

Source: Intel Corporation
Title: On network beam switching and refinement (BM P-2)
Agenda item: 8.1.4.1
Document for: Discussion and Decision

1. Introduction

In the RAN 1 #86 meeting the following agreements on DL beam management have been made [1]:

- The following DL L1/L2 beam management procedures are supported within one or multiple TRPs:
 - P-1: is used to enable UE measurement on different TRP Tx beams to support selection of TRP Tx beams/UE Rx beam(s)
 - » For beamforming at TRP, it typically includes a intra/inter-TRP Tx beam sweep from a set of different beams
 - » For beamforming at UE, it typically includes a UE Rx beam sweep from a set of different beams
 - » FFS: TRP Tx beam and UE Rx beam can be determined jointly or sequentially
 - P-2: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s)
 - » From a possibly smaller set of beams for beam refinement than in P-1
 - » Note: P-2 can be a special case of P-1
 - P-3: is used to enable UE measurement on the same TRP Tx beam to change UE Rx beam in the case UE uses beamforming
 - Strive for the same procedure design for Intra-TRP and inter-TRP beam management
 - » Note: UE may not know whether it is intra-TRP or inter TRP beam
 - Note: Procedures P-2&P-3 can be performed jointly and/or multiple times to achieve e.g. TRP Tx/UE Rx beam change simultaneously
 - Note: Procedures P-3 may or may not have physical layer procedure spec. impact
 - Support managing multiple Tx/Rx beam pairs for a UE
 - Note: Assistance information from another carrier can be studied in beam management procedures
 - Note that above procedure can be applied to any frequency band
 - Note that above procedure can be used in single/multiple beam(s) per TRP

Note: multi/single beam based initial access and mobility treated within a separate RAN1 agenda item

In our companion contribution [2], we have discussed the procedure 1 (P-1) of DL beam management, in which TRP/UE beams are acquired using beam sweeping from a full set of beams. P-1 is used to acquire the initial TRP/UE beam and to discover other candidate TRP/UE beams. However, after suitable TRP/UE beams are identified using P-1, only local refinements are enough to maintain the link. Although it is still possible to rely on P-1 to maintain the link, a dedicated P-2 is beneficial to reduce the UE power consumption. It also allows more implementation flexibility to apply finer beam in P-2 than in P-1. And at the same time, UE may respond faster to movement, rotation and channel blockage using P-2 instead of P-1. In this contribution, we provide our views on the beam management procedure P-2. We are envisioning two kinds of TRP beam change for P-2. The first kind of beam change is named as **beam refinement** which allows TRP beam change between beams having strong spatial correlation. The second kind of beam change is named as **beam switching** which allows TRP beam change between beams having low or no spatial correlation.

2. TRP Beam Refinement Scenarios

Before performing procedure P-2, TRP/UE has performed procedure P-1 at least once successfully and at least one pair of TRP/UE beam has been identified. With procedure P-2 for beam refinement, the TRP beam can be changed to a new beam. Figure 1 lists several possible beam refinement scenarios:

- Beam Refinement Scenario-1: TRP beam refinement among beams having the same beam width as P-1 but higher spatial granularity.
- Beam Refinement Scenario-2: TRP beam refinement using narrower beam width as P-1 but similar spatial beam direction.
- Beam Refinement Scenario-3: TRP beam refinement using the same beam width and the same spatial beam granularity as P-1.

