | 0                      | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1                          |                        |   | 6 | 4 |   |   |   | 6 | 4 |   |
| 2                          |                        |   | 4 |   |   |   |   | 4 |   |   |

|   |  |  |   |   |   |  |  |   |   |  |
|---|--|--|---|---|---|--|--|---|---|--|
| 3 |  |  | 4 | 4 | 4 |  |  |   |   |  |
| 4 |  |  | 4 | 4 |   |  |  |   |   |  |
| 5 |  |  | 4 |   |   |  |  |   |   |  |
| 6 |  |  | 7 | 7 | 5 |  |  | 7 | 7 |  |

## 2-7. UE procedure for determining PUCCH assignment in LTE

Uplink control information (UCI) in subframe  $n$  shall be transmitted

- on PUCCH using format 1/1a/1b or 2/2a/2b if the UE is not transmitting on PUSCH in subframe  $n$
- on PUSCH if the UE is transmitting on 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

Throughout this section, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted  $k$ , the first subframe of the next radio frame is denoted  $k+1$ .

The following combinations of uplink control information on PUCCH are supported:

- HARQ-ACK using PUCCH format 1a or 1b
- HARQ-ACK using PUCCH format 1b with channel selection
- Scheduling request (SR) using PUCCH format 1
- HARQ-ACK and SR using PUCCH format 1a or 1b
- CQI using PUCCH format 2
- CQI and HARQ-ACK using PUCCH format
  - 2a or 2b for normal cyclic prefix
  - 2 for extended cyclic prefix

The scrambling initialization of PUCCH format 2, 2a and 2b is by C-RNTI.

The parameter *Simultaneous-AN-and-CQI* provided by higher layers determine if a UE can transmit a combination of CQI and HARQ-ACK on PUCCH in the same subframe.

For TDD, two ACK/NACK feedback modes are supported by higher layer configuration.

- ACK/NACK bundling and
- ACK/NACK multiplexing

For TDD UL-DL configuration 5, only ACK/NACK bundling is supported.

TDD ACK/NACK bundling is performed per codeword across  $M$  multiple DL subframes associated with a single UL subframe  $n$ , where  $M$  is the number of elements in the set  $K$  defined in Table 11, by a logical AND operation

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of all the individual PDSCH transmission (with and without corresponding PDCCH) ACK/NACKs and ACK in response to PDCCH indicating downlink SPS release. The bundled 1 or 2 ACK/NACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD ACK/NACK multiplexing and a subframe  $n$  with  $M > 1$ , where  $M$  is the number of elements in the set  $K$  defined in Table 11, spatial ACK/NACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual ACK/NACKs and PUCCH format 1b with channel selection is used. For TDD ACK/NACK multiplexing and a subframe  $n$  with  $M = 1$ , spatial ACK/NACK bundling across multiple codewords within a DL subframe is not performed, 1 or 2 ACK/NACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

Table 11: Downlink association set index  $K : \{k_0, k_1, \dots, k_{M-1}\}$  for TDD

| UL-DL<br>Configuration | Subframe $n$ |   |                              |            |      |   |   |            |   |   |
|------------------------|--------------|---|------------------------------|------------|------|---|---|------------|---|---|
|                        | 0            | 1 | 2                            | 3          | 4    | 5 | 6 | 7          | 8 | 9 |
| 0                      | -            | - | 6                            | -          | 4    | - | - | 6          | - | 4 |
| 1                      | -            | - | 7, 6                         | 4          | -    | - | - | 7, 6       | 4 | - |
| 2                      | -            | - | 8, 7, 4, 6                   | -          | -    | - | - | 8, 7, 4, 6 | - | - |
| 3                      | -            | - | 7, 6, 11                     | 6, 5       | 5, 4 | - | - | -          | - | - |
| 4                      | -            | - | 12, 8, 7, 11                 | 6, 5, 4, 7 | -    | - | - | -          | - | - |
| 5                      | -            | - | 13, 12, 9, 8, 7, 5, 4, 11, 6 | -          | -    | - | - | -          | - | - |
| 6                      | -            | - | 7                            | 7          | 5    | - | - | 7          | 7 | - |

2-8. Carrier aggregation in LTE-A

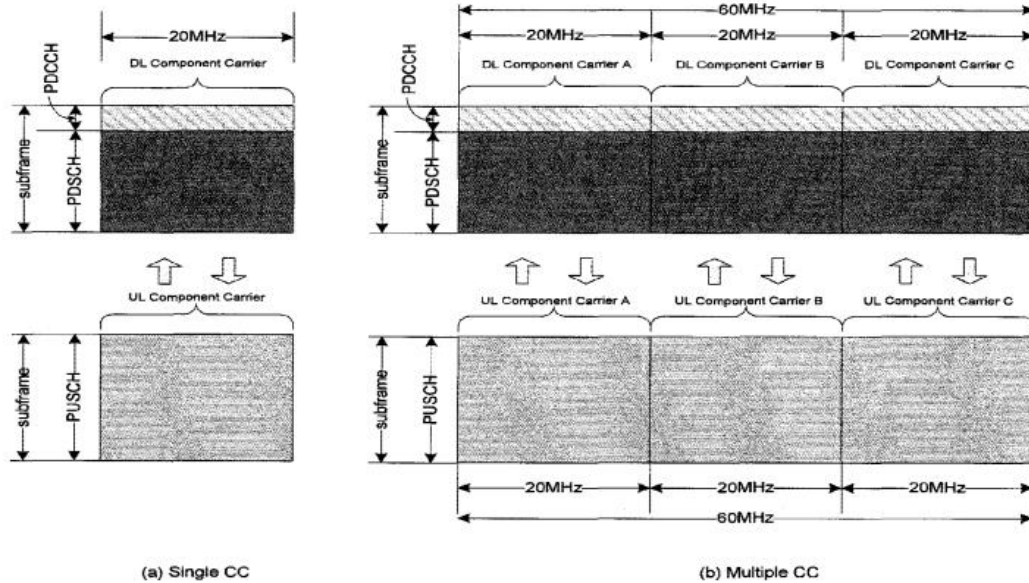


Figure 8 : Subframe structure of 3GPP LTE Release-8 system and LTE-A system with CC aggregation

As the increased demands for the high data rate transmission, the mobile communication system composed of aggregated multiple CCs (component carriers) is now being researched. For example, Figure 8 (b) illustrates the DL/UL subframe structure considered in 3GPP LTE-A (LTE-Advanced) system where multiple CCs are aggregated (in this example, 3 carriers exist), while Figure 8 (a) illustrates a single carrier operation as in conventional systems. As shown in Figure 8 (b), a UE can monitor and receive DL signal/data from multiple DL CCs at the same time. However, even if a cell is managing  $N$  DL CCs, the network may configure a UE with  $M$  DL CCs where  $M \leq N$  so that the UE's monitoring of the DL signal/data is limited to those  $M$  DL CCs. In addition, the network may configure  $L$  DL CCs as the main DL CCs from which the UE should monitor/receive DL signal/data with a priority, either UE-specifically or cell-specifically, where  $L \leq M \leq N$ .

Moreover, for cross-CC scheduling of LTE-A UEs, the introduction of carrier indicator field (CIF) has been considered. The baseline of PDCCH transmission for LTE-A is summarized as below, and configuration for the presence or absence of the CIF within PDCCH is semi-statically and UE-specifically enabled by higher layer signaling.

- CIF disabled: PDCCH on a DL CC assigns PDSCH resources on the same DL CC and PUSCH resources on a single linked UL CC
  - No CIF
  - Same as Rel-8 PDCCH structure (same coding, same CCE-based resource mapping) and DCI formats
- CIF enabled: PDCCH on a DL CC can assign PDSCH or PUSCH resources in one of multiple aggregated

DL/UL CCs using the CIF

- Rel-8 DCI formats extended with the CIF
  - CIF (if configured) is a fixed 3-bit field
  - CIF (if configured) location is fixed irrespective of DCI format size
- Reusing Rel-8 PDCCH structure (same coding, same CCE-based resource mapping)

In the case of presence of CIF, desirably, the eNB may assign the PDCCH monitoring DL CC set for reduction of blind decoding complexity at the UE side. This CC set is a portion of the entire aggregated DL CCs and the UE only performs detection/decoding of PDCCHs scheduled for it on this set. In other words, to schedule PDSCH/PUSCH for a UE, the eNB transmits PDCCHs only through the PDCCH monitoring DL CC set. The PDCCH monitoring DL CC set may be set UE-specific or UE-group-specific or cell-specific. For example, Figure 9 shows a DL subframe for a LTE-A UE for which 3 DL CCs are aggregated, and DL CC A is configured as the PDCCH monitoring DL CC. If the CIF is disabled, each DL CC can transmit only the PDCCH scheduling its own PDSCH without the CIF, by following the Rel-8 PDCCH principle. On the other hand, if the CIF is enabled by UE-specific higher layer signaling, only DL CC A can transmit the PDCCHs scheduling not only its own PDSCH but also PDSCHs of the other CCs, by using the CIF. Note that no PDCCH is transmitted on DL CC B and C which are not configured as the PDCCH monitoring DL CC.

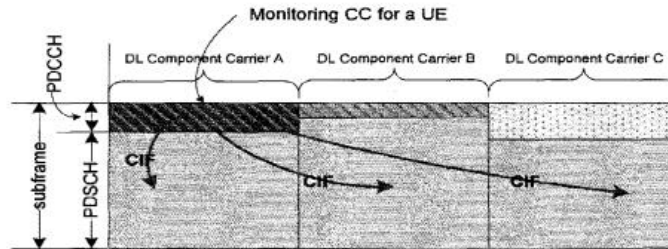


Figure 9 : Subframe structure of LTE-A system with CIF for cross-CC scheduling

## 2-9. PDCCH assignment procedure in LTE-A

The control region of each serving cell (i.e. CC) consists of a set of CCEs, numbered from 0 to  $N_{CCE,k} - 1$ , where  $N_{CCE,k}$  is the total number of CCEs in the control region of subframe  $k$ . The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signaling for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space  $S_k^{(L)}$  at aggregation level  $L \in \{1, 2, 4, 8\}$  is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate  $m$  of the search space  $S_k^{(L)}$  are given by

$$L \left\{ (Y_k + m') \bmod \lfloor N_{CCE,k} / L \rfloor \right\} + i$$

where  $Y_k$  is defined below,  $i = 0, \dots, L-1$ . For the common search space (i.e. CSS)  $m' = m$ . For the UE specific search space (i.e. USS), for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then  $m' = m + M^{(L)} \cdot n_{CI}$  where  $n_{CI}$  is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then  $m' = m$ , where  $m = 0, \dots, M^{(L)} - 1$ .  $M^{(L)}$  is the number of PDCCH candidates to monitor in the given search space.

The UE shall monitor one common search space at each of the aggregation levels 4 and 8 on the primary cell (i.e. PCC). A UE not configured with a carrier indicator field shall monitor one UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell. A UE configured with a carrier indicator field shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signaling. The common and UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell  $c$  shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the UE specific search space of serving cell  $c$ . A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field. For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the UE specific search space for PDCCH with carrier indicator field.

A UE is not expected to monitor the PDCCH of a secondary cell (i.e. SCC) if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured with carrier indicator field for a given serving cell and configured to monitor PDCCH candidates with CRC scrambled by C-RNTI with a common payload size and with the same first CCE index  $n_{CCE}$  in the

- common search space
- UE specific search space

may assume that only the PDCCH in the common search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C-RNTI, where the PDCCH candidates may have one or more possible values of CIF for

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the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

The aggregation levels defining the search spaces are listed in Table 12. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell.

For the common search spaces,  $Y_k$  is set to 0 for the two aggregation levels  $L = 4$  and  $L = 8$ . For the UE-specific search space  $S_k^{(L)}$  at aggregation level  $L$ , the variable  $Y_k$  is defined by

$$Y_k = (A \cdot Y_{k-1}) \bmod D$$

where  $Y_{-1} = n_{RNTI} \neq 0$ ,  $A = 39827$ ,  $D = 65537$  and  $k = \lfloor n_s/2 \rfloor$ ,  $n_s$  is the slot number within a radio frame. The RNTI value used for  $n_{RNTI}$  is defined in [3] as a kind of UE's ID.

Table 12: PDCCH candidates monitored by a UE

| Type        | Search space $S_k^{(L)}$ |                | Number of PDCCH candidates $M^{(L)}$ |
|-------------|--------------------------|----------------|--------------------------------------|
|             | Aggregation level $L$    | Size [in CCEs] |                                      |
| UE-specific | 1                        | 6              | 6                                    |
|             | 2                        | 12             | 6                                    |
|             | 4                        | 8              | 2                                    |
|             | 8                        | 16             | 2                                    |
| Common      | 4                        | 16             | 4                                    |
|             | 8                        | 16             | 2                                    |

## 2-10. ACK/NACK multiplexing in LTE

Under the situation that a UE should simultaneously transmit multiple ACK/NACKs corresponding to multiple data units received from the eNB, in order to maintain the single-carrier property of ACK/NACK signals and reduce the total ACK/NACK transmission power, ACK/NACK multiplexing method based on PUCCH resource selection can be considered. With ACK/NACK multiplexing, contents of the ACK/NACK responses for multiple data units are identified by the combination of the PUCCH resource used in actual ACK/NACK transmission and the one of QPSK modulation symbols. For example, if we assume one PUCCH resource carries 4 bits and 4 data units can be transmitted in maximum (here we assume HARQ operation for each data unit can be managed by single ACK/NACK bit), the ACK/NACK result can be identified at the TX node as in the following Table 13.

Table 13 : Example of ACK/NACK multiplexing based on PUCCH resource selection

| HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3) | $n_{\text{PUCCH}}^{(1)}$   | $b(0), b(1)$ |
|----------------------------------------------------|----------------------------|--------------|
| ACK, ACK, ACK, ACK                                 | $n_{\text{PUCCH},1}^{(1)}$ | 1, 1         |
| ACK, ACK, ACK, NACK/DTX                            | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0         |
| NACK/DTX, NACK/DTX, NACK, DTX                      | $n_{\text{PUCCH},2}^{(1)}$ | 1, 1         |
| ACK, ACK, NACK/DTX, ACK                            | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0         |

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|                                    |                            |      |
|------------------------------------|----------------------------|------|
| NACK, DTX, DTX, DTX                | $n_{\text{PUCCH},0}^{(1)}$ | 1, 0 |
| ACK, ACK, NACK/DTX, NACK/DTX       | $n_{\text{PUCCH},1}^{(1)}$ | 1, 0 |
| ACK, NACK/DTX, ACK, ACK            | $n_{\text{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, NACK/DTX, NACK | $n_{\text{PUCCH},3}^{(1)}$ | 1, 1 |
| ACK, NACK/DTX, ACK, NACK/DTX       | $n_{\text{PUCCH},2}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, ACK       | $n_{\text{PUCCH},0}^{(1)}$ | 0, 1 |
| ACK, NACK/DTX, NACK/DTX, NACK/DTX  | $n_{\text{PUCCH},0}^{(1)}$ | 1, 1 |
| NACK/DTX, ACK, ACK, ACK            | $n_{\text{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK, DTX, DTX           | $n_{\text{PUCCH},1}^{(1)}$ | 0, 0 |
| NACK/DTX, ACK, ACK, NACK/DTX       | $n_{\text{PUCCH},2}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, ACK       | $n_{\text{PUCCH},3}^{(1)}$ | 1, 0 |
| NACK/DTX, ACK, NACK/DTX, NACK/DTX  | $n_{\text{PUCCH},1}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, ACK       | $n_{\text{PUCCH},3}^{(1)}$ | 0, 1 |
| NACK/DTX, NACK/DTX, ACK, NACK/DTX  | $n_{\text{PUCCH},2}^{(1)}$ | 0, 0 |
| NACK/DTX, NACK/DTX, NACK/DTX, ACK  | $n_{\text{PUCCH},3}^{(1)}$ | 0, 0 |
| DTX, DTX, DTX, DTX                 | N/A                        | N/A  |

In Table 2, HARQ-ACK(i) indicates the ACK/NACK result for the data unit i (there are maximum 4 data units, that is, from data unit 0 to data unit 3 in this example). In Table 2, DTX means there is no data unit transmitted for corresponding HARQ-ACK(i) or the RX node doesn't detect the existence of the data unit corresponding to HARQ-ACK(i).  $n_{\text{PUCCH},x}^{(1)}$  indicates the PUCCH resource which should be used in actual ACK/NACK transmission, where there are 4 PUCCH resources,  $n_{\text{PUCCH},0}^{(1)}$ ,  $n_{\text{PUCCH},1}^{(1)}$ ,  $n_{\text{PUCCH},2}^{(1)}$ , and  $n_{\text{PUCCH},3}^{(1)}$  in maximum.  $b(0), b(1)$  indicates two bits carried by the selected PUCCH resource. Modulation symbol which is transmitted through PUCCH resource is decided according to the bits. For example, if the RX node receives and decodes 4 data units successfully, the RX node should transmit two bits, (1, 1), using PUCCH resource  $n_{\text{PUCCH},1}^{(1)}$ . For another example, if the RX node receives 4 data units, fails in decoding (or misses) the first and the third data units (corresponding to HARQ-ACK(0) and HARQ-ACK(2)) and decodes the second and the fourth data units (corresponding to HARQ-ACK(1) and HARQ-ACK(3)) successfully, the RX node should transmit (1, 0) using  $n_{\text{PUCCH},3}^{(1)}$ . By linking the actual ACK/NACK contents with the combination of PUCCH resource selection and the actual bit contents in the transmitted PUCCH resource in this way, ACK/NACK transmission using single PUCCH resource for multiple data units is possible.

In ACK/NACK multiplexing method, basically, NACK and DTX are coupled as NACK/DTX as shown in Table 2 if at least one ACK exists for all data units. This is because combinations of PUCCH resource and QPSK symbol are insufficient to cover all ACK/NACK hypotheses based on decoupling of NACK and DTX. On the other hand, for the

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case that no ACK exists for all data units (in other words, NACK or DTX only exists for all data units), single definite NACK case is defined as the case that only one of HARQ-ACK(i)s is NACK decoupled with DTX. In this case, PUCCH resource linked to the data unit corresponding to single definite NACK can be also reserved to transmit the signal of multiple ACK/NACKs.

## 2-11. ACK/NACK transmission for LTE-A

In an LTE-A system, transmitting a plurality of ACK/NACK information/signals for a plurality of PDSCHs transmitted via a plurality of DL CCs via a specific UL CC is considered. For this purpose, unlike ACK/NACK transmission using PUCCH format 1a/1b in a conventional Rel-8 LTE, it may be considered to channel code the plurality of ACK/NACK information (for example Reed-Muller code, Tail-biting convolutional code, and the like) and then transmit the plurality of ACK/NACK information/signals using PUCCH format 2 or a new PUCCH format (for example, E-PUCCH format) of a varied form, which is based on block-spreading as described below.

### • Block-spreading

Block-spreading technique is a method to modulate control information/signal (for example, ACK/NACK and the like) transmission using SC-FDMA method, which is different from PUCCH format 1 or 2 series in existing LTE. In this method, the symbol sequence is transmitted by time-domain spreading by OCC (Orthogonal Cover Code) as shown in Figure 10, and the control signals of a plurality of UEs can be multiplexed to the same RB using OCC. In the previous PUCCH format 2, one symbol sequence is transmitted over the time domain and UE multiplexing is performed using cyclic shift (that is, CCS) of the CAZAC sequence, while in the block-spreading-based E-PUCCH format, one symbol sequence is transmitted over the frequency domain and UE multiplexing is performed using OCC-based time-domain spreading. As an example, Figure 10 shows how one symbol sequence is transmitted by generating five SC-FDMA symbols using an OCC of length-5 (SF = 5) and transmitting them. In the example shown in the figure, a total of two RS symbols are used for one slot, but various other applications can also be considered, such as using three RS symbols and an OCC of SF=4. Here, the RS entities can be generated from a CAZAC sequence with a specific cyclic shift and transmitted in a form with a characteristic OCC applied (multiplied) to a plurality of RS symbols in the time domain.

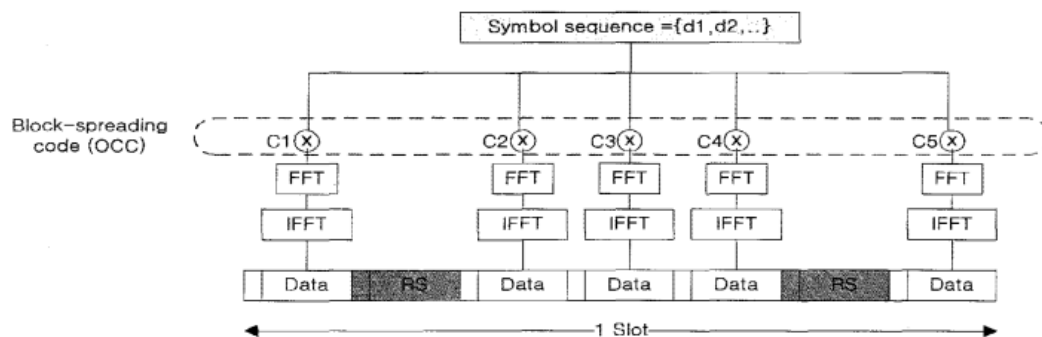


Figure 10. Example of E-PUCCH format based on block-spreading (that is, PUCCH format 3)

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For ease of explanation, this special channel coding based ACK/NACK transmission method that uses PUCCH format 2 or E-PUCCH format is referred to as "multi-bit ACK/NACK coding" transmission method. This method refers to the transmission of ACK/NACK coded blocks generated by channel coding the ACK/NACK or DTX information for PDSCHs of a plurality of DL CCs (meaning PDCCHs are not received/detected). For example, if the terminal operates in SU-MIMO mode and receives two codewords (CW) from a certain DL CC, it can transmit a total of four feedback states of ACK/ACK, ACK/NACK, NACK/ACK, and NACK/NACK for each CW for that CC, or it can have up to five feedback states including DTX. Furthermore, if a terminal receives a single CW, it can have up to three states of ACK, NACK, and DTX (if NACK is treated the same as DTX, it can have two states, which are ACK and NACK/DTX). Therefore, if a terminal aggregates up to 5 DL CCs and operates in SU-MIMO mode on all CCs, it can have up to  $5^5$  feedback states that can be transmitted, and the ACK/NACK payload size to represent them is 12 bits in total (if DTX is treated the same as NACK, the number of feedback states is  $4^5$  and the ACK/NACK payload size to represent these is 10 bits in total).

In the previous ACK/NACK multiplexing (for example, ACK/NACK selection) method applied to the existing Rel-8 TDD system, an implicit ACK/NACK selection method is considered, which basically uses the implicit PUCCH resource corresponding to the PDCCH (that is, linked to the lowest CCE index) that schedules each PDSCH of the UE to secure the PUCCH resource of each UE. On the other hand, LTE-A FDD systems are basically considering a plurality of ACK/NACK transmissions for a plurality of PDSCHs transmitted through a plurality of DL CCs via one specific UL CC, which is set UE-specific, and for this purpose, an "ACK/NACK selection" method is considered, which uses a combination of explicit PUCCH resources pre-scheduled for each UE via implicit PUCCH resources linked to the PDCCH that schedules a specific, some, or all DL CCs (that is., linked to the lowest CCE index nCCE, or linked to nCCE and nCCE+1) or via the implicit PUCCH resource and RRC signaling.

