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Proposal for IEEE 802.16m Paging Area Design

Shantidev Mohanty and Muthaiah Venkatachalam

1. Introduction and Background

During idle mode operation a mobile station (MS) performs location update when it moves from one paging group to another. Thus, the air-link signaling overhead associated with location update is proportional to the number of location updates. Therefore, larger paging groups decrease the air-link signaling overhead associated with location update due to fewer number of location updates. On the other hand, when an idle mode MS needs to be paged, as all the base stations (BSs) of MS's current paging area broadcast the paging message for the MS the air-link signaling overhead associated with paging operation is proportional to the size of a paging group. Therefore, the design of paging group needs careful consideration to minimize the total air-link signaling overhead associated with location update and paging operation.

In this contribution an attempt has been made to provide recommendations on the design principles for the paging groups to minimize the air-link signaling overhead associated with location update and paging in IEEE 802.16m wireless systems.

This contribution proposes the design of paging areas based on the geographic location of the idle mode AMSs.

2. Proposed Paging Area Design Considerations

3.1 Geo-location based Paging Area Design:

This contribution proposes geo-location based paging area design so that an idle mode MS is always located in the central region of a paging area when it performs location update in a new paging area. Using this proposal every time an idle mode MS moves to a new paging area it is new paging area is designed in such a way that the MS is located in the center of the new paging area during location update.

Using geo-location based paging area (PA) a PA of an idle mode MS is a logical region of the network that is centered around the current location of the MS. The current location of the idle mode MS corresponds to the most recent location information stored in the PC of the said idle mode MS. This logical PG that is constructed using the location of the idle mode MSs is referred to as Location-based Paging Area (LPG) in the remaining part of this document. The shape of LPG of an idle mode MS with center at the current location of the MS can be circular, elliptic, rectangular or any of shape that can be decided based on different factors such as the mobility pattern of the MS, network coverage etc. For example, an MS moving on a freeway may have a PG that is along the freeway, whereas an MS moving in the downtown of a city may have a circular PG. This is because the MS moving in the freeway will most likely remain in the freeway whereas the MS in the downtown will most likely move in a random direction. Although different shapes for LPG is possible, circular LPG is consider to illustrate this concept. The concepts proposed in this contribution are considered to be used when the PG of an idle mode is decided based on the current location of the MS.