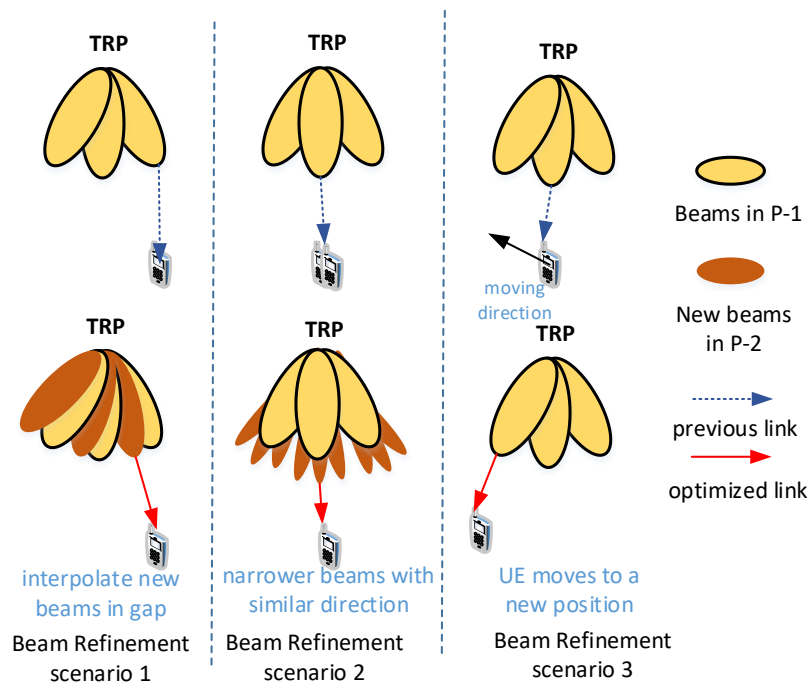


Figure 1: Beam refinement scenarios

For Beam Refinement scenario 1 and 2, dedicated reference signals are required since different beams are used in P-2 compared to P-1. However, for Beam Refinement scenario 3, the same reference signal of P-1 can be used. But it will still be beneficial to use a dedicated reference signal for Beam Refinement scenario 3 due to less UE power consumption and more prompt responses to channel changes. Since the refined TRP beam is expected to be spatially correlated with the previous TRP beam, UE can receive both of the TRP beams before and after refinement with the same UE beam. And UE beam can be further refined using procedure P-3. With multiple antenna panels at TRP side, this implies a FDM structure of the RS for TRP beam refinement to reduce the refinement latency. Two alternatives exist for the beam training reference signals used in P-2.

- Alternative 1: P-2 reuses the same beam training reference signals as P-1.
- Alternative 2: P-2 uses dedicated beam training reference signals which are different from P-1.

Table 1 shows the comparison of the two beam training reference signal alternatives for P-2. And the two beam training reference signals can support different refinement procedures as shown in Figure 2. When the same beam

training reference signal is used for beam refinement, TRP beam correlation table or TRP beam groups may be used to reduce the UE beam refinement complexity.

Table 1: The comparison of two RS alternatives for P-2

RS for refinement	Advantages	Disadvantages
Alternative 1: Same RS as in P-1	1. Does not require extra triggering and reference signals. 2. If wide beam is used, maybe beneficial for extremely high UE mobility scenario.	1. Only Beam Refinement scenario 3 can be supported. 2. Refinement latency is determined by RS periodicity and #of beams for P-1.
Alternative 2: Different RS as in P-1	1. All the Beam Refinement scenarios are supported. 2. UE power consumption for refinement can be reduced. 3. Faster TRP beam refinement as responding to channel changes. 4. Allowing refine TRP beams not only considering signal quality but also considering interference.	1. Require dedicate reference signals and the related design of signaling and procedure. But the same reference signals as CSI acquisition can be used.

From specification’s viewpoint, it would be desirable to support different **Beam Refinement** scenarios with the same procedure and reference signal structure. And the same procedure and reference signal structure is forward compatible enough to accommodate various future implementations.

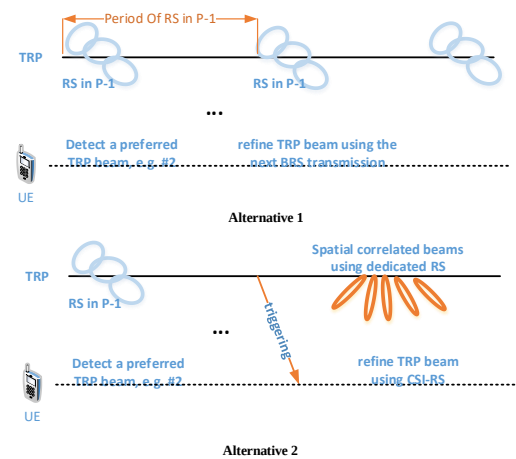


Figure 2: Refinement procedures supported by two reference signal alternatives for P-2

Observation 1: multiple TRP beam refinement scenarios may require dedicated beam training reference signal for beam management procedure P-2 compared to P-1.

Observation 2: the TRP beam refinement among spatially correlated TRP beams may allow a FDM like RS structure to reduce TRP beam refinement latency with multiple TRP antenna panels.

Proposal 1:

- *Dedicated RS, e.g. UE specific CSI-RS, is used for TRP beam refinement.*
 - *CSI-RS ports beamformed by spatially correlated TRP beams may have a FDM like structure and allows UE to receive with the same UE beam.*

3. TRP Beam Switching Scenarios

Beam switching allows Tx beam to change from the previous beam to another one with low or no spatial correlation. For UE with beamforming, it usually involves UE side beam switching. And this is also one of the key difference from TRP **beam refinement**. **Beam switching** can be either initiated by the network, e.g. due to better MU-MIMO transmission or initiated by the UE, e.g. UE detects that the previous beam is no more useful due to channel blockage in the surrounding environment. **Error! Reference source not found.** illustrates three potential scenarios for TRP Beam Switching. For all the three scenarios, **beam switching** can only happen between identified candidate beams by P-1 and further refined by P-2 via **beam refinement** and cannot happen between arbitrary beams.

