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Re:	This contribution is a response to " IEEE 802.16j-06/034 Call for Technical Proposals regarding IEEE Project 802.16j" (2006-12-12) .
Abstract	This contribution describes the proposed distributed scheduling in 802.16j system.
Purpose	This document is provided in response for Call for Technical Proposals regarding IEEE Project 802.16j .
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Distributed Scheduling In 802.16j System

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1. Introduction

This document focuses on distributed scheduling for 802.16j system, analyzing two types distributed scheduling: fully distributed scheduling and distributed scheduling with cooperation. Finally, it proposes the standard text for distributed scheduling in 802.16j system.

Two types of distributed scheduling can be used in 802.16j system:

- ✧ Fully distributed scheduling: MR-BS and RSs schedule the uplink bandwidth completely independently.
- ✧ Distributed scheduling with cooperation: MR-BS cooperates with RSs to optimize the traffic transfer.

Using fully distributed scheduling, bandwidth request/allocation in each link is completely independently. That is: in each link, the bandwidth is allocated by each link's super ordinate node, not by MR-BS. At the same time, when to originate bandwidth request/grant and pool is only based on the local link information, such as QoS of the service flow, local link resource, not on other links' information, such as path information and other links' time delay. So bandwidth request/allocation and pooling in one link can't lead to any other link's bandwidth request/allocation and polling. See section 2.1 for more details.

Obviously, fully distributed scheduling results in transferring the traffic on a multi-hop link with long time delay. Figure 1 shows one of the examples of the fully distributed scheduling in 802.16j system.

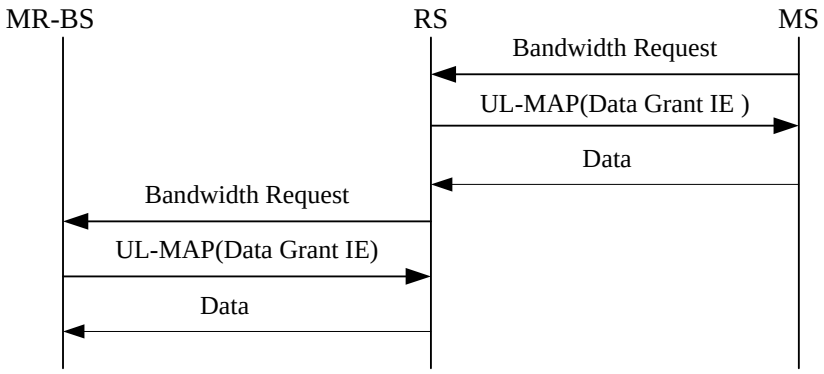

Figure 1 An example of the fully distributed scheduling

Using distributed scheduling with cooperation, each link's bandwidth is scheduled by each link's super ordinate node. However, the MR-BS and RSs originate bandwidth request/grant and pool based on both local link information and other links' information. They cooperate to optimize the traffic transfer, for example, shorten the time delay. See section 2.2 for more details.

For example: When the traffic reaches a RS, this RS has requested the bandwidth for the traffic in advance. As an optimal case, the bandwidth grant for the traffic should be issued at the same frame when the traffic arriving at the RS according to the 802.16e standard. Then at the next frame, the traffic can be delayed to the RS's super ordinate node. Figure 2 is an example of distributed scheduling with cooperation.

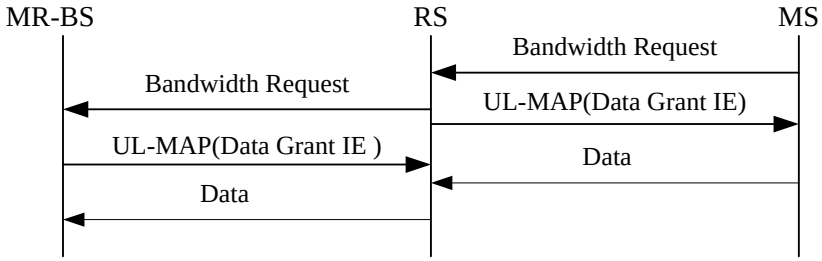

Figure 2 An example of distributed scheduling with cooperation

2. Proposed distributed scheduling in 802.16j

2.1 Fully distributed scheduling

2.1.1 Bandwidth request

If the bandwidth request isn't incurred by the pooling, when the traffic reaches a RS, the RS will check whether its uplink bandwidth at its super ordinate is enough or not. If no or not having enough bandwidth for the traffic, the RS will buffer the traffic and request the bandwidth from its super ordinate node. When the RS gets the enough uplink bandwidth, it will relay the traffic.

A Request may come as a stand-alone bandwidth request header or it may come as a PiggyBack. The capability of Piggyback Request is optional.

