Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Relay Support for Distributed Scheduling and its Bandwidth Request/Allocation Mechanism**
Date Submitted	**2007-01-08**
Source(s)	Haihong Zheng, Yousuf Saifullah, Shashikant Maheshwari Nokia 6000 Connection Drive, Irving, TX Voice: +1 972 894 5000 Haihong.1.Zheng@nokia.com, Yousuf.Saifullah@nokia.com, Shashikant.Maheshwari@nokia.com Aik Chindapol Siemens Corporate Research 755 College Road East, Princeton, NJ, USA Voice: +1 609 734 3364 Fax: +1 609 734 6565 Email: aik.chindapol@siemens.com
Re:	This is in response to the call for proposal, 80216j-06_034.pdf, sent out by 802.16j TG.
Abstract	This contribution proposes distributed scheduling service and its bandwidth allocation and request mechanism for multi-hop relay system.
Purpose	Add proposed spec changes.
Notice	
Release	
Patent Policy and Procedures	

Relay Support for Distributed Scheduling and its Bandwidth Request/Allocation Mechanism

Haihong Zheng, Yousuf Saifullah and Shashikant Maheshwari

Nokia

Aik Chindapol

Siemens Corporate Research

1. INTRODUCTION

As RSs are introduced between BS and MS, modifications in the specification are required to support scheduling service, bandwidth allocation and request mechanisms. The following scheduling models could be used in 802.16j system.

- Centralized, where MR-BS make centralized control of the resource over both relay links and access links.
- Distributed, where the resource over the relay or access link is managed by the associated RS. Two modes of the distributed scheduling service can be used.
    - Distributed with MR-BS coordination on bandwidth grants, termed as Coordination mode
    - Distributed without MR-BS coordination on bandwidth grants, termed as Non-coordination mode

This contribution proposes the distributed scheduling service and its associated bandwidth allocation and request mechanism.

2. DISTRIBUTED SCHEDULING SERVICE

With distributed scheduling services, MR-BS only schedules the traffic transmitted on its direct link. Each RS generates its own MAP and schedules the traffic it received based on the QoS requirement of the service flow. RSs shall not change the CID and SFID originally assigned by the MR-BS to the service flow.

The downlink traffic is scheduled by MR-BS or RS and transmitted to its subordinate neighbor. After receiving the downlink traffic, the RS makes its own scheduling decision, generates the DL-MAP and transmits the traffic accordingly. The MR-BS or the RS should schedule the traffic considering the factors such as capacity, current load condition, and potential resource to be used for retransmission for all the remaining subordinate stations on the relay path.

The uplink traffic is scheduled and transmitted by RS upon receiving from its subordinate neighbor. The bandwidth for transmiting the uplink traffic is allocated by its superordinate neighbor. Therefore, if the RS starts to request its superordinate neighbor for bandwidth after receiving traffic from its subordinate neighbor, the delay for the uplink traffic could be significant especially if the number of RS on a relay path is large. In addition, if the bandwidth at its superordinate neighbor is not available for such allocation, the traffic needs to be buffered, which leads to further delay or potentially being dropped. Such delay may be acceptable for non-realtime traffic, but not for realtime traffic. In order to reduce the delay, the bandwidth for a RS to transmit the uplink traffic could be allocated beforehand. Two modes of distributed scheduling are proposed as following.

- Coordination mode: In this mode, the bandwidth request received from it subordinate neighbor is first processed by a RS to check resource availability and then forwarded to its superordinate neighbor. The bandwidth grant received from its superordinate neighbor triggers the bandwidth grant from a RS to its subordinate neighbor. See section **Error! Reference source not found.** for details. This mode is applicable to realtime services.

- Non-coordination mode: In this mode, the bandwidth request received from its subordinate neighbor is processed the RS by first allocating the bandwidth using the UL-MAP and then forwarding the request to it superordinate neighbor. In another word, the bandwidth request received by a RS directly triggers the bandwidth grant at the RS. See section **Error! Reference source not found.** for details. This mode is applicable to non-realtime services.