- Beam Switching Scenario-1: TRP beam switching among beams from the same TRP but with low spatial correlation.
- Beam Switching Scenario-2: TRP beam switching among beams from different TRPs which are connected to the same Synchronize Source (SS) or with ideal backhaul.
- Beam Switching Scenario-3 (maybe considered as hand over): TRP beams switching among beams from different TRPs which are connected to different SSs or without ideal backhaul.

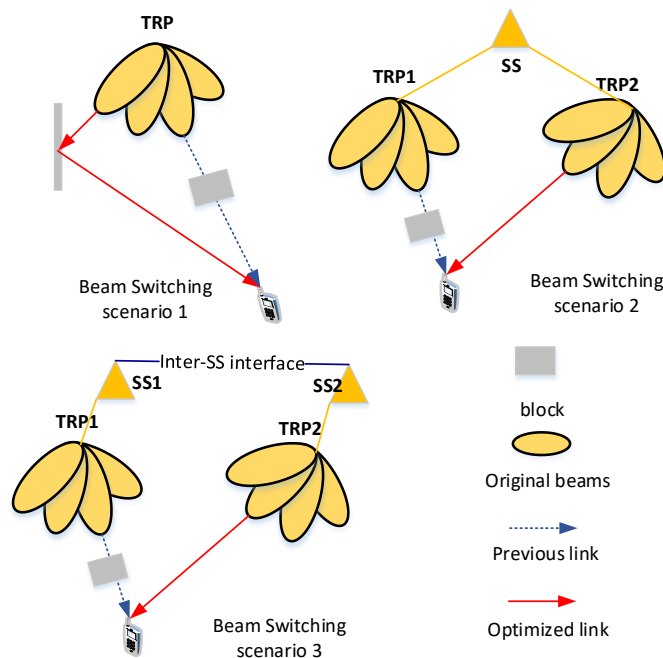


Figure 3: Beam switching scenarios

For Beam Switching scenario 1 and 2, in which TRP beams change within the same SS, the forthcoming data can be transferred to the new TRP beams without interruption. Since this procedure only involves beam change within the same control unit, it can be achieved with physical layer control signalling. However, for Beam Switching scenario 3, it may need assistance from the higher layer and may be similar as handover procedure. Generally, if Tx beam from TRP1 of SS1 is no longer appropriate due to the abrupt channel change such as blockage, UE needs to perform random access procedure to TRP2. To minimize the interruption of data communication during inter-SS

beam switching, the original SS should forward the data communication context to the target SS appropriately through inter-SS interface. In addition, the original TRP should inform UE SS information of the target TRPs so that UE could distinguish scenario 3 from scenario 2 to perform beam measurement.

Since more than one antenna panel is used at UE side in NR systems, the identified top TRP beams maybe better received by either single UE panel or multiple UE panels. As such, the reference signal to enable beam switching could be transmitted during one OFDM symbol or several OFDM symbols, as shown in Figure 4:

- UE uses single panel for P-2: all the identified top TRP beams in P-1 are received by single UE panel, and TRP beam switching requires UE beam switching using the same panel. From reference signal's perspective, the reference signals for beams before and after switching would require a TDM like structure when UE side beamforming is used. Thus UE can receive the beams before and after switching using different UE beams.
- UE uses multiple panels for P-2: all the identified top TRP beams in P-1 are received by multiple UE panels. Since UE could generate multiple Rx beams simultaneously by using several panels, it could perform beam switching during one OFDM symbol. Thus, reference signals for beams before and after switching could be FDMed if they are received by different UE panels.

