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Mobility Enhancement for Rel-18

RAN Rel-18 Workshop

28th June – 2nd July 2021

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Mobility Enhancements: Motivation (1)

1. Dual-Active Protocol Stack (DAPS) handover has been specified in Rel. 16 to reduce the interruption time for FR1-FR1, FR1-FR2, FR2-FR1 scenarios but not for intra-frequency FR2-FR2.
   - Close to 0ms interruption time during handover in both DL and UL allows to deploy services with high reliability requirements in 1) FR2 localized deployments such as IIoT services in factory/or high-speed train or 2) DC deployments with FR2 as PCell.
   - There is inherent end-2-end UL latency (of at least 2 Xn signaling messages, > 10 ms) in DAPS handover as data forwarding to UPF cannot start immediately.
2. Handover interruption time solutions requiring a single transceiver can be enough for use cases not requiring very high reliability, e.g., some IIoT use cases, mobility broadband.

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Mobility Enhancements: Motivation (2)

3. To achieve high reliability, outage events caused by both mobility failures and handovers have to be reduced. Otherwise, network tenants must ensure by e.g., planning that mobility failures do not occur frequently which is difficult to guarantee in some scenarios.
4. The basic operation of Conditional Handover (CH0) has been specified in Rel. 16 and is being considered in many verticals in Rel. 17 (e.g. NTN, IAB). However, many issues slipped out from Rel. 16 and have not been addressed:
   - Fast degradation of signal power (caused by obstacles) and frequent handovers in FR2.
   - Higher fallback to contention-based RA in CHO compared to baseline handover.
   - Enhancement for CHO cancelation procedure.
   - Impact of MPE event on CHO (and baseline handover)
   - Interaction of UE beam refinement with L3 mobility

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Mobility Enhancements: Motivation (3)

5. As of Rel. 16, Conditional Handover (CHO) and Conditional PSCell Change (CPC) cannot be configured at the same time (restriction to be imposed by OAM). This restriction limits the benefits of CPC and addition (CPAC) features which cannot be used when CHO is configured and vice-versa.
6. The PSCell access in conditional handover with (MR-)DC connection (with same or different SN) is performed irrespective of the PSCell radio link quality, i.e. the random access to PSCell is performed when the CHO execution condition, evaluated using PCell measurements, is met. This may lead to PSCell access failure if the radio link of the PSCell is not sufficient.

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Mobility Enhancements: Objectives (1)

1. To study and specify solution(s) that:
   - Reduce handover interruption time close to 0 ms in both DL and UL for intra-frequency FR2-FR2 scenario
   - Improve the end-2-end UL latency in DAPS handover.
2. To study and specify solution(s) that can minimize the interruption time during handover in FR1 and FR2 using a single transceiver, e.g. Make-before-break and/or RACH-less handover.
3. To study and specify solution(s) providing both mobility robustness and interruption time reduction in FR1 and FR2 scenarios, e.g. inter-working of CHO and DAPS (or with any other solution reducing interruption time like make-before-break and/or RACH-less HO).

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Mobility Enhancements: Objectives (2)

4. To study and specify enhancements for (conditional) handover focusing on the following identified areas, but not limited to:
   - FR2 related CHO enhancements (Fast cell selection, enhanced CHO execution), Random access, X2/Xn signaling, MPE handling in mobility (baseline HO and CHO), UE beam refinement during/before handover
5. To study and specify the inter-working of CHO and CPAC procedures focusing on the following solutions but not limited: 1) Allow CHO and CPAC procedures to be active at the same time (preferred option), and/or 2) Allow a more dynamic solution than OAM (using inter-node communication between MN and SN) that ensures that CHO and CPAC are not configured simultaneously for a UE (decision for allowing CHO or CPAC can be done per UE).

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Mobility Enhancements: Objectives (3)

6. To study and specify solutions to improve the robustness of PSCell access focusing on the following solution but not limited to: Allow conditional PSCell access for conditional inter-MN handover with (MR)-DC configuration

<u>Note: All objectives have to be studied and specified in centralized and distributed architectures (CU-DU split, intra-CU/inter-CU/inter-DU)</u>

