**3GPP TSG RAN WG1 #118 R1-2406027**

**Maastricht, NL, August 19th – 23rd, 2024**

**Source: Intel Corporation**

**Title: Enhancements for Event-driven Beam Management**

**Agenda item: 9.2.1**

**Document for: Discussion and Decision**

# Introduction

In this paper, we provide details on MIMO Phase 5 work item on UE event-driven beam management procedures with respect to the justification and objectives as detailed in the Rel-19 MIMO WID in [1]:

|  |
| --- |
| **Justification:**  In legacy beam management procedures, the network may configure/activate frequent periodic or semi-persistent beam reporting (e.g., N best beams and corresponding L1-RSRPs) or triggers frequent aperiodic beam reporting to timely acquire the best/preferred beam for data/control transmissions. However, this clearly results in large UL reporting overhead and control signaling overhead. At the same time, if less frequent beam reporting is configured, the network could not always acquire ‘best/preferred’ beam(s) as the beam reporting by the UE may be outdated, thus leading to performance degradation. Given that UE has better and more-timely knowledge of beam quality changes, UE-initiated beam reporting procedure can lead to more timely beam reports yet with reduced reporting overhead. Under such a procedure, if the UE determines that e.g., current beam(s) quality becomes poor, UE can trigger beam reporting without the network needing to configure or trigger frequent reporting. |
| **Objective:**   1. Specify enhancement to facilitate UE-initiated/event-driven beam management for reducing overhead and/or latency, assuming the unified TCI while leveraging (as much as possible) legacy CSI measurement and reporting configuration frameworks, targeting FR2 and sTRP with intra- and inter-cell beam management    1. UL signaling content(s) (and procedure(s) as required) for UE-initiated/event-driven beam reporting facilitating fast beam switching.    2. UL signaling medium/container considering the UE-initiated/event-driven nature of the UL transmission, designed primarily for the purpose of beam reporting. |

In this paper, we outline the procedures needed for event-driven beam management including various options for measurement and reporting procedures which can provide gains over legacy beam measurement and reporting.

# L1 Procedures for Event-Driven Beam Management

## Definition of Additional L1 Events

At the RAN1#117 meeting, the following agreement was made regarding the trigger events for UE initiated beam reporting [4]. Note that it was already agreed to support Event-2, i.e., Quality of at least one new beam, such as L1-RSRP, becomes a threshold value better than the current beam. Based on the UE measurements on the candidate beams and event triggering, timing beam tracking can be realized for UE initiated beam management.

|  |
| --- |
| **Agreement**  On UE-initiated/event-driven beam reporting, regarding trigger events, the following Event-1 and 7a/7b, are provided for down-selection or combination in RAN1#118 (possible outcome is that no new event is supported)   * Event-1: Quality of the current beam is worse than a certain threshold. * Event-7a: Quality of at least one new beam, such as L1-RSRP, becomes a threshold value better than the RS derived from the activated TCI state with the **worst** quality. * Event-7b: Quality of at least one new beam, such as L1-RSRP, becomes a threshold value better than the RS derived from the activated TCI state with the **best** quality. |

For Event-2, the beam tracking accuracy may depend on the other candidate beams which are measured by the UE. In systems with a large number of beams, it may not always be possible for the UE to conduct measurements on the “best” candidate beams which can further impact the performance of UEIBM if it relies solely on Event-2. In this regard, it is important to consider other events as well to enhance overall performance.

In particular, events based on Event 1 can ensure that the UE detects current beam deterioration but has not found a better candidate beam from the measured beams (or from the beams that are configured for measurements). Although it may be possible to configure the UE to measure many candidate beams, this procedure has the disadvantage of high measurement RS overhead and increased measurement latency. Events based on event-1 can thus be useful for reducing candidate beam measurement RS overhead.

Candidate beam measurement and comparison are also inherent parts of beam failure recovery methods. However, in UEIBM, the primary use case is to identify a better candidate beam than the current one, which differs from BFR operations where the main goal is to determine if beam failure has occurred based on BFD RS measurements. For UEIBM, the requirements are stricter since the motivation is for beam tracking. The UE may need to measure different beams to identify a best one, which involves substantial configuration and overhead for the UE to constantly measure a large set of candidate beams. Note that Event 2 is not triggered if the same candidate beam does not satisfy the threshold for certain consecutive number of times. In such a case reporting of the candidate beams (best M) may still be useful.