On the other hand, a situation may also be considered in an LTE-A TDD system, in which a plurality of CCs is aggregated (CA), and accordingly, transmitting a plurality of ACK/NACK information/signals for a plurality of PDSCHs transmitted via a plurality of DL subframes and a plurality of CCs via a specific CC (for example, A/N CC) in the UL subframe corresponding to the plurality of DL subframes is considered. Here, unlike the previous LTE-A FDD, a method wherein a plurality of ACK/NACKs corresponding to the maximum number of CWs that can be transmitted through all CCs assigned to the UE is transmitted to all of the plurality of DL subframes (that is, SF) (that is, full ACK/NACK) is considered, or a method wherein transmission is performed after reducing the total number of ACK/NACK transmissions by applying ACK/NACK bundling to the CW and/or CC and/or SF domain (that is, bundled ACK/NACK) (here, CW bundling means applying ACK/NACK bundling for CW to each DL SF for each CC, CC bundling means applying ACK/NACK bundling for all or some CCs to each DL SF, and SF bundling means applying ACK/NACK bundling for all or some DL SFs to each CC. As a characteristic SF bundling method, an "ACK-counter" method can be considered, which provides the total number of ACKs per CC (or the number of some ACK) to all PDSCH or DL grant PDCCH received by each CC). In this case, depending on the ACK/NACK payload per UE, that is the size of the ACK/NACK payload for transmitting full or bundled ACK/NACK set for each UE,

a ACK/NACK transmission method based on "multi-bit ACK/NACK coding" or "ACK/NACK selection" can be configurably applied.

## 2-12. Random access procedure in LTE

An LTE UE can only be scheduled for UL transmission if its UL transmission timing is synchronized. The LTE random access channel (RACH) therefore plays a key role as an interface between non-synchronized UEs and the orthogonal transmission scheme of the LTE UL radio access [3]. LTE uses the RACH for initial network access, but in LTE the RACH cannot carry any user data. Instead, the LTE RACH is used to achieve UL time synchronization for a UE which either has not yet acquired, or has lost, its UL synchronization. Once UL synchronization is achieved for a UE, the eNB can schedule orthogonal UL transmission resources for it.

The LTE random access procedure comes in two forms, allowing access to be either contention-based (implying an inherent risk of collision) or contention-free. A UE initiates a contention-based random access procedure for all use-cases including the initial access. In this procedure, a RACH preamble signature is randomly chosen by the UE, with the result that it is possible for more than one UE simultaneously to transmit the same signature, leading to a need for a subsequent contention resolution process. For the use-cases such as handover, the eNB has the option of preventing contention occurring by allocating a dedicated signature to a UE, resulting in contention-free access (namely, dedicated random access). This is faster than contention-based access - a factor which is particularly important for the case of handover, which is time-critical. These two procedures are outlined in Figure 11.

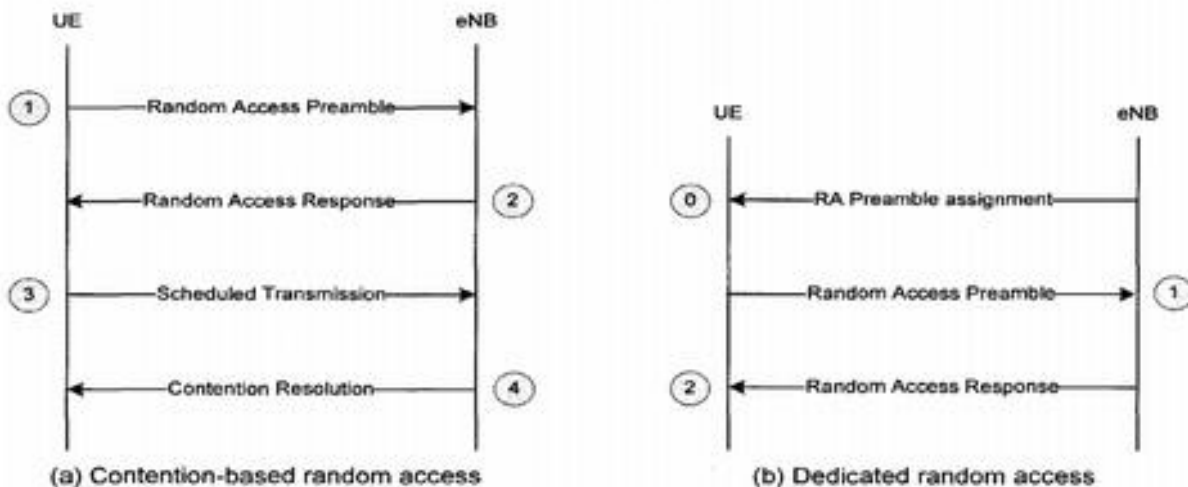


Figure 11. Random access procedures of 3GPP LTE Release-8 system

The four steps of the contention-based random access procedure are provided as below:

- Step 1: RACH preamble transmission (from UE to eNB in UL)
- Step 2: Random access response (from eNB to UE in DL)

- Step 3: Layer 2 / Layer 3 message (from UE to eNB in UL)
- Step 4: Contention resolution message (from eNB to UE in DL)

On the other hand, the dedicated random access procedure consists of the following three steps:

- Step 0: RACH preamble assignment via dedicated signalling (from eNB to UE in DL)
- Step 1: RACH preamble transmission (from UE to eNB in UL)
- Step 2: Random access response (from eNB to UE in DL)

The Random Access Response (RAR) is sent by the eNodeB on the Physical Downlink Shared CHannel (PDSCH), and addressed with an ID, the Random Access Radio Network Temporary Identifier (RA-RNTI), identifying the time-frequency slot in which the preamble was detected. If multiple UEs had collided by selecting the same signature in the same preamble time-frequency resource, they would each receive the RAR. The RAR conveys the identity of the detected preamble, a timing alignment instruction (i.e. TA: Timing Advance) to synchronize subsequent uplink transmissions from the UE, an initial uplink resource grant for transmission of the Step 3 message, and an assignment of a Temporary Cell Radio Network Temporary Identifier (C-RNTI) (which may or may not be made permanent as a result of the next step – contention resolution).

#### (1) Transmission timing adjustments

Upon reception of a timing advance command, the UE shall adjust its uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell. The timing advance command indicates the change of the uplink timing relative to the current uplink timing as multiples of  $16 T_s$ . The start timing of the random access preamble is specified in [1]. The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell.

In case of random access response, 11-bit timing advance command,  $T_A$ , indicates  $N_{TA}$  values by index values of  $T_A = 0, 1, 2, \dots, 1282$ , where an amount of the time alignment is given by  $N_{TA} = T_A \times 16$ .  $N_{TA}$  is defined in [1].

In other cases, 6-bit timing advance command,  $T_A$ , indicates adjustment of the current  $N_{TA}$  value,  $N_{TA,old}$ , to the new  $N_{TA}$  value,  $N_{TA,new}$ , by index values of  $T_A = 0, 1, 2, \dots, 63$ , where  $N_{TA,new} = N_{TA,old} + (T_A - 31) \times 16$ . Here, adjustment of  $N_{TA}$  value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing by a given amount respectively.

For a timing advance command received on subframe  $n$ , the corresponding adjustment of the timing shall apply from the beginning of subframe  $n+6$ . When the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe  $n$  and subframe  $n+1$  are overlapped due to the timing adjustment, the UE shall transmit complete subframe  $n$  and not transmit the overlapped part of subframe  $n+1$ .

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command, the UE changes  $N_{TA}$  accordingly.

**(2) Random Access Response Grant**

The higher layers indicate the 20-bit UL Grant to the physical layer. This is referred to the Random Access Response Grant in the physical layer. The content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit
- Fixed size resource block assignment – 10 bits
- Truncated modulation and coding scheme – 4 bits
- TPC command for scheduled PUSCH – 3 bits
- UL delay – 1 bit
- CSI request – 1 bit

The UE shall use the single-antenna port uplink transmission scheme for the PUSCH transmission corresponding to the Random Access Response Grant and the PUSCH retransmission for the same transport block.

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below.

The fixed size resource block assignment field is interpreted as follows:

if  $N_{RB}^{UL} \leq 44$

Truncate the fixed size resource block assignment to its  $b$  least significant bits, where  $b = \lceil \log_2(N_{RB}^{UL} \cdot (N_{RB}^{UL} + 1) / 2) \rceil$ , and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

else

Insert  $b$  most significant bits with value set to '0' after the  $N_{UL\_hop}$  hopping bits in the fixed size resource block assignment, where the number of hopping bits  $N_{UL\_hop}$  is zero when the hopping flag bit is not set to 1 when the hopping flag bit is set to 1, and  $b = \left( \lceil \log_2(N_{RB}^{UL} \cdot (N_{RB}^{UL} + 1) / 2) \rceil - 10 \right)$ , and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

end if

The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 defined for PUSCH transmission in [3]. The TPC command  $\delta_{msg2}$  shall be used for setting the power of the PUSCH, and is interpreted according to Table 14.

**Table 14: TPC Command  $\delta_{msg2}$  for Scheduled PUSCH**

| TPC Command | Value (in dB) |
|-------------|---------------|
| 0           | -6            |
| 1           | -4            |
| 2           | -2            |
| 3           | 0             |
| 4           | 2             |
| 5           | 4             |
| 6           | 6             |
| 7           | 8             |

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission. In contention based random access procedure, the CSI request field is reserved. The UL delay applies for both TDD and FDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced.

### (3) DCI format 1A

DCI format 1A is used for the compact scheduling of one PDSCH codeword in one cell and random access procedure initiated by a PDCCH order. The following information is transmitted by means of the DCI format 1A:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
  - Flag for format0/1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A
- Format 1A is used for random access procedure initiated by a PDCCH order only if format 1A CRC is scrambled with C-RNTI and all the remaining fields are set as follows:
- Localized/Distributed VRB assignment flag – 1 bit is set to '0'
  - Resource block assignment –  $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL} + 1)/2) \rceil$  bits, where all bits shall be set to 1
  - Preamble Index – 6 bits
  - PRACH Mask Index – 4 bits
  - All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Localized/Distributed VRB assignment flag – 1 bit as defined in [3]
- Resource block assignment –  $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL} + 1)/2) \rceil$  bits as defined in [3]:
  - For localized VRB:
    - $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL} + 1)/2) \rceil$  bits provide the resource allocation
  - For distributed VRB:
    - If  $N_{RB}^{DL} < 50$  or if the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI
      - $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL} + 1)/2) \rceil$  bits provide the resource allocation
    - Else

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- 1 bit, the MSB indicates the gap value, where value 0 indicates  $N_{\text{gap}} = N_{\text{gap},1}$  and value 1 indicates  $N_{\text{gap}} = N_{\text{gap},2}$

-  $\lceil \log_2(N_{\text{RB}}^{\text{DL}}(N_{\text{RB}}^{\text{DL}} + 1)/2) \rceil - 1$  bits provide the resource allocation,

where  $N_{\text{gap}}$  is defined in [1].

- Modulation and coding scheme – 5bits as defined in [3]
- HARQ process number – 3 bits (FDD) , 4 bits (TDD)
- New data indicator – 1 bit
  - If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:
    - If  $N_{\text{RB}}^{\text{DL}} \geq 50$  and Localized/Distributed VRB assignment flag is set to 1
      - the new data indicator bit indicates the gap value, where value 0 indicates  $N_{\text{gap}} = N_{\text{gap},1}$  and value 1 indicates  $N_{\text{gap}} = N_{\text{gap},2}$ .
    - Else the new data indicator bit is reserved.
  - Else
    - The new data indicator bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in [3]
  - If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:
    - The most significant bit of the TPC command is reserved.
    - The least significant bit of the TPC command indicates column  $N_{\text{PRB}}^{\text{1A}}$  of the TBS table defined of [3].
    - If least significant bit is 0 then  $N_{\text{PRB}}^{\text{1A}} = 2$  else  $N_{\text{PRB}}^{\text{1A}} = 3$ .
  - Else
    - The two bits including the most significant bit indicates the TPC command
- Downlink Assignment Index (this field is present in TDD for all the uplink –downlink configurations and only applies to TDD operation with uplink –downlink configuration 1-6. This field is not present in FDD) – 2 bits
- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PDSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in [3]

If the number of information bits in format 1A mapped onto a given search space is less than that of format 0 for scheduling the same serving cell and mapped onto the same search space, zeros shall be appended to format 1A until the payload size equals that of format 0. If the number of information bits in format 1A belongs to one of the sizes in Table 15, one zero bit shall be appended to format 1A.

**Table 15: Ambiguous Sizes of Information Bits.**

|                                          |
|------------------------------------------|
| {12, 14, 16, 20, 24, 26, 32, 40, 44, 56} |
|------------------------------------------|

When the format 1A CRC is scrambled with a RA-RNTI, P-RNTI, or SI-RNTI then the following fields among the fields above are reserved:

- HARQ process number
- Downlink Assignment Index (used for TDD only and is not present in FDD)

### 2-13. PHICH resource configuration in LTE

The PHICH carries the hybrid-ARQ ACK/NACK. Multiple PHICHs mapped to the same set of resource elements constitute a PHICH group, where PHICHs within the same PHICH group are separated through different orthogonal sequences. A PHICH resource is identified by the index pair  $(n_{\text{PHICH}}^{\text{group}}, n_{\text{PHICH}}^{\text{seq}})$ , where  $n_{\text{PHICH}}^{\text{group}}$  is the PHICH group number and  $n_{\text{PHICH}}^{\text{seq}}$  is the orthogonal sequence index within the group.

For frame structure type 1, the number of PHICH groups  $N_{\text{PHICH}}^{\text{group}}$  is constant in all subframes and is given by

$$N_{\text{PHICH}}^{\text{group}} = \begin{cases} \lceil N_g (N_{\text{RB}}^{\text{DL}} / 8) \rceil & \text{for normal cyclic prefix} \\ 2 \cdot \lceil N_g (N_{\text{RB}}^{\text{DL}} / 8) \rceil & \text{for extended cyclic prefix} \end{cases}$$

where  $N_g \in \{1/6, 1/2, 1, 2\}$  is provided by higher layers. The index  $n_{\text{PHICH}}^{\text{group}}$  ranges from 0 to  $N_{\text{PHICH}}^{\text{group}} - 1$ .

For frame structure type 2, the number of PHICH groups may vary between downlink subframes and is given by  $m_i \cdot N_{\text{PHICH}}^{\text{group}}$  where  $m_i$  is given by Table 6.9-1 and  $N_{\text{PHICH}}^{\text{group}}$  by the expression above. The index  $n_{\text{PHICH}}^{\text{group}}$  in a downlink subframe with non-zero PHICH resources ranges from 0 to  $m_i \cdot N_{\text{PHICH}}^{\text{group}} - 1$ .

**Table 6.9-1: The factor  $m_i$  for frame structure type 2**

| Uplink-downlink configuration | Subframe number $i$ |   |   |   |   |   |   |   |   |   |
|-------------------------------|---------------------|---|---|---|---|---|---|---|---|---|
|                               | 0                   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0                             | 2                   | 1 | - | - | - | 2 | 1 | - | - | - |
| 1                             | 0                   | 1 | - | - | 1 | 0 | 1 | - | - | 1 |
| 2                             | 0                   | 0 | - | 1 | 0 | 0 | 0 | - | 1 | 0 |
| 3                             | 1                   | 0 | - | - | - | 0 | 0 | 0 | 1 | 1 |
| 4                             | 0                   | 0 | - | - | 0 | 0 | 0 | 0 | 1 | 1 |
| 5                             | 0                   | 0 | - | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 6                             | 1                   | 1 | - | - | - | 1 | 1 | - | - | 1 |

### 2-14. HARQ timing for CA between TDD and FDD

For PDSCH transmitted through a FDD cell when TDD PCell and FDD SCell are carrier aggregated (carrier aggregation, CA),

if ACK/NACK is transmitted through the UE subframe of the TDD Pcell by applying PDCCH/PDSCH-to-ACK/NACK timing (for example 4 ms) defined in existing FDD cell as is in timing of ACK/NACK transmission to the UE, ACK/NACK cannot be transmitted if TDD PCell is defined as DL subframe in ACK/NACK transmission timing. Therefore, in order to provide ACK/NACK transmission for more DL subframes in the FDD cell, the new DL HARQ timing may be applied instead of the PDCCH/ PDSCH-to-ACK/NACK timing defined in the reference FDD cell. Similarly, UL HARQ timing may also apply the new HARQ timing. The following HARQ timings that can be discussed and approved in current LTE systems are summarized below.

- 1) DL HARQ timing (PDSCH to HARQ-ACK timing) for TDD SCell in case of FDD PCell
  - A. Self-scheduling case: follow DL HARQ timing of FDD PCell
  - B. Cross-carrier scheduling case: follow DL HARQ timing of FDD PCell
- 2) UL HARQ timing (UL grant DCI to PUSCH, PUSCH to PHICH) for TDD SCell in case of FDD PCell
  - A. Self-scheduling case: follow UL HARQ timing of TDD scheduled cell timing
  - B. Cross-carrier scheduling case
    - i. Option UL-A1:
      1. For FDD scheduling cell case, follow TDD scheduled cell timing
      2. For TDD scheduling cell case, reference U/D configuration for UL timing is derived by scheduling and scheduled cells U/D configuration following Rel-11 LTE rule.
    - ii. Option UL-B1
      1. For FDD scheduling cell case, 4ms for UL grant to PUSCH, 6ms for PUSCH to PHICH
      2. For TDD scheduling cell case, reference U/D configuration for UL timing is derived by scheduling and scheduled cells U/D configuration following Rel-11 LTE rule.
- 3) DL HARQ timing (PDSCH to HARQ-ACK timing) for FDD SCell in case of TDD PCell
  - A. Self-scheduling case
    - i. Option 1: for each TDD PCell U/D configuration, follow TDD PCell timing + additional new timings for the DL subframes for which DL HARQ timing is not defined in TDD PCell timing (or new timings for each TDD PCell U/D configuration to address more DL subframes than defined in TDD PCell)
    - ii. Option 2: Follow reference U/D configuration defined (or configured) for the FDD SCell. (Configurable) reference U/D configuration depends on the TDD PCell's U/D configuration. (new timing can be added to the reference U/D configuration to support more DL subframes with HARQ-ACK feedback)
  - B. Cross-carrier scheduling case: same options (option 1 and option 2) as in self-scheduling case, or else, only follow TDD PCell timing
- 4) UL HARQ timing (UL grant DCI to PUSCH, PUSCH to PHICH) for FDD SCell in case of TDD PCell
  - A. Self-scheduling case: follow FDD scheduled cell timing
  - B. Cross-carrier scheduling case

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- i. Option UL-A2:
  - 1. For TDD scheduling cell case, follow scheduling cell timing
  - 2. For FDD scheduling cell case, follow FDD timing
- ii. Option UL-B2:
  - 1. For TDD scheduling cell case, 4ms for UL grant to PUSCH, 6ms for PUSCH to PHICH
  - 2. For FDD scheduling cell case, follow FDD timing

An example of HARQ timing (for example, DL association set index) applicable to the above DL HARQ timing option 1 is shown in Table A below. In the table below, UL-DL conf. means the U/D configuration of the TDD PCell, HARQ timing means the type/index of HARQ timing configured with option 1 for the TDD PCell U/D configuration, and [] in the DL association set index column means the newly created DL association set index for the TDD PCell U/D configuration. The examples of reference U/D configuration applicable to FDD SCell in DL HARQ option 2 are shown in Tables B-1, B-2, and B-3 below.

Table A.

| UL-DL Conf. | HARQ timing | Subframe <i>n</i> |   |                                    |                  |            |   |   |                  |             |        |
|-------------|-------------|-------------------|---|------------------------------------|------------------|------------|---|---|------------------|-------------|--------|
|             |             | 0                 | 1 | 2                                  | 3                | 4          | 5 | 6 | 7                | 8           | 9      |
| 0           | 0A          | -                 | - | 6, [5]                             | [5], [4]         | 4          | - | - | 6, [5]           | [5], [4]    | 4      |
| 0           | 0B          |                   |   | 6, [5], [4]                        |                  | [5], 4     |   |   | 6, [5], [4]      |             | [5], 4 |
| 1           | 1           | -                 | - | 7, 6, [5]                          | [5], 4           | -          | - | - | 7, 6, [5]        | [5], 4      | -      |
| 1           | 1*          |                   |   | 7, 6                               | [6], [5], 4      |            |   |   | 7, 6             | [6], [5], 4 |        |
| 2           | 2           | -                 | - | 8, 7, 6, [5], 4                    | -                | -          | - | - | 8, 7, 6, [5], 4  | -           | -      |
| 3           | 3           | -                 | - | 11, [10], [9], [8], 7, 6           | 6, 5             | 5, 4       | - | - | -                | -           | -      |
| 3           | 3a          | -                 | - | 11, [10], 7, 6                     | [10], 6, 5       | [10], 6, 4 |   |   |                  |             |        |
| 4           | 4           | -                 | - | 12, 11, [10], [9], 8, 7            | 7, 6, 5, 4       |            |   |   |                  |             |        |
| 4           | 4a          |                   |   | 12, 11, [10], 8, 7                 | [10], 7, 6, 5, 4 |            |   |   |                  |             |        |
| 5           | 5           | -                 | - | 13, 12, 11, [10], 9, 8, 7, 6, 5, 4 | -                | -          | - | - | -                | -           | -      |
| 6           | 6           | -                 | - | [6], 7                             | 7, [6]           | [6], 5     | - | - | 7                | 7, [6], [5] | -      |
| 6           | 6*          | -                 | - | 7                                  | 7, [6], [5]      | 6          | - | - | 7, [6], [5], [4] | 7           | -      |

Table B-1.

| TDD PCell U/D configuration | Allowed reference configuration for FDD SCell |
|-----------------------------|-----------------------------------------------|
| 0                           | {0, 1, 2, 3, 4, 5, 6}                         |
| 1                           | {1, 2, 4, 5}                                  |

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|   |                    |
|---|--------------------|
| 2 | {2, 5}             |
| 3 | {3, 4, 5}          |
| 4 | {4, 5}             |
| 5 | {5}                |
| 6 | {1, 2, 3, 4, 5, 6} |

Table B-2.

| TDD PCell U/D configuration | Allowed reference configuration for FDD SCell |
|-----------------------------|-----------------------------------------------|
| 0                           | {2, 4, 5}                                     |
| 1                           | {2, 4, 5}                                     |
| 2                           | {2, 5}                                        |
| 3                           | {4, 5}                                        |
| 4                           | {4, 5}                                        |
| 5                           | {5}                                           |
| 6                           | {2, 4, 5}                                     |

Table B-3.

| TDD PCell U/D configuration | Allowed reference configuration for FDD SCell (2 aggregated cells) | Allowed reference configuration for FDD SCell (more than 2 aggregated cells) |
|-----------------------------|--------------------------------------------------------------------|------------------------------------------------------------------------------|
| 0                           | 5                                                                  | 2                                                                            |
| 1                           | 5                                                                  | 2                                                                            |
| 2                           | 5                                                                  | 2                                                                            |
| 3                           | 5                                                                  | 4                                                                            |
| 4                           | 5                                                                  | 4                                                                            |
| 5                           | 5                                                                  | Not applicable                                                               |
| 6                           | 5                                                                  | 2                                                                            |

## 2-15. FDD HARQ-ACK feedback procedures

For FDD and for a UE transmitting HARQ-ACK using PUCCH format 1b with channel selection or PUCCH format 3, the UE shall determine the number of HARQ-ACK bits,  $O$ , based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

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A UE that supports aggregating at most 2 serving cells with frame structure type 1 shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

A UE that supports aggregating more than 2 serving cells with frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in section 10.1.2.1 and procedures for more than one configured serving cell are given in section 10.1.2.2.