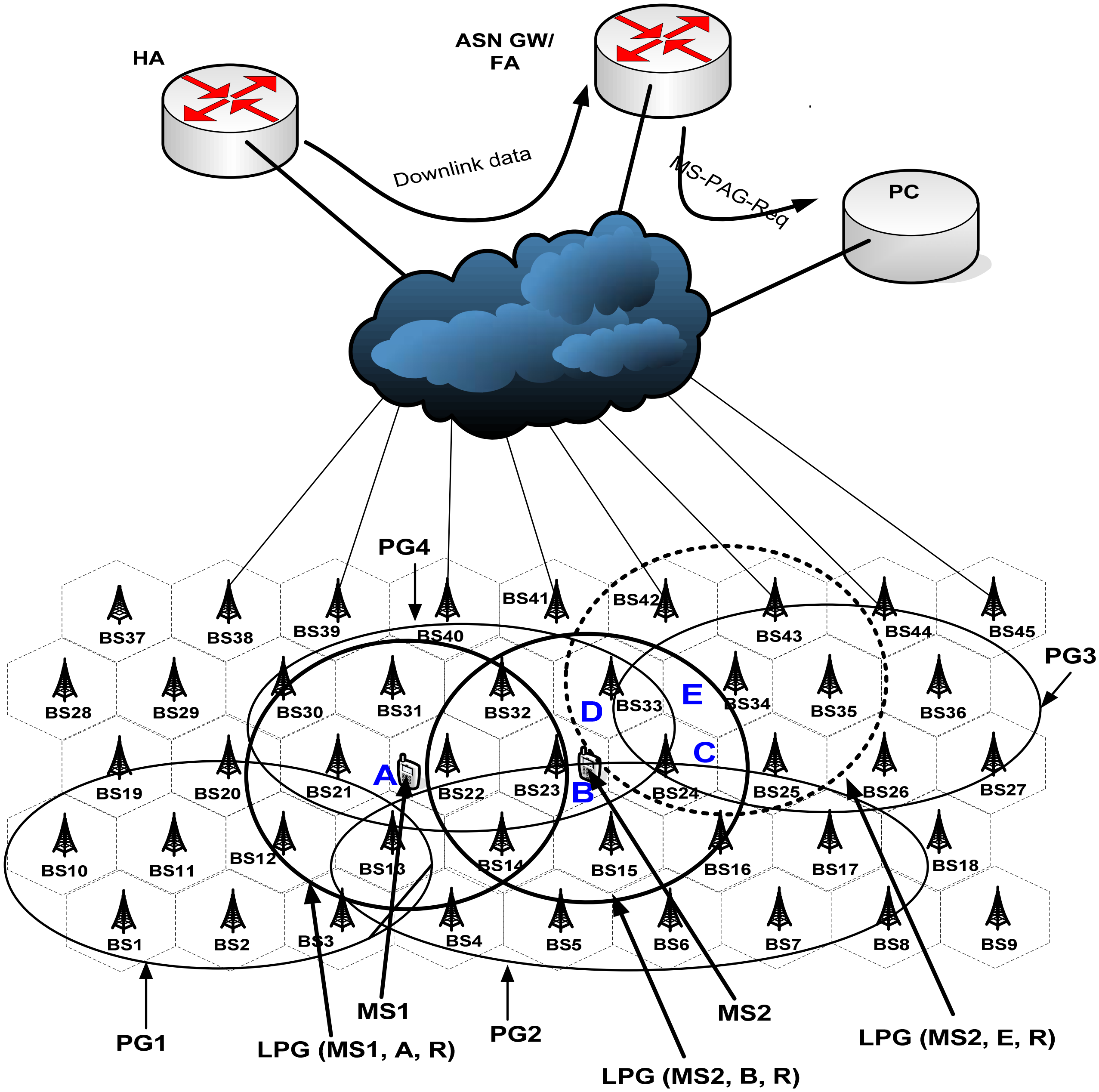

Figure 1: Idle mode operation when LPG is used.

The geo-location based PA design is illustrated in Figure 1 that shows the LPG of two idle mode MSs, MS1 and MS2. Figure 1 also shows the statically configured PAs of reference mobile WiMAX system that are designed without considering the location of idle mode MSs. As described earlier in IEEE 802.16e the network coverage area is logically divided into different PAs either during initial network deployment or during the operation of the network. PG1, PG2, PG3, and PG4 are designed in this way. When these PGs are used to manage idle mode operations, the idle mode MSs moving in the boundary region of multiple PGs perform frequent location update and hence suffer from significantly larger location update overhead. For example, considering the dimensioning of PG1, PG2, PG3, and PG4 shown in Figure 1 when an idle mode MS moves from B to C (PG2 to PG3), C to D (PG3 to PG4), and from D to B (PG4 to PG2) the said idle mode MS performs three location updates although it has traveled only small distance.