Therefore, in addition to Event 2, event definition based on Event 1 can provide advantage of reducing overhead by triggering L1 measurement/reporting for candidate beams based on quality of current beam. The coexistence and triggering of multiple events are also beneficial, depending on the overhead considerations and viability of the measured non-serving beams as better candidate beams.

**Proposal 1:**

* Event-1 is supported for UEIBM.
* Multiple event types can be simultaneously configured and triggered by a UE.

For Events 7a and 7b, the primary motivation is to ensure the timely update of the set of activated TCI states. Based on UE measurements and reporting of new beams, the gNB may activate a new set of TCI states for beam tracking. While this can be useful, defining an event framework specifically for this purpose may not be necessary. The gNB can potentially handle this through legacy periodic measurement reporting and MAC-CE-based updates of activated beams.

Further, for Event 7a, at least one new beam is K dB better than the RS derived from the activated TCI state with the worst quality. Depending on the activated TCI states, this could result in a large number of event triggers, which would consume overhead without clear benefits for current beam (indicated TCI state) quality. Conversely, for Event 7b, at least one new beam is K dB better than the RS derived from the activated TCI state with the best quality. This stringent condition may lead to infrequent beam reporting, which may not be desirable in term of latency in updating the activated TCI states.

Based on the discussions above, in our view, events 7a and 7b are not supported for UEIBM.

**Proposal 2:**

* Events 7a and 7b are not supported for UEIBM.

## Timer/Counter

In RAN1#117, the following agreement was reached for triggering event determination for Event-2 [2].

|  |
| --- |
| **Agreement**  Regarding the triggering event determination for Event 2:   * If within a time window (which is configurable), the number of Event-2 instance(s) for at least one same new beam is greater than or equal to a configurable number M, UE initiated beam report occurs.   + Note: Event-2 instance for a new beam is determined if the L1-RSRP of the new beam becomes a threshold value better than the current beam   Above feature is subject to UE capability.   * Basic feature: Once the L1-RSRP of the new beam becomes a threshold value better than the current beam, UE initiated beam report occurs   FFS: Whether the above is captured in RAN1 or RAN2 specification |

In this case, we expect that the resulting specifications would come from both RAN1 and RAN2 (MAC).

An L1 instance (perhaps associated with a candidate beam) that is passed onto MAC should be discussed in addition to a periodicity definition (perhaps associated with the max periodicity of the candidate beams). We expect that the window size to be configured by higher layers. In addition, the procedure for triggering (and resetting of counters/timers) can be discussed and defined in RAN2.

**Proposal 3:**

* Regarding triggering event determination, discuss definition of an L1 instance and periodicity of an instance in RAN1

## Measurements for UEIBM

### Current Beam Measurements

At the RAN1#117 meeting, the following agreements were made with regards to RS measurements for the current beam for UE initiated beam management [4].

|  |
| --- |
| **Agreement**  Regarding RS measurement for the current beam for Event 2, for Option-2a, support the both schemes as follows.   * Scheme-1: RS for current beam is the QCL RS in the indicated TCI state   + FFS: Whether/How to handle the case if only one TRS is configured in the indicated TCI state. * Scheme-2: the RS for current beam is the SSB which is QCLed with the QCL RS in the indicated TCI state. * Enabling one of either Scheme-1 or Scheme-2 is selected by NW.   + FFS: The above selection is via an explicit RRC parameter or an implicit manner, e.g., if the RS(s) for new beam are CSI-RS, Scheme-1 is enabled; otherwise, Scheme-2 is enabled.   + (**Working Assumption**) Enabling of either Scheme-1 or Scheme-2 should ensure the same RS type for RS measurement for current beam and new beam. * The above QCL RS is the RS w.r.t. QCL-TypeD, if there are two QCL RSs in the indicated TCI state.   **Agreement**  Regarding RS measurement for the current beam for Event 2, for Option-2a, besides for scheme-1 and scheme-2, further study the following for handling the case that only one TRS is configured in the indicated TCI state.   * Option-1: Introducing additional scheme: the RS for current beam can be a CSI-RS for beam management derived from the QCL RS in the indicated TCI state; * Option-2: Further support TRS as measurement RS of current beam for determining L1-RSRP * Option-3: Introducing additional scheme: The RS for current beam is explicitly configured by RRC or MAC-CE (Option-2C in RAN1 116b agreement). * Option-4: No further enhancement (i.e., in such case, Scheme-2 is used) * Others are not precluded. |

For the RS measurement for the current beam for Event-2, both Scheme 1 and Scheme 2 are supported, which allows the network to decide on whether trigger event is based on monitoring of wide (SSB) beams or a mixture of wide and narrow (CSI-RS) beams. For either Scheme 1 or Scheme 2, it is more consistent to use the same RS type for measuring L1-RSRP of both the current beam and the candidate beams.

