3GPP TSG RAN WG1 NR Ad-Hoc#2 **R1-1710596**

Qingdao, P.R. China 27th – 30th June 2017

Agenda Item: **5.1.2.2.2**

Source: **Lenovo, Motorola Mobility**

Title: **Discussion of beam recovery procedure**

Document for: **Discussion**

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1 Introduction

An important feature of 5G NR is beam management[1]. To manage and maintain effective beam link pairs, recovery from beam failures is needed. A UE may initiate the beam recovery process by sending beam failure recovery request to gNB. In RAN1#88bis, it was concluded that UE beam failure recovery includes beam failure detection, new candidate beam identification, beam failure recovery request, and gNB response to UE beam failure recovery request and UE monitoring [2]:

Agreements:

- UE Beam failure recovery mechanism includes the following aspects
  - Beam failure detection
  - New candidate beam identification
  - Beam failure recovery request transmission
  - UE monitors gNB response for beam failure recovery request
- Beam failure detection
  - UE monitors beam failure detection RS to assess if a beam failure trigger condition has been met
  - Beam failure detection RS at least includes periodic CSI-RS for beam management
    - SS-block within the serving cell can be considered, if SS-block is also used in beam management as well
  - FFS: Trigger condition for declaring beam failure
- New candidate beam identification
  - UE monitors beam identification RS to find a new candidate beam
  - Beam identification RS includes
    - Periodic CSI-RS for beam management, if it is configured by NW
    - Periodic CSI-RS and SS-blocks within the serving cell, if SS-block is also used in beam management as well
- Beam failure recovery request transmission
  - Information carried by beam failure recovery request includes at least one followings
    - Explicit/implicit information about identifying UE and new gNB TX beam information
    - Explicit/implicit information about identifying UE and whether or not new candidate beam exists
    - FFS:
      - Information indicating UE beam failure
      - Additional information, e.g., new beam quality
  - Down-selection between the following options for beam failure recovery request transmission
    - PRACH
    - PUCCH
    - PRACH-like (e.g.,different parameter for preamble sequence from PRACH)
  - Beam failure recovery request resource/signal may be additionally used for scheduling request
- UE monitors a control channel search space to receive gNB response for beam failure recovery request
  - FFS: the control channel search space can be same or different from the current control channel search space associated with serving BPLs
  - FFS: UE further reaction if gNB does not receive beam failure recovery request transmission

APPLE 1006

In RAN1#89 meeting, it was further confirmed to use both PRACH and PUCCH for beam failure recovery request [3]:

Agreements:

- Support the following channel(s) for beam failure recovery request transmission:
  - Non-contention based channel based on PRACH, which uses a resource orthogonal to resources of other PRACH transmissions, at least for the FDM case
    - FFS other ways of achieving orthogonality, e.g., CDM/TDM with other PRACH resources
    - FFS whether or not have different sequence and/or format than those of PRACH for other purposes
    - Note: this does not prevent PRACH design optimization attempt for beam failure recovery request transmission from other agenda item
    - FFS: Retransmission behavior on this PRACH resource is similar to regular RACH procedure
  - Support using PUCCH for beam failure recovery request transmission
    - FFS whether PUCCH is with beam sweeping or not
    - Note: this may or may not impact PUCCH design
  - FFS Contention-based PRACH resources as supplement to contention-free beam failure recovery resources
    - From traditional RACH resource pool
    - 4-step RACH procedure is used
    - Note: contention-based PRACH resources is used e.g., if a new candidate beam does not have resources for contention-free PRACH-like transmission
  - FFS whether a UE is semi-statically configured to use one of them or both, if both, whether or not support dynamic selection of one of the channel(s) by a UE if the UE is configured with both

Agreements:

- To receive gNB response for beam failure recovery request, a UE monitors NR PDCCH with the assumption that the corresponding PDCCH DM-RS is spatial QCL'ed with RS of the UE-identified candidate beam(s)
  - FFS whether the candidate beam(s) is identified from a preconfigured set or not
  - Detection of a gNB's response for beam failure recovery request during a time window is supported
    - FFS the time window is configured or pre-determined
    - FFS the number of monitoring occasions within the time window
    - FFS the size/location of the time window
    - If there is no response detected within the window, the UE may perform re-tx of the request
      - FFS details
  - If not detected after a certain number of transmission(s), UE notifies higher layer entities
    - FFS the number of transmission(s) or possibly further in combination with or solely determined by a timer

In this contribution we provide our view on further details of beam failure recovery request.