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Background

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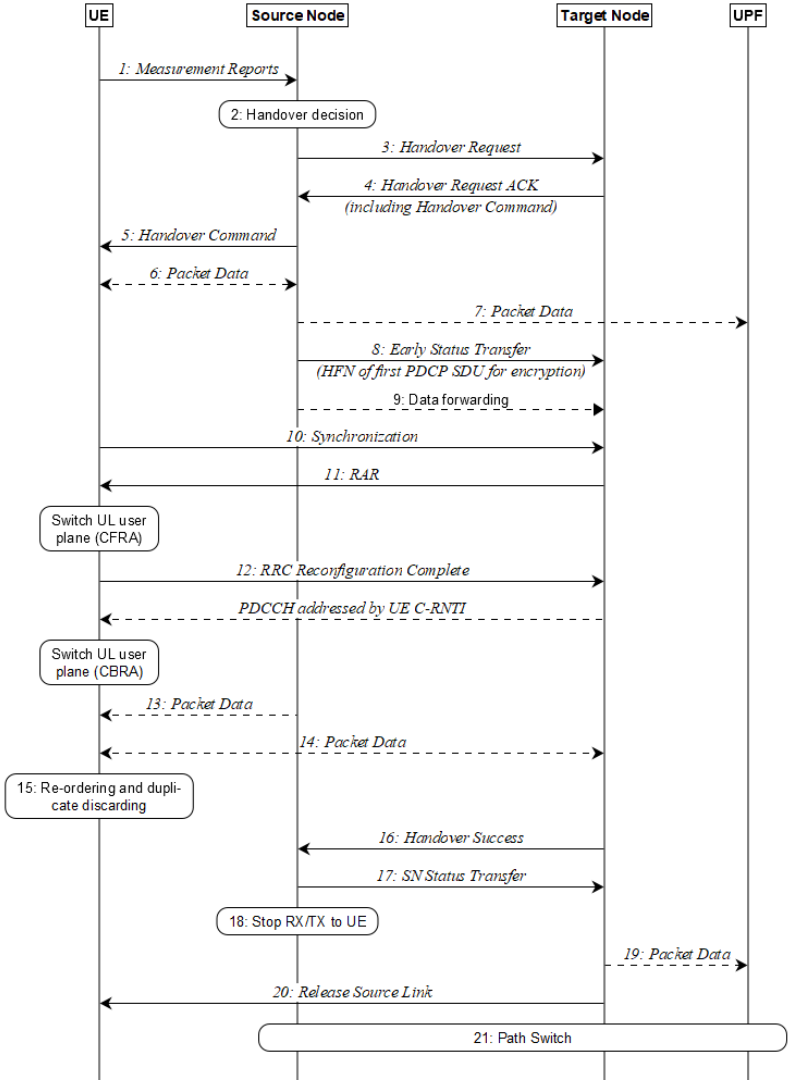
Background Information for Objective #1

- DAPS handover has been specified in NR Rel. 16 for FR1-FR1, FR1-FR2 and FR2-FR1 scenarios as a solution to reduce the handover interruption time in DL to 2ms in some cases.
- However, DAPS handover is not specified for intra-frequency FR2-FR2 handover in Rel. 16
- Moreover, in DAPS the UL data cannot be forwarded immediately to UPF until the source cell is released.



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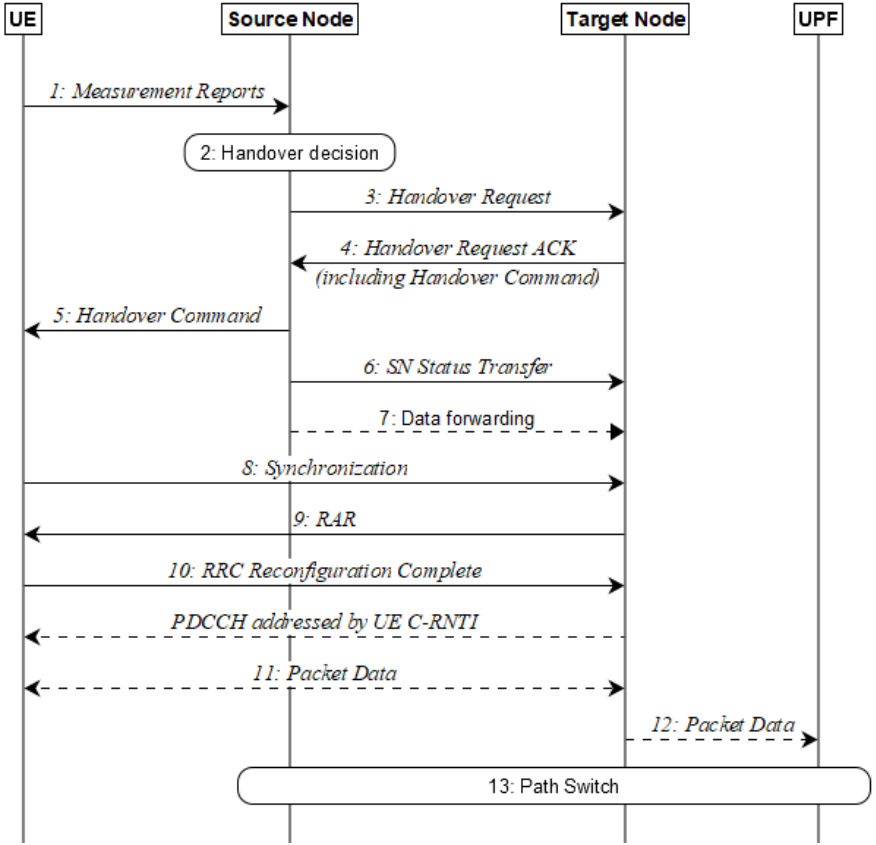
Background Information for Objective #2

- The interruption time in baseline handover starts in step 5 and ends in step 11 and can be approximately 71 ms in FR1 and 55 ms in FR2.

