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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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x the first digit:

1 presented to TSG for information;

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

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1 Scope

The present document covers the Study on Mobile Relay for E-UTRA . The objective is to first identify scenario(s) and requirements then identify the key properties of Mobile Relays and assess the benefits of Mobile Relays over existing solutions in fast-moving environments.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 36.912: "Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)".

[3] 3GPP TR 36.806: "Evolved Universal Terrestrial Radio Access (E-UTRA); Relay architectures for E-UTRA (LTE-Advanced)".

[4] 3GPP TR 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

[5] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply.
A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

4 Scenario and requirements

4.1 Scenario

High speed public transportation is being deployed worldwide at an increased pace. Hence, providing multiple services of good quality to users on high speed vehicles is important yet more challenging than typical mobile wireless environments.

The mobile relay SI focuses on the high speed train scenario as the target deployment scenario to study. High speed train scenario can be characterized as:

- The trains operated with high speed, e.g. 350 km/h
- Known trajectory
- High penetration loss of the radio signal through the well shield carriages
- UEs on the trains are stationary or move at pedestrian speed w.r.t. relay nodes
- …

A reference scenario for high speed train is depicted in Figure 4.1.

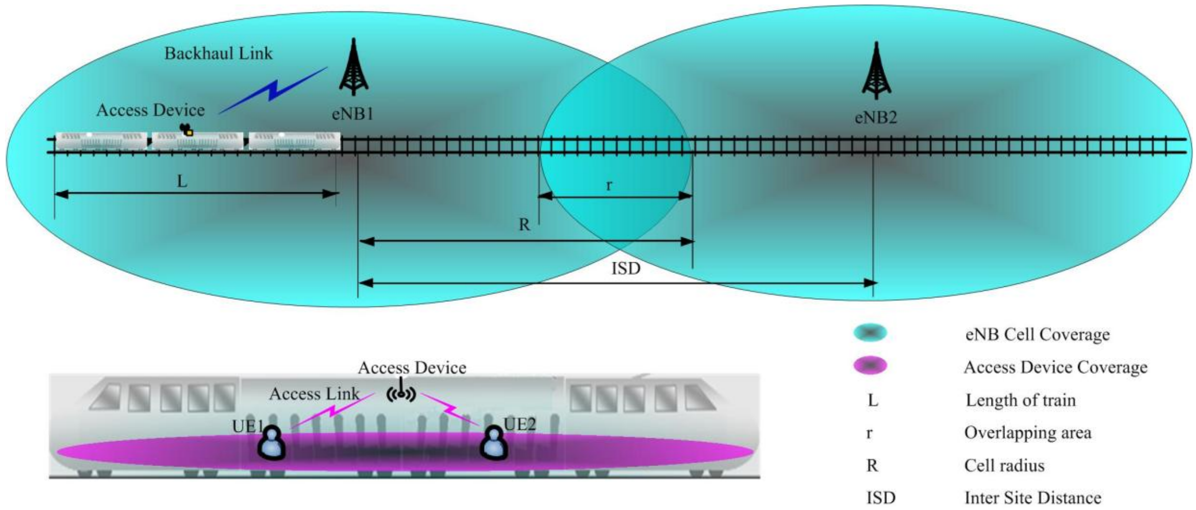

Figure 4.1: A reference scenario for high speed train

The TGV Eurostar in Europe is 393 m long, moves at speed reaching 300 km/h.
The Shinkansen in Japan has similar characteristics, with 480 m long, 300 km/h of commercial speed.
The high speed train in China is 432 m long moving at speed reaching 350 km/h.

Due to fast moving and well shield carriage, the network in high speed train scenario faces severe Doppler frequency shift and high penetration loss, reduced handover success rate and increased power consumption of UEs.

To improve the coverage of the train deployment, access devices can be mounted on the high speed train, providing a wireless backhaul connection via the eNBs along the railway by outer antenna e.g. installed on top of the train, and wireless connectivity to the UEs inside carriages by inner antenna installed inside.

4.2 Requirements

- **Spectrum model**

The mobile relay study should be based on the scenario that both backhaul link spectrum and access link spectrum belong to the same operator. The spectrum model where backhaul link spectrum and access link spectrum belong to different operators should also be supported.

- **Multi-RAT support**

One operator may have multiple RATs in operation. In order to reduce the effort of optimizing the deployment for high speed train scenario, multi-RAT support of mobile relay should also be studied, which means to allow LTE on backhaul link and different air interface technologies, e.g. LTE/3G/2G/Wi-Fi, on the access link.

NOTE: According to the charging and security requirements discussed in SA2, the mobile relay supporting Wi-Fi access point should be considered as a trusted non-3GPP access.

- **In-band and Out-band operation**

Both in-band (when applicable) and out-band mobile relay will be considered in this study item. The concepts of in-band and out-band relay are defined in 3GPP TR 36.814 [4].

5 Solutions

5.1 Existing solutions

5.1.1 Dedicated deployment of macro eNBs

To optimize coverage along the train line, operators deploy dedicated base stations and/or backhaul to cover the railway tracks with directive antennas, thus addressing radio layer issues and enabling a dedicated path for all train-generated traffic. UEs on the train are directly served by these dedicated base stations.

To reduce UE handover failure rate, the main points are to extend the cell coverage and to increase the interval of handovers, which means to increase the overlap area. Some network parameters may also be optimized, e.g. in order to improve the cell selection/reselection/TAU procedure of idle mode UEs. Different solutions can be used.

A particular type of deployment can involve transmission points with high and low power, i.e. HetNet deployment. When targeting fast-moving vehicles, it could be appropriate to deploy high-power cells together with low-power cells. In order to reduce the signalling load due to frequent handovers, the high-power cells with large coverage areas can be configured as the serving node. Low-power cells can be added in order to improve capacity and to provide high data rates. Depending on the actual network setup, different approaches could be possible, such as:

With Carrier Aggregation (CA) - The Primary Component Carrier (PCC) can be transmitted by the high-power cell, whereas the Secondary Component Carrier (SCC) can be transmitted by the low-power cell. Cross-carrier scheduling from the PCC can reduce the signalling load due to handovers of the SCC. Without CA - a macro eNB (high-power transmission point) can be extended by low-power transmission points such as remote radio units (RRUs). When sharing the same cell ID, the closest RRU can serve the train without the need for handovers between RRUs belonging to the same macro cell.

5.1.2 Dedicated deployment of macro eNBs + L1 repeaters

L1 repeaters amplify and forward signals in a certain frequency band. If the TX and the RX antennas are sufficiently isolated (i.e. inside vs. outside the train), repeaters can transmit the amplified signal on the same frequency as the received signal. Since repeaters do not re-generate the received signal, they are particularly useful when deployed at positions with advantageous SINR, while SINR cannot be improved by L1 repeaters since both noise and desired signal are amplified and forwarded by the L1 repeater. On the basis of optimized deployment of dedicated macro base stations along the railway, L1 repeaters can be deployed on the train to overcome the penetration loss through walls and windows. Being connected through a L1 repeater, UEs can reduce their transmit power, thereby increasing battery life.

5.1.3 LTE as Backhaul, Wi-Fi as Access on Board

This solution addresses Wi-Fi-capable UEs, arguably the vast majority in the near future. The wireless node mounted on board the train connects as an LTE UE to the eNB, and provides coverage on board as a Wi-Fi AP. All UEs on board can use this node for data connections or VoIP calls, while continuing to use the existing 2G RAT for voice. This solution can be built with currently available technology and requires no changes to specifications, so it is likely to be less complex and to cost less than a mobile relay. An optimized outdoor antenna (e.g. a smart antenna mounted on the train roof) can be envisaged to enhance the performance of the backhaul link.

The same captive portals, authentication and payment systems, etc. commonly deployed at stations, airports, and other public Wi-Fi hotspots can also be made available on board, in order to give customers the same experience. An added benefit of Wi-Fi access is also the possibility to locally terminate on-board services (entertainment, meal ordering/reservations, navigation, on-board webcams, etc.). All such services can be offered directly to user terminals without going through the CN or having to set up a local breakout (e.g. LIPA/SIPTO), as required with other solutions.

This solution also enables any Wi-Fi-only devices to use the LTE network as backhaul for their data connections. The wireless coverage on board is unaffected by the train movement because the UE part of the node handles mobility with the eNB, transferring the bundle of all data connections at every handover.

5.2 Mobile relay

The mobile relays are base stations/access points mounted on the high speed trains. The mobile relay is connected wirelessly to Donor eNB (DeNB) via the Un radio interface. The mobile relay provides wireless connectivity service to end users inside the vehicle. In addition to the eNB functionality, mobile relays support a subset of the UE functionality to connect to the DeNB.

5.2.1 Functions

From a specification point of view, functionalities defined for fixed relays in Rel-10 also apply to mobile relays, unless explicitly specified. Due to the mobility of the Mobile Relay, further enhancements or new procedures may be required in order to support all existing network functionalities.

Mobile relays may support multi-RAT functionalities. This means an LTE Un provides the backhaul link, while different air interface technologies, e.g. LTE/3G/2G/WiFi, may be supported on the access link.

Mobile relays continue to provide uninterrupted connectivity for the user plane and control plane of the served UEs to their respective core network nodes, when the Un connection is changed to different DeNBs as the mobile relay moves through the coverage of the network.

5.2.2 Architecture

The mobile relay architecture should fulfil the following principle(s):

- Principle: Mobile relay's Serving GW serves as mobility anchor point for mobile relay inter-DeNB handovers.

NOTE: The Relay-GW/PGW/SGW may be changed for routing optimization purpose, where applicable. The change of Relay-GW/PGW/SGW is independent of the RN mobility procedure and may be performed after HO completes. Whether there are further issues are FFS in mobile relay scenario.

5.2.2.1 Alt.1

5.2.2.1.1 Overview

This architecture is based on the Alt.1 architecture defined for fixed relay.

Alt 1 relay node architecture is shown in Figure 5.2.2.1-1 below with the following properties:

- S1-U interface for the UE is between the RN and SGW of the UE.
- S1-MME interface for the UE is between RN and MME of the UE.
- UL S1-U and S1-MME packets of a UE served by mobile RN are sent on the mobile relay user plane EPS bearers from the RN to the RN P/SGW of the relay. Similarly DL S1-U and S1-MME packets are sent to the mobile relay via the P/SGW of the relay.
- Mobile relay HO reuses existing UE handover procedures with some enhancement/modification if needed.
- UE PDN connection and RN PDN connection are preserved during mobile relay handover.

