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Source(s)	Rakesh Taori, Jicheol Lee, Heewon Kang, Hokyu Choi, Hyunjeong Kang, Jungshin Park, Jack Jang, Youngkyo Baek, Jung Je Son, MingXia Xu Samsung Electronics Company, 416, Maetan-3 dong, Yeongtong Gu Suwon, South Korea. 443-742. Masato Okuda, Michiharu Nakamura, Keiichi Nakatsugawa Fujitsu Contact rakesh.taori@samsung.com jicheol.lee@samsung,com hkang@samsung.com
Re:	
Abstract	This document analyzes the different solutions that are possible for relay. The document argues that whether a function should be located in the ARS or the ABS should be decided on the basis of performance (overhead, latency).
Purpose	
Notice	
Release	
Patent Policy	

Addressing the missing MAC functions in 16m Relay (Section 15.6)

1 Introduction

1.1 Background

In Session 63.5, the text adopted in the Chapter on Relay (15.6) contained some empty sections (e.g. Handover, Idle mode). Additionally, there are some sections (e.g. ARQ), which although not empty, do not contain sufficient details for testing interoperable implementations.

The reason why these sections were left empty, or are otherwise incomplete, is the lack of consensus in TGm on the location of these functions (in the base station (BS) or the relay station (RS).)

1.2 What this document is about

In this document, we attempt to

(1) Identify and analyze three distinct solution profiles for relay

(2) Compare two important UMAC functions (Handover and Network Entry) for the various solutions

(3) Provide a basis for discussion to make an appropriate decision for 16m relay

The proposed text provided in Section 5 will be updated on the basis of discussions during Session #64 (Atlanta).

2 Relay solution profiles

There is no consensus on how to name relay systems. There is not even an agreement on the exact dimensions along which relay systems can be classified (L1-relay, L2-relay or L3-relay; Transparent or non-transparent relay, Amplify & forward or decode & forward relays, and so on...). Most of the classifications are at best “imprecise” and at worst misleading, and above all none of these are universally agreed.

So, we will just call the three most discussed approaches in TGm as Solution 1, 2 and 3. Below is an attempt to capture the most salient features of these three solutions. Despite the fact that a very short description seldom captures the entire solution accurately, and any attempt to do so is likely to attract much controversy, a succinct characterization is nevertheless attempted for each of the solutions.

- Solution 1:
  - The original goal of such an approach is to avoid any change to the base station specification.
  - The 802.16m control messages from the MS will be terminated at the RS.
  - L2-address management (e.g. STID) is performed at the RS.
  - The RS will terminate R6/R8 signaling and the GRE data tunnel.
  - The BS will relay the R6/R8 messages and data between the ASN-GW and the RS.

- Solution 2:
  - The intention behind this solution is to avoid changes to the network, and minimize over-the-air control/data path overhead
  - The 802.16m control messages from the MS will be terminated at the BS.
  - L2-address management (e.g. STID) is performed at the BS.
  - The BS will terminate the R6/R8 termination and the GRE data tunnel.
  - The RS will relay the 802.16m air-interface messages between the BS and the MS.
- Solution 3:
  - The primary intent of this solution is to reduce the over-the-air overhead, incurred in the data path, of Solution 1.
  - The 802.16m control messages from the MS will be terminated at the RS.
  - L2-address management (e.g. STID) is performed at the BS.
  - The RS will generate R6/R8 signaling messages and will send this over-the-air to the BS.
  - The BS will terminate the GRE data tunnel, and will relay the R6/R8 messages between the ASN-GW and the RS.

Next, we provide a table that specifies the location of the detailed functions, for each of the aforementioned solutions.

NOTE: Even though the table shows the location for some functions as "BS" or "RS", there might be some additional signaling among the entities to support that function. Consider the following examples:

① For admission control of the flows during Handover and Network entry, the RS may have to communicate with the BS, for instance, to check the resource availability on the BS-RS link.

② For macro scheduling of the resources (e.g. FFR partitioning, detailed frame structure configurations), new messages may be required on the BS-RS link.

③ To achieve end-to-end QoS, new messages may have to be defined on the BS-RS link.

Level-1 Function Heading	Sub-Level Functions	Solution 1	Solution 2	Solution 3
MS Network Entry	L1 Ranging	RS	RS	RS
	L2 Ranging (incl. TSTID Assignment)	RS	BS	BS and RS
	SBC Req/Rsp	RS	BS	RS
	Security (PKM)	RS	BS and RS	RS
	Reg Req/Rsp (incl. STID Assignment)	RS	BS	BS and RS
	Pre-Provisioned SF set up	RS	BS	RS
RS Network Entry		Same as MS's	Same as MS's	Same as MS's
RS Configuration	Frame Structure, Premable assignment etc.	BS	BS	BS
MS Connection Set up (QoS)	FID allocation	RS	BS	BS and RS
	Flow admission	BS and RS	BS and RS	BS and RS
MS's sleep control	Sleep Entry/Exit	RS	BS	RS
	Dynamic scheduling (Listening Window Extension etc.)	RS	RS	RS
MS's Idle mode	Idle mode Entry	RS	BS	RS
	Paging	RS	BS	RS
	Idle mode exit	RS	BS	RS
Handover	Context Transfer including remaining data	RS	BS	RS
	Admission Control including STID/FID alloc	BS and RS	BS and RS	BS and RS
Scheduling	Macro resource (FFR partition, Frame Structure Configuration)	BS	BS	BS
	Micro resource (per frame scheduling, A-MAP IE etc.)	RS	RS	RS
Security	Access link	RS	RS	RS
	Relay link	BS	BS	BS
BW Request	BW Req code & CDM Alloc IE	RS	RS	RS
	BW Req Header + Grant	RS	RS	RS
Data Transmission	MPDU formation	RS	BS and RS	BS and RS
	ARQ	RS	BS and RS	RS
	GRE tunnel termination	RS	BS	BS
RS Deregistration		BS	BS	BS

3 Considerations for Handover and Network Entry

We consider two approaches in this section. One in which the Handover and Network Entry related control resides in the RS (Solution 1 and 3) and the other where the control resides in the BS (Solution 2).

