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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
62/350,453	06/15/2016		260	0203-1928		

CONFIRMATION NO. 6069

FILING RECEIPT

68103

Jefferson IP Law, LLP
1130 Connecticut Ave., NW, Suite 420
Washington, DC 20036



Date Mailed: 06/23/2016

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

Inventor(s)

Byoungsoon JUNG, Seoul, KOREA, REPUBLIC OF;
Jungmin MOON, Suwon-si, KOREA, REPUBLIC OF;
Seunghoon PARK, Seoul, KOREA, REPUBLIC OF;
Anil AGIWAL, Suwon-si, KOREA, REPUBLIC OF;
Sunheui RYOO, Yongin-si, KOREA, REPUBLIC OF;
Jungsoo JUNG, Seongnam-si, KOREA, REPUBLIC OF;
Hyunseok RYU, Yongin-si, KOREA, REPUBLIC OF;
Hyunkyuu YU, Suwon-si, KOREA, REPUBLIC OF;

Applicant(s)

Samsung Electronics Co., Ltd., Suwon-si, KOREA, REPUBLIC OF;

Power of Attorney: The patent practitioners associated with Customer Number 68103

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: No

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

If Required, Foreign Filing License Granted: 06/22/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/350,453**

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

page 1 of 3

Non-Publication Request: No

Early Publication Request: No

Title

SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK
OPERATION IN A BEAM-FORMING BASED SYSTEM

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

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

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

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

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

LICENSE FOR FOREIGN FILING UNDER
Title 35, United States Code, Section 184
Title 37, Code of Federal Regulations, 5.11 & 5.15

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

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NOT GRANTED

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

SelectUSA

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

Provisional Application for Patent Cover Sheet

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

Inventor(s)

Inventor 1 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Byounghoon		JUNG	Seoul		KR

Inventor 2 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Jungmin		MOON	Suwon-si		KR

Inventor 3 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Seunghoon		PARK	Seoul		KR

Inventor 4 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Anil		AGIWAL	Suwon-si		KR

Inventor 5 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Sunheui		RYOO	Yongin-si		KR

Inventor 6 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Jungsoo		JUNG	Seongnam-si		KR

Inventor 7 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Hyunseok		RYU	Yongin-si		KR

Inventor 8 Remove

Given Name	Middle Name	Family Name	City	State	Country i
Hyunkyu		YU	Suwon-si		KR

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

Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM
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Attorney Docket Number (if applicable)	0203-1928
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Correspondence Address

Direct all correspondence to (select one):

☒ The address corresponding to Customer Number	☐ Firm or Individual Name
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Customer Number	68103
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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

Entity Status

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

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

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

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

Signature	/Ronald S. GRUBB/		Date (YYYY-MM-DD)	2016-06-15	
First Name	Ronald S.	Last Name	Grubb	Registration Number (If appropriate)	48672

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

Privacy Act Statement

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

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

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

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

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED 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	
	Byounghoon		JUNG		
Residence Information (Select One) US Residency ● Non US Residency Active US Military Service					
City	Seoul	Country of Residence ⁱ	KR		

Mailing Address of Inventor:

Address 1	No. 708-302, 22, Sumyeong-ro 2ga-gil, Gangseo-gu				
Address 2					
City	Seoul	State/Province			
Postal Code		Country ⁱ	KR		

Inventor	2				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Jungmin		MOON		
Residence Information (Select One) US Residency ● Non US Residency Active US Military Service					
City	Suwon-si	Country of Residence ⁱ	KR		

Mailing Address of Inventor:

Address 1	No. 205, 66, Yeongtong-ro 331beon-gil, Yeongtong-gu				
Address 2					
City	Suwon-si, Gyeonggi-do	State/Province			
Postal Code		Country ⁱ	KR		

Inventor	3				Remove
Legal Name					

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Seunghoon		PARK	
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service				
City	Seoul	Country of Residence ⁱ	KR	

Mailing Address of Inventor:

Address 1	No. 405-304, 50, Mapo-daero 11-gil, Mapo-gu			
Address 2				
City	Seoul	State/Province		
Postal Code		Country ⁱ	KR	
Inventor	4			Remove
Legal Name				

Prefix	Given Name	Middle Name	Family Name	Suffix
	Anil		AGIWAL	
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service				
City	Suwon-si	Country of Residence ⁱ	KR	

Mailing Address of Inventor:

Address 1	No. 104-1902, 363, Hyowon-ro, Yeongtong-gu			
Address 2				
City	Suwon-si, Gyeonggi-do	State/Province		
Postal Code		Country ⁱ	KR	
Inventor	5			Remove
Legal Name				

Prefix	Given Name	Middle Name	Family Name	Suffix
	Sunheui		RYOO	
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service				
City	Yongin-si	Country of Residence ⁱ	KR	

Mailing Address of Inventor:

Address 1	No. 604-1802, 14			
Address 2	Heungdeok 2-ro 117beon-gil, Giheung-gu			
City	Yongin-si, Gyeonggi-do	State/Province		
Postal Code		Country ⁱ	KR	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		

Inventor	6				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Jungsoo		JUNG		
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service					
City	Seongnam-si	Country of Residence ⁱ	KR		

Mailing Address of Inventor:

Address 1	No. 922-1002, 29, Seopangyo-ro, Bundang-gu				
Address 2					
City	Seongnam-si, Gyeonggi-do	State/Province			
Postal Code		Country ⁱ	KR		

Inventor	7				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Hyunseok		RYU		
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service					
City	Yongin-si	Country of Residence ⁱ	KR		

Mailing Address of Inventor:

Address 1	No. 501-1103, 37				
Address 2	Heungdeok 1-ro 79beon-gil, Giheung-gu				
City	Yongin-si, Gyeonggi-do	State/Province			
Postal Code		Country ⁱ	KR		

Inventor	8				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Hyunkyu		YU		
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service					
City	Suwon-si	Country of Residence ⁱ	KR		

Mailing Address of Inventor:

Address 1	No. 2304-1201, 23				
Address 2	Gwanggyohosu-ro 152beon-gil, Yeongtong-gu				

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928	
		Application Number		
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM			
City	Suwon-si, Gyeonggi-do		State/Province	
Postal Code		Country	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	68103		
Email Address	usdocketing@jeffersonip.com	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		
Attorney Docket Number	0203-1928	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Publication Information:

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

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.			
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	68103		

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED 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, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

Prior Application Status		Remove
Application Number	Continuity Type	Prior Application Number
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.		Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(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).

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

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

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

Authorization to Permit Access:

☒ Authorization to Permit Access to the Instant Application by the Participating Offices

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		

If 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 World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.		
Applicant	1	Remove
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.		
Clear		
☒ Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.		Person who shows sufficient proprietary interest
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:		

Name of the Deceased or Legally Incapacitated Inventor :		
If the Applicant is an Organization check here. ☒		
Organization Name	Samsung Electronics Co., Ltd.	
Mailing Address Information For Applicant:		
Address 1	129, Samsung-ro, Yeongtong-gu	
Address 2		
City	Suwon-si, Gyeonggi-do	State/Province
Country	KR	Postal Code
Phone Number		Fax Number

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		
Email Address			
Additional Applicant Data may be generated within this form by selecting the Add button.			Add

Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.				
Assignee	1			
Complete this section only if non-applicant assignee information is desired to be included on the patent application publication in accordance with 37 CFR 1.215(b). Do not include in this section 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), as the patent application publication will include the name of the applicant(s).				
				Remove
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	0203-1928
		Application Number	
Title of Invention	SYSTEM, METHOD, AND APPARATUS OF BEAM TRACKING AND BEAM FEEDBACK OPERATION IN A BEAM-FORMING BASED SYSTEM		

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Title of the Invention

System, Method, and Apparatus of Beam Tracking and Beam Feedback Operation in a Beam-forming based System

0. Summary of the Invention

In an eNB/UE system performing communication using an analogue beam (a beam with a fixed physical direction), an available beam may be changed. In order to track the changed beam and change a beam in use, a Medium Access Control (MAC) Layer operation is proposed.

Key points of the invention: a protocol and a method of feeding back measured beam information to other party, and a method of changing a beam used by both parties using the feedback.

- + Method of determining the need for beam change by UE
 - If the performance of a beam in use becomes low or a beam (another beam) which is better than the beam in use is observed, a beam measurement entity (UE) determines that a beam in use needs to be changed.
 - UE determines to transmit, to an eNB, feedback for requesting beam information and a corresponding determined detail
- + Beam feedback configuration of UE
 - Identification of beam to transmit information as feedback
 - If a reference signal containing a beam ID is received or a beam ID of the received signal is known:
 - ◆ Feedback containing a corresponding ID (legacy technology)
 - If a reference signal without a beam ID is received:
 - ◆ A corresponding beam receiving time, transmitted information regarding an eNB antenna port, which may be derived from a reception frequency location (or a corresponding frequency location) (due to presence of prior information), etc., are transmitted instead of a beam ID
 - ◆ The eNB saves a beam used for transmission, a transmission timing, and a port used for transmission, maps them with corresponding received feedback information, and selects a beam.

+ Beam feedback of UE

- Available uplink beam feedback
 - [Dedicated Feedback] Uplink beam feedback is used by a specified UE in such a way that an eNB allocates a specified resource operated based on scheduling, such as beam/time/frequency, to the UE
 - [UL Beam Sweep Feedback] Uplink beam feedback is used by UE in such a way that: an eNB sets a reception interval, sweeping available beams, and UE repeats transmission of the identical information, with respect to reception beams of eNBs that differ from each other in the set interval
 - ◆ Transmittable, despite beam change, without causing any problems
 - ◆ A specified resource in a corresponding interval may be scheduled to a specified UE
 - ◆ A corresponding interval may be used so that a number of unspecified UEs perform transmission freely (e.g., 3GPP LTE RACH)
- Beam feedback according to the present invention
 - The present invention provides various beam feedback methods using a combination of a Dedicated Feedback method and a UL Beam Sweep Feedback method
 - Embodiment 1: Basically, UE always uses Dedicated Feedback. When detecting that a beam in use needs to be changed, UE performs UL Beam Sweep Feedback.
 - Embodiment 2: Basically, UE uses Dedicated Feedback. In a state where UE recognizes that a beam in use needs to be changed, if the UE estimated that the performance of a legacy beam is low, it performs UL Beam Sweep Feedback
 - Etc. (refer to the following description)

1. Background of the Invention

A. Field of the Invention

The present invention designs: a beam feedback procedure that informs a beam using entity (eNB) of beam information observed and measured by a beam measuring entity (UE) in an environment and a wireless communication

system where UE and eNB using MIMO antennas coexist, or a system employs a beamforming, particularly, an analogue beamforming, without delay; and a method of continuously tracking beams using the beam feedback procedure.

B. Description of Related Art

1) Definition of issues and environment considered in the invention

- Beamforming technology and system (based on LTE)
 - ✧ Analogue beamforming:
 - ✓ Create a physical beam using a multiple array antenna
 - ✓ Only transmit/receive once in one direction
 - ✓ Using a number of antennas: increases the intensity of directivity to be higher and thus makes it possible to transmit signals to a further distance, under the same power condition; and forms a beam with a relatively large antenna gain (beam width/beam length difference, etc., according to the number of antennas)
 - ✓ Beam length is long; however, it supports only a narrow range (an angle of $10^{\circ} \sim 20^{\circ}$)
 - ✧ Digital beamforming:
 - ✓ A performance optimization technology using multiple channels between antennas with different levels of intensity in a multiple antenna transmission/reception environment
 - ✓ Applying a pre-coding scheme to data to be transmitted to individual antennas and thus using different channel characteristics as much as possible
 - ✓ Single-user MIMO and Multi-user MIMO can be supported
 - ✧ Uplink: transmission from a station to a base station:
 - ✓ Basically, transmission is performed via a resource that is allocated and reserved by an eNB (base station)
 - ✓ UE which needs to perform uplink transmission transmits a request for a resource that an eNB has allocated, i.e., scheduling request (SR), and is allocated the resource for uplink transmission.

More specifically, UE: transmits SR; then transmits a buffer status report (BSR) via a resource which has been allocated by the eNB; notifies the eNB of the use of uplink data; is allocated a resource; and performs uplink transmission. The UE performs transmission, via contention with another UE or via contention-based random access channel (RACH)

- Problems in legacy technology
 - ✧ When an analogue beamforming is used in an existing system where an eNB needs to pre-reserve a resource for uplink transmission, the resource cannot be used due to a change in the beam direction between timings where the resource is reserved and used.
 - ✓ In a system using a number of analogue beams for transmission/reception, a UE and an eNB select a specified beam which can be estimated to have high performance and perform the transmission/reception of information via the selected beam.
 - ✓ In this case, the eNB pre-reserves a resource for uplink transmission by UE, to use the best beam or a beam with the lowest number of problem that the eNB has known about at the pre-reservation time.
 - ✓ However, a reserved beam resource may experience a change in channel due to movement of UE or other variables (e.g., an obstacle that abruptly appears, such as, a car, etc., weather change, etc.).
 - ✓ When feedback transmission of uplink beam information fails due to change in channel of a reserved beam resource, a legacy technology has not resolved the problem immediately.
 - ✓ These problems appear on general uplink transmission as well as beam feedback.
 - ✓ A beam management technique is needed that exchanges beam state information between a UE and an eNB, tracks a change of a beam rapidly, and applies the beam to the transmission.

- ✧ Types of methods coping with the state degradation of a channel in use are limited
 - ✓ In the case of the legacy technology (a system using an omni-antenna, a system using a digital beamforming, etc.), the state of a channel that has been used may be low quality. In order to resolve this problem, the low quality channel is changed to another channel of another frequency. Alternatively, if a radio link failure (RLF) condition is satisfied, the legacy technology needs to declare the failure and then attempt to re-connect to the network.
 - ✓ However, in the case of a system using an analogue beamforming, although the channel state of a beam that the system has used becomes low quality, the probability that another available beam will exist at the same location is high. In this case, the system may maintain the connectivity via the available beam.

2) Background Art

In the case of the legacy technology (a system using an omni-antenna, a system using a digital beamforming, etc.), the state of a channel that has been used may be low quality. In order to resolve this problem, the low quality channel is changed to another channel of another frequency. Alternatively, if a radio link failure (RLF) condition is satisfied, the legacy technology needs to declare the failure and then attempt to re-connect to the network.

However, in the case of a system using an analogue beamforming, although the channel state of a beam that the system has used becomes low quality, the probability that another available beam will exist at the same location is high. In this case, the system may maintain the connectivity via the available beam.

- Problems of the background art
 - ✧ Methods of feeding back beam/channel information and of measuring beam/channel in a digital beamforming system, e.g., an legacy LTE, etc.:

- ✓ UE receives a specified signal transmitted from an eNB and detects the channel quality (e.g., reference signal, etc.)
 - ✓ UE processes and packages the channel quality into feedback information (e.g., CQI, RI, PMI, etc.)
 - ✓ UE transmits feedback (e.g., PUCCH, PUSCH, etc.) via a resource allocated by the eNB
 - ✓ UE: transmits an uplink transmission request (or a request for allocating a resource for uplink transmission) to an eNB; is allocated a resource; and transmits feedback.
- ◇ Methods of measuring beam/channel and of feeding back beam/channel information in a system using an analogue beamforming; and a problem that will occur if using a legacy technology:
- ✓ *When the performance of an analogue beam used by UE/eNB becomes low, the UE/eNB cannot receive signals from the other party via the analogue beam.*
 - ✓ *UE/eNB needs to measure a beam and inform the other party of information regarding an alternative/candidate beam → Random access and wide beam using method are proposed.*
 - ✓ UE receives a specified signal transmitted from an eNB and detects the channel quality (e.g., reference signal, etc.)
 - ✓ UE processes and packages information regarding a desired beam and the channel quality of the beam into feedback information (e.g., Beam ID, CQI, RI, PMI, etc.)
 - ✓ UE transmits feedback (e.g., PUCCH, PUSCH, etc.) via a resource allocated by the eNB
 - ✓ UE: transmits an uplink transmission request (or a request for allocating a resource for uplink transmission) to an eNB; is allocated a resource; and transmits feedback.

2) Objective of the invention

The present invention designs: a beam feedback procedure that informs an eNB of beam information observed and measured by UE in an environment and a wireless communication system where UE and eNB using MIMO antennas coexist, or a system employs a beamforming, particularly, an analogue beamforming, without delay; and a method of continuously tracking beams using the beam feedback procedure.

2. Detailed description of the invention

A. Configuration of the invention

The present invention designs: a beam feedback procedure that informs an eNB of beam information observed and measured by UE in an environment and a wireless communication system where UE and eNB using MIMO antennas coexist, or a system employs a beamforming, particularly, an analogue beamforming, without delay; and a method of continuously tracking beams using the beam feedback procedure.

The system is configured as shown in Fig. 1.

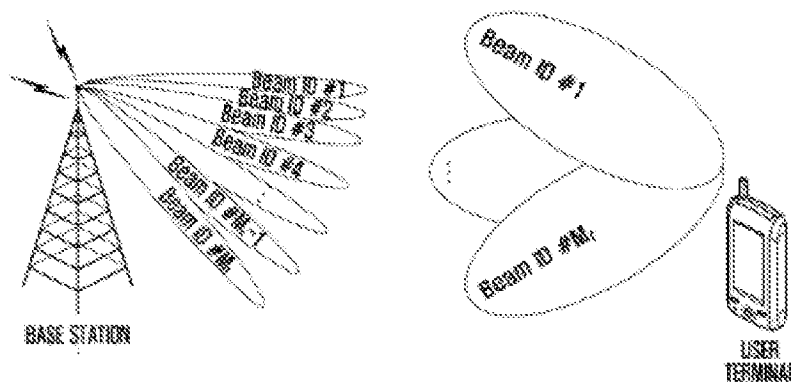


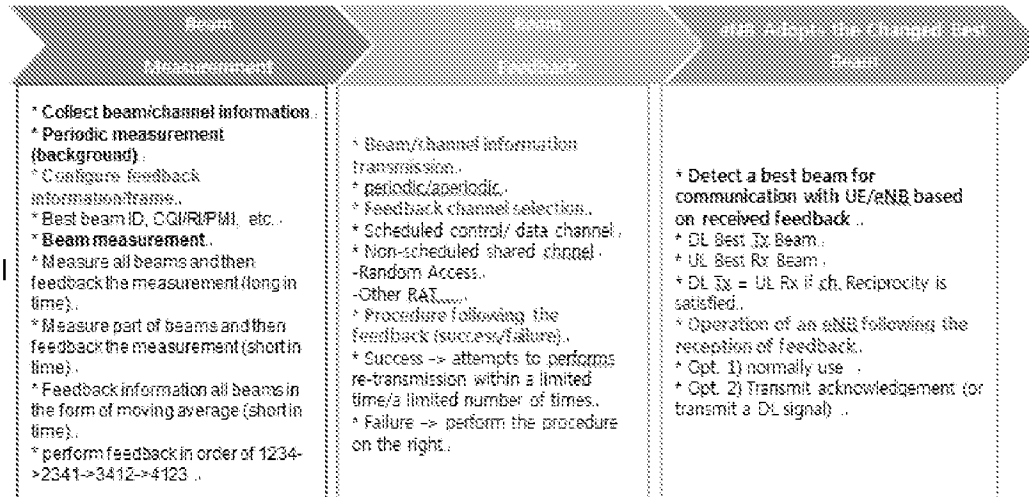
Fig. 1 shows a diagram showing the configuration of the system.

With reference to Fig. 1, the system includes UE and an eNB forming analogue beams in various directions. The analogue beam used by an eNB and UE may be formed by a number of small antenna arrays. The analogue beam performs wireless transmission/reception in one direction, using one antenna array group once. When one or more antenna array groups which may be simultaneously operated are included, the analogue beam may perform wireless transmission/reception in one or more directions once.

The present invention provides an environment where: an eNB and UE each use one beam and perform one transmission/reception, using a pair of beams, once.

A detailed description is explained as follows.

1) Basic beam management and beam tracking procedure



In an analogue beamforming system, an eNB and UE need to detect a channel state of a transmission/reception beam in real time, and to maintain and change a beam tracking and using the channel state. To this end, the following operations are needed.

A. Beam Measurement

- Beam measurement is performed to measure channels of beam pairs created by a combination of beams between UE and neighboring eNB
- Beam measurement may be periodically or aperiodically performed by UE or eNB
- The present invention are not limited by types of beam measurement methods, assuming an environment where UE or eNB may measure channel states of each other's beam pairs

B. Beam feedback

- Beam feedback is an operation that UE informs an eNB of its measuring beam information
- Since a transmission node, i.e., an eNB (or UE), does not know downlink (or uplink) beam information, UE (or eNB) needs to perform feedback
- Beam information feedback may be periodically or aperiodically performed
- UE or eNB may perform beam information feedback to each other
- The present invention is described in such a way that UE transmits its measuring beam information to an eNB. However, it should be understood that the present invention is not limited to beam feedback performed by UE. The present invention may also be modified in such a way that an eNB transmits its measuring beam information to UE.
- The beam feedback method according to the present invention is described in detail below.

C. Applying information related to beam change

- eNB (or UE) is capable of determining a beam pair to be used later, based on received beam feedback information
- eNB (or UE) is capable of performing a number of operations to use the determined beam pair
 - i. Feedback transmission/reception node uses a new (change) beam immediately, without any response
 - ii. Feedback reception node performs the transmission of a message (ctrl msg, data msg, ...) as a response
 - 1. Feedback transmission node receives a response message and then starts to use a beam pair contained in a corresponding message

2) Identification of available beam feedback methods

A. Identification of feedback method according to feedback cycles

- Periodic feedback
 1. When a resource allocable entity (eNB) allocates a resource at every time period, a measurement entity (UE) transmits feedback via the allocated resource.
 2. When resources are not periodically allocated, a measurement entity (UE) requests the periodic allocation of resources, and transmits feedback
- Aperiodic feedback
 1. When a resource allocable entity (eNB) determines to receive feedback, based on a timing and a criterion, and allocates a resource, a measurement entity (UE) transmits feedback via the allocated resource
 2. A measurement entity (UE) determines to transmit feedback, based on a timing and a criterion, request the allocation of a resource, and transmits feedback

B. Identification according to feedback methods

- **Dedicated feedback**
 1. Using eNB designated resource and beam
 - Using periodic feedback resource allocated by eNB
 - Using periodic Scheduling Request (SR) resource allocated by eNB
 - i. UE notifies: an eNB of an amount of feedback data in such a way as to transmit an SR and a buffer status report (BSR) to resources allocated by the eNB; is allocated resources; and performs the transmission of feedback
 2. Channel : Uplink control/ data channel (PUCCH/PUSCH)
(Consideration Needed: # of users, CH capacity, method of including CQI/ RI/ PMI)
 3. Scheduled using 'the current best beam' at the scheduling time
- **UL Beam Sweep Feedback**

Uplink beam feedback used in such a way that: eNB sets a reception

interval, sweeping available beams, and in a set interval, UE repeats transmission of the identical information to reception beams of eNBs that differ from each other.

