

Project	IEEE 802.16j Multihop Relay Task Group	
Title	Signaling for Efficient Routing	
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Re:	This document is in response to call for technical proposals IEEE 80216-06/027 dated 15 October 2006. This document proposes text regarding signaling for efficient routing for insertion in baseline document IEEE 80216j-06/026.	
Abstract	This contribution proposes signaling for efficient routing that efficiently supports multihop relay for IEEE 802.16j. This contribution also provides the technical rationale for the proposed signaling.	
Purpose	Text is included for insertion in the IEEE 802.16j amendment to the standard.	
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Signaling for Efficient Routing

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Introduction

In the IEEE 802.16j standard, Relay Stations (RS) are introduced to improve coverage, extend range and enhance capacity of the IEEE 802.16e cellular systems. In the scope of the IEEE 802.16j, introduction of relays into an IEEE 802.16e network is to be seamless with respect to the Subscriber Station (SS)/Mobile Station (MS) operation. To satisfy the backwards compatibility requirement with IEEE 802.16e, a Relay Station (RS) must appear as a complete BS to an MS by broadcasting its own 802.16e preamble and UL/DL control information. In an IEEE 802.16j network, this preamble and control information will be utilized by MS for network entry and handover processes as already standardized for 802.16e networks. However, an 802.16e network is a single-hop network with all over-the-air transmissions sent directly between a BS and its subordinate MS. When used in a multi-hop topology of an 802.16j system, it is likely that these legacy network entry and handover procedures will lead to suboptimum network attachment decisions at an MS, since these procedures are not designed to take into account the overall quality of routes for various MS network attachment options. Specifically, consider the following two examples of the legacy 802.16e network attachment procedures leading to suboptimum decisions in an 802.16j network:

1. An MS detects a stronger preamble signal from an RS than from a BS and proceeds to establish network attachment through the RS. However, the path to the MMR-BS through the RS may involve multiple hops, and the overall capacity or other metric of interest for that path may be lower than that of the direct link to the MMR-BS. Hence, a signaling and corrective routing mechanisms are needed to facilitate handover of the MS from the RS to the BS, if necessary.
2. An MS detects a stronger preamble from the BS than from an RS and proceeds to establish direct UL and DL links with the BS. This network attachment decision is optimum with respect to the DL communication. However, as the transmit power of the BS is significantly higher than that of the RS, pathloss on the MS-to-BS link may still be significantly higher than that on the MS-to-RS link. In this case, the network entry decision by the MS may be suboptimum with respect to the UL communication. Again, routing and signaling mechanisms are necessary to route UL communication through the RS, if necessary.

In this contribution, new signaling procedures and MAC management messages are proposed to enable appropriate route selection for the MS upon its entry into an IEEE 802.16j network. The proposed approach is completely transparent to a legacy 802.16e MS and relies on the existing mobility management messages defined in the IEEE 802.16e standard.

General Description

Figure 1 shows the two possible routes for the DL and UL in a system that allows a maximum of one relay in the route between the BS and the SS/MS. The link metric of each hop or link is represented by C_{xy} , where x is the source of the hop and y is the destination of the hop. Note that x and y can take on labels of B for the BS, R for the RS, and S for the MS.

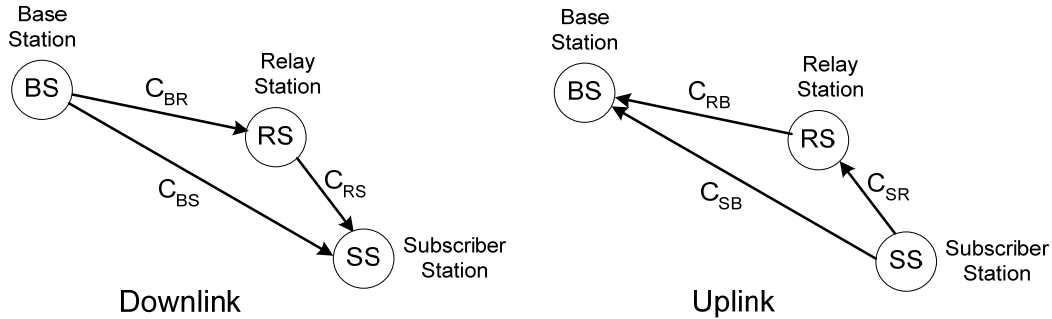


Figure 1. Possible DL and UL routes for a system that includes a single relay.