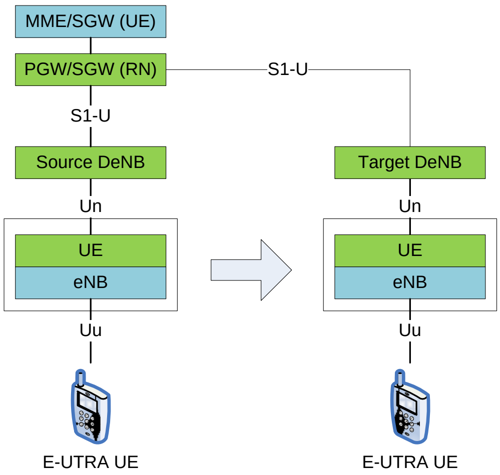

Figure 5.2.2.1-1: Alt.1 relay architecture

5.2.2.1.2 Mobility procedure

Figure 5.2.2.1-2 shows the RN inter-DeNB mobility procedure under architecture Alt.1, which is identical with the procedure for Inter-eNB mobility of UE defined in 3GPP TS 36.300 [5]. There is no additional signalling for UE HO in both RAN and core network side during the RN mobility, i.e., the RN HO is transparent to the UE in both the RAN and core network.

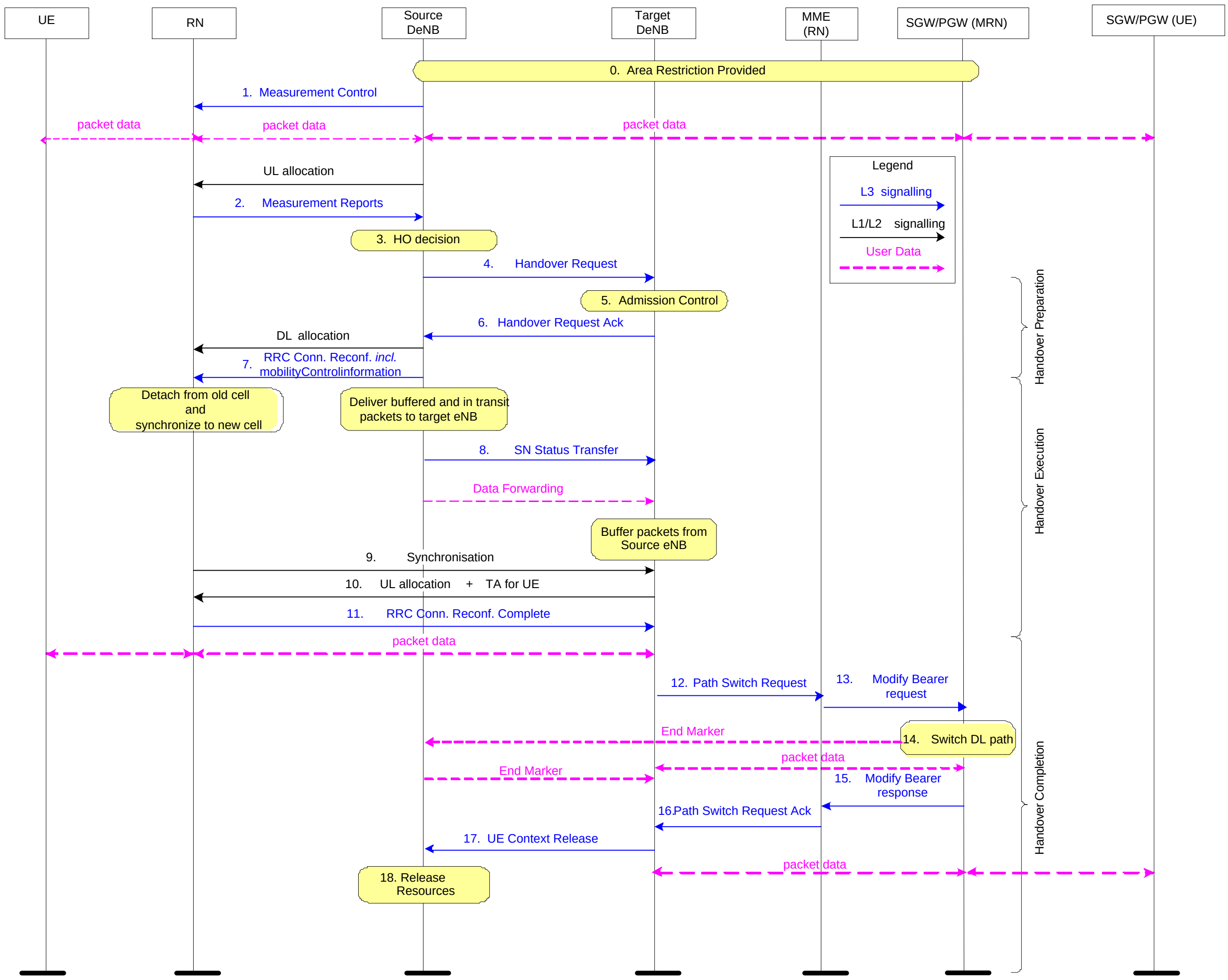

Figure 5.2.2.1-2: RN mobility procedure (Alt 1)

5.2.2.2 Alt.2

5.2.2.2.1 Overview

This architecture is based on the Alt.2 architecture defined for fixed relay.

Alt 2 relay node architecture is shown in Figure 5.2.2.2-1 below with the following properties:

- The MR's S/P-GW and Relay GW are located in the initial DeNB where the mobile relay attaches for normal operation. When the relay is HO to another DeNB, it still uses the S/P-GW and Relay GW collocated in the initial DeNB. The UE EPS bearer is transparent to the target DeNB.
- S1-U interface for the UE is between the RN and Relay GW (of the initial DeNB) and between the Relay GW and the SGW of the UE.
- S1-MME interface for the UE is between RN and Relay GW (of the initial DeNB) and between the Relay GW and the MME of the UE.
- UL S1-U and S1-MME packets of a UE served by mobile RN are sent on the mobile relay user plane EPS bearers from the RN to the RN P/SGW in the initial DeNB of the relay. Similarly DL S1-U and S1-MME packets are sent to the mobile relay via the P/SGW in the initial DeNB of the relay.
- Mobile relay HO reuses existing UE handover procedures with some enhancement/modification if needed.
- UE PDN connection and RN PDN connection are preserved during mobile relay handover.

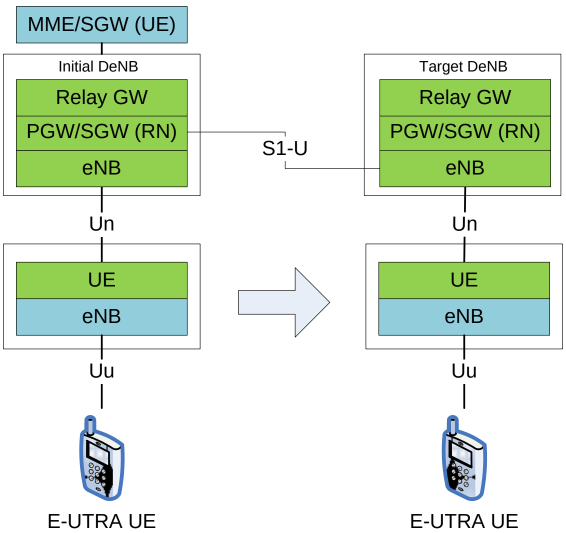

Figure 5.2.2.2-1: Alt.2 with Relay GW and PGW/SGW collocated with initial DeNB

5.2.2.2.2 Mobility procedure

Figure 5.2.2.2-2 shows the RN inter-DeNB mobility procedure under architecture Alt.2, which is basically the same as the procedure under Alt.1, except the RN PGW/SGW is always located in the initial DeNB where the mobile relay attaches for normal operation. There is no additional signalling for UE HO in both RAN and core network side during the RN mobility, i.e., the RN HO is transparent to the UE in both the RAN and core network.

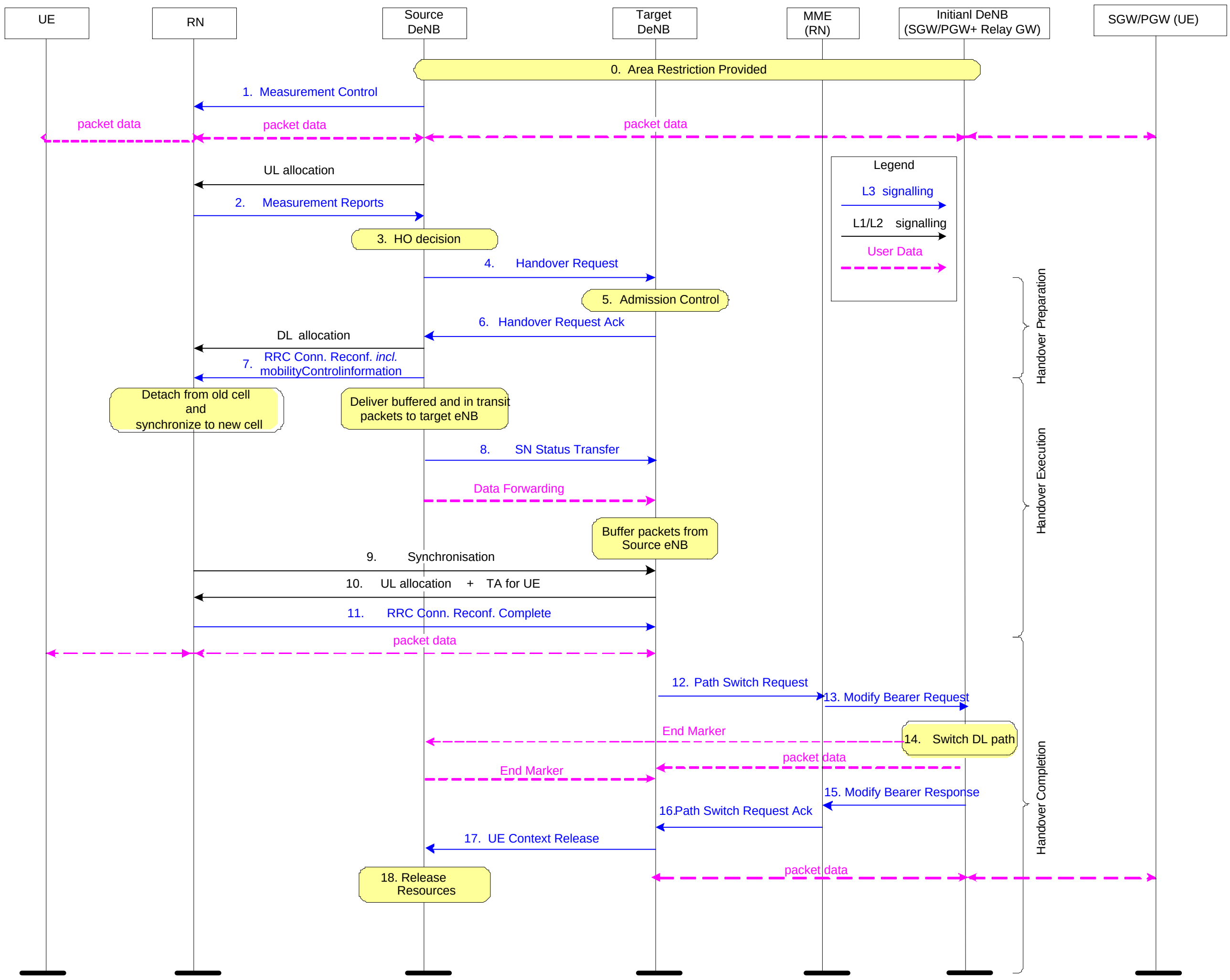

Figure 5.2.2.2-2: RN mobility procedure (Alt 2)