2.1.2 Bandwidth Grant

If the 802.16j system grants the unsolicited bandwidth to the MS, when to grant the bandwidth is decided by the super ordinate node based on the local link information, such as QoS of service flow and local link resource, not on other links' information.

2.1.3 Polling

If the 802.16j system pools the MS without PM bit set in the Grant Management Message, when to poll the subordinate node is decided by the super ordinate node based on the local link information, such as QoS of service flow and local link resource, not on other links' information.

Fully distributed scheduling can be applied to nrtPS and BE services, which aren't real-time service.

2.2 Distributed scheduling with cooperation

2.2.1 Bandwidth request

For an uplink service flow, bandwidth request is sent from the MS firstly. A Request may come as a stand-alone bandwidth request header or it may come as a PiggyBack. The capability of Piggyback Request is optional.

If the request comes as a response to the polling from the super ordinate node, according to the Allocation Start Time for the uplink bandwidth, the request is sent at the next frame after the polling is received.

Otherwise, the request is sent unsolicited by the MS which has some data to send. When the bandwidth request arrives at a link's super ordinate node, the super ordinate node requests the bandwidth from its own super ordinate node at the next frame or after several frames, based on the QoS of the service flow, link resource, path information and time delay information. Then, the bandwidth request is sent hop by hop until it arrives at the MR-BS. Figure 2 illustrates the bandwidth request/grants procedure.

2.2.2 Bandwidth Grant

If the grant comes as a response to the bandwidth request from the subordinate node, the bandwidth grant for a service flow will be issued from the MS's access station firstly. Following the bandwidth requests, the bandwidth grant is issued in the same order as the bandwidth request order. At last the bandwidth grant is issued from the MR-BS. Figure 2 illustrates the grants mechanism when the grant is incurred by the bandwidth request.

If the 802.16j system grants unsolicited bandwidth to the MS, some measures should be taken to assure the grant is issued from the MS's access station firstly, in order to accelerate the traffic transfer and to avoid the bandwidth grants ineffective, for the bandwidth grant in 802.16e system is for the next frame. So a new UL_MAP IE, RS SCH IE, is generated by the MR-BS firstly and sent to its subordinate node, based on the local and other links' information (QoS of service flow, local link resource, path information, other links' time delay). RS SCH IE includes bandwidth information, how much bandwidth will be granted, and the number of frames, when the grant will be issued. When the subordinate node receives the RS SCH IE, it will generate a new RS SCH IE for its own subordinate node, according to the received RS SCH IE, the local and other links' information. The RS SCH IE will be sent to all the RSs in the relay path and the MS's access station should not send this IE to the MS, so there is no any change for the MS.

Figure 3 illustrates the grants mechanism when the grant is issued without bandwidth request.

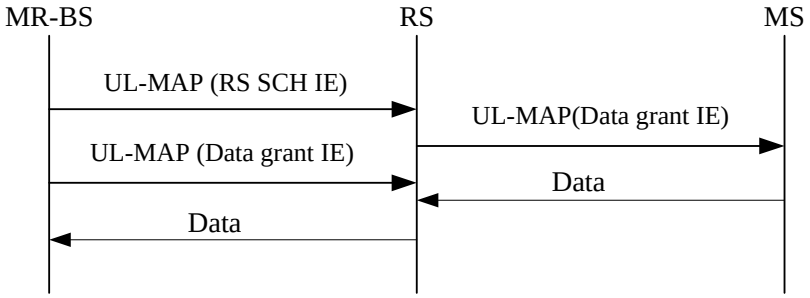

Figure 3 An example of proposed grant procedure

2.2.3 Polling

Similar with the bandwidth grant, the polling in the 802.16j system is not an explicit message, but a bandwidth allocation in the UL_MAP. The polling can be issued unsolicited by each link's super ordinate node or as a response to the Grant Management Message with PM bit set, which is set by a MS with currently active UGS connection when the MS needs to be polled to request bandwidth for non-UGS connection.

From the point view of scheduling, the relationship between pooling with the PM bit in the Grant Management Message is the same as the relationship between bandwidth grant with the bandwidth request. Accordingly, the RS SCH IE can be applied to accelerate data transfer in the condition where each super ordinate node shall poll its subordinate node.

Figure 4 illustrates the polling mechanism in the 802.16j system when the polling is issued by the super ordinate node. Figure 5 illustrates the polling mechanism in the 802.16j system when the polling is the response to the PM bit.