3.1 Handover

For handover, two typical scenarios are studied::

1. Intra-BS HO: In this scenario, the AMS attached to an ARS (RS1) hands over to another ARS (RS2) that is associated with the same ABS.
2. Inter-BS HO: In this scenario, the AMS attached to an ARS (RS1) under an ABS (BS1) hands over to another ARS (RS2) that is associated to another ABS (BS2)

In the figures below, the blue text shows the message exchange triggered by the HO-REQ message from the AMS during the HO preparation phase. The red text shows the message transactions triggered by the HO_CMD message. The green text shows the messages triggered by the RNG_REQ message which is transmitted by the AMS. The detailed steps, such as bandwidth request/grant, have been omitted for simplicity.

NOTE: The R6 messages relayed over-the-air on the BS-RS link may need to be transmitted using the L2_XFER method defined in 802.16m/D2.

3.1.2 Intra-BS Handover

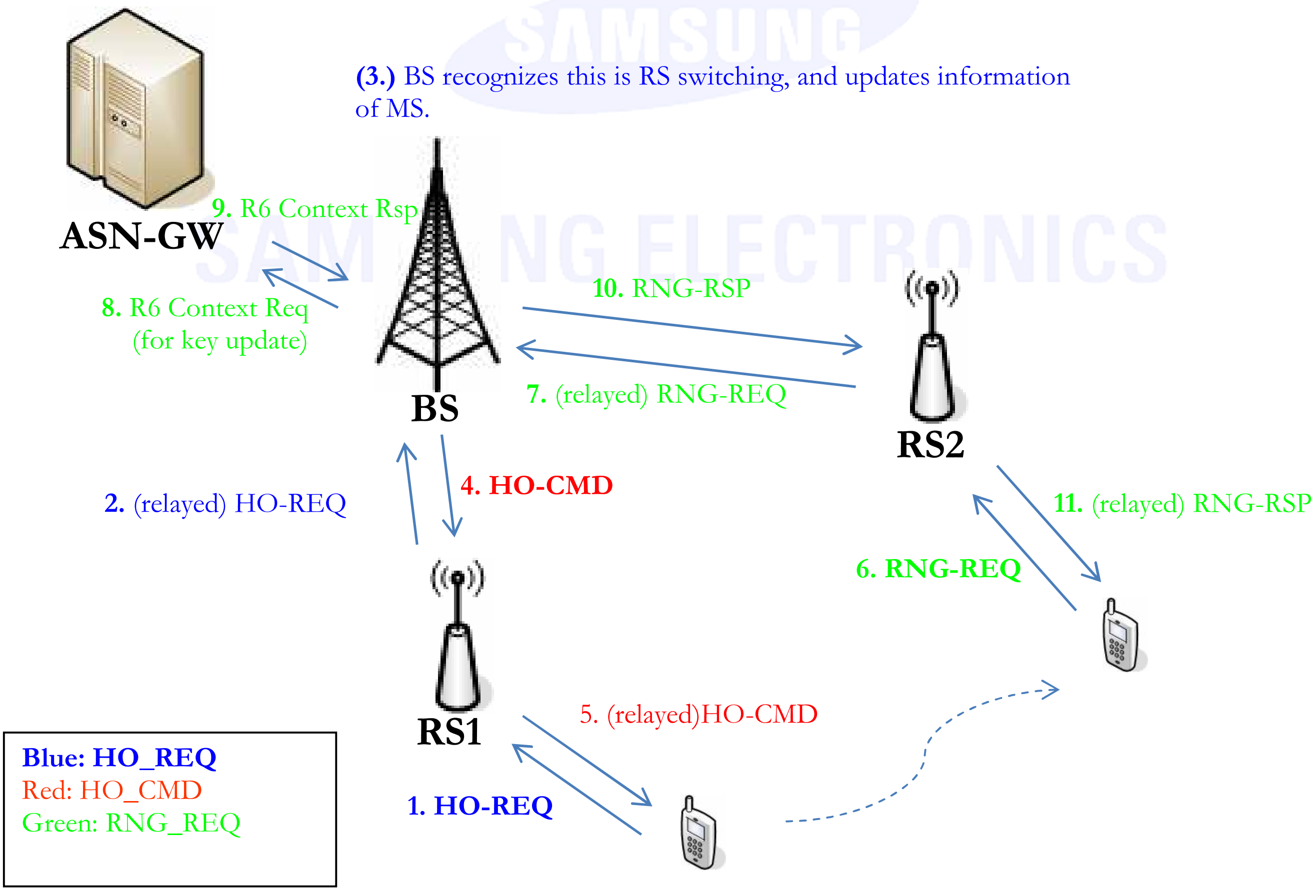

Figure 1: Intra-BS Handover when the Handover control is located at the ABS.

1. MS sends an AAI_HO-REQ message to its serving ARS (RS1).
2. The serving ARS relays the AAI_HO-REQ to the serving BS.
3. BS recognizes this is RS switching, and updates information of MS.
4. BS sends AAI_HO-CMD message to the ARS (RS1).
5. ARS relays the AAI_HO-CMD message to the MS.
6. MS sends AAI_RNG-REQ to the target ARS (RS2).
7. The target ARS relays AAI_RNG-REQ to the serving BS.
8. BS sends an R6 Context-Req message to the ASN GW to retrieve the AK Key Context.
9. ASN GW responds with R6 Context-Rsp to the BS.
10. BS sends AAI_RNG-RSP message to the target ARS (RS2).
11. The target ARS relays AAI_RNG-RSP message to the MS.