The type of scheduling services (i.e., UGS, rtPS, ertPS, nrtPS, and BE) for distributed scheduling service remains the same in 802.16j system.

3. SECURITY CONSIDERATION

Bandwidth request may come as a stand-alone bandwidth request header or piggyback request or PM bit. The piggyback request and PM bit are carried in the Grant Management subheader, which could be encrypted together with the user traffic. Therefore, in these cases, the intermediate RSs are not able to understand the request unless it has the security key to decrypt the packet. However, distributing security key over the air interface introduces a large amount of security issues and currently there is not a security model proposed to support it. In addition, decryption of every MAC PDU at each RS leads to large processing overhead and possible processing delay. Therefore, if the bandwidth request is carried in the piggyback request or PM bit, the intermediate RS should only use the coordination mode scheduling services.

4. BANDWIDTH REQUEST AND ALLOCATION MECHANISM FOR DISTRIBUTED SCHEDULING

4.1 Bandwidth Request and Allocation in Coordination Mode

4.1.1 Bandwidth Request

Bandwidth request is sent from MS to MR-BS via one or more RS on the relay path. The request may come as a stand-alone bandwidth request header or a PiggyBack Request or a contention based CDMA bandwidth request defined for WirelessMAN-OFDMA. In the first two cases, RS forwards the same request towards the MR-BS. In the last case, the RS sends a Ranging Code defined for RS bandwidth request to MR-BS (see section **Error! Reference source not found.** for details).

The bandwidth request received from it subordinate neighbor is first processed by the RS to check resource availability. If there is resource available for the request, it forwards the request to its superordinate neighbor; otherwise, it simply ignores the request. The bandwidth request is forwarded over the uplink path until it reaches the MR-BS.

4.1.2 Bandwidth Grant

Bandwidth grant is issued on hop-by-hop basis, i.e., each station including MR-BS and RSs on a relay path grants bandwidth to its subordinate neighbor station.

Upon receiving bandwidth request for a connection from a RS, the MR-BS checks resource availability and issues bandwidth grant to its subordinate neighbor RS. The bandwidth grant received from its superordinate neighbor triggers the bandwidth grant from a RS to its subordinate neighbor. Therefore, the uplink bandwidth grant is issued from a RS when the bandwidth is allocated from all its superordinate stations.

However, in the single hop system, the bandwidth grant is for the next frame. If the same mechanism is used in the multihop system, when the RS receives the uplink traffic from its subordinate neighbor, the bandwidth grant from its superordinate neighbor may already expire, as illustrated in Figure 1.