Geo-location based PA design is illustrated using MS1 and MS2. It is considered that MS1 enters into idle mode, i.e., transition from connected mode to idle mode when it was located at point A. Similarly, it is considered that MS2 enters into idle mode when it was located at point B. As shown in Figure 1 the Location-based Paging Group (LPG) of MS1 is a circle centers at A and with radius R. This R can be decided either by the idle mode MS or its PC during using different factors. For example using MS1's speed as proposed in the adaptive paging area design concept described in Section 3.2, fast moving idle could have larger PGs compared to slow moving idle mode MSs. Other factors and/or different methods could be used to determine the right value of R for an idle mode MSs and this contribution is applicable irrespective of the methods used to determine the size of a LPG. It may be noted that as the LPGs shown in Figure 1 are assumed to be circular, they can be specified by two parameters: center of the LPG and the radius (R) of the LPG. When other shapes are considered for LPG they can be specified using appropriate parameters. For example, elliptical LPGs can be specified using the center of the ellipse, the lengths of the major and minor axis of the ellipse. Considering circular LPGs, the LPGs in Figure 1 are uniquely identified by three parameters: idle mode MS that a LPG belongs to, center of the LPG, the radius of the LPG. The LPGs are specified using the following notation **LPG (idle mode MS that a LPG belongs to, center of LPG, radius of the LPG).** For example, LPG (MS1, A, R), LPG (MS2, B, R) and LPG (MS2, E, R) shown in Figure 1. For description of geo-location based PA design it is assumed that the radius of LPGs of different idle mode MSs is the same. It may be noted that the proposed concept is applicable when the radius of the PGs of different idle mode MSs are different.

The LPGs for idle mode MSs, MS1 and MS2 are considered to be circular with the center at the location where these MSs enters into idle mode. After entering idle mode when these MSs performs location update during their idle mode operation, (as described later) the LPG is centered at the location where these MSs perform location update. Thus, the LPG of an idle mode MS is centered at the location where the said MS enters into idle mode or at the location where the said MS performs its most recent location update.

As shown in Figure 1 the LPGs for MS1 and MS2 are different as they entered into idle mode from different locations. Similarly, it can be easily seen that when multiple idle mode MSs are present in the network, they may have different LPGs based on the location where they entered into idle mode or the location where they performed their most recent location updates.

The advantages of geo-location based PA can be easily observed by considered the movement of MS2 from B to C, C to D, and D to B. As these locations (A, B, C, and D) are located close to each other, these are all inside the LPG (MS2, B, R). Thus, when MS2 moves between these points, it does not have to perform location update. This reduces the unnecessary location update overhead that is incurred static configuration of PA is used as described earlier.

For idle mode MSs moving in a particular direction the geo-location based PA can be designed in such a way that instead of making the PA centered around the current location of the idle mode MS, the PA that is along the direction of MS's movement has one of its ends at MS's current location and is extended in the direction of MS's movement. This way the geo-location based PA can adapt to the movement pattern of an idle mode MS.

The location of an idle mode MS can be determined using different methods. For example Global Positioning System (GPS)-based location estimation technique can be used for this purpose. Other location estimation techniques such as assisted-GPS can be used for this purpose. In addition, triangulation technique using the location of three near by BSs can also be used to determine the location of the MS. Any other technique can be used to determine the location of the idle mode MSs. The location of a BS can also used to as the approximate location of the idle mode MSs in the coverage of the BS.

When geo-location based PA design is used, the procedures and the associated message flows during MS entering idle mode, location update, paging and idle mode exit operations are carried out as described in Appendix A.

3. Proposed Text for SDD

------------------------------- Text Start --

[Insert the following text to 10.5.2.1.4 after line 3]

The AMS may confirm whether it exists in the same paging group as it has most recently belonged by using its location information.

[Insert the following text to 10.5.2.3.2.1 after line 11]

The AMS may determine the change of paging group by using its location information.

------------------------------- Text End --

4. References

[1] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and P802.16Rev2/D3 (February 2008).

[2] WiMAX Forum™ Mobile System Profile, Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02), http://www.wimaxforum.org/technology/documents.

[3] IEEE 802.16m-08/003r1, "The Draft IEEE 802.16m System Description Document"

[4] K. L. Yueng and S. Nanda, "Optimal Mobile-Determined Micro-Macro Cell Selection," : Proc. of IEEE International Symposium in Personal, Indoor and Mobile Radio Communications (PIMRC), 1995, Toronto, Canada (September 1995) pp. 294-299.