More specifically, if SSB is used as the source RS for measuring the L1-RSRP of the current beam, then candidate beams should also be measured with respect to SSBs. Otherwise, comparisons between the current beam and candidate beams may not be valid, as L1-RSRP measurements differ between CSI-RS and their corresponding SSBs. Therefore, it is appropriate to ensure the same RS type for RS measurements of the current and new beams for both Scheme 1 and Scheme 2.

**Proposal 4:**

* Confirm the working assumption that enabling of either Scheme-1 or Scheme-2 should ensure the same RS type for RS measurement for current beam and new beam.

It was briefly discussed in RAN1#117 the situation for a beam report if only TRS is configured in the indicated TCI state which is feasible in FR1 (scheme-1). In this case our first preference is Option-4 which is to handle it using scheme-2. Our second preference is Option-1 which is basically FR2 configuration of QCL (TRS + CSI-RS for BM) in FR1.

**Proposal 5:**

* In case only TRS is configured in the indicated TCI state, no further specifications enhancement is required and scheme-2 can be used.

### Candidate Beam Measurements for Event-2

At the RAN1#117 meeting, the following agreements were made with regards to RS measurements for the new beam for UE initiated beam management [4].

|  |
| --- |
| **Agreement**  Regarding RS measurement for the new beam for Event 2, at least Option-3a is supported   * Option-3a (explicit manner): The RS(s) for new beam(s) are explicitly configured * FFS: Option-3b/3c   + Option-3b: The RS(s) for new beam(s) are implicitly derived from QCL RS(s) of activated TCI state(s).   + Option-3c: The RS(s) for new beam(s) are implicitly derived from QCL RS(s) of TCI state(s) in a configured subset of the legacy RRC-configured TCI state list   **Agreement**  Regarding explicit RS configuration for new beam measurement for Event 2, down-select the following options in the RAN1#118:   * Option-1: The RS(s) for new beam(s) are explicitly configured in one RS resource set associated with an CSI reporting configuration;   + FFS: The RS in the RS resource set can be updated by MAC-CE. * Option-2: A list of RS(s) for new beam measurement can be configured by RRC, and a subset can be activated for new beam measurement by MAC-CE.   + FFS: If a list size is small, MAC-CE activation is not needed * Option-3: A list of RS resource(s) for new beam measurement can be configured by RRC, and a subset of RS resource(s) in the list can be provided for new beam measurement by indicated TCI state. * Others are not precluded. * FFS: Each RS for new beam measurement should be associated with a configured joint/DL TCI state which can be used as the indicated TCI state |

Regarding the RS configuration for the new candidate beams for Event-2, several options are identified on the configuration and potential update of new beams. Among these options, Option 1 follows the legacy configuration where RS for new beams are configured in one RS resource set associated with an CSI reporting configuration. This solution is sensible in case a large number of new beams are configured for UE initiated beam reporting (to avoid repeated RRC reconfiguration as the UE moves through the NW). This, in turn, would lead to increased measurement latency, which may not be desirable for timely tracking of the candidate beams. Note that the effectiveness of Event-2 triggering highly depends on the UE's ability to successfully identify and track the best candidate beam(s) for a set of “K” consecutive measurement instances.

In order to address the issue of measurement latency due to a large set of candidate beams, Option 2 with MAC-CE can be considered to dynamically activate a subset of configured candidate beams, thereby reducing UE complexity and latency in beam measurement. With such an MAC-CE based indication, gNB can update the appropriate subset of beams in a timely manner for beam tracking without RRC reconfiguration. Option 3 can also achieve fast adaptation of candidate beams by linking the subset of new beams with the indicated TCI state. However, this approach would introduce substantial signaling overhead, as the association needs to be provided for each activated or configured TCI state.

Considering the dynamic update of RS configuration of candidate beams, measurement latency and signalling overhead, it is more appropriate to support Option 2, i.e., a list of RS(s) for new beam measurement can be configured by RRC, and a subset can be activated for new beam measurement by MAC-CE.