2 Discussion

A UE can be configured with PRACH resources for reporting beam failure to gNB and initiate beam recovery process. Based on the agreement in the last meeting, this PRACH resource can be configured for beam recovery request only and orthogonal to other PRACH transmissions. FDM, TDM and/or CDM can be used to guarantee orthogonality. There are multiple reasons that UEs, in both RRC_IDLE mode and RRC_CONNECT mode, require to transmit in PRACH resources. From the system point of view, a UE may access the PRACH channel for the following reasons:

For IDLE mode UE:
- Initial access from RRC_IDLE;
- On-demand SI request transmission

For INACTIVE mode UE:
- On-demand SI request transmission
- Transition from RRC_INACTIVE to RRC_CONNECTED

For CONNECTED mode UE:

- RRC Connection Re-establishment procedure;
- Handover;
- DL data arrival during RRC_CONNECTED requiring random access procedure, e.g. when UL synchronisation status is "non-synchronised";
- UL data arrival during RRC_CONNECTED requiring random access procedure, e.g. when UL synchronisation status is "non-synchronised" or there are no PUCCH resources for SR available.
- Beam recovery request transmission

Because IDLE mode UE and INACATIVE mode UEs do not have UL synchronization with the gNB, they are subject to larger timing offset at the gNB receiver and may require longer CP and guard time. For CONNECTED mode UEs synchronized to gNB, they do not need longer CP or guard time. A shorter PRACH format similar to LTE PRACH preamble format 0 may be used. Therefore the best PRACH configuration or preamble format may be different for RRC_IDLE UE and RRC_CONNECTED UE requesting beam recovery. To reduce the PRACH resource overhead, it is best that the PRACH used by RRC_CONNECTED UE for beam failure recovery request do not share the same time and frequency resource with the PRACH used by RRC_IDLE or RRC_INACTIVE UE, so each type of UEs can transmit with the their respective best PRACH formats.

Proposal 1: Separate frequency and time resources are configured for PRACH for beam failure recovery for RRC_CONNECTED UEs and PRACH for RRC_IDLE UEs.

A separate PRACH resource or resource pools may be assigned for beam recovery request transmission. In the current agreement, non-contention based PRACH channel is defined as PRACH that uses a resource orthogonal to resources of other PRACH transmissions. If the number of RRC_CONNECTED UEs is large, there may not be enough resources to configure each UE a dedicated contention-free PRACH resource for beam recovery. In order to allow flexibility for resource allocation and flexibility for gNB implementation, both dedicated PRACH and shared PRACH should be supported. The gNB may assign time and frequency resources to accommodate all the needs for RRC_CONNECTED UEs, while assigning either dedicated preambles to individual UEs, or a pool of PRACH sequences to multiple UEs, for transmission of beam failure recovery request. In the latter case, a UE may choose a PRACH sequence from the configured sequence pool to transmit its request. Although contention may take place in this case, it is only contending for the attention of the gNB with other RRC_CONNECTED UEs making the same request. Because the beam failure and recovery process is independent between different UEs, we do not expect heavy collision with reasonable configuration of PRACH resources. Combining dedicated and shared preambles for UE beam failure recovery request allows gNB the flexibility to allocate the amount of dedicated or shared sequences based on the number of RRC_CONNECTED UEs and their perceived mobility and channel condition.

Proposal 2: A RRC_CONNECTED may be either configured a dedicated preamble, or a pool of preambles, for transmission of beam failure recovery request, in configured time and frequency resources.

To further reduce the contention on the beam recovery request PRACH, gNB may further limit the access of to the PRACH resource if a UE is able to transmit using the shared PRACH resource pool only if it is explicitly enabled. The gNB can monitor the beam link quality to a UE through the beam management process (P1 or P2), and use MAC CE enable the UE's access through the configured shared PRACH resource pool when the quality of the beam link pair degrades close to the beam failure threshold. It is up to gNB to enable or disable the access to shared resource pool. Additional information can be found in our companion RAN2 contribution [??].

Proposal 3: UE's access to the shared PRACH resource pool to request beam failure recovery can be further controlled by gNB through MAC CE.