- For many services not requiring very high reliability, the handover interruption time can be reduced by using solutions requiring a single transceiver which is much less demanding than DAPS in terms of radio resources and signaling.

- Make-before-break (MBB) and/or RACH-less handover can reduce the interruption time during the handover and as such improve the UE performance.



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Background Information for Objective #3

- Conditional handover (CHO) minimizes radio link failures (RLFs) and handover failures (HOFs).
- DAPS reduces the interruption down to 2 ms in DL by receiving simultaneously from source and target cells of handover.
- To achieve both mobility robustness and interruption time reduction, both features shall be configured simultaneously which is currently not possible.
- As such, it would be desirable to have a mobility solution reducing both mobility failures and interruption time during handover.

Type of handover \ Outage impairing reliability of services	Outage in Successful HO	Outage due to RLF	Outage due to Handover Failure
Conditional Handover (CHO) of Rel. 16	Not Reduced	Reduced	Reduced
DAPS Handover of Rel. 16	Reduced	Not Reduced	Not Reduced
CHO & DAPS (C-DAPS) Handover for Rel. 18	Reduced	Reduced	Reduced

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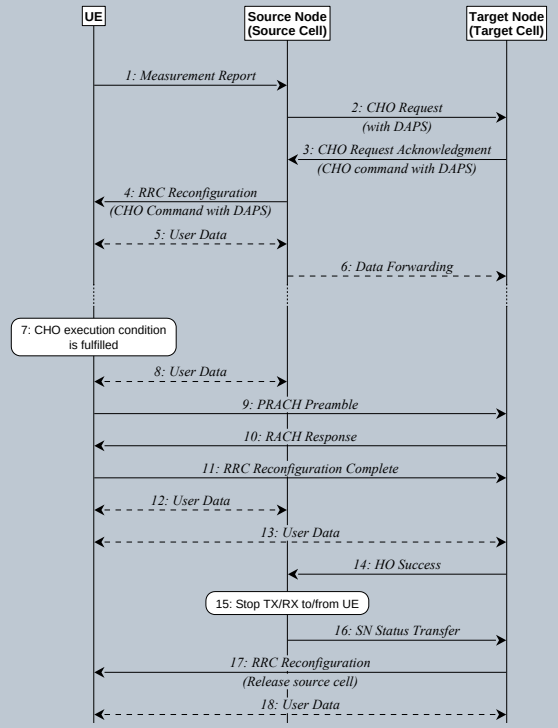
Inter-working of DAPS and CHO for Improved Reliability
Performance Evaluation

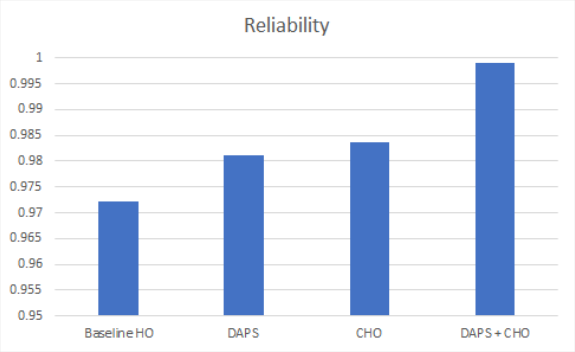
- Outage occurs during:
  - Beam failure/Radio Link Failure
  - Beam Failure recovery
  - Handover
  - Re-establishment (in case of RLF and handover failure).
- Handover options
  - Baseline Handover (Rel.15)
  - Dual Active Protocol Stack (DAPS)
  - Conditional Handover (CHO)
  - DAPS and CHO
- $Reliability = 1 - \frac{Time\ of\ Outage}{Time\ of\ Service}$

Potential DAPS and CHO Inter-working



Evaluation

Parameter	Value
Simulation time	10 s
Warmup period	3 s
UE Speed	120 kph
RLF Qin Threshold	-6 dB
RLF Qout Threshold	-8 dB
Beam Failure Detection Qout Threshold	-8 dB
Beam Failure Detection Timer	50 ms
Beam Failure Instance Max Count	5
Handover Preparation Delay	50 ms
Baseline Handover Execution Interruption	40 ms
DAPS Handover Execution Interruption	2 ms