**Proposal 6:**

* Support Option 2, i.e., a list of RS(s) for new beam measurement can be configured by RRC, and a subset can be activated for new beam measurement by MAC-CE.

## Contents for UE Initiated Beam Report

At the RAN1#117 meeting, the following agreement was agreed regarding the contents for UE initiated beam reporting [4].

|  |
| --- |
| **Agreement**  On UE-initiated/event-driven beam reporting, regarding UL signaling content(s) of L1-RSRP report depending on Event-2, in a report instance, at least Option-3 is supported   * Option-3: N ≥ 1 beam(s) are reported in the report instance,   + At least one of N reported beam(s) should satisfy the condition of Event-2   + N is configured by gNB     - FFS: candidate value of ‘N’.   + FFS: RRC can enable or disable whether current beam is always reported in addition to the N beams * FFS: Option-1/1a/1b/2. * Above applies at least for the single CC case   **Agreement**  On UE-initiated/event-driven beam reporting, regarding L1-RSRP report format Option-3 depending on Event-2, for a report instance where N ≥ 1 beam(s) are reported, the following is supported.   * RRC can enable or disable whether current beam is always reported   + - When enabled by RRC, the current beam + N beams from the measurement RSs for new beam(s) are reported       * Note: The reported current beam is NOT counted in the N reported beams.     - When disabled by RRC, N beams are reported. |

For the contents of Event-2 for UEIBM, event is triggered when at least one of N reported beams satisfies the conditions, which would allow timely adaptation of new beams. Further, whether current beam is always reported in addition to the N beams can be enabled or disabled by RRC signalling. In case when RRC configuration enables whether current beam is always reported, it may provide certain information for the gNB to make proper decision.

When RRC configuration disables whether current beam is always reported, it may be up to UE measurement or decision on whether current beam is included in the report. It should be noted that even if the measured L1-RSPR for current beam is not included in the beam report, the gNB may still be able to obtain certain information on the quality of current beam based on the triggering condition of Event-2. Further, when the current beam quality is better than the worst of the N candidate beams, the current beam can be included in the report if current beam is configured as part of candidate beams. In such a scenario, whether to report the current beam can also be flexibly determined at the UE.

**Proposal 7:**

* When RRC disables whether current beam is always reported, it is up to UE measurement and decision on whether current beam is included in the report.

## UL Signaling Medium/Container

In this section, we present our views on UL signalling medium and container for UE initiated beam reporting, including UCI in the first PUCCH and second uplink channel for carrying beam report.

### UCI in the First PUCCH

At the RAN1#117 meeting, the following working assumption was made on the first PUCCH for both Mode A and Mode B for UE initiated beam reporting [4].

|  |
| --- |
| **Working Assumption**  On beam report transmission procedure for UE-initiated/event-driven beam reporting   * For mode-A, at least support one-bit indication in the first PUCCH channel to request a resource for a second UL channel to carry beam report.   + In such case, a periodic PUCCH resource (with PUCCH format 0/1) is configured by dedicated RRC signaling. * For mode-B, at least support one-bit indication in the first PUCCH channel to notify a second UL channel to carry beam report.   + In such case, a periodic PUCCH resource (with PUCCH format 0/1) is configured by dedicated RRC signaling. * FFS: Whether/how to support multi-bit indication in the first PUCCH for mode-A and mode-B, e.g., when multi-event(s) are approved. * FFS: details on the dedicated RRC signaling * Above applies at least for the single CC case. |

In the first step of Mode A and Mode B, UE either needs to request a resource to gNB or notify the second uplink channel to carry beam report. As indicated in the working assumption, at least one-bit indication in the first PUCCH channel is supported for both Mode A and Mode B. This is preferable towards a unified solution in the first step across both Mode A and Mode B, which can help minimize the specification impact and simplify the implementation effort. In our view, working assumption on the first PUCCH for both Mode A and Mode B should be confirmed for UE initiated beam reporting.

Given that one-bit indication in the first PUCCH channel is supported, it is natural to configure a dedicated SR on PUCCH resource for requesting a resource in Mode A and notifying the second uplink channel to carry beam report in Mode B. This dedicated SR configuration aligns with the legacy design principle, where SR serves the purpose of requesting uplink resource. More importantly, this solution can help reduce the implementation effort at the gNB receiver as the legacy SR detection mechanisms can be reused.