Note that in this contribution, it is assumed that the MS-to-BS connections are either one-hop or two-hop connections (i.e., involving at most one RS). In general, a path to the BS may involve multiple intermediate RS, and hence may span more than two hops. However, a BS-to-MS or MS-to-BS route involving more than one RS may be viewed as a virtual two-hop route by collapsing all intermediate hops between the BS and the access RS into a single hop of with some effective link metric C_{BR} or C_{RB} , where the effective link metric is a function of the individual link metrics on the intermediate hops. An example of this simplification for a DL route involving two RS is shown in Figure 2. Finally, as part of a route evaluation procedure, metrics for two routes both involving RS may have to be compared. An example of such a topology is also shown in Figure 2. In general, the signaling procedures proposed in this contribution apply to routes involving an arbitrary number of individual RS with minor modifications. For brevity, the signaling procedures proposed in this contribution will be described for the topologies shown in Figure 1 only. Hence, without loss of generality, the following four cases need to be considered:

1. MS linked to RS, downlink
2. MS linked to BS, downlink
3. MS linked to RS, uplink
4. MS linked to BS, uplink

Each of these cases is described in detail below. In this contribution, it is proposed that the responsibility of maintaining routes in the cell rests solely with BS. Hence, all information needed to make the relaying decision needs to be conveyed to the BS, possibly via relaying by intermediate RS. In general, other routing approaches that are to some degree distributed are also possible. Note that this contribution addresses route formation and maintenance once an MS has completed an initial network entry procedure. An approach combining MS network entry procedure with routing of MS UL transmissions is proposed in [1].

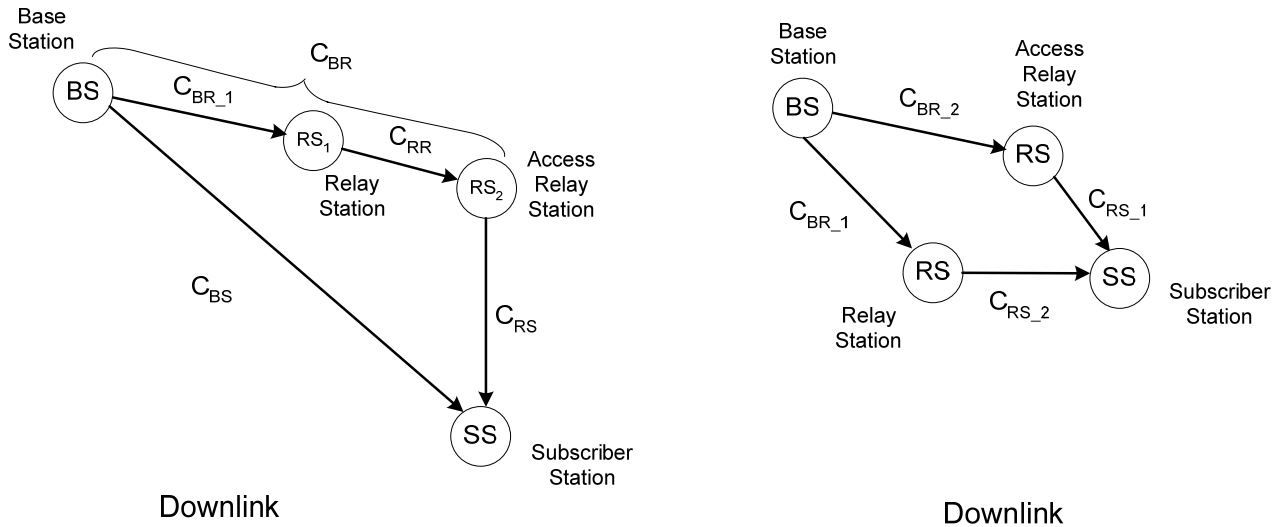


Figure 2. Example of downlink routes involving multiple relays.

Case 1: MS linked to RS, downlink

In this case, it is assumed that the BS wants to evaluate whether a direct BS-to-MS link is more appropriate than the two hop route BS-to-RS-to-MS currently in use by the MS. In order to perform this evaluation, the BS needs knowledge of the link metrics C_{BS} , C_{BR} , and C_{RS} . It is assumed that C_{BR} is known at the BS. For instance, it is assumed that channel quality feedback and link adaptation procedures are utilized on the BS-to-RS link. Hence, C_{BR} can be derived from the modulation and coding rate used by the BS on the BS-to-RS link.

