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

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Re: This is in response to the call for proposal, 80216j-07_07r2.pdf, sent out by 802.16j TG.

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Abstract This contribution proposes distributed scheduling service and its bandwidth allocation and request mechanism for multi-hop relay system.

Purpose Add proposed spec changes.

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

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.

The distributed scheduling mechanism, especially the associated bandwidth request and allocation mechanism depends on the security model to be adopted and used in multi hop relay system. In the centralized security model, the security keys are kept by the MS and MR-BS and there is no need to distribute the MS associated keys to the intermediate RS. In the distributed security model, RSs need the MS security keys to decrypt the user traffic and/or to perform message authentication, and therefore it requires the MS security key to be distributed to the intermediate RS.

In the distributed scheduling mechanism proposed in [2], the access RS allocates resources directly upon receiving the bandwidth request from a MS. Such scheme requires the distributed security model. The reason is as following. As defined in .16, there are three types of bandwidth requests - Bandwidth Request Header, Piggybacked Bandwidth Request, and PM bit. The Bandwidth Request header contains the aggregate bandwidth or incremental bandwidth, while the Piggybacked Bandwidth Request only contains incremental bandwidth. Therefore, the RS needs to understand all three types of bandwidth request in order to properly process the bandwidth request from the MS. However, the Piggybacked BW request and the PM bit are carried in the Grant Management subheader, which could be encrypted by the MS together with the user data traffic. Therefore, without knowing the TEK of the MS, the RS won't be able to decrypt the packet and understand the bandwidth requested in the Piggybacked BW request or PM bit. Therefore, such distributed scheduling mechanism requires a distributed security model, where the security keys for MS need to be distributed to the RS. However, the distributed security model is not available at the current moment.

This contribution proposes the distributed scheduling service and its associated bandwidth allocation and request mechanism, which works with a simple centralized security model, where the security keys for MS stays in the MR-BS.

2. DISTRIBUTED SCHEDULING SERVICE AND BANDWITH REQUEST AND ALLOCATION MECHANISM

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 transmitting the uplink traffic is allocated by its superordinate neighbor.

2.1 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 2.4 for details).

The bandwidth request received from its 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.

2.2 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.

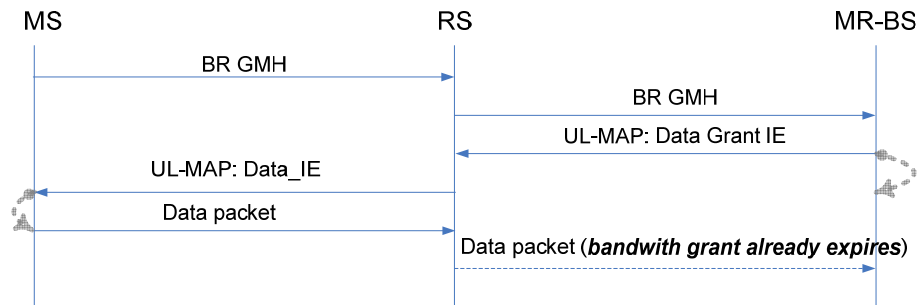


Figure 1: UL Allocation synchronization problem with relays

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.

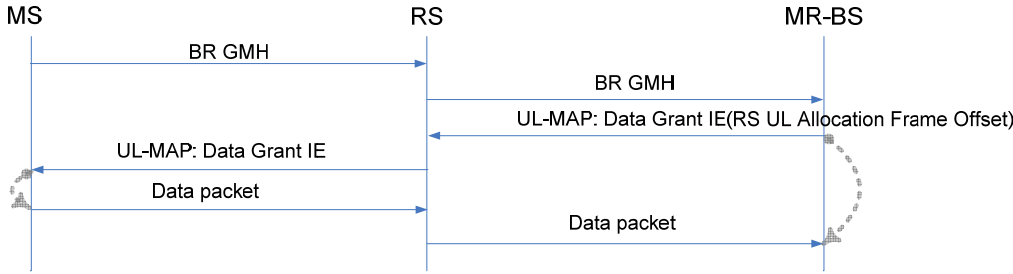


Figure 2: Example Bandwidth Request and Grant Procedure

2.3 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 2.2). 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. Figure 3 illustrates the polling procedure using the proposed bandwidth grant scheme.