For UE initiated beam reporting, if the event is not triggered, UE would not transmit the SR, e.g., negative SR. This process is similar to the SCell-BFR framework as defined in Rel-16, where in the first step of BFR procedure, UE transmits an LRR to indicate beam failure to the gNB and in response, the gNB grants UL resources for transmission of the BFR MAC-CE from the UE over PUSCH to report candidate beams and index of the failed SCells.

**Proposal 8:**

* For UEIBM, confirm the working assumption for the first PUCCH for both Mode A and Mode B.
* Support dedicated SR configuration for the first PUCCH.

In the working assumption, it is FFS on whether and how to support multi-bit indication in the first PUCCH for Mode A and Mode B. For multi-bit UCI in the first step, one of the main benefits is to accommodate flexible beam report payload size, which may apply for the case of multi-CC beam reporting or when multiple events are supported. However, in order to support multiple events, a single bit UCI or SR design can be straightforwardly extended, where each event may be associated with one dedicated SR configuration, and subsequently the second uplink channel can be used to carry the beam report for the triggered event.

In addition, even if variable payload sizes for beam report are supported for UE initiated beam reporting, legacy design with two CSI parts may be reused, where the first CSI part can be used to carry essential information, e.g., event index, while the second CSI part may be used to carry the beam report associated with the indicated event index. In this regard, the need to support multi-bit UCI in the first step for Mode A and Mode B is not clear. It should be noted that substantial specification impact may be expected if multi-bit UCI, i.e., with a new UCI type is supported, especially considering the complicated collision handling rule with same or different priorities.

Hence, in our view, multi-bit UCI in the first step is not supported for UE initiated beam reporting.

**Proposal 9:**

* For UEIBM, multi-bit UCI in the first step is not supported.

### UL Channel for Carrying Beam Report

At the RAN1#117 meeting, the following agreement was made regarding the beam report transmission procedure and uplink channel for Mode A [4].

|  |
| --- |
| **Agreement**  On beam report transmission procedure for UE-initiated/event-driven beam reporting, regarding Mode-A, the DCI format in Step-2 comprises UL-grant DCI format, and the second channel in Step-3 is at least PUSCH.   * The UL-grant DCI format at least comprises DCI format 0\_1/0\_2.   + FFS: DCI format 0\_3 * FFS: How to trigger the UEI beam report by the UL-grant DCI format * FFS: the DCI format in Step-2 comprises DL-grant DCI format, and the second channel in Step-3 is PUCCH.   + - 1-bit field in the DL-grant DCI format is introduced to indicate the transmission of the UEI beam report       * The PUCCH resource for HARQ-ACK transmission can be reused to carry both the HARQ-ACK and UEI beam report.     - The DL-grant DCI format at least comprises DCI format 1\_1/1\_2.       * FFS: DCI format 1\_3 |

In Mode A, it was agreed that gNB dynamically allocates the uplink resource via UL grant DCI for the UE to transmit the beam report on PUSCH. To enable the dynamic beam report in Mode A, the existing CSI reporting framework can be straightforwardly extended. In particular, CSI request field in the DCI format 0\_1/0\_2 can be reused, where a trigger state can be associated with UE initiated beam reporting, following the same design principle for the LTM CSI reporting as defined in NR.

Further, it was agreed to further study whether to support using DL grant in Step 2 and PUCCH as the second channel for carrying beam report in Step 3. This approach is similar to A-CSI on PUCCH, which was discussed in Rel-16/17 URLLC. Note that this mechanism can be beneficial in case of DL heavy scenarios as this allows the use of single DCI instead of two DCIs for triggering A-CSI on PUSCH. However, substantial specification impact may be envisioned if A-CSI on PUCCH is introduced for UE initiated beam reporting, especially considering the timeline for processing PDSCH reception and A-CSI reporting, and UCI multiplexing when PUCCH overlaps with PUSCH, etc. Hence, given the fact that A-CSI report on PUCCH is currently not supported in the NR, it is not preferrable to support using DL grant in Step 2 and PUCCH as the second channel for carrying beam report in Step 3.