**2-15-1. FDD HARQ-ACK procedure for one configured serving cell**

HARQ-ACK transmission on two antenna ports ( $p \in [p_0, p_1]$ ) is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  for transmission of HARQ-ACK in subframe  $n$  for  $\tilde{p}$  mapped to antenna port  $p$  for PUCCH format 1a/1b [3], where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe  $n-4$ , or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe  $n-4$ , the UE shall use  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$  for antenna port  $p_0$ , where  $n_{\text{CCE}}$  is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and  $N_{\text{PUCCH}}^{(1)}$  is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port  $p_1$  is given by  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$ .
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe  $n-4$ , the value of  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$  for antenna port  $p_0$  and the second PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$  for antenna port  $p_1$ , otherwise, the PUCCH resource value maps to a single PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$  for antenna port  $p_0$ .

**2-15-2. FDD HARQ-ACK procedures for more than one configured serving cell**

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in section 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in section 10.1.2.2.2.

HARQ-ACK transmission on two antenna ports ( $p \in [p_0, p_1]$ ) is supported for PUCCH format 3.

**(1) PUCCH format 1b with channel selection HARQ-ACK procedure**

For FDD with two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit  $b(0)b(1)$  on PUCCH resource  $n_{\text{PUCCH}}^{(1)}$  selected from  $A$  PUCCH resources,  $n_{\text{PUCCH},j}^{(1)}$  where  $0 \leq j \leq A-1$  and  $A \in \{2,3,4\}$ , according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe  $n$  using

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PUCCH format 1b. HARQ-ACK( $j$ ) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH associated with serving cell  $c$ , where the transport block and serving cell for HARQ-ACK( $j$ ) and  $A$  PUCCH resources are given by Table 10.1.2.2.1-1.

A UE configured with a transmission mode that supports up to two transport blocks on serving cell,  $c$ , shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH indicating downlink SPS release associated with the serving cell  $c$ .

**Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK( $j$ ) for PUCCH format 1b HARQ-ACK channel selection**

| A | HARQ-ACK( $j$ )   |                    |                    |                    |
|---|-------------------|--------------------|--------------------|--------------------|
|   | HARQ-ACK(0)       | HARQ-ACK(1)        | HARQ-ACK(2)        | HARQ-ACK(3)        |
| 2 | TB1 Primary cell  | TB1 Secondary cell | NA                 | NA                 |
| 3 | TB1 Serving cell1 | TB2 Serving cell1  | TB1 Serving cell2  | NA                 |
| 4 | TB1 Primary cell  | TB2 Primary cell   | TB1 Secondary cell | TB2 Secondary cell |

The UE shall determine the  $A$  PUCCH resources,  $n_{\text{PUCCH},j}^{(1)}$  associated with HARQ-ACK( $j$ ) where  $0 \leq j \leq A-1$  in

Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe  $n-4$  on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe  $n-4$  on the primary cell, the PUCCH resource is  $n_{\text{PUCCH},j}^{(1)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ , and for transmission mode that supports up to two transport blocks, the PUCCH resource  $n_{\text{PUCCH},j+1}^{(1)}$  is given by  $n_{\text{PUCCH},j+1}^{(1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$  where  $n_{\text{CCE}}$  is the number of the first CCE used for transmission of the corresponding PDCCH and  $N_{\text{PUCCH}}^{(1)}$  is configured by higher layers.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe  $n-4$ , the value of  $n_{\text{PUCCH},j}^{(1)}$  is determined according to higher layer configuration and Table 9.2-2. For transmission mode that supports up to two transport blocks, the PUCCH resource  $n_{\text{PUCCH},j+1}^{(1)}$  is given by  $n_{\text{PUCCH},j+1}^{(1)} = n_{\text{PUCCH},j}^{(1)} + 1$
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe  $n-4$  on the secondary cell, the value of  $n_{\text{PUCCH},j}^{(1)}$ , and the value of  $n_{\text{PUCCH},j+1}^{(1)}$  for the transmission mode that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that supports up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources ( $n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)}$ ), otherwise, the PUCCH resource value maps to a single PUCCH resource  $n_{\text{PUCCH},j}^{(1)}$ .

Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

| Value of 'TPC command for PUCCH'                                                                                                                                                                  | $n_{\text{PUCCH},j}^{(1)}$ or $(n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)})$ |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| '00'                                                                                                                                                                                              | The 1st PUCCH resource value configured by the higher layers                           |
| '01'                                                                                                                                                                                              | The 2 <sup>nd</sup> PUCCH resource value configured by the higher layers               |
| '10'                                                                                                                                                                                              | The 3 <sup>rd</sup> PUCCH resource value configured by the higher layers               |
| '11'                                                                                                                                                                                              | The 4 <sup>th</sup> PUCCH resource value configured by the higher layers               |
| Note: $(n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)})$ are determined from the first and second PUCCH resource lists configured by $n1\text{PUCCH-AN-CS-List-r10}$ in [11], respectively. |                                                                                        |

Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for  $A = 2$ 

| HARQ-ACK(0) | HARQ-ACK(1) | $n_{\text{PUCCH}}^{(1)}$   | $b(0)b(1)$ |
|-------------|-------------|----------------------------|------------|
| ACK         | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 1,1        |
| NACK/DTX    | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 0,0        |
| NACK        | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 0,0        |
| DTX         | NACK/DTX    | No Transmission            |            |

Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for  $A = 3$ 

| HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | $n_{\text{PUCCH}}^{(1)}$   | $b(0)b(1)$ |
|-------------|-------------|-------------|----------------------------|------------|
| ACK         | ACK         | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 1,0        |
| NACK/DTX    | ACK         | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 0,1        |
| NACK/DTX    | NACK/DTX    | ACK         | $n_{\text{PUCCH},2}^{(1)}$ | 1,1        |
| ACK         | ACK         | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 1,0        |
| NACK/DTX    | ACK         | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 0,1        |
| NACK/DTX    | NACK/DTX    | NACK        | $n_{\text{PUCCH},2}^{(1)}$ | 0,0        |
| NACK        | NACK/DTX    | DTX         | $n_{\text{PUCCH},0}^{(1)}$ | 0,0        |
| NACK/DTX    | NACK        | DTX         | $n_{\text{PUCCH},0}^{(1)}$ | 0,0        |
| DTX         | DTX         | DTX         | No Transmission            |            |

Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for  $A = 4$ 

| HARQ-ACK(0) | HARQ-ACK(1) | HARQ-ACK(2) | HARQ-ACK(3) | $n_{\text{PUCCH}}^{(1)}$   | $b(0)b(1)$ |
|-------------|-------------|-------------|-------------|----------------------------|------------|
| ACK         | ACK         | ACK         | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | ACK         | ACK         | $n_{\text{PUCCH},2}^{(1)}$ | 0,1        |
| NACK/DTX    | ACK         | ACK         | ACK         | $n_{\text{PUCCH},1}^{(1)}$ | 0,1        |
| NACK/DTX    | NACK/DTX    | ACK         | ACK         | $n_{\text{PUCCH},3}^{(1)}$ | 1,1        |
| ACK         | ACK         | ACK         | NACK/DTX    | $n_{\text{PUCCH},1}^{(1)}$ | 1,0        |
| ACK         | NACK/DTX    | ACK         | NACK/DTX    | $n_{\text{PUCCH},2}^{(1)}$ | 0,0        |
| NACK/DTX    | ACK         | ACK         | NACK/DTX    | $n_{\text{PUCCH},1}^{(1)}$ | 0,0        |
| NACK/DTX    | NACK/DTX    | ACK         | NACK/DTX    | $n_{\text{PUCCH},3}^{(1)}$ | 1,0        |
| ACK         | ACK         | NACK/DTX    | ACK         | $n_{\text{PUCCH},2}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | NACK/DTX    | ACK         | $n_{\text{PUCCH},2}^{(1)}$ | 1,0        |
| NACK/DTX    | ACK         | NACK/DTX    | ACK         | $n_{\text{PUCCH},3}^{(1)}$ | 0,1        |
| NACK/DTX    | NACK/DTX    | NACK/DTX    | ACK         | $n_{\text{PUCCH},3}^{(1)}$ | 0,0        |
| ACK         | ACK         | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 1,1        |
| ACK         | NACK/DTX    | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 1,0        |
| NACK/DTX    | ACK         | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 0,1        |
| NACK/DTX    | NACK        | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 0,0        |
| NACK        | NACK/DTX    | NACK/DTX    | NACK/DTX    | $n_{\text{PUCCH},0}^{(1)}$ | 0,0        |
| DTX         | DTX         | NACK/DTX    | NACK/DTX    | No Transmission            |            |

## (2) PUCCH format 3 HARQ-ACK procedure

For FDD with PUCCH format 3, the UE shall use PUCCH resource  $n_{\text{PUCCH}}^{(3,\tilde{p})}$  or  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  for transmission of HARQ-ACK in subframe  $n$  for  $\tilde{p}$  mapped to antenna port  $p$  where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe  $n-4$ , or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe  $n-4$  on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  with  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$  for antenna port  $p_0$ , where  $n_{\text{CCE}}$  is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and  $N_{\text{PUCCH}}^{(1)}$  is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port  $p_1$  is given by  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$ .
- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected in subframe  $n-4$ , the UE shall use PUCCH format 1a/1b and PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  where the value of  $n_{\text{PUCCH}}^{(1,\tilde{p})}$  is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with

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the first PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$  for antenna port  $p_0$  and the second PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$  for antenna port  $p_1$ , otherwise, the PUCCH resource value maps to a single PUCCH resource  $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$  for antenna port  $p_0$ .

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH in subframe  $n-4$ , the UE shall use PUCCH format 3 and PUCCH resource  $n_{\text{PUCCH}}^{(3,\tilde{p})}$  where the value of  $n_{\text{PUCCH}}^{(3,\tilde{p})}$  is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource  $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$  for antenna port  $p_0$  and the second PUCCH resource  $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$  for antenna port  $p_1$ , otherwise, the PUCCH resource value maps to a single PUCCH resource  $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$  for antenna port  $p_0$ . A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.

Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

| Value of 'TPC command for PUCCH' | $n_{\text{PUCCH}}^{(3,\tilde{p})}$                                       |
|----------------------------------|--------------------------------------------------------------------------|
| '00'                             | The 1st PUCCH resource value configured by the higher layers             |
| '01'                             | The 2 <sup>nd</sup> PUCCH resource value configured by the higher layers |
| '10'                             | The 3 <sup>rd</sup> PUCCH resource value configured by the higher layers |
| '11'                             | The 4 <sup>th</sup> PUCCH resource value configured by the higher layers |

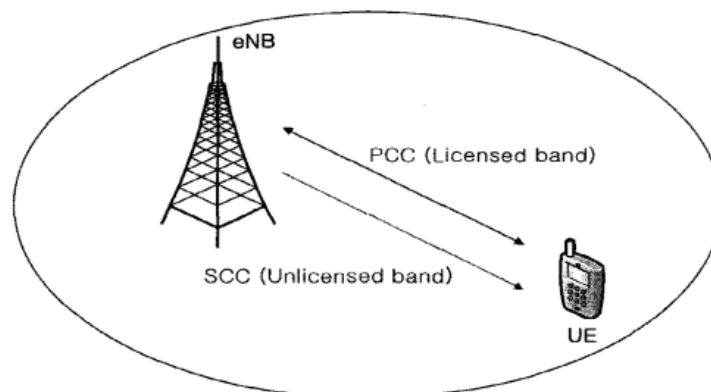
## 2-16. LTE in unlicensed band (LTE-U)

Efficient utilization of limited frequency bands is becoming an increasingly important requirement for the next generation of wireless communication systems as more and more communication devices demand greater communication capacity. Cellular communication systems, such as LTE systems, are also exploring the use of unlicensed bands for traffic offloading, such as the 2.4 GHz band used by conventional WiFi systems or the newly emerging 5 GHz band. Basically, unlicensed bands assume that wireless transmission and reception is based on competition between communicating nodes, requiring each communicating node to perform channel sensing to ensure that no other communicating nodes are transmitting signals before transmitting a signal. This is called clear channel assessment (CCA), and an eNB or UE in an LTE system may also need to perform CCA to transmit signals in unlicensed bands (referred to as LTE-U bands for convenience). In addition, when an eNB or UE in an LTE system transmits signals, other communication nodes, such as WiFi, must also perform CCA to ensure that they do not cause interference. For example, in the WiFi standard (801.11ac), the CCA threshold is defined as -62 dBm for non-WiFi signals and -82 dBm for WiFi signals, which means that an STA or AP will not transmit a signal to avoid causing interference if, for example, a non-WiFi signal is received with a power greater than -62 dBm. Characteristically, in a WiFi system, an STA or AP may perform CCA and transmit a signal if a signal above the CCA threshold for more than 4us is not detected.

## Section 1

The designations of base stations described in the present application are used as umbrella terms to include remote radio head (RRH), eNB, transmission point (TP), reception point (RP), relay, and the like. In the following, the proposed method is described based on the 3GPP LTE system for ease of description. However, the scope of systems to which the proposed method is applicable can be extended to systems other than the 3GPP LTE system (for example, UTRA and the like).

The present invention proposes a resource banding method and an accompanying UE operation in a cell/carrier wherein the available resource bands are secured/configured in an aperiodic or discontinuous manner, such as in the case of an unlicensed band wherein exclusive use of a particular system is not guaranteed. In one example, an eNB may transmit signals to a UE or a UE may transmit signals to an eNB under a carrier aggregation situation of a licensed band, LTE-A Band, and an unlicensed band (hereinafter referred to as "LTE-U Band" for convenience), as shown in FIG. 1. In the following description, for ease of description of the proposed approach, a situation wherein the UE is configured to perform wireless communications over two component carriers (CCs) in each of the licensed and unlicensed bands is assumed. Here, as one example, the carrier in the licensed band may be interpreted as a primary carrier (Primary CC; may be referred to as PCC or PCell) and the carrier in the unlicensed band may be interpreted as a secondary carrier (Secondary CC; may be referred to as SCC or SCell). However, the proposed methods of the present invention can be extended and applied to situations wherein a plurality of licensed bands and a plurality of unlicensed bands are used as carrier aggregation techniques, and can also be applied to situations where only unlicensed bands are used to transmit and receive signals between eNBs and UEs. Furthermore, the proposed methods of the present invention can be extended not only to 3GPP LTE systems but also to systems with other characteristics.



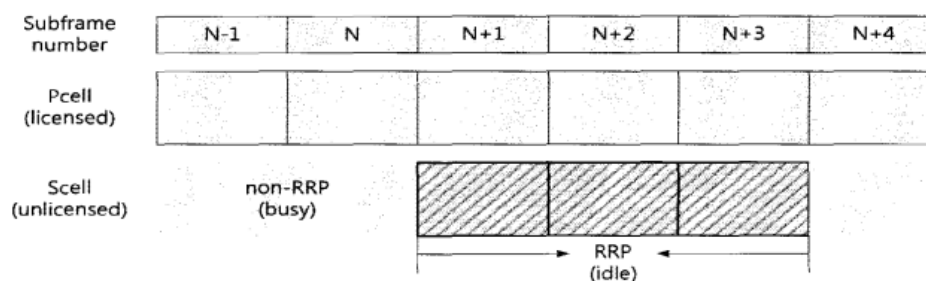
&lt;FIG. 1&gt;

In order for base stations and terminals to communicate in the LTE-U band, they must first be able to compete with other non-LTE communications systems (e.g., WiFi) to occupy/secure the spectrum for a specific time period (for convenience, the time period occupied/secured for communications in the LTE-U band is referred to hereafter as the reserved resource period (RRP)). There may be a number of ways to secure such RRP intervals. Typically, a method is possible wherein a specific reservation signal is transmitted so that other communication system devices such as WiFi can recognize that the radio channel is busy, or RS and data signals are continuously transmitted so that signals above a certain power level are constantly transmitted during the RRP interval. In this way, if the base station has predetermined the RRP time interval for occupying the LTE-U band

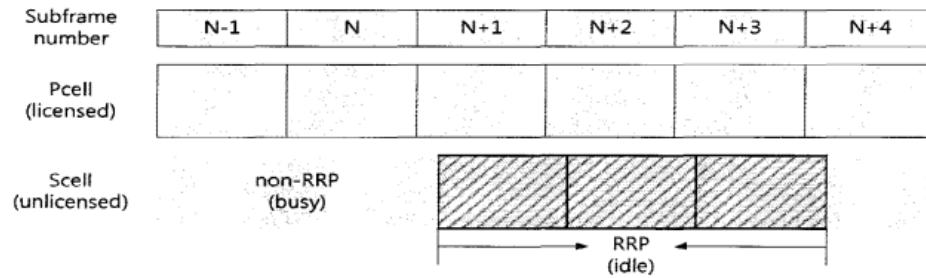
the base station can inform the device in advance so that the device can maintain a constant transmission/reception link during the indicated RRP interval. The method of informing the terminal of the RRP time may be by communicating the RRP time interval information to the terminal through another CC (for example, the LTE-A band) to which the terminal is connected in a form of the above carrier aggregation.

As another example of unlicensed band behaviour operating in a competition-based random-access fashion, the eNB may first perform carrier sensing (CS) before transmitting or receiving data. The eNB may check whether the current channel state of the SCell is busy or idle, and if it is determined to be idle, the eNB may transmit a scheduling grant through the (E)PDCCH of the PCell (that is, cross carrier scheduling (CCS)) or the PDCCH of the SCell, and attempt to send or receive data. At this time, as one example, an RRP interval consisting of M consecutive subframes (SFs) can be set. Here, the eNB may inform the UE of the M values and the purpose of the M SFs in advance via higher layer signaling (using PCell) or physical control/data channel. The start point of the RRP interval may be set periodically (or semi-statically) by higher layer signaling. Alternatively, the start point of an RRP segment may be specified by physical layer signaling at SF #n or at SF #(n-k) when it is desired to set the RRP start point at SF #n.

On the other hand, the subframes configuring such an RRP may be configured by a form in which the subframe boundary and subframe number/index are aligned with the Pcell as shown in FIG. 2 (such a case is referred to as "aligned-RRP"), or may be configured to even support a form in which the subframe boundary or subframe number/index is not aligned with the Pcell as shown in FIG. 3 (such a case is referred to as "floating-RRP"). In the present invention, when a subframe boundary between cells is spaced, it may mean that the spacing between the subframe boundaries of two different cells is less than or equal to a certain time (for example, CP length, or X usec where  $x \geq 0$ ). Also, in the present invention, Pcell may refer to a specific cell (for example, a cell in a licensed band (that is, L-band), and the like.) that is referenced to determine the subframe (and/or symbol) boundary of a cell in the U-band (that is, Ucell) in terms of time (and/or frequency) synchronization.



<FIG. 2>



<FIG. 3>

## 2-17. New RAT for next generation system

As more and more communication devices require larger communication capacity, the need for improved mobile broadband communication is emerging compared to the existing radio access technology. In addition, massive MTC (Machine Type Communications), which connects a large number of devices and objects to provide various services anytime, anywhere, is also one of the major issues to be considered in next-generation communication. In addition, communication system design considering reliability and latency-sensitive services/UE is being discussed. As such, the introduction of next generation radio access technology considering enhanced mobile broadband communication, massive MTC, URLLC (Ultra- Reliable and Low Latency Communication), and the like, is being discussed, and in this invention, the technology is called new RAT for convenience.

[Self-contained subframe structure]

In order to minimize data transmission latency in TDD systems, a self-contained subframe structure as shown in Figure 2-1 is considered for the fifth generation of new RAT .

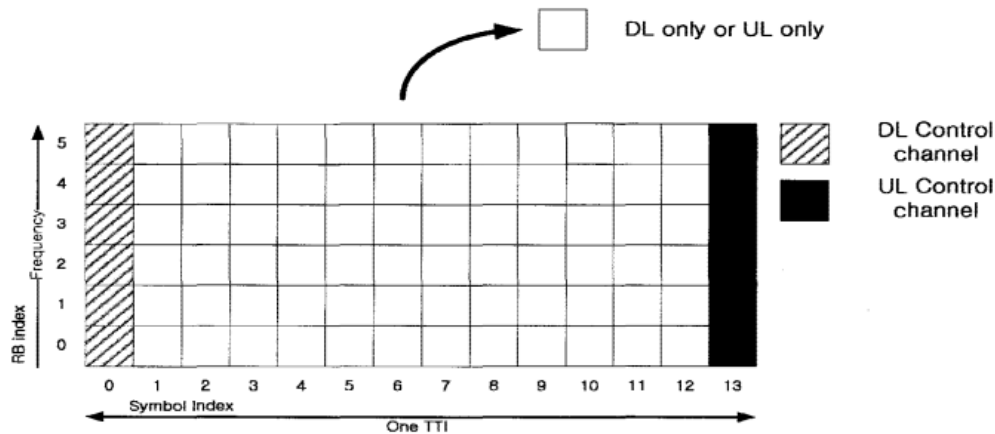


Figure A. Self-contained subframe structure

**Section 1**

In Figure A, the hatched area represents the downlink control channel, and the black area represents the uplink control channel. The unmarked area may be used for downlink data transmission or may be used for uplink data transmission. The characteristic of this structure is that DL transmission and UL transmission proceed sequentially within one subframe, allowing DL data to be sent and UL ACK/NACK to be received within the subframe. As a result, the time it takes to retransmit data when a data transmission error occurs is reduced, thereby minimizing the latency of final data delivery.

As one example of the above self-contained subframe type that can be configured/set in a system operating based on New RAT, at least the following four subframe types can be considered (the following is an expression in time order within the subframe).

- 1) DL control interval + DL data interval + GP + UL control interval
- 2) DL control interval + DL data interval
- 3) DL control interval + GP + UL data interval + UL control interval
- 4) DL control interval + GP + UL data interval

In this self-contained subframe structure, a time gap is required for the base station and the UE to switch from transmission mode to reception mode or from reception mode to transmission mode. For this purpose, some OFDM symbols at the time point of transition from DL to UL in the subframe structure can be set as a guard period (GP), and in the present invention, for convenience, the above subframe type is referred to as self-contained SF.

**[Analog beamforming]**

In millimeter waves (mmW), installation of a plurality of antennas becomes possible as the wavelength becomes short. That is, the wavelength is 1 cm, and thus 100 antenna elements can be installed in total as a form of a 2-dimensional arrangement at a spacing of 0.5 lambda (wavelength) on a 5 by 5 panel. Therefore, in mmW, the coverage is increased, or throughput is increased by increasing the beamforming (BF) advantage using a plurality of antenna elements.

In this case, if there is a TXRU (transceiver unit) such that the transmission power and phase adjustment is possible for each antenna element, independent beamforming is possible for each frequency resource. However, installing TXRUs on each antenna element reduces the efficiency in terms of the price. Thus, a method is considered, wherein a plurality of antenna elements is mapped onto one TXRU and the direction of the beam is adjusted by an analogue phase shifter. Such analog beamforming methods can make one beam direction for the entire band, and thus has a drawback of being capable of performing frequency-selective beaming.

As an intermediate form between the digital BF and analog BF, a hybrid BF can be considered that has B TXRUs, the number of which is smaller than the number of antenna elements Q. In this case, although there are differences depending on the method for connecting B TXRUs and Q antenna elements, the number of directions of the beams that can be transmitted simultaneously is limited to B or less.

**2-18. Resource Allocation for PDCCH with uplink DCI Format**

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH with uplink DCI format.

**Section 1**

If the resource allocation type bit is not present in the uplink DCI format, only resource allocation type 0 is supported. If the resource allocation type bit is present in the uplink DCI format, the selected resource allocation type for a decoded PDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the uplink PDCCH DCI format detected.