1. Transmittable, despite beam change, without causing any problems
2. A specified resource in a corresponding interval may be scheduled to a specified UE
3. A corresponding interval may be used so that a number of unspecified UEs perform transmission freely (e.g., 3GPP LTE RACH)

4. **Contention-free RACH**

- Transmission of beam feedback, based on content-free-based random access
- UE transmits a preset preamble → eNB performs the reception, sweeping an analog beam
- Using pre-determined (eNB designated UE specific) preamble sequence
(Consideration Needed : # of users, # of preamble sequences)
 - i. Opt. 1) One dedicated sequence per UE (acquire when initial entry),
 - ii. Opt. 2) eNB allocate sequence to active (connected) UEs only. (no contention-free RACH for idle UEs)
- eNB is able to receive this RACH regardless of best eNB beam, using eNB beam sweep
- UE transmits this contention-free RACH, using the known best UE beam

5. **Contention-based RACH**

- Transmission of beam feedback, based on contention-based random access
- UE selects and transmits a preamble → eNB performs the

reception, sweeping an analog beam

- eNB is able to receive this RACH regardless of best eNB beam, using eNB beam sweep
- UE transmits this contention-free RACH, using the known best UE beam

3) A detailed description regarding beam feedback and beam-tracking procedure according to the present invention

[Base Line Operation & Main Idea]

State: UE/eNB performs wireless communication for transmission/reception using a specified analogue beam

Assumption: Downlink beam measurement is only performed due channel reciprocity

(eNB may detect a beam to be used, via only feedback of UE)

Operations:

1. UE periodically perform beam measurement to select a communicable beam or a best beam (downlink)
2. UE ascertains that a serving beam has not been, based on the beam measurement result, and continues to perform communication using the same beam.

Condition: (Current beam measurement > Threshold) and (Another beam < current beam + Threshold)

3. Degradation of communication performance while UE is used or beam measurement result

Condition: (Current beam measurement < Threshold) or (Another beam > current beam + Threshold)

A. Attempt to detect new best beam based on UE beam measurement

I. When no new best beam is in the identical eNB

1. Radio Link Failure (RLF) procedure

A. Attempt to re-connect to identical/neighboring eNB until RLF condition is satisfied

B. Declare RLF and attempt to re-connect to

identical/neighboring eNB if RLF condition is satisfied

- ii. (Another beam $>$ current beam + Threshold) if a new best beam is in the identical eNB
4. (The idea of the present invention if the condition, item 3.A.ii., is satisfied)
- A. When an existing best beam can be continuously used, despite the change of a best beam
(condition: (another beam $>$ current beam + Threshold) and (current beam measurement $>$ Threshold))
 - i. When a pre-allocated uplink feedback resource has existed and UE has known about the resource, the UE feeds back a condition as to whether a beam is changed, using the resource
 - ii. When a pre-allocated uplink feedback resource has not existed, the UE feeds back a condition as to whether a beam is changed, using one of the following methods
 - B. When UE does not have a resource to transmit feedback to an eNB, despite the use of an existing best beam, or cannot use the existing best beam,
 - i. State: UE has known both a previous beam and a new best beam, and an eNB has known about only a previous beam
 - ii. State: eNB does not know about a beam to receive information from corresponding UE
 - 1. Method for UE to perform transmission of feedback in an interval where an eNB perform reception by sweeping different beams (eNB beam sweeping reception interval)
 - When eNB sets an interval receiving information, sequentially or by sweeping a reception beam using another resource, shares the interval information with UE, UE feeds back information regarding the changed best beam to the eNB, using the interval
 - A. eNB allocates each UE a specified resource of a beam

sweeping reception interval, and receives feedback from the UE

- i. eNB sets resources to receive using beams that differ from each other, allocates part of the resources to a specified UE, and notifies the UE of the allocated resource
- ii. Method of notifying UE of the resource allocation
 1. When UE initially connects to a network, the resource is periodically allocated (persistent),
 2. When a best beam is not changed between UE and eNB, a resource which can be used later is previously allocated to a best beam (semi-persistent)
 3. Since UE whose beam is changed does not know about an eNB beam that it can hear, eNB periodically performs the notification for the UE, using all beams (which causes resource waste)
- iii. Resources corresponding to the number of eNB antennas need to be allocated to each UE; however, not all UEs always use corresponding resources. Therefore, the larger the number of UEs and the number of antennas, the more the overhead and the amount of resource waste.
- iv. Resources allocated to each UE are allocated to all (or part) of eNB's reception beams; however, the number of beams which are actually available is relatively small. Therefore, feedback transmitted via another resource causes resource waste.
- v. The method for eNB to allocate each UE a specified resource of a beam sweeping reception interval and to receive feedback from the UE may cause large resource waste.

- B. eNB does not allocate each UE a specified resource of a beam sweeping reception interval, and UEs receives feedback via random access
 - i. eNB sets resources to receive using beams that differ from each other, and makes a notification so that UEs to use can transmit information via a random access protocol, without allocating a corresponding resource to a specified UE (an existing LTE RACH procedure)
 - ii. Since an eNB may not allocate each UE a specified resource of a beam sweeping reception interval, an amount of resource waste may be relatively small.
- 2. Method for eNB to receive feedback from UEs using a wide/omni beam, instead of a directivity beam
 - A. eNB allocates each UE a specified resource of a reception interval, using a wide/omni beam, and receives feedback via the resource
 - i. eNB sets resources to receive using a wide/omni beam, allocates part of the resources to a specified UE, and notifies the UE of the allocated resource
 - ii. Method of notifying UE of the resource allocation
 - 1. When UE initially connects to a network, the resource is periodically allocated (persistent),
 - 2. When a best beam is not changed between UE and eNB, a resource which can be used later is previously allocated to a best beam (semi-persistent)
 - 3. Since UE whose beam is changed does not know about an eNB beam that it can hear, eNB periodically performs the notification for the UE, using a wide/omni beam (which causes

resource waste)

- iii. Resources need to be allocated to each UE; however, not all UEs always use corresponding resources. Therefore, the larger the number of UEs, the more the overhead and the amount of resource waste.
- iv. The method for eNB to allocate each UE a specified resource of a reception interval using a wide/omni beam and to receive feedback from the UE may cause large resource waste.

B. eNB does not allocate each UE a specified resource of a reception interval using a wide/omni beam, and UEs receives feedback, via random access, in a reception interval, using a wide/omni beam of the eNB.

4) Operations and procedures according to embodiments of the present invention are explained in detail.

In the following embodiments, the term 'user equipment (UE)' is referred to as a beam measurement entity performing beam measurement. The term 'evolved Node B (eNB)' is referred to as a beam using entity configured to: transmit a reference signal for beam measurement; allocate a resource to a beam measurement entity; and use the measurement beam information fed back by the beam measurement entity.

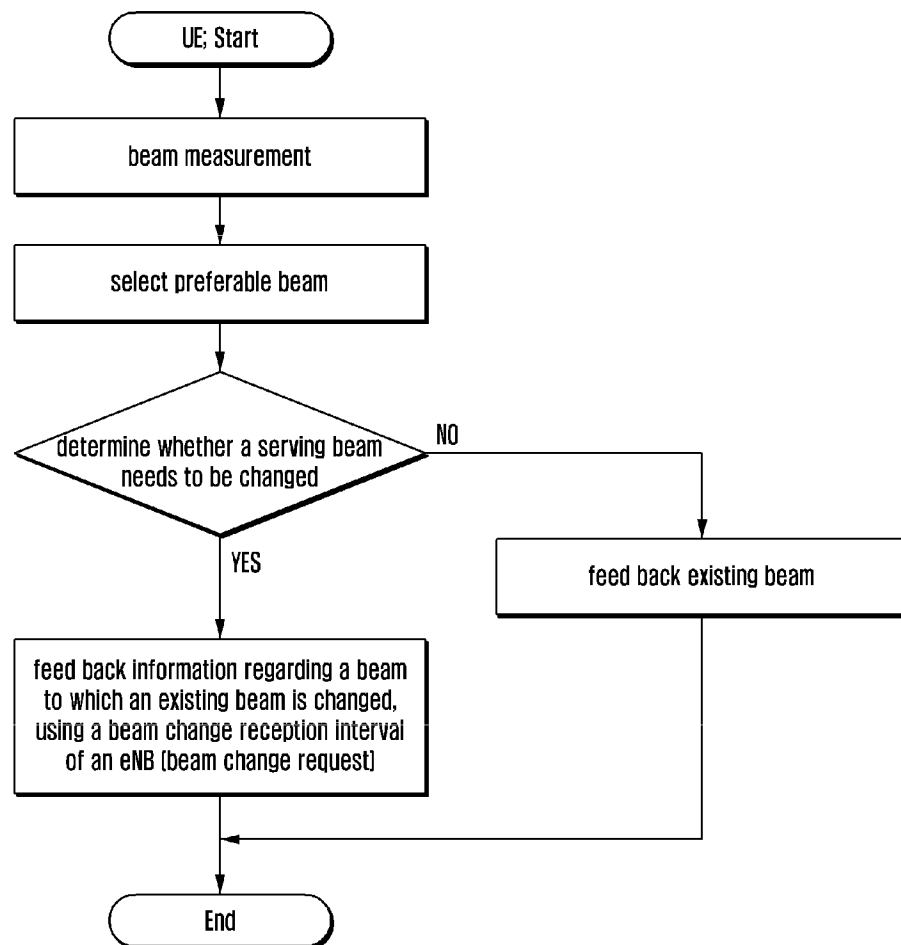
In the following embodiments, if one beam of a beam measurement entity and one beam of a beam using entity, which may be estimated to have the best performance, are determined from among the analogue beams that a beam measurement entity and a beam using entity can use, the two beams of the two entities form one beam pair, which is called 'best beam.'

The beam measurement entity may notify all beam using entities of information regarding the best beam pair as feedback. Alternatively, the beam measurement entity may notify a corresponding beam measurement entity of information regarding only one beam that a beam using entity will

use (e.g., UE may notify a corresponding UE of information regarding only one beam of an eNB, which will be used if the eNB transmits/receives information to the corresponding UE).

A. Operations of UE

- **[Operation 1: Feedback using an eNB beam change reception interval if beam change is needed]**



-
- Beam measurement method and preferable beam selection method are not objects that the present invention are claiming
- Assuming that one beam pair or N beam pairs from among a total number of avail beam pairs is/are selected as UE preferable beam pair,
- Conditions to determine whether a serving beam pair (hereafter called

a beam pair) needs to be changed

1. When the performance of a serving beam (a beam current in use) is less than a specified threshold
(current beam < Threshold)
 2. The performance of a new beam is greater than or equal to a sum of the performance of a current serving beam and a specified threshold
(new beam > current beam + Threshold)
 3. When a current serving beam fails in transmitting, over a preset number of attempts, within a preset period of time
 4. The 'performance of a beam' may be a numeral value to determine whether communication performed via a beam succeeds or fails, e.g., RSSI, CQI, RSRP, RSRQ, SNR, SINR, etc.
- Feedback of an existing beam (current serving beam information)
1. Feedback of the performance of a current serving beam
 2. Information related to beam change is not needed
 3. The 'performance of a beam' may be a numeral value to determine whether communication performed via a beam succeeds or fails, e.g., RSSI, CQI, RSRP, RSRQ, SNR, SINR, etc.
 4. [When Dedicated Feedback is used] corresponding feedback may be a resource that an eNB dedicatedly allocated to a specified UE
 - Allocation information:
 - i. Information regarding allocated frequency (sub-carrier, resource block location information)
 - ii. Information regarding allocated time (sub-frame, symbol location)
 - iii. Information to which the allocated frequency and time is mapped and that UE may previously detect and share
- Method of feeding back a beam to be changed using an eNB beam change reception interval (beam change request method)
1. [When UL Beam Sweep Feedback is used] When an interval

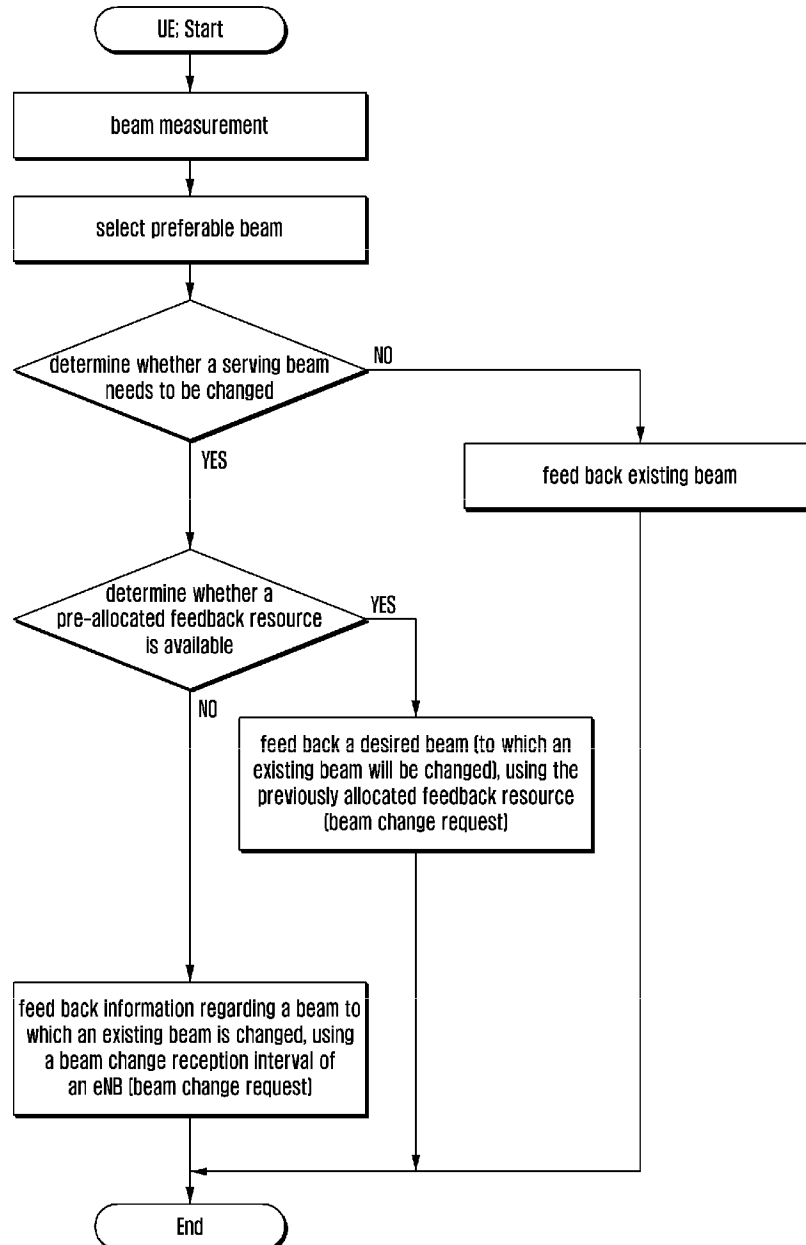
where an eNB performs reception by sweeping a reception beam is allocated, uplink beam feedback may be successfully transmitted, using a corresponding interval, despite the change of a beam.

- A corresponding eNB beam change reception interval may be an interval that is allocated for specified UE and in which only the specified UE or a group including the UE can perform transmission.
- A corresponding eNB beam change reception interval may be an interval that is allocated for a number of unspecified UEs and in which the unspecified UEs can perform transmission
 - i. e.g., RACH
- Information regarding a corresponding eNB beam change reception interval may be contained in information regarding a network (e.g., MIB, SIB, etc.) that an eNB notifies via a broadcasting channel or information regarding a network (dl scheduling information) that an eNB unicasts to each UE using a downlink control channel (PDCCH).
- UE detects information regarding the eNB beam change reception interval, and transmits beam feedback which includes a beam change request for changing a serving beam (which may explicitly include a bit or array or which may implicitly recognize the transmission of a corresponding request as a beam change request) using a corresponding interval.
- An eNB may receive UE's feedback information regarding a beam to be changed and a beam that has been used, using the eNB beam change reception interval.
- When there is no beam feedback and beam change request method using a beam change reception interval of an eNB, although a new beam capable of performing communication exists, UE, which can no longer use a beam that it has used, does not use the new beam. Therefore, the UE needs to wait

until a radio link failure (RLF) condition is satisfied, and then perform an initial access procedure where it newly connects to a network.

- i. In an extremely high frequency band with strong directivity, such as, mmWave, etc., a radio link may have various obstacles due to a passing vehicle, user's movement, etc., and may experience frequent beam change within a relatively short period of time (e.g., less than 50 ms).
- ii. In a state where UE has changed its location slightly and has another beam pair available for communication with a corresponding eNB (or a connected eNB), if the UE performs the determination of radio link failure to an existing network and the re-connection thereto, it may cause a waste of time.
- iii. Therefore, the present invention provides a method that stably and rapidly transmits a beam change request according to the beam change and the beam quality measurement earlier than an existing radio link failure, using a beam change reception interval of an eNB.

[Operation 2: Feedback after determining whether a pre-allocated feedback resource is available, despite the need of beam change]



- The operation of corresponding UE describes that: if UE that needs to change its current beam is exclusively allocated an uplink feedback resource for corresponding UE by an eNB via a beam that the eNB has known about, UE further determines whether it transmits beam

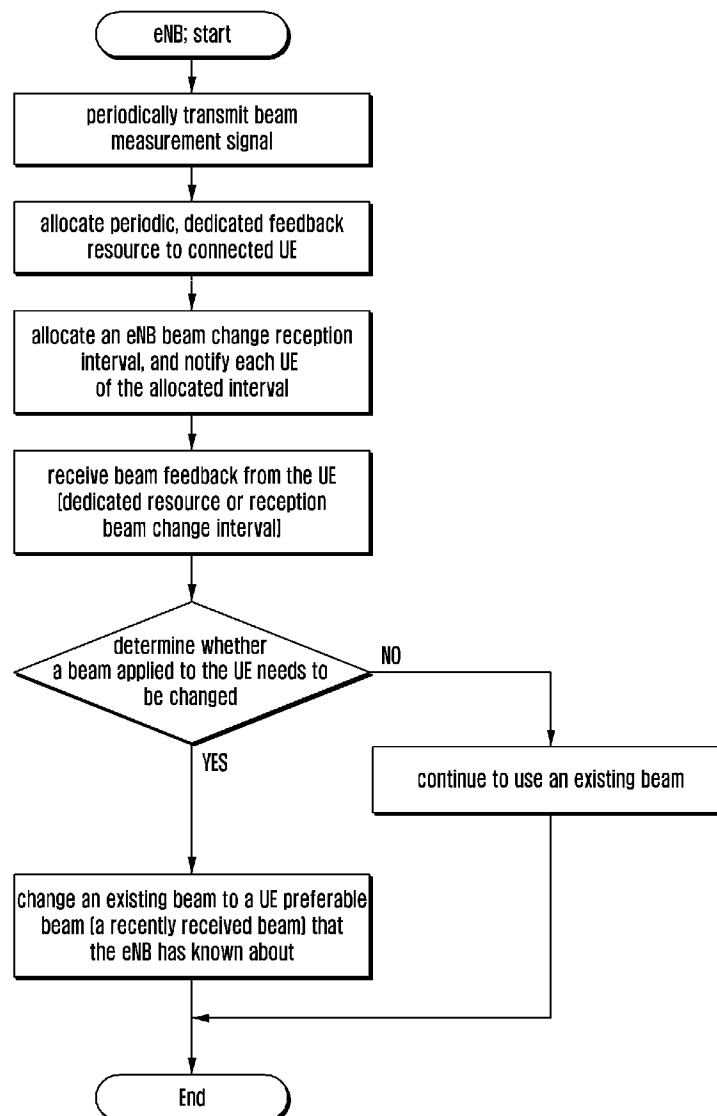
feedback that has used a corresponding resource.

- Conditions to determine whether a pre-allocated feedback resource is available
 1. The performance of a serving beam > threshold
 2. When a certain number of times of successive transmission is successful within a specified period of time right before using a serving beam
 3. The 'performance of a beam' may be a numeral value to determine whether communication performed via a beam succeeds or fails, e.g., RSSI, CQI, RSRP, RSRQ, SNR, SINR, etc.
- Method of feeding back a beam to be changed using an eNB beam change reception interval (beam change request method)
 1. [When UL Beam Sweep Feedback is used] When an interval where an eNB performs reception by sweeping a reception beam is allocated, uplink beam feedback may be successfully transmitted, using a corresponding interval, despite the change of a beam.
 - A corresponding eNB beam change reception interval may be an interval that is allocated for specified UE and in which only the specified UE or a group including the UE can perform transmission.
 - A corresponding eNB beam change reception interval may be an interval that is allocated for a number of unspecified UEs and in which the unspecified UEs can perform transmission
 - i. e.g., RACH
 - Information regarding a corresponding eNB beam change reception interval may be contained in information regarding a network (e.g., MIB, SIB, etc.) that an eNB notifies via a broadcasting channel or information regarding a network (dl scheduling information) that an eNB unicasts to each UE using a downlink control channel (PDCCH).
 - UE detects information regarding the eNB beam change

reception interval, and transmits beam feedback which includes a beam change request for changing a serving beam (which may explicitly include a bit or array or which may implicitly recognize the transmission of a corresponding request as a beam change request) using a corresponding interval.

- An eNB may receive UE's feedback information regarding a beam to be changed and a beam that has been used, using the eNB beam change reception interval.
- When there is no beam feedback and beam change request method using a beam change reception interval of an eNB, although a new beam capable of performing communication exists, UE, which can no longer use a beam that it has used, does not use the new beam. Therefore, the UE needs to wait until a radio link failure (RLF) condition is satisfied, and then perform an initial access procedure where it newly connects to a network.
 - i. In an extremely high frequency band with strong directivity, such as, mmWave, etc., a radio link may have various obstacles due to a passing vehicle, user's movement, etc., and may experience frequent beam change within a relatively short period of time (e.g., less than 50 ms).
 - ii. In a state where UE has changed its location slightly and has another beam pair available for communication with a corresponding eNB (or a connected eNB), if the UE performs the determination of radio link failure to an existing network and the re-connection thereto, it may cause a waste of time.
 - iii. Therefore, the present invention provides a method that stably and rapidly transmits a beam change request according to the beam change and the beam quality measurement earlier than an existing radio link failure, using a beam change reception interval of an eNB.

Operations of eNB



- eNB periodically allocates a dedicated feedback resource to connected UE
- eNB allocates and notifies an interval where it performs reception by sweeping a reception beam (UL Beam Sweep Feedback period)
 1. Corresponding information may be configured as follows:
 - A scheduling signal including one or more of the following: an eNB beam change reception interval frequency (frequency, sub-frame number, resource block number, channel number, etc.), time (time, frame number, sub-frame number, after a slot/sub-frame/frame/a period of time right after transmitting a

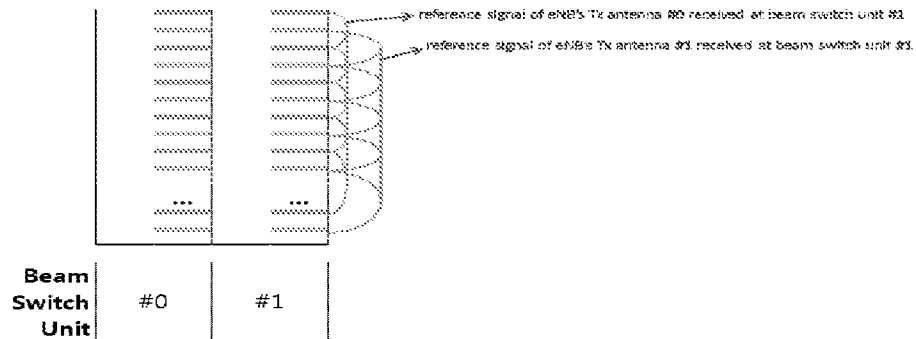
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corresponding notification, etc.), and beam resource information.