Appendix A

When geo-location based PA is used, the procedures and the associated message flows during MS entering idle mode, location update, paging and idle mode exit operations are carried out as described below. It may be noted that the messages that are exchanged during these operations may include several information fields. In the following description only those information fields that are related to geo-location based PA are specifically mentioned and it is assumed that other information fields are present. Other information not related to this concept is not explicitly mentioned in the following description.

1. MS entering Idle Mode

MS initiated idle mode entry is considered to illustrate the operations during MS entering idle mode to describe the procedures carried out during idle mode entry of an MS when geo-location based PA is used. For example, the following procedures are used by MS1 and MS2 when they enter into idle mode from location A and B, respectively as shown in Figure 1. It may be noted that the procedures for network initiated MS entering idle mode has similar steps. The steps for MS initiated idle mode entry are as follows.

- When an MS decides to initiate idle mode, it sends deregistration request (DREG-REQ) message using the format defined in IEEE 802.16e to its serving BS (SBS). Along with other information specified in IEEE 802.16e standard, the MS includes its current location in the DREG-REQ message. The MS may include its desired LPG radius in the DREG-REQ. The MS location information can be encoded using the X, Y, and Z co-ordinates of the location. Other methods can be used by an idle mode MS to convey its current location in the DREG-REQ message.
- Upon receiving the DREG-REQ the SBS sends Data Path Release Request (Data Path Rel Req) message to the corresponding FA to trigger the data path release process for the MS. Along with other information contained in the Data Path Rel Req includes MS identification (MSID), SBS identification (BSID), MS location information, LPG radius (if present in the DREG-REQ message), MS's anchor PC identification (PCID).
- When the FA receives the Data Path Rel Req, it sends MS Information Report (MS Info Rprt) message to the PC identified by the PCID of the Data Path Rel Req message. Along with other information MS Info Rprt contains the following information: MSID, MS location information, and LPG radius (if present in the Data Path Rel Req message).
- When the PC receives the MS Info Rprt message, it adds the MSID and its location information to its ldle Mode MS Information Table. The PC uses the ldle Mode MS Information Table to stores information about its idle mode MSs. If the MS Info Rprt contains information about MS's desired LPG radius and the PC agrees with this value, then PC may decide to use the LPG radius value requested by the MS to determine the size of the LPG for the MS. It may be noted that the PC may decide to LPG of size different than what the MS requested for. Once the PC decides about the LPG radius for the MS, it adds the LPG radius information to the entry in its ldle

Mode MS Information Table corresponding to this MS. After the PC decides about the size of MS's LPG, it sends MS Information Response (MS Info Rsp) to the FA. MS Info Rsp message contains MSID, LPG radius, and PCID.

- When the FA receives the MS Info Rsp message, the FA adds the MSID, PCID information along with other information to its table and sends Data Path Release Response (Data Path Rel Rsp) message containing MSID, PCID, and LPG radius to the SBS.
- The SBS sends DREG-CMD message containing the PCID and LPG radius to the MS upon receiving Data Path Rel Rsp message. The MS goes to idle mode upon receiving DREG-CMD. The MS stores the PCID, information about its LPG center and radius to use during its idle mode operation. It may be noted that the LPG center is the location of the MS when it initiated its idle mode entry.

The message flow for MS entering the idle mode is shown in Figure 2.