**8.1.1 Uplink Resource allocation type 0**

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by  $n_{VRB}$ . A resource allocation field in the scheduling grant consists of a resource indication value ( $RIV$ ) corresponding to a starting resource block ( $RB_{START}$ ) and a length in terms of contiguously allocated resource blocks ( $L_{CRBs} \geq 1$ ). The resource indication value is defined by

$$\begin{aligned} &\text{if } (L_{CRBs} - 1) \leq \left\lfloor N_{RB}^{UL} / 2 \right\rfloor \text{ then} \\ &\quad RIV = N_{RB}^{UL} (L_{CRBs} - 1) + RB_{START} \\ &\text{else} \\ &\quad RIV = N_{RB}^{UL} (N_{RB}^{UL} - L_{CRBs} + 1) + (N_{RB}^{UL} - 1 - RB_{START}) \end{aligned}$$

**8.1.2 Uplink Resource allocation type 1**

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size  $P$  as given in table

7.1.6.1-1 assuming  $N_{RB}^{UL}$  as the system bandwidth. A combinatorial index  $r$  consists of  $\left\lceil \log_2 \left( \binom{\left\lceil N_{RB}^{UL} / P + 1 \right\rceil}{4} \right) \right\rceil$

bits. The bits from the resource allocation field in the scheduling grant represent  $r$  unless the number of bits in the resource allocation field in the scheduling grant is

- smaller than required to fully represent  $r$ , in which case the bits in the resource allocation field in the scheduling grant occupy the LSBs of  $r$  and the value of the remaining bits of  $r$  shall be assumed to be 0; or
- larger than required to fully represent  $r$ , in which case  $r$  occupies the LSBs of the resource allocation field in the scheduling grant.

The combinatorial index  $r$  corresponds to a starting and ending RBG index of resource block set 1,  $s_0$  and  $s_1 - 1$ , and resource block set 2,  $s_2$  and  $s_3 - 1$  respectively, where  $r$  is given by equation  $r = \sum_{i=0}^{M-1} \binom{N - s_i}{M - i}$  defined in section 7.2.1 with  $M=4$  and  $N = \left\lceil N_{RB}^{UL} / P \right\rceil + 1$ . Section 7.2.1 also defines ordering properties and range of values that  $s_i$  (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

## 2-19. Code block based data transmission in LTE

### 5.1.4 Rate matching

#### 5.1.4.1 Rate matching for turbo coded transport channels

The rate matching for turbo coded transport channels is defined per coded block and consists of interleaving the three information bit streams  $d_k^{(0)}$ ,  $d_k^{(1)}$  and  $d_k^{(2)}$ , followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-1. The output bits for each code block are transmitted as described in section 5.1.4.1.2.

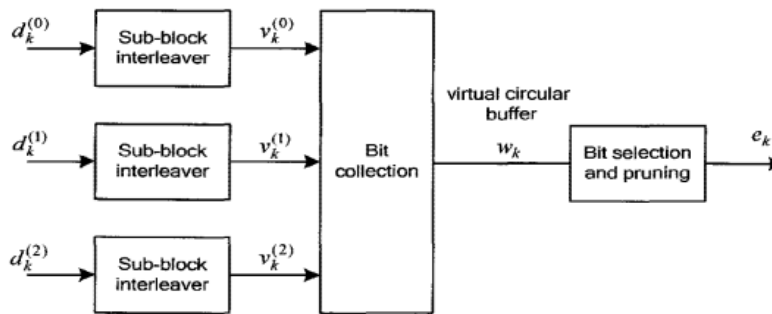


Figure 5.1.4-1. Rate matching for turbo coded transport channels.

The bit stream  $d_k^{(0)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as  $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, \dots, v_{K_{\Pi}-1}^{(0)}$  and where  $K_{\Pi}$  is defined in section 5.1.4.1.1.

The bit stream  $d_k^{(1)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as  $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, \dots, v_{K_{\Pi}-1}^{(1)}$ .

The bit stream  $d_k^{(2)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as  $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, \dots, v_{K_{\Pi}-1}^{(2)}$ .

The sequence of bits  $e_k$  for transmission is generated according to section 5.1.4.1.2.

##### 5.1.4.1.1 Sub-block interleaver

The bits input to the block interleaver are denoted by  $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, \dots, d_{D-1}^{(i)}$ , where  $D$  is the number of bits. The output bit sequence from the block interleaver is derived as follows:

- (1) Assign  $C_{subblock}^{TC} = 32$  to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2, ...,  $C_{subblock}^{TC} - 1$  from left to right.
- (2) Determine the number of rows of the matrix  $R_{subblock}^{TC}$ , by finding minimum integer  $R_{subblock}^{TC}$  such that:

$$D \leq (R_{subblock}^{TC} \times C_{subblock}^{TC})$$

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

- (3) If  $(R_{subblock}^{TC} \times C_{subblock}^{TC}) > D$ , then  $N_D = (R_{subblock}^{TC} \times C_{subblock}^{TC} - D)$  dummy bits are padded such that  $y_k = \langle NULL \rangle$  for  $k = 0, 1, \dots, N_D - 1$ . Then,  $y_{N_D+k} = d_k^{(i)}$ ,  $k = 0, 1, \dots, D-1$ , and the bit sequence  $y_k$  is written into the  $(R_{subblock}^{TC} \times C_{subblock}^{TC})$  matrix row by row starting with bit  $y_0$  in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \dots & y_{C_{subblock}^{TC}-1} \\ y_{C_{subblock}^{TC}} & y_{C_{subblock}^{TC}+1} & y_{C_{subblock}^{TC}+2} & \dots & y_{2C_{subblock}^{TC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}} & y_{(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}+1} & y_{(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}+2} & \dots & y_{(R_{subblock}^{TC} \times C_{subblock}^{TC}-1)} \end{bmatrix}$$

For  $d_k^{(0)}$  and  $d_k^{(1)}$ :

- (4) Perform the inter-column permutation for the matrix based on the pattern  $\langle P(j) \rangle_{j \in \{0, 1, \dots, C_{subblock}^{TC}-1\}}$  that is shown in table 5.1.4-1, where  $P(j)$  is the original column position of the  $j$ -th permuted column. After permutation of the columns, the inter-column permuted  $(R_{subblock}^{TC} \times C_{subblock}^{TC})$  matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \dots & y_{P(C_{subblock}^{TC}-1)} \\ y_{P(0)+C_{subblock}^{TC}} & y_{P(1)+C_{subblock}^{TC}} & y_{P(2)+C_{subblock}^{TC}} & \dots & y_{P(C_{subblock}^{TC}-1)+C_{subblock}^{TC}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}} & y_{P(1)+(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}} & y_{P(2)+(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}} & \dots & y_{P(C_{subblock}^{TC}-1)+(R_{subblock}^{TC}-1) \times C_{subblock}^{TC}} \end{bmatrix}$$

- (5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted  $(R_{subblock}^{TC} \times C_{subblock}^{TC})$  matrix. The bits after sub-block interleaving are denoted by  $v_0^{(i)}, v_1^{(i)}, v_2^{(i)}, \dots, v_{K_{\Pi}-1}^{(i)}$ , where  $v_0^{(i)}$  corresponds to  $y_{P(0)}, v_1^{(i)}$  to  $y_{P(1)+C_{subblock}^{TC}}, \dots$  and  $K_{\Pi} = (R_{subblock}^{TC} \times C_{subblock}^{TC})$ .

For  $d_k^{(2)}$ :

- (4) The output of the sub-block interleaver is denoted by  $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, \dots, v_{K_{\Pi}-1}^{(2)}$ , where  $v_k^{(2)} = y_{\pi(k)}$  and where

$$\pi(k) = \left( P \left( \left\lfloor \frac{k}{R_{subblock}^{TC}} \right\rfloor \right) + C_{subblock}^{TC} \times (k \bmod R_{subblock}^{TC}) + 1 \right) \bmod K_{\Pi}$$

The permutation function  $P$  is defined in Table 5.1.4-1.

**Table 5.1.4-1 Inter-column permutation pattern for sub-block interleaver.**

| Number of columns<br>$C_{subblock}^{TC}$ | Inter-column permutation pattern<br>$\langle P(0), P(1), \dots, P(C_{subblock}^{TC}-1) \rangle$                                        |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 32                                       | $\langle 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30, 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31 \rangle$ |

**5.1.4.1.2 Bit collection, selection and transmission**

The circular buffer of length  $K_w = 3K_{\Pi}$  for the  $r$ -th coded block is generated as follows:

$$\begin{aligned} w_k &= v_k^{(0)} & \text{for } k = 0, \dots, K_{\Pi} - 1 \\ w_{K_{\Pi}+2k} &= v_k^{(1)} & \text{for } k = 0, \dots, K_{\Pi} - 1 \\ w_{K_{\Pi}+2k+1} &= v_k^{(2)} & \text{for } k = 0, \dots, K_{\Pi} - 1 \end{aligned}$$

Denote the soft buffer size for the transport block by  $N_{IR}$  bits and the soft buffer size for the  $r$ -th code block by  $N_{cb}$  bits. The size  $N_{cb}$  is obtained as follows, where  $C$  is the number of code blocks computed in section 5.1.2:

$$N_{cb} = \min\left(\left\lceil \frac{N_{IR}}{C} \right\rceil, K_w\right) \quad \text{for DL-SCH and PCH transport channels}$$

$$N_{cb} = K_w \quad \text{for UL-SCH and MCH transport channels}$$

where  $N_{IR}$  is equal to:

$$N_{IR} = \left\lfloor \frac{N_{soft}}{K_C \cdot K_{MIMO} \cdot \min(M_{DL\_HARQ}, M_{limit})} \right\rfloor$$

where:

If the UE signals *ue-Category-v10xy*, and is configured with transmission mode 9 for the DL cell,  $N_{soft}$  is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category-v10xy* [6]. Otherwise,  $N_{soft}$  is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category* [6].

If  $N_{soft} = 35982720$ ,

$$K_C = 5,$$

elseif  $N_{soft} = 3654144$  and the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell,

$$K_C = 2$$

else

$$K_C = 1$$

End if.

$K_{MIMO}$  is equal to 2 if the UE is configured to receive PDSCH transmissions based on transmission modes 3, 4, 8 or 9 as defined in section 7.1 of [3], and is equal to 1 otherwise.

$M_{DL\_HARQ}$  is the maximum number of DL HARQ processes as defined in section 7 of [3].

$M_{limit}$  is a constant equal to 8.

Denoting by  $E$  the rate matching output sequence length for the  $r$ -th coded block, and  $rv_{idx}$  the redundancy version number for this transmission ( $rv_{idx} = 0, 1, 2$  or  $3$ ), the rate matching output bit sequence is  $e_k$ ,  $k = 0, 1, \dots, E-1$ .

Define by  $G$  the total number of bits available for the transmission of one transport block.

Set  $G' = G / (N_L \cdot Q_m)$  where  $Q_m$  is equal to 2 for QPSK, 4 for 16QAM and 6 for 64QAM, and where

- For transmit diversity:
- $N_L$  is equal to 2,
- Otherwise:

- $N_L$  is equal to the number of layers a transport block is mapped onto

Set  $\gamma = G' \bmod C$ , where  $C$  is the number of code blocks computed in section 5.1.2.

if  $r \leq C - \gamma - 1$

set  $E = N_L \cdot Q_m \cdot \lfloor G' / C \rfloor$

else

set  $E = N_L \cdot Q_m \cdot \lceil G' / C \rceil$

end if

Set  $k_0 = R_{subblock}^{TC} \cdot \left( 2 \cdot \left\lceil \frac{N_{cb}}{8R_{subblock}^{TC}} \right\rceil \cdot rv_{idx} + 2 \right)$ , where  $R_{subblock}^{TC}$  is the number of rows defined in section 5.1.4.1.1.

Set  $k = 0$  and  $j = 0$

while  $\{ k < E \}$

if  $w_{(k_0+j) \bmod N_{cb}} \neq \text{NULL}$

$e_k = w_{(k_0+j) \bmod N_{cb}}$

$k = k + 1$

end if

$j = j + 1$

end while

#### 5.1.4.2 Rate matching for convolutionally coded transport channels and control information

The rate matching for convolutionally coded transport channels and control information consists of interleaving the three bit streams,  $d_k^{(0)}$ ,  $d_k^{(1)}$  and  $d_k^{(2)}$ , followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-2. The output bits are transmitted as described in section 5.1.4.2.2.

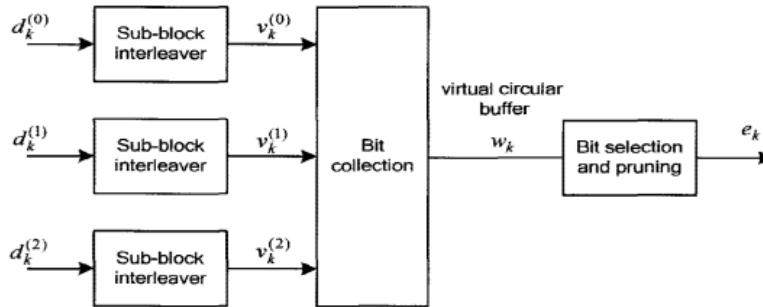


Figure 5.1.4-2. Rate matching for convolutionally coded transport channels and control information.

The bit stream  $d_k^{(0)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as  $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, \dots, v_{K_{\Pi}-1}^{(0)}$  and where  $K_{\Pi}$  is defined in section 5.1.4.2.1.

**Section 1**

The bit stream  $d_k^{(1)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as  $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, \dots, v_{K_{\Pi}-1}^{(1)}$ .

The bit stream  $d_k^{(2)}$  is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as  $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, \dots, v_{K_{\Pi}-1}^{(2)}$ .

The sequence of bits  $e_k$  for transmission is generated according to section 5.1.4.2.2.

**5.1.4.2.1 Sub-block interleaver**

The bits input to the block interleaver are denoted by  $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, \dots, d_{D-1}^{(i)}$ , where  $D$  is the number of bits. The output bit sequence from the block interleaver is derived as follows:

- (1) Assign  $C_{subblock}^{CC} = 32$  to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2, ...,  $C_{subblock}^{CC} - 1$  from left to right.

- (2) Determine the number of rows of the matrix  $R_{subblock}^{CC}$ , by finding minimum integer  $R_{subblock}^{CC}$  such that:

$$D \leq (R_{subblock}^{CC} \times C_{subblock}^{CC})$$

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

- (3) If  $(R_{subblock}^{CC} \times C_{subblock}^{CC}) > D$ , then  $N_D = (R_{subblock}^{CC} \times C_{subblock}^{CC} - D)$  dummy bits are padded such that  $y_k = \langle NULL \rangle$  for  $k = 0, 1, \dots, N_D - 1$ . Then,  $y_{N_D+k} = d_k^{(i)}$ ,  $k = 0, 1, \dots, D-1$ , and the bit sequence  $y_k$  is written into the  $(R_{subblock}^{CC} \times C_{subblock}^{CC})$  matrix row by row starting with bit  $y_0$  in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \dots & y_{C_{subblock}^{CC}-1} \\ y_{C_{subblock}^{CC}} & y_{C_{subblock}^{CC}+1} & y_{C_{subblock}^{CC}+2} & \dots & y_{2C_{subblock}^{CC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}} & y_{(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}+1} & y_{(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}+2} & \dots & y_{(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}-1} \end{bmatrix}$$

- (4) Perform the inter-column permutation for the matrix based on the pattern  $\langle P(j) \rangle_{j \in \{0, 1, \dots, C_{subblock}^{CC}-1\}}$  that is shown in table 5.1.4-2, where  $P(j)$  is the original column position of the  $j$ -th permuted column. After permutation of the columns, the inter-column permuted  $(R_{subblock}^{CC} \times C_{subblock}^{CC})$  matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \dots & y_{P(C_{subblock}^{CC}-1)} \\ y_{P(0)+C_{subblock}^{CC}} & y_{P(1)+C_{subblock}^{CC}} & y_{P(2)+C_{subblock}^{CC}} & \dots & y_{P(C_{subblock}^{CC}-1)+C_{subblock}^{CC}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}} & y_{P(1)+(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}} & y_{P(2)+(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}} & \dots & y_{P(C_{subblock}^{CC}-1)+(R_{subblock}^{CC}-1) \times C_{subblock}^{CC}} \end{bmatrix}$$

- (5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted  $(R_{subblock}^{CC} \times C_{subblock}^{CC})$  matrix. The bits after sub-block interleaving are denoted by  $v_0^{(i)}, v_1^{(i)}, v_2^{(i)}, \dots, v_{K_{\Pi}-1}^{(i)}$ , where  $v_0^{(i)}$  corresponds to  $y_{P(0)}$ ,  $v_1^{(i)}$  to  $y_{P(0)+C_{subblock}^{CC}}$  ... and  $K_{\Pi} = (R_{subblock}^{CC} \times C_{subblock}^{CC})$

**Table 5.1.4-2 Inter-column permutation pattern for sub-block interleaver.**

| Number of columns<br>$C_{subblock}^{CC}$ | Inter-column permutation pattern<br>$\langle P(0), P(1), \dots, P(C_{subblock}^{CC} - 1) \rangle$                                      |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 32                                       | $\langle 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31, 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30 \rangle$ |

This block interleaver is also used in interleaving PDCCH modulation symbols. In that case, the input bit sequence consists of PDCCH symbol quadruplets [2].

#### 5.1.4.2.2 Bit collection, selection and transmission

The circular buffer of length  $K_w = 3K_\Pi$  is generated as follows:

$$\begin{aligned} w_k &= v_k^{(0)} & \text{for } k = 0, \dots, K_\Pi - 1 \\ w_{K_\Pi + k} &= v_k^{(1)} & \text{for } k = 0, \dots, K_\Pi - 1 \\ w_{2K_\Pi + k} &= v_k^{(2)} & \text{for } k = 0, \dots, K_\Pi - 1 \end{aligned}$$

Denoting by  $E$  the rate matching output sequence length, the rate matching output bit sequence is  $e_k$ ,  $k = 0, 1, \dots, E - 1$ .

Set  $k = 0$  and  $j = 0$

while  $\{ k < E \}$

if  $w_{j \bmod K_w} \neq \text{NULL}$

$$e_k = w_{j \bmod K_w}$$

$$k = k + 1$$

end if

$$j = j + 1$$

end while

#### 5.1.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences  $e_{rk}$ , for  $r = 0, \dots, C - 1$  and  $k = 0, \dots, E_r - 1$ . The output bit sequence from the code block concatenation block is the sequence  $f_k$  for  $k = 0, \dots, G - 1$ .

The code block concatenation consists of sequentially concatenating the rate matching outputs for the different code blocks. Therefore,

Set  $k = 0$  and  $r = 0$

while  $r < C$

Set  $j = 0$

while  $j < E_r$

$$f_k = e_{rj}$$

$$k = k + 1$$

```
         $j = j + 1$   
    end while  
     $r = r + 1$   
end while
```

### 5.3.2 Downlink shared channel, Paging channel and Multicast channel

Figure 5.3.2-1 shows the processing structure for each transport block for the DL-SCH, PCH and MCH transport channels. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per DL cell. The following coding steps can be identified for each transport block of a DL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding
- Rate matching
- Code block concatenation

The coding steps for PCH and MCH transport channels, and for one transport block of DL-SCH are shown in the figure below. The same processing applies for each transport block on each DL cell.

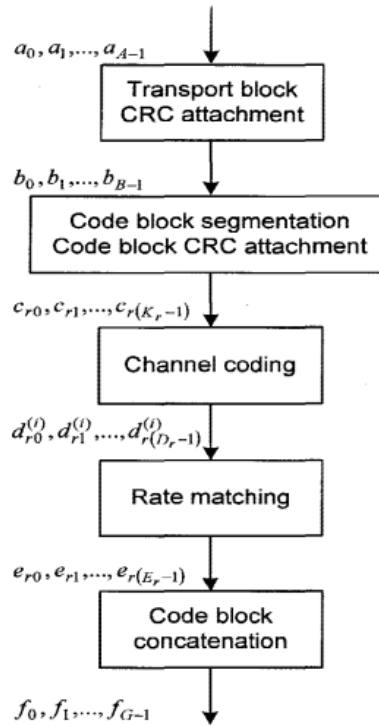


Figure 5.3.2-1: Transport block processing for DL-SCH, PCH and MCH.

### 5.3.2.1 Transport block CRC attachment

Error detection is provided on transport blocks 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 transport block according to section 5.1.1 setting  $L$  to 24 bits and using the generator polynomial  $g_{\text{CRC24A}}(D)$ .

### 5.3.2.2 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.

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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  $r$ .

**5.3.2.3 Channel coding**

Code blocks are delivered to the channel coding block. They 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.  $D_r = K_r + 4$ .

**5.3.2.4 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  $r$ .

**5.3.2.5 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. This sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 6.3.1 of [2]. In case of multiple transport blocks per TTI, the transport block to codeword mapping is specified according to section 5.3.3.1.5, 5.3.3.1.5A or 5.3.3.1.5B, depending on the DCI Format.

**7.1.8 Storing soft channel bits**

Both for FDD and TDD, if the UE is configured with more than one serving cell, then for each serving cell, for at least  $K_{\text{MIMO}} \cdot \min(M_{\text{DL\_HARQ}}, M_{\text{limit}})$  transport blocks, upon decoding failure of a code block of a transport block, the UE shall store received soft channel bits corresponding to a range of at least  $w_k, w_{k+1}, \dots, w_{\text{mod}(k+n_{\text{SB}}-1, N_{\text{ch}})}$ , where:

$$n_{\text{SB}} = \min \left( N_{\text{ch}}, \left\lceil \frac{N'_{\text{soft}}}{C \cdot N_{\text{cells}}^{\text{DL}} \cdot K_{\text{MIMO}} \cdot \min(M_{\text{DL\_HARQ}}, M_{\text{limit}})} \right\rceil \right),$$

$w_k$ ,  $C$ ,  $N_{cb}$ ,  $K_{MIMO}$ , and  $M_{limit}$  are defined in Section 5.1.4.1.2 of [4].

$M_{DL\_HARQ}$  is the maximum number of DL HARQ processes.

$N_{cells}^{DL}$  is the number of configured serving cells.

If the UE signals *ue-Category-v10xy*,  $N'_{soft}$  is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category-v10xy* [11]. Otherwise,  $N'_{soft}$  is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category*[11].

In determining  $k$ , the UE should give priority to storing soft channel bits corresponding to lower values of  $k$ .  $w_k$  should all correspond to a received soft channel bit. The range  $w_k, w_{k+1}, \dots, w_{\text{mod}(k+n_{sb}-1, N_{cb})}$  may include subsets not containing received soft channel bits.

### 3. Composition of Invention

For existing LTE systems, a method wherein, when the size of DL data (that is, TB size) becomes a fixed level or more, the bit stream to be sent via PDSCH is divided into a plurality of CB (Code Block) and is transmitted in a form in which channel coding and CRC are separately applied for each CB, is applied. When reception (decoding) of even one of the plurality of CBs included in one PDSCH fails, the UE operates such that HARQ-ACK feedback corresponding to the PDSCH is reported to eNB using NACK and that this allows all CBs to be retransmitted from eNB. In other words, the HARQ operation for DL data in the existing LTE has a structure that is performed based on the scheduling/transmission from eNB in the unit of TB and the HARQ-ACK feedback configuration from the UE corresponding to this in the unit of TB.