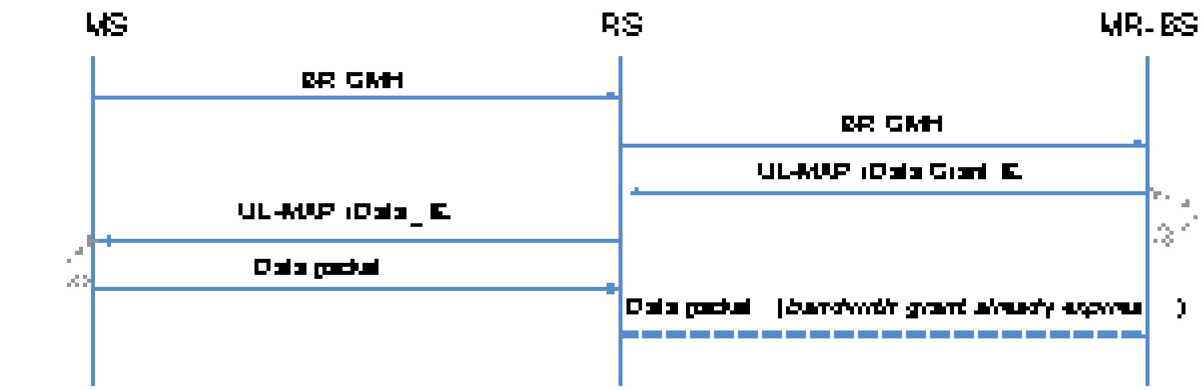

Figure 1: UL Allocation synchronization problem with relays

In order to synchronize bandwidth grants for the uplink bursts over multiple hops, the start time for the UL allocation to each RS should vary on the path so that the bandwidth grant is available when the uplink burst is relayed. RS-UL-Allocation_IE is proposed as an UL MAP IE for indicating the duration of the bandwidth grant as well as the frame offset, after which the bandwidth grant is effective. Figure 2 illustrates the proposed bandwidth request and grant mechanism.

The frame offset in the RS-UL-Allocation_IE is set by the station issuing the bandwidth grant; considering the transmission delay (e.g., based on the number of hops to the MS). This enhancement only applies to the MR-BS or a RS. No change to MS is required.

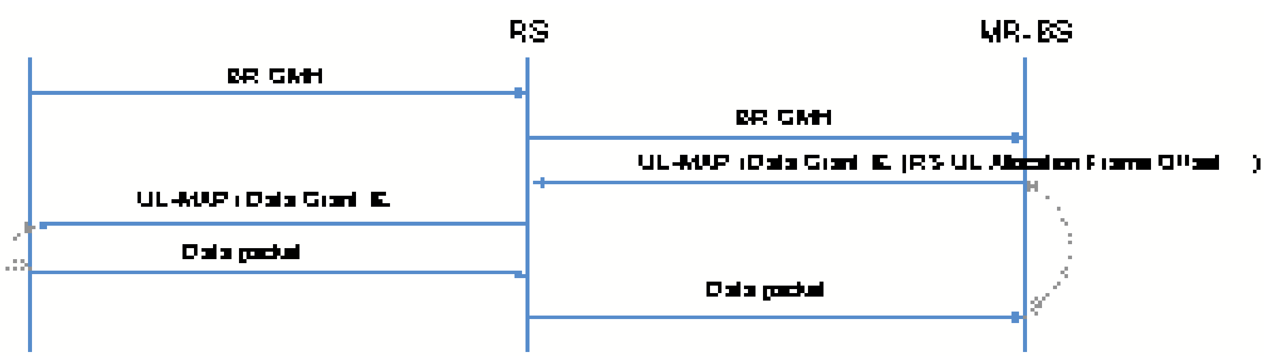

Figure 2: Example Bandwidth Request and Grant Procedure

4.1.3 Polling

The poll issued from a RS is triggered by a poll from its superordinate neighbor. Since the poll is not an explicit message, but bandwidth allocated in the UL-MAP, the bandwidth grant synchronization issue and its solution apply to polling as well (section **Error! Reference source not found.**). The MR-BS sends poll for an MS attached to a RS, by sending RS-UL-Allocation_IE to the RS. If there are multiple RSs between MR-BS and MS, then each RS uses RS-UL-Allocation_IE to indicate the poll for its subordinate neighbor RS. **Error! Reference source not found.** illustrates the polling procedure using the proposed bandwidth grant scheme.