2. Method of notifying corresponding information may be implemented as follows.

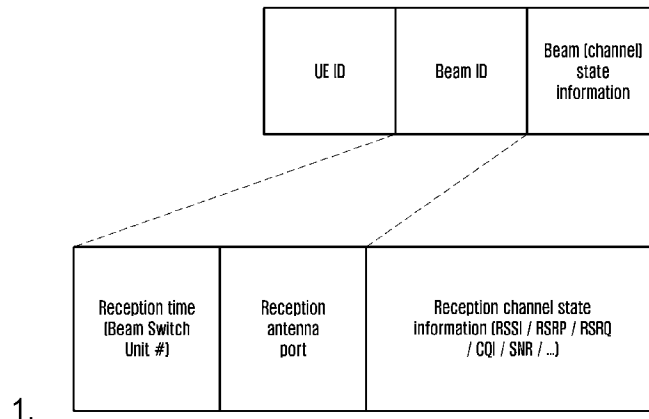
- Since the information is described on the standard, UE and eNB know that the information exists at a specified frame location. Therefore, a particular notification signal does not need to be transmitted.
 - The information is included in a broadcasting message (BCH, MIB, SIB, ...)
 - The information is included in a unicast message transmitted to specified UE (PDCCH, PDSCH)
- eNB receives feedback from each UE via a periodic dedicated feedback resource or a reception beam change reception interval
 - When a corresponding feedback does not include a request for changing an existing serving beam of UE, the eNB continues to use the existing beam. When a corresponding feedback includes a request for changing an existing serving beam of UE, the eNB changes the existing beam to a corresponding beam as a serving beam.

B. Procedure for creating beam feedback frames, using a reception time, a reception location, a reception antenna port, etc. of a beam measurement reference signal received by UE



- *UE obtains a reception location of each beam measurement reference signal as follows.*
 1. When a pre-determined pattern/protocol is described in the standard
 2. When an eNB informs UE of patterns to transmit beam measurement reference signal of different ports, via any other resource (e.g., transmission using BCH, MIB, SIB, etc.)
 - Transmission information may contain the following content:
 - i. The number of corresponding eNB's transmitting antennas (x) → transmission is repeated every x in a sub-carrier, and a beam measurement reference signal will be transmitted.
(e.g., x = 2, and this means that information regarding the same port is repeatedly transmitted every two sub-carriers. When a reference is, however, identical: reference = from the top, the bottom and the middle of an eNB's using frequency band, etc.)
 - ii. Correct transmission locations according to ports may be included → mod (x,2), etc.
- UE is capable of transmitting feedback that does not include an

explicit beam ID

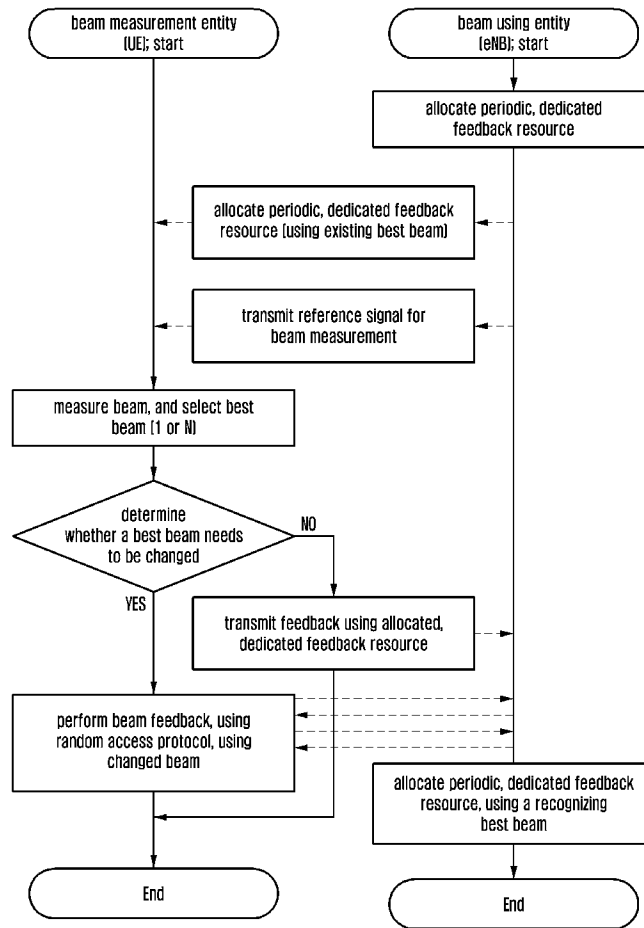


5) Embodiments including operations and transmission information between UE and eNB:

In the following embodiments, the random access feedback method does not need to employ random access methods used in other standards, such as, 3GPP LTE. The beam feedback method is referred to as a method of transmitting feedback using an interval in which the eNB performs reception, sweeping a beam.

A. Procedure employing a combination of a periodic dedicated feedback method and an aperiodic random access feedback method

- **[Embodiment A-1]** Procedure using random access feedback when a best beam measured by UE is changed from an existing best beam



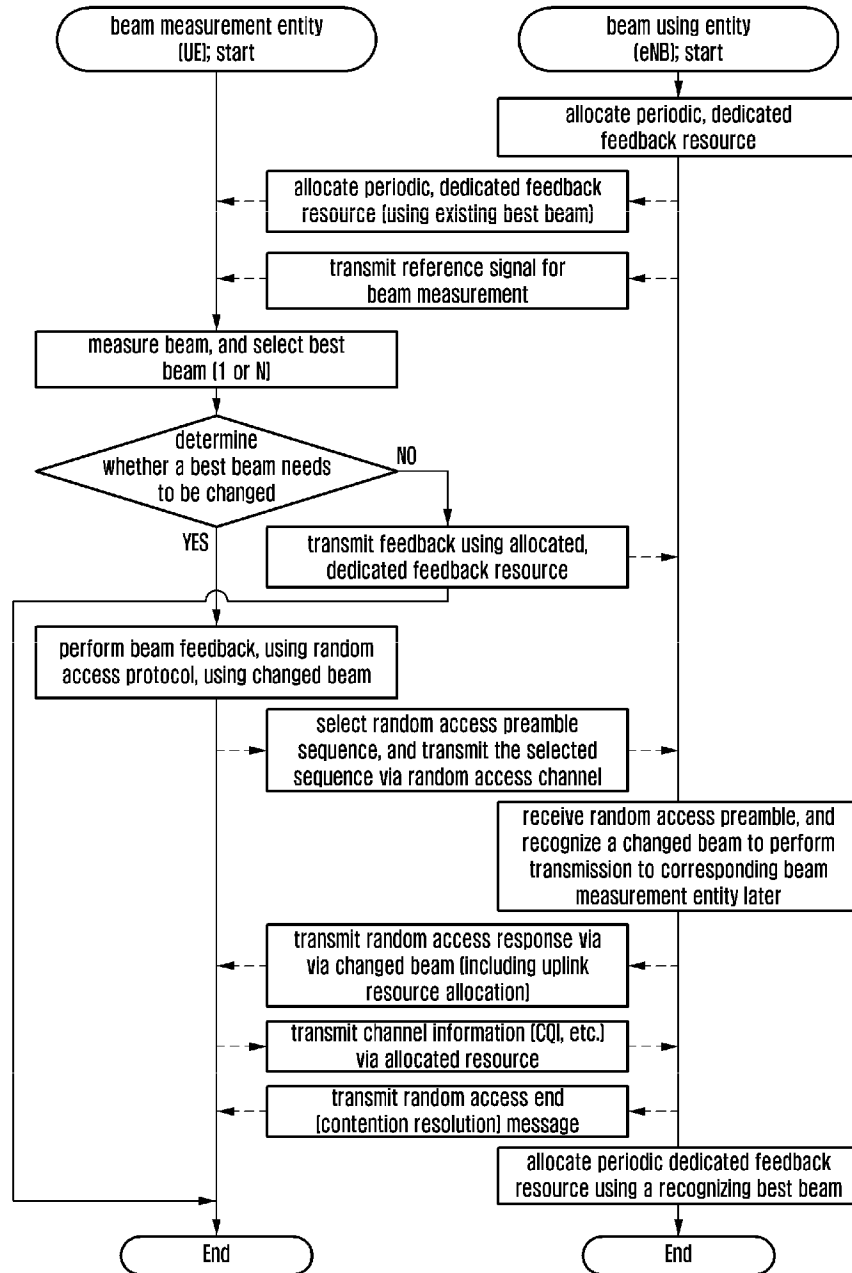
- In the drawing, the solid line represents the progress of processes and the dotted line represents wireless transmission.
- Operations
 1. eNB periodically allocates a dedicated feedback resource using a UE's best beam that it has currently known about
 - Allocation information may be transmitted to each UE, via a downlink control/data channel, etc.
 - Information regarding an allocated resource through which UE will transmit the following feedback via uplink: uplink beam, frequency, time, etc.
 2. UE periodically performs the beam measurement and the best beam selection
 3. The operations, the allocation and notification of a resource as in

item No. 1 and the beam measurement and the best beam selection as in item No. 2, may be performed in any other order.

The present invention also includes operations performed in other orders: item No. 1 → No. 2; and item No. 2 → No. 1

4. UE compares a best beam, selected based on the beam measurement, with a best beam that it has used, and determines whether beam change is needed (another beam > current beam + Threshold)
 - 4-1) If a beam is not changed, UE transmits feedback via an uplink beam feedback resource allocated by the best beam that has been used
 - 4-2) If a beam is changed, UE performs beam feedback to an eNB, using a random access protocol, using the changed beam (which will be described in detail in the following Embodiment 1-1)
- The present invention considers a random access scheme which may be a contention-based RACH and a contention-free RACH which are used in the existing LTE. Alternatively, the present invention may also employ a random access scheme, similar to the scheme based on a contention-based RACH and a contention-free RACH, which allows UEs to attempt to perform transmission using arbitrary or pre-set information (sequence), etc. during an interval where an eNB performs reception without knowing which UE will attempt to perform transmission.
- In the embodiment, information regarding a best beam performing feedback may also be information regarding one or more beams.

- **[Embodiment A-1-1]** Procedure using random access feedback when a best beam measured by UE is changed from an existing best beam (a detailed random access protocol)



Operations

1. Basic operations are identical to those of [Embodiment 1] described above
2. The embodiment is implemented from the operation as in item No. 4-2) of [Embodiment 1], referring to 3GPP LTE RACH (operation

- using a random access channel)
- If a beam is changed as in item No. 4-2) of [Embodiment 1], UE performs beam feedback to an eNB, using a random access preamble protocol, using the changed beam.
3. UE detects a changed beam, and determines to transmit beam feedback to an existing eNB, using a random access protocol, using the changed beam
 4. Determination of preamble sequence
 - For a contention-based RACH, UE arbitrarily selects a preamble sequence (that an eNB can use, which is noticed by the eNB) from among the preamble sequences that the UE has known about
 - For a contention-free RACH, UE uses a preamble sequence allocated by an existing network
 5. The selected preamble sequence uplink transmission is performed using a resource and a random access transmission interval in a preset frame structure (PRACH)
 - The current preamble sequence does not include information regarding UE
 6. eNB determines whether UE selecting a preamble succeeds/fails in performing uplink transmission, via an PRACH through which the eNB performs reception by sweeping a beam.
 - A beam receiving a corresponding preamble is a beam that corresponding UE will use.
 - eNB has not yet known about UE performing the transmission of a preamble, the preamble, and the purpose of the preamble.
 - i. UE may attempt to perform the RACH transmission for network initial/re-connection.
 - ii. UE may attempt to perform the RACH transmission in order to re-obtain synchronization since uplink is asynchronized.
 - iii. UE may attempt to perform the RACH transmission in order to transmit feedback for beam change (an RACH

performing condition of new UE, which is claimed by the present invention).

7. eNB indicates corresponding preamble transmission UE by Random Access Radio Network Temporary Identifier (RA-RNTI), based on a transmission/reception time of each preamble. The eNB: selects a beam receiving a corresponding preamble as a best beam; allocates an uplink resource with the selected beam (UL Grant); creates a random access response (RAR) message from the uplink resource; and transmits the message to UE, within a random access response interval (RAR window).
 - When channel reciprocity is assumed, a best beam suitable for UE to perform transmission is identical to a best beam that an eNB may use to perform transmission.
 - UEs selecting different random access sequences: check information contained in RAR messages; determine whether information transmitted by each of the UEs is correctly received; and identify corresponding RAR messages transmitted to them respectively (i.e., determine whether an RAR containing an RA-RNTI according to a time that each of the UEs performed transmission is transmitted).
 - When UE opens an RAR message received via its RA-RNTI and ascertains that its transmitted preamble ID is identical to a preamble ID in a corresponding RAR, it determined that the corresponding RAR is the RAR of the preamble transmitted by the UE and performs the following procedure.
 - i. Determine a TC-RNTI contained in the RAR as an ID to use in the next uplink message transmission.
 - ii. Obtain uplink synchronization using Timing Advance information contained in an RAR.
 - iii. Detect UL Grant in an RAR, and then an uplink transmission resource of the next message.

8. UE transmits channel information, best beam information, etc.

(feedback), according to uplink resource scheduling information (UL Grant) contained in a received random access response

- RACH is used for uplink beam feedback (which is claimed by the present invention)
- UE selects a sender ID for feedback information as a TC-RNTI, and transmits the sender ID, along with an ID representing that a corresponding message is an uplink beam feedback message.

i. Method for eNB to identify that a message received via a UL Grant resource is uplink beam feedback information:

<Uplink message using UL Grant contains C-RNTI information that has been previously used, so that eNB can recognize that corresponding UE is a connected UE >

<Uplink message using UL Grant contains information indicating that a corresponding message is UL beam feedback, so that eNB can update (or change) beam information regarding corresponding UE >

1. [Explicit] When a corresponding message category explicitly specifies UL Beam Feedback

TC-RNTI	Category (UL Beam Feedback)	C-RNTI	Beam Feedback Information
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2. [Implicit] Although a sender ID of a corresponding message is TC-RNTI, the message contains an ID (C-RNTI) specifying that a corresponding message sender is a connected UE and includes beam information (beam ID, beam reception location, beam channel performance, etc.) that corresponding UE needs to change

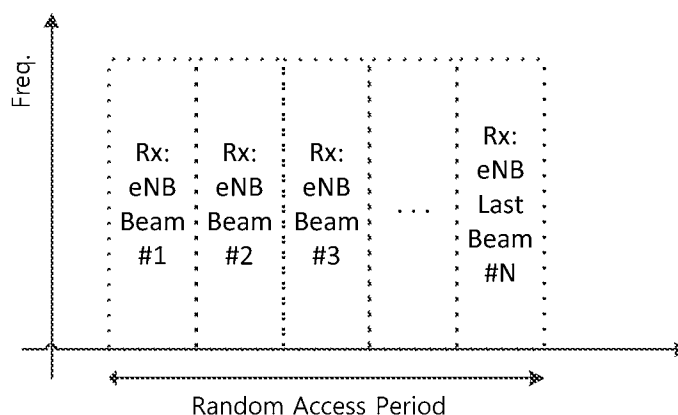
TC-RNTI	C-RNTI	Beam Feedback Information
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A. In this case, UE informs a network that a transmission node of a corresponding message is the UE itself (C-RNTI), and analyzes the corresponding message to perform beam feedback and beam change.

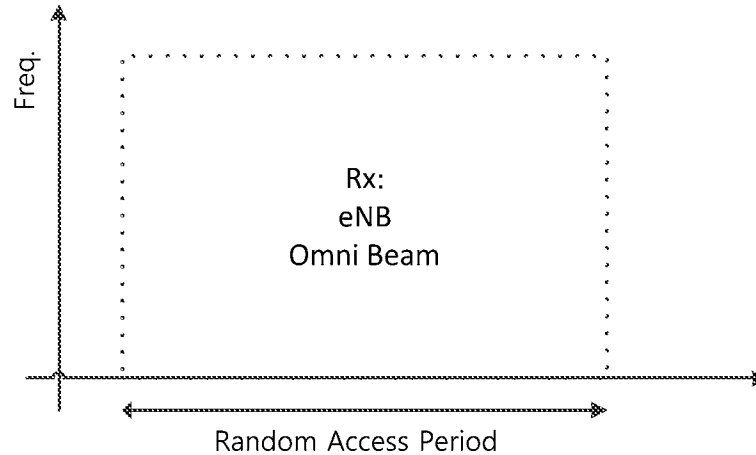
3. The eNB receives a corresponding message, recognizes that the transmission node of the corresponding message is specified UE that has been connected (using C-RNTI), and updates or modifies beam information regarding the corresponding UE (using beam feedback information).

9. eNB receives UE information transmitted via a UL Grant resource, and transmits, to the UE, an acknowledgement message in response to the reception (contention resolution: simultaneous transmission, resolution of random access collision between UEs selecting the identical preamble)

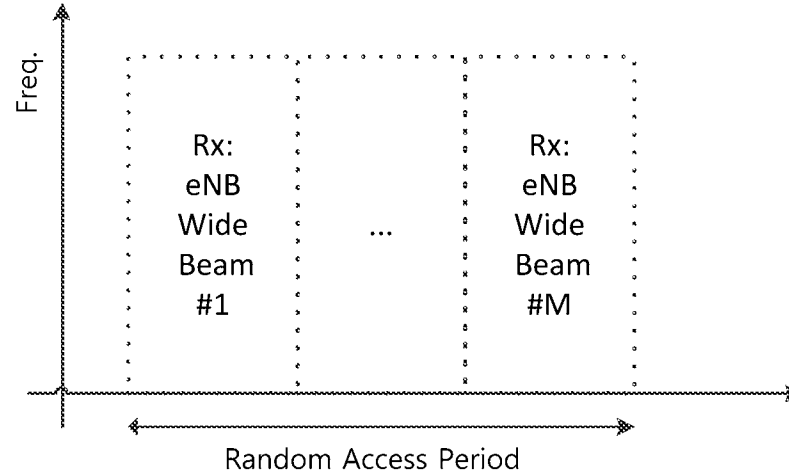
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- **[Embodiment A-1-2]** Random access channel and interval configuration, and preamble transmission, using an analogue directivity beam



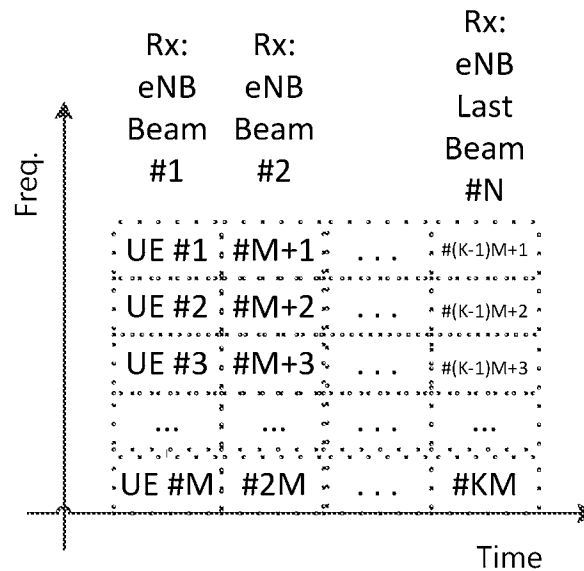
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- **[Embodiment A-1-3]** Random access channel and interval configuration, and preamble transmission using an omni beam



-
- **[Embodiment A-1-4]** Random access channel and interval configuration, and preamble transmission using an wide beam
-



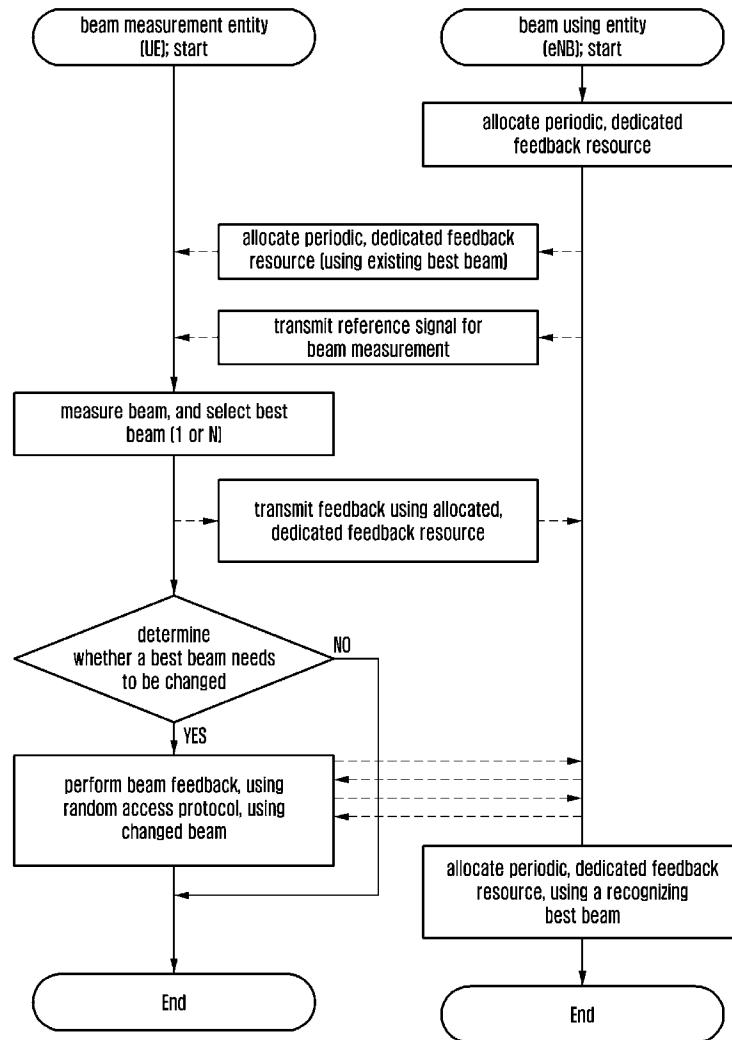
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- In Embodiment A-1 described above, periodic dedicated feedback resources are allocated as follows.
- 1. **[Embodiment A-1-5]** In order to allocate the periodic dedicated feedback resource, eNB determines resources that individual UEs will use to perform transmission (scheduling) and allocates resources to the UEs.



-
- If eNB allocates resources to all users (or a specified user), enables the users (or the specified user) to transmit uplink information at a specified location, and notifies the individual users of the uplink information, the users feed back beam information to the eNB via corresponding resources.
- Transmission method of allocation information regarding a corresponding resource may be implemented with various methods. The allocation information transmission method may be implemented in such a way as to transmit any type of information if the information can be transmitted, containing information regarding an allocated resource, e.g., a frequency and time. For example, the allocation information may be transmitted in the form of downlink control information (DCI) transmitted using 3GPP LTE PDCCH.
- An Rx beam received by the eNB may be: an analogue beamforming form of beam with N different directions; a digital beamforming form of beam which is received at the same timing, overlapping with another, but is encoded by an encoding scheme that differs from that of the overlapping beam; or an omni-beam with the same directivity.
- In the embodiment, information regarding a best beam performing

feedback may also be information regarding one or more beams.