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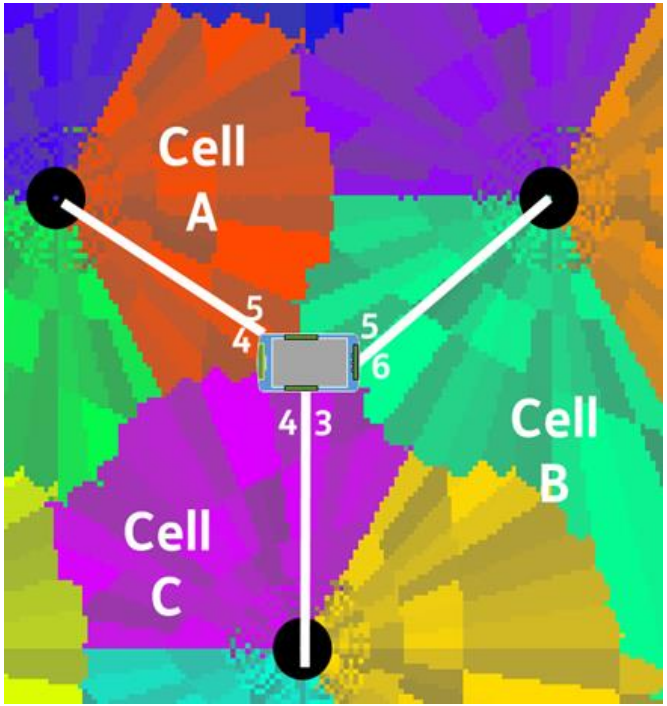
Background Information for Objective #4

Example 1: Fast Cell Selection using CHO

- In FR2, due to the small wavelength, moving obstacles (e.g. cars) may temporally block the radio propagation to the serving cell and thus make a handover necessary.
- Similarly, obstacles in the vicinity of the UE may also block any transmission into a certain direction (in particular the hand of a person holding the UE)
- When narrow beams are used for transmission also at the UE side, rotating the UE may also lead to handovers (in particular if the spherical coverage is not 100%).
- Even if the UE is static, rotation or blockers may lead to very frequent and continuous handovers between cell A, B and C.
- Fast cell selection mode enabled by CHO (and RACH-less execution) can help to perform slim switching between cells A, B and C with much less signaling overhead.



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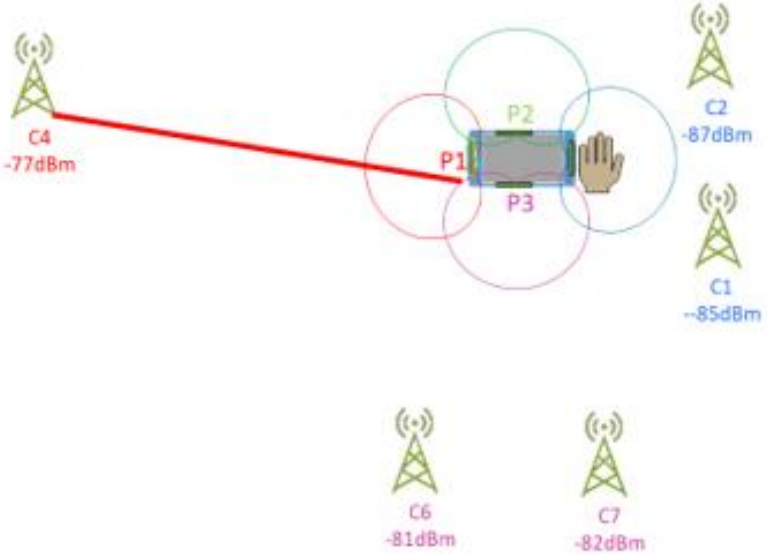
Background Information for Objective #4

Example 2: Enhanced Measurement Events for MPUE

- Hand blockage (to panel 1 in figure) can cause a high and abrupt signal loss in the serving cell C1, e.g., 15 dB in 100-200 ms.
- A measurement report to the serving cell, for the sake of preparing a new cell C4 in conditional handover, may get lost due to this rapid degradation.
- Cells, e.g. C4, that are detected on panels that are different from serving one, can be prepared early enough to be used as fallback in case of blockage.
- Enhancements for measurement reporting triggering are needed to trigger early preparation on non-serving panel.