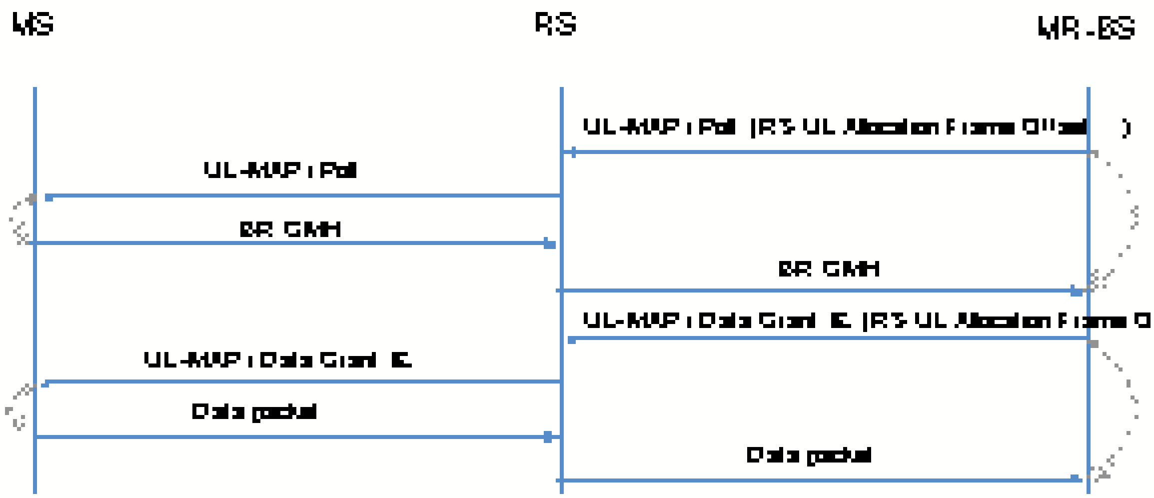

Figure 3: Example Polling and Bandwidth Request/Grant Procedure

4.1.4 Contention-based CDMA Bandwidth Request for WirelessMAN-OFDMA

Once receiving a ranging code allocated to Bandwidth Request from a MS, instead of forwarding the ranging code, RS sends a different Ranging Code defined for RS bandwidth request to MR-BS. Such special Ranging Code is allocated during RS network entry process (see contribution C80216j-06_189r1 for more details). The processing procedure of sending the bandwidth request and bandwidth grant follows the process defined in 4.1.1 and 4.1.2.