5.2.2.3 Alt.2 enhancement

5.2.2.3.1 eAlt.2-1: Alt.2 with dual Rel-10 relays for HO

5.2.2.3.1.1 Overview

One Rel-10 Relay cannot support mobility, but in case there are two Rel-10 Relay entities in a mobile relay device, relay mobility can be handled with two such entities being collocated, as shown in Figure 5.2.2.3.1-1. From the networks perspective, each logical RN cell is identified by a separate ECGI. Whereas from the perpective of UEs served by the mobile relay node, the two logical RN cells sharing the same PCI are identified by separate ECGIs. The two RN entities act as two relays that attach to two nighboring DeNBs, and can provide the similar function as RN handover.

Alt 2 relay node with dual Rel-10 relays supports HO as follows:

- When RN_UE1 connects to DeNB Cell1, all the UEs in the train are served by logical RN Cell1.
- When the train moves into the coverage of DeNB2 Cell2, RN_UE2 attaches to DeNB2 Cell2, and activates logical RN_Cell2.
- The bearers for all UEs under logical RN_Cell1 are transferred to logical RN_Cell2, using a modified S1 or X2 HO procedure.
- After all the UE bearers are transferred to logical RN_Cell2, logical RN_UE1 detaches from DeNB1 Cell1, and releases S1/X2 connections.
- If the train keeps moving and reaches DeNB3 Cell3 coverage, RN_UE1 attaches to DeNB3 Cell3 and the process repeats

Alt 2 relay node with dual Rel-10 relays is shown in Figure 5.2.2.3.1-1 below with the following properties:

- There are two logical RN UEs that work alternatively to support the high speed train scenario.
- There is one RN cell with a single PCI from the perspective of the UEs served by the RN.
- From the perspective of the network, there are two RN cells, each identified by a different ECGI.
- Rel-10 RN startup procedure can be reused.
- The bearer mapping solution of Rel-10 Relay can be reused.
- As an optimization, group mobility to reduce the latency and signalling load, detailed solution is FFS.

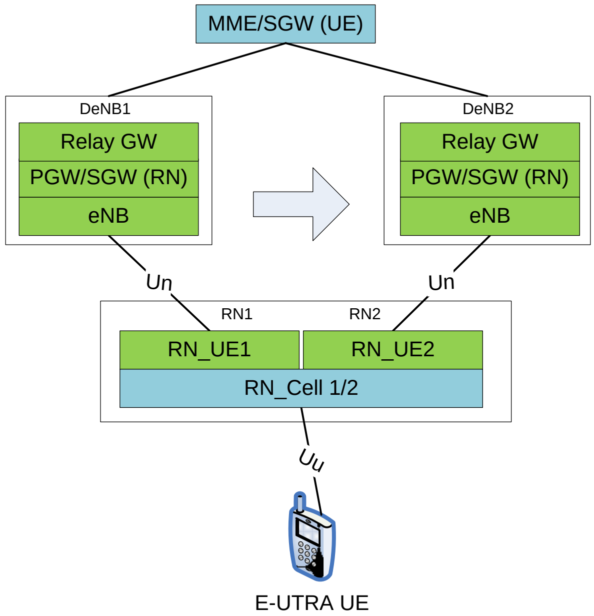

Figure 5.2.2.3.1-1: Alt.2 with dual Rel-10relays for HO

Further optimization to speed up the RN startup procedure may be needed, e.g.

- OAM informs RN ECGI under each DeNB cell to the RN in Phase I

5.2.2.3.1.2 Mobility procedure

The handoff of RN traffic from DeNB1 to DeNB2 involves three steps:

1. Attach RN_UE2, and setup corresponding bearers to the SGW/PGW function in DeNB2. Configure the ECGI for RN_Cell2 to correspond to DeNB2, and establish S1 and possibly X2 interfaces for the RN_Cell2.
2. Transfer bearer path and context of UEs served by the Mobile Relay, from DeNB1/RN_UE1 to DeNB2/RN_UE2. This may correspond to a HO of UE from RN_Cell1 to RN_Cell2, or may only involve a path switch.
3. Detach of RN_UE1 from DeNB1.

Step1: Attach to DeNB2

The attach procedure for a Rel-10 RN is reused. It is assumed that phase I has already been completed, and so only phase II of the attach is repeated for each new DeNB as defined in 3GPP TS 36.300 [5]. In the Rel-10 RN attach, the DeNB provides the IP address of its embedded S-GW/P-GW function to the RN's MME, this procedure can only proceed once RN_UE2 can establish a RRC connection with DeNB2. Therefore, in this approach, the attach is triggered once the Mobile Relay enters into suitable radio coverage of DeNB2.

Note that during the attach procedure, the connection of RN_UE1 to DeNB1 is maintained. Thus RN_UE2 attach, plus the transfer of UE traffic from RN-UE1 to RN_UE2 should occur while the Mobile Relay is within the region of coverage overlap between the two donor eNBs. Figure 5.2.2.3.1-2 below illustrates the message flow for this method.

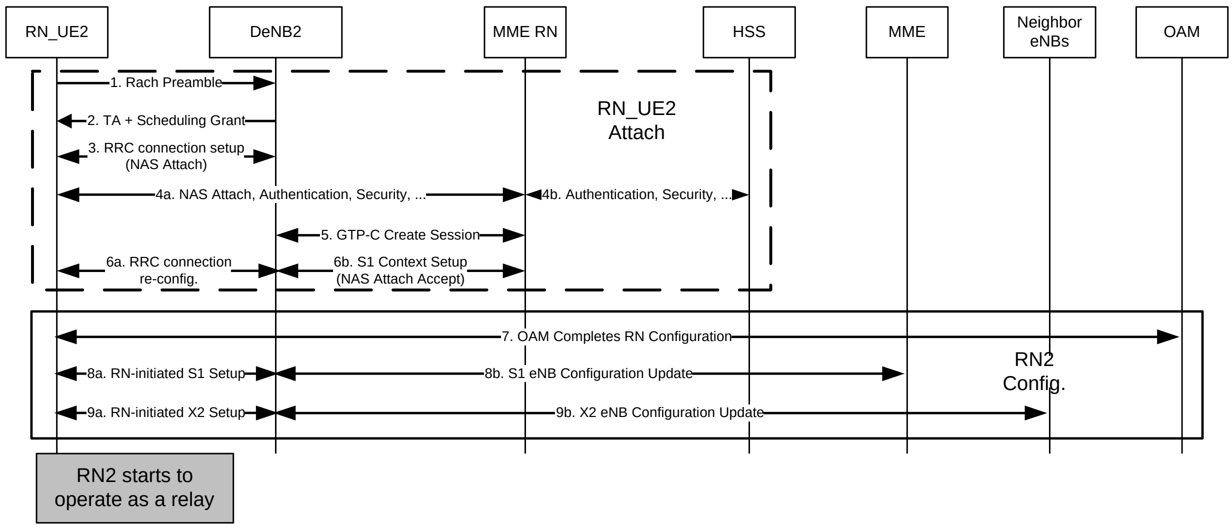

Figure 5.2.2.3.1-2: Message flow, direct attach of RN_UE2 to DeNB2

Step 2: Transfer of UE bearers

During the RN configuration, RN_Cell2 is assigned a different ECGI than RN_Cell1. Thus from the network's perspective, RN_Cell1 and RN_Cell2 are different cells. However, from the UE's perspective, there is single RN cell identified by its PCI. the UE's bearers are transferred from RN_Cell1 to RN_Cell2 only from the perspective of the CN. This process is transparent to the UE, and no HO is experienced by the UE itself.

Figure 5.2.2.3.1-3 illustrates the message flow, reusing the X2 HO message flow. Note that as both RN cells are in the same device, data packets delivered to RN_UE1 over the Un interface, but not yet delivered to the UE over the Uu interface can be logically transferred to RN_Cell2. Likewise the SN status is logically transferred from RN_Cell1 to RN_Cell2.

However, there is still a need to transfer the UEs context to DeNB2. Therefore, we assume the HO request/HO response is still exchanged, in order to transfer the UE context. It is FFS if a more optimized solution can be used to transfer the UE context.

It is FFS to decide if the delivery of these packets can be optimized via an X2 connection from RN_Cell2 to DeNB1 (proxied by DeNB2). It is also FFS to determine if UE measurements are useful to aid in these handoffs.