We cannot assume a UE always has a PRACH resource, dedicated or shared, configured for its beam failure recovery request. For example, a beam failure may occur before the gNB configures this preamble or preamble pools for the UE. As a back, a UE should be able to transmit its beam failure recovery request through a PRACH resource configured for other purposes whenever available. In this case, if it transmits a beam failure recovery request and receives a RAR from the gNB, the UE may signal the beam failure recovery details to the gNB in Message 3.

Proposal 4: If the PRACH sequence for beam failure recovery request is not configured, a RRC_CONNECTED UE making beam recovery request may access through other PRACH resources.

Besides PRACH, PUCCH can also be used to transmit beam failure recovery request. When a UE has a good candidate beam that it can transmit with, it can transmit its beam recovery request through PUCCH more reliably and also with less latency than the 4 step PRACH process. In this case, PUCCH should be given higher priority than PRACH. However, due to the time-sensitive nature of the beam failure recovery request, it is important that the

request is sent to the gNB as soon as possible. If the PRACH resource is available before the next PUCCH, UE should transmit the beam failure recovery request in PRACH. However, PUCCH can be used efficiently only if UE has a good candidate beam to send it. When a UE does not have a candidate beam, it needs to resort to beam sweeping to send the PUCCH. This is both time and resource consuming. Therefore no beam sweeping should be allowed for UE to transmit the beam recovery request through PUCCH.

Proposal 5: A UE should transmit beam failure recovery request in the first available PUCCH or PRACH.

Proposal 6: Beam sweeping is not used when UE transmits beam recovery request with PUCCH.

When a UE transmits beam failure recovery request in a non-dedicated PRACH resource, due to potential collision with other PRACH transmitted in the same resource, there is no guarantee that it will be successful at the first attempt. Subsequent transmission in PUCCH should be allowed before it receives the corresponding Message 2 in the RAR window to enhance the reliability and to reduce the latency. But it receives Message 2 afterwards, it should respond to Message 2 and follow through the 4 step RACH process.

Proposal 7: A UE can transmit additional beam failure recovery request through PUCCH after it first transmits using PRACH and before it receives the corresponding Message 2.

After sending the beam recovery request, either through PRACH or PUCCH, the UE waits for response from the gNB. The procedure should be different depending on whether the request was sent in PRACH or PUCCH. For PRACH, the regular 4-step RACH procedure should be used, with the RAR window defined as in regular PRACH procedure. The duration of the RAR window can be configured differently than the other PRACH. If the request was sent in PUCCH, a separate time window should be used. The duration of the time window can be configured, and the UE can monitor the PDCCH response from gNB continuously in the time window.

Proposal 8: If beam failure recovery request is sent in PRACH, RAR window should be used; if the beam failure recovery request is sent in PUCCH, a separate time window can be configured. For both cases, a UE should monitor PDCCH from gNB continuously in the time window.

3 Conclusion

We have analyzed the requirement for transmitting beam failure recovery request through PRACH and PUCCH, based on the properties of PRACH and PUCCH resources and transmission. Based on the analysis, we have made the following proposals:

Proposal 1: CDM is not used between PRACH for beam failure recovery for RRC_CONNECTED UEs and PRACH for RRC_IDLE UEs.

Proposal 2: A RRC_CONNECTED may be either configured a dedicated preamble, or a pool of preambles, for transmission of beam failure recovery request, in configured time and frequency resources.

Proposal 3: UE's access to the shared PRACH resource pool to request beam failure recovery can be further controlled by gNB through MAC CE.

Proposal 4: If the PRACH sequence for beam failure recovery request is not configured, a RRC_CONNECTED UE making beam recovery request may access through other PRACH resources.

Proposal 5: A UE should transmit beam failure recovery request in the first available PUCCH or PRACH.

Proposal 6: Beam sweeping is not used when UE transmits beam recovery request with PUCCH.

Proposal 7: A UE can transmit additional beam failure recovery request through PUCCH after it first transmits using PRACH and before it receives the corresponding Message 2.

Proposal 8: If beam failure recovery request is sent in PRACH, RAR window should be used; if the beam failure recovery request is sent in PUCCH, a separate time window can be configured. For both cases, a UE should monitor PDCCH from gNB continuously in the time windoe.

References

[1] 3GPP TR38.802, “Study on new radio (NR) access technology: physical layer aspects”.

[2] Chairman’s notes, RAN1#88bis.

[3] Chairman’s notes, RAN1#89.

[4] RAN2-1706905, “Resource configuration for beam failure recovery request”, Lenovo, Motorola Mobility.