**Proposal 10:**

* In Mode A, DL grant DCI format in Step 2 and PUCCH in Step 3 is not supported.
* For UL grant DCI, CSI request field is reused, where a trigger state can be associated for UE initiated beam reporting

In Mode B, after UE sends the SR in the first PUCCH once the event is triggered, the UE transmits the beam report in the second uplink channel. In our view, either PUCCH or PUSCH can be supported as the second uplink channel in Mode B. In general, the BLER target for PUCCH is 1%, which is more reliable than the 10% BLER target for PUSCH. However, PUCCH for different UEs is typically configured with dedicated and non-overlapping resources. When payload size of beam report is relatively large, the amount of resources allocated for PUCCH for different UEs may be substantial, which may not be desirable from system perspective. Conversely, by using orthogonal DMRS ports, MU-MIMO operation can be employed for the transmission of PUSCH, which can help improve the system capacity in comparison to PUCCH.

Based on the discussions above, it would be more appropriate to support both PUCCH and PUSCH as the second uplink channel in Mode B with one of two channels configured by RRC signalling for operation. This approach offers good flexibility for the gNB to allocate proper resource and channel for carrying beam report in the second step, depending on various use cases and deployment scenarios.

It should be noted that when PUSCH is utilized for the second uplink channel, Type 1 CG-PUSCH resource configuration may be reused to carry the beam report. To enhance the reliability of PUSCH, repetitions or HARQ operation may be considered for PUSCH carrying beam report in Mode B. In addition, further study may be needed on the support of beam reports on CG-PUSCH without UL-SCH for Mode B.

**Proposal 11:**

* In Mode B, both PUCCH and PUSCH can be supported as the second uplink channel.
  + One of these two channels can be configured by RRC signalling for carrying beam report.

To ensure proper operation for Mode B, association between the first PUCCH resource and the second uplink channel resource may need to be established. In particular, after detecting the positive SR from the UE, the gNB may attempt to decode the second uplink channel for beam report based on the linkage.

One straightforward approach is to follow the design principle for 2-step RACH, where MsgA PRACH preamble and MsgA PUSCH resource unit are associated based on a configured slot offset. In the case of Mode B for UE initiated beam reporting, same periodicity and slot offset may be configured for the first PUCCH resource and the second uplink channel resource. Alternatively, flexible resource allocation, e.g., with different periodicities may be configured for the first PUCCH and the second uplink channel. In such a scenario, specific rule may be defined to associate the first PUCCH and the second uplink channel.

**Proposal 12**

* In Mode B, support association between the first PUCCH and the second uplink channel resource.

### Cross-CC and Multi-CC Beam Reporting

At the RAN1#116b meeting, it was agreed that cross-CC beam reporting is supported for UE initiated beam management for both Mode A and Mode B [3]. In current specification, a trigger state include more than one CSI reporting configurations, where each CSI reporting configuration can be associated with one CC. This design principle can be straightforwardly applied to the UE initiated beam management with cross-CC or multi-CC beam reporting.

For a single CC case, Event-2 is defined as quality of at least one new beam, such as L1-RSRP, becomes a threshold value better than the current beam. To enable cross-CC or multi-CC beam reporting, further discussion is needed on the conditions to trigger the events, e.g., whether the event is triggered only if the condition for any of CC is satisfied or if the conditions for all of CCs are satisfied.

In addition, when UE sends the cross-CC or multi-CC beam reporting, it would be preferable to consider a fixed payload size for beam reporting to avoid misunderstanding between gNB and UE, which may also depend on the number of CCs for beam reporting. In case when a variable payload size for beam reporting is needed, framework on two CSI parts may be applied, where certain information including CC index may be included in the CSI part 1 (with known size at the gNB) so that gNB may determine the total payload size accordingly for UE initiated beam reporting.

**Proposal 13**

* For cross-CC and multi-CC beam reporting, further discuss the event trigger and beam report content for Mode A and Mode B.

### Switching Mechanism for Mode B

The main difference between legacy L1 beam reporting and event driven reporting is that, in the latter case, the report is expected to be less frequent and in general one-shot to avoid overhead due to periodic reporting and latency due to reporting periodicity. In the legacy approach, if the gNB misses an L1 report, it can simply wait for the next periodic report to track the optimal beam. However, with a one-shot report, missing the report can lead to sub-optimal performance, as the UE may not realize the report was missed and, typically, would not retransmit the aperiodic report.

For Mode B of UE-initiated beam reporting, pre-configured PUSCH resources may be cancelled due to collisions with semi-statically scheduled DL symbols or higher priority uplink transmissions as defined in NR. In addition, gNB may not be able to successfully decode the PUSCH carrying the beam report due to poor channel conditions. In such scenarios, it is not preferable for the UE to wait for the next opportunity to restart the first and second steps in Mode B to retransmit the beam report. This would significantly increase reporting latency for UEIBM, especially when a relatively large periodicity is configured for the first PUCCH resource and the second uplink channel.