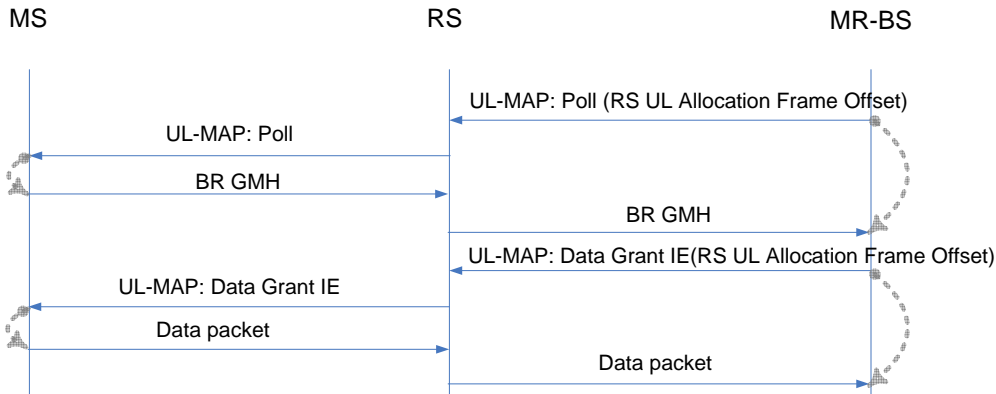


Figure 3: Example Polling and Bandwidth Request/Grant Procedure

2.4 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 2.1 and 2.2.

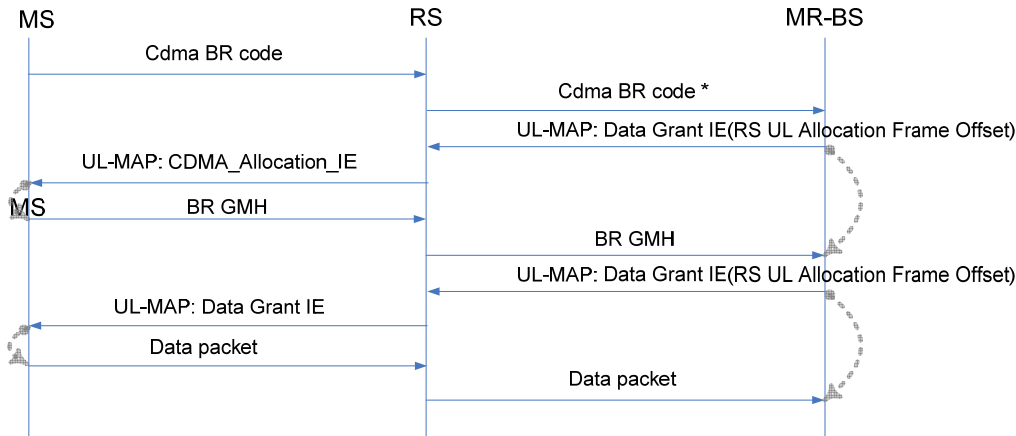


Figure 4: Example Contention-based CDMA Bandwidth Request Procedure

3. CHANGES TO THE SPECIFICATION

Insert new subclause 6.3.6.7.2

6.3.6.7.2 Bandwidth Request and Allocation Mechanisms with Centralized Security

With centralized security model, where keys for the MS are kept at the MR-BS without being distributed to the RS, the bandwidth request is not processed by the intermediate RS, but simply forwarded towards the MR-BS.

6.3.6.7.2.1 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 its 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.

6.3.6.7.2.2 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 S1 illustrates the bandwidth request and grant procedure.

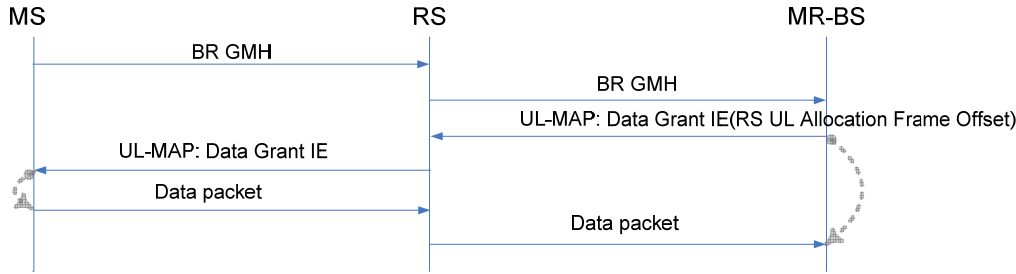


Figure S1: Bandwidth Request and Grant Procedure

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In the case that the UIUC given in the RS-UL-Allocation IE is not applicable due to change of radio condition, the MR-BS may send a regular Data Grant IE, which will overwrite the grant given in the pervious RL-UL-Allocation IE for the same frame. When a RS receives grants in both RS-UL-Allocation IE and a regular Data Grant IE for the same MS CID for the same frame, it ignores the grants in the RS-UL-Allocation IE and uses the grants in the regular Data Grant IE instead.