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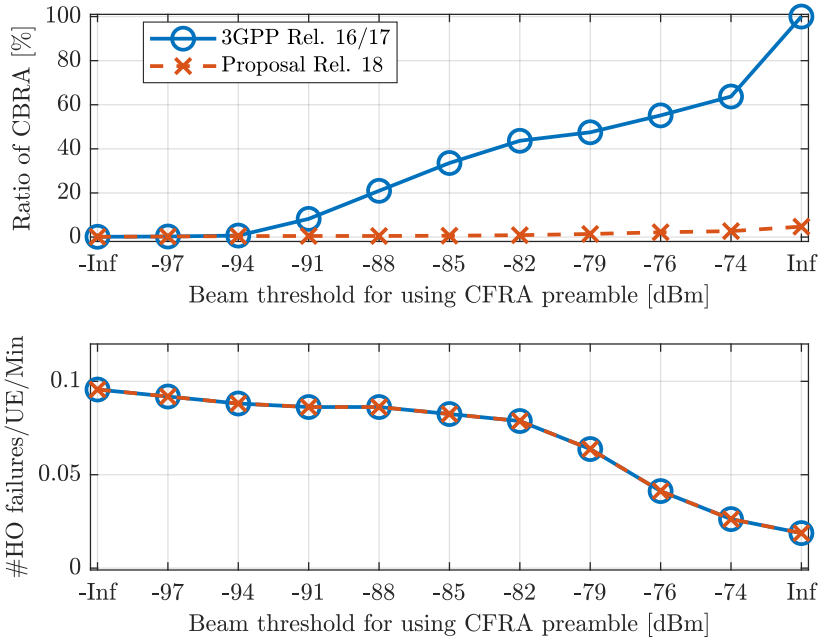
Background Information for Objective #4

Example 3: Reducing Contention-Free Random Access (CFRA) Fallback

- For CHO, there could be significant time between preparation and execution.
- It is very likely, that the CFRA-prepared beam in CHO target gets outdated.
- Trying the CFRA-prepared beam too desperately will result in CHO failure.
- Consequently, many CHOs will fall back to Contention-based random access (CBRA) causing longer interruption and more signaling in case of contention.
- Solutions may comprise
  - Updating CFRA resources
  - Changing beam selection in RACH procedure



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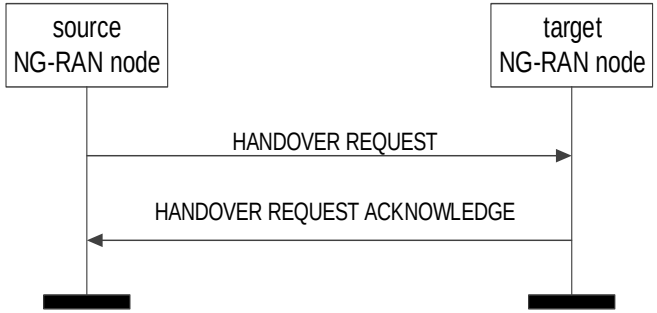
Background Information for Objective #4

Example 4: Enhanced CHO Cancelation Procedure

- In Rel. 16, the target cell may indicate using CHO Cancel message to the source cell that it wants to modify the CHO preparation for the UE, i.e. update CFRA resources, or accept a previously rejected PDU session, etc.
- Before initiating a new CHO request to the target cell for replacing the existing CHO preparation, the source cell needs to de-configure the CHO preparation from the UE before it can initiate new CHO request. This is needed to avoid race condition.
- De-configuring the CHO preparation may lead to an RLF.
- In Rel. 16, target node implementation may save two UE contexts, however, the source node is not aware of the target node implementation capability.
- Target node can signal to the source if it can store one or multiple UE contexts. If target cell can support multiple UE contexts the source node does not need to de-configure the UE before initiating new CHO request, saving in turn unnecessary RLFs.