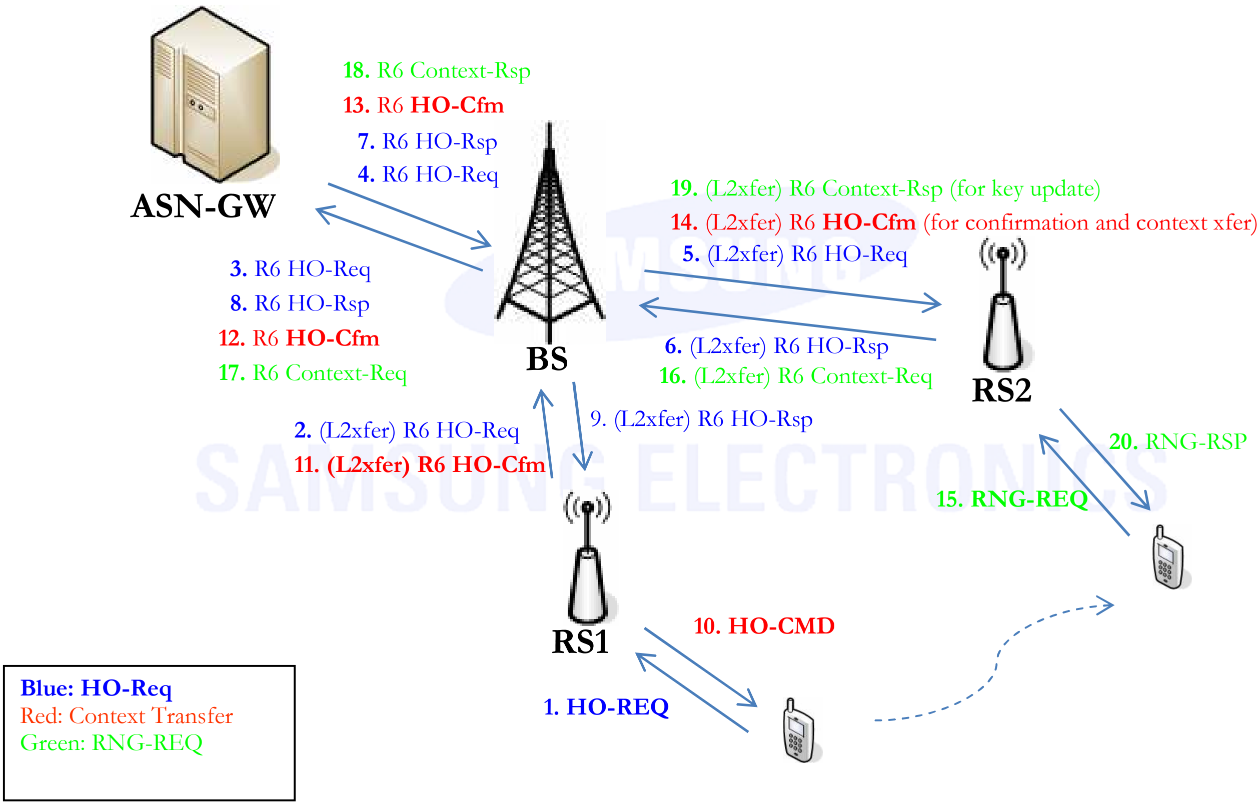

Figure 2: Intra-BS Handover when handover control is located at the ARS (Solution 1 and 3.) (See Note 1&2)

1. MS sends an AAI_HO-REQ message to its serving ARS (RS1).
2. The serving ARS sends an R6 HO-Req message to the serving BS.
3. BS relays the R6 HO-Req message to the ASN GW
4. The ASN GW forwards R6 HO-Req message to the serving BS.
5. The serving BS relays R6 HO-Req message to the target ARS (RS2)

6. The target ARS responds with R6 HO-Rsp message to the serving BS.
7. BS relays R6 HO Rsp to the ASN GW.
8. The ASN GW forwards R6 HO Rsp message to the serving BS.
9. The serving BS relays R6 HO Rsp message to the serving ARS (RS1).
10. The serving ARS (RS1) decides the target for HO (RS2) and sends AAI_HO-CMD to the MS.
11. The serving ARS Sends R6 HO-Cfm message to the serving BS.
12. The serving BS relays the R6 HO-Cfm to the ASN GW.
13. The ASN GW forwards R6 HO-Cfm message to the serving BS.
14. The serving BS relays R6 HO-Cfm message to the target ARS (RS2).
    The target ARS updates the information for upcoming MS handover.
15. MS sends AAI_RNG-REQ to the target ARS (RS2).
16. The target ARS sends R6 Context-Req message to the serving BS to retrieve the AK Key Context.
17. The serving BS relays an R6 Context-Req message to the ASN GW.
18. The ASN GW sends R6 Context-Rsp to the serving BS.
19. The serving BS relays R6 Context-Rsp message to the target ARS (RS2).
20. The target ARS sends AAI_RNG-RSP message to the MS.