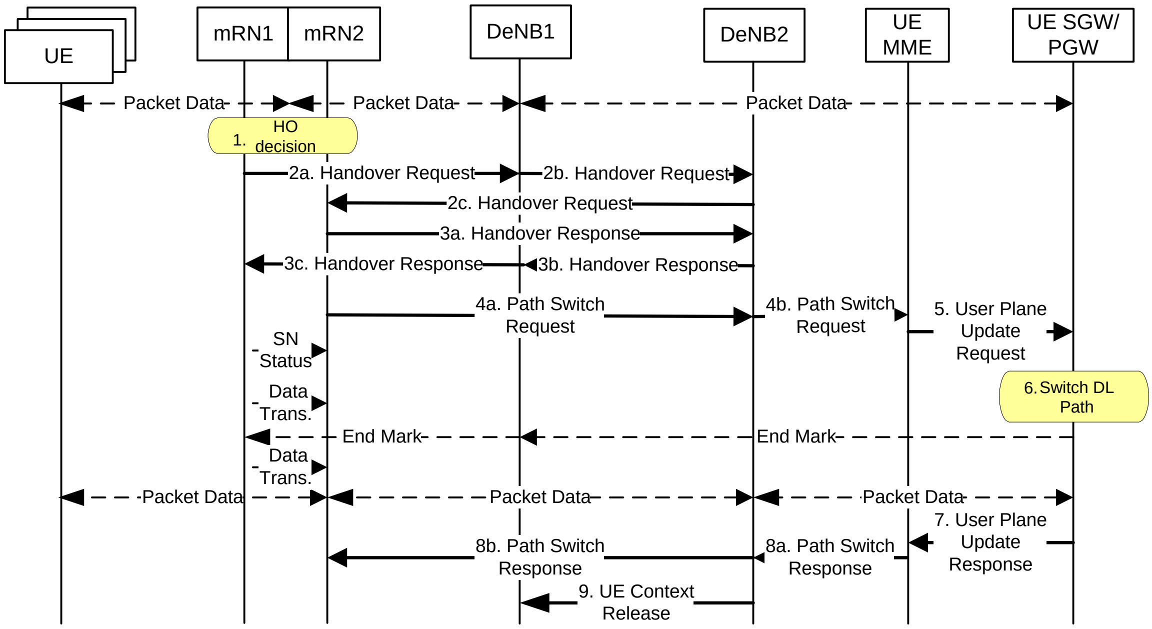

Figure 5.2.2.3.1-3: Mobility procedure for UEs under mobile RN

Step 3: Detach of RN_UE1 from DeNB1

After all UE traffic flows have been transferred from RN_UE1 to RN_UE2, RN_UE1 can be detached from DeNB1. This follows the RN detach procedure for Rel-10 UEs as defined in 3GPP TS 36.300 [5]. This procedure is illustrated in Figure 5.2.2.3.1-4 for completeness.

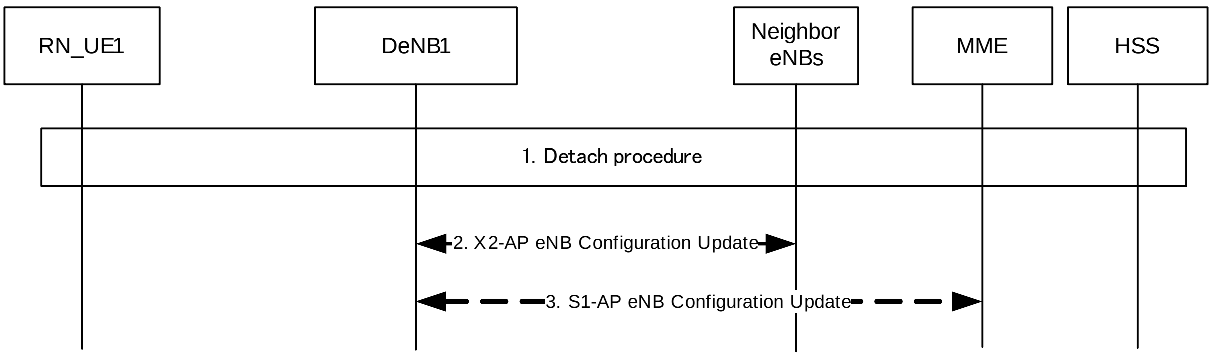

Figure 5.2.2.3.1-4: Detach of RN_UE1 from DeNB1

5.2.2.3.2 eAlt.2-2: Alt.2 with Relay GW and PGW collocated with initial DeNB

5.2.2.3.2.1 Overview

The architecture option for mobile relay scenario is shown in Figure 5.2.2.3.2-1 below with the following properties:

- The PGW of the mobile relay and Relay GW is located in the initial DeNB where the mobile relay attaches for normal operation. When the mobile relay handovers to another DeNB, it still uses the PGW of the mobile relay and Relay GW collocated in the initial DeNB; the SGW of the mobile relay is relocated to the target DeNB.
- S5/S8 interface of the mobile relay is between initial DeNB and target DeNB.
- S1-U interface for UE served by the mobile relay is between the mobile relay and Relay GW (of the initial DeNB) and between the Relay GW and the SGW of the UE.
- S1-MME interface for UE served by the mobile relay is between the mobile relay and Relay GW (of the initial DeNB) and between the Relay GW and the MME of the UE.
- After handover, UL S1-U and S1-MME packets of a UE served by the mobile relay are sent on the user plane EPS bearers of the mobile relay from the mobile relay to the SGW of the mobile relay and eNB collocated in the target DeNB, then to the PGW of the mobile relay and Relay GW collocated in the initial DeNB.
- No UE context needs to be transferred during mobile relay handover.
- Because PGW of the mobile relay is not changed during mobile relay handover, IP address of the mobile relay is not needed to change. The relocation or redirection of PGW of the mobile relay and Relay GW is not needed. However, the Relay GW/PGW of the mobile relay may be changed for route optimization purpose, which is FFS.

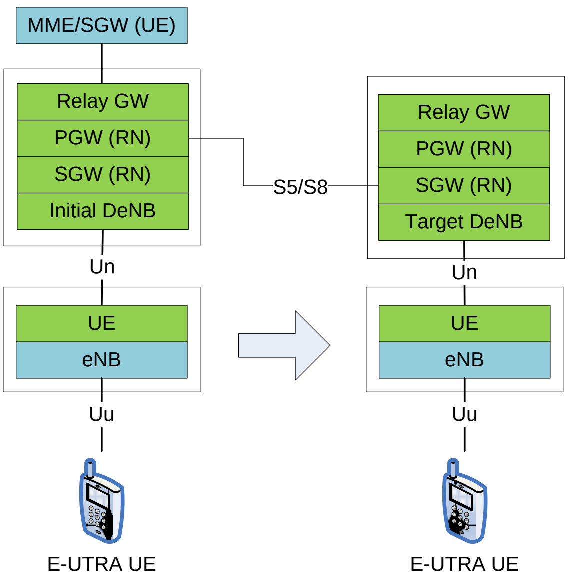

Figure 5.2.2.3.2-1: Alt.2 with Relay GW and PGW collocated with initial DeNB

There are also two options that can be applied to S5/S8 interface between initial DeNB and target DeNB in this architecture:

(1) Option 1 (PMIP solution): Figure 5.2.2.3.2-2 shows the control plane protocol stack for option 1. Because the Relay GW is located in the initial DeNB, S1AP/SCTP/IP connections between mobile relay and initial DeNB are transparent to target DeNB. GRE tunnels are created between LMA (i.e. PGW of the mobile relay)) and MAG (i.e. SGW of the mobile relay). Figure 5.2.2.3.2-3 shows the user plane protocol stack. GTP/UDP/IP connections between mobile relay and initial DeNB are transparent to target DeNB. Figure 5.2.2.3.2-4 shows the control plane protocol stack for S5/S8 interface between initial DeNB and target DeNB.

(2) Option 2 (GTP solution): Figure 5.2.2.3.2-5 shows the mobile relay control plane protocol stack for option 2. Because the Relay GW is located in the initial DeNB, S1AP/SCTP/IP connections between mobile relay and initial DeNB are transparent to target DeNB. GTP-U tunnels are created between PGW of the mobile relay and SGW of the mobile relay. Figure 5.2.2.3.2-6 shows the mobile relay user plane protocol stack. GTP/UDP/IP connections between mobile relay and initial DeNB are transparent to target DeNB. Figure 5.2.2.3.2-7 shows the control plane protocol stack for S5/S8 interface when GTP-U is selected.

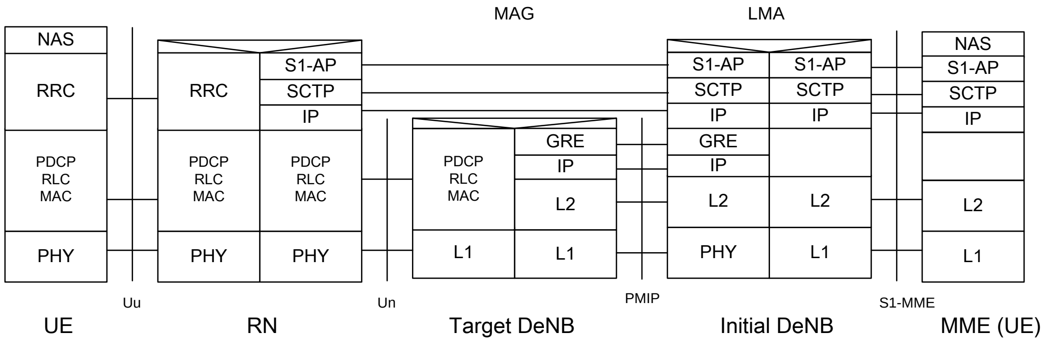

Figure 5.2.2.3.2-2. Control plane protocol stack (option 1: PMIP)

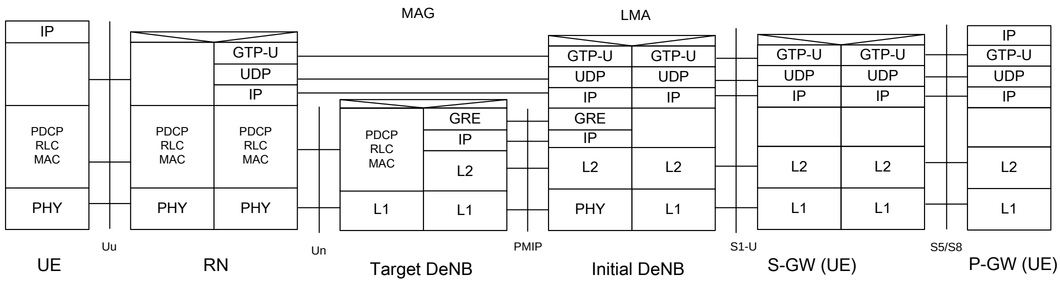

Figure 5.2.2.3.2-3. User plane protocol stack (option 1: PMIP)

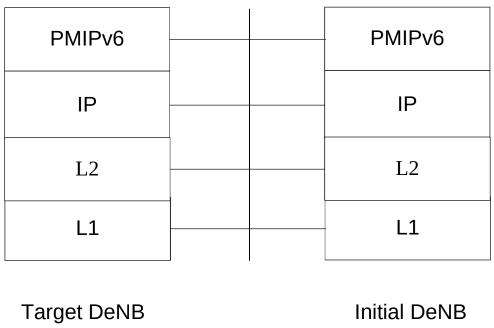

Figure 5.2.2.3.2-4. Control plane protocol stack for PMIP (option 1)