Similarly, C_{RS} is known by the RS as the RS and the MS regularly exchange data. The remaining required link metric C_{BS} can be obtained at the RS as follows: the RS can request the MS to measure link quality on the BS-to-MS link by sending an 802.16e-defined MOB_SCN-RSP and specifying only the BS of interest in the N_Recommended_BS_Index message field. The MS can then report the link quality, such as RSSI or CINR measured based on the BS preamble, using the MOB_SCN-REP message. Consequently, the BS can obtain all the information using the process described in Figure 3. If based on the feedback, the direct link from the BS to the MS is deemed more appropriate than the current route, the BS sends a message to the RS to initiate handover at the MS to the BS. This handover could be forced at the MS by sending MOB_BSHO-REQ message to the MS from the RS. This handover should be signaled as mandatory in the message. To enable the signaling in Figure 3, five new messages are proposed in this contribution:

1. RS_CAP_DL-REQ: used by the BS to request RS to report C_{RS}
2. RS_CAP_DL-RSP: used by the RS to report C_{RS}
3. RS_MEAS_MS-REQ: to notify the RS to send MOB_SCN-RSP to the MS
4. RS_MEAS_MS-RSP: used by the RS to report response of the MS in the MOB_SCN-REP to the BS.
5. RS_INITIATEHO-REQ: to inform the RS that it needs to initiate handoff of the MS to the BS
6. RS_INITIATEHO-RSP: acknowledgment of the RS_INITIATEHO-REQ message

Note that these messages are exchanged between the BS and the RS and are completely transparent to the MS. Furthermore, the response messages, RS_CAP_DL-RSP and RS_MEAS_MS-RSP, could be send to the BS from the RS in an unsolicited manner. By relying on reciprocity of uplink and downlink paths in a TDD system, the preceding signaling approach could be also used to obtain the necessary uplink link metrics as well.

However, a more efficient approach, not requiring explicit preamble measurements, is proposed below for evaluation of uplink routes.

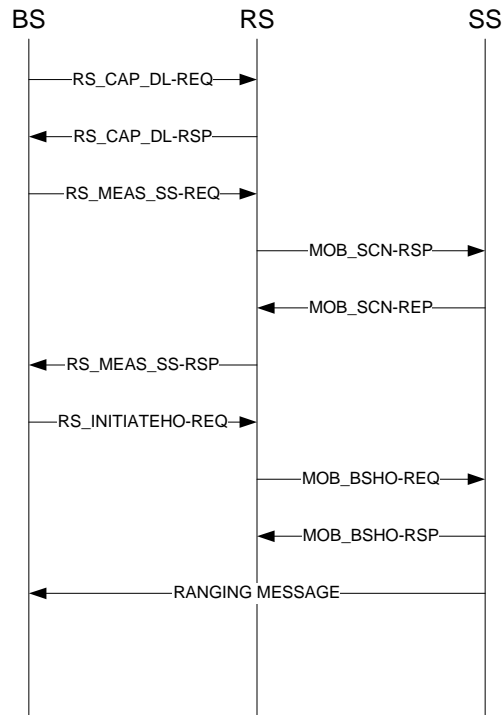


Figure 3. Bounce diagram illustrating a downlink handoff from the RS to the BS.

Case 2: MS linked to BS, downlink

Similarly to the preceding scenario, to evaluate path metrics associated with the direct and two-hop paths to the MS, the BS requires knowledge of the C_{BS} , C_{BR} , and C_{RS} link metrics. In this case the BS has direct knowledge of the C_{BS} and C_{BR} , since it maintains direct communication links with both the RS and the MS. The only remaining link metric required for evaluation of the two paths is C_{RS} . Again, this link metric can be obtained similarly to Case 1, with the only difference that the BS uses the MOB_SCN-RSP message to force the MS to measure RSSI or other link quality metric and report back it to the BS in the MOB_SCN-REP message. This process is illustrated in Figure 4, with the MS performing handover to the RS, if it is deemed necessary at the BS. In this case, no additional signaling is necessary. However, in order to improve the robustness of the handoff process, we propose to add an optional message, RS_IMMINEHTHO to notify the RS of the imminent MS connection. Alternatively, fast handover signaling already defined in the IEEE 802.16e standard may be used to complete the handover procedure.