3.1.2 Inter-BS Handover

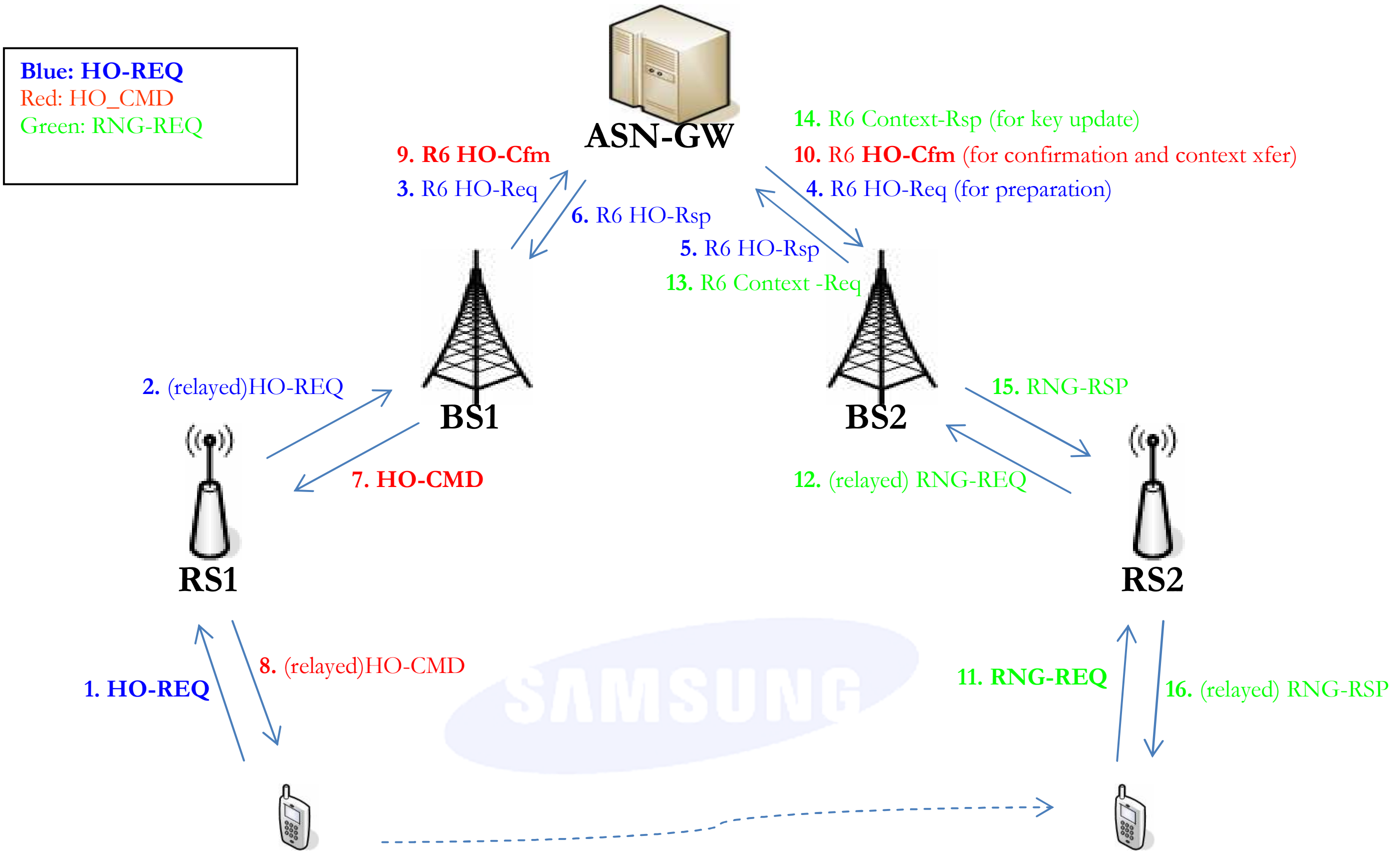

Figure 3: Inter-BS Handover when the Handover control is located at the ABS

1. MS sends an AAI_HO-REQ message to its serving ARS (RS1).
2. The serving ARS relays the AAI_HO-REQ to the serving BS (BS1).
3. The serving BS sends R6 HO-Req message to the ASN GW.
 recognizes this is RS switching, and updates information of MS.
4. The ASN GW forwards R6 HO-Req message to the target BS (BS2).
5. The target BS responds with R6 HO-Rsp message to the ASN GW.
6. The ASN GW forwards R6 HO-Rsp message to the serving BS (BS1).
 The serving BS decides the handover target (RS2).
7. The serving BS sends AAI_HO-CMD message to the ARS (RS1).
8. The ARS relays the AAI_HO-CMD message to the MS.
9. The serving BS sends R6 HO-Cfm message to the ASN GW.
10. The ASN GW forwards R6 HO-Cfm message to the target BS.
 The target BS updates information for upcoming MS handover.
11. MS sends AAI_RNG-REQ to the target ARS (RS2).
12. The target ARS relays AAI_RNG-REQ to the target BS.
13. The target BS sends an R6 Context-Req message to the ASN GW to retrieve the AK Key Context.
14. The ASN GW responds with R6 Context-Rsp to the target BS.