6.3.6.7.2.3 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. 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.

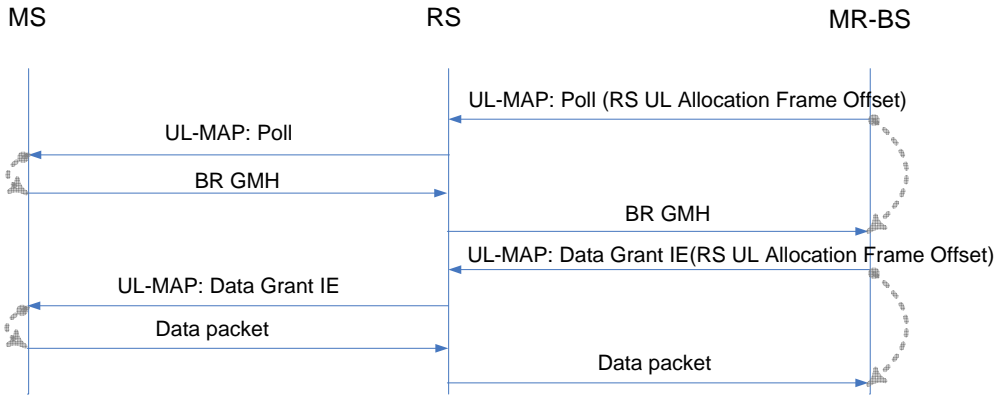


Figure S2: Polling and Subsequent Bandwidth Grant Procedure

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6.3.6.7.2.4 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 6.3.6.7.2.2.

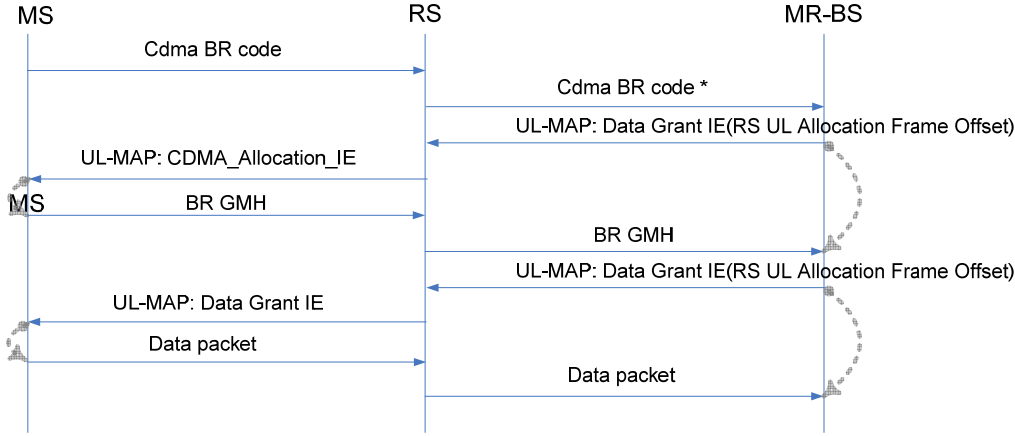


Figure S3: CDMA Bandwidth Request and Subsequent Bandwidth Grant procedure

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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 ... 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 distributed scheduling, and is not applicable to MS/SS. The station (e.g. MR-BS or RS) providing the grants may aggregate multiple allocations to different connections in a single RS-UL-Allocation IE.

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	

<u>for(i=0; i< number of allocation; i++) {</u>		<u>The number of allocation can be derived based on the Length field</u>
<u> CID</u>	<u>16 bits</u>	<u>The CID for the MS</u>
<u> RS UL Allocation Frame Offset</u>	<u>8 bits</u>	<u>In terms of number of frames</u>
<u> Duration</u>	<u>8 bits</u>	<u>In OFDMA slots (see 8.4.3.1)</u>
<u>}</u>		
<u> UIUC</u>	<u>4 bits</u>	
<u> Reserved</u>	<u>4 bits</u>	
<u>}</u>		

CID

Indicates the CID for the MS, for which the allocation will be used

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

UIUC

Indicates the UIUC used for the transmission over the relay link

4. REFERENCE

[1] C80216j-07_039.pdf, Resource request for bandwidth, Shashikant Maheshwari et. al., Nokia, Fujitsu and Intel

[2] C802.16j-06_026r2.pdf, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Multihop Relay Specification