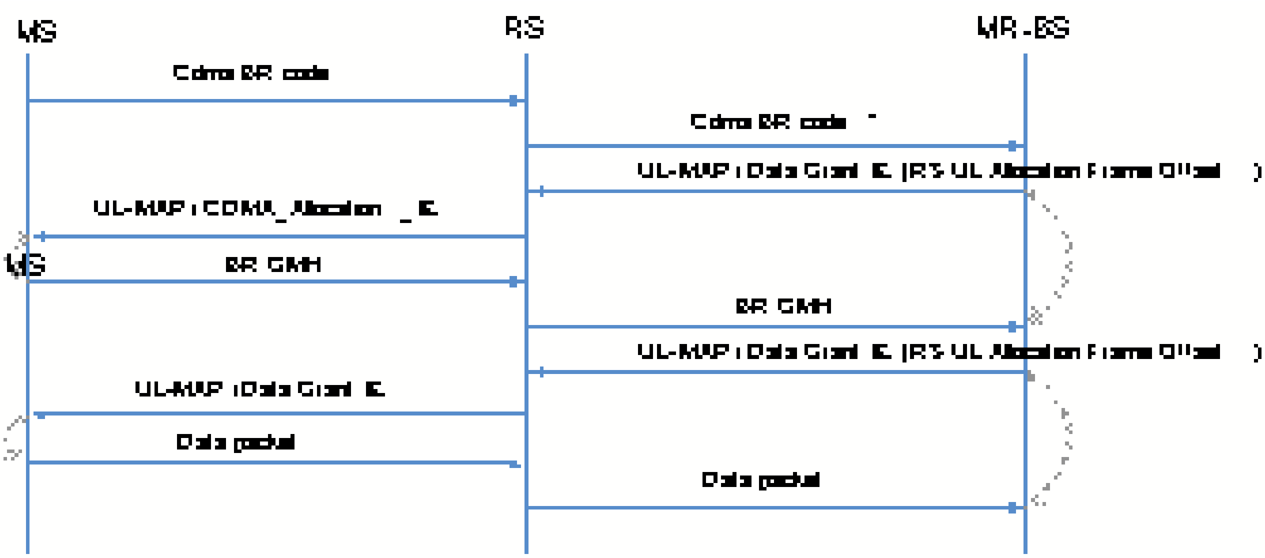

Figure 4: Example Contention-based CDMA Bandwidth Request Procedure

4.2 Bandwidth Request and Allocation in Non-coordination Mode

4.2.1 Bandwidth Request

Bandwidth request can be sent from MS to the RS to which it directly attaches, or from a RS to its superordinate neighbor. The request may come as a stand-alone bandwidth request header or a PiggyBack Request or a contention based CDMA bandwidth request defined for WirelessMAN-OFDMA.

The received bandwidth request triggers the RS to check resource availability. If there is resource available for the request, it issues the grants.

4.2.2 Bandwidth Grant

Once receiving a bandwidth request from its subordinate neighbor, the RS provides the bandwidth grant if there is enough resource to support the request. The bandwidth grant also triggers the RS to send bandwidth request to its superordinate neighbor. Such process continues until the MR-BS provides the grant.

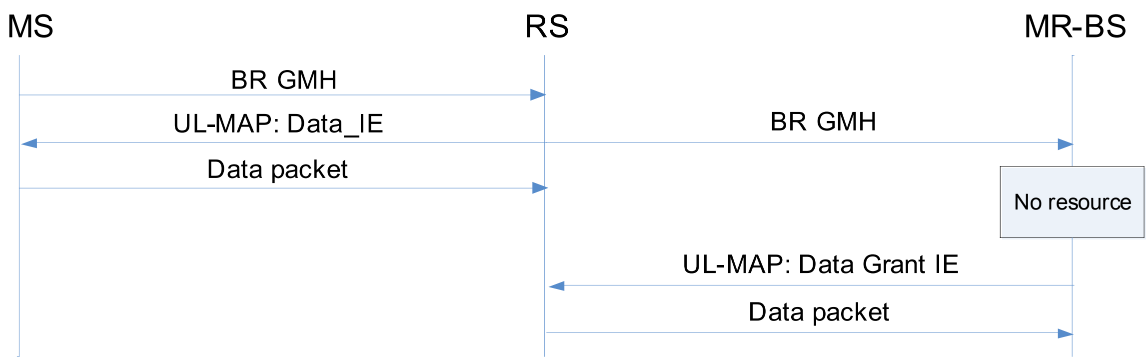

Figure 5: Example Bandwidth Request and Grant Procedure

4.2.3 Polling

Similar to the bandwidth grant, polling is issued on hop-by-hop basis, i.e., MR-BS or RS issues the poll (specified in UL-MAP) to its subordinate neighbor (e.g., RS or MS). Each RS makes decision on when to send a poll.

4.2.4 Contention-based CDMA Bandwidth Request for WirelessMAN-OFDMA

The contention-based CDMA Bandwidth Request is processed similar to that in the non-coordination mode at the cdma contention phase. The processing procedure of sending the bandwidth request header and bandwidth grant follows the process defined in 4.2.1 and 4.2.2.

5. CHANGES TO THE SPECIFICATION

Insert subclause 6.3.5.3

<u>6.3.5.3 Relay Scheduling Service</u>

<u>6.3.5.3.2 Distributed Scheduling Service</u>

With distributed scheduling services, MR-BS only schedules the traffic transmitted on its direct link. Each RS generates its own MAP and schedules the traffic it receives based on the QoS requirement of the service flow. RSs shall not change the CID and SFID originally assigned by the MR-BS to the service flow.

The downlink traffic is scheduled by MR-BS or RS and transmitted to its subordinate neighbor. After receiving the traffic, the RS makes its own scheduling decision, generates the DL-MAP and transmits the traffic accordingly.

The uplink traffic is scheduled and transmitted by RS upon receiving from its subordinate neighbor. The bandwidth to transmit the uplink traffic is allocated by its superordinate neighbor.