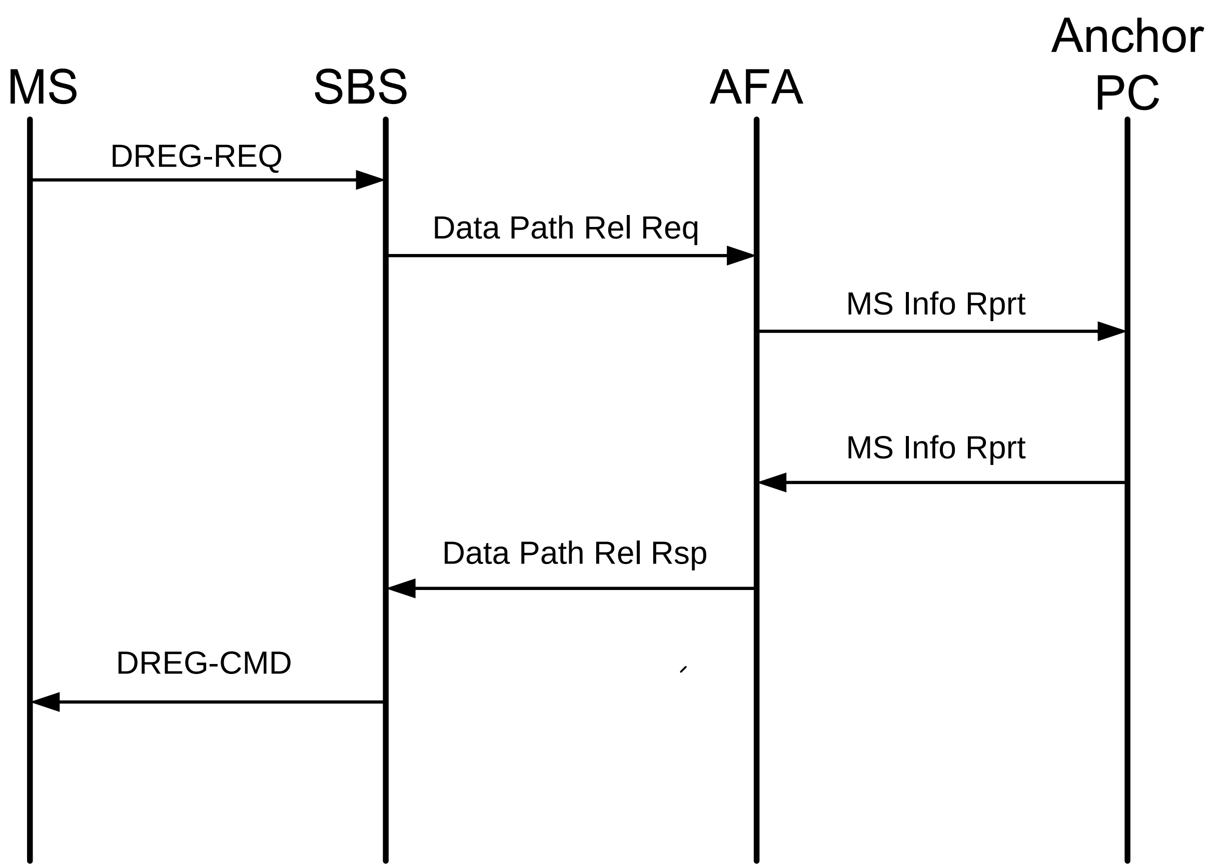

Figure 2: Message flows for MS entering idle mode.

2. MS Performing Location Update

When geo-location based PA is used an idle mode MS learns its current location during its Paging Listening Interval (PLI). Then, it determines if its current location is inside its LPG region. The MS learns about it by determining the distance between its current location and its LPG center. Assuming that (X, Y, Z) co-ordinates are used to denote the location information; the distance (D_{ms}) of MS's current location from the center of its LPG is given by Eq. (1).

$$D_{ms} = \sqrt{(X_c - x)^2 + (Y_c - y)^2 + (Z_c - z)^2} \text{ ------Eq. (1)}$$

where (X_c, Y_c, Z_c) are the co-ordinates of the LPG center and (x, y, z) are the co-ordinates of MS's current location. If D_{ms} is greater than its LPG radius, then the MS learns that it has moved out of its LPG and needs to perform location update.

