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| Abstract | This contribution proposes a practical design for the synchronous multicast and broadcast service (MBS) transmission to achieve macro diversity in the MR networks. |
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| Purpose | To propose design and text for MBS transmission synchronization in the MR networks. |
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# Synchronous MBS Transmission for Macro Diversity in MR Networks

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## Introduction

This contribution proposes a practical design for the synchronous multicast and broadcast service (MBS) transmission to achieve macro diversity in the WiMAX MR networks.

All the related RS(s) defined in [1] are expected to be synchronized to achieve the macro diversity in the MBS transmission. Previous work in [2] reveals MBS transmission synchronization may be achieved by previously transmitting data on the relay link to all the RS(s) while informing the RS(s) how long they should wait. The waiting time is the difference between the delay of the longest relay path from MR-BS to any Access RS in the MR-cell and the delay from MR-BS to the specific Access RS with the transit delay through any RS being pre-determined and fixed by the "RS Downlink Processing Delay" reported by the RS to the MR-BS during RS network entry.~~maximum of the all the RSs' processing delays~~. The processing delay is reported to MR-BS via SBC-REQ. However, there are several issues regarding this synchronization method:

> The current solution enforces a strict time for forwarding at each intermediate RS (based on the DR reported by the RS). It unnecessarily constrains the flexibility of scheduling at the intermediate RSs and can cause a decrease in the MR-cell's capacity to handle other delay-constrained traffic when compared to the case if intermediate RSs were allowed to forward anytime before their MBS data forwarding deadlines. To allow MBS data synchronization, the basic requirement is only that all RS's within the MR-cell receive the MBS data to be sent over the access link in time for the access RSs to transmit the MBS data successfully in the same (assigned) frame.
> The current solution assumes that all types of MBS traffic being relayed should be treated equally.
> There is currently no mechanism defined to help the MR-BS to identify situations when the transit delay allowances at intermediate RSs needs to be adjusted or should be adjusted to improve relaying performance.
> ~~Processing delay is the only factor used in determining the total delay over the relay path, other delays are not considered, such as transmission delay (propagation delay, network delay, etc) and queuing delay.~~
> ~~The total delay at each RS can be impacted by many factors, such as loading, channel condition of the RS, etc. Using the current method alone as defined in [2], a RS needs to report a "maximum" delay possible in SBC-REQ to ensure on-time MBS data delivery. However, using a "maximum" delay causes unnecessary latency in MBS transmission and over-engineering of the system (such as the size of buffer).~~
> As defined in [2], when a RS enters or exits the network (or due to other change at RS), the wait time can change and the MR-BS sends unsolicited SBC-RSP to all RS with the modified wait time. Since there is no acknowledgment of SBC-RSP message, MR-BS has no information on whether any RS has received the SBC-RSP message and when the wait time will be changed at the RS. This can cause synchronization problem that can not be corrected until next wait time change.

~~To solve the issues as stated above, An~~an ~~enhancement~~ alternative solution is proposed ~~to the current standard is necessary =~~to provide~~ensure~~ the synchronized delivery of MBS data in a MBS zone. The proposed solution supports MBS data synchronization by directing all RSs to transmit MBS data at a specific frame over the access link. The delivery of MBS data to each RS is ensured by using a delay-constrained QoS definition for each relaying connection (multicast or unicast) along the relay paths instead

of a fixed transmission time at each intermediate RS. The QoS approach is consistent with mechanisms already provided by 802.16e.  In addition, modification to current baseline is included to address some of the issues listed above (such as unacknowledged SBC-RSP)

In addition, the proposed text change makes a modification on the messages used to carry RS delay information and Waiting Time. It is more appropriate to use REG-REQ/RSP messages since SBC-REQ/RSP should only contain the minimum set of parameters that allows the RS to establish communication with MR-BS prior to authentication. Other negotiated parameters related to transport connections should be carried in REG-REQ/RSP messages which are protected by HMAC/CMAC.

## Proposed Solution

In this contribution, an adaptive method is introduced to provide synchronized transmission of MBS data in a MBS zone.  The following section provides a detailed description of this method.

As defined in IEEE802.16j-06/026r3[3]2, each RS still reports its delay in SBCS-REQ message to MR-BS. MR-BS determines cumulative delay based on information received from RS and scheduling information such as the availability of relay zone. When MBS data is scheduled, the transmission time of the MBS data on the access links is determined by a centralized MBS scheduler that is outside the scope of this standard, but the maximum transit delays through all RSs in the paths to all access RSs serving MSs receiving the MBS data is are determined based on cumulative delay calculated by the MR-BS controlling the MR-cells. Therefore, the MR-BS is responsible for achieving successful delivery of the MBS data to all required access RSs within its MR-cell by the appropriate configuration of delay-constrained QoS along all required relay paths so that all access RSs will receive the MBS data before the required transmission time on the access links. The synchronization among multiple MR-