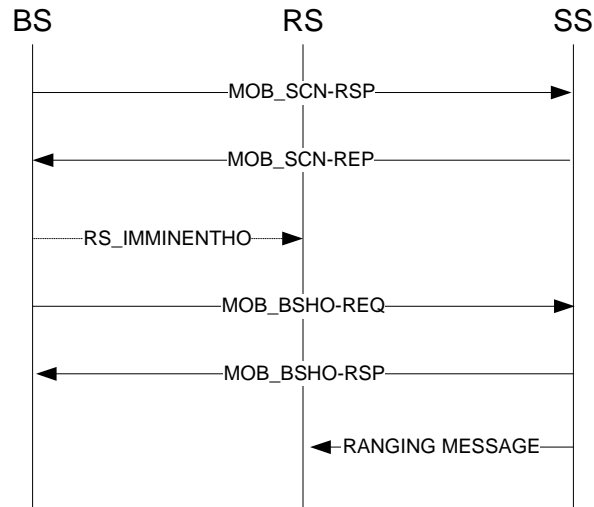


Figure 4. Bounce diagram illustrating a downlink handoff from the BS to the RS.

Case 3: MS linked to RS, uplink

The process to facilitate path evaluation on the uplink is quite similar as the corresponding Case 1 on the downlink. The key differences are: 1) the BS requests the RS to report C_{SR} , instead of C_{RS} as in Case 1; 2) the BS can perform the C_{SB} measurement with a simpler process, as explained in the following. There are two possibilities: (i) a centralized scheduler is utilized at the BS; (ii) a decentralized scheduler is utilized at the RS. With a centralized scheduler, the BS is aware of the RS impending uplink transmissions and the exact burst allocation for this transmission. Hence, the BS can use the embedded UL OFDMA PUSC pilots to estimate RSSI or another relevant link metric and derive C_{SB} . With a decentralized scheduling algorithm, the BS is informed of the burst allocation for the impending MS transmission by the RS that ultimately schedules the transmission.

In order to enable this process, two 802.16j specific messages need to be defined:

1. RS_CAP_UL-REQ: used by the BS to request RS to report C_{SR}
2. RS_CAP_UL-RSP: used by the RS to report C_{SR}

Note that the response message RS_CAP_UL-RSP could be sent to the BS from the RS in an unsolicited manner. Additionally, for the decentralized scheduling case, a message is needed indicating the resource assignment of the MS on the UL:

RS-UL_MAP_RX-REP

The same message is also proposed in the contribution on transparent relaying [1]. As a result of the UL evaluation procedure, the BS may begin to receive UL transmissions from the MS directly in a transparent manner to the MS, or it may initiate a handover procedure to establish direct connectivity on both the DL and UL links.

Case 4: MS linked to BS, uplink

Conceptually, the route evaluation in this case is very similar to Case 3. A complication that arises in this case is that the BS needs to estimate C_{SR} even though the MS is not connected with the RS on UL. However, this difficulty can again be resolved by utilizing the RS-UL_MAP_RX-REP message to inform the RS of the burst allocation for an impending UL transmission by the MS, which can then proceed with the C_{SR} estimation

process. As a result of the UL route evaluation procedure, the BS may proceed with a transparent relay procedure, whereby MS UL transmissions are transparently relayed through the RS to the BS. This procedure is further detailed in [1]. Alternatively, the BS may initiate a handover procedure of the MS to the RS to establish relayed paths for both the uplink and downlink communication flows.

References

[1] C80216j-06_160, "Support for a simplified uplink-only relaying mode," Nov. 2006.

Proposed Text Changes

Add a new section 6.3.2.3.AA

Section 6.3.2.3.AA RS_CAP_DL-REQ.

This message shall be sent by the BS to the RS to request that the RS measure and report the link quality on the RS to MS link.

Syntax	Size	Notes
RS_CAP_DL-REQ_Message_Format() {		
Management Message Type=TBD	8 bits	
Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based: Bit 0: RS to MS CINR mean Bit 1: RS to MS RSSI mean Bit 2: RS to MS DIUC Bits 3-7: reserved
}		

Parameters shall be as follows:

CID (in the generic MAC header)

RS Primary Management CID.

The following parameters shall be as follows for the RS_CAP_DL-REQ message:.

Report metric

Bitmap indicator of trigger metrics that the BS requests the RS to report.

Bit 0: RS to MS CINR mean

Bit 1: RS to MS RSSI mean

Bit 2: RS to MS DIUC. This is the DIUC that the RS most recently used when transmitting to the MS

Bits 3-7: reserved; shall be set to zero.