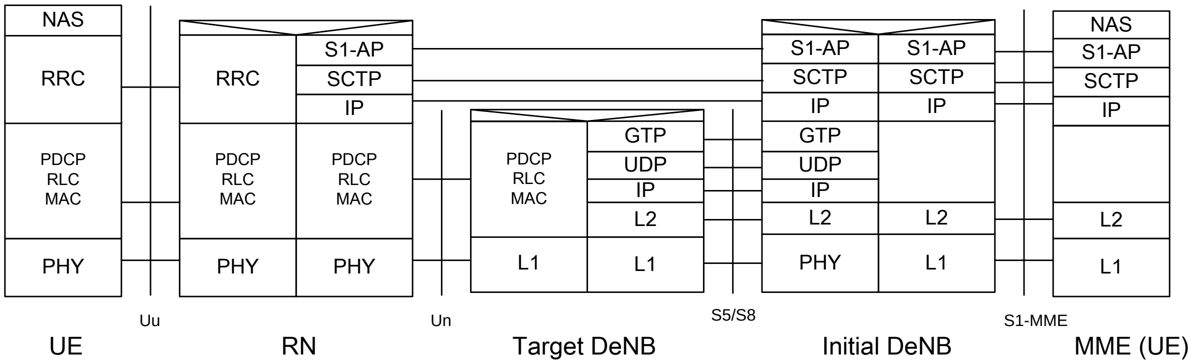

Figure 5.2.2.3.2-5. User plane protocol stack (option 2: GTP)

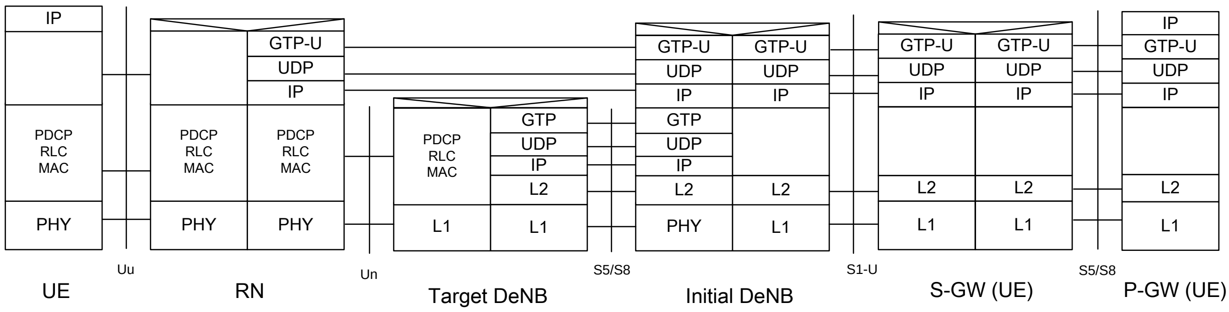

Figure 5.2.2.3.2-6. User plane protocol stack (option 2: GTP)

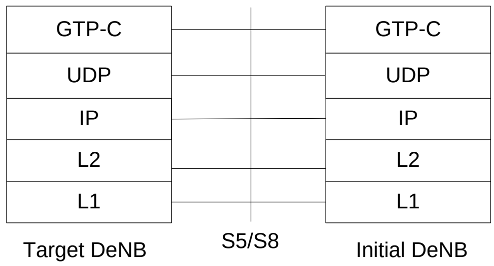

Figure 5.2.2.3.2-7. Control plane protocol stack for GTP (option 2)

5.2.2.3.2.2 Mobility procedure

Figure 5.2.2.3.2-8 shows the RN inter-DeNB mobility procedure for option 1. The HO procedure for option 1 is enhanced by PMIP operations, e.g. the Proxy Binding Update (PBU)/Proxy Binding Acknowledgement (PBA) between the LMA (Initial DeNB) and the MAG (Target DeNB). The path switch for UEs is unnecessary in option 1, since the LMA keeps the mobile relay's P-GW unchanged during mobility. Figure 5.2.2.3.2-9 shows the mobile relay inter-DeNB mobility procedure for option 2. An S5/S8 Bearer is updated from Source DeNB to Target DeNB during handover. More steps are needed than the procedure in Rel-10 since SGW of the mobile relay and PGW of the mobile relay are separated here. However, comparing with the number of users in a normal cell, the number of Mobile relays is very small. It will not bring so much signaling load to network.

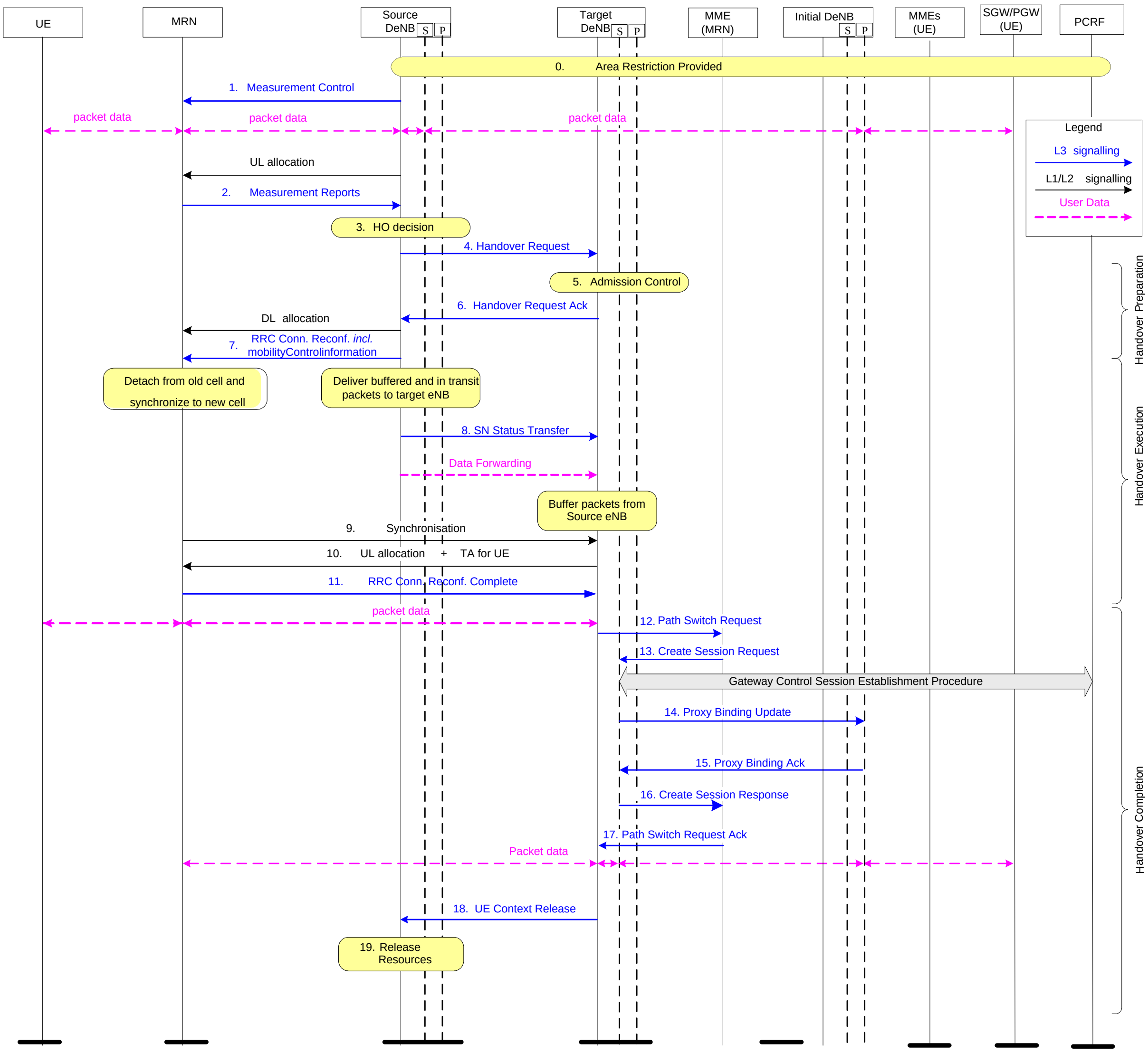

Figure 5.2.2.3.2-8: RN mobility procedure (option 1: PMIP)