Depending on the sequence of sending bandwidth request and allocation by the RSs, two modes apply to the distributed scheduling service.

- Coordination mode: In this mode, the bandwidth request received from it subordinate neighbor is first processed by a RS to check resource availability and then forwarded to its superordinate neighbor. The bandwidth grant received from its superordinate neighbor triggers the bandwidth grant from a RS to its subordinate neighbor. See section 6.3.6.7.2.1 for details. This mode is applicable to realtime services or the scenario where the bandwidth request is carried in piggyback bandwidth request or PM bit.
- Non-coordination mode: In this mode, the bandwidth request received from its subordinate neighbor is processed the RS by first allocating the bandwidth using the UL-MAP and then forwarding the request to it superordinate neighbor. In another word, the bandwidth request received by a RS directly triggers the bandwidth grant at the RS. See section 6.3.6.7.2.2 for details. This mode is applicable to the non-realtime services in the scenario where the bandwidth request is carried in the bandwidth request header.

The type of scheduling services (i.e., UGS, rtPS, ertPS, nrtPS, and BE) for distributed scheduling service remains the same in 802.16j system.

Insert new subclause 6.3.6.7

6.3.6.7 Relay Bandwidth allocation and request mechanism

6.3.6.7.2 Bandwidth Allocation and Request Mechanisms for Distributed Scheduling

6.3.6.7.2.1 Bandwidth Allocation and Request Mechanisms in Coordination Mode

6.3.6.7.2.1.1 Bandwidth Request

Bandwidth request is sent from MS to MR-BS via one or more RS on the relay path. The request may come as a stand-alone bandwidth request header or a PiggyBack Request or a contention based CDMA bandwidth request defined for WirelessMAN-OFDMA. In the first two cases, RS forwards the same request to the MR-BS. In the last case, the RS sends a Ranging Code defined for RS bandwidth request to MR-BS. Such special Ranging code is allocated during RS network entry process.

The bandwidth request received from it subordinate neighbor is first processed by the RS to check resource availability. If there is resource available for the request, it forwards the request to its superordinate neighbor; otherwise, it simply ignores the request. The bandwidth request is forwarded over the uplink path until it reaches the MR-BS.

6.3.6.7.2.1.2 Bandwidth Grant

Bandwidth grant is specified in the UL-MAP and issued on hop-by-hop basis, i.e., each station including MR-BS and RSs on a relay path issues the bandwidth grant to its subordinate neighbor station. Upon receiving bandwidth request for a connection, the MR-BS checks resource availability and issues bandwidth grant to its subordinate neighbor RS. The bandwidth grant received from its superordinate neighbor triggers the bandwidth grant from a RS to its subordinate neighbor.

In order to synchronize bandwidth grants over multi hops on a relay path, each bandwidth grant to a RS is carried in an RS-UL-Allocation_IE, which includes the resource information as well as the number of frames, in which the bandwidth grant becomes effective. RS should not use RS-UL-Allocation_IE for bandwidth grants to MSs. Figure 44a illustrate the synchronization of bandwidth grants over multiple hops.

6.3.6.7.2.1.3 Polling

Similar to the bandwidth grant, the polling is issued on hop-by-hop basis, i.e., MR-BS and each RS on a relay path issues the poll to its direct subordinate neighbor. The poll issued from a RS is triggered by a poll from its superordinate neighbor. In order to synchronize the polls over multi hops on a relay path, each poll to a RS is carried in an RS-UL-Allocation_IE, which includes the resource information as well as the number of frames, in which the poll becomes effective. RS should not use RS-UL-Allocation_IE for polls to MSs.