To address this issue and avoid unnecessary latency for beam reporting, it may be more appropriate to support dynamic scheduling of beam report on DG-PUSCH for Mode B in case when gNB successfully detects the first PUSCH, but fails to decode the second uplink channel carrying beam report, as illustrated in Figure 4. This approach is analogous to 2-step RACH procedure, where if gNB successfully detects MsgA PRACH, but fails to decode MsgA PUSCH, it would trigger a fallback mechanism to switch from 2-step RACH to 4-step RACH procedure. Such a switching mechanism would help enable timely beam reporting, thereby reducing reporting and beam update latency.

A diagram of a diagram

Description automatically generated

Figure . Dynamic scheduling of beam report for Mode B

**Proposal 14**

* For Mode B, consider to support dynamic scheduling of beam report on DG-PUSCH if gNB successfully detects the first PUSCH, but fails to decode the second uplink channel carrying beam report.

## Beam Indication Latency Reduction

In the discussion so far, the focus has been towards addressing measurement and reporting latency. However, as shown in the Figure 1, there is an additional latency component from beam indication after the beam report has been successfully received by the gNB. This latency could also be significantly large depending on the acknowledgement transmission for the beam indication DCI and the subsequent beam application time.

For event triggered beam reporting, since the UE can monitor the beam quality in a more granular manner and potentially on different UE Rx beams, it may be possible for the UE to report beams to the gNB such that the beams in the report can be received by the UE using the same Rx beam assumption. Under these circumstances, the gNB can autonomously start using a reported beam without the need for waiting for beam application time. Therefore, this method of UE-aided beam application can result in reasonable latency gains.

**Proposal 15:**

* Consider UE assistance information for beam application latency reduction for UEIBM.

# Conclusions

In this contribution, we presented our views on UE initiated and event driven beam management. Further, we summarize the proposals as follows:

**Proposal 1:**

* Event-1 is supported for UEIBM.
* Multiple event types can be simultaneously configured and triggered by a UE.

**Proposal 2:**

* Events 7a and 7b are not supported for UEIBM.

**Proposal 3:**

* Regarding triggering event determination, discuss definition of an L1 instance and periodicity of an instance in RAN1

**Proposal 4:**

* Confirm the working assumption that enabling of either Scheme-1 or Scheme-2 should ensure the same RS type for RS measurement for current beam and new beam.

**Proposal 5:**

* In case only TRS is configured in the indicated TCI state, no further specifications enhancement is required and scheme-2 can be used.

**Proposal 6:**

* Support Option 2, i.e., a list of RS(s) for new beam measurement can be configured by RRC, and a subset can be activated for new beam measurement by MAC-CE.

**Proposal 7:**

* When RRC disables whether current beam is always reported, it is up to UE measurement and decision on whether current beam is included in the report.

**Proposal 8:**

* For UEIBM, confirm the working assumption for the first PUCCH for both Mode A and Mode B.
* Support dedicated SR configuration for the first PUCCH.

**Proposal 9:**

* For UEIBM, multi-bit UCI in the first step is not supported.

**Proposal 10:**

* In Mode A, DL grant DCI format in Step 2 and PUCCH in Step 3 is not supported.
* For UL grant DCI, CSI request field is reused, where a trigger state can be associated for UE initiated beam reporting

**Proposal 11:**

* In Mode B, both PUCCH and PUSCH can be supported as the second uplink channel.
  + One of these two channels can be configured by RRC signalling for carrying beam report.

**Proposal 12**

* In Mode B, support association between the first PUCCH and the second uplink channel resource.

**Proposal 13**

* For cross-CC and multi-CC beam reporting, further discuss the event trigger and beam report content for Mode A and Mode B.

**Proposal 14**

* For Mode B, consider to support dynamic scheduling of beam report on DG-PUSCH if gNB successfully detects the first PUSCH, but fails to decode the second uplink channel carrying beam report.

**Proposal 15:**

* Consider UE assistance information for beam application latency reduction for UEIBM.

# References

1. RP-234007, New WID: NR MIMO Phase 5, Samsung (Moderator), 3GPP TSG RAN Meeting#102, Edinburgh, Scotland, December 2023.
2. Chairman’s notes, RAN1#117 Meeting, May 2024
3. Chairman’s notes, RAN1#116b Meeting, April 2024