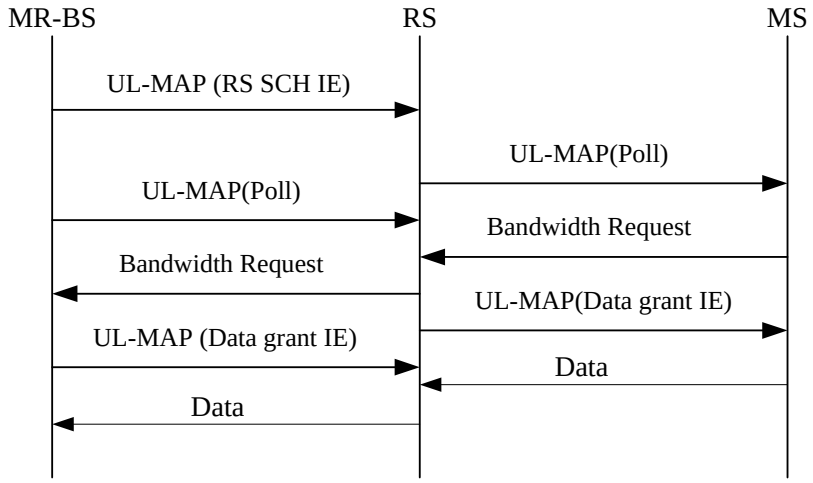

Figure 4 An example of proposed polling and bandwidth request/grant procedure

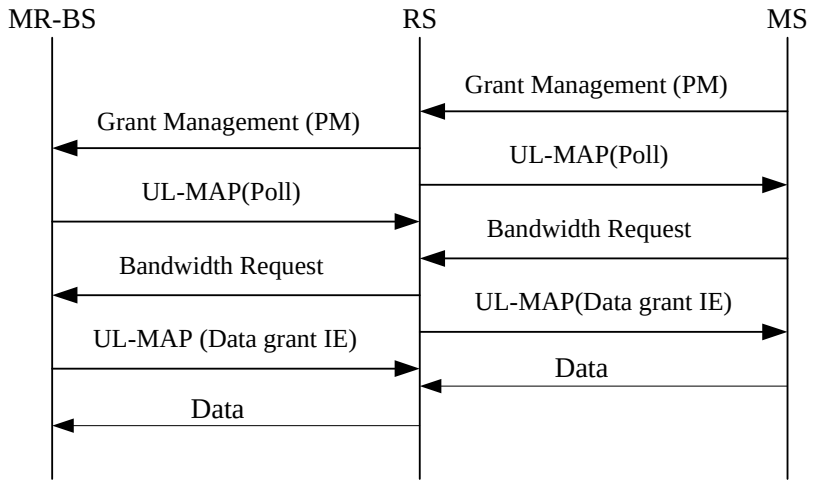

Figure 5 An example of proposed PM, polling and bandwidth request/grant procedure

3. Proposed text

6.3.5 Scheduling services

6.3.5.2.1 UGS

Insert the follow at the end of this clause:

In the 802.16j system, to meet a UGS service flow's need, the MMR- BS and RSs along the link shall grant fixed size bandwidth to its subordinate node on the real-time periodic basis.

The RS SCH IE and the bandwidth grant mechanism of distributed scheduling with cooperation may be used to accelerate the data transfer. The RS SCH IE sequence, generated by the MR-BS and the intermediate RSs, is used only once before the periodic granting is issued. When the MS needs to be polled to request bandwidth for non-UGS connection, the pooling mechanism of distributed scheduling with cooperation may be used to accelerate the Grant Management transfer.

6.3.5.2.2 rtPS

Insert the follow at the end of this clause:

In the 802.16j system, to meet an rtPS service flow's need, the MMR- BS and RSs along the link shall poll its subordinate node on the real-time periodic basis.

The RS SCH IE and the pooling mechanism of distributed scheduling with cooperation may be used to accelerate the bandwidth request transfer. The RS SCH IE sequence, generated by the MR-BS and the intermediate RSs, is only used once before the periodic pooling is issued.

6.3.5.2.2.1 Extended rtPS

Insert the follow at the end of this clause:

In the 802.16j system, to meet an Extended rtPS service's need, the MMR- BS and RSs along the link shall grant dynamic size bandwidth to its subordinate node on the real-time periodic basis.

Before the periodic granting is issued, the MR-BS may originate the RS SCH IE sequence. The MS may request changing the size of the UL allocation by either using an extended piggyback request field of the Grant Management subheader or using BR field of the MAC signaling headers or sending a codeword over CQICH. The MR-BS and the intermediate RSs shall not change the size of UL allocations until receiving another bandwidth change request from the MS.

In case that no unicast bandwidth request opportunities are available, the MS may use contention request opportunities for that connection, or send the CQICH codeword to inform the MR-BS of its having the data to send. If the MR-BS receives the CQICH codeword, the MR-BS may originate the RS SCH IE sequence again and then start allocating the UL bandwidth.

6.3.5.2.3 nrtPS

Insert the follow at the end of this clause:

In the 802.16j system, nrtPS shall offers unicast polls on a regular basic. The MR-BS and the intermediate RSs may poll the subordinate node independently or harmonized by the RS SCH IE.