10. The BS sends AAI_RNG-RSP message to the target ARS (RS2).
11. The target ARS relays AAI_RNG-RSP message to the MS.

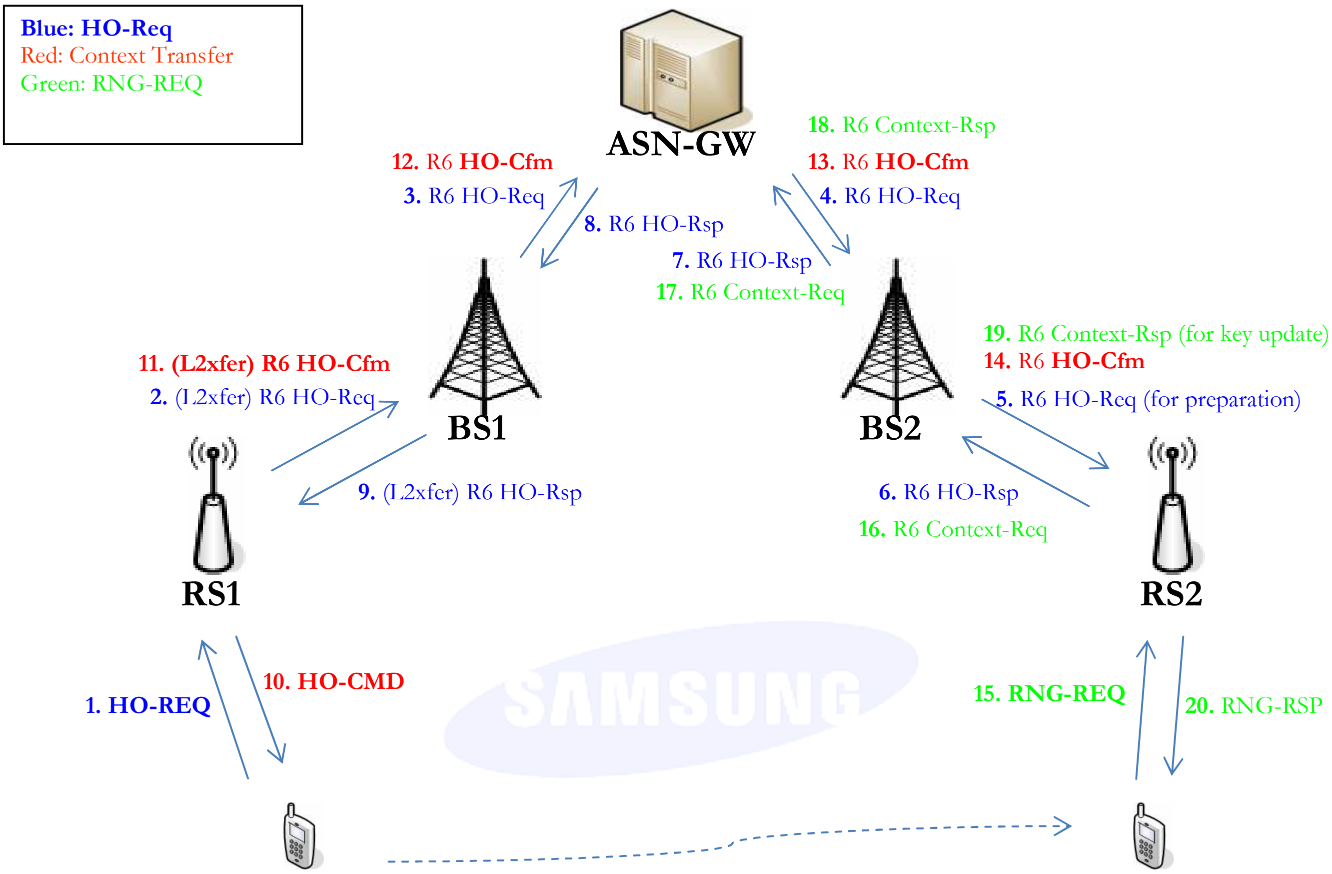

Figure 4: Inter-BS handover when control Handover control is located in the ARS (Solution 1&3). (See Note 1&2)

1. MS sends an AAI_HO-REQ message to its serving ARS (RS1).
2. The serving ARS sends an R6 HO-Req message to the serving BS (BS1).
3. The serving BS relays the R6 HO-Req message to the ASN GW
4. The ASN GW forwards R6 HO-Req message to the target BS.
5. The target BS relays R6 HO-Req message to the target ARS (RS2)
6. The target ARS responds with R6 HO-Rsp message to the target BS.
7. The target BS relays R6 HO-Rsp to the ASN GW.
8. The ASN GW forwards R6 HO-Rsp message to the serving BS.
9. The serving BS relays R6 HO-Rsp message to the serving ARS (RS1).
10. The serving ARS (RS1) decides the target for HO (RS2) and sends AAI_HO-CMD to the MS.
11. The serving ARS (RS1) Sends R6 HO-Cfm message to the serving BS (BS1).
12. The serving BS relays the R6 HO-Cfm to the ASN GW.
13. The ASN GW forwards R6 HO-Cfm message to the target BS.
14. The target BS relays R6 HO-Cfm message to the target ARS (RS2).
    The target ARS updates the information for upcoming MS handover.
15. MS sends AAI_RNG-REQ to the target ARS (RS2).

16. The target ARS sends R6 Context-Req message to the target BS to retrieve the AK Key Context.
17. The target BS relays an R6 Context-Req message to the ASN GW.
18. The ASN GW sends R6 Context-Rsp to the target BS.
19. The target BS relays R6 Context-Rsp message to the target ARS (RS2).
20. The target ARS sends AAI_RNG-RSP message to the MS.

NOTE 1: In Figure 2 and 4, we use L2_XFER to relay the R6 messages over-the-air on the BS-RS link.

NOTE 2: In order to support data integrity during handover, the buffered data at the serving ARS (RS1) may need to be transferred to the target ARS (RS2). Additional air-link bandwidth may need to be negotiated on the BS-RS link to establish the data-integrity path.

3.2 "AMS Network Entry" Function

For network entry, we consider the message transactions for the aforementioned two approaches.

The scenario that we are considering assumes:

- RS has already performed network entry and the signaling path between the BS and the RS is already established.
- A new MS performs network entry with an RS.
- The MS has already performed L1 ranging with the RS and the PHYs are synchronized.
- The figure illustrates the message exchange starting with the RNG_REQ message form the AMS until the REG_RSP (STID allocation) is delivered to the AMS.