On the other hand, the new RAT system can basically have larger (wider) system (carrier) BW compared to LTE, and due to this, there is a high probability that the (maximum) TB size becomes larger than that of the existing LTE, and accordingly, the number of CBs constituting one TB can also become larger than that in LTE. Therefore, if HARQ-ACK feedback in the unit of TB is performed even in such a situation, retransmission scheduling in the unit of TB must be accompanied even when decoding error (for example, NACK) has occurred only for a small portion of CBs, and thus the resource use efficiency can be reduced. Furthermore, in a new RAT system environment, an operation wherein data type 2 (for example, URLLC) that has a small time duration (TTI) and is delay-sensitive via a portion (symbol) of the resources allocated for transmission of data type 1 (for example, eMBB) that has a large time duration (TTI) and is delay-sensitive can be supported, and due to an influence of interference signals that has a time-sensitive property including this, a phenomenon wherein decoding error (for example, NACK) is concentrated into a certain portion from among the plurality of CBs constituting one TB for data type 1.

In the present invention, in consideration of these operational properties of the new RAT system, a method is proposed, wherein the (retransmission) scheduling is performed in the unit of CB or of CB group (CBG) and the HARQ-ACK feedback is configured/transmitted in the unit of CB/CBG. More specifically, a method for configuring a CBG, a method for configuring HARQ-ACK (that is, A/N) feedback, a method for operating a reception soft buffer of UE, and a method for handling a certain mismatch situation are proposed. For CBG described below, all CBs (constituting a single TB) can be configured as one CBG, or a portion of a plurality of CB is composed of one CBG, or each of one CBs can be configured into one CBG. Furthermore, in the following,  $\text{floor}(X)$  means the floor function that expresses the maximum integer no larger than  $X$ ,  $\text{ceiling}(X)$  means the ceiling function that expresses the minimum integer that is larger than  $X$ , respectively, and  $\text{mod}(A, B)$  means the remainder for when  $A$  is divided by  $B$ .

#### (X) Method for Configuring CB

- 1) Method X-1: Given  $C_n$ , which is the number of bits constituting one CB, based on which  $C_m$  CBs are configured  
For this method,  $C_n$ , which is the number of bits that constitute one CB, can be defined as the same one value regardless of the size of TB or defined as different values (proportional to the TB size) for each TB size in advance, or can be indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and according to this, when the total number of bits that constitute the TB is  $C_k$ , the total of  $C_m = \text{floor}(C_k/C_n)$  or  $C_m = \text{ceiling}(C_k/C_n)$  CBs can be configured. For the former, only one CB is composed of  $(C_n + \text{mod}(C_k, C_n))$  bits, and the remaining  $(C_m - 1)$  CBs can be each composed of  $C_n$  bits,

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and for the latter, only one CB is composed of  $\text{mod}(C_k, C_n)$  bits, and the remaining  $(C_m - 1)$  CBs can be composed of  $C_n$  bits each. Accordingly, for the former,  $C_n$  can mean the minimum number of bits that constitute one CB, and for the latter,  $C_n$  can mean the maximum number of bits that constitute one CB, respectively.

Also, as another method, a method wherein the number of bits per CB is equally allocated (near-equal) to the entire CB can be applied, and specifically, when  $C_m = \text{floor}(C_k/C_n)$  CBs are configured in the above,  $\text{mod}(C_k, C_n)$  CBs are composed of  $(C_n + 1)$  bits and the remaining CBs can be composed of  $C_n$  bits, and when  $C_m = \text{ceiling}(C_k/C_n)$  CBs are configured,  $(C_n - \text{mod}(C_k, C_n))$  CBs are composed of  $(C_n - 1)$  bits and the remaining CBs can be composed of  $C_n$  bits. Therefore, for the former,  $C_n$  can mean the minimum number of bits that constitute one CB, and for the latter,  $C_n$  can mean the maximum number of bits that constitute one CB, respectively.

On the other hand, when the above method is applied, one or more specific (small) CBs from among the total of  $C_m$  CBs can be composed of a small number of bits compared to the remaining other CBs, a method for grouping  $C_m$  CBs, which have unequal sizes, into  $M$  pluralities of CBGs may be necessary. Specifically, the cases can be classified into the case wherein  $C_m$ , which is the total number of CBs, can be classified into the case wherein a multiple of the number of CBGs  $M$  for and the case wherein  $C_m$  is not a multiple of the number of CBGs  $M$ , and for each case, CB grouping methods as the following can be considered. In the following, the CBG size can mean the number of CBs per CBG. On the other hand, when  $C_m$  is not a multiple of  $M$ , the size can vary for each CBG, and the maximum differences between CBGs can be considered to be 1 CB.

- A) When  $C_m$  is a multiple of  $M$  (all CBG has the same size)
  - A. Opt 1-1: Configure such that a small CB is distributed to all CBG as much as possible
  - B. Opt 1-2: Configure such that a small CB belongs to some CBGs in a small number as much as possible
- B) When  $C_m$  is not a multiple of  $M$  (sizes can vary for each CBG)
  - A. Opt 2-1: Configure such that a small CB belongs to a CBG of a relatively large size
  - B. Opt 2-2: Configure such that a small CB belongs to a CBG of a relatively small size
  - C. Opt 2-3: Either Opt 1-1 or Opt 1-2 above is applied

As one example, when a configuration of  $M=3$  CBGs is considered in a situation wherein  $C_m=7$  CB indices 1, 2, 3, 4, 5, 6, and 7 are respectively composed of 5, 5, 5, 5, 5, 5, and 2 bits, applying the above Opt2-1 can result in the configuration wherein CB indices {1, 2}, {3, 4}, {5, 6, 7} respectively are configured into CBG indices 1, 2, and 3, and applying Opt 2-2 above can result in the configuration wherein CB indices {1, 2, 3}, {4, 5}, {6, 7} are configured into CBG indices 1, 2, and 3. As another example, when a configuration of  $M=3$  CBGs is considered in a situation wherein  $C_m=7$  CB indices 1, 2, 3, 4, 5, 6, and 7 are respectively composed of 5, 5, 5, 5, 4, 4, and 4 bits, applying the above Opt2-1 can result in the configuration wherein CB indices {1, 2}, {3, 4}, {5, 6, 7} respectively are configured into CBG indices 1, 2, and 3, and applying Opt 2-2 above can result in the configuration wherein CB indices {1, 2, 3}, {4, 5}, {6, 7} are configured into CBG indices 1, 2, and 3, and on the other hand, when the Opt 1-1 above is applied, CB indices {1, 2, 5}, {3, 6}, {4, 7} are configured into CBG indices 1, 2, and 3, and when the Opt 1-2 above is applied, CB indices {1, 2}, {3, 4}, {5, 6, 7} can be respectively configured into CBG indices 1, 2, and 3.

Additionally, the size of CBG for which the probability of retransmission is high can be reduced as much as possible by including a small number of CBs in a CGB corresponding to a portion for which the decoding reliability may be low

(for example, a signal for which the CB size is relatively small or is separated far away from DMRS temporally, is separated far away from the point in time of the CSI feedback or which is mapped into a symbol adjacent to SRS (or PUCCH or PRACH) as possible, and in order to achieve this, CBG can be configured using a method as follows.

- a) Regular CBs are gradually formed in the unit of X-bits starting from a low CB index, and then small CBs are formed in the unit of Y-bits starting from a certain CB index ( $Y < X$ )
- b) (Sequentially from a low CB index) Regular CBGs are formed by bundling in the unit of M CBs from a low CBG index, and then from a certain CBG index, small CBGs are formed by bundling in the unit of K CB units ( $K < M$ )
- c) From a low CBG index, signals are sequentially mapped using a frequency-first (or time-first) method

On the other hand, when the setting is such that  $C_n > C_k$ , the form is such that all bits of TB are configured as a single CB, and thus, in this case, one CB that includes  $C_k$  bits can be configured.

2) Method X-2:  $C_m$ , which is the total number of CBs, is given, and each CB is configured in the unit of  $C_n$  bits based on this. For this method, the total number of CBs  $C_m$  can be defined as one identical value or as values different for each TB size (proportional to the TB size) in advance regardless of the TB size or indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and according to this, when the total number of bits constituting the TB is  $C_k$ , each CB can be configured in the unit of the total  $C_n = \text{floor}(C_k/C_m)$  or  $C_n = \text{ceiling}(C_k/C_m)$ . For the former, only one CB is composed of  $(C_n + \text{mod}(C_k, C_n))$  bits, and the remaining  $(C_m - 1)$  CBs can be composed of  $C_n$  bits each, and for the latter, only one CB is composed of  $\text{mod}(C_k, C_n)$  bits and the remaining  $(C_m - 1)$  CBs can be composed of  $C_n$  bits each. Accordingly, for the former,  $C_n$  can mean the minimum number of bits constituting one CB, and for the latter,  $C_n$  can mean the maximum number of bits constituting one CB, respectively.

Also, as another method, a (near-equal) method wherein the number of bits per CB is allocated equally to the entire CB can be applied, and specifically, for CB configuration in the unit of  $C_n = \text{floor}(C_k/C_m)$  bits,  $\text{mod}(C_k, C_n)$  CBs may be composed of  $(C_n + 1)$  bits and the remaining CBs can be composed of  $C_n$  bits, and for a CB configuration in the unit of  $C_n = \text{ceiling}(C_k/C_m)$ ,  $(C_n - \text{mod}(C_k, C_n))$  CBs can be composed of  $(C_n - 1)$  bits and the remaining CBs can be composed of  $C_n$  bits. Therefore, for the former,  $C_n$  can mean the minimum number of bits constituting one CB, and for the latter,  $C_n$  can mean the maximum number of bits constituting one CB, respectively.

3) Method X-3: Given  $T_m$ , which is a minimum number of bits that constitute one CB, configure the CB based on this. For this method, each of all the CBs constituting one TB can be set to consist of at least  $T_m$  bits or more, and as one example, when it is assumed that the TB size (that is, the total number of bits constituting the TB) is  $C_k$ ,  $C_{m.\text{max}}$  is calculated, which is the maximum  $C_m$  that satisfies the inequality  $C_k/C_m \geq T_m$  to consider an operation of dividing the TB into the total of  $C_{m.\text{max}}$  CBs can be considered.

4) Method X-4: When the number of CBs is of a fixed level or more, scheduling in the unit of CB or grouping between a plurality of CBs is performed

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For this method, in a state wherein  $C_n$ , which is the number of bits that constitute one CB (for example, whether by being defined in advance or via a certain signaling), is given, the setting/definition can be such that (retransmission) scheduling in the unit of CB or CBG for the corresponding TB is applied only when  $K$ , which is the total number of CBs that constitute one TB, is  $T_s$  or more, and the setting/definition can be such that, when the total number of CBs  $K$  is  $T_g$  or more, plurality of CBs are grouped to configure one CBG (in this case, the setting can be  $T_s < T_g$ )

## (A) Method for configuring CBGs

- 1) Method A-1: Given  $N$ , which is the total number of CB constituting one CBG,  $M$  CBGs are configured based on this  
For this method,  $N$ , which is the number of CBs constituting one CBG, can be defined as the same one value regardless of the size of TB or defined as different values (proportional to the TB size) for each TB size in advance, or can be indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and according to this, when the total number of bits that constitute the TB is  $K$ , each CBG can be configured in the unit of  $M = \text{floor}(K/N)$  or  $M = \text{ceiling}(K/N)$  CBs in total. For the former, only one CBG is composed of  $(N + \text{mod}(K, N))$  CBs, and the remaining  $(M-1)$  CBGs can be each composed of  $N$  CBs, and for the latter, only one CBG is composed of  $\text{mod}(K, N)$  CBs, and each of the remaining  $(M-1)$  CBGs can be composed of  $N$  CBs. On the other hand, the UE can perform transmission by configuring  $A/N$  bits for each CBG configured in this manner. Therefore, for the former,  $N$  can mean the minimum number of CBs that constitute one CBG, and for the latter,  $N$  can mean the maximum number of CBs that constitute one CBG, respectively.

Also, as another method, a method wherein the number of CBGs per CB is equally allocated (near-equal) to the entire CBG can be applied, and specifically, when  $M = \text{floor}(K/N)$  CBGs are configured in the above,  $\text{mod}(K, N)$  CBGs are composed of  $(N+1)$  CBs and the remaining CBGs can be composed of  $N$  CBs, and when  $M = \text{ceiling}(K/N)$  CBGs are configured,  $(N - \text{mod}(K, N))$  CBGs are composed of  $(N-1)$  CBs and the remaining CBGs can be composed of  $N$  CBs. Therefore, for the former,  $N$  can mean the minimum number of CBs that constitute one CBG, and for the latter,  $N$  can mean the maximum number of CBs that constitute one CBG, respectively.

On the other hand, when  $N$  and  $K$  are set such that  $N > K$ , all CBs that constitute the TB belong to one CBG, and therefore, in this case, one CBG that contains  $K$  CBs can be configured.

- 2) Method A-2: Given  $M$ , which is the total number of CBG, each CBG is configured in the unit of  $N$  CBs based on this  
For this method,  $M$ , which is the total number of CBGs, can be defined as the same one value regardless of the size of TB or defined as different values (proportional to the TB size) for each TB size in advance, or can be indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and according to this, when the total number of bits that constitute the TB is  $K$ , each CBG can be configured in the unit of  $N = \text{floor}(K/M)$  or  $N = \text{ceiling}(K/M)$  CBs in total. For the former, only one CBG is composed of  $(N + \text{mod}(K, M))$  CBs, and the remaining  $(M-1)$  CBGs can be each composed of  $N$  CBs, and for the latter, only one CBG is composed of  $\text{mod}(K, M)$  CBs, and each of the remaining  $(M-1)$  CBGs can be composed of  $N$  CBs. On the other hand, the UE can perform transmission by configuring  $A/N$  bits for each CBG configured in this manner. Therefore,

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for the former,  $N$  can mean the minimum number of bits that constitute one CBG, and for the latter,  $N$  can mean the maximum number of CBs that constitute one CBG, respectively.

Also, as another method, a (near-equal) method wherein the number of CBs per CBG is allocated equally to the entire CBG can be applied, and specifically, for CBG configuration in the unit of  $N = \text{floor}(K/M)$  CBs,  $\text{mod}(K, N)$  CBGs can be composed of  $(N+1)$  CBs and the remaining CBGs can be composed of  $N$  CBs, and for CBG configuration in the unit of  $N = \text{ceiling}(K/M)$ ,  $(N - \text{mod}(K, N))$  CBGs may be composed of  $(N-1)$  CBs and the remaining CBGs can be composed of  $N$  CBs. Therefore, in the former,  $N$  can mean the minimum number of CBs constituting one CBG, and in the latter,  $N$  may mean the maximum number of CBs constituting one CBG, respectively.

On the other hand, when  $M$  and  $K$  are set such that  $M > K$ , each CB becomes one CBG, which can configure  $K$  CBGs total, and in this case, a method wherein, 1) In a state wherein the total A/N feedback is composed of  $M$  bits, the  $(M-K)$  bits that do not correspond to an actual CBG are processed using NACK or DTX, or 2) the A/N feedback itself is composed of  $K$  bits that correspond to the actual CBG, can be considered.

3) Method A-3: CBG configurations based on a tree (or nested) structure for the number of CBGs  $M$  and the CBG size  $N$

For this method, CBGs can be configured such that there is a tree structure for the total number of the CBGs  $M$  (for example,  $M_1, M_2, \dots$ ) and the number of CBs configuring the CBG, that is, the CBG size  $N$  (for example,  $N_1, N_2, \dots$ ). In this case, a plurality of CBG configurations that is mutually different, can be set based on a plurality of  $(M, N)$  combinations for one TB (size) that is mutually different, and considering the CBG configurations for  $(M_1, N_1)$  and  $(M_2, N_2)$  with respect to mutually different  $(M, N)$  combinations, when  $M_1 < M_2$ , the setting can be such that  $N_1 > N_2$ . Furthermore, one CBG for  $(M_1, N_1)$  can be configured to include one or more CBGs for  $(M_2, N_2)$ , and conversely one CBG for  $(M_2, N_2)$  can be configured to belong to only one specific CBG for  $(M_1, N_1)$ . Furthermore,  $M_2$  can be set to be a multiple of  $M_1$  and/or  $N_1$  can be set to be a multiple of  $N_2$ , and  $M$  can be characteristically set to be a value in the form of  $2^m$  ( $m=0, 1, \dots$ ). On the other hand, one among: the index for the above  $M$  or  $N$  or  $(M, N)$  combination; and CBG index possible by all  $(M, N)$  combinations can be indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and the UE can perform transmission by configuring the A/N bits for each CBG configured to correspond to the index. Furthermore, the above  $M$  or  $N$  can be defined as one identical value in advance regardless of the TB size or can be defined as different (proportional to the TB size) values for each TB size in advance.

As one example of this method, a method as the following can be considered, wherein the total number of CBs that constitute a TB is assumed to be  $K=16$ , and in a state wherein each CB is indexed as  $k=0, 1, \dots, 15$ , the numbers of CBGs are set to be  $M=\{1, 2, 4, 8, 16\}$  and the sizes of CBGs corresponding to each thereof is set to be  $N=K/M=\{16, 8, 4, 2, 1\}$  ("nested CBG example 1").

- a) When  $(M, N) = (1, 16)$ , only one CBG is configured and the CBG includes all 16 CBs.
- b) When  $(M, N) = (2, 8)$ , 2 CBGs are configured, and 8 mutually different CBs are included for each CBG. In this case, one CBG includes 2 CBGs of when  $(M, N)=(4, 4)$  below.

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- c) When  $(M,N) = (4, 4)$ , 4 CBGs are configured and four CBs that are mutually different for each CBG. In this case, one CBG includes 2 CBGs of when  $(M,N)=(8, 2)$  below.
- d) When  $(M,N) = (8, 2)$ , 8 CBGs are configured, and 2 mutually different CBs are included for each CBG
- e) When  $(M,N) = (16, 1)$ , 16 CBGs are configured, and only one mutually different CB is included for each CBG.

As in the above example, in a state wherein a plurality of  $(M, N)$  combinations that are mutually different are configured/designated in advance, one an index of a specific  $M$  or  $N$  or  $(M, N)$  combination, or a CBG index that is possible by all  $(M, N)$  combinations can be indicated to the UE (in the above example, there are 5 possible  $M$  or  $N$  or  $(M, N)$  combinations, and this corresponds to the case wherein CBG indices possible by all  $(M, N)$  combinations are set to be 31 types {corresponding to the sum of the possible  $M$  values  $\{1, 2, 4, 8, 16\}$ }, and the UE can operate so as to perform decoding and configuration/transmission of the corresponding A/N feedback in a state wherein a CBG configuration that correspond to the indicated  $M$  and/or  $N$  index for the scheduled DL data (for example, TB or CBG) is assumed.

By generalizing this method, for the CBG configurations having  $(M1, N1)$  and  $(M2, N2)$ , which are mutually different  $(M,N)$  combinations, when  $M1 < M2$ , by an only condition that the setting is such that  $N1 \geq N2$ , a CBG configuration of a plurality of CBGs for one TB (size) can be set. As one example, a method as the following can be considered such that, in a state wherein: the total number of CBs constituting the number of TB is assumed to be  $K=6$ ; and each CB is indexed by  $k=0, 1, \dots, 5$ , the number of CBGs is set to be  $M=\{1, 2, 3, 6\}$  and that the CBG size corresponding to each thereof is set to be  $N=K/M=\{6, 2, 3, 1\}$  ("nested CBG example 2").

- a) When  $(M,N) = (1, 6)$ , only one CBG is configured and the CBG contains all 6 CBs.
- b) When  $(M,N) = (2, 3)$ , 2 CBGs are configured, and each CBG contains 3 CBs that are mutually different, for example, each of the sets of CB indices  $\{0, 1, 2\}$  and  $\{3, 4, 5\}$  constitutes one CBG.
- c) When  $(M,N) = (3, 2)$ , three CBGs are configured, and each CBG includes 2 CBs that are mutually different, for example, each of the sets of CB indices  $\{0, 1\}$ ,  $\{2, 3\}$ ,  $\{4, 5\}$  constitutes one CBG.
- d) When  $(M,N) = (6, 1)$ , 6 CBGs are configured, and each CBG contains only one CB that are mutually different.

Also, as another example, a method as the following can be considered, such that, assuming that the total number of CB configuring the TB is  $K=9$ , in a state wherein each CB is indexed by  $k=0, 1, \dots, 8$ , the number of CBG is set to be  $M=\{1, 2, 3, 6\}$  and the CBG size that corresponds to each thereof is set to be  $N=\{9, (5 \text{ or } 4), 3, (2 \text{ or } 1)\}$  ("nested CBG example 3").

- a) When  $(M,N) = (1,9)$ , only one CBG is configured and the CBG contains all 9 CBs.
- b) When  $(M,N) = (2, 5 \text{ or } 4)$ , the total of 2 CBGs are configured, and one CBG contains 5 units, and the other CBG contains 4 CBs respectively, for example, each of the sets of CB indices  $\{0, 1, 2, 3, 4\}$  and  $\{5, 6, 7, 8\}$  constitutes one CBG.
- c) When  $(M,N) = (3, 3)$ , three CBGs are configured, and for each CBG, 3 CBs that are mutually different are included, for example, each of the sets of CB indices  $\{0, 1, 2\}$ ,  $\{3, 4, 5\}$ , and  $\{6, 7, 8\}$  constitutes one CBG.
- d) When  $(M,N) = (6, 2 \text{ or } 1)$ , the total of 6 CBGs are configured, among which three CBGs include two CBs and the other three CBGs contains one CB respectively, for example, each of the sets of CB indices  $\{0, 1\}$ ,  $\{2, 3\}$ ,  $\{4, 5\}$ ,

{6}, {7}, and {8} constitutes one CBG configures one CBG.

Therefore, by indexing a total of 12 ( $=1+2+3+6$ ) CBGs, which are configured as above (based on 4 mutually different (M, N) combinations), the operation can be performed such that CBGs that are scheduled (at eNB) for retransmission are indicated (via DCI) and/or that A/N feedback for the CBG that is indicated (at the UE) indicated (at the UE) is configured and transmitted based on this.

On the other hand, in consideration of the DCI overhead for CBG indication to be scheduled and /or the UCI overhead for configuring the corresponding A/N feedback, L, which is the total number of the CBG indices that are configured in a nested form as above, can be set to be identical for each TBS, or can be set such that the bit overhead for CBG indication for each TBS is identical (for example, such that the value of  $\text{ceiling}(\log_2(L))$  is identical).

4) Method A-4: Configuring CBs that belong to a set of a certain number of symbols (and set of a certain number of RBs) into one CBG  
For this method, in a state wherein the time interval (and/or the frequency region) during which a TB is transmitted is divided into a plurality of symbol sets (and/or a plurality of RB sets), CBs transmitted via each symbol set (and/or each RB set) can be configured as one CBG. In this case, information for the number of symbols in each symbol set (that is, SG: Symbol Group) or the number of symbols that constitute a single SG (and/or the number of RBs in each RB set (that is, RBG) or the number of RBs constituting a single RBG) can be indicated to the UE via semi-static (for example, RRC) or dynamic (for example, DCI) signaling, and the UE can perform transmission by configuring A/N bits for each CBG configured by such methods.