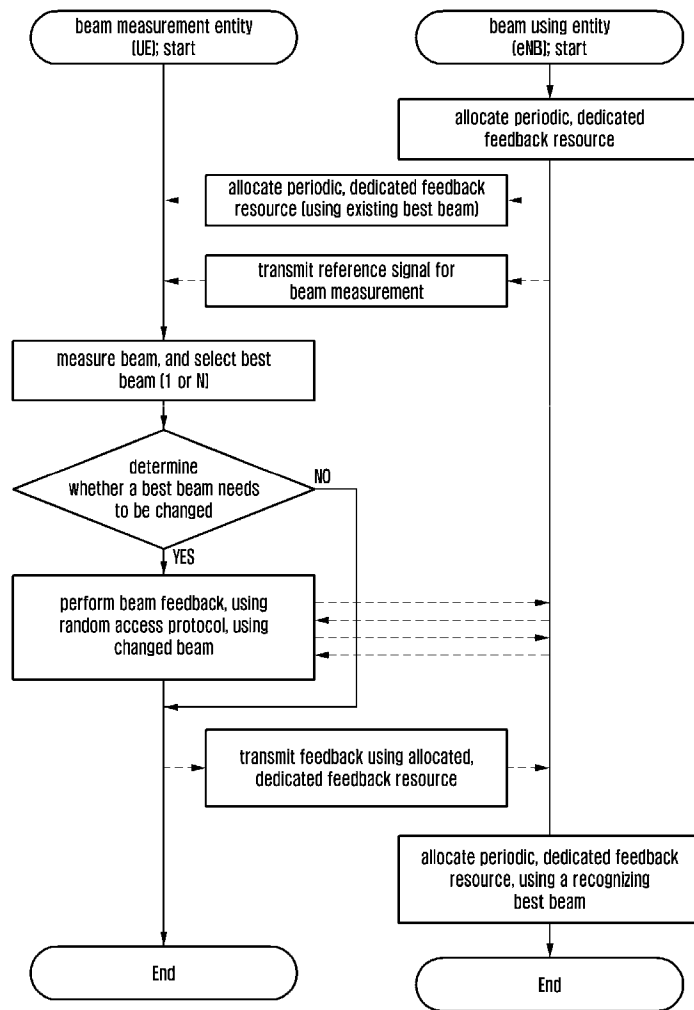
- **[Embodiment A-2]** When a best beam measured by UE is changed from an existing best beam, random access feedback is used (feedback using a pre-allocated dedicated feedback resource is transmitted regardless of best beam change (when a best beam is changed, pre-allocated feedback is transmitted earlier than a random access protocol))



- In the embodiment, feedback transmission is attempted using a pre-allocated, dedicated feedback resource, regardless of best beam change, and simultaneously feedback is also performed using random access according to a condition as to whether a best beam is

changed.

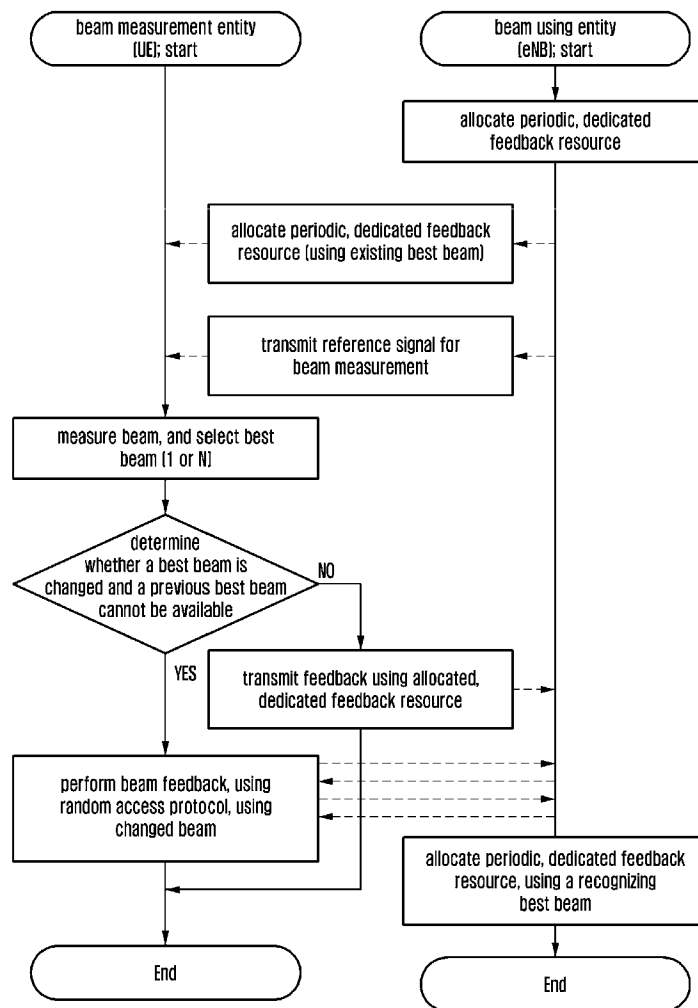
- Operations:
 1. eNB periodically allocates dedicated uplink feedback resource using a best beam of UE that it has recognized
 2. UE always (or if possible) attempts to transmit feedback using an allocated feedback resource
 3. If a beam has been changed, the embodiment performs beam feedback, using the same random access protocol as [Embodiment A-1].
- In the embodiment, information regarding a best beam performing feedback may also be information regarding one or more beams.
- **[Embodiment A-2-1]** When a best beam measured by UE is changed from an existing best beam, random access feedback is used (feedback using a pre-allocated dedicated feedback resource is transmitted regardless of best beam change (Embodiment A-2-1 is modified from Embodiment A-2; and when a best beam is changed, pre-allocated feedback is transmitted later than a random access protocol))



- The condition as to whether a best beam is changed may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.
 1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing beam performance < Threshold))

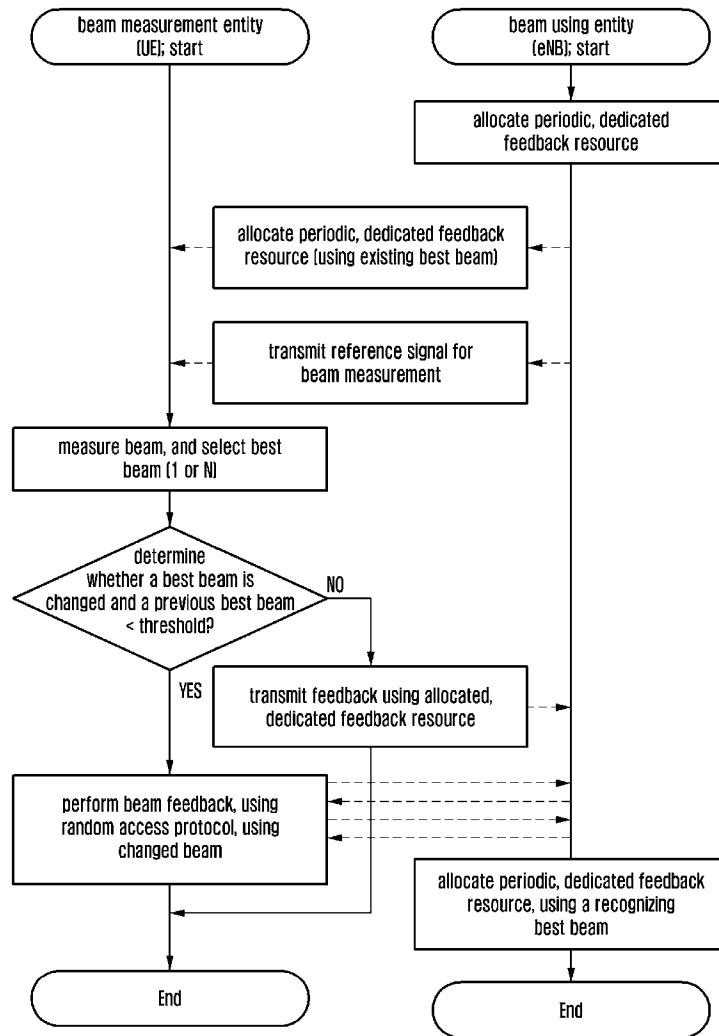
4. etc.

- In the embodiment, information regarding a best beam performing feedback may also be information regarding one or more beams.
- **[Embodiment A-3]** When a best beam measured by UE is changed from an existing best beam and a previous best beam cannot be available, random access feedback is used



- When UE ascertains that a best beam is change and a best beam that has been used is not available for communication, based on a beam measurement result, ((another beam > current beam + Threshold_1) and (a condition that current beam cannot be available is satisfied)), it performs beam feedback using a random access protocol.

1. Method of determining that a previous best beam is not available for communication
 - When a measurement value of a previous best beam channel (RSSI, RSRP, RSRQ, SNR, SINR, etc.) is less than or equal to a specified threshold [= Embodiment 4]
 - When a previous best beam is not included within the top K (or K% from the top) in the ranking of the beams, derived from the beam measurement
 - When a previous best beam is included within the bottom K (or K% from the bottom) in the ranking of the beams, derived from the beam measurement
- In the embodiment, information regarding a best beam performing feedback may also be information regarding one or more beams.
-
- **[Embodiment A-4]** When a best beam measured by UE is changed from an existing best beam and the channel quality of a previous best beam is less than a specified threshold, random access feedback is used
-

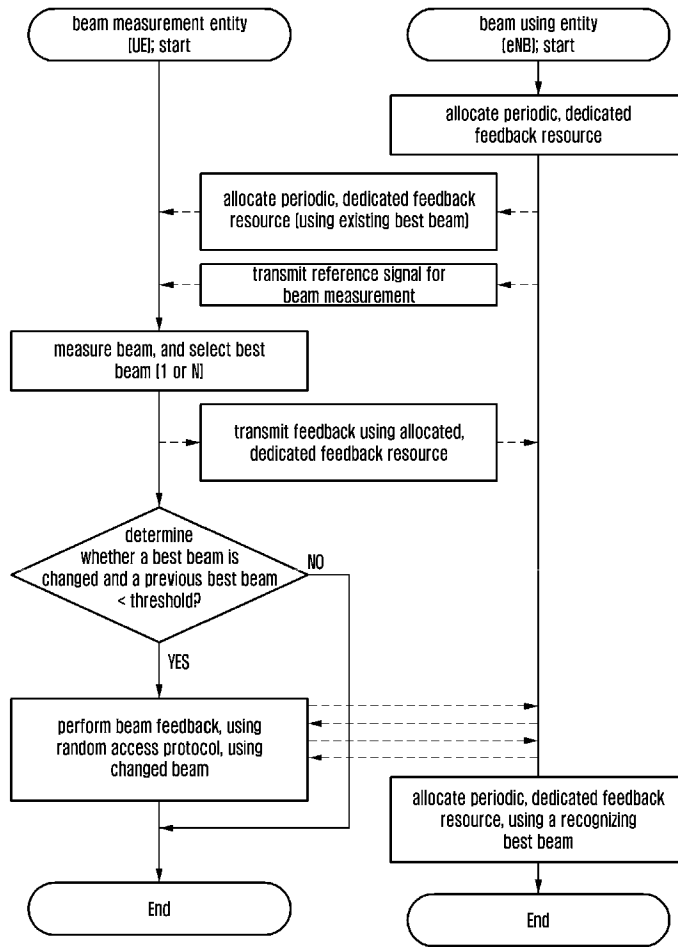


- The condition as to whether a best beam is changed may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.
 1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing

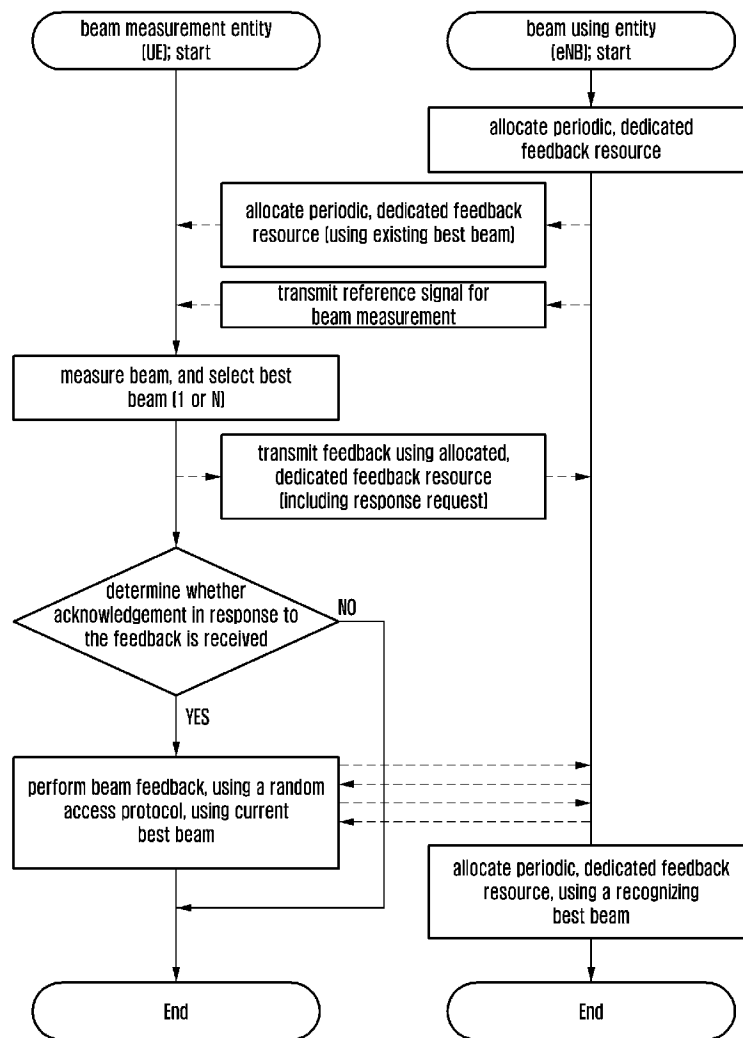
beam performance < Threshold))

4. etc.

- In the embodiment, information regarding a best beam performing feedback may also be information regarding one or more beams.
-
- **[Embodiment A-5]** When a best beam measured by UE is changed from an existing best beam and the channel quality of a previous best beam is less than a specified threshold ((another beam > current beam + Threshold_1) and (current beam < Threshold_2)), random access feedback is used (feedback using a pre-allocated dedicated feedback resource is transmitted regardless of best beam change (when a best beam is changed, a pre-allocated feedback is transmitted earlier than a random access protocol; however, a pre-allocated feedback may be transmitted later than a random access protocol)



- The condition as to whether a best beam is changed may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.
 1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing beam performance < Threshold))
 4. etc.
-
-
- **[Embodiment A-6]** When UE transmits uplink feedback using a pre-allocated, dedicated feedback resource, but has not received an acknowledgement in response to the uplink feedback, the UE performs random access feedback using a best beam that it currently knows about



- Feedback message that UE transmits via a dedicated feedback resource which has been previously allocated may contain information requesting a response (or acknowledgement) of an eNB in response to the corresponding feedback
 1. Information requesting a corresponding response may be a bit (indicator) located at a specified location in a preset PHY or MAC message.
 2. Information requesting a corresponding response may be a preset sequence.
 3. A corresponding response needs to be received within a preset period of time after feedback information is transmitted.
- Feedback message that UE transmits via a dedicated feedback

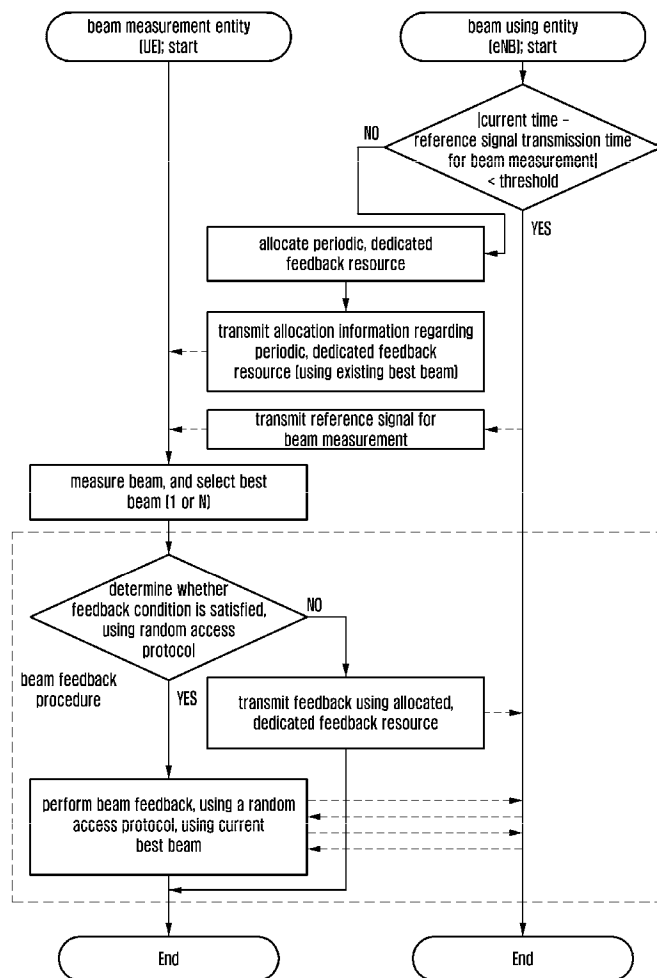
resource which has been previously allocated does not include a specified response request message; however, UE may request a response from the eNB, using preset methods as follows.

1. A method may be preset so that a response to every feedback message is always transmitted.
2. A method may be preset so that UE and an eNB exchange signals/messages with each other before transmitting a feedback message, and then the eNB transmits, to the UE, a response with respect to several feedback messages (one or more feedback messages)
3. A method may be preset so that UE and an eNB exchange signals/messages with each other before transmitting a feedback message, and then the eNB transmits, to the UE, a response with respect to feedback messages transmitted before the condition is destroyed/cancelled.

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B. Feedback transmission method: 1) eNB delays allocating a feedback resource to UE until a beam measurement interval after beam measurement or 2) UE performs transmission of feedback after beam measurement, ignoring a pre-allocated feedback resource,

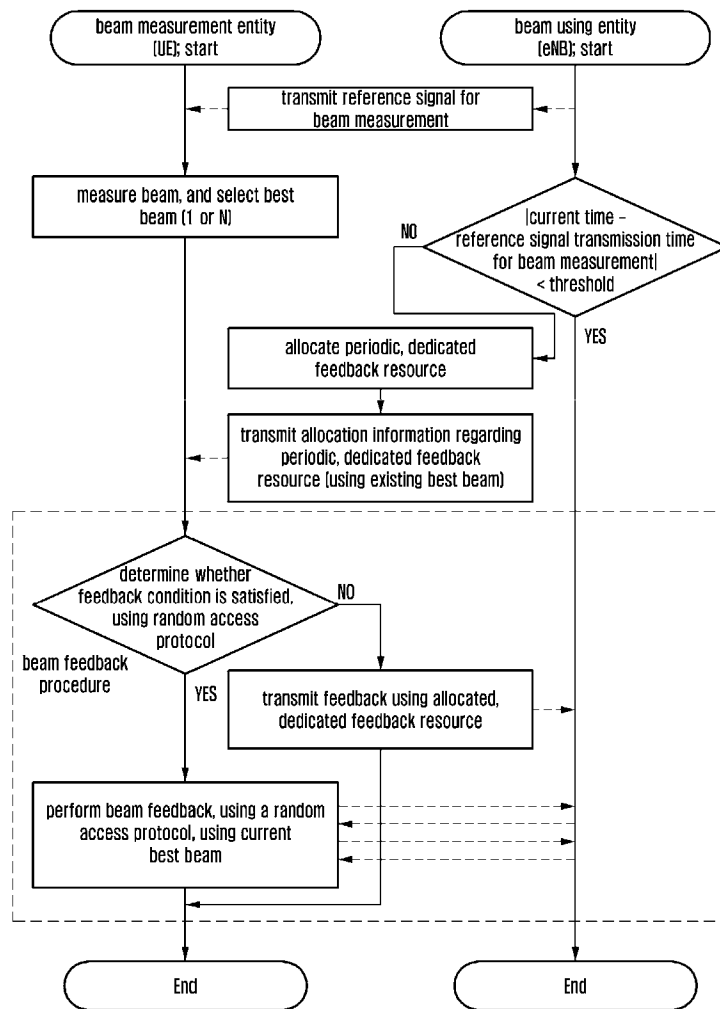
- **[Embodiment B-1]** eNB does not allocate a dedicated feedback resource before beam feedback and before feedback reception.



- When the difference between the current time and the transmission time of a reference signal for beam measurement is less than or equal to a specified threshold, eNB does not perform the allocation of a feedback resource.
- In the beam feedback procedure in a dotted-line rectangle, when UE satisfies a feedback condition using random access, it performs beam feedback using a random access protocol using a current best beam. On the other hand, when UE does not satisfy a feedback condition using beam random access, it performs beam feedback using an allocated, dedicated feedback resource. It should be understood that the present invention may also include various examples modified from the feedback procedure.
- The condition for the random access feedback may include any type

of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.

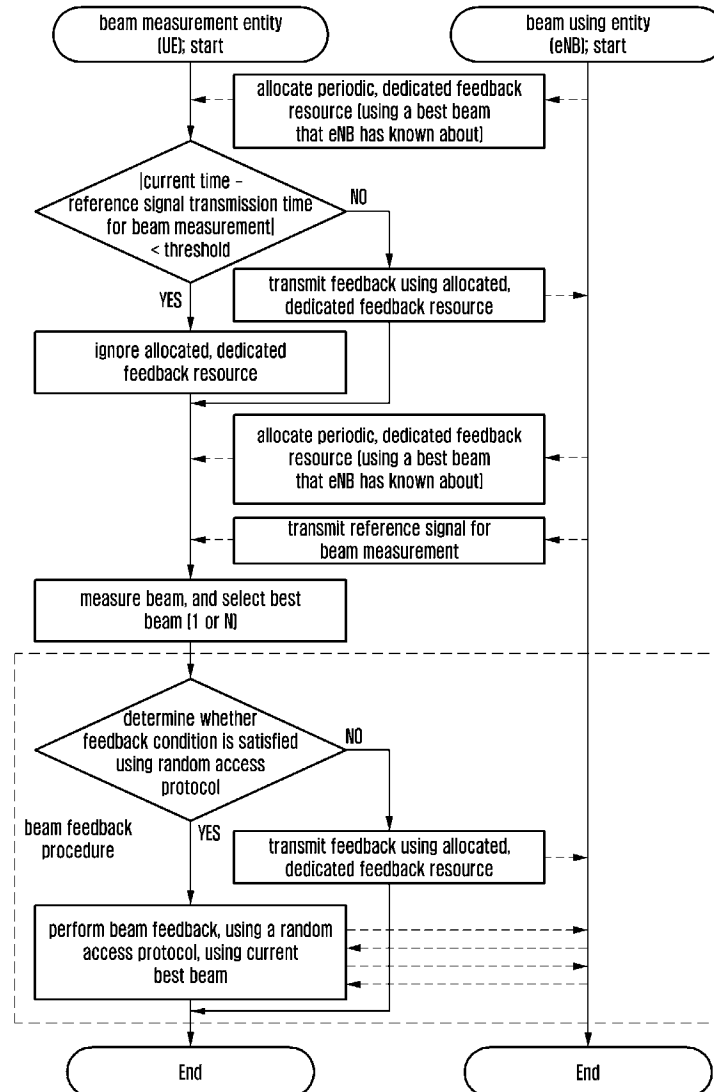
1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing beam performance < Threshold))
- **[Embodiment B-1-1]** eNB does not allocate a dedicated feedback resource before beam feedback and before feedback reception (if a periodic, dedicated feedback resource allocation message is transmitted after a reference signal for beam measurement is transmitted)



- The condition for the random access feedback may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.
 1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing beam performance < Threshold))

4. etc.

- **[Embodiment B-2]** UE does not perform transmission within a specified time before performing beam measurement and before transmitting feedback, ignoring an allocated, dedicated feedback resource.