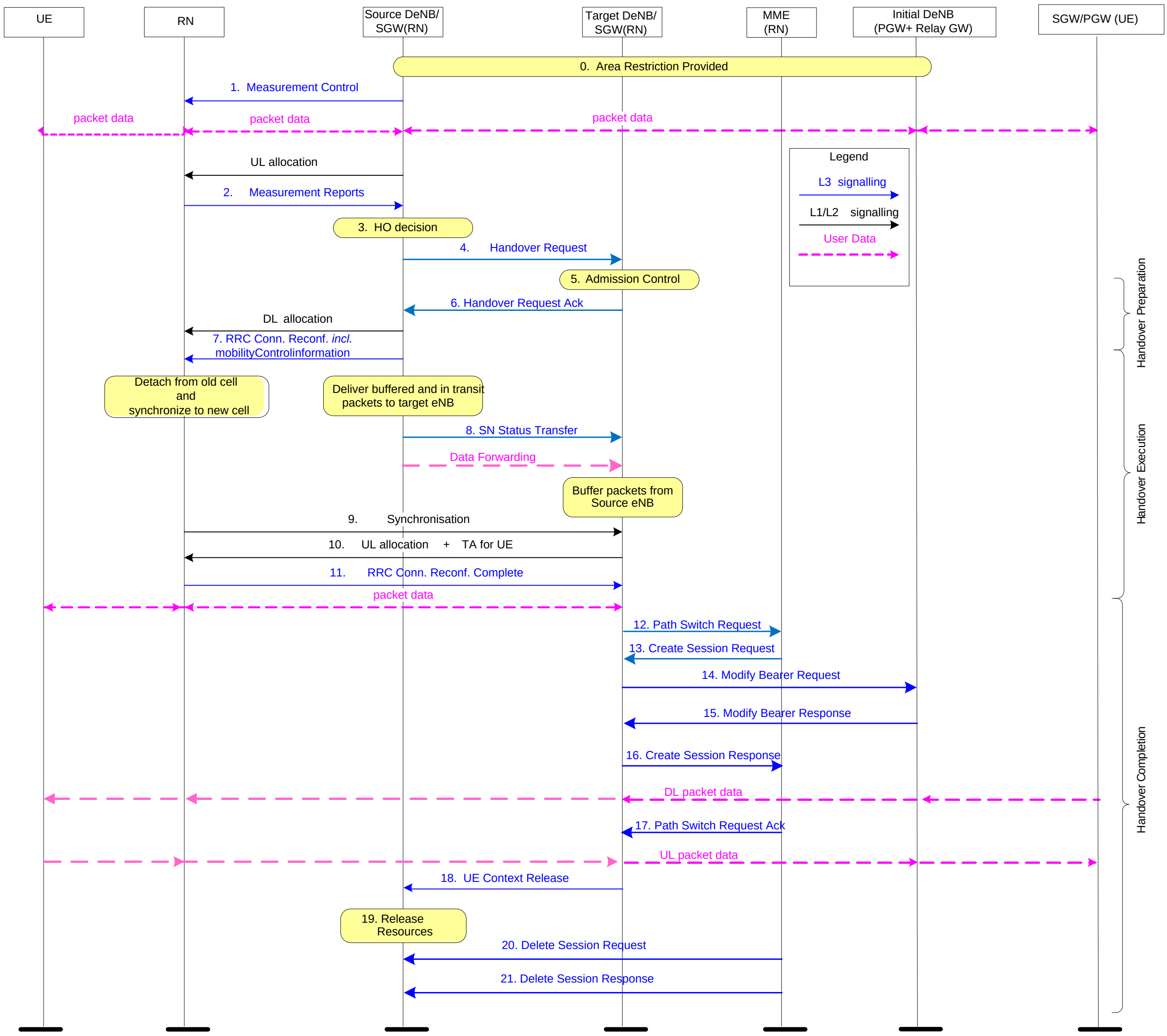

Figure 5.2.2.3.2-9: RN mobility procedure (option 2: GTP)

5.2.2.3.3 eAlt.2-3: Alt.2 with Relay GW and PGW/SGW separated from initial DeNB

5.2.2.3.3.1 Overview

Alt 2 can be further optimized by moving the RN PGW/SGW functionality and relay GW into a separate mobility anchor while still keeps the S1/X2 functionality, as shown in figure 5.2.2.3.3-1.

Alt.2 (described in section 5.2.2.2) can be considered a special case of this alternative where the initial relay P/SGW selection was to the P/SGW at the initial DeNB where the relay starts normal operation.

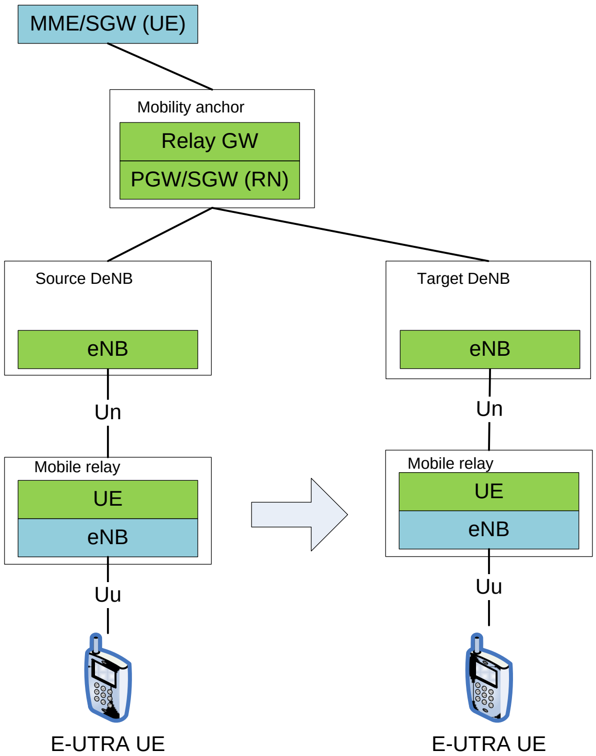

Figure 5.2.2.3.3-1. Alt.2 with Relay GW and PGW/SGW separated from initial DeNB

5.2.2.3.3.2 Mobility procedure

The RN inter-DeNB mobility procedure under architecture Alt2 enhancement with separate Mobility Anchor is basically the same as the procedure under Alt 1 and Alt.2, except the "Initial DeNB" is replaced by "Mobility Anchor".

5.2.2.4 Alt.4

5.2.2.4.1 Overview

Alt 4 relay node architecture is shown in Figure 5.2.2.4-1 below with the following properties:

- S1-U interface for the UE is between the RN and Relay GW and between the Relay GW and the SGW of the UE.
- S1-MME interface for the UE is between RN and Relay GW and between the Relay GW andMME of the UE. For control plane packets of a UE served by mobile RN, the S1/X2 AP messages are carried by SRB over Un interface.
- For S1-U packets of a UE served by mobile RN, each EPS bearer of a UE connected to the RN is mapped to separate radio bearers over the Un interface (one-to-one mapping).
- Mobile relay HO reuses existing UE handover procedures with some enhancement/modification if needed.

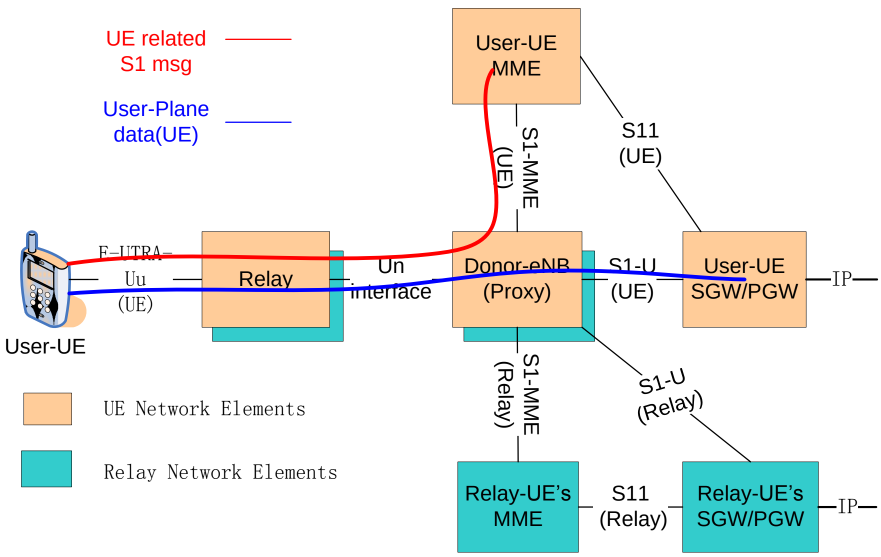

Figure 5.2.2.4-1: Alternative 4 Relay Architecture

5.2.2.4.2 Mobility procedure

Figure 5.2.2.4-2 shows the RN (together with UEs under the mobile RN) inter-DeNB mobility procedure under architecture Alt.4.

In Alt4, the DeNB is aware of every UE under the MRN and DeNB will store information for each bearer of such UE. The information expected to be stored is, reference to TR36.086:

- UE identity
- Radio Bearer Configuration information Un (expected that part can be common for a group of bearers).
- Addressing per bearer: <EPS-bearer-id, Un bearer-id, GTP endpoint>
- QoS information per bearer (as signalled over S1-AP).

In the case of mobile relay HO, UE context for UEs in the mobile RN should be transferred to the target DeNB during handover preparation phase.

Each EPS bearer of a UE connected to the RN is mapped to separate radio bearers over the Un interface (one-to-one mapping). In order to identify individual UE bearers on the Un interface a UE identifier needs to be added to one of the PDCP, RLC or MAC protocol layers; i.e., some parts of the legacy MAC/RLC/PDCP protocols would need to be modified. The Un DRB for each UE EPS bearer can be established during either HO execution phase together with RN Un bearer establishment (e.g. via HO COMMAND, OPTION1) or HO completion phase where RN Un bearer is already established(e.g. via RRC Connection Reconfiguration, OPTION2).

After the RN HO is completed, the target DeNB needs to perform the path switch procedure for each UE to switch the path to the target DeNB.

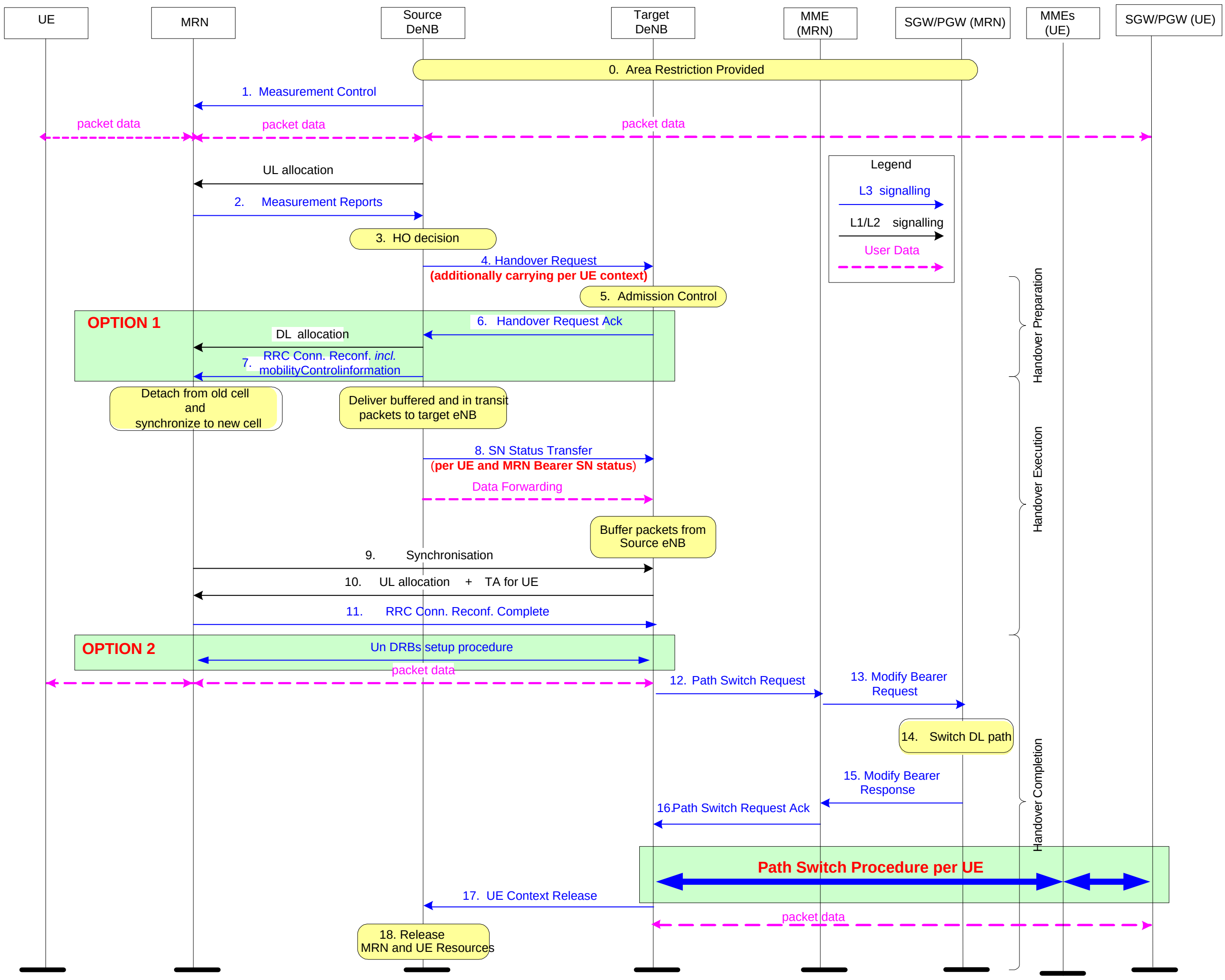

Figure 5.2.2.4-2: RN mobility procedure (Alt 4)

6 Comparison

The criteria developed in the Table 6.1 apply to the comparison for both between mobile relay solutions, and mobile relay over existing solutions.