Furthermore, even in this case, method that configures the CBG to have a tree structure as in the above method A-3 for the number of symbols that constitute one SG or the total number of SGs configured within the TB transmission time interval (and/or the number of RBs that constitute one RBG or the total number of RBGs configured within the TB transmission frequency interval) is possible. Based on the above nested CBG examples 1, 2, and 3, for example, assuming that the total number of symbols (or RB) constituting the TB is  $K=16$  or 6 or 9, a plurality of SGs (or RBGs) that has mutually nested structures in a form similar to the above nested CBG examples 1, 2, and 3 can be configured in a state wherein each symbol (or RB) is indexed by  $k=0, 1, \dots, 15$  or  $k=0, 1, \dots, 5$  or  $k=0, 1, \dots, 8$  (depending on the above K value). Furthermore, for the above SG (and/or RBG) size and number, defined as identical one value regardless of the TB size, or defined as mutually different (proportional to the TB size) for each TB size in advance.

On the other hand, when this method has been applied, when one CB is mapped/transmitted over a plurality of SGs (and/or RBGs), the CB: Opt 1) can be configured by a CBG that corresponds to the SG that has the lowest or highest symbol index (and/or RBG that has the lowest or highest RB index, or Opt. 2); or can be configured by a CBG that corresponds to SG (and/or RBG) that contains the most of coded bits of the CB.

Alternatively, if a CB is mapped/transmitted across multiple SGs (and/or RBGs), then from the CBG configuration/instruction perspective for (retransmission) scheduling at the eNB, set the CB to be included commonly to all of the multiple CBGs corresponding to the multiple SGs (/RBGs), but from the perspective

of configuring CBG-specific A/N feedback at the UE, the A/N bits may be configured for each CBG to be transmitted, while only including the CB in the CBG corresponding to a specific one of the plurality of SGs (/RBGs). In this case, characteristically, the UE selects a specific CBG containing the corresponding CB (when configuring A/N feedback) 1) if there is a CBG containing a CB that is NACK even if the corresponding CB is excluded, among them (based on the application of Opt 1/2), and if no such CBG exists, it may operate to select one (based on the application of Opt 1/2) among all multiple CBGs (including the corresponding CB from a scheduling perspective), and 2) even if the decoding result of the corresponding CB is ACK, it can be operated to select one of all multiple CBGs (including the corresponding CB from a scheduling perspective) (based on the application of Opt 1/2). On the other hand, when multiple CBGs including the same CB are scheduled at the same time, the CB may be operated to be transmitted only once, and even in this case, it may be transmitted in a form that is included in only one specific CBG index (based on the application of Opt 1/2 above) of those multiple CBG indices. By generalizing the above method, from the perspective of CBG configuration/instruction for eNB scheduling, a CB may be set to be commonly included in multiple CBGs, and from the perspective of configuring CBG-specific A/N feedback by the UE, the CB may be operated to be included in only one of those multiple CBGs, in which case the above method may be applied.

As another method, in order to prevent one CB from being mapped/transmitted across multiple SGs (and/or RBGs), or in order to make the number of data bits belonging to each CBG as equal as possible across CBGs, the following method can be considered. Considering the scheduled TBS as A bits and the number of SGs or RBGs (or CBGs in general) allocated to the TBS as M, each CBG can first be allocated (A/M) or ceiling(A/M) or floor(A/M) data bits. Next, a plurality of CBs belonging to each CBG can be configured by applying Methods X-1/2/3, with the number of data bits allocated to each CBG replaced by the number of bits  $C_k$  corresponding to the TBS in Methods X-1 or X-2 or X-3 above. On the other hand, the coded bits for a single CBG configured as above may be mapped/transmitted to only one SG or RBG.

Meanwhile, it is possible to vary the number of symbols comprising one SG depending on the number of symbols allocated for data transmission and/or the number of RBs (or TBS). For example, the larger the number of symbols allocated for data transmission (to make the number of CBGs as equal as possible), the larger the number of symbols per SG may be configured, and the larger the number of RBs (or TBS) allocated for data transmission (to make the CBG size as equal as possible), the smaller the number of symbols per SG may be configured. Similarly, it is possible to vary the number of RBs comprising one RBG depending on the number of RBs and/or number of symbols (or TBS) allocated for data transmission. For example, the larger the number of RBs allocated for data transmission (to make the number of CBGs as equal as possible), the larger the number of RBs per RBG may be configured, and the larger the number of symbols (or TBS) allocated for data transmission (to make the CBG size as equal as possible), the smaller the number of RBs per RBG may be configured.

#### 5) Method A-5: Configuring the total number of CBGs M and CBG size (number of CBs in a CBG) N by TB size (TBS)

In this method, the (M, N) combination for CBG configuration is set (differently) for each TBS, where, for the number of DCI bits for CBG indication and/or UCI payload size for the corresponding A/N feedback configuration to be scheduled, it may be determined (e.g., as  $M_{\max}$  or ceiling( $M_{\max} / K$ ) or ceiling( $\log_2(M_{\max})$ ) bits) based on the maximum value  $M_{\max}$  among the M values set for each TBS (wherein K is a positive integer, e.g.,  $K = 2$ ).

Further, as an additional method, if the set of (M, N) combinations to be applied per TBS is referred to as a TBS-CBG table, it may be contemplated that a plurality of such TBS-CBG tables are defined/set in advance and one of such plurality of tables is indicated to the UE via semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling, in which case the (M, N) combinations corresponding to the same TBS may be configured differently among such plurality of TBS-CBG tables. Accordingly, the UE may be operable to determine the (M, N) combination corresponding to the TBS indicated via the DL/UL scheduling DCI by referring to the corresponding TBS-CBG table indicated, and to perform DL/UL data transmission/receipt and A/N feedback transmission based on the determined (M, N) combination.

As another method, one may consider dividing the entire set of TBSs into a plurality of TBS ranges and applying a different CBG configuration method to each TBS range. For an example, within a specific TBS range 1, the above method A-1 or the method of configuring a different number of CBGs M per TBS (or the same CBG size N) may be applied, while for a different TBS range 2, the above method A-2 or the method of configuring the same number of CBGs M per TBS may be applied, wherein TBS range 2 may be comprised of TBSs that are larger than the TBSs in TBS range 1 to account for DCI overhead and/or UCI payload. Alternatively, it is also possible to apply the same CBG configuration method for each of the plurality of TBS ranges, but apply different CBG number/size parameter values between the TBS ranges. For example, the above method A-2 or the method of configuring the CBG number M equally for each TBS is applied to each of TBS range 1/2, but a different value of M may be set between TBS ranges 1 and 2, such that M for TBS range 2 is set to a value greater than M for TBS range 1. As another example, a method configured using the above method A-1, or a method wherein the CBG size (number of CBs per CBG) N is configured to be the same for each of TBS range 1/2, but a different value of N may be set between TBS range 1 and 2, in which case N of TBS range 2 may be set to a value greater than N of TBS range 1.

6) Method A-6: Apply interleaving between CBs belonging to the same CBG before data-to-resource mapping

In the case of this method, inter-CB interleaving is applied between multiple CBs (coded bits) belonging to the same CBG prior to data-to-resource (RE) mapping (e.g., RE mapping based on frequency-first manner) to account for the effects of interference (e.g., URLLC puncturing operation as described above) with specific (e.g., time-selective) patterns. Specifically, for multiple CBs (coded bits) belonging to the same CBG, 1) intra-CB interleaving within each CB is applied first, followed by inter-CB interleaving, or 2) only inter-CB interleaving is applied, omitting intra-CB interleaving (if CBG-based HARQ operation is set).

Meanwhile, in all of the above proposed methods, the values of M, N, and K values may be set/instructed to the same value for different TB sizes, or may be set/instructed to different values for different TB sizes, or may be set/instructed to the same value for some (e.g., N) and different values for others (e.g., M, K) depending on the TB size. Also, considering how one DL data scheduling/transmission is performed over a plurality of slots, one symbol set (SG) in the above proposed method may be configured/set as a slot (in which case, the symbol index in the above is applied by replacing it with the slot index).

**(B) HARQ-ACK Feedback Methods****1) Method B-1: Configure/transmit a (minimum) range containing all NACKs on a CBG index as feedback**

In this method, given a CBG configuration method (e.g., number/size of CBGs), and considering the decoding error (i.e., NACK) over successive CBG indices due to time-selective interference, the UE may operate to either 1) feedback to the eNB the CBG index of the first NACK and the CBG index of the last NACK (on a CBG index), or 2) feedback the CBG index of the first NACK and the distance between the first NACK and the last NACK. Characteristically, cases 1) and 2) may be signaled using either the RIV indication method applied to UL resource allocation type 0 in 2-18 above or the combinatorial index method applied to UL resource allocation type 1. In this case, the CBG configuration method may include any of the above proposed methods A-1/2/3/4.

As an additional method, one of the plurality of CBG configuration methods (e.g., number/size of CBGs) may be directly selected by the UE, and based on the selected CBG configuration, the UE may either 1) determine a (minimum) CBG range containing the NACK as described above and feedback the NACK CBG range together with the selected CBG configuration information to the eNB, or 2) configure individual A/N bits for each CBG and feedback them (together with the selected CBG configuration information) to the eNB. In this case, the CBG configuration method may include the above proposed methods A-1/2/3/4.

Furthermore, the above method may also be applied to the scheduling of CBGs from the eNB, wherein 1) the first and last CBG indices at which the (re)transmission is to be performed, or 2) the first CBG index and the total number L of CBGs to be (re)transmitted, may be indicated via the DL data scheduling DCI. In this case, the UE may operate (receive) assuming/considering that 1) the set of CBGs corresponding to the first and last CBG indices and the indices in between, or 2) the set of CBGs corresponding to the first CBG index and the subsequent L consecutive indices, have been scheduled via the corresponding DCI.

**2) Method B-2: Feedback the (smallest size) CBG containing all NACKs from the CBG configurations in the tree structure**

In this method, given a plurality of CBG configurations (e.g., (M, N) combinations) based on the tree structure as in method A-3 above, the UE may be operated to select one specific CBG configuration, determine the CBG index containing all NACKs based on the selected CBG configuration, and feedback the selected CBG configuration information together with the corresponding NACK CBG index to the eNB. In the case of NACK CBGs, it may be desirable that a single CBG is selected that has the smallest size while containing all NACKs, i.e., the UE may operate to first select a particular CBG configuration among a plurality of CBG configurations having a tree structure such that a single CBG has the smallest size while containing all NACKs, to determine one CBG index that includes all NACK based on the selected CBG based on the selected CBG configuration, and to feedback these (along with the configuration information of the selected CBG configuration) to eNB.

Similarly, given a plurality of CBG configurations having the same SG (and/or RBG) based tree structure as in Method A-4 above (based on different SG (/RBG) sizes/numbers),

the UE may select one CBG configuration based on a particular SG (/RBG), determine a CBG index containing all NACKs based on the selected CBG configuration, and feedback the selected CBG configuration (or corresponding SB (/SBG) configuration) information together with the corresponding NACK CBG index to the eNB.

Furthermore, the above methods may also be applied to CBG scheduling from the eNB, in particular, given a plurality of CBG configurations (e.g., M and/or N (combinations) or SB(/RBG) sizes/numbers) having a tree structure as in methods A-3 or A-4 above, one CBG index based on one specific CBG configuration may be indicated via a DL data scheduling DCI. In this case, the UE may operate (receive) assuming/believing that the set of CBGs belonging to that CBG index has been scheduled via that DCI.

**3) Method B-3: Keeping CBG configuration and corresponding A/N configuration the same during one HARQ process**

In this method, in order to prevent unnecessary retransmission of RLC level DL data due to A/N error of a specific CBG, the CBG configuration and the corresponding A/N feedback configuration may be kept the same during one HARQ process (i.e., until its termination) for scheduling (indication) of retransmission (CBG) at the eNB. The CBG configuration and the A/N feedback configuration corresponding to the CBG configuration may be kept the same, specifically, the CBG configuration and the A/N feedback configuration initially applied/instructed for scheduling/transmitting DL data having a specific HARQ process ID and the corresponding A/N feedback configuration may be operated to remain the same until the end of that process (e.g., until decoding is successful for all CBs comprising the TB of that DL data, or until a new DL data scheduling with the same HARQ process ID (with NDI toggled) is initiated). In the above, the initially applied/instructed CBG and A/N configuration information may be indicated to the UE via semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., (Initial) DL data scheduling DCI).

In this case, the UE may configure the A/N bits for each CBG to feedback, but for each CBG, the UE may operate to feedback NACK for that CBG until decoding is successful (regardless of whether the CBG is scheduled or not), and after decoding is successful, the UE may operate to feedback ACK for that CBG (regardless of whether the CBG is scheduled or not, and until the end of the corresponding HARQ process).

**4) Method B-4: Setting the corresponding A/N transmission timing delay differently according to the number of scheduled CBs/CBGs**

For this method, you can consider setting the corresponding A/N transmission timing delay (i.e., the time interval between receiving DL data and transmitting the corresponding A/N feedback) differently depending on the number of CBs or CBGs scheduled simultaneously for the same TB (size). Specifically, the smaller the number of CBs or CBGs scheduled, the smaller the corresponding A/N delay can be set. For example, the corresponding A/N delay may be set smaller when some CBs or CBGs are scheduled compared to when the entire TB, i.e., all CBs, are scheduled, the corresponding A/N delay may be set smaller when fewer CBGs are scheduled assuming the same CBG size (i.e., number of CBs in a CBG configuration), and the corresponding A/N delay may be set smaller when a smaller CBG size is configured assuming the same number of scheduled CBGs.

**5) Method B-5: Set CBG configuration (CBG number/size) differently between DL data scheduling and A/N feedback**

For this method, it may be contemplated to set the CBG configuration (e.g., number/size of CBGs) applied to DL data scheduling/transmission (e.g., indicated via the DL data scheduling DCI) and the CBG configuration applied to A/N feedback corresponding to the DL data reception differently, specifically, the (M, N) combination for DL data scheduling (indicated via the DCI) and the (M, N) combination for A/N feedback configuration may be set to different values. For example, the combination (M1, N1) may be set for DL data scheduling and the combination (M2, N2) may be set for A/N feedback, such that when comparing case 1 with  $M1 > M2$  (and  $N1 < N2$ ) and case 2 with  $M1 < M2$  (and  $N1 > N2$ ), the number of DCI bits may be increased while the number of retransmission DL data resources and A/N feedback bits may be decreased in case 1, and the number of DCI bits may be decreased while the number of retransmission DL data resources and A/N feedback bits may be increased in case 2.

6) Method B-6: Setting different A/N transmission timing delay for each CBG for multiple scheduled CBGs

For this method, you may consider setting different A/N transmission timing delays for each CBG (i.e., TDM transmission of A/Ns per CBG) for multiple simultaneously scheduled CBGs, such that the A/N delay corresponding to a CBG transmitted via a lower symbol (or slot) index is smaller (so that it is fed back via a relatively faster symbol (or slot) timing).

7) Method B-7: Configuring A/N feedback corresponding to the (re)transmission scheduling of TB units (consisting of M CBGs)

In this method, the A/N bit configuration of the TB unit and the A/N bit configuration of the CBG unit are configured according to whether A/N feedback is performed by semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., (initial) DL data scheduling DCI), and in the case of CBG unit A/N bit configuration, the corresponding A/N payload size (and PUCCH format for the corresponding A/N transmission) may be set via semi-static (e.g., RRC) signaling. In this case, for a given (fixed) A/N payload size (e.g., M bits), the total number of CBGs comprising a TB may be determined (e.g., M equal to the total number of A/N bits), and accordingly, the number of CBGs comprising a TB (M) may be set to be the same for different TB sizes, and accordingly, the number of CBs comprising one CBG may be set to be different (e.g., proportional to the TB size) depending on the TB size. On the other hand, if the total number of CBs comprising the TB is equal to or less than the given A/N payload size, the full A/N feedback may be configured by allocating A/N bits to each CB without grouping for CBs, and if the total number of CBs N is less than the given A/N payload size M (bits), the A/N feedback may be operated to 1) NACK the remaining (M - N) bits not allocated to A/N per CB, or 2) change the A/N payload size itself to N (bits) equal to the total number of CBs.

On the other hand, for each TB size, the number of CBs comprising the corresponding TB and the CBG configuration based thereon (e.g., the total number of CBs comprising the TB, M, and the number of CBs comprising a single CBG, N) may be determined according to a predetermined rule, and the A/N payload size and the corresponding PUCCH format may be set based on the number of CBGs set in a given TB. For example, the PUCCH format and the set of candidate PUCCH resources used for CBG-based A/N transmission may be independently (differently) set for each TB size (and thus the total number of CBGs M).

Furthermore, the value of M and/or the corresponding PUCCH format may be determined by semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., DL data scheduling DCI) to the UE, e.g., a plurality of combinations of M values and PUCCH formats (and candidate PUCCH resource sets) may be pre-specified, and a specific one combination may be indicated via DCI (e.g., when an M value is indicated, the corresponding M value is indicated, For example, an M value may be indicated and a PUCCH format (and a set of candidate PUCCH resources) predetermined for that M value may be automatically determined, or a PUCCH format may be indicated and an M value predetermined for that PUCCH format may be automatically determined), or both the M value and the PUCCH format may be indicated independently via the RRC and/or DCI.

Alternatively, the N values and/or the corresponding PUCCH formats may be indicated to the UE via semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., DL data scheduling DCI) to the UE, such that a plurality of N values and a plurality of corresponding (M, PUCCH format (and a set of candidate PUCCH resources)) combinations are specified in advance, and one particular combination is indicated via DCI (e.g., when the N value is indicated, the PUCCH format specified in the corresponding M value is indicated), or For example, when an N value is specified, a PUCCH format (and a set of candidate PUCCH resources) specified for the M value may be automatically determined, or when a PUCCH format is specified, a total number of CBGs and a number of CBs per CBG may be automatically determined based on a corresponding A/N payload size (e.g., M bits)), or both the N value and the PUCCH format may be independently indicated via the RRC and/or DCI.

#### 8) Method B-8: Configure A/N feedback in response to retransmission of some CBGs (out of M CBGs comprising the TB)

For this method, when scheduling retransmissions for L ( $L < M$ ) or fewer CBGs out of the total M CBGs comprising the TB, Opt 1) the same A/N payload size (e.g., M bits) as in the case of A/N feedback corresponding to TB-wise (re)transmission (as in Method B-7 above) is applied (so that, for example, the actual A/N is mapped to only L bits and the remaining ( $M - L$ ) bits can be treated as NACK), Alternatively, Opt 2) a different (e.g., smaller) A/N payload size (and PUCCH format) may be applied than in the case of A/N feedback corresponding to TB unit (re)transmission, wherein the A/N payload size (and PUCCH format) may be varied (e.g., consisting of only L bits) depending on the scheduled CBG number L value. In this case, L may be indicated to the UE as a single value via semi-static (e.g., RRC) signaling or as a dynamically changing value via dynamic (e.g., DCI) signaling (e.g., DL data scheduling DCI), and in the former case, the corresponding CBG indication signaling may be configured to allow scheduling of up to L CBGs out of a total of M CBGs via per CBG scheduling DCI. Furthermore, it may be configured to perform retransmission scheduling (from the eNB) only for L ( $L < M$ ) or fewer CBGs out of the total M CBGs comprising the TB, and in this case, if the number of CBGs to be scheduled exceeds L, it may operate to perform TB-level scheduling (DCI transmission).

In the case of Opt 1 and Opt 2 above, it is basically assumed that the CBG configuration initially applied/instructed in the TB scheduling/transmission (e.g., the total number of CBGs M comprising the TB and the number of CBs N comprising a single CBG) remains the same during the HARQ process, and further, in the case of Opt 1, the A/N payload size may be set to (e.g., M bits), but in order to configure the A/N feedback only for the actual scheduled CBGs, the CBs belonging to all of the L scheduled CBGs (each consisting of N CBs) may be reorganized into M CBGs (consisting of a smaller number of CBs than N) such that the overall A/N feedback is configured based on the allocation of A/N bits per CBG. On the other hand, in the case of the CBG retransmission scheduling DCI corresponding to the A/N feedback in Opt 2 above, the corresponding signaling may be configured in the form of 1) a retransmission CBG indication based on the total number of CBGs M regardless of the A/N payload size change, or 2) a CBG indication assuming that the set of CBGs (consisting of less than or equal to M CBs) that the UE has feedback as NACK is the total CBG configuration.

Furthermore, it is possible to indicate to the UE via semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., DL data scheduling DCI) whether the same (fixed) A/N payload size (and PUCCH format) should always be applied for CBG (retransmission) scheduling regardless of the number of scheduled CBGs as in Opt 1 above, or whether the A/N payload size (and PUCCH format) should be changed (dynamically) according to the number of scheduled CBGs as in Opt 2 above, RRC) or dynamic (e.g., DCI) signaling (e.g., DL data scheduling DCI) to indicate to the UE whether to change the A/N payload size (and PUCCH format) according to the number of scheduled CBGs as in Opt 2 above.

9) Method B-9: A/N feedback on a CBG basis only if some of the CBGs (out of M CBGs comprising the TB) are NACK

In this method, you can configure/transmit CBG-level A/N feedback (e.g., assign individual A/N bits for each CBG) only if L or fewer ( $L < M$ ) CBGs are NACK out of the total M CBGs that comprise the TB, and if the number of CBGs that are NACK exceeds L, you can operate to configure/transmit TB-level A/N feedback. In this case, since the CBG-level A/N feedback is configured only for L or fewer NACKs, the retransmission CBG (index) indication through the CBG-level (retransmission) scheduling DCI may be configured in the form of 1) an indication for L or fewer CBGs out of the total M CBGs, or 2) a CBG indication assuming that the set of CBGs (L or fewer) that the UE has fed back as NACKs is the entire CBG configuration. More specifically, in this case, the UE may consider indexing all combinations of selecting i CBGs out of the total of M CBGs for all values of i for  $i = \{1, \dots, L\}$ , and feeding one of those indices back to the eNB as the set of CBGs that are NACK.

10) Method B-10: CBG retransmission scheduling and A/N feedback with maximum number of CBGs limited to M

For this method, from the eNB scheduling point of view, the entire CBG configuration may consist of no more than M CBGs and may operate to indicate to the UE the retransmission of L ( $L \leq M_r \leq M$ ) CBGs among them, where M has a fixed value for at least one TB transmission or one HARQ process, while  $M_r$  (and L) values may change at each (retransmission) scheduling point.

In this case, from an A/N feedback perspective, the UE shall either Opt 1) configure A/N feedback based on the maximum possible number of CBGs, M (e.g., configure the entire A/N payload size to be M bits, but treat the  $(M - L)$  bits corresponding to the actual unscheduled CBGs as NACK or DTX), or Opt 2) configure A/N feedback based on the total number of CBGs,  $M_r$ , at the time of scheduling (e.g., configure the entire A/N payload size to be  $M_r$  bits, but treat the  $(M_r - L)$  bits corresponding to the actual unscheduled CBGs as NACK or DTX), total A/N payload size of  $M_r$  bits, but NACK or DTX the  $(M_r - L)$  bits corresponding to the actual unscheduled CBGs), or Opt 3) configure the A/N feedback based on the number of scheduled CBGs L (e.g., configure the total A/N payload size of L bits and map/transmit A/N bits per scheduled CBG). In the case of Opt 2/3 above, the A/N payload size may change depending on the  $M_r$  value or the L value, and the PUCCH format (and the set of candidate PUCCH resources) used to transmit the A/N feedback (based on different  $M_r$  values or different L values) may change accordingly (i.e., set differently depending on the  $M_r$  value or the L value).

Furthermore, in this case, the overall Mr configuration of CBGs for retransmission scheduling in the eNB may be configured for the entire set of CBs comprising the TB (i.e., the overall set of CBGs is equal to the entire TB), or it may be configured for a specific subset of all CBs (i.e., the overall set of CBGs corresponds to a subset of the TB). In the former case, the Mr value at a particular scheduling point for one TB transfer or one HARQ process may be constrained to be set to a value that is always less than or equal to the Mr value at the previous scheduling point. In the latter case, the specific subset of CBs may be considered either 1) as the set of CBs belonging to the L CBGs scheduled at the previous scheduling point, or 2) as the set of CBs belonging to the CBGs that were NACKed by the UE among the L CBGs scheduled.