Add a new section 6.3.2.3.AB

Section 6.3.2.3.AB RS_CAP_DL-RSP.

In response to the RS_CAP_DL-REQ message, the RS shall send an RS_CAP_DL-RSP.

Syntax	Size	Notes
RS_CAP_DL-RSP_Message_Format() {		
Management Message Type=TBD	8 bits	

Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based: Bit 0: RS to MS CINR mean Bit 1: RS to MS RSSI mean Bit 2: RS to MS DIUC Bits 3-7: reserved
If (Report metric[Bit 0]==1)		
RS to MS CINR mean	8 bits	
If (Report metric[Bit 1]==1)		
RS to MS RSSI mean	8 bits	
If (Report metric[Bit 2]==1)		
RS to MS DIUC	8 bits	Bits 0-3: DIUC Bits 4-7: reserved
}		

The RS_CAP_DL-RSP message shall include the following parameters:

CID (in the generic MAC header)

RS Primary Management CID.

The following parameters shall be as follows for the RS_CAP_DL-RSP message:

Report metric

Bitmap indicator of trigger metrics that the RS to reports.

RS to MS CINR mean

Indicates the CINR measured by the RS from the particular MS.

The value shall be interpreted as a signed byte with units of 0.5 dB. The measurement shall be performed on the subcarriers of the BS-to-RS preamble which are active in the particular BS s segment.

RS to MS RSSI mean

Indicates the Received Signal Strength measured by the RS from the particular BS. The value shall be interpreted as an unsigned byte with units of 0.25 dB, such that 0x00 is interpreted as -103.75 dBm, an MS shall be able to report values in the range -103.75 dBm to -40 dBm. The measurement shall be performed on the BS-to-RS preamble.

RS to MS DIUC

Indicates the DIUC that the RS most recently used when transmitting to the MS.

Add a new section 6.3.2.3.AC

Section 6.3.2.3.AC RS_MEAS_MS-REQ.

The BS shall send this message to the RS to request it to send a MOB_SCN-RSP message to the MS in order to measure the link quality of the BS-to-MS link.

Syntax	Size	Notes
RS_MEAS_MS-REQ_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	Primary management CID of the MS
Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based:

		Bit 0: BS CINR mean Bit 1: BS RSSI mean Bits 2-7: reserved
}		

The parameters of the RS_MEAS_MS_REQ shall be as follows:

CID

Primary management CID of the MS

Report metric

Bitmap indicator of trigger metrics that the BS requests the MS to report.

Bit 0: BS CINR mean

Bit 1: BS RSSI mean

Bits 2-7: reserved; shall be set to zero.

Add a new section 6.3.2.3.AD

Section 6.3.2.3.AD RS_MEAS_MS-RSP.

The RS shall send this message to the BS in reply to an RS_MEAS_MS-REQ in order to report the link quality of the BS-to-MS link.

Syntax	Size	Notes
RS_MEAS_MS-RSP_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	Primary management CID of the MS
Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based: Bit 0: BS CINR mean Bit 1: BS RSSI mean Bits 2-7: reserved
If (Report metric[Bit 0]==1)		
BS CINR mean	8 bits	
If (Report metric[Bit 1]==1)		
BS RSSI mean	8 bits	
}		

The parameters of the RS_MEAS_MS_RSP shall be as follows:

CID (in the generic MAC header)

RS Primary Management CID.

Report metric

Bitmap indicator of trigger metrics that the RS to reports.

BS CINR mean

The BS CINR mean parameter indicates the CINR measured by the MS from the particular BS.

The value shall be interpreted as a signed byte with units of 0.5 dB. The measurement shall be performed on the subcarriers of the frame preamble which are active in the particular BS segment

BS RSSI mean

The BS RSSI mean parameter indicates the Received Signal Strength measured by the RS from the particular BS. The value shall be interpreted as an unsigned byte with units of 0.25 dB, such that 0x00 is interpreted as -

103.75 dBm, an MS shall be able to report values in the range -103.75 dBm to -40 dBm. The measurement shall be performed on the frame preamble.

Add a new section 6.3.2.3.AE

Section 6.3.2.3.AE RS_INITIATEHO-REQ.

When the BS determines that an MS connected to one of its downstream RS should establish a direct path with the BS, the BS shall instruct the RS to send an RS_INITIATEHO-REQ:

Syntax	Size	Notes
RS_INITIATEHO-REQ_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	Primary management CID of the MS
}		

Add a new section 6.3.2.3.AF

Section 6.3.2.3.AF RS_INITIATEHO-RSP.