NOTE: Existing solution of "Dedicated deployment of macro eNBs" will not be part of the comparison.

Table 6.1 Mobile relay and existing solutions

Metric	Mobile relay solutions						Existing solutions	
	Alt.1	Alt.2	eAlt.2-1	eAlt.2-2	eAlt.2-3	Alt.4	L1 repeater	LTE as backhaul, Wi-fi as access
RN Complexity	The same RN as Rel-10 with minor difference that MRN supports NNSF.	The same RN as Rel-10.	MRN=2 Rel-10 RN-like entities. Additional difference from Rel-10 RN, e.g.,: - Uu signalling of Legacy UE HO procedure is not performed - RN start up procedure; - Higher MRN complexity is required to ensure correct sequence, e.g., used between RN startup and UE context transfer, data forwarding, etc. - Ability to map the 2 UEs into one MR entity	The same RN as Rel-10.	The same RN as Rel-10 with minor difference that MRN needs to setup S1 interface with mobility anchor.	New model New functionalities needed for one-to-one mapping between two DRBs (one over Un and one over Uu) that need to be kept synchronized.	N/A	N/A
DeNB Complexity	Rel-10 eNB with integrity protection for S1/X2 signaling. The DeNB may need to know whether it is a Rel-10 RN or a Rel-11 MR	Rel-10 DeNB with ability to handle the separation of P-GW/S-GW collocated in the Initial DeNB, and the eNB function collocated in the target DeNB	The DeNB may need the enhancement to support concurrent UEs' context transfer from source to target.	Rel-10 DeNB with S5/S8 interface. If PMIP based S5/S8 is adopted, DeNB need to additionally support PMIP related protocol	Rel-10 DeNB with limited impact, e.g.: - Rel-10 eNB with integrity protection for S1/X2 signaling; - Maybe impacted for the new GW selection mechanism for MRN.	RRC/PDCP/RLC/MAC impact on top of Rel-10 eNB Additional logic to map the traffic received from an entity other than the MR's SGW to radio bearer. Also need enhancement to handle UEs context and Un DRB setup.	N/A	N/A

Metric		Mobile relay solutions						Existing solutions	
		Alt.1	**Alt.2**	**eAlt.2-1**	**eAlt.2-2**	**eAlt.2-3**	**Alt.4**	**L1 repeater**	**LTE as backhaul, Wi-fi as access**
Node Impact	MME	The MR's MME may need to know whether it is a Rel-10 RN or a Rel-11 MR Dependent on the final security mechanism, the UE's MME may need to use pre-defined DSCP value (or other information) for DL S1-C.	No impact foreseen.based on Rel-10.	The MR's MME may need to know whether it is a Rel-10 RN or a Rel-11 MR (FFS)	MME is mandatory to perform SGW relocation at every MRN Inter-DeNB HO. The MR's MME may need to know whether it is a Rel-10 RN or a Rel-11 MR The MME need to know the IP address of the SGW collocated in the target DeNB during the HO procedure.	Need new GW selection mechanism to select the Mobility Anchor for MR's S/P-GW. The MR's MME may need to know whether it is a Rel-10 RN or a Rel-11 MR	The MR's MME need to know whether it is a Rel-10 RN or a Rel-11 MR In case of S1 HO, the MME need to know the new UE context information added in the HO Req message.	No impact	No impact
	S/P-GW	May require reconfiguring the DSCP setting in UE's SGW/PGW to support the correct mapping in MR's PGW)	No impact	No impact	No impact	New entity including Relay GW functionality . Also need to support the S1-C/U interface	No impact (FFS)	No impact	No impact
Deployment	Deployment flexibility and complexity	DeNB deployment optimization along train path.	DeNB deployment optimization along train path. IP connectivity between distant DeNBs is required to ensure MRN mobility	DeNB deployment optimization along train path Possible impact on the network planning on the geometry of the DeNB cells	DeNB deployment optimization along train path IP connectivity between distant DeNBs is required to ensure MRN mobility	DeNB deployment optimization along train path	DeNB deployment optimization along train path.	eNB deployment optimization along train path	eNB deployment optimization along train path
	Scalability with respect to number of RNs	No issue due to small number of RNs under each DeNB Additional S1 interface to UE-MME for each additional MR	No issue due to small number of RNs under each DeNB					N/A	N/A

Metric		Mobile relay solutions						Existing solutions	
		Alt.1	**Alt.2**	**eAlt.2-1**	**eAlt.2-2**	**eAlt.2-3**	**Alt.4**	**L1 repeater**	**LTE as backhaul, Wi-fi as access**
	Scalability with respect to number of UEs	No issue due to UE EPS bearer aggregation with similar QoS on Un					Number of DRBs could be a scalability issue on Un even with a small number (i.e. >7) of UEs connect to RN	No issue.	No issue.
Standardization Effort and Complexity		Low	Low	Low (some aspects FFS)	Low	Medium	High	RAN4 effort is needed.(FFS)	No impact
UE mobility	Complexity	UE HO is avoided by performing RN HO	UE HO is avoided by performing RN HO	UE HO is performed similarly with legacy UE HO procedures, except signalling over Uu interface is not needed.	UE HO is avoided by performing RN HO	UE HO is avoided by performing RN HO	UE HO is performed similarly with legacy UE HO procedures, except signalling over Uu interface is not needed.	Same UE mobility procedure as Rel-8, but frequently performed.	N/A
	Efficiency	N/A	N/A	DeNB is aware of per UE S1/X2 handover signalling, signalling routing optimisation can be provided. Unacknowledged packets over Un in DeNB1 cannot be forwarded to DeNB2, but should be sent to mobile RN before RN_UE1 is detached._	N/A	N/A	DeNB is aware of per UE S1/X2 handover signalling, signalling routing optimisation can be provided	eNB is aware of per UE S1/X2 handover signalling, signalling routing optimisation can be provided	N/A
	Delay	Handover signalling involves transmission between the DeNB and the RN P/S-GW, so the delay might be higher depending on network deployment.	Similar with Atl.1, the transmission is between initial DeNB and the target DeNB.	No extra handover signalling delay Extra delay may be caused by following reasons: - The startup of RN-UE2 attach to DeNB2 during change of the working RN entity; - Transfer of UE bears between DeNB1 and DeNB2; - Optimization FFS.	Similar with Atl.1, the transmission is between initial DeNB and the target DeNB, and bearer setup between RN SGW and PGW.	Similar with Atl.1, the transmission is between the DeNB and the mobility anchor.	No extra handover signalling delay	No extra handover signalling delay	No extra handover signalling delay

Metric		Mobile relay solutions						Existing solutions	
		Alt.1	**Alt.2**	**eAlt.2-1**	**eAlt.2-2**	**eAlt.2-3**	**Alt.4**	**L1 repeater**	**LTE as backhaul, Wi-fi as access**
QoS	QoS Control: UE AMBR; ARP; QCI; Control plane	RN bearer granularity					UE bearer granularity	UE bearer granularity	The QoS of telecommunication services of UEs on board train cannot be ensured
	Admission control for individual UE bearers	No admission control for individual UE during the change of DeNB, The DeNB can only accept or reject all traffic of a specific QCI.	No admission control for individual UE during the change of DeNB. The DeNB can only accept or reject all traffic of a specific QCI.	Admission control for individual UE is available following Rel-8 principle according to implementation.	No admission control for individual UE during the change of DeNB. The DeNB can only accept or reject all traffic of a specific QCI.	No admission control for individual UE during the change of DeNB. The DeNB can only accept or reject all traffic of a specific QCI.	Admission control for individual UE is available following Rel-8 principle according to implementation.	Admission control for individual UE is available following Rel-8 principle.	N/A
S1 impact		Low	No impact	Optimization for path switch and group mobility FFS	Low	Medium	FFS. Impact on S1 transport	No impact	No impact
X2 impact		Low					FFS. Impact on X2 transport	No impact	No impact
Security		Rel-10 mechanism can be reused when the DeNB is aware of which MR's EPS bearer carries S1/X2 signaling	Rel-10 mechanism can be reused			Rel-10 mechanism can be reused when the DeNB is aware of which MR's EPS bearer carries S1/X2 signaling	Rel-8 mechanism is assumed to be reused with. Bearer ID extension is assumed to be extended.	Rel-8 mechanism can be reused	Wi-fi access link is untrusted User data security cannot be assured.
Support for multi-RAT		It's possible only deployment of LTE DeNB along railways is needed with RN multi-RAT implementation. The 2G/3G/LTE/WiFi traffic is transparent to the P/SGW and DeNB,	The LTE traffic is proxy in the initial DeNB. The 2G/3G/Wifi traffic is transparent to the DeNB,	Similar to Alt.2 but proxy relocation FFS	The same as Alt.2	Maybe same as Alt.2	FFS	Base stations of each RAT need to be deployed along the railways. L1 repeater needs to support appropriate bands	N/A

<table>
<tr><th rowspan="2">Metric</th><th colspan="6">Mobile relay solutions</th><th colspan="2">Existing solutions</th></tr>
<tr><th>Alt.1</th><th>Alt.2</th><th>eAlt.2-1</th><th>eAlt.2-2</th><th>eAlt.2-3</th><th>Alt.4</th><th>L1 repeater</th><th>LTE as backhaul, Wi-fi as access</th></tr>
<tr><td>Support for MR's mobility</td><td>Existing UE handover procedures can be reused with some enhancement/ modification if needed.</td><td>Existing UE handover procedures can be reused with some enhancement/modification if needed.</td><td>No real MRN handover procedure is performed during MRN moving. The two RN entities within MRN work alternatively instead.</td><td>Existing UE handover procedures can be reused with some enhancement/modification if needed. However, SGW is relocated everytime for Inter-DeNB mobility of MRN.</td><td>Existing UE handover procedures can be reused with some enhancement/modification.</td><td>Existing UE handover procedures can be reused with some enhancement/modification if needed.</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Signalling overhead</td><td>Low.
Individual UE handovers are replaced by a single mobile relay handover on the backhaul link. The mobile relay handover remains transparent to UEs</td><td>Low.
The same as Alt.1</td><td>High.
Slightly lower than that in L1 repeater case.
All UEs under RN_Cell1 are handed over to RN_Cell2, via S1/X2 HO per UE.