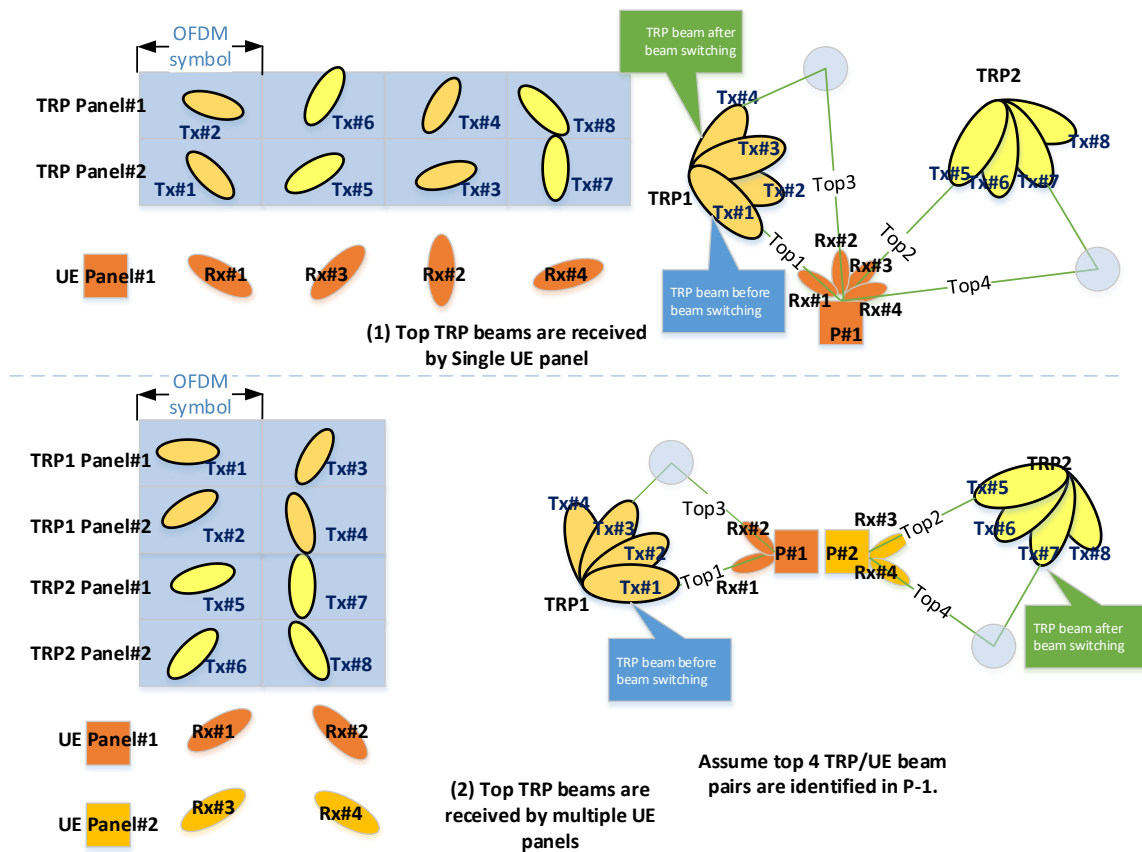


Figure 4: RS structures for beam switching

Observation 3: compared with TRP beam refinements, beam switching are among spatially uncorrelated beams.

Observation 4: TRP side beam switching naturally involves UE side beam switching.

Proposal 2:

- In order to enable better design of beams in P-2 for beam switching, UE may report whether the identified top TRP beams in P-1 can be received simultaneously or not.

4. TRP beam refinement/switching based on Interference

Various interferences exist in the network, such as inter-cell interference, intra-cell interference by MU-MIMO transmission etc. With non-precoded CSI-RS, it is possible to handle such interference, e.g. MU-MIMO interference, using digital signal processing. However, in a beam centric environment with analog beams at both TRP and UE, it may be more feasible to take into account those interference in the recommended TRP beam. In consideration of reducing interference, criterion of beam refinement/switching may include at least the following options:

- Option-1: maximizing the receiving Signal Power.
- Option-2: maximizing the ratio of Signal Power and Interference Power.

The interference can be measured from either zero power CSI-RS or BRRS REs in the same symbol or from interference beam based non zero power CSI-RS REs.

Observation 5: *TRP beam refinement may need to consider not only signal power but also interference power.*

Proposal 3:

- *Zero power CSI-RS or interference beam based non zero power CSI-RS can be sent in the same OFDM symbol as RS to carry signal beam to enable TRP beam refinement considering both signal and interference.*

5. Conclusions

In this contribution we have provided our views on network beam refinement. From the discussion, we have achieved the following observations and proposals.

Observation 1: *multiple TRP beam refinement scenarios may require dedicated beam training reference signal for beam management procedure P-2 compared to P-1.*

Observation 2: *the TRP beam refinement among spatially correlated TRP beams may allow a FDM like RS structure to reduce TRP beam refinement latency with multiple TRP antenna panels.*

Observation 3: *compared with TRP beam refinements, beam switching are among spatially uncorrelated beams.*

Observation 4: *TRP side beam switching naturally involves UE side beam switching.*

Observation 5: *TRP beam refinement may need to consider not only signal power but also interference power.*

Proposal 1:

- *Dedicated RS, e.g. UE specific CSI-RS, is used for TRP beam refinement.*
 - *CSI-RS ports beamformed by spatially correlated TRP beams may have a FDM like structure and allows UE to receive with the same UE beam.*

Proposal 2:

- *In order to enable better design of beams in P-2 for beam switching, UE may report whether the identified top TRP beams in P-1 can be received simultaneously or not.*

Proposal 3:

- *Zero power CSI-RS or interference beam based non zero power CSI-RS can be sent in the same OFDM symbol as RS to carry signal beam to enable TRP beam refinement considering both signal and interference.*

References

- [1] R1-168278, WF on DL beam management, Intel Corporation et, al
- [2] R1-1609516, Beam management for initial and candidate beam discovery (BM P-1), Intel Corporation