When the BS determines that an MS connected to one of its downstream RS should establish a direct path with the BS, the BS shall instruct the RS to send an RS_INITIATEHO-REQ:

An RS can optionally acknowledge an RS_INITIATEHO-REQ with the RS_INITIATEHO-RSP message:

Syntax	Size	Notes
RS_INITIATEHO-RSP_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	Primary management CID of the MS
}		

Add a new section 6.3.2.3.AG

Section 6.3.2.3.AG RS_IMMINENTHO.

The BS may optionally send this message to notify the RS of the imminent handoff of an MS to the RS.

Syntax	Size	Notes
RS_IMMINENTHO_Message_Format() {		
Management Message Type=TBD	8 bits	
MAC ID	48 bits	MAC ID of the MS that will handoff to the RS
}		

Add a new section 6.3.2.3.AH

Section 6.3.2.3.AH RS_CAP_UL-REQ.

This message shall be sent by the BS to the RS in order to request measurement of the quality of the MS to-RS link.

Syntax	Size	Notes
RS_CAP_UL-REQ_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	MS primary management CID
Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based: Bit 0: MS CINR mean Bit 1: MS RSSI mean Bit 2: MS UIUC Bits 3-7: reserved
}		

The parameters shall be set as follows in the RS_CAP_UL-REQ message:

CID (in the generic MAC header)

RS Primary Management CID.

Report metric

Bitmap indicator of trigger metrics that the BS requests the RS to report.

Bit 0: MS CINR mean

Bit 1: MS RSSI mean

Bit 2: MS UIUC

Bits 3-7: reserved; shall be set to zero.

Add a new section 6.3.2.3.AI

Section 6.3.2.3.AI RS_CAP_UL-RSP.

In response to the RS_CAP_UL-REQ message, the RS shall send an RS_CAP_UL-RSP:

Syntax	Size	Notes
RS_CAP_UL-RSP_Message_Format() {		
Management Message Type=TBD	8 bits	
Report metric	8 bits	Bitmap indicating metrics on which the corresponding triggers are based: Bit 0: BS CINR mean Bit 1: BS RSSI mean Bit 2: MS UIUC Bits 3-7: reserved
If (Report metric[Bit 0]==1)		
MS CINR mean	8 bits	
If (Report metric[Bit 1]==1)		
MS RSSI mean	8 bits	
If (Report metric[Bit 2]==1)		
MS UIUC	8 bits	Bits 0-3: UIUC

		Bits 4-7: reserved
}		

The parameters shall be set as follows in the RS_CAP_UL-RSP message:

CID (in the generic MAC header)

RS Primary Management CID.

Report metric

Bitmap indicator of trigger metrics that the RS reports to the BS.

Bit 0: BS CINR mean

Bit 1: BS RSSI mean

Bits 2-7: reserved; shall be set to zero.

MS CINR mean

The MS CINR mean parameter indicates the CINR measured by the RS from the particular MS.

The value shall be interpreted as a signed byte with units of 0.5 dB. The measurement shall be performed on the subcarriers that are assigned to the UL burst of the MS of interest.

BS RSSI mean

The BS RSSI mean parameter indicates the Received Signal Strength measured by the RS from the particular MS of interest. The value shall be interpreted as an unsigned byte with units of 0.25 dB, such that 0x00 is interpreted as -103.75 dBm, and RS shall be able to report values in the range -103.75 dBm to -40 dBm. The measurement shall be performed on the subcarriers that are assigned to the UL burst of the MS of interest.

MS UIUC

Indicates the UIUC that the RS most recently assigned to the MS.

Add a new section 6.3.2.3.AJ

Section 6.3.2.3.AJ RS-UL_MAP_RX-REP

To enable UL link metric estimation procedures for an MS, the RS and the BS shall exchange this message to indicate the particular UL burst allocation made to the MS.

Syntax	Size	Notes
RS-UL_MAP_RX- REP_Message_Format() {		
Management Message Type=TBD	8 bits	
CID	16 bits	Primary management CID of the MS
UIUC	4 bits	
OFDMA symbol offset	7 bits	
Length	4 bits	Length of the MS uplink zone
Permutation	2 bits	
PUSC UL_IDcell	7 bits	
First slot in zone	10 bits	First slot of the allocation for the MS
Length	10 bits	Length of the allocation for the MS