#### 11) Method B-11: Handling of (subsequent) CBGs scheduled for retransmission prior to A/N feedback transmission

In a situation where a CBG retransmission for the same TB is scheduled at a time prior to the transmission of the A/N feedback corresponding to the reception of a specific TB (hereinafter referred to as “original TB”) (hereinafter referred to as “subsequent CBG”), the operation of transmitting the A/N feedback reflecting the reception combining for the subsequent CBG at the time of the first A/N may not be possible because the end of decoding for the subsequent CBG is too late. In this case, receive combining may refer to the operation of storing the subsequent CBG after flushing the buffer in which the previously received signal is stored. In this case, the UE may either 1) transmit the A/N feedback based on the decoding result only for the original TB at the first A/N time point and perform receive combining for the subsequent CBG (for A/N feedback at a later time point), or 2) transmit the A/N feedback based on the decoding result including the receive combining of the subsequent CBG at a time point that is a certain delay later than the first A/N time point, in which case the A/N transmission at the first A/N time point may be omitted (dropped) or only the A/N for the original TB may be transmitted.

In UL data scheduling situations, similarly to the above, a (subsequent) CBG retransmission for the same TB may be scheduled at a time prior to a specific (original) TB transmission, where the time of the original TB transmission (referred to as “TX timing 1”) and the time of the subsequent CBG transmission (referred to as “TX timing 2”) may be different, with TX timing 2 being slower than TX timing 1. In this case, the UE may operate with TX timing 1 to transmit only the remaining scheduled original TB signal, excluding the CBG corresponding to the subsequent CBG (e.g., puncturing the RE/RB/symbol to which the CBG is mapped), while with TX timing 2 it may transmit the subsequent CBG scheduled for retransmission as is.

Furthermore, in a cross-slot scheduling situation for DL data, similarly to the above, a (subsequent) CBG retransmission for the same TB may be scheduled via a specific (original) TB reception prior to a (subsequent) TB reception, where the original TB reception (referred to as “TX timing 1”) and the subsequent CBG reception (referred to as “TX timing 2”) may be different and TX timing 2 may be directed to a later time than TX timing 1. In this case, the UE may operate to receive only the remaining signals with TX timing 1 excluding the CBG corresponding to the subsequent CBG from the original TB signal scheduled (e.g., puncturing for the RE/RB/symbol to which the CBG is mapped), while with TX timing 2 it may receive the subsequent CBG as scheduled for retransmission.

#### (C) How to operate the soft buffer

1) Method C-1: Determine the minimum buffer size per CB based on the total sum of the number of CBs belonging to the CBG that is NACK

For this method, for the (minimum) buffer size (Bt) per TB allocated to one HARQ process or one TB, the buffer size (Bc) divided by the total number of CBs (Cn) belonging to the CBG(s) that the UE has fed back (to the eNB) as NACK is the minimum buffer size per CB from the UE receiving perspective (e.g., For example,  $B_c = B_t / C_n$  (e.g., the minimum number of (soft channel) bits that the UE should store in the buffer for each CB for said TB transmission), and as a specific example of this, one may consider substituting C for Cn in the following equation in 2-19 above.

$$n_{SB} = \min \left( N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{MIMO} \cdot \min(M_{DL\_HARQ}, M_{limit})} \right\rfloor \right)$$

In this case, there is an advantage of increasing the minimum buffer size per CB (e.g., because  $C > C_n$ ) compared to the conventional method based on A/N feedback in TB units, at which time, for Cn applied to one HARQ process or one TB transmission, the operation can be performed to 1) determine Cn based on only the initial A/N feedback (CBG with double NACK) composed of CBG units (i.e., apply the same Cn until the end of the HARQ process), or 2) determine Cn based on the A/N feedback (CBG with double NACK) at each point of A/N transmission, Cn is applied to the same until the end of the HARQ process), or 2) it can be operated to determine based on the A/N feedback (CBG with double NACK) at each point of A/N transmission (i.e., Cn is determined and applied according to the NACK CBG at each scheduling/feedback point).

2) Method C-2: (limited/circular buffer) rate-matching operation at the eNB for retransmitted CBG signals

In this method, when performing (limited/circular buffer) rate-matching based on the NACK fed back (from the UE) or the whole CBG that needs to be retransmitted from the eNB perspective, an A/N error may cause a mismatch between the NACK CBG from the eNB perspective and the NACK CBG fed back by the UE, To eliminate this mismatch, the eNB may either 1) behave (and the UE may assume/act on the assumption) that it always performs retransmission scheduling for all CBGs that have been fed back as NACK (from the UE) (or for which it has not received ACK feedback) all at once/simultaneously (i.e., ), or 2) (allowing retransmission scheduling for only some of the total NACK CBGs at the eNB), but indicating to the UE via DL data scheduling DCIs the total CBG information (e.g. number/index of NACK CBGs) that have been NACK-fed back or need to be retransmitted (or have not received ACK feedback) from the eNB perspective (e.g. number/index of NACK CBGs).

In this case, the (minimum) buffer size per TB (Bt) allocated to one HARQ process or one TB may be determined by dividing the buffer size (Bc) by the sum of the number of CBs belonging to the CBG(s) that have been fed back as NACK or that require retransmission (or that have not received ACK feedback) from the eNB perspective (Cn), It may be considered to determine the minimum buffer size per CB from an eNB transmission perspective (e.g.,  $B_c = B_t / C_n$ ), and as a specific example of this, it may be considered to substitute C for Cn in the following formula in 2-19 above.

$$N_{cb} = \min \left( \left\lfloor \frac{N_{IR}}{C} \right\rfloor, K_w \right)$$

In this case, compared to the conventional method that applies only TB unit retransmissions, it has the advantage of increasing the minimum buffer size per CB (e.g., because  $C > C_n$ ), and the  $C_n$  applied to one TB transmission can be 1) determined at the time of the first CBG unit retransmission executed (i.e., applying the same  $C_n$ , which has been determined in this manner, until the end of the HARQ process), or 2) determined at each point of CBG unit retransmission (i.e., determine according to the number of CBGs which have been fed back to NACK as of each time point or for which retransmission is necessary (or for which ACK feedback has not been received)).

**3) Method C-3: Applying power offset to A/N feedback PUCCH transmission according to CBG unit scheduling**

For this method, the power offset added/applied to PUCCH transmissions carrying A/N feedback organized on a CBG basis shall be based on Opt 1) the total number of CBGs to which A/N bits are assigned or subject to A/N feedback (without distinction between ACK/NACK), or Opt 2) the number of CBGs scheduled by the eNB, or Opt 3) the number of NACK CBGs indicated (from the eNB) in Method C-2 indicated by eNB above, or Opt 4) the number of NACK CBGs from the UE, or Opt 5) the number of CBGs in Opt 2 above, taking into account how the A/N feedback is configured as in Method B-3 above, Opt 6) the number of CBGs in Opt 3 above, plus the total number of CBGs that were unscheduled but fed back as ACKs; or Opt 7) the number of CBGs in Opt 3 above, plus the total number of CBGs that were unscheduled but fed back as ACKs; or Opt 8) the power offset added/applied to the A/N PUCCH transmission at a particular timing, excluding the CBGs that were already fed back as ACKs at a point prior to that timing, (e.g., the larger the number of CBGs in Opt 1/2/3/4/5/6/7 above, the larger the corresponding power offset is added/applied).

**(D) Mismatch handling method**

**1) Method D-1: Mismatch between CBG specific A/N information reported by the UE and CBG scheduled for retransmission by the eNB**

In this method, there may be a mismatch (due to an A/N error) between the CBG specific A/N information reported by the UE and the corresponding retransmission scheduled CBG index from the eNB, e.g., the CBG index scheduled from the eNB may not contain some of the CBGs reported by the UE as NACK and/or may contain CBGs that have already been reported as ACK. In this case, the UE shall either Opt 1) map the A/N result after combining and decoding for the scheduled CBGs that were previously fed back as NACK, or Opt 2) map ACK again (without combining/decoding) for the scheduled CBGs that were previously fed back as ACK, or Opt 3) map NACKs for all CBGs, or Opt 4) perform TB-wide NACK feedback or TB-wide retransmission requests, or Opt 5) operate to discard the corresponding CBG scheduling DCI. On the other hand, it is also possible to apply one of the above Opt 1/2 if the scheduled CBG contains the entire CBG that was fed back with NACK before the scheduled CBG, and one of the above Opt 3/4/5 if not.

**2) Method D-2: Mismatch between TB-wide applied CRC and per CB and/or per CBG applied CRC**

In this method, the results of the CRC checks at the UE (e.g., pass or fail) may be different between the CRC applied to the entire TB, CRC applied in the unit for CB, and CRC applied in the unit of CRC. For example, the results of the CRC checks at the UE and/or CBG units may all be passes while the results of the CRC checks at the TB as a whole may be fails, or conversely, the results of the CRC checks at the TB as a whole may be

passes while the results of the CRC checks at at least one CB and/or CBG unit may be fails, in which case the UE may operate to apply one of Opt 3/4/5 above. In another example, the results of the CRC checks of the CBs belonging to a particular CBG may all be pass, while the CRC check result of the entire CBG may be fail, or conversely, the CRC check result of the entire CBG may be pass even though the CRC check result of at least one CB belonging to a particular CBG may fail, in which case the UE may map the CBG to NACK and feedback, or the UE may act to apply one of Opt 3/4/5.

**(E) Configure CBG Scheduling DCI****1) Method E-1: Configure and set the Redundancy Version (RV) in the CBG unit's scheduling (DCI)**

For this method, configure only one RV field in the (retransmission) scheduling DCI in CBG units, 1) with the same size as the RV field in the scheduling DCI in TB units, but apply the RV value indicated in that field equally to all scheduled CBGs (where, RV value is the same as for TB-level scheduling), or 2) configure separate RV fields for each CBG, each of which can be smaller in size than the RV field in the TB-level scheduling DCI (but with fewer RV values than for TB-level scheduling).

**2) Method E-2: Perform retransmission scheduling for some CBGs (out of M CBGs comprising the TB)**

In this method, it may be operated to enable retransmission scheduling for only up to L ( $L < M$ ) CBGs out of the total M CBGs comprising the TB, where L may be indicated to the UE as a single value through semi-static (e.g., RRC) signaling. Accordingly, up to L CBGs out of a total of M CBGs may be indicated through a CBG unit scheduling DCI, and for retransmission scheduling for CBGs beyond L, a TB unit scheduling DCI (or a flag in the DCI indicating TB-by-TB (re)transmission scheduling) may be applied. Furthermore, in this case, a method can be considered in detail, wherein, for every value of  $i = \{1, \dots, L\}$ , all combinations of selecting i CBGs out of the total of M CBGs are indexed and the set of CBGs corresponding to one of those indices is indicated to the UE via a CBG retransmission scheduling DCI.

On the other hand, considering the early termination of the TB decoding operation at the UE, it is possible to 1) perform decoding sequentially one CB at a time for each CBG, alternating for multiple CBGs (e.g., CB1 in CBG-1  $\rightarrow$  CB1 in CBG-2  $\rightarrow$  ... CB1 in CBG-M  $\rightarrow$  CB2 in CBG-1  $\rightarrow$  ...), or 2) sequentially decode each CBG (by index) in a CBG-by-CBG manner (e.g., CBs in CBG-1  $\rightarrow$  CBs in CBG-2  $\rightarrow$  ...), and if a CBG that is NACK is encountered, the system may be operated to feedback the NACK for all subsequent CBGs (by index) (omitting the decoding operation).

On the other hand, the CBG unit retransmission scheduling and CBG-specific A/N feedback configuration operation may not be applied/set for DL/UL data transmitted based on the SPS method, and accordingly, the CBG unit retransmission scheduling and CBG-specific A/N feedback configuration operation may be

applied/set only for DL/UL data transmitted based on the general scheduling method other than the SPS method, and the TB unit scheduling and TB-specific A/N feedback operation may be applied/set for DL/UL data transmitted based on the SPS method. Also, for DL/UL data scheduled via DCI (or specific DCI format) transmission based on UE (group) CSS (and/or Msg3 scheduled from RAR accompanying random access process and Msg4 transmitted for contention resolution purpose), retransmission scheduling on CBG basis and A/N feedback configuration operation on CBG basis may not be applied/set. As a result, retransmission scheduling on a CBG basis and A/N feedback configuration operation on a CBG basis may be applied/set only for DL/UL data transmissions scheduled via USS-based DCI transmissions rather than CSS, while TB-based scheduling and A/N feedback operation on a TB basis may be applied/set for DL/UL data (and/or Msg3/4) transmissions scheduled via CSS-based DCI transmissions.

On the other hand, when considering a situation where the above intentional URLLC puncturing behavior is applied in a co-channel inter-cell environment, it may be desirable to minimize at least the interference impact of URLLC signals transmitted by a particular cell on DMRS signals used for receiving DL/UL data in other cells. For this purpose, it may be contemplated that the cells communicate/exchange with each other the symbol position information to be used for DMRS transmission in each cell and/or the symbol position information to be used for URLLC (puncturing) transmission in each cell.

The application of the proposed methods of the present invention may not be limited to the DL data scheduling and transmission situation, (for example, by replacing the DL data (scheduling DCI) with UL data (scheduling DCI) in the above) and the operating principles of the proposed methods (e.g., configuring CB/CBG according to TB, setting UL data transmission timing, configuring CBG scheduling DCI, etc.

## **5. Reference**

- [1] 3GPP TS 36.211 V10.2.0, *Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 10)*
- [2] 3GPP TS 36.212 V10.2.0, *Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 10)*
- [3] 3GPP TS 36.213 V10.2.0, *Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer Procedures (Release 10)*

**DESCRIPTION OF THE RELATED ART**

**[0001]** Universal mobile telecommunications system (UMTS) is a 3rd Generation (3G) asynchronous mobile communication system operating in wideband code division multiple access (WCDMA) based on European systems, global system for mobile communications (GSM) and general packet radio services (GPRS). The long-term evolution (LTE) of UMTS is under discussion by the 3rd generation partnership project (3GPP) that standardized UMTS.

**[0002]** The 3GPP LTE is a technology for enabling high-speed packet communications. Many schemes have been proposed for the LTE objective including those that aim to reduce user and provider costs, improve service quality, and expand and improve coverage and system capacity. The 3G LTE requires reduced cost per bit, increased service availability, flexible use of a frequency band, a simple structure, an open interface, and adequate power consumption of a terminal as an upper-level requirement.

**[0003]** FIG. 1 is a block diagram illustrating network structure of an evolved universal mobile telecommunication system (E-UMTS). The E-UMTS may be also referred to as an LTE system. The communication network is widely deployed to provide a variety of communication services such as voice (VoIP) through IMS and packet data.

**[0004]** As illustrated in FIG. 1, the E-UMTS network includes an evolved UMTS terrestrial radio access network (E-UTRAN), an Evolved Packet Core (EPC) and one or more user equipment. The E-UTRAN may include one or more evolved NodeB (eNodeB) 20, and a plurality of user equipment (UE) 10 may be located in one cell. One or more E-UTRAN mobility management entity (MME)/system architecture evolution (SAE) gateways 30 may be positioned at the end of the network and connected to an external network.

**[0005]** As used herein, "downlink" refers to communication from eNodeB 20 to UE 10, and "uplink" refers to communication from the UE to an eNodeB. UE 10 refers to communication equipment carried by a user and may be also referred to as a mobile station (MS), a user terminal (UT), a subscriber station (SS) or a wireless device.

**[0006]** An eNodeB 20 provides end points of a user plane and a control plane to the UE 10. MME/SAE gateway 30 provides an end point of a session and mobility management function for UE 10. The eNodeB and MME/SAE gateway may be connected via an S1 interface.

**[0007]** The eNodeB 20 is generally a fixed station that communicates with a UE 10, and may also be referred to as a base station (BS) or an access point. One eNodeB 20 may be deployed per cell. An interface for transmitting user traffic or control traffic may be used between eNodeBs 20.

**[0008]** The MME provides various functions including NAS signalling to eNodeBs 20, NAS signalling security, AS Security control, Inter CN node signalling for mobility between 3GPP access networks, Idle mode UE Reachability (including control and execution of paging retransmission), Tracking Area list management (for UE in idle and active mode), PDN GW and Serving GW selection, MME

selection for handovers with MME change, SGSN selection for handovers to 2G or 3G 3GPP access networks, Roaming, Authentication, Bearer management functions including dedicated bearer establishment, Support for PWS (which includes ETWS and CMAS) message transmission. The SAE gateway host provides assorted functions including Per-user based packet filtering (by e.g. deep packet inspection), Lawful Interception, UE IP address allocation, Transport level packet marking in the downlink, UL and DL service level charging, gating and rate enforcement, DL rate enforcement based on APN-AMBR. For clarity MME/SAE gateway 30 will be referred to herein simply as a "gateway," but it is understood that this entity includes both an MME and an SAE gateway.

**[0009]** A plurality of nodes may be connected between eNodeB 20 and gateway 30 via the S1 interface. The eNodeBs 20 may be connected to each other via an X2 interface and neighboring eNodeBs may have a meshed network structure that has the X2 interface.

**[0010]** FIG. 2 is a block diagram depicting architecture of a typical E-UTRAN and a typical EPC. As illustrated, eNodeB 20 may perform functions of selection for gateway 30, routing toward the gateway during a Radio Resource Control (RRC) activation, scheduling and transmitting of paging messages, scheduling and transmitting of Broadcast Channel (BCCH) information, dynamic allocation of resources to UEs 10 in both uplink and downlink, configuration and provisioning of eNodeB measurements, radio bearer control, radio admission control (RAC), and connection mobility control in LTE\_ACTIVE state. In the EPC, and as noted above, gateway 30 may perform functions of paging origination, LTE-IDLE state management, ciphering of the user plane, System Architecture Evolution (SAE) bearer control, and ciphering and integrity protection of Non-Access Stratum (NAS) signaling.

**[0011]** FIGS. 3(a) and 3(b) are block diagrams depicting the user-plane protocol and the control-plane protocol stack for the E-UMTS. As illustrated, the protocol layers may be divided into a first layer (L1), a second layer (L2) and a third layer (L3) based upon the three lower layers of an open system interconnection (OSI) standard model that is well known in the art of communication systems.

**[0012]** The physical layer, the first layer (L1), provides an information transmission service to an upper layer by using a physical channel. The physical layer is connected with a medium access control (MAC) layer located at a higher level through a transport channel, and data between the MAC layer and the physical layer is transferred via the transport channel. Between different physical layers, namely, between physical layers of a transmission side and a reception side, data is transferred via the physical channel.

**[0013]** The MAC layer of Layer 2 (L2) provides services to a radio link control (RLC) layer (which is a higher layer) via a logical channel. The RLC layer of Layer 2 (L2) supports the transmission of data with reliability. It should be noted that the RLC layer illustrated in FIGS. 3(a) and 3(b) is depicted because if the RLC functions are implemented in and performed by the MAC layer, the RLC layer itself is not required. The PDPCP layer of Layer 2 (L2) performs a header compression function that reduces unnecessary control information such that data being transmitted by employing Internet protocol (IP) packets, such as IPv4 or IPv6, can be efficiently sent over a radio (wireless) interface that has a relatively small bandwidth.

**[0014]** A radio resource control (RRC) layer located at the lowest portion of the third layer (L3) is only defined in the control plane and controls logical channels, transport channels and the physical channels in relation to the configuration, reconfiguration, and release of the radio bearers (RBs). Here, the RB signifies a service provided by the second layer (L2) for data transmission between the terminal and the UTRAN.

**[0015]** As illustrated in FIG. 3(a), the RLC and MAC layers (terminated in an eNodeB 20 on the network side) may perform functions such as Scheduling, Automatic Repeat Request (ARQ), and Hybrid Automatic Repeat Request (HARQ). The PDCP layer (terminated in eNodeB 20 on the network side) may perform the user plane functions such as header compression, integrity protection, and ciphering.

**[0016]** As illustrated in FIG. 3(b), the RLC and MAC layers (terminated in an eNodeB 20 on the network side) perform the same functions for the control plane. As illustrated, the RRC layer (terminated in an eNodeB 20 on the network side) may perform functions such as broadcasting, paging, RRC connection management, Radio Bearer (RB) control, mobility functions, and UE measurement reporting and controlling. The NAS control protocol (terminated in the MME of gateway 30 on the network side) may perform functions such as a SAE bearer management, authentication, LTE\_IDLE mobility handling, paging origination in LTE\_IDLE, and security control for the signaling between the gateway and UE 10.

**[0001]** The RRC state may be divided into two different states such as a RRC\_IDLE and a RRC\_CONNECTED. In RRC\_IDLE state, the UE 10 may receive broadcasts of system information and paging information while the UE specifies a Discontinuous Reception (DRX) configured by NAS, and the UE has been allocated an identification (ID) which uniquely identifies the UE in a tracking area and may perform PLMN selection and cell re-selection. Also, in RRC-IDLE state, no RRC context is stored in the eNodeB.

**[0002]** In RRC\_CONNECTED state, the UE 10 has an E-UTRAN RRC connection and a context in the E-UTRAN, such that transmitting and/or receiving data to/from the network (eNodeB) becomes possible. Also, the UE 10 can report channel quality information and feedback information to the eNodeB.

**[0003]** In RRC\_CONNECTED state, the E-UTRAN knows the cell to which the UE 10 belongs. Therefore, the network can transmit and/or receive data to/from UE 10, the network can control mobility (handover and inter-RAT cell change order to GERAN with NACC) of the UE, and the network can perform cell measurements for a neighboring cell.

**[0004]** In RRC\_IDLE mode, the UE 10 specifies the paging DRX (Discontinuous Reception) cycle. Specifically, the UE 10 monitors a paging signal at a specific paging occasion of every UE specific paging DRX cycle.

**[0005]** The paging occasion is a time interval during which a paging signal is transmitted. The UE 10 has its own paging occasion.

**[0006]** A paging message is transmitted over all cells belonging to the same tracking area. If the UE 10 moves from one tracking area to another tracking area, the UE will send a tracking area update message to the network to update its location.

**[0007]** A physical channel transfers signaling and data between layer L1 of a UE and eNB. As illustrated in FIG. 4, the physical channel transfers the signaling and data with a radio resource, which consists of one or more sub-carriers in frequency and one more symbols in time.

**[0008]** One sub-frame, which is 1.0 ms. in length, consists of several symbols. The particular symbol(s) of the sub-frame, such as the first symbol of the sub-frame, can be used for downlink control channel(PDCCH). PDCCHs carries dynamic allocated resources, such as PRBs and MCS

**[0009]** A transport channel transfers signaling and data between the L1 and MAC layers. A physical channel is mapped to a transport channel.

**[0010]** Downlink transport channel types include a Broadcast Channel (BCH), a Downlink Shared Channel (DL-SCH), a Paging Channel (PCH) and a Multicast Channel (MCH). The BCH is used for transmitting system information. The DL-SCH supports HARQ, dynamic link adaptation by varying the modulation, coding and transmit power, and both dynamic and semi-static resource allocation. The DL-SCH also may enable broadcast in the entire cell and the use of beamforming. The PCH is used for paging a UE. The MCH is used for multicast or broadcast service transmission.