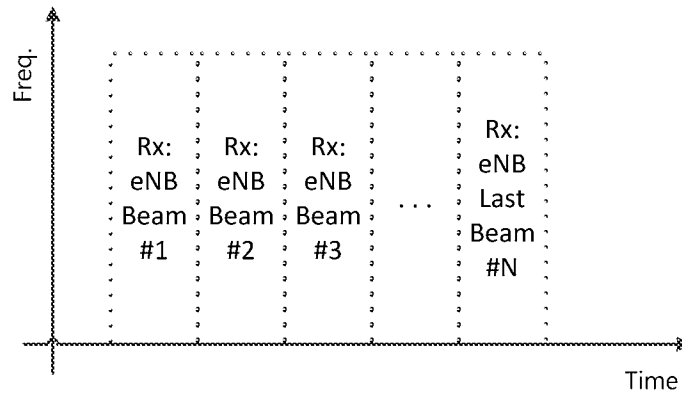


- The condition for the random access feedback may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.

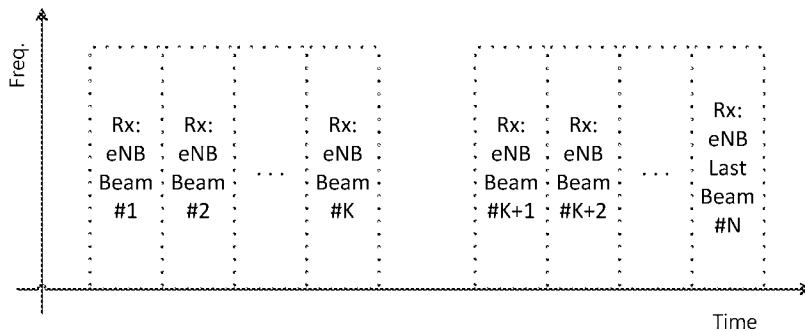
- The condition as to whether a best beam is changed may include any type of determination condition if it can ascertain that feedback needs to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.
 1. When the transmission channel performance of an existing best beam becomes low (existing beam performance < Threshold)
 2. When a best beam is changed (new best beam > existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam > existing beam + Threshold) and (existing beam performance < Threshold))

- Operations of [Embodiment C-1] and [Embodiment A-1] are identical to each other, except that, when a best beam is changed, Embodiment C-1 performs beam feedback, using a beam sweeping reception interval of an eNB, instead of using random access, using the changed beam.

- eNB beam sweeping reception interval and operations of the eNB
 1. eNB beam sweeping reception interval: A preset period of time during which an eNB receives channel information, by sweeping a beam. An existing RACH reception time and a resource (PRACH) also correspond to the interval.
 - [Fig. C-1-1] An example of an eNB beam sweeping reception interval



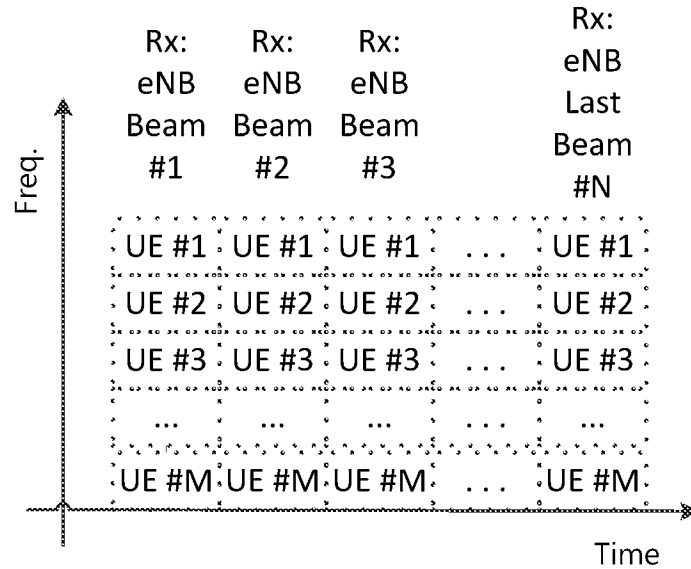
-
- An Rx beam received by the eNB may be: an analogue beamforming form of beam with N different directions; a digital beamforming form of beam which is received at the same timing, overlapping with another, but is encoded by an encoding scheme that differs from that of the overlapping beam; or an omni-beam with the same directivity.
-
- [Fig. C-1-2] The eNB beam sweeping reception intervals do not always need to be close to each other.



-
- An Rx beam received by the eNB may be: an analogue beamforming form of beam with N different directions; a digital beamforming form of beam which is received at the same timing, overlapping with another, but is encoded by an encoding scheme that differs from that of the overlapping beam; or an omni-beam with the same directivity.

□

2. [Fig. C-2] eNB may determine resources that individual UEs will use to perform transmission in eNB beam sweeping reception intervals (scheduling) and allocates resources to the individual UEs.

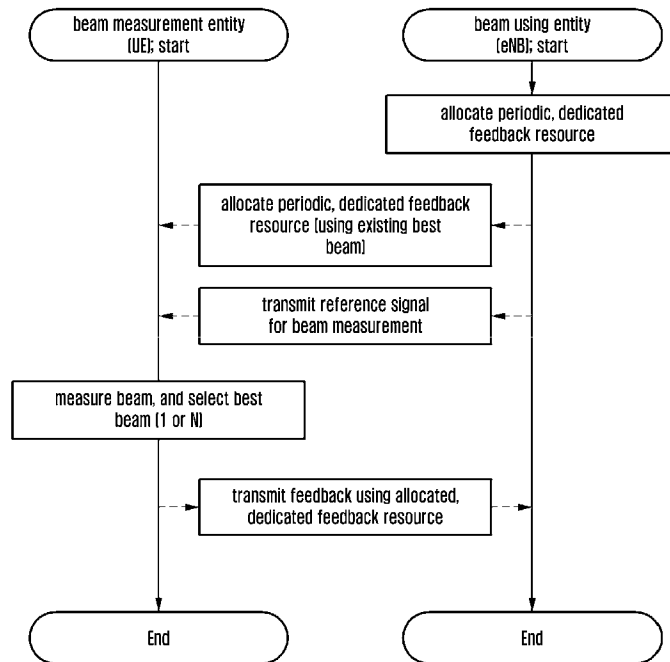


□

- If eNB allocates resources to all users (or a specified user), enables the users (or the user) to transmit uplink information, and allocates an interval performing reception by sweeping a beam, although the users (or user) do not know a beam available for communication, the users (or user) can transmit information to the eNB, which is advantageous. However, when there are a relatively small number of beam that the eNB can use to perform reception, resources allocated to the other beams are wasted, which is disadvantageous.
- An Rx beam received by the eNB may be: an analogue beamforming form of beam with N different directions; a digital beamforming form of beam which is received at the same timing, overlapping with another, but is encoded by an encoding scheme that differs from that of the overlapping beam; or an omni-beam with the same directivity.

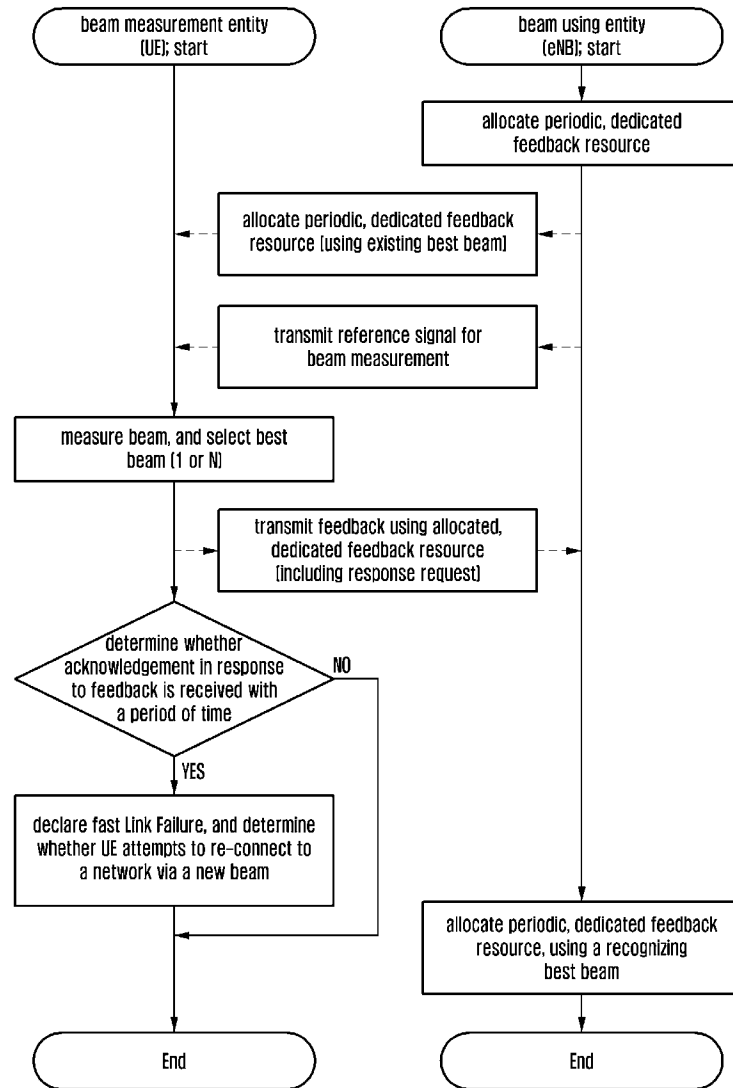
D. Procedure using only a periodic dedicated feedback method

- **[Embodiment D-1]** Method for UE to transmit beam feedback using only a dedicated feedback resource allocated by an existing best beam that a beam using entity has known about



- When a beam is changed, UE continuously attempts to perform feedback using a dedicated feedback resource that an existing best beam allocates via an existing best beam, without performing a specified operation.
- Feedback failure and beam-tracking failure due to beam change use the re-connection performed due to a failure of the existing transmission (Radio Link Failure, etc.).
- When feedback succeeds in transmission, UE and eNB can communicate with each other via a best beam.
- When feedback fails in transmission, best beams between UE and eNB discord with each other, which causes to increase the probability of communication failure, so that the UE and eNB need to perform Radio Link Failure.

- **[Embodiment D-2]** Method for UE to transmit beam feedback using only a dedicated feedback resource including an acknowledgement request, and procedure for UE to perform the fast re-connection attempt using the acknowledgement request in response to the feedback



- The transmission of feedback including a response request is the same as in [Embodiment A-6].
- If UE has not received a response request within a preset period of time despite a number of attempts to transmit feedback including the response request, UE determines that the current beam state is no

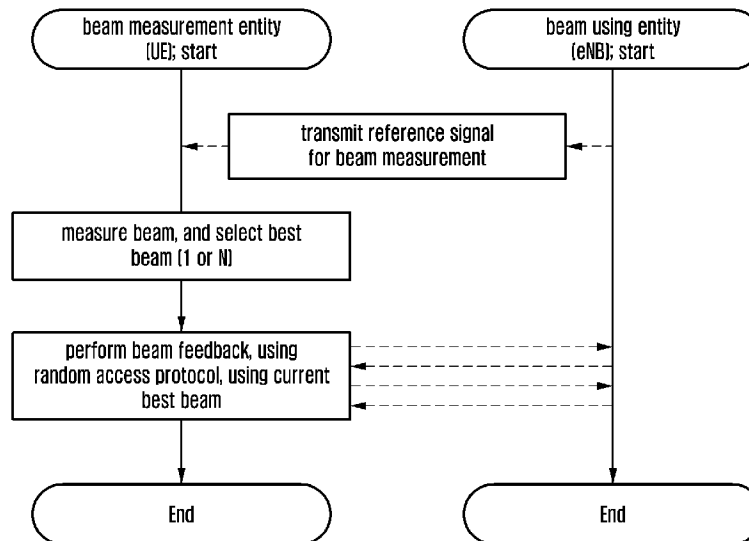
longer suitable for uplink communication, declares fast link failure, and re-connects to a network using a new beam.

- In this case, if the network detects that uplink feedback transmission has not been performed by UE via an allocated feedback resource within a period of time, it may also declare link failure on the UE
 1. In a state where the network holds information regarding UE on which link failure is declared for a period of time, it may support the UE to perform fast re-connection using another beam.
 2. In a state where the network releases the connection of UE on which link failure is declared (or discards information regarding the UE), when the UE attempts to perform re-connection, the network may follow an existing re-connection procedure.

E. Procedure using only periodic random access

- **[Embodiment E-1]** Beam feedback using periodic random access

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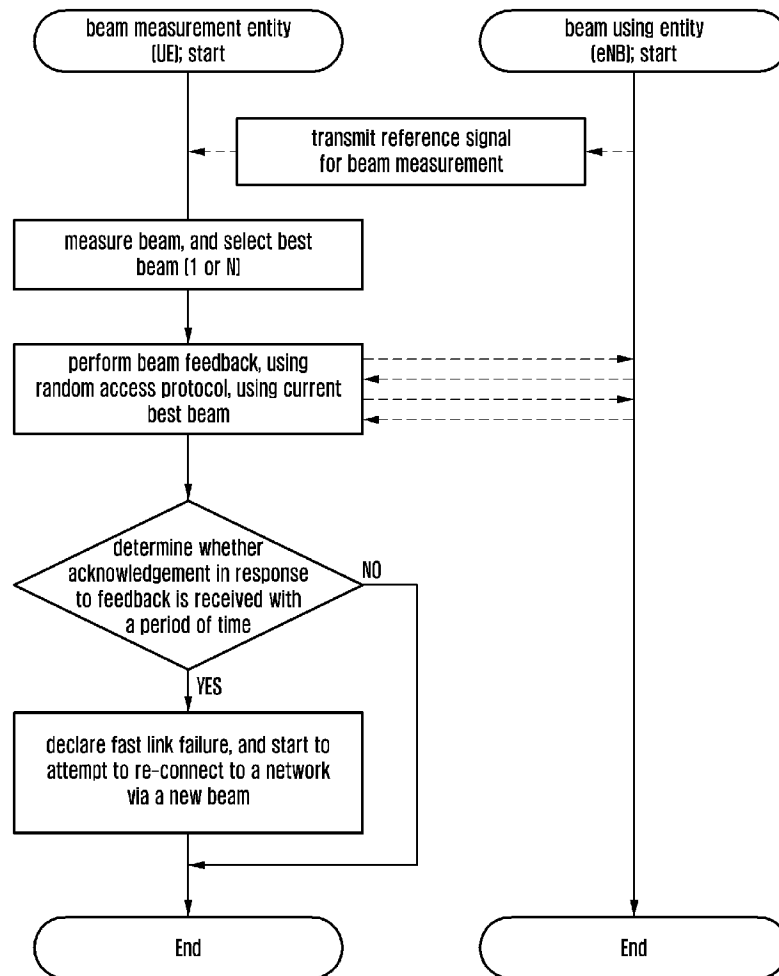


- Transmission of feedback using only a random access resource periodically allocated by a network
- The random access resource is an eNB beam sweeping reception interval, and requires more an amount of resource occupation in order to receive the same information which causes a large amount of

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waste of resource.

- A collision between information transmitted by UE may occur, and this decreases the performance, such as, a delay, etc.
- The present invention considers a random access scheme which may be a contention-based RACH and a contention-free RACH which are used in the existing LTE. Alternatively, the present invention may also employ a random access scheme, similar to the scheme based on a contention-based RACH and a contention-free RACH, which allows UEs to attempt to perform transmission using arbitrary or pre-set information (sequence), etc. during an interval where an eNB performs reception without knowing which UE will attempt to perform transmission.
-
- **[Embodiment E-2]** Transmission of beam feedback using periodic random access, and procedure for attempting fast re-connection using a condition as to whether an acknowledgement in response to the feedback is received



- If a condition is satisfied which UE has not received a response request within a preset period of time despite a number of attempts to transmit feedback using random access, the UE: ascertains that the current beam state is not suitable for uplink communication; declares fast link failure; and re-connects to a network, using a new beam.

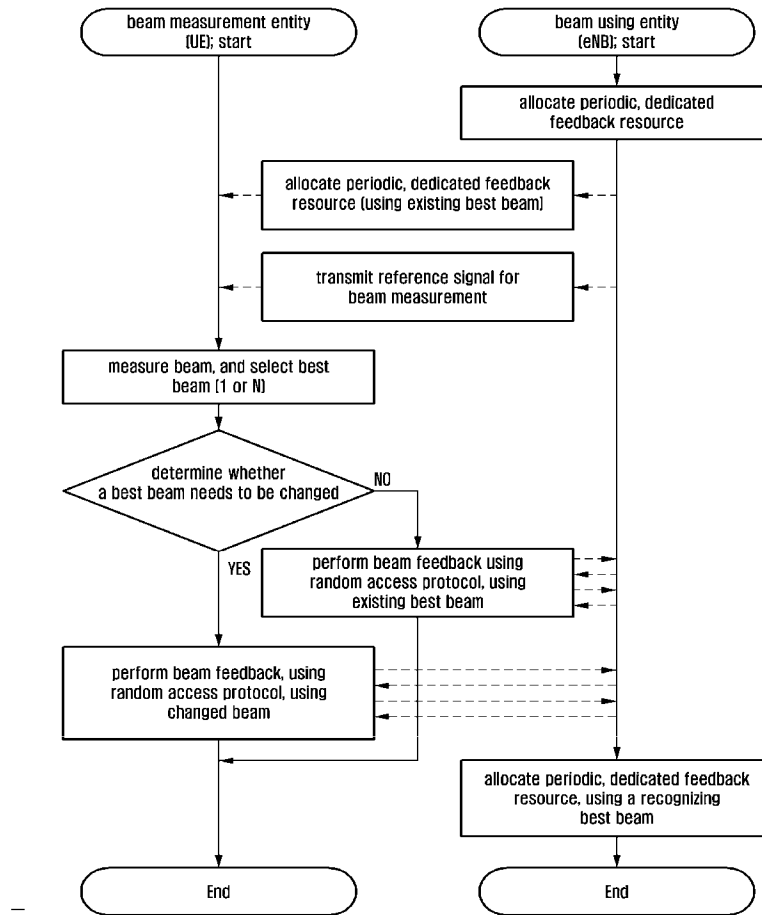
1. The conditions to determine that a response request has not been received within a preset period of time:

- Random Access Response (RAR) message in response to a single transmission of Random Access Preamble is not received with a preset period of time
- Random Access Response (RAR) message in response to a preset number of times of transmission of Random Access Preamble is not received even once with a preset period of

time

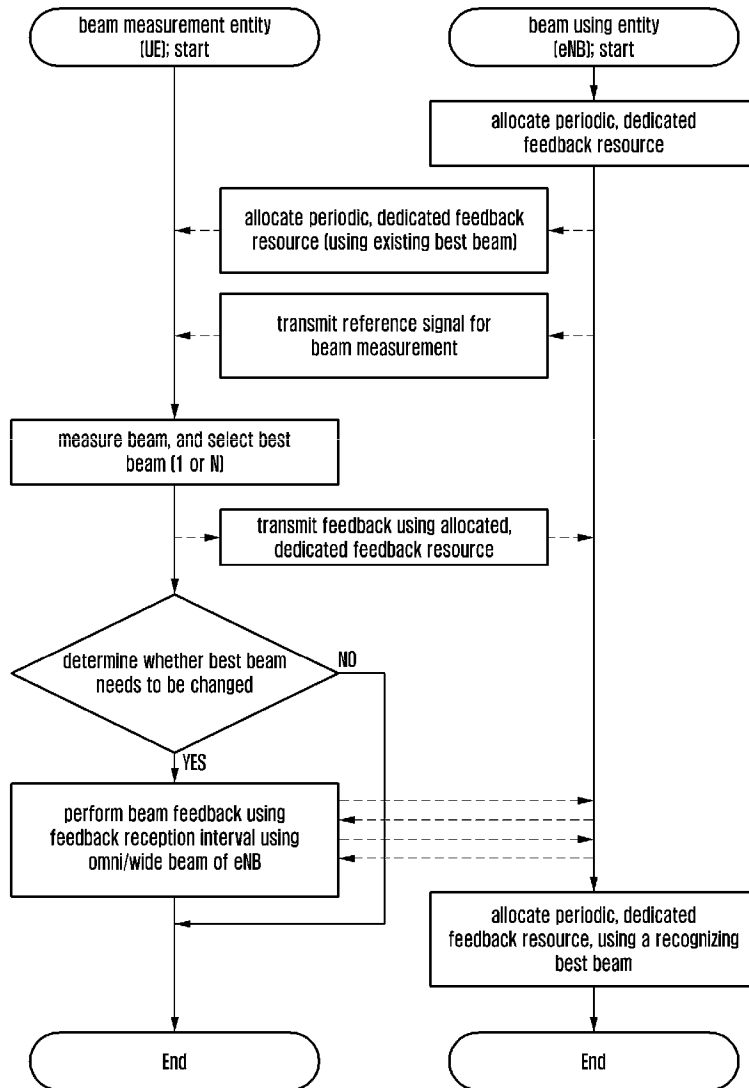
- Random Access Response (RAR) message in response to a preset number of attempts of transmission (including the number of re-transmission attempts) of Random Access Preamble within a preset period of time is not received even once.
- In this case, if the network detects that uplink feedback transmission has not been performed by UE via an allocated feedback resource within a period of time, it may also declare link failure on the UE
 1. In a state where the network holds information regarding UE on which link failure is declared for a period of time, it may support the UE to perform fast re-connection using another beam.
 2. In a state where the network releases the connection of UE on which link failure is declared (or discards information regarding the UE), when the UE attempts to perform re-connection, the network may follow an existing re-connection procedure.

F. Procedure employing a combination of a periodic random access feedback method and an aperiodic random access feedback method



G. Procedure employing a combination of a periodic dedicated feedback method and an aperiodic feedback method using a wide beam

- **[Embodiment G-1]** Transmission of feedback using a reception range of an omni/ wide beam that an eNB manages when a best beam is changed or the performance of an existing analogue beam becomes low



- Assumption: Information may be transmitted/received via an analogue beam with narrow directivity.
- For an instance that the beam direction is turned away or UE does not know a beam for reception, the eNB may operate an interval for receiving wireless information using an omni-beam or a wide beam.
- UE may transmit information to the eNB, using (1) a random access or (2) a resource which is always allocated to each UE, during the interval.
-
- The condition as to whether a best beam is changed may include any type of determination condition if it can ascertain that feedback needs

to be further transmitted, in addition to a dedicated feedback resource allocated by an eNB. An example of the determination condition is described as follows.

1. When the transmission channel performance of an existing best beam becomes low (existing beam performance $<$ Threshold)
 2. When a best beam is changed (new best beam $>$ existing beam + Threshold)
 3. When a best beam is changed and the transmission channel performance of an existing best beam becomes low ((new best beam $>$ existing beam + Threshold) and (existing beam performance $<$ Threshold))
- The feedback transmission using the allocated, dedicated feedback resource may be performed regardless of the best beam change. Alternatively, the feedback transmission using the allocated, dedicated feedback resource may not be performed, based on the determination as to whether the best beam is changed.
 -

H. Procedure for eNB to determine a schedule using beam-related feedback of UE

- **[Embodiment H-1]** UE receives a beam measurement reference signal transmitted from an eNB and measures the beam intensity. UE feeds back an index of a beam, received with the highest level of beam intensity, and the beam intensity corresponding to the beam index (e.g., beam quality) to the eNB.
- The beam index and information regarding the beam intensity corresponding to the beam index is transmitted via an uplink control channel (e.g., PUCCH) or an uplink data channel (e.g., PUSCH). The eNB is capable of specifying a channel through which UE will transmit feedback, via a downlink control channel. In this case, the uplink control channel through which UE performs transmission may be allocated so that its cycle is the same as an eNB's transmission cycle of a beam measurement reference signal or is a multiple of a transmission cycle of a beam measurement reference signal.