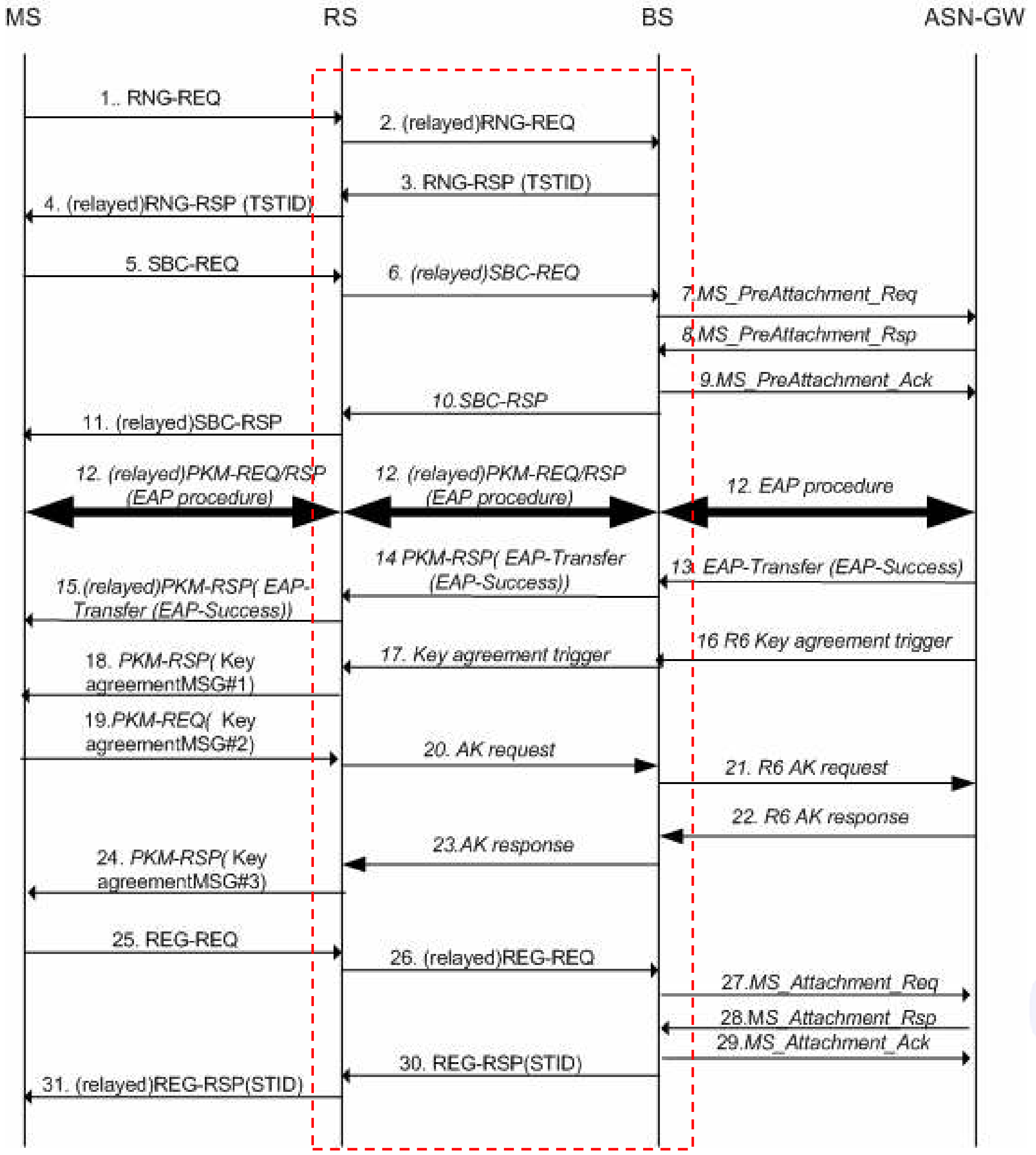

Figure 5: Message Sequence Chart for Network Entry when control is located at the ABS.