**[0011]** Uplink transport channel types include an Uplink Shared Channel (UL-SCH) and Random Access Channel(s) (RACH). The UL-SCH supports HARQ and dynamic link adaptation by varying the transmit power and potentially modulation and coding. The UL-SCH also may enable the use of beamforming. The RACH is normally used for initial access to a cell.

**[0012]** The MAC sublayer provides data transfer services on logical channels. A set of logical channel types is defined for different data transfer services offered by MAC. Each logical channel type is defined according to the type of information transferred.

**[0013]** Logical channels are generally classified into two groups. The two groups are control channels for the transfer of control plane information and traffic channels for the transfer of user plane information.

**[0014]** Control channels are used for transfer of control plane information only. The control channels provided by MAC include a Broadcast Control Channel (BCCH), a Paging Control Channel (PCCH), a Common Control Channel (CCCH), a Multicast Control Channel (MCCH) and a Dedicated Control Channel (DCCH). The BCCH is a downlink channel for broadcasting system control information. The PCCH is a downlink channel that transfers paging information and is used when the network does not know the location cell of a UE. The CCCH is used by UEs having no RRC connection with the network. The MCCH is a point-to-multipoint downlink channel used for transmitting MBMS control information from the network to a UE. The DCCH is a point-to-point bi-directional channel used by UEs having an RRC connection that transmits dedicated control information between a UE and the network.

**[0015]** Traffic channels are used for the transfer of user plane information only. The traffic channels provided by MAC include a Dedicated Traffic Channel (DTCH) and a Multicast Traffic Channel (MTCH). The DTCH is a point-to-point channel, dedicated to one UE for the transfer of user information

and can exist in both uplink and downlink. The MTCH is a point-to-multipoint downlink channel for transmitting traffic data from the network to the UE.

**[0016]** Uplink connections between logical channels and transport channels include a DCCH that can be mapped to UL-SCH, a DTCH that can be mapped to UL-SCH and a CCCH that can be mapped to UL-SCH. Downlink connections between logical channels and transport channels include a BCCH that can be mapped to BCH or DL-SCH, a PCCH that can be mapped to PCH, a DCCH that can be mapped to DL-SCH, and a DTCH that can be mapped to DL-SCH, a MCCH that can be mapped to MCH, and a MTCH that can be mapped to MCH.

**[0017]** It is known that different cause values may be mapped on the signature sequence used to send messages between a UE and eNB and that either Channel Quality Indicator (CQI) or path loss and cause or message size are candidates for inclusion in the initial preamble. FIG. 5 illustrates different messages exchanged between a UE and eNB during initial access.

**[0018]** When a UE wishes to access the network and determines a message to be transmitted, the message may be linked to a purpose and a cause value may be determined. The size of the ideal message number 3 illustrated in FIG. 5 may also be determined by identifying all optional information and different alternative sizes, such as by removing optional information, or an alternative "scheduling request" message may be used.

**[0019]** The UE acquires necessary information for the transmission of the preamble, UL interference, Pilot Transmit power and required Signal-to-Noise Ratio (SNR) for the preamble detection at the receiver or combinations thereof. This information must allow the calculation of the initial transmit power of the preamble. It is beneficial to transmit the uplink message in the vicinity of the preamble from a frequency point of view in order to ensure that the same channel is used for the transmission of the message.

**[0020]** The UE should take into account the uplink interference and the uplink path loss in order to ensure that the network receives the preamble with a minimum SNR. The uplink interference can be determined only in the ENodeB and, therefore, must be broadcast by the ENodeB and received by the UE prior to the transmission of the preamble. The uplink path loss can be considered to be similar to the downlink path loss and can be estimated by the UE from the received Rx (receiver) signal strength when the transmit power of some pilot sequence of the cell is known to the UE.

**[0021]** The required uplink SNR for the detection of the preamble would typically depend on the NodeB configuration, such as a number of Rx antennas and receiver performance. There may be advantages to transmitting the rather static Transmit power of the pilot and the necessary uplink SNR separately from the varying uplink interference and possibly the power offset required between the preamble and the message.

**[0022]** The initial transmission power of the preamble can be roughly calculated according to the following formula:

**[0023]**  $\text{Transmit power} = \text{TransmitPilot} - \text{RxPilot} + \text{ULInterference} + \text{Offset} + \text{SNRRequired}.$

**[0024]** Therefore, any combination of SNRRequired, ULInterference, TransmitPilot and Offset can be broadcast. In principle, only one value must be broadcast. This is essentially the method in current UMTS systems, although the UL interference in LTE will mainly be neighboring cell interference that is probably more constant than in UMTS.

**[0025]** The UE determines the initial uplink transmit power for the transmission of the preamble as explained above. The receiver in the eNB is able to estimate the absolute received power as well as the relative received power compared to the interference in the cell. The eNB will consider a preamble detected if the received signal power compared to the interference is above an eNB known threshold.

**[0026]** The UE performs power ramping in order to ensure that a UE can be detected even if the initially estimated transmission power for the preamble is not adequate. Another preamble will most likely be transmitted if no acknowledgement or a negative acknowledgement is received by the UE before the next random access attempt. The transmit power of the preamble can be increased, and / or the preamble can be transmitted on a different uplink frequency in order to increase the probability of detection. Therefore, the actual transmit power of the preamble that will be detected does not necessarily correspond to the initial transmit power of the preamble as initially calculated by the UE.

**[0027]** The UE must determine the possible uplink transport format. The transport format, which may include Modulation and Coding Scheme (MCS) and a number of resource blocks that should be used by the UE, depends mainly on two parameters, specifically the SNR at the eNB and the required size of the message to be transmitted.

**[0028]** In practice, a maximum UE message size, or payload, and a required minimum SNR correspond to each transport format. In UMTS, the UE determines before the transmission of the preamble whether a transport format can be chosen for the transmission according to the estimated initial preamble transmit power, the required offset between preamble and the transport block, the maximum allowed or available UE transmit power, a fixed offset and additional margin. The preamble in UMTS need not contain any information regarding the transport format selected by the UE since the network does not need to reserve time and frequency resources and, therefore, the transport format is indicated together with the transmitted message.

**[0029]** The eNB must be aware of the size of the message that the UE intends to transmit and the SNR achievable by the UE in order to select the correct transport format upon reception of the preamble and then reserve the necessary time and frequency resources. Therefore, the eNB cannot estimate the SNR achievable by the UE according to the received preamble because the UE transmit power compared to the maximum allowed or possible UE transmit power is not known to the eNB, given that the UE will most likely consider the measured path loss in the downlink or some equivalent measure for the determination of the initial preamble transmission power.

**[0030]** The eNB could calculate a difference between the path loss estimated in the downlink compared and the path loss of the uplink. However, this calculation is not possible if power ramping is used and the UE transmit power for the preamble does not correspond to the initially calculated UE transmit

power. Furthermore, the precision of the actual UE transmit power and the transmit power at which the UE is intended to transmit is very low. Therefore, it has been proposed to code the path loss or CQI estimation of the downlink and the message size or the cause value in the uplink in the signature.

**[0031]**

**[0032]**

**[0033]** Brief Description of the Drawings

**[0034]** FIG. 1 illustrates a block diagram illustrating network structure of an evolved universal mobile telecommunication system (E-UMTS).

**[0035]** FIG. 2 illustrates a block diagram depicting architecture of a typical E-UTRAN and a typical EPC.

**[0036]** FIG. 3(a) illustrates the user-plane protocol for the E-UMTS.

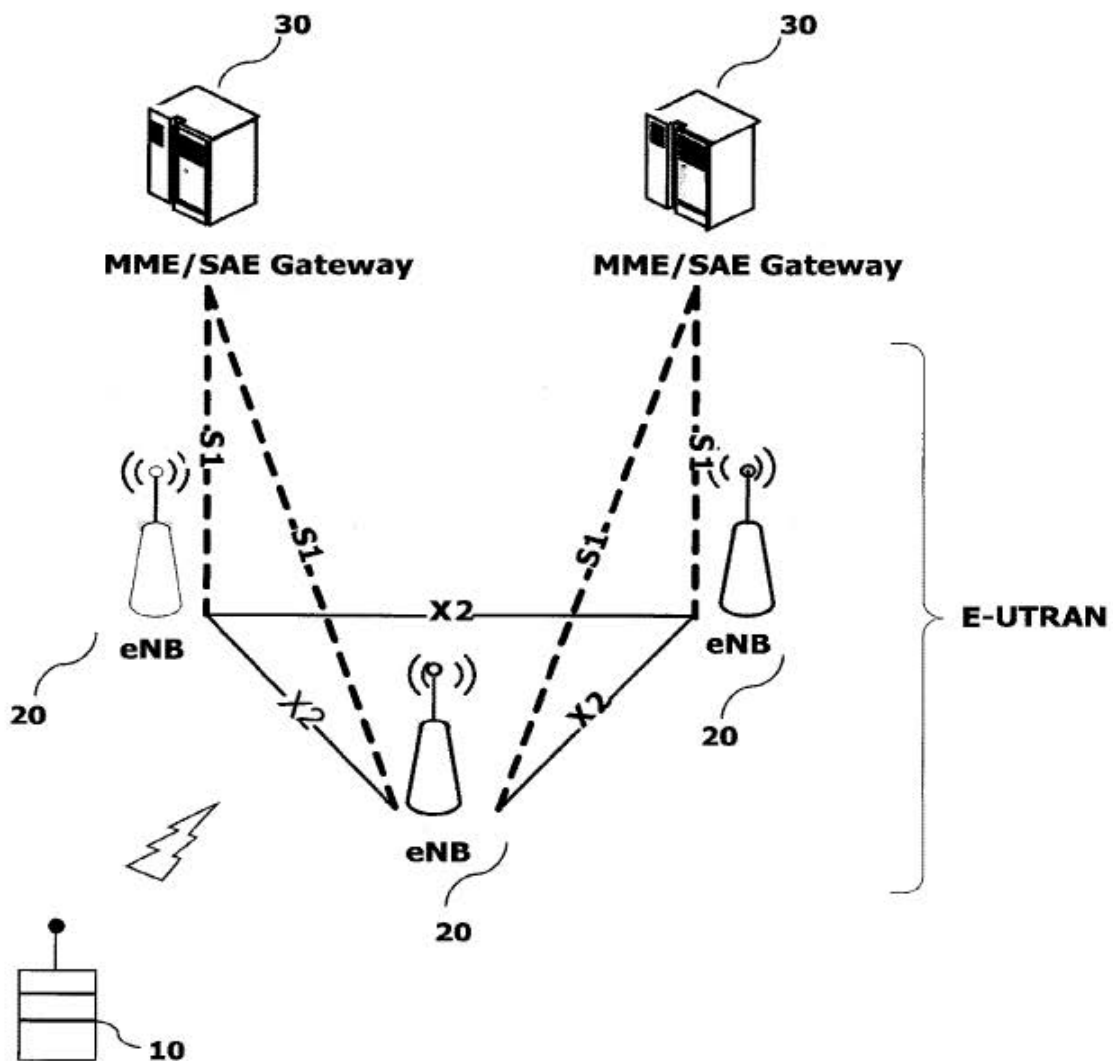
**[0037]** FIG. 3(b) illustrates the control-plane protocol stack for the E-UMTS

**[0038]** FIG. 4 illustrates a Structure of the physical channel.

**[0039]** FIG. 5 illustrates a Random Access procedure for E-UTRAN initial access.

**[0040]** FIG. 6 illustrates a block diagram of a mobile station (MS) or access terminal (AT) according to the present invention.

**Fig. 1**



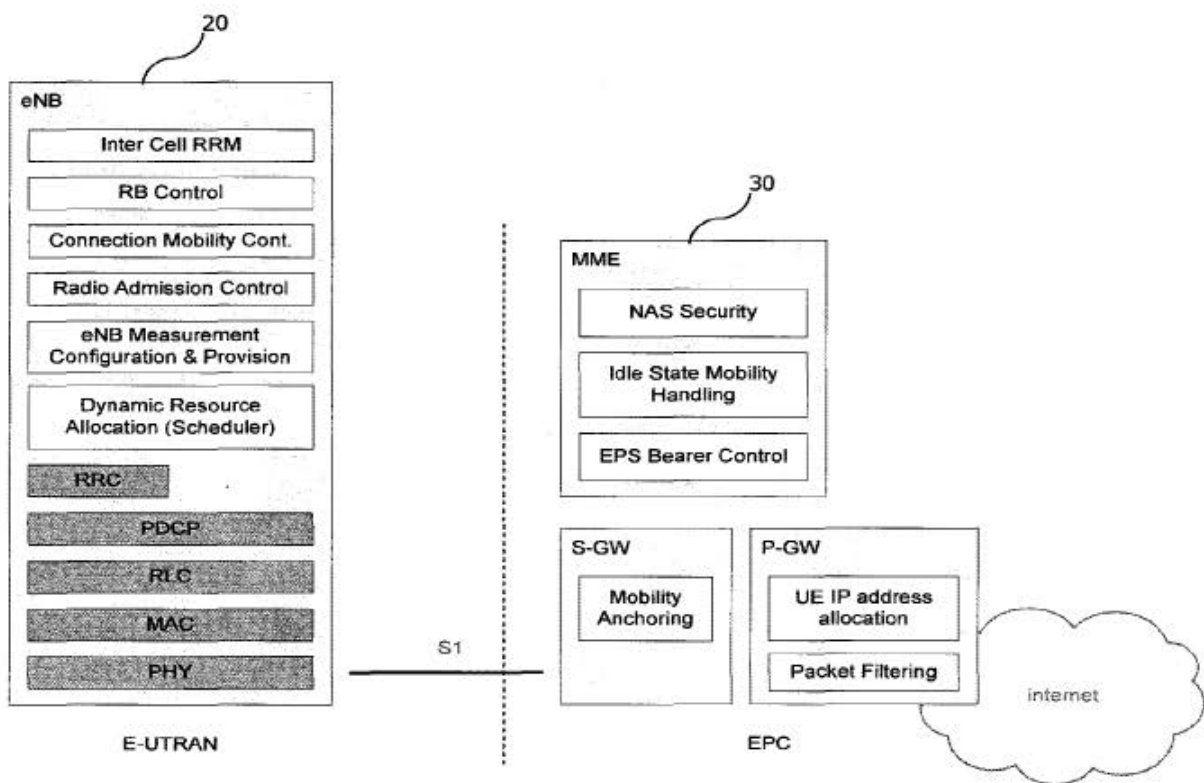


**Fig. 3(a)**

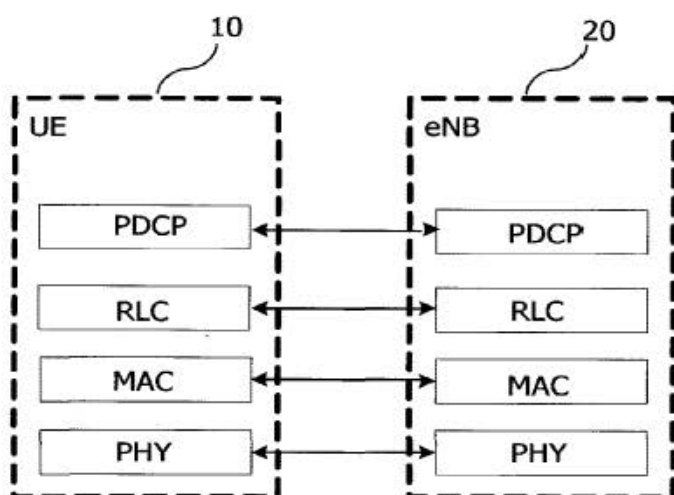


**Fig. 3(b)**

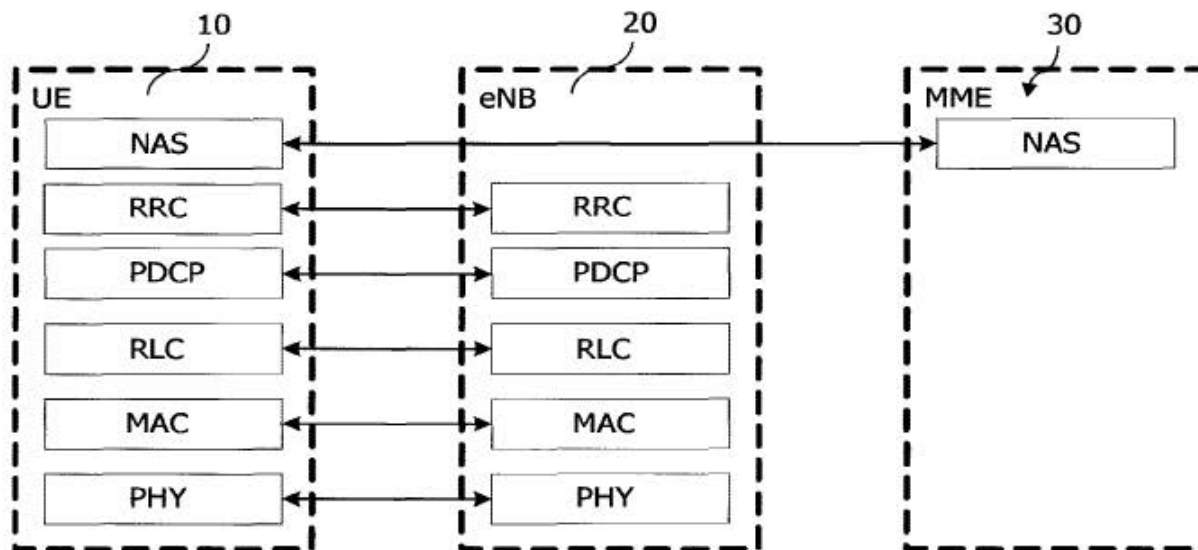


**Fig. 4**  
**Structure of the physical channel**

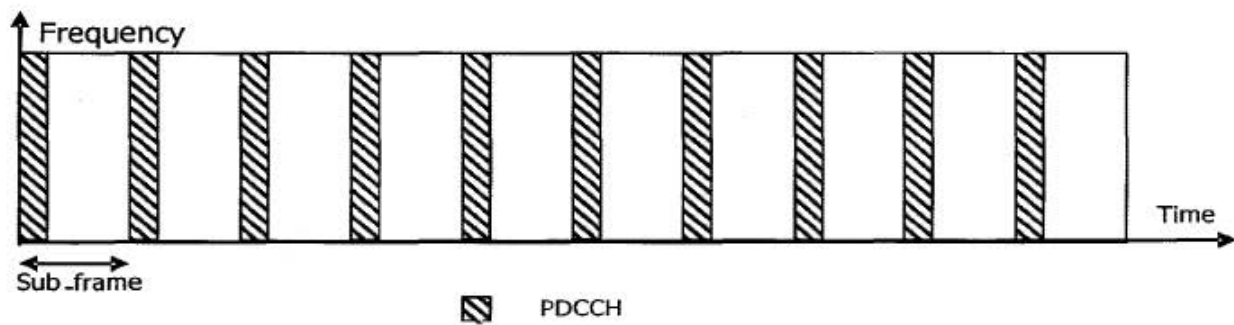


**Fig. 5**  
**Random Access procedure for E-UTRAN initial access**

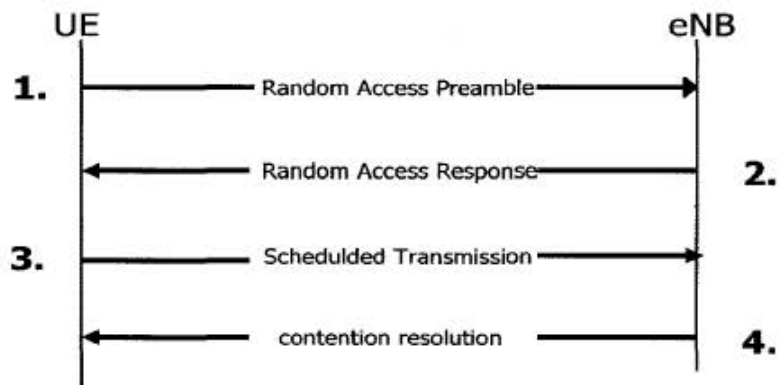
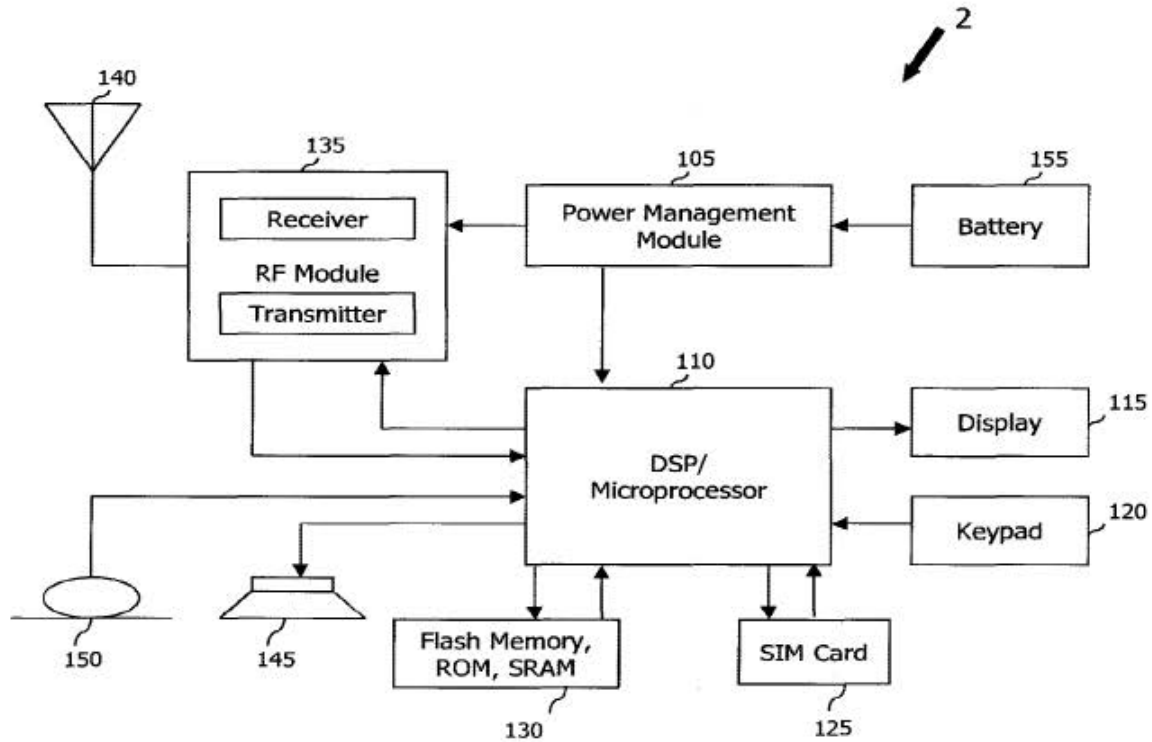


**Fig. 6**  
**MOBILE STATION/ACCESS TERMINAL**



| Electronic Acknowledgement Receipt   |                                                                   |
|--------------------------------------|-------------------------------------------------------------------|
| EFS ID:                              | 29111155                                                          |
| Application Number:                  | 62501048                                                          |
| International Application Number:    |                                                                   |
| Confirmation Number:                 | 8283                                                              |
| Title of Invention:                  | METHOD OF DATA SCHEDULING AND HARQ OPERATION FOR NEW RADIO SYSTEM |
| First Named Inventor/Applicant Name: | Suckchel YANG                                                     |
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| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Application Data Sheet         | UT17-0756_ADS.pdf | 1826390<br>2d725a8ef158324e65a85d2362f1aef39523ec1 | no               | 10               |
| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                |                   |                                                    |                  |                  |
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| <b>Warnings:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                |                   |                                                    |                  |                  |
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