During its PLI if the MS learns that it is inside its LPG, then the MS determines whether or not its current serving BS is located inside its LPG. It may be noted that the serving BS is the one from which the idle mode MS receives the broadcast messages. To determine whether or not its serving BS is located inside its LPG, the MS listens for broadcast message containing the location information of the BS. The BS can broadcast their location information by including this information in different broadcast messages such as Mobile Paging Advertisement (MOB-PAG-ADV), downlink channel descriptor (DCD) message etc. It may be noted that the BSs could use other methods to broadcast their location information. The idle mode MS determines the distance between its current serving BS and its LPG center, D_{bs}, using Eq. (2).

$$D_{ms} = \sqrt{(X_c - X_b)^2 + (Y_c - Y_b)^2 + (Z_c - Z_b)^2} \text{ ------Eq. (2)}$$

where (X_c, Y_c, Z_c) are the co-ordinates of the LPG center and (X_b, Y_b, Z_b) are the co-ordinates of MS's current serving BS location. If D_{bs} is greater than its LPG radius, then the MS learns that its current serving BS is outsize of its LPG. In this case the idle mode realizes that it needs to perform location update.

Using procedures described above an idle mode MS learns that it needs to perform location update.

An example scenario for location update for idle mode MS2 is illustrated in Figure 1 when MS2 is located at E during one of its PLI. When MS2 is located at E, it learns that it is inside its current LPG centered at A with radius of R. However, it learnt that its current serving BS, BS34 in Figure 1 is outside the LPG. Thus, MS2 performs location update and updates its LPG from LPG (MS2, A, R) to LPG (MS2, E, R). It may be noted that after every location update, the new LPG of the MS is centered at the location where the MS performs location update. For example, in the example scenario of Figure 1 point E becomes the center of MS2's new LPG as MS2 performs location update when it was located at E.

The message flows for location update procedures are shown in Figure 3. The location update procedure has the following steps.

- The MS sends ranging request (RNG-REQ) message to the serving BS (SBS) indicating that it needs to perform location update. The MS includes its anchor PC ID and its current location in the RNG-REQ message.

- Upon receiving RNG-REQ the SBS sends a location update request (LU_Req) message to the anchor PC of the said idle mode MS identified by PCID included in the RNG-REQ message. The LU_Req contains the following information: MSID, PCID, and current location information of the MS. Upon receiving the LU_Req message, the PC updates the location of the MS and sends the location update response (LU_Rsp) message to idle mode MS's current SBS.
- When the SBS receives the LU_RSP, it sends ranging response (RNG-RSP) to the MS informing about the successful completion of location update. Then, SBS sends location update confirm (LU_Confirm) message to the anchor PC of the MS.