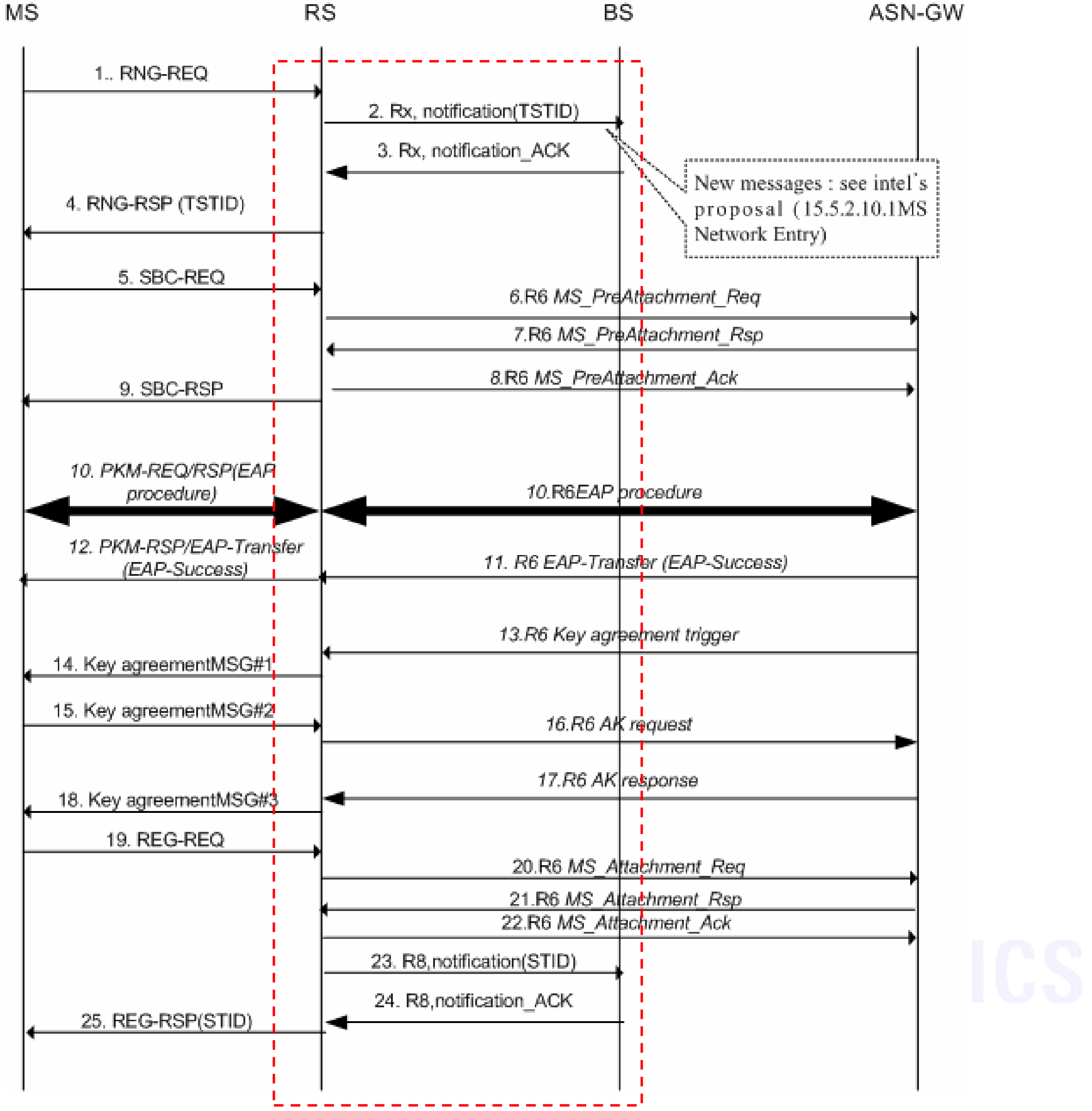

Figure 6: Network Entry when control is located at the ARS

4 Discussion

TGm should consider the following when making a decision::

- Regardless of the solution, it seems that changes to the BS specifications are required. Therefore, the assumption that "relay support can be enabled without changing the BS implementations" needs to be reconsidered.
  - New messages need to be defined on the BS-RS link to enable BS-RS communication, which is required for the configuration of the RS, Macro scheduling of resources, admission control, QoS, L2-address management, for instance.
- Overhead on the BS-RS link should be considered
  - Solution 1 and 3 may incur more overhead for exchanging control messages on the BS-RS link

compared to solution 2. This includes the number of messages as well as the protocol overhead
  - Solution 1 incurs more overhead on the data path (IP header + GRE header).
- Impact of latency on critical functions such as Handover
  - It appears that Solution 1 and 3 require more messages on the BS-RS link. The impact on latency should be considered.
- Implementation complexity
  - RS may behave unlike a typical MS (BW request, ARQ, QoS behavior). So we need to consider the impact on the required changes to the existing implementations.

The text proposed in the next section allows the MAC function to be located in the ABS and the ARS. Based on the above analysis and details, TGm should discuss whether to keep two options or choose one. The text proposed below should be modified in accordance with the final TGm decision.

5 Proposed text changes

=== Proposed text changes begins here ===

[Note to the editor: Insert the following text in the indicated sections]

15.6.2.5.2 AMS scanning of neighbor ABSs/ARSs

If the scanning information is managed by the ABS, an ARS shall relay AAI_SCN-REQ, AAI_SCN-RSP and AAI_SCN-REP messages between an AMS and the ABS. Based on the AMS scanning information in the AAI_SCN-REQ message and the AAI_SCN-RSP message, the access ARS schedules AMS' data transmission.

If the scanning information is managed at the ARS, the AAI_SCN-REQ, AAI_SCN-RSP and AAI_SCN-REP messages are transmitted between the access ARS and the AMS.

15.6.2.5.3 AMS Handover process

If the Handover process is managed by the ABS, messages such as AAI_HO-REQ, AAI_HO-CMD and AAI_HO-IND messages between an AMS and the ABS shall be forwarded by the ARS.

If a serving ABS recognizes that its AMS attaches to a new access station or Resource retain timer expires, and the AMS's old access station is an ARS that is controlled by the ABS, the ABS sends the AAI_INFO-DEL message to make the ARS discard AMS context information. Upon receiving the AAI_INFO DEL message, the ARS shall transmit AAI_MSG-ACK as a reply and remove the AMS context information.

The AMS context, such as AMS supporting physical parameters and MAC features, Service Flow parameters and Security context shall be managed and possessed by a serving ABS of an AMS. When an AMS performs handover under the same ABS i.e., between the ABS and its ARS or between an ARS of the ABS and another ARS of the ABS, some procedures of network re-entry such as SBC/PKM/REG transaction can be omitted. The AMS context shall be transferred from the ABS to the target access station.

When the target access station does not exist in the same ABS, the serving ABS communicates with the target ABS for AMS context via the backbone network.

If the Handover process is managed at the ARS, the handover process as defined in subclause 15.2.6.3 is applied wherein each instance of ABS is replaced by ARS]

15.6.2.12 Sleep Mode

If the sleep mode is managed by the ABS, then for the AMSs attached to an ARS, the AAI_SLP-REQ/RSP messages are exchanged between the ABS and the AMS through the ARS. All the other procedures related to AMS's sleep mode operation are implemented at the ARS-as defined in Section 15.3.11.

If the sleep mode is managed at the ARS, the procedures described in Section 15.2.16 are apllied wherein each instance of ABS is replaced by the ARS.

15.6.2.13 Idle Mode

15.5.3.13.1.1 Idle mode initiation

If the idle mode functions are managed at the ABS, the access ARS shall relay the AAI_DREG-REQ/CMD message between the ABS and the AMS. An operation of idle mode entry with an ARS involved is shown in Figure xxx.