6.3.6.7.2.1.4 Contention-based CDMA Bandwidth Requests for WirelessMAN-OFDMA

Once receiving a ranging code allocated to Bandwidth Request from a MS, instead of forwarding the ranging code, RS sends a different Ranging Code defined for RS bandwidth request to MR-BS. Such special Ranging Code is allocated during RS network entry process. Upon receiving such Ranging Code, the MR-BS issues the bandwidth grant to its subordinate neighbor RS. The bandwidth grant is carried in an RS-UL-Allocation_IE, which includes the resource information as well as the number of frames, in which the bandwidth grant becomes effective. The RS process the bandwidth grant in the same way as specified in section 6.3.6.7.2.1.1.

6.3.6.7.2.2 Bandwidth Allocation and Request Mechanisms in Non-coordination Mode

6.3.6.7.2.2.1 Bandwidth Request

Bandwidth request is sent from MS to the access RS or from RS to its superordinate neighbor including MR-BS. The request may come as a stand-alone bandwidth request header or a PiggyBack Request or a contention based CDMA bandwidth request defined for WirelessMAN-OFDMA. In the first two cases, RS forwards the same request to the MR-BS. In the last case, the RS sends a Ranging Code defined for RS bandwidth request to MR-BS. Such special Ranging code is allocated during RS network entry process. If the Piggyback Request from MS is encrypted and the access RS doesn’t have the encryption key, the non-coordination mode cannot be used.

The bandwidth request received from it subordinate neighbor is first processed by the RS to check resource availability. If there is resource available for the request, it issues the bandwidth grant, and then forwards the request to its superordinate neighbor. Such process continues until the MR-BS issues the grant.

6.3.6.7.2.2.2 Bandwidth Grant

Bandwidth grant is specified in the UL-MAP and issued on hop-by-hop basis, i.e., each station including MR-BS and RSs on a relay path issues the bandwidth grant to its subordinate neighbor station. Upon receiving bandwidth request for a connection, a RS or the MR-BS checks resource availability and issues bandwidth grant to the requesting station.

6.3.6.7.2.2.3 Polling

Similar to the bandwidth grant, the polling is issued on hop-by-hop basis, i.e., MR-BS and each RS on a relay path issues the poll to its direct subordinate neighbor. Each RS makes its own decision on when to issue the poll.

6.3.6.7.2.2.4 Contention-based CDMA Bandwidth Requests for WirelessMAN-OFDMA

The contention-based CDMA Bandwidth Request is processed similar to that in the non-coordination mode at the cdma contention phase. The processing procedure of sending the bandwidth request header and bandwidth grant follows the process defined in 6.3.6.7.2.2.1 and 6.3.6.7.2.2.2.

Update Table 290c as indicated in the following Table.

Table 290c – Extended-2 UIUC Code Assignment for UIUC=11

Extended UIUC (Hexadecimal)	Usage
09 – 0D	Reserved
09	RS UL Allocation IE
0A	RS CDMA Allocation IE
0B … 0D	Reserved

Insert new subclause 8.4.5.4.29

8.4.5.4.29 RS UL Allocation IE

This IE specifies the uplink allocation for the receiving RS used for relaying bursts in the hybrid scheduling, and is not applicable to MS/SS.

Table T1 – RS UL Allocation IE format

Syntax	Size	Notes
RS UL Allocation IE() {		
Extended-2 UIUC	8 bits	RS_UL_Allocation_IE() = 0x09
Length	8 bits	
RS UL Allocation Frame Offset	8 bits	In terms of number of frames
Duration	8 bits	In OFDMA slots (see 8.4.3.1)
}		

RS UL Allocation Frame Offset
Indicates the number of frame, starting from the next frame, in which the bandwidth grant for RS is valid.

Duration
Indicates the duration of allocation, in units of OFDMA slots

6. REFERENCE

[1] C80216j-07_039.pdf, Resource request for bandwidth, Shashikant Maheshwari et. al., Nokia, Fujitsu and Intel
[2] C80216j-07_031.pdf, Path Management in multi-hop Relay Systems, Haihong Zheng et. al., Nokia and Huawei