Alternatively, the uplink control channel through which UE performs transmission may be aperiodically allocated by an eNB scheduler.

- The beam index and information regarding the beam intensity corresponding to the beam index, transmitted by the UE via an uplink channel, may be expressed as x bits. For example, the beam index may be 8 bits, and the information regarding the beam intensity may be 5 bits. X bits may be scrambled via a cell-specific or UE-specific scrambling sequence. In the scrambling process, cell-specific information (e.g., cell ID) and/or UE-specific information (RNTI) may be used. UE and eNB need to regulate which information they use to perform the scrambling operation.
- Scrambled result of x bits has a CRC of y bits, e.g., $y = 8$ bits, and then processed to create coded bits of z bits by a channel encoder. In this case, the CRC may be used for the re-transmission of HARQ-ACK/NACK. For example, when an eNB receives information of z bits, regarding the beam intensity and a beam index that UE transmitted via an uplink control channel/data channel, it decodes the received information and determines whether error occurs in the decoded result, based on the CRC. If error occurred in the decoded result (NACK), the eNB may request re-transmission from the UE (HARQ). On the other hand, if error has not occurred in the decoded result (ACK), the eNB does not transmit ACK. UE initiates a timer from its transmission timing. If UE does not receive a re-transmission request from the eNB until the timer has expired, it implicitly recognizes that the information has been successfully transmitted to the eNB.
- CRC is not used for the re-transmission of HARQ-ACK/NACK, but is used for beam-scheduling of an eNB. For example, if an eNB determines whether error occurs in a decoded result via a CRC. If error occurred in a decoded result (NACK), the eNB does not allocate a beam to corresponding UE.
- An eNB checks a CRC for information regarding the beam intensity and a beam index, transmitted from a number of UEs via an uplink control channel or a data channel. If the eNB ascertains that error

occurred in a decoded result, it may change its beam direction.

I. Beam feedback resource allocation, Beam feedback using the allocated resource, and Beam feedback procedure using beam change notification (if beam change is successful)

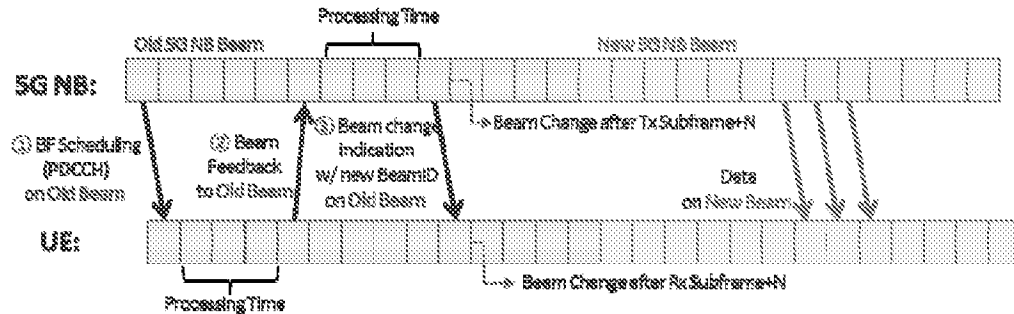


Figure is a diagram that describes a successful beam feedback procedure and beam change.

- **[Embodiment I-1]** eNB (5G Node-B or 5G NB) and UE perform beam feedback resource allocation, beam feedback using the allocated resource, and beam change, based on the following procedure.

- 1) eNB determines and notifies a beam feedback period
 - A. eNB is capable of setting a cycle or a time interval during which beam feedback is performed one or more times.
 - B. eNB is capable of notifying individual UEs of the set cycle or the set time interval. The notification method may be one of the following message transmissions:
 - i. Notify an RRC message that contains an element specifying a beam feedback duration
 - ii. Notify a Downlink Control message (via PDCCH) that contains an element specifying a beam feedback duration
 - iii. Notify a Downlink MAC-CE message (via PDSCH) that contains an element specifying a beam feedback duration
 - iv. Notification using a method capable of containing an element specifying a beam feedback duration
 - C. Candidates of a cycle or a time interval which can be set are as

follows:

- i. Full beam sweep duration: a period of time that UE takes to observe all beam pairs of UE and an eNB
- ii. 5G NB Tx Beam Sweep duration: a period of time that UE takes to observe all eNB beam pairs for one UE beam
- iii. Every Beam Reference Signal measurement duration: a least beam observation cycle of UE (e.g., Beam Reference Signal subframe transmission time interval)
- iv. Any specified time interval

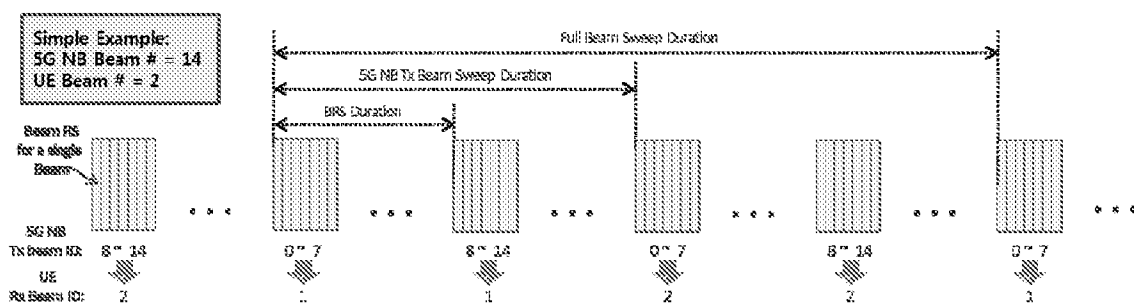


Figure 1 is a diagram showing three types of beam-related interval as a candidate for a beam feedback cycle/interval

2) Procedure 1: eNB may allocate a beam feedback resource for corresponding UE before a preset cycle of beam feedback has elapsed from the previous beam feedback.

- A. eNB may perform the allocation of a corresponding resource, periodically, during each a fixed time interval, using a preset, specified resource. eNB may also allocate a corresponding resource, adaptively, according to the channel quality and the resource usage state.
- B. Corresponding resource may be allocated by one of the following methods:
 - i. Periodically allocate a fixed resource via an RRC message.
 - ii. Allocate an Uplink resource (PUCCH/ PUSCH) via a PDCCH.
 1. The allocated PDCCH resource may be used for eNB to perform transmission to a corresponding UE and to allocate a resource after beam feedback is transmitted

and before a preset cycle of beam feedback has elapsed.

A. eNB allocates a beam feedback resource to corresponding UE before the cycle of beam feedback has elapsed, as follows.

i. eNB allocates a resource which is estimated as the last uplink time/frequency/beam resource that the eNB can allocate to a specified UE before a cycle of beam feedback has elapsed from a timing point that the eNB received beam feedback transmitted from the UE.

ii. Allocation using the first uplink time/frequency/beam resource that eNB can allocate to specified UE after a specified timing point (e.g., half, 3/4, 4/5, etc.) within a cycle of beam feedback from a timing point that the eNB received beam feedback transmitted from the UE.

2. The allocated PDCCH resource may be used for eNB to perform transmission to corresponding UE and to allocate a resource after beam feedback is transmitted and after a preset cycle of beam feedback has elapsed.

A. eNB allocates a beam feedback resource to corresponding UE after the cycle of beam feedback has elapsed, as follows.

i. Allocation using the first uplink time/frequency/beam resource that the eNB can allocate to specified UE after a cycle of beam feedback has elapsed from a timing point that the eNB received beam feedback transmitted from the UE.

3. The transmission of an allocated PDCCH resource may be used for UE to update an expiration timer of a preset cycle of beam feedback, without determining whether the cycle of beam feedback has elapsed.

- 3) Procedure $\perp$: UE feeds back information regarding one best beam or one or more multiple beams via an allocated resource.
- A. Feedback of the beam information is performed via one of the following channel:
- i. Uplink transmission control channel (PUCCH)
 - ii. Uplink transmission shared data channel (PUSCH)
 - iii. Uplink transmission control channel and data channel (PUCCH and PUSCH)
 1. The number of uplink transmission beams is reported via PUCCH (PUCCH transmission including an element including the number of beams requested for transmission); a resource is collocated; and corresponding beam IDs and the beam state information are transmitted via PUSCH
 - iv. A radio frequency and a time resource, available for uplink transmission
- B. Beam information feedback may include information regarding a number of beam pairs or a number of eNB beams, such as the quality and IDs of one or more beams.

Beam ID #1	Beam (channel) state information	Beam ID #2	Beam (channel) state information
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- 4) Procedure $\perp$: eNB: analyzes received beam feedback; ascertains that a beam of corresponding UE needs to be change; selects a corresponding beam; and transmits a beam change instruction including an ID of the selected beam.
- A. The beam change indication may be a frame including a specified beam ID.
- B. The eNB may transmit the beam change indication at any time, regardless of the beam feedback, in order to a scheduling beam for UE. However, it is more natural for the eNB to transmit, after

- receiving the beam feedback, a beam change indication, using information regarding a corresponding beam, and to perform beam change.
- C. Channel for the beam change indication may be one of the following:
- i. Downlink transmission control channel (PDCCH)
 - ii. Downlink transmission shared data channel (PDSCH)
- D. eNB: transmits the beam change indication; allocates a resource which corresponding UE will use, via a corresponding beam, after a preset period of time (or a present number of subframes); and sets a corresponding beam as a serving beam for the UE (i.e., a current best beam, a current serving beam).
- E. UE: receives the beam change indication; recognizes that a corresponding eNB will allocate a resource corresponding UE, via a corresponding beam, after a preset period of time (or a preset number of subframes); and sets a corresponding beam as a serving beam for the eNB (i.e., a current best beam, a current serving beam).
- F. The embodiment may be implanted in such a way that: when the eNB receives beam feedback and then transmits the beam change indication within a preset period of time, UE receives the indication within a corresponding period of time. In this case, the beam change indication may serve as ACK/NACK in response to the beam feedback.
- i. In a state where the beam change indication serves as ACK/NACK, when UE receives a beam change indication of NACK or has not receives a beam change indication, in response to its beam feedback, it may perform the following operations:
 1. Transmission of beam feedback transmission through the transmission of a resource allocation request (Scheduling request)
 2. Transmission of beam feedback through RACH

transmission

3. Wait until the next beam feedback transmission, not in operation.

5) ACK in response to beam change indication

A. ACK is received

- i. After performing the transmission/reception of a Beam Change Indication (after K subframes after the transmission/reception), eNB and UE change their serving beam right after a specified time
- ii. If a beam does not need to be changed (best beam = current serving beam), the indication is not transmitted.
- iii. If a beam needs to be changed or UE fails in receiving an indication from an eNB,
 1. eNB changes the current beam to a new beam
 2. UE continues using the current beam

A. UE may re-set a beam according to the following procedure as in **[Embodiment I-2]**

B. ACK is not received

- i. After performing the transmission/reception of a Beam change Indication, eNB and UE performs the transmission/reception of ACK/NACK to each other, within a preset period of time, the eNB and UE change their serving beam right after a specified time (after K subframes after the transmission/reception) only when a corresponding ACK is transmitted/received.
- ii. In this case, the ACK may be transmitted via PUCCH/ PUSCH, etc. The ACK needs to be transmitted/received within a period of time after the transmission/reception of a Beam change indication.

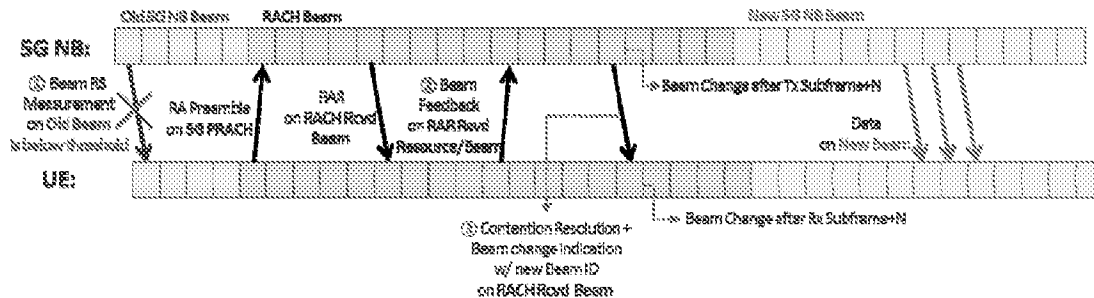
- With reference to Fig. 1, the 'processing time' is referred to a period of time required for the eNB and UE to analyze received information and to package information for transmission. The information transmission

time is allocated and set to a fixed resource according to the standard or may be longer than a period of time that information takes to be actually transmitted. eNB manages information transmission in such a way that it receives information and sets a transmission time for the next information in response to the received information to be longer than the 'processing time'.

- **[Embodiment I-2]** When the allocation of a beam feedback resource, the transmission of beam feedback, the transmission of a beam change indication, etc., are performed, UE triggers Beam Feedback as follows.

- 1) When the performance of a beam that has been used becomes low,
 - A. If {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been measured and used < Threshold} & {the quality of a 5G NB Beam (or a new best beam pair) that has not been used > Threshold} → UE triggers transmission of beam feedback using an interval in which an eNB performs reception, sweeping a beam.
 - i. The threshold is referred to as an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) with which an eNB and UE compare the channel quality of a corresponding beam. If the eNB and UE ascertain that the value is less than or equal to the threshold, they determine that the channel quality is not suitable for communication.
 - ii. The eNB may notify the UE of the threshold (a notification method: a specified message in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter in a DCI, etc.). The threshold may also be set by UE.
 - iii. Transmission of beam feedback using an RACH may be performed in such a way that beam feedback is included in a msg.3 of an RACH and is then transmitted along therewith as shown in the following drawing.
 - iv. If beam change is needed, a beam change indication is

included in a contention resolution serving as a msg.4 of an RACH, and is then transmitted along therewith as shown in the following drawing



- v. The beam feedback or the beam change indication message may be transmitted/received by an RACH Received Beam which is changed from a current serving beam via an RACH procedure, separately from an RACH message.
- i. It should be understood that the beam feedback method is not limited to RACH. That is, beam feedback may be transmitted in any interval in which an eNB can perform reception, sweeping a beam.

- 2) When the performance of a beam that has been used becomes low,
 - A. If {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been measured and used < Threshold_out} & {the quality of a 5G NB Beam (or a new best beam pair) that has not been used > Threshold_in} → UE triggers transmission of beam feedback using an interval in which an eNB performs reception, sweeping a beam.
 - i. The threshold_out may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) that an eNB and UE use to determine that the channel quality of a corresponding beam is not suitable for communication with each other.
 - ii. The threshold_in may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR,

etc.) that an eNB and UE use to determine that the channel quality of a corresponding beam is suitable for communication with each other.

- iii. The eNB may notify the UE of the threshold_out and the threshold_in (a notification method: a specified parameter in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter of a DCI, etc.). The threshold_out and the threshold_in may also be set by UE.
- iv. If the condition is satisfied, the UE may perform the transmission of beam feedback as follows.
 - 1. If uplink is synchronized, UE transmits, to an eNB capable of transmitting a preamble of a relatively short cyclic prefix according to uplink synchronization, a corresponding preamble in uplink and requests a resource for beam feedback therefrom, in an interval in which the eNB performs reception, sweeping a beam. If the UE is allocated the requested resource, it performs the transmission of beam feedback.
 - A. UE may transmit a corresponding preamble when an eNB performs reception using a specified beam (which is a beam to which the UE desires to change an existing beam) in an interval in which the eNB performs reception, sweeping a beam, thereby requesting the eNB to change a beam to a corresponding beam. In this case, the eNB may change a beam to a corresponding beam in response to the request or may transmit a signal for instructing beam change, without allocating a resource.
 - B. If an interval in which a preamble for beam change is transmitted is an interval in which a Scheduling Request is transmitted, beam feedback may be included in an UL Grant resource of an SR and then transmitted along therewith.

- C. If beam change is needed, an eNB may transmit a beam change indication in response to beam feedback.
- 2. If uplink is not synchronized or if, although uplink is synchronized, UE is not allocated a preamble with a relatively short cyclic prefix by an eNB, the UE transmits a preamble, arbitrarily selected based on contention or contention-free, or a preamble with a relatively long cyclic prefix allocated by the eNB, in an interval in which the eNB perform reception, sweeping a beam, thereby requesting an uplink resource from the eNB and transmitting beam feedback via the allocated uplink resource.
 - A. UE may transmit a corresponding preamble when an eNB performs reception using a specified beam (which is a beam to which the UE desires to change an existing beam) in an interval in which the eNB performs reception, sweeping a beam, thereby requesting the eNB to change a beam to a corresponding beam. In this case, the eNB may change a beam to a corresponding beam in response to the request or may transmit a signal for instructing beam change, without allocating a resource.
 - B. If an interval in which a preamble for beam change is transmitted is an RACH, beam feedback may be included in an msg. 3 of an RACH and then transmitted along therewith.
 - C. If beam change is needed, a beam change indication is included in a contention resolution, i.e., an msg.4 of the RACH, and then transmitted.
- v. It should be understood that the beam feedback method is not limited to RACH. That is, beam feedback may be transmitted in any interval in which an eNB can perform reception, sweeping a beam.

- 3) Beam feedback when a target beam which has a higher performance than an existing serving beam is discovered
 - A. If {the quality of a 5G NB Beam (or a scheduling beam pair) that has been measured and used > Threshold_in} & {the quality of a newly measured 5G NB Beam (or a new best beam pair) > an existing serving 5G NB Beam + Threshold2} → UE triggers transmission of beam feedback using an interval in which an eNB performs reception, sweeping a beam
 - i. The threshold_in may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) that an eNB and UE use to determine that the channel quality of a corresponding beam is suitable for communication with each other.
 - ii. The eNB may notify the UE of the threshold_in and the Threshold2 (a notification method: a specified parameter in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter of a DCI, etc.). The threshold_in and the Threshold2 may also be set by UE.
 - B.
 - i. A pre-allocated resource is required which can transmit an RS via a beam that has been used.
 - C. Although the condition, item A, is satisfied, if an allocated SR transmission resource does not exist within a period of time (e.g., x subframes or y msec) or from the beginning → Transmission of beam feedback using an RACH is performed.
- 4) Beam feedback when a target beam which has a higher performance than an existing serving beam is discovered
 - A. If {the quality of a newly measured 5G NB Beam (or a new best beam pair)} > {an existing serving 5G NB Beam + offset_trigger} → UE triggers transmission of beam feedback using an interval in which an eNB performs reception, sweeping a beam

- i. The offset_trigger is referred to as a value representing the difference between the two beam quality levels. The offset_trigger may be a difference (e.g., dB) between estimation or measurement values of beam channels (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.).
 - ii. The eNB may notify the UE of the offset_trigger (a notification method: a specified parameter in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter of a DCI, etc.). The offset_trigger may also be set by UE.
- B.
- i. A pre-allocated resource is required which can transmit an RS via a beam that has been used.
- C. Although the condition, item A, is satisfied, if an allocated SR transmission resource does not exist within a period of time (e.g., x subframes or y msec) or from the beginning → Transmission of beam feedback using an RACH is performed.

5) When beam feedback is not transmitted within a Timer (=beam feedback cycle)

Define Threshold1 = Threshold of beam quality which determines the availability of wireless communication using the beam.

Define Feedback_Timer = timer reset whenever beam feedback transmitted

- A. If {Feedback_Timer expires} & {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been measured and used $\geq$ threshold_in} → UE triggers transmission of beam feedback using an interval in which an eNB performs reception, sweeping a beam
- i. The threshold_in may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) that an eNB and UE use to determine that the channel

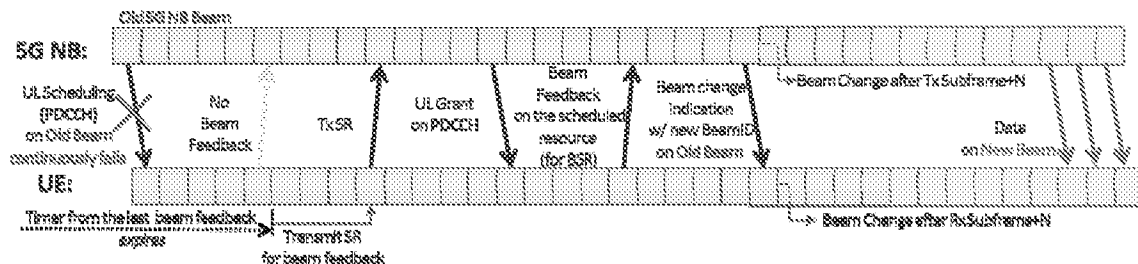
quality of a corresponding beam is suitable for communication with each other.

- ii. The eNB may notify the UE of the threshold_{in} (a notification method: a specified parameter in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter of a DCI, etc.). The threshold_{in} may also be set by UE.

B.

- i. If the quality of a beam (or a beam pair) that has been used is greater than or equal to a threshold, UE, which has not transmitted beam feedback during a specified cycle, is allocated an SR resource by an eNB, and transmits beam feedback through the allocated resource.
 1. After transmitting an SR for corresponding beam feedback, UE may be allocated a resource for a buffer size request (BSR), with an UL Grant, by an eNB.
 2. In this case, corresponding UE may transmit beam feedback using the resource allocated with an UL Grant.
 3. In this case, corresponding UE may transmit a BSR for beam feedback, using a resource allocated with an UL Grant

A. If UE has transmitted a BSR, it may transmit beam feedback in uplink using a resource allocated by a corresponding eNB.



- C. Else If {Feedback_Timer expires} & {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been measured and

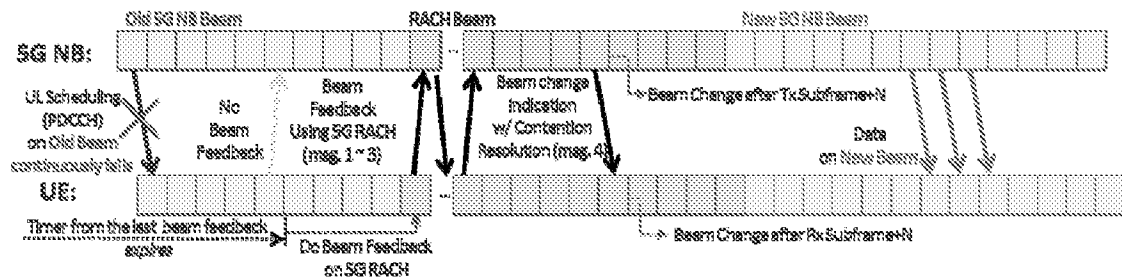
used < Threshold1} & {the quality of a measured 5G NB Beam (or a scheduling beam pair) > Threshold1} → Transmission of beam feedback using an RACH.

- i. If the quality of a beam (or a beam pair) that has been used is less than or equal to a threshold, UE, which has not transmitted beam feedback during a specified cycle, is capable of transmitting, to an eNB, information, and Beam Feedback, via a random access channel, using a random access protocol.
 1. Transmission of beam feedback using an RACH may be performed in such a way that beam feedback is contained in an msg.3 of an RACH and then transmitted via the message, as shown in the following drawing.
 2. If a beam needs to be changed, the beam change indication is contained in a contention resolution as an msg.4 of an RACH and then transmitted along therewith, as shown in the following drawing.
 3. The beam feedback or the beam change indication message may be transmitted/received by an RACH Received Beam which is changed from a current serving beam via an RACH procedure, separately from an RACH message.

D. A condition substituting item No. C) or Else If {Feedback_Timer expires} & {the quality of a 5G NB Best Beam (or Best beam pair) that has been measured and used < Threshold1} → Transmission of beam feedback using an RACH.