Higher signalling overhead due to group mobility not supported</td><td>Medium
Slightly higher than Alt.1/Alt.2/eAlt.2-3, because signalling overhead caused by RN SGW relocation each time when RN handover</td><td>Low.
The same as Alt.1</td><td>High- .
Slightly lower than that in L1 repeater case, because HO Command and HO Complete procedure is saved over Uu

Higher signalling overhead due to group mobility not supported</td><td>High.
All UEs receiving from/transmission to L1 repeater are handed over to the target eNBs, via S1/X2 HO per UE.

Higher signalling overhead due to group mobility not supported</td><td>Medium

Low overhead for PS data due to group mobility

High overhead for CS voice due to individual HOs for each UE</td></tr>
<tr><td>Impact on UE energy consumption</td><td colspan="6">Reduced UE energy consumption benefits from:
- avoidance of penetration loss
- minimized UE mobility measurement
- avoidance of frequent UE handovers</td><td>Reduced UE energy consumption benefits from:
- avoidance of penetration loss</td><td>Only small benefit on saving UE energy consumption because 3GPP UEs need normal mobility measurements to keep reachable.</td></tr>
<tr><td>Handover success rate</td><td colspan="2">Improved HO success rate benefits from:
- better radio link quality due to avoidance of penetration loss, Doppler
- Possible signalling congestion avoided due to group handover</td><td>Improved HO success rate benefits from:
- better radio link quality due to avoidance of loss, Doppler</td><td colspan="3">The same as Alt.1</td><td>Improved HO success rate benefits from:
- better radio link quality due to avoidance of penetration loss</td><td>Improved HO success rate benefits from:
- better radio link quality due to avoidance of penetration loss for service through WiFi access

No improvement on voice service since voice service is using 2G networks along the train path.</td></tr>
</table>

Metric	Mobile relay solutions						Existing solutions	
	Alt.1	Alt.2	eAlt.2-1	eAlt.2-2	eAlt.2-3	Alt.4	L1 repeater	LTE as backhaul, Wi-fi as access
Backhaul link stability	Improved Un backhaul link stability comparing to Rel-8~Rel-10 UE Uu due to enhanced techniques can be implemented, e.g., higher transmission power, more sensitive receiver, advanced antenna processing		Potential interference between two co-existent Un interfaces to source and target DeNB May be addressed through enhanced implementation techniques, e.g. advanced antenna processing, enhanced radio resource management	The same as Alt.1			N/A	The same as Alt.1
Voice call support and continuity	Supported. Voice call and its continuity are supported in the same w ay as previous releases in both on board and getting on/off the train scenarios. Supported.						Supported. Voice call and its continuity are supported in the same w ay as previous releases in both on board and getting on/off the train scenarios.	Partly supported. CS voice call(using 2G) and its continuity are supported in the same w ay as previous releases in on board scenario; Packet voice continuity while boarding/leaving the train is not currently supported
Quality of access link	Good. UE access link is not subject to high speed effects						Not as good as MR due to re-transmission of high speed effects on the backhaul	Not assured for the reasons, e.g., - The quality is possibly decreased due to the increase of numbers of UEs accessed . - Interference due to the unlicensed ISM band, .
Support of multiple concurrent services	Supported						Supported	Not supported.
Support for local services	extend LIPA for MR(FFS)						Not supported	Supported

Matrix Fields interpretation (informative):

RN Complexity: What is the complexity in specification, design and implementation of the MR? How easy it is to derive such node from existing nodes?

DeNB Complexity: What is the complexity in specification, design and implementation of the DeNB? How easy it is to derive such node from existing nodes, considering both eNB and Rel-10 DeNB?

Node Impact: MME: Any upgrades needed in the MME to support MRs, considering MME supporting Rel-10 relay? Can the release 9/release 10 bearer setup, modification and QoS control be enough or major upgrades required?

S/P-GW: Any upgrades needed in the S/P-GW to support MRs? Can the release 9/release 10 S/P-GW be able to support RNs or major upgrades required?

Deployment: Deployment flexibility and complexity: Is the deployment sub-optimal or is it already optimised to a viable level? Can the deployment be easily optimised?

Scalability (with respect to number of MRs and number of UEs): How does the deployment cope with increasing numbers of supported RNs and UEs (connected to RNs)?

Co-deployment with Rel-10 RN: How easy it is to deploy the alternative given the current Rel-9 architecture as a reference starting point?

Standardization Effort and Complexity: What is the anticipated impact on standardization? Is it easy to standardize the alternative as is, or are simplifications required? Is there any unclear issue that can end up being a showstopper delaying the standardization process? Is the alternative achievable for release 10 or should it be postponed for future releases?

UE mobility: Complexity: Relaying is expected to work with release 8 UEs, but are there any differences from the UE handover procedures of release 8, from the CN point of view?

Efficiency: Any unnecessary back and forth forwarding?

Delay: What is the total required time for a UE handover? What is the handover interruption time? Does the delay fall within the limits set by release 8 standards?

QoS: QoS Control (UE AMBR; ARP; QCI; Control plane): Can we control the DL AMBR of UEs over the Un interface? Can the ARP of the UE EPS bearers be used during admission over the Un? Are the nine QCIs of release 8 sufficient or there is a need to define new ones? Will it be possible to keep the requirements of the release 8 QCIs as is, or would they have to be redefined taking the extra delay incurred due to relaying?

Can we satisfy the requirements of control plane messages between the RN and MME? Can control plane messages such as S1/X2 be transported over the Un with the required priority within signalling radio bearers? Or do they have to be mapped to DRBs? If so, are the current QCIs capable of satisfying the requirements? How about the impact of head of line blocking if DRBs are used for signalling transport?

Can the QoS of telecommunication services of UEs on board train be ensured according to the existing mechanism defined in the spec?

Admission control for individual UE bearers: Is admission control performed individually for UE bearers during the moving of RN? Are there any impacts of the way admission control is performed?

S1 impact: How is S1AP impacted with respect to the currently available protocol? How efficient is the S1 messaging, especially in the case of high density deployment? Does the RN have to keep S1 links directly with the MME and as such use part of the Un resources for S1 maintenance, such as SCTP keep alive or GTP-U echo messages? If so, what is the impact on overall system utilization as well as the incurred S1 latency?

X2 impact: How is X2AP impacted with respect to the currently available protocol? How efficient is the X2 messaging, especially in the case of high density deployment? Does the RN have to keep X2 connections with all neighbour RNs at all time, as well as (non-donor) eNBs, or it has to keep only one X2 towards the donor eNB? What is the impact of both cases on the Un resource utilization, i.e. considering the SCTP keep alive and GTP-U echo messages as well as signalling required to enable optimizations such as ICIC where the RN might be required to forward its load information towards all the nodes with which it has X2 connection with?

Security: What is the impact on security? Can we still keep the security requirements of release 8 (ciphering for both SRBs and DRBs and integrity protection for SRBs)? What kind of security mechanisms should be used over the Un of mobile relay? Does the mechanism defined for Rel-10 RN can be reused?

Can the user data security be ensured?

Support for multi-RAT: What is the complexity in specification, design and implementation to support LTE backhaul while 2G/3G/LTE/Wi-Fi access?

Support for MR's mobility: What is the complexity in specification, design and implementation of the mobility of the Mobile Relay?

Signalling overhead: What is the situation in terms of overall signalling load during the MRs moving across the DeNBs, together with the handling of UEs under service of MRs?

Impact on UE energy consumption: What is the impact on UEs energy(battery) consumption for the UEs under MRs cell when moving with the MRs?

Handover success rate: How does the solution bring benefit to the improvement of handover success of UEs?

Backhaul link stability: How does the solution impact the reliability of backhaul link?

Voice call support and continuity: How is voice call supported? Any impact/drawback/improvement to support CS voice call? Is continuity of voice call available in the case when UE get on/off the train?

Quality of access link: What radio conditions are likely to be created for UEs in this deployment, in terms of e.g., quality of radio connection, radio channel interference, user experience?

Support of multiple concurrent services: Is there any restrictions on the support of multiple services for one UE at the same time? E.g. the QoS of both voice call and internet service are ensured at the same time?

Support for local services: How are locally terminated on-board services supported?

7 Conclusions

Select Alt.1 and Alt.2 for further work on mobile relays.

Annex A: Change history

Change history					
Date	**TSG #**	**TSG Doc.**	**Subject/Comment**	**Old**	**New**
2011-10			TR skeleton	0.0.0	0.0.1
2011-11			Scenario and requirements, existing solutions and performance matrix	0.0.1	0.0.2
2012-04			Updated according to the progress in RAN3#75bis: Mobile relay solutions, comparison framework, one more existing solution; TR number updated.	0.0.2	0.1.0
2012-05			TP on Multi-RAT requirement in R3-121174 Comparison in R3-121468 Mobile relay functions TP	0.1.0	1.0.0
2012-06	RP-56	RP-120694	Presented to RAN#56 for Information		1.0.0
2012-08			TP on conclusion to implement way forward proposal in R3-121890	1.0.0	1.1.0
2012-09	RP-57	RP-121230	Presented to RAN#57 for Approval but only noted. RAN#57 moved to Rel-12. Updated WID RP-111377=>RP-121443. Completion 09/12=>06/13	1.1.0	2.0.0
2012-10			MCC clean-up	2.0.0	2.0.1
2013-07			MCC clean-up	2.0.1	2.0.2