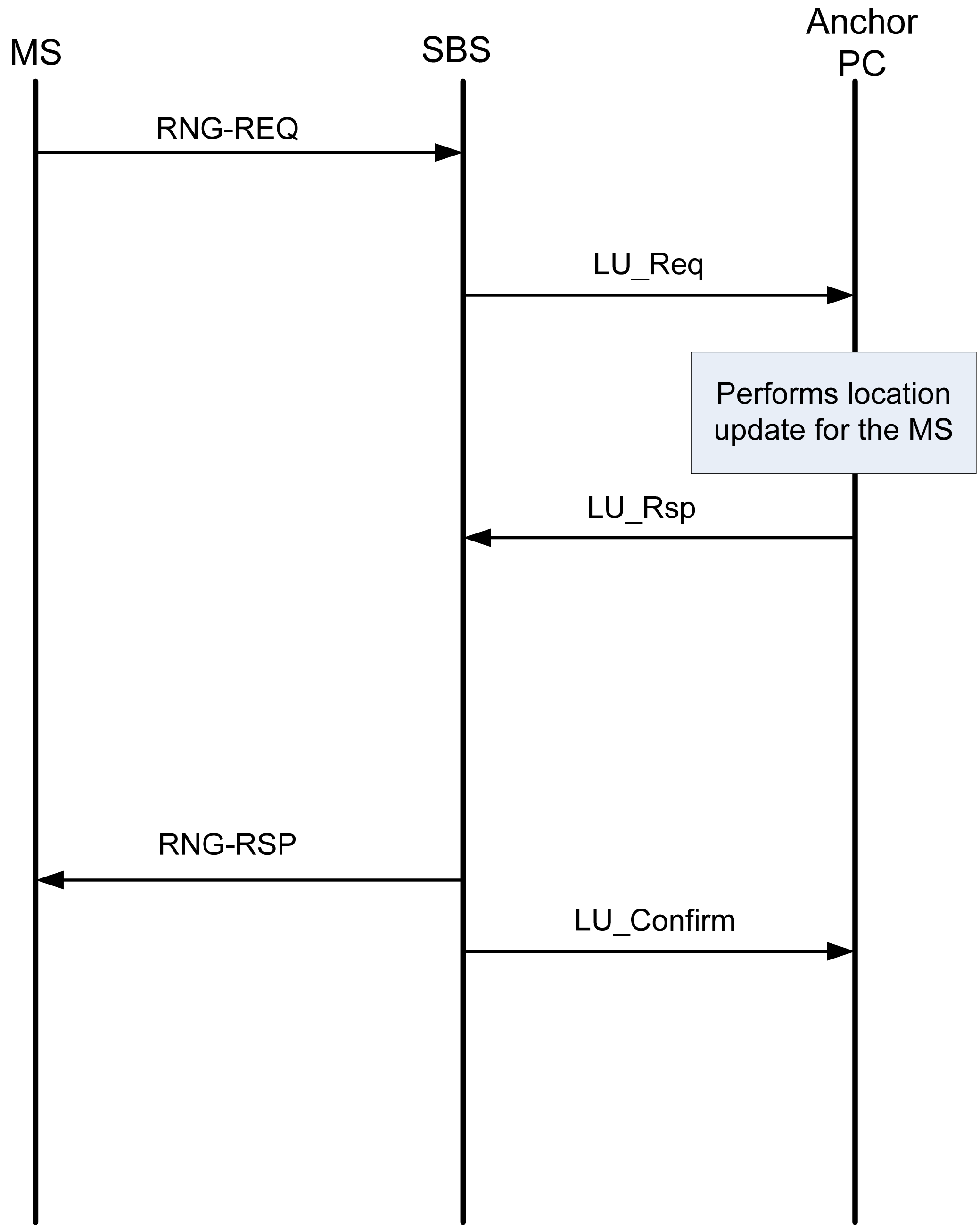

Figure 3: Message flows for location update.

3. MS Paging and MS Exiting Idle Mode

When the network want to locate an idle mode MS, it pages the MS using MOB-PAG-ADV message. It may be noted that the need to locate an idle mode user arises mostly because of the arrival of new packets destined for the MS. For the remaining part of this document, we assume that all the packets destined for the MS first reaches MS's home agent (HA). Then HA forwards the packets to the FA using Mobile IP address binding that is present in its database. It may be noted that the FA is the AFA if the user is in idle mode. The FA learns that the MS is in idle mode. Then, the FA and sends a MS Paging Request (MS-PAG-Req) message to the anchor PC of the MS. When the PC receives the paging message, the PC broadcasts paging message to all the BSs in the LPG of the MS. The MS resides in the coverage area of one these BSs and it receives the paging message and replies to it through ranging request (RNG-REQ) message indicating that it wants to exit idle mode and perform network re-entry from idle mode. This RNG-REQ message is received by MS's current serving BS (SBS). Then the SBS assists the idle mode MS to perform network re-entry from idle mode. The message flow for paging is shown in Figure 4.