- i. If the quality of a beam (or a beam pair) that has been used is less than or equal to a threshold, UE, which has not transmitted beam feedback during a specified cycle, is capable of transmitting, to an eNB, information, and Beam Feedback, via a random access channel, using a random access protocol.

1. Transmission of beam feedback using an RACH may be performed in such a way that beam feedback is contained in an msg.3 of an RACH and then transmitted via the message, as shown in the following drawing.
2. If a beam needs to be changed, the beam change indication is contained in a contention resolution as an msg.4 of an RACH and then transmitted along therewith, as shown in the following drawing.
3. The beam feedback or the beam change indication message may be transmitted/received by an RACH Received Beam which is changed from a current serving beam via an RACH procedure, separately from an RACH message.

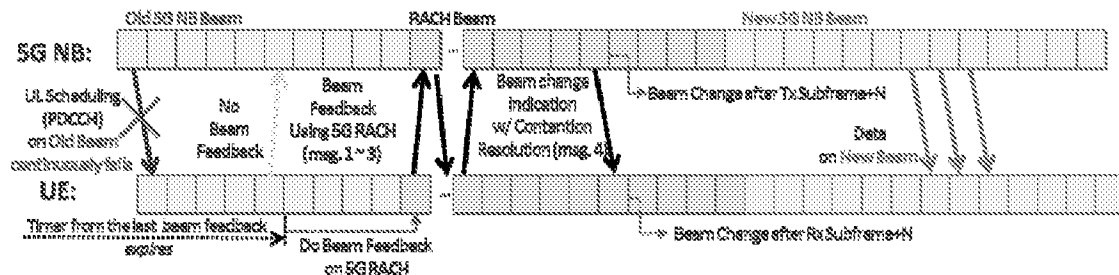


- 6) Alternatively, as a procedure substituting the procedure of item No. 3), when beam feedback is not performed within a Timer (e.g., a beam feedback cycle), the beam feedback may be performed using an RACH.

- i. Define Feedback_Timer = timer reset whenever beam feedback transmitted
- ii. Define Threshold1 = Threshold of beam quality which determines the availability of wireless communication using the beam.
- iii. If (Feedback_Timer expires) & (There is at least one beam > Threshold1)
→ Transmission of beam feedback using an RACH
- iv. Transmission of beam feedback using an RACH may be performed in such a way that beam feedback is contained in

an msg.3 of an RACH and then transmitted via the message, as shown in the following drawing.

- v. If a beam needs to be changed, the beam change indication is contained in a contention resolution as an msg.4 of an RACH and then transmitted along therewith, as shown in the following drawing.
- vi. The beam feedback or the beam change indication message may be transmitted/received by an RACH Received Beam which is changed from a current serving beam via an RACH procedure, separately from an RACH message.



7) Alternatively, as a procedure substituting the procedure of item No. 3), when a downlink resource is not allocated to corresponding UE within a Timer (e.g., a beam feedback cycle), beam feedback may be performed using an RACH.

- Define PDCCH_Timer = timer reset whenever PDCCH received
- Define Threshold1 = Threshold of beam quality which determines the availability of wireless communication using the beam.
- If (PDCCH_Timer expires) & (There is at least one beam > Threshold1)
 ➔ Transmission of beam feedback using an RACH

[Method of triggering transmission of beam feedback based on UE events]

If UE meets the following conditions, it performs transmission of beam feedback via methods described in the next chapter.

1. If {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has

- been used < Threshold_out} & {the quality of a 5G NB Beam (or a new best beam pair) that has not been used > Threshold_out}
2. If {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been used < Threshold_out} & {the quality of a 5G NB Beam (or a new best beam pair) that has not been used > Threshold_in}
 3. If {the quality of a newly measured 5G NB Beam (or a new best beam pair)} > {the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been used + offset_trigger}
 4. If {the quality of a 5G NB Beam (or a scheduling beam pair) that has been measured and used > Threshold_in} & {the quality of a newly measured 5G NB Beam (or a new best beam pair) > the quality of a 5G NB Best Beam (or a scheduling beam pair) that has been used + offset_trigger}
 5. If (uplink beam feedback is not transmitted within a specified timer: timer expired)
 6. If { uplink beam feedback is not transmitted within a specified timer: timer expired) } & {the other conditions (1~4) are satisfied}
7. Definition of thresholds used for the conditions:
- i. The threshold_out may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) that an eNB and UE use to determine that the channel quality of a corresponding beam is not suitable for communication with each other.
 - ii. The threshold_in may be an absolute channel estimation or measurement value (e.g., RSRP, RSRQ, RSSI, CQI, SNR, etc.) that an eNB and UE use to determine that the channel quality of a corresponding beam is suitable for communication with each other.
 - iii. The eNB may notify the UE of the offset_trigger (a notification method: a constant described in the standard, a specified parameter in an RRC message, MAC data, a specified parameter in an MAC-CE, a specified parameter in an DCI, etc.). The offset_trigger may also be set by UE.
 - iv. The eNB may notify the UE of the threshold_out, threshold_in, and offset_trigger (a notification method: constants described in the standard, specified parameters in an RRC message, MAC data, specified

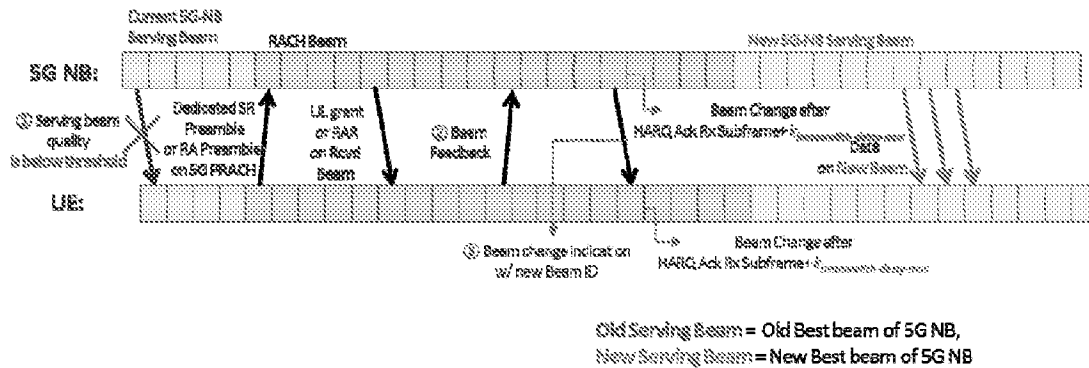
parameters in an MAC-CE, specified parameters in an DCI, etc.). The threshold_out, threshold_in, and offset_trigger may also be set by UE.

[Method of transmitting beam feedback based on UE events]

If the condition is satisfied, UE may perform the transmission of beam feedback as follows.

1. If uplink is synchronized (if timeAlignmentTimer has not expired or a condition is satisfied), UE transmits, to an eNB capable of transmitting a preamble of a relatively short cyclic prefix according to uplink synchronization, a corresponding preamble in uplink and requests a resource for beam feedback therefrom, in an interval in which the eNB performs reception, sweeping a beam. If the UE is allocated the requested resource, it performs the transmission of beam feedback.
 - A. UE may transmit a corresponding preamble when an eNB performs reception using a specified beam (which is a beam to which the UE desires to change an existing beam) in an interval in which the eNB performs reception, sweeping a beam, thereby requesting the eNB to change a beam to a corresponding beam. In this case, the eNB may change a beam to a corresponding beam in response to the request or may transmit a signal for instructing beam change, without allocating a resource.
 - B. If an interval in which a preamble for beam change is transmitted is an interval in which a Scheduling Request is transmitted, beam feedback may be included in an UL Grant resource of an SR and then transmitted along therewith.
 - C. If beam change is needed, an eNB may transmit a beam change indication in response to beam feedback.
2. If uplink is not synchronized or if, although uplink is synchronized, UE is not allocated a preamble with a relatively short cyclic prefix by an eNB, the UE transmits a preamble, arbitrarily selected based on contention, or a preamble that an eNB allocates based on contention-free, in an interval in which the eNB perform reception, sweeping a beam, thereby requesting an uplink resource from the eNB and transmitting beam feedback via the allocated uplink resource.

- D. UE may transmit a corresponding preamble when an eNB performs reception using a specified beam (which is a beam to which the UE desires to change an existing beam) in an interval in which the eNB performs reception, sweeping a beam, thereby requesting the eNB to change a beam to a corresponding beam. In this case, the eNB may change a beam to a corresponding beam in response to the request or may transmit a signal for instructing beam change, without allocating a resource.
 - E. If an interval in which a preamble for beam change is transmitted is an RACH, beam feedback may be included in an msg. 3 of an RACH and then transmitted along therewith.
 - F. If beam change is needed, a beam change indication is included in a contention resolution, i.e., an msg. 4 of the RACH, and then transmitted.
3. Corresponding UE may transmit, to an eNB, a transmittable message requesting resource allocation, a message transmitting beam feedback or a message requesting beam change, regardless of uplink synchronization, in an interval the eNB performs reception, sweeping a beam, thereby notifying the eNB that the corresponding UE needs to change a beam.
- G. UE may transmit, to an eNB, a signal that the eNB can receive and has previously regulated with the UE. The corresponding signal may be a signal of a relatively very short length (short preamble/beacon/reference signal/pilot signal) which can be transmitted via a relatively narrow frequency band which has been regulated between the eNB and UE.
 - H. If the eNB receives a corresponding signal and needs to determine whether the received signal is transmitted from specified UE, it may perform corresponding operations and also operations to change a scheduling beam for corresponding UE.
4. Alternatively, UE may transmit beam feedback in the form of piggyback (MAC-CE) or multiplexing (UCI) of uplink Data via a pre-allocated resource for uplink transmission.
5. It should be understood that the beam feedback method is not limited to RACH. That is, beam feedback may be transmitted in any interval in which an eNB can perform reception, sweeping a beam.



[Method of selecting and transmitting feedback beam of UE]

If beam feedback can be performed, based on events and via resources allocated by an eNB, as described above, UE is capable of selecting a beam via the following methods, and performing feedback based on the selected beam.

1. Method of selecting a feedback beam
 - A. Feedback (1 or N) in order of quality of measured/estimated beam from the best
 - B. Offset-based beam feedback
 - i. BSI feedback (new beam) if the new beam's $BRSRP > \text{serving beam's } BRSRP + \text{beamReportingRSRPoffset dB}$
 - ii. If not, the serving beam is reported.
2. N and $\text{beamReportingRSRPoffset}$ may be constants described in the standard. Alternatively, N and $\text{beamReportingRSRPoffset}$ may be set by an eNB, using an RRC message, DCI, etc. or may be set or selected by UE.
3. Method of transmitting beam feedback
 - A. Beam feedback may be transmitted in such a way that uplink control information containing information regarding beam feedback is multiplexed by a method that an eNB has notified through DCI scheduling corresponding beam feedback, and then transmitted.
 - B. Beam feedback may be transmitted in the form of MAC-CE as follows.

6.1.3.9 BSI Feedback MAC Control Element

The Beam State Information (BSI) Feedback MAC control element is identified by a 5G-MAC PDU subheader with LCID as specified in table 6.2.1-2. It consists of N BSI fields, corresponding to N beams. The field BSI is defined as follows:

- BI (9-bit) : this field indicates the beam index;
- BRSRP (7-bit): this field indicates the beam reference signal received power of the beam.

The BSI Feedback MAC control element is defined as follows (figure 6.1.3.9-1).

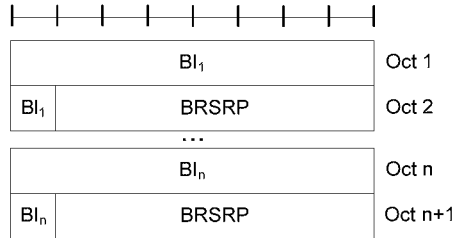


Figure 6.1.3.9-1: BSI Feedback MAC control element

Although the MAC-CE is described in such a way that BI is 9 bits in length, it should be understood that the length may be less than 8 bits or greater than 9 bits.

An example of a 3-bit BI is described as follow:

6.1.3.x RBSI Feedback MAC Control Element

The Refined Beam State Information (RBSI) MAC control element is identified by a 5G-MAC PDU subheader with LCID as specified in table 6.2.1-2. It has a fixed size and consists of a 3-bit RBI field and 7-bit RB-RSRP field. The RBSI Feedback MAC control element is defined as follows (figure 6.1.3.x-1).

- RBI (3-bit) : this field indicates the beam index;
- RB-RSRP (7-bit): this field indicates the received RSRP of the beam;
- R: reserved bit, set to "0".

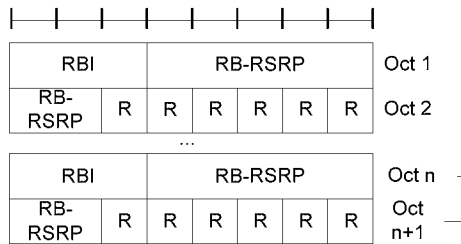


Figure 6.1.3.x-1: RBSI Feedback MAC control element

Although the MAC-CE is described in such a way as to include only eNB's beam information (Beam ID), it should be understood that it may also include a UE's beam ID (or a UE port, UE beam direction, the number of UE beams, etc.) as follows.

6.1.3.9 BSI Feedback MAC Control Element

The Beam State Information (BSI) Feedback MAC control element is identified by a 5G-MAC PDU subheader with LCID as specified in table 6.2.1-2. It consists of N BSI fields, corresponding to N beams. The field BSI is defined as follows:

- BI_1 (9-bit) : this field indicates the Node-B beam index;
- BI_2 (9-bit) : this field indicates the UE beam index;
- BRSRP (7-bit): this field indicates the beam reference signal received power of the beam.

The BSI Feedback MAC control element is defined as follows (figure 6.1.3.9-1).

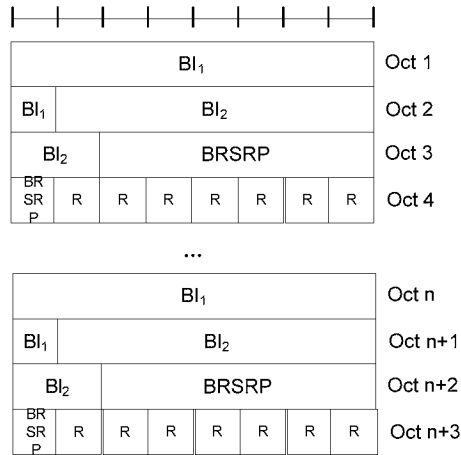


Figure 6.1.3.9-1: BSI Feedback MAC control element

[Beam change method of UE/eNB]

1. eNB changes a scheduling beam of UE in such a way to transmit, to UE, an MAC-CE including a beam change indication containing information regarding a desired beam to which an existing beam is changed, as follows.
 - A. If an MAC-CE is transmitted, UE and an eNB may change a beam after a specified subframe from a subframe transmitting/receiving HARQ ACK/NACK of MAC-CE.
 - i. The eNB may notify information regarding a corresponding subframe via an RRC, MAC, and PHY message. The information regarding a corresponding subframe may be a constant described in the standard.
 - ii. An example of the MAC-CE structure of a beam change message that an eNB can transmit in order to change a corresponding beam is shown in the following diagram. Although the example includes

only a beam ID of an eNB changing a beam, it should be understood that the MAC-CE may also include a beam ID of UE (or a UE port, UE beam direction, the number of UE beams, etc.).

6.1.3.7 BRS Beam Change Indication MAC Control Element

The BRS Beam Change Indication MAC control element is identified by a 5G-MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a 9-bit BI field. The BRS Beam Change Indication MAC control element is defined as follows (figure 6.1.3.7-1).

- BI (9-bit) : this field indicates the beam index;
- R : reserved bit, set to “0”.

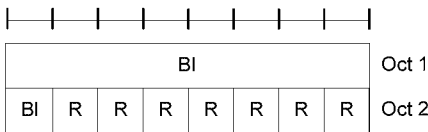


Figure 6.1.3.7-1: BRS Beam Change Indication MAC control element

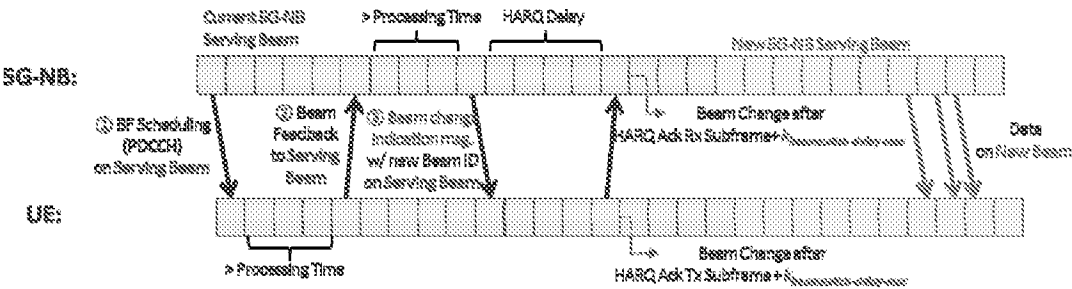
6.1.3.8 BRRS Beam Change Indication MAC Control Element

The BRRS Beam Change Indication MAC control element is identified by a 5G-MAC PDU subheader with LCID as specified in table 6.2.1-1. It has a fixed size and consists of a 3-bit RBI field. The BRRS Beam Change Indication MAC control element is defined as follows (figure 6.1.3.8-1).

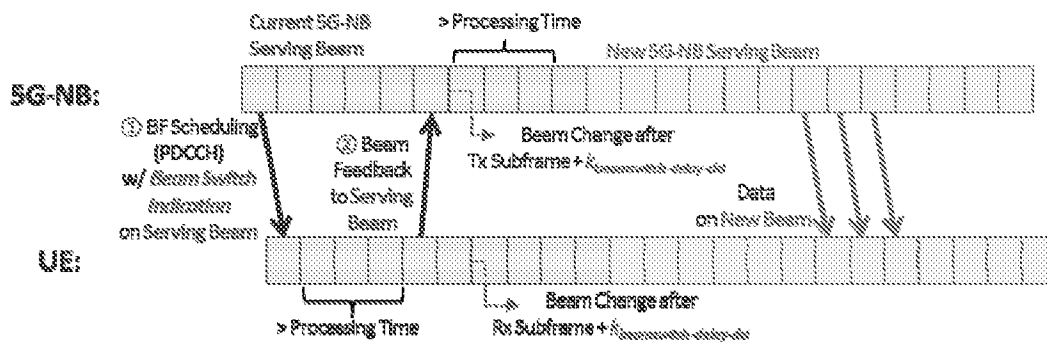
- RBI (3-bit) : this field indicates the beam index;
- R : reserved bit, set to “0”.



Figure 6.1.3.8-1: BRRS Beam Change Indication MAC control element



2. An eNB may perform beam change in such a way as to: allocate a beam feedback resource to UE; add a beam change acceptance field using corresponding feedback to a resource allocation message; and change a beam immediately after a specified subframe without transmitting a specified indication message after beam feedback.



[Embodiment X]

The embodiment may be applied to an RACH procedure where UE performs: initial cell access, cell access after RLF occurred, access in a target cell during handover, beam recovery when determining beam misalignment, cell access in an idle mode due to paging reception or uplink data creation, etc.

For example, if UE performs initial cell access, an RACH procedure is described as follows.

If UE obtains downlink synchronization from an eNB and selects a beam (whose signal quality is greater than or equal to that of a best beam or a threshold) through which it can communicate with an eNB, it transmits an RACH preamble using a resource corresponding to the beam. The UE receives, from the eNB, an acknowledgement message (i.e., RAR message) in response to the RACH preamble, and determines whether the RAR message contains beam feedback indication information. If the RAR message contains beam feedback indication information, the UE transmits feedback in response to the beam of the eNB, according to the beam feedback indication information. The beam feedback indication information includes at least one of the following: the number of beams for feeding back an intensity level of signal; a resource for transmitting beam feedback; a transmission timing of beam feedback; a format of beam feedback (L1 signal including UCI or a higher layer message including MAC CE); a format of indicator instructing to change an existing beam to a beam reporting beam feedback (UE changes an existing beam to the reported beam, voluntarily or after receiving a beam change indication signal from an eNB); and timing information when an existing beam is changed to a beam reporting beam feedback. In another embodiment, allocation information regarding a resource

to transmit beam feedback may be received with being multiplexed with MSG4 or received after MSG4.

An eNB and UE, performing transmission/reception of beam feedback according to beam feedback indication information via the RAR message, may change a beam according to beam feedback information regarding the UE or may perform a procedure after the transmission/reception of beam feedback, while maintaining the current beam.

After receiving the RAR message, the UE transmits a beam feedback message/signal along with MSG3, according to the beam feedback indication. Alternatively, after receiving the RAR message, the UE transmits MSG3, and then beam feedback message/signal, according to the beam feedback indication information. Alternatively, after receiving the RAR message, the UE transmits a beam feedback message/signal before transmitting MSG3, according to the beam feedback indication information. The expression, 'after the MSG3 transmission,' is referred to as an interval between an MSG3 transmission timing and an MSG4 reception timing, using a separate resource and the MSG3. The expression, 'after the MSG3 transmission,' corresponds to a timing after the MSG3 transmission and the MSG4 reception, using a separate resource and the MSG3. The expression, 'after the MSG3 transmission,' corresponds to a timing after the MSG3 transmission or before the MSG4 reception, using a separate resource and the MSG3.

If UE is set to voluntarily change an existing beam to a reported beam according to the beam feedback indication information, the UE changes an existing beam to the reported beam at the beam change timing and then communicates with the eNB.

If UE is set to receive a beam change indication signal from an eNB and perform beam change according to the beam feedback indication information, the UE receives a beam change indication signal from an eNB, changes an existing beam to a beam instructed by the beam change indication signal, and then communicates with the eNB. The beam change timing information may be set to a system value or may be received from the eNB.

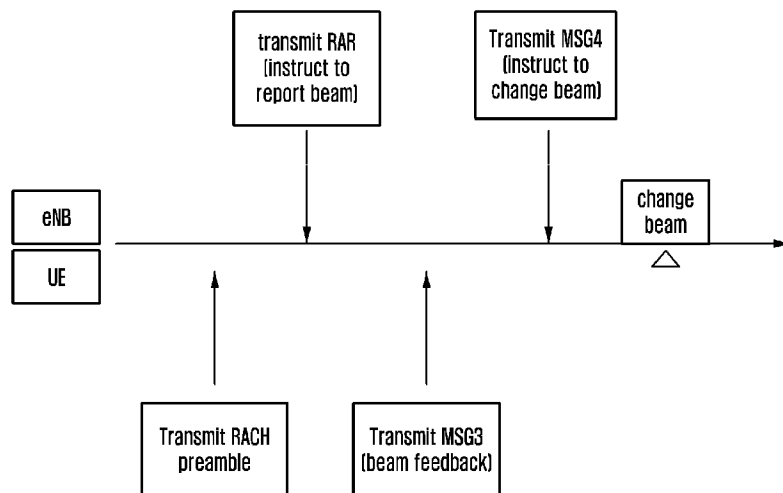
The beam change indication signal corresponds to: a signal transmitted via the

MSG4; an L1/higher layer signal transmitted along with the MSG4; or a signal transmitted separately from the MSG4. If the beam change indication signal corresponds to a signal transmitted separately from the MSG4, the transmission timing of the beam change indication signal corresponds to an interval between the MSG 3 transmission timing and the MSG 4 reception timing. If the beam change indication signal corresponds to a signal transmitted separately from the MSG4, the transmission timing of the beam change indication signal corresponds to a timing before the MSG3 transmission. If the beam change indication signal corresponds to a signal transmitted separately from the MSG4, the transmission timing of the beam change indication signal corresponds to a timing after the MSG4 reception.