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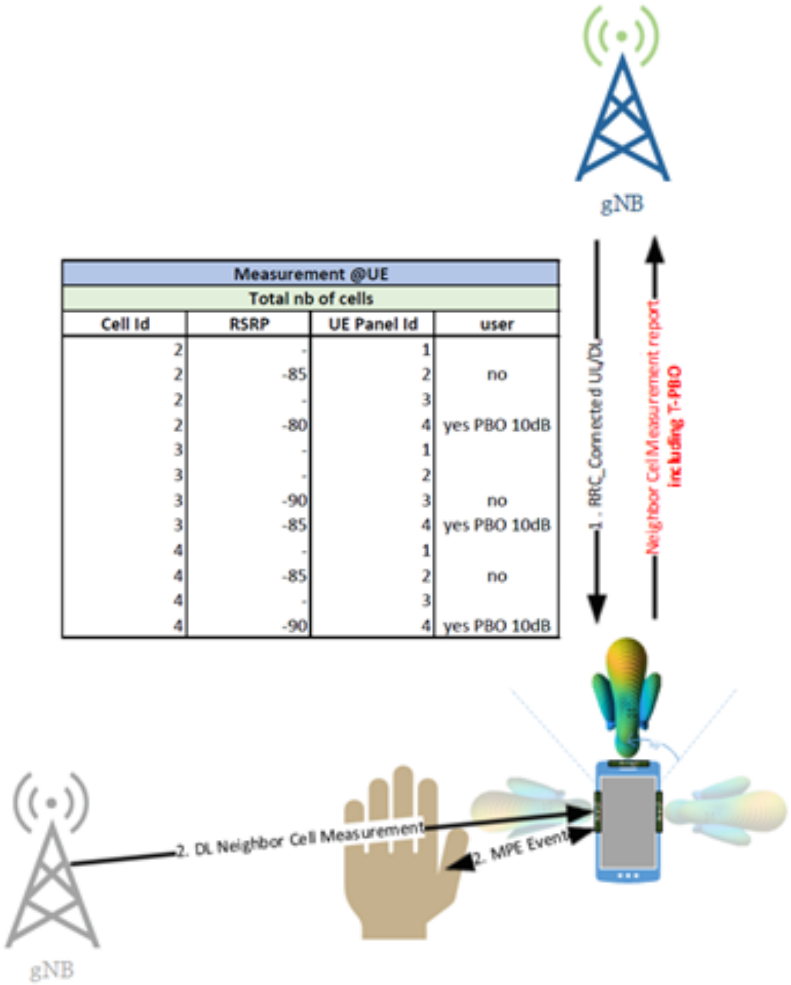
Background Information for Objective #4

Example 5: MPE Handling in Baseline Handover

- The measurement report sent to serving gNB does not include information on the status of the panel used for a neighbour cell measurement, specifically:
  - MPE events with Power Back Off (PBO)
  - Panels being covered or partly covered, thus providing poor UL radio link quality (independently of DL quality)
- In addition, the target gNB does not have all MPE status related information of the UE being handed over to make a decision on whether it 1) should accept, reject the HO/or some of the handed over PDU session or 2) tailor in the handover command the initial access and data scheduling configuration of PUSCH for the UE with MPE event. This may lead to handover failures in the worst cases and to sub-optimum throughput and waste of resources in the best case.
- Potential solutions
  - Calculating Target cell PBO (T-PBO) on non-serving array, then transmitting T-PBO to serving gNB along with neighbour cell measurements report (e.g. RSRP).
  - New measurement events for triggering MPE status related information.
  - Source gNB may indicate to the target gNB the MPE status related information of the UE during handover.



Measurement @UE			
Total nb of cells			
Cell Id	RSRP	UE Panel Id	user
2	-	1	
2	-85	2	no
2	-	3	
2	-80	4	yes PBO 10dB
3	-	1	
3	-	2	
3	-90	3	no
3	-85	4	yes PBO 10dB
4	-	1	
4	-85	2	no
4	-	3	
4	-90	4	yes PBO 10dB

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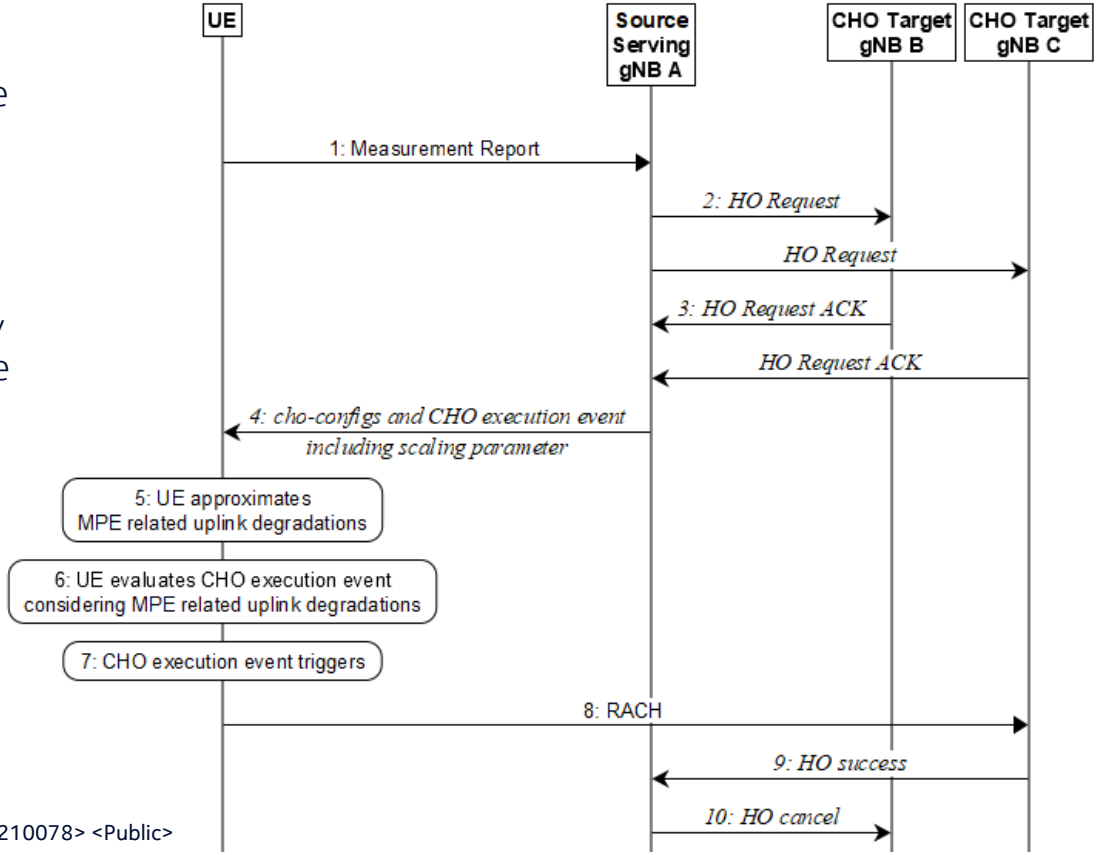
Background Information for Objective #4