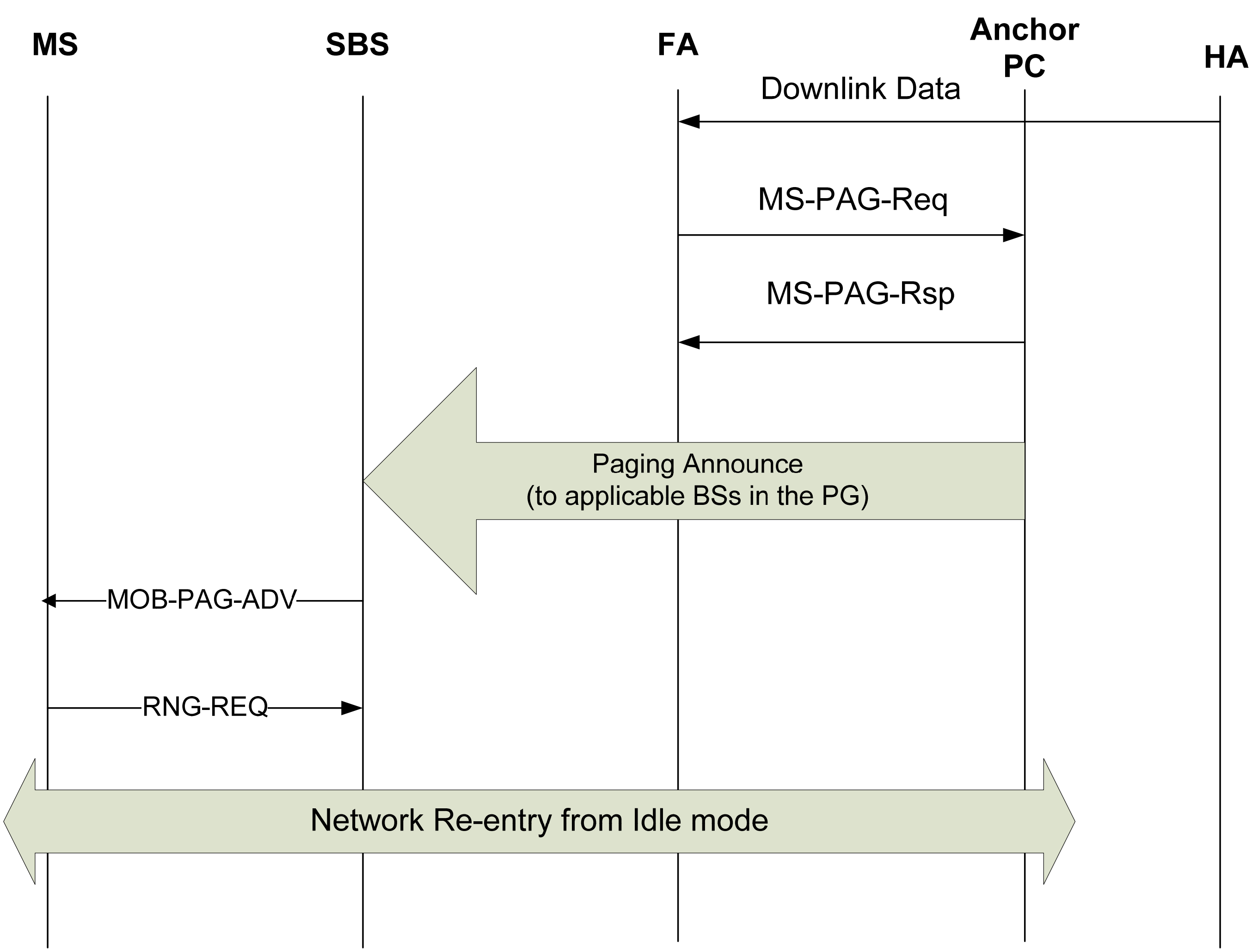

Figure 4: Message flows for Paging and MS network re-entry.

It may be noted that the messages that are exchanged during these operations may include several information fields. In the following description only those information fields that are related to geo-location based PA are specifically mentioned and it is assumed that other information fields are present. Other information not related to geo-location based PA is not explicitly mentioned in the description of different operations associated with idle mode.