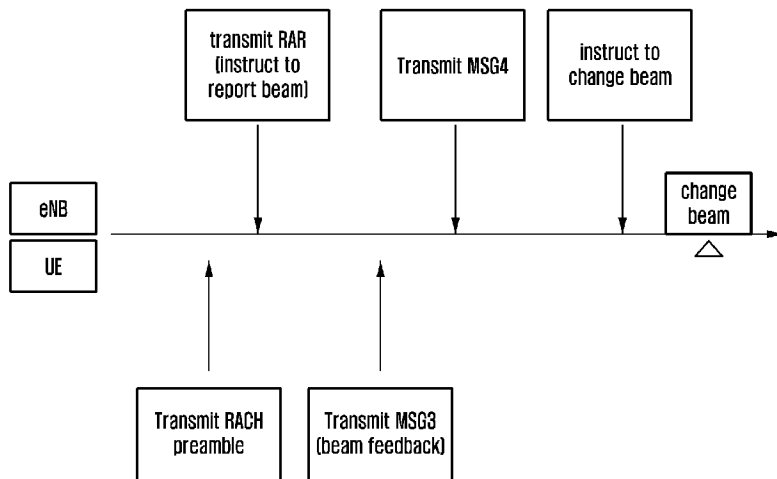
If the RAR message does not contain the beam feedback indication information, the UE may transmit beam feedback via MSG3 which is transmitted in response to the RAR message. If beam feedback is transmitted via the MSG3, the eNB may transmit a beam change indication via MSG4 or a separate signaling operation.

The following figures are diagrams showing various embodiments described above (however, not all embodiments are shown).

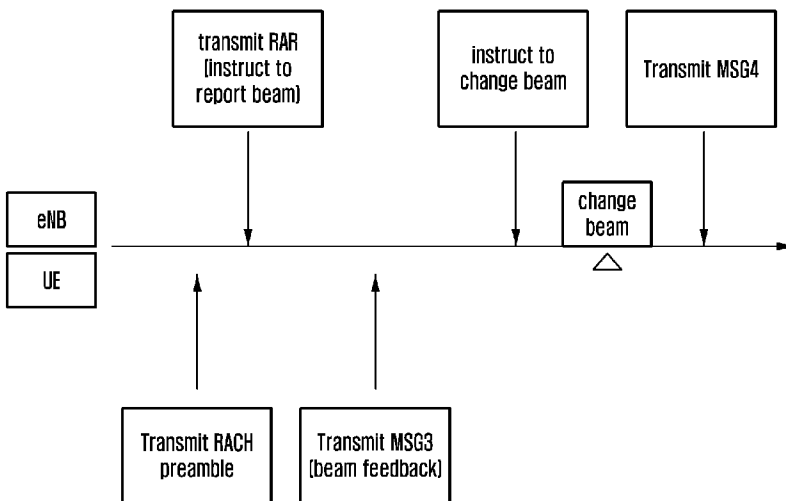
(Description of the figure: Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is contained in MSG4 or multiplexed with MSG4.)



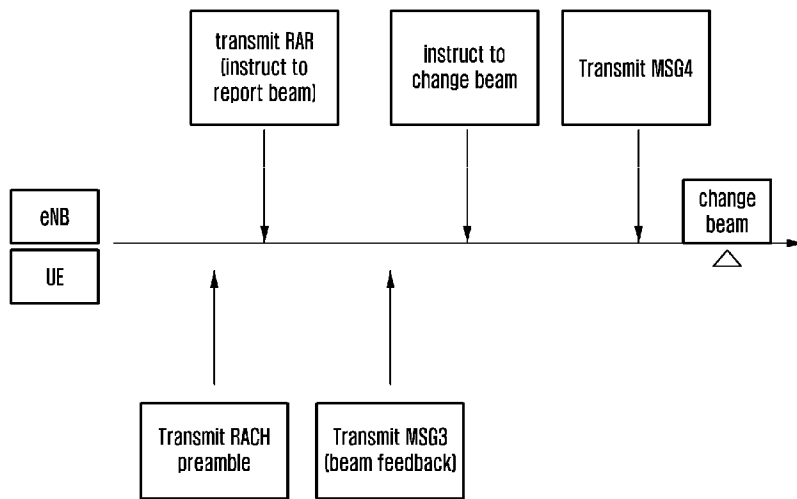
(Description of the figure: Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is transmitted after MSG4.)



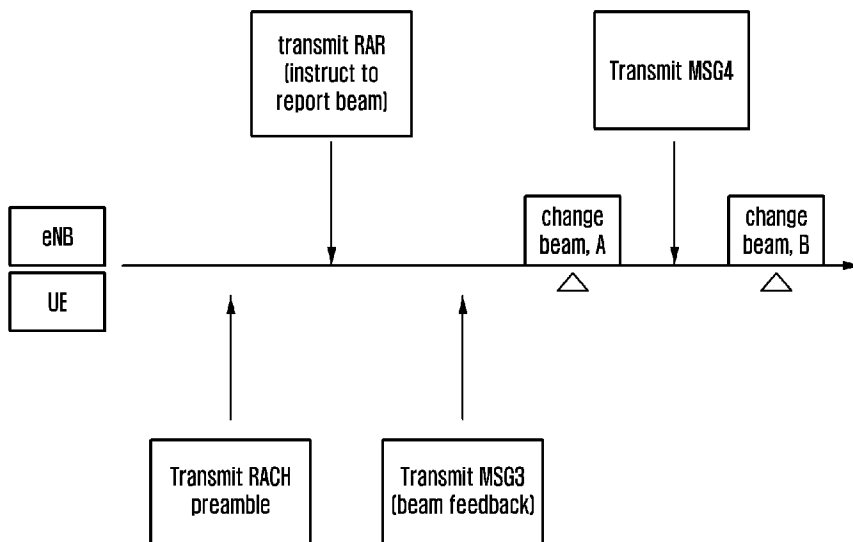
(Description of the figure: Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is transmitted separately before the transmission of MSG4. Beam change is performed before the transmission/reception of MSG4.)



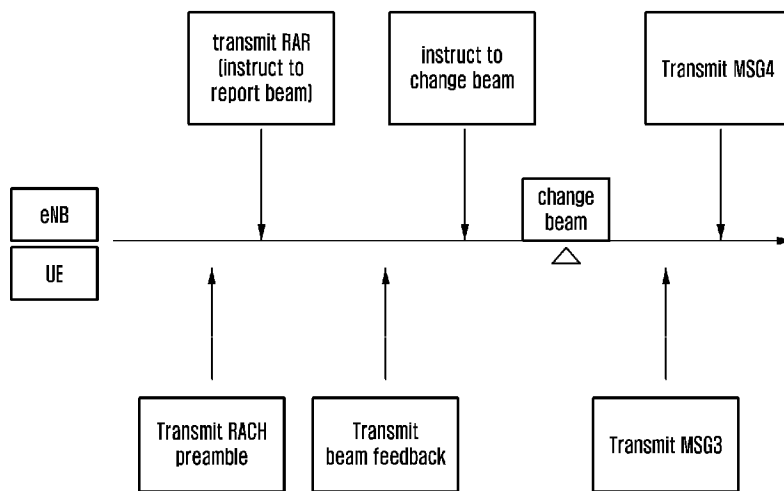
(Description of the figure: Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is transmitted separately before the transmission of MSG4. Beam change is performed after the transmission/reception of MSG4.)



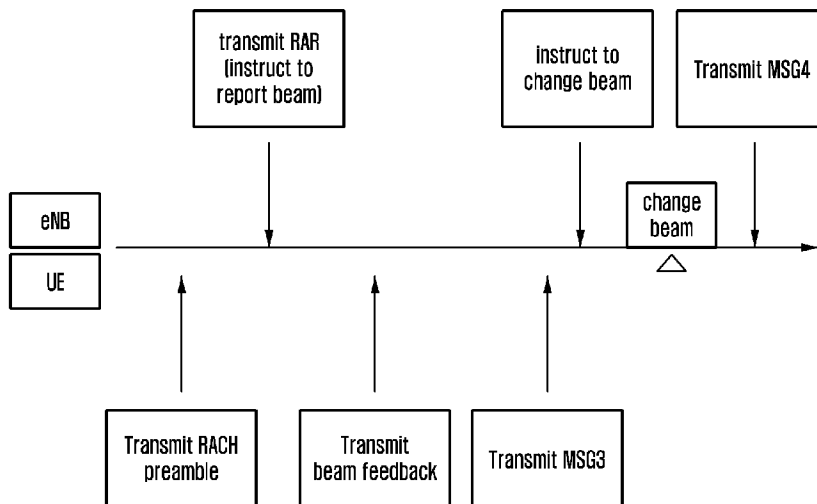
(Description of the figure: Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is not signaled (implicit beam change indication). Beam change is performed at a timing A or B)



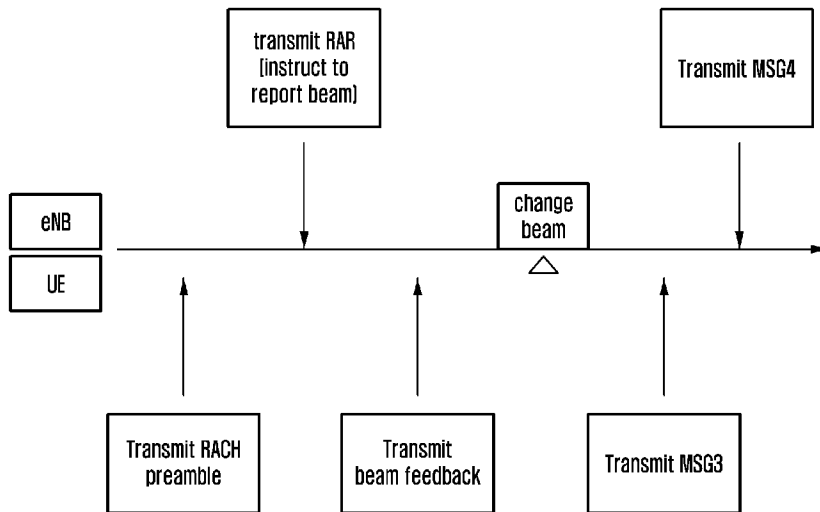
(Description of the figure: Beam feedback and Beam change indication are performed before the transmission/reception of MSG3/MSG4. Beam change is performed before the transmission of MSG3/MSG4)



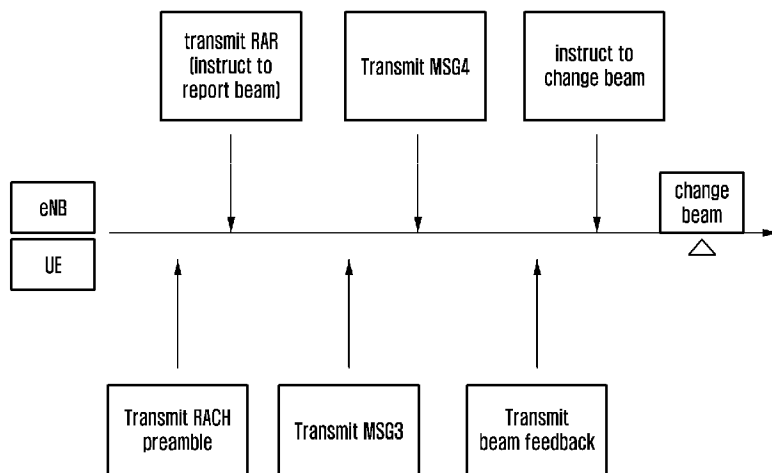
(Description of the figure: Beam feedback is transmitted before the transmission of MSG3. Beam change indication is performed between MSG3 and MSG4. Beam change is performed before MSG4)



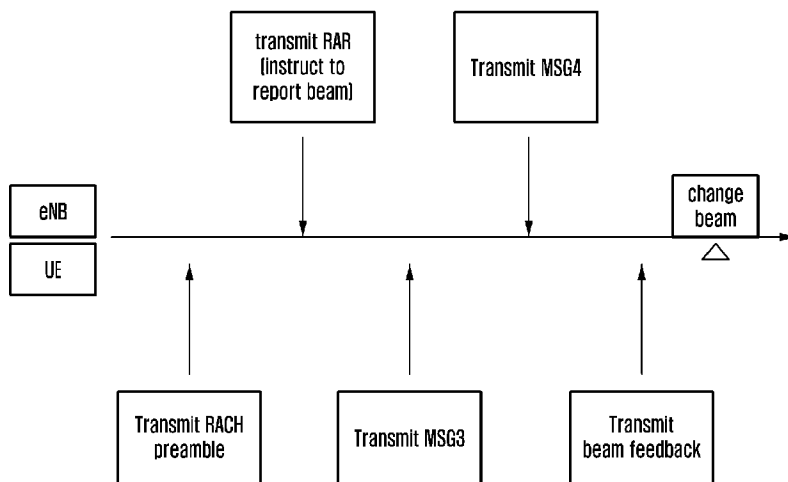
(Description of the figure: Beam feedback is transmitted before MSG3. Beam change indication is not performed (implicit beam change indication). Transmission/reception of MSG3/MSG4 is performed after beam change)



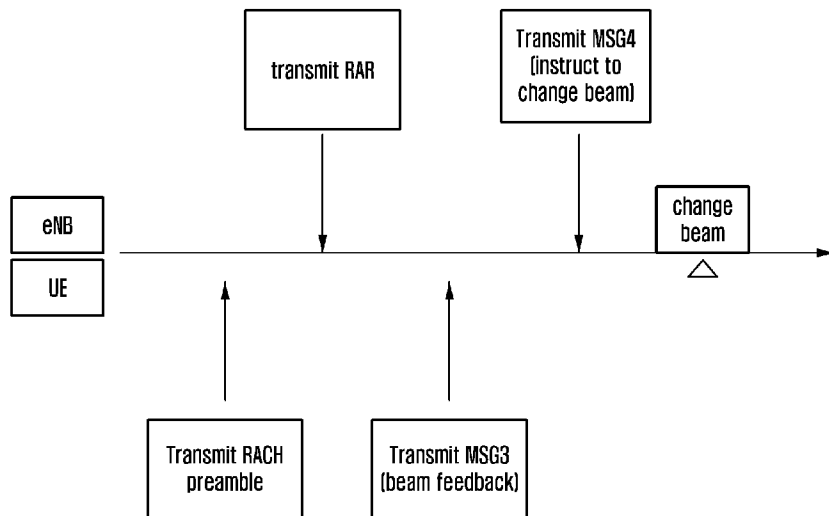
(Description of the figure: Beam feedback and Beam change indication are performed after the transmission/reception of MSG3/MSG4. Information regarding a beam feedback transmission resource is instructed via RAR transmission, via MSG4 transmission, or separately after the transmission of MSG4)



(Description of the figure: Beam feedback and Beam change indication are performed after the transmission/reception of MSG3/MSG4. Information regarding a beam feedback transmission resource is instructed via RAR transmission, via MSG4 transmission, or separately after the transmission of MSG4. Beam change indication is implicitly performed)



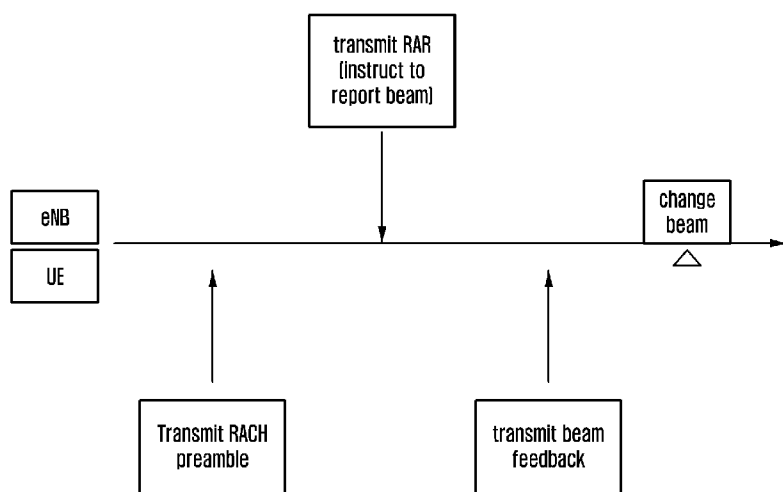
(Description of the figure: if an RAR message does not contain beam feedback indication information, beam change is performed, via MSG3 and MSG4, after the transmission/reception of beam feedback and a beam change indication, respectively. MSG4 contains information regarding an explicit beam change indication. Alternatively, MSG4 and an explicit beam change indication signal are multiplexed with each other.



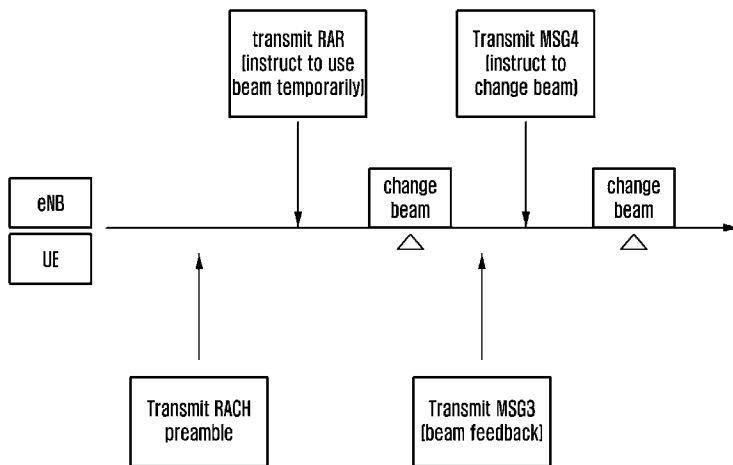
In the case of the RACH procedure performing handover to a target cell, UE and an eNB: perform the transmission/reception of an RAR message containing the beam

report indication information without performing the transmission/reception of MSG3 or MSG4; and perform the transmission/reception of beam feedback and a beam change signal via a separate signaling process after transmitting/receiving the RAR message. In this case, the beam report indication information contains at least one of the following: allocation information regarding a resource for a beam feedback signal, a condition as to whether an implicit/explicit beam change signal is transmitted, and allocation information regarding a resource for a beam change signal.

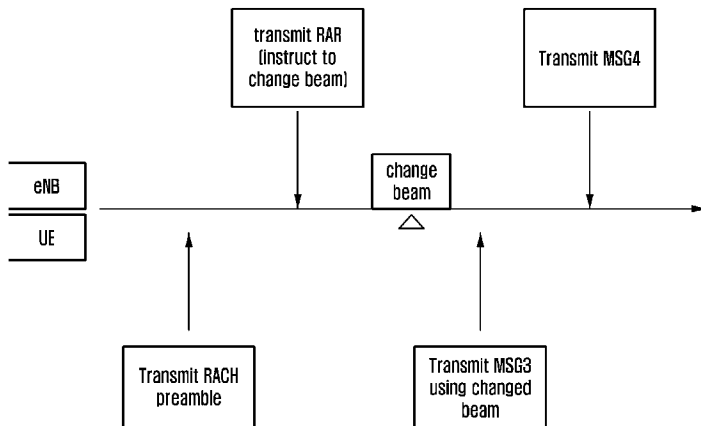
(Description of the figure: Beam feedback is transmitted after the transmission/reception of an RAR containing beam report indication information. Beam change is performed based on an implicit beam change indication)



(Description of the figure: An eNB allocates a resource by temporarily using a beam receiving an RACH preamble via an RAR. In this case, if the eNB receives one RACH preamble, it performs resource allocation for one beam. If the eNB receives two or more RACH preambles transmitted from the same UE, it may transmit an RAR using the best one of the received preambles. Beam feedback is contained in MSG3 or multiplexed with MSG3. A beam change indication is contained in MSG4 or multiplexed with MSG4.)

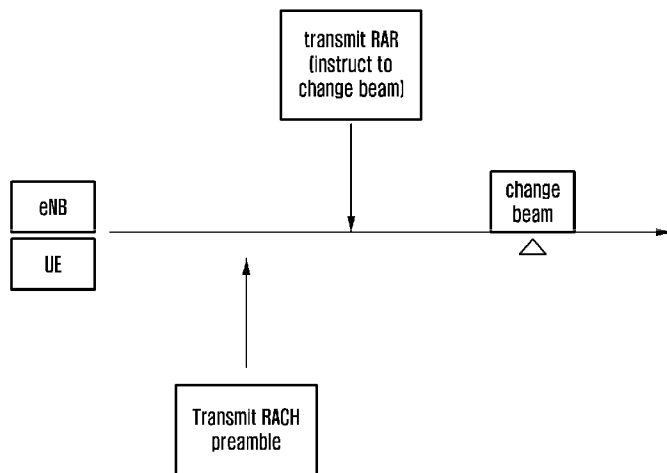


(Description of the figure: An eNB instructs to perform beam change in order to use a best beam receiving an RACH preamble via an RAR as a serving beam. In this case, if the eNB receives one RACH preamble, it performs resource allocation for one beam. If the eNB receives two or more RACH preambles transmitted from the same UE, it may transmit an RAR using the best one of the received preambles. The eNB and UE change an existing beam to a corresponding beam, and then perform the transmission of MSG3 and MSG4.)



(Description of the figure: Beam change is performed after the transmission/reception of an RAR containing beam change indication information. Beam change is performed based on an explicit beam change indication. A corresponding beam change indication may be transmitted, separately from an

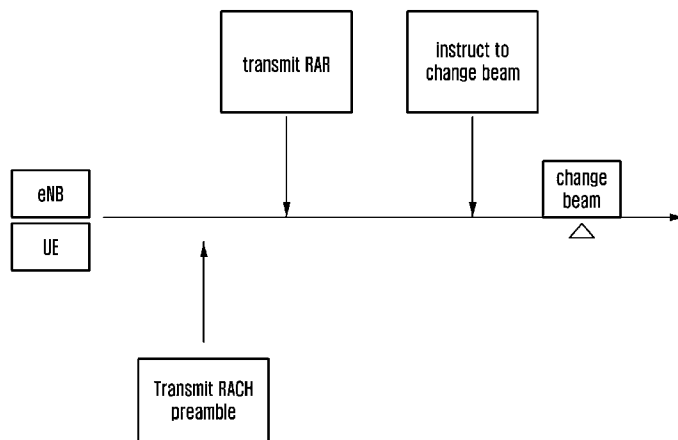
RAR.)



The beam change indication may be contained in the message in a form of MAC-CE, or may be multiplexed in a form of field in a DCI.

In the case of the RACH procedure performing handover to a target cell, UE and an eNB: perform the transmission/reception of an RAR message and a beam change indication message without performing the transmission/reception of MSG3 or MSG4; and change a serving beam to a corresponding beam. In this case, the beam report indication information may contain at least one of the following: allocation information regarding a resource for a beam feedback signal, a condition as to whether an implicit/explicit beam change signal is transmitted, and allocation information regarding a resource for a beam change signal.

(Description of the figure: Beam change is performed after the transmission/reception of an RAR containing beam change indication information. Beam change is performed based on an explicit beam change indication. A corresponding beam change indication may be transmitted, separately from an RAR.)



In the embodiments described above, an RACH preamble may be replaced with an SR request signal (or an SR request preamble) of UE; the RAR transmission may be replaced with the UL Grant transmission of an eNB; MSG3 may be replaced with a message which is transmitted using a resource that an eNB allocated as UL grant for SR transmission; and MSG4 may be replaced with an acknowledgement message of an eNB in response to a message that UE transmitted via a resource that an eNB allocated as UL grant for SR transmission.

In the embodiments described above, the RACH-related transmission may also be part of the Dedicated RACH.