Example 6: MPE Handling in Conditional Handover

- In CHO, it is desirable to consider the MPE related degradation of a candidate target cell in handover execution.
- Based on information from the candidate CHO target cell (e.g., power control parameters) that is provided by the source cell, the UE can approximate the prospect MPE related UL degradation of a candidate target cell.
- The computed MPE related uplink can be then considered in the CHO execution condition to determine a more suitable target cell and a better execution time for the CHO



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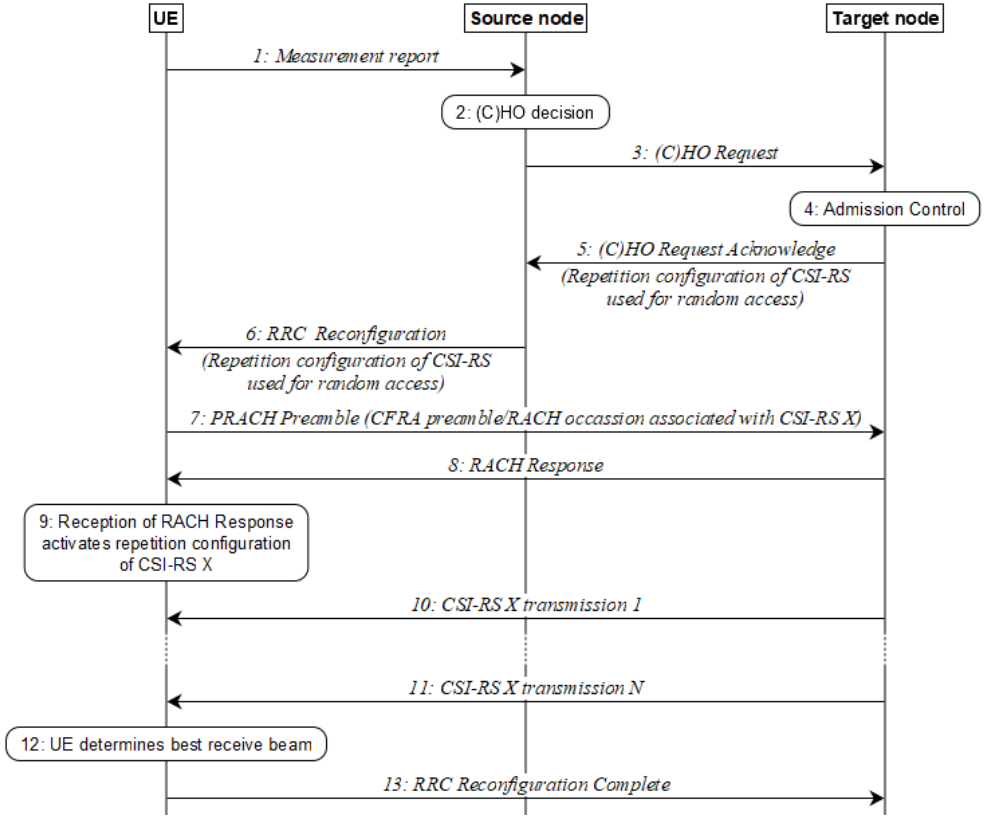
Background Information for Objective #4

Example 7: UE beam alignment before or during HO/CHO

P3

- Currently, the UE beam refinement (P3) procedure can be performed only after the handover execution is completed. For this, the new serving cell indicates to the UE the index of CSI-RS whose transmission will be repeated.
- Performing UE beam refinement after the handover execution causes additional signalling overhead and increases the delay to setup the narrow beam by 15-20 ms.
- Potential solutions:
  - Integrate the UE beam refinement during the handover procedure for CSI-RS based random access.
  - Enable the UE beam refinement of a CHO candidate target cell before the CHO execution is performed.