6.3.5.2.4 BE

Insert the follow at the end of this clause:

In the 802.16j system, in order for BE service to work correctly, the MS may use contention request opportunities as well as be pooled and granted bandwidth.

Insert new sub clause 6.3.6.7

6.3.6.7 Relay support for Scheduling

6.3.6.7.1 Distributed Scheduling

6.3.6.7.1.1 Fully Distributed Scheduling

6.3.6.7.1.1.1 Request

If the bandwidth request is generated unsolicited, when the traffic reaches a RS, the RS will check whether its uplink bandwidth at its super ordinate is enough or not. If no or not having enough bandwidth for the traffic, the RS will buffer the traffic and request the bandwidth from its super ordinate node. When the RS gets the enough uplink bandwidth, it will relay the traffic.

A Request may come as a stand-alone bandwidth request header or it may come as a PiggyBack. The capability of Piggyback Request is optional.

6.3.6.7.1.1.2 Grant

If the 802.16j system grants the unsolicited bandwidth to the MS, when to grant the bandwidth is decided by the super ordinate node based on the local link information, such as QoS of service flow and local link resource, not on other links' information.

6.3.6.7.1.1.3 Polling

If the 802.16j system pools the MS without PM bit set in the Grant Management Message, when to poll the subordinate node is decided by the super ordinate node based on the local link information, such as QoS of service flow and local link resource, not on other links' information.

6.3.6.7.1.2 Distributed Scheduling with Cooperation

6.3.6.7.1.2.1 Request

For an uplink service flow, bandwidth request is sent from the MS firstly. A Request may come as a stand-alone bandwidth request header or it may come as a PiggyBack. The capability of Piggyback Request is optional.

If the request comes as the response to the polling from the super ordinate node, the request is sent at the next frame after the polling is received, based on the 802.16e standard. Otherwise, the request is generate unsolicited by the MS which has data to send. When the bandwidth request is received by a RS, the RS requests the bandwidth from its own super ordinate node at the next frame or after several frames, based on the local link and other links information. At last the bandwidth arrives at the MR-BS after being sent hop by hop.

6.3.6.7.1.2.2 Grant

If the grant comes as the response to the bandwidth request from the subordinate node, the bandwidth grant is issued in the same order as the bandwidth request order.

If the 802.16j system grants the unsolicited bandwidth to the MS, the RS SCH IE is generated by the MR-BS firstly and sent to its subordinate node, based on the local and other links' information (QoS of service flow, local link resource, path information, other links' time delay). The RS SCH IE includes bandwidth information, how much bandwidth will be granted, and the number of frames, when the grant will be issued. When the subordinate node receives the RS SCH IE, it will create a new RS SCH IE for its own subordinate node, according to the received RS SCH IE, the local and other links' information. The RS SCH IE will be sent to all the RSs in a relay path and the MS's access station should not send this IE to the MS, so there is no any change for the MS.

6.3.6.7.1.2.3 Polling

Similar with the bandwidth grant, the polling in the 16j system is not an explicit message, but a bandwidth allocation in the UL_MAP. The polling can be issued by each link's super ordinate node or the response to the PM bit in the Grant Management Message, which is set by a MS with currently active UGS connection when the MS needs to be polled to request bandwidth for non-UGS connection.

From the point view of scheduling, the relationship between individual pooling with the PM bit in the Grant Management Message is the same as the relationship between bandwidth grant with the bandwidth request. Accordingly, the RS SCH IE can be applied in the condition where the pooling is issued unsolicited by each link's super ordinate node.

Update Table 290c as indicated in the following Table

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

Extended UIUC(Hexadecimal)	Usage
<TBD>	RS SCH IE
<TBD>	Reserved

Insert new sub clause 8.4.5.4.29:

8.4.5.4.29 RS SCH IE

This IE specifies when to allocate the uplink bandwidth and how much bandwidth to be allocated to the receiving RS, not for the MS.

Table T1-RS SCH IE format

Syntax	Size	Notes
RS SCH IE () {	-	-
Extended-2 UIUC	8bit	RS SCH IE()=<TBD>
Length	8bit	
RS UL Allocation Frame offset	8bit	In terms of number of frames
Duration	8bit	In OFDMA slots (see 8.4.3.1)

}		

RS UL Allocation Frame offset

Indicates the number of frames, starting from the next frame, in which the bandwidth grant for the RS is issued.

Duration

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

References

[1] IEEE 802.16mmr-06/002r1, “Draft P802.16j PAR and Five Criteria: Mobile Multihop Reply"
[2] IEEE 802.16j-06/016r1, “Proposed Technical Requirements Guideline for IEEE 802.16 Relay TG"
[3] IEEE 802.16j-06/017r2, “Table of Contents of Task Group Working Document"