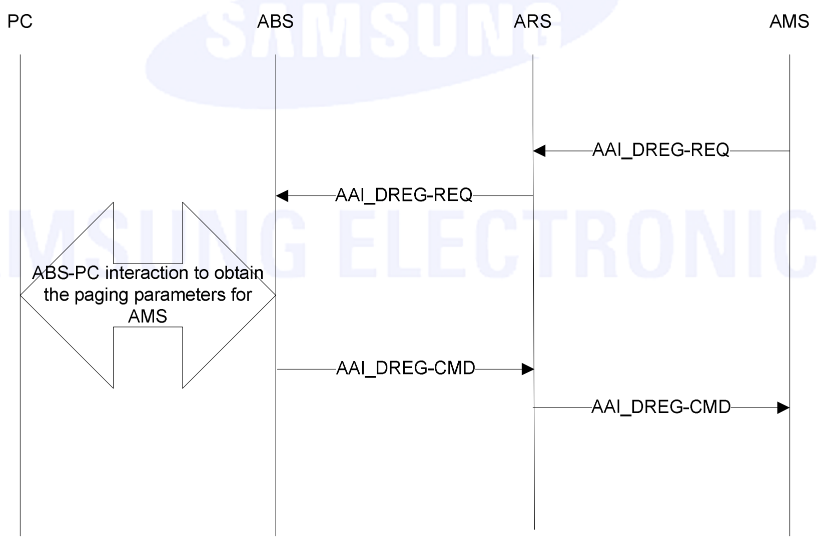

Figure xxx – Call flow for idle mode entry in the relay cell

If the idle mode functions are managed at the ARS, the procedures defined in 15.2.17.1 (Idle mode initiation) are applied wherein each instances of ABS is replaced by ARS.

15.5.2.13.1.2 Broadcast paging message and operation of paging listening interval

In Relay System, when paging is needed to some AMSs in a Paging Group, ARSs belonging to the Paging

Group shall be involved to transmit AAI_PAG-ADV to the AMSs.

If the idle mode functions are managed at the ABS, the paging information shall be transmitted by an ABS to the ARSs in a relay link then the ARS shall forward to its subordinate AMSs. When the ABS need to transmit paging information to the ARSs, the ABS shall calculate the time to transmit in consideration of ARS's processing delay, and so that the ARSs have enough time to decode and transmit the AAI_PAG-ADV message and paging delay will be minimized. The paging information is sent through an R_PAG-ADV message for relay link. When the ABS transmits the R_PAG-ADV message to the ARSs, it may include ARS transmit frame number to the ARSs.

When the ABS transmits R_PAG-ADV to its subordinate ARS, the Paging Group ID for this paging information and the temporary ID for each AMS to receive the AAI_PAG-ADV message is included in the R_PAG-ADV message. When the ARS received the R_PAG-ADV, the ARS realizes paging information of AMSs and makes the Paging Group ID bitmap in order to transmit AAI_PAG-ADV. The ARS shall compose a PGID Info message including the Paging Group ID where the ARS is involved.

A Paging Interval may be included in the R_PAG_ADV message transmitted in the relay link to inform ARS of the Paging Listening Interval for each paged AMS.

The ARS delay is given to the ABS as a capability parameter of an AAI_SBC-REQ message. The ABS sends R_PAG-ADV over the relay link as a pre-transmission ARS delay earlier than the normal AAI_PAG-ADV transmission time. The ABS shall wait for the ARS delay, and then sends AAI_PAG-ADV over the access link.

After transmitting the broadcast paging message with Action Code 'Perform network re-entry' and Perform ranging to establish location', if the ARS does not receive AAI_RNG-REQ from the AMS paged until the next Paging Listening Interval which , the ARS shall retransmit the Broadcast Paging message. Every time the ARS retransmits the broadcast paging message, it decreases the predefined paging retry count by one.

When an ARS receives the AAI_RNG-REQ for location updating or network reentry, it shall relay the AAI_RNG-REQ to the ABS, and stop sending Broadcast Paging message.

When an ABS receives the AAI_RNG-REQ, it shall stop sending Broadcast Paging message. It may generate and send paging stop command to its subordinate ARSs who are still sending the broadcast paging message. When an ARS receives the paging stop command, it shall stop sending Broadcast Paging message.
When an ABS receives paging stop announcement from paging controller, the ABS may generate and send paging stop command to its subordinate ARSs who is still sending the broadcast paging message

If the idle mode functions are managed at the ARS, the procedures defined in 15.2.17.2.1 (Broadcast paging message) are applied wherein each instances of ABS is replaced by ARS.

15.5.2.13.1.3 Location Update and Network Re-entry

If the idle mode functions are managed at the ABS, in the Relay-cell, the ARS shall relay the AAI_RNG-REQ/RSP message between the ABS and the AMS.

If the idle mode functions are managed at the ARS, the procedures defined in 15.2.17.4.2 (Locatino update process) and 15.2.17.5 (Network reentry from Idle mode) are applied wherin each instances of ABS is replaced by ARS.

15.5.2.13.1.4 R_PAG-ADV Message

Table XXX—R_PAG-ADV message format

Syntax	Size(bit)	Notes
R_PAG-ADV_Message_format(){		
Management Message Type =XX	8	
Num_Paging_Group_IDs	16	Number of Paging Group IDs in this message
For (i=0; i<Num_Paging_Group_IDs; i++) {		
Paging Group ID	16	
Number_TempIDs	12	
For(j=0; j<Num_TempIDs; j++){		
Temp_ID	12	
Paging Interval		Paging cycle and offset information
Action Code	2	Paging action instruction to AMS 0b00=Perform network reentry Required 0b01=Perform Ranging to establish location 0b10= Perform LBS measurement 0b11=Reserved
Stop Paging	1	0b0= paging start command 0b1= paging stop command
}		
}		
}		

Paging Interval

This informs the ARS about the Paging Listening Interval for each paged AMS, including paging cycle and paging offset. When the Paging Interval is not included, Stop Paging shall be set to 0.

15.5.2.13.2 Idle mode handling in distributed control

When an AMS is attached to an ARS for idle mode operation, procedures defined in 15.3.12 of IEEE 802.16/D1 where each instances of ABS is replaced by ARS.]