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Background Information for Objective #5

- In Rel. 16, it has been agreed that the network (e.g. via OAM) ensures that conditional handover (CHO) and Conditional PSCell Change (CPC) are not configured simultaneously to UE. This solution has two drawbacks:
  - Restrictive as the inter-working is possible in many cases.
  - Static in the sense that OAM solution is too rigid to allow dynamic decision to allow CHO or CPC for each UE.
- Both CHO and CPC configurations can be active at the same time by defining the signaling and UE behaviour to resolve the dependencies between the two procedures:

CHO Target MCG Config	CHO Target SCG Config	Source SCG-CPC Allowed
Any Config	No	Yes
Any Config	New PSCell: Full SCG-Config, Release-and-Add	Yes
Any Config	New PSCell: Delta config over Source SCG	Yes, but Target SCG needs to be released in CHO configuration of source MN.

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Background Information for Objective #6

- If CHO is performed from source MN to target MN change, target SN may no longer be a valid to access/connect to when the CHO execution condition, evaluated using PCell measurements, is met.
- The radio link of the prepared PSCell may degrade leading to PSCell access failure) or another PSCell could become more relevant while waiting for the CHO execution to be met.
- Checking the radio link quality/strength of the target PSCell before performing random access would be useful to avoid failures.

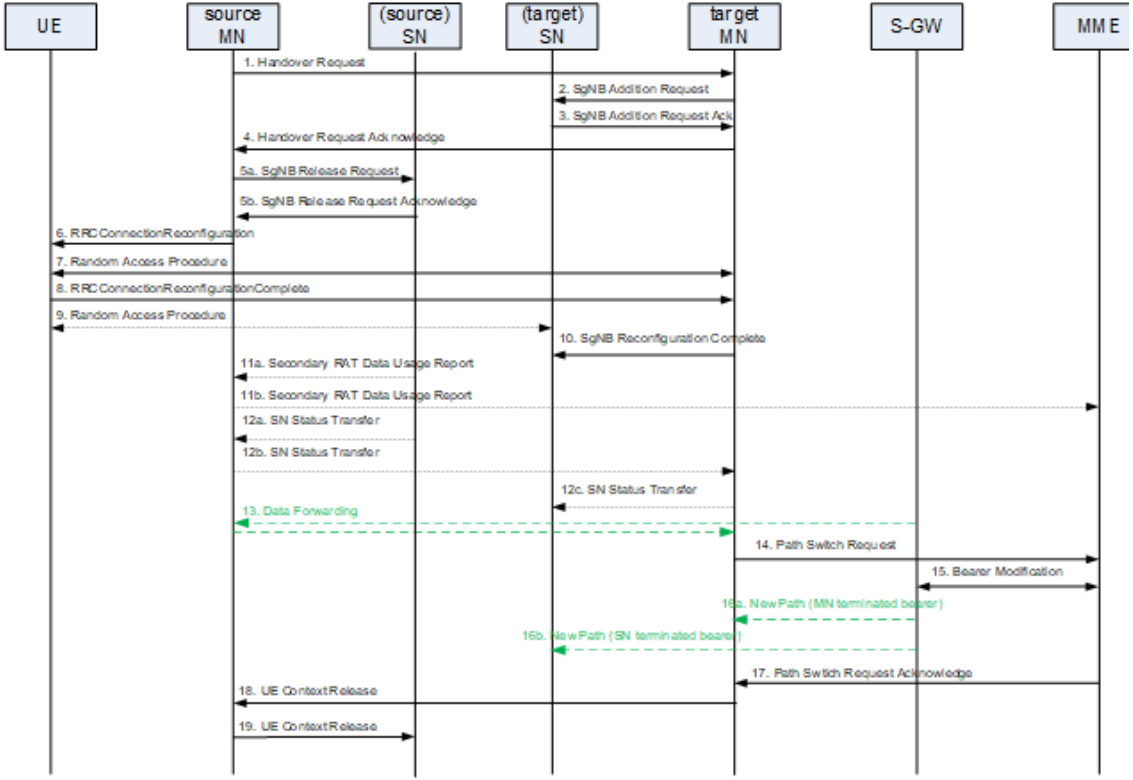

Figure 10.7.1-1: Inter-MN handover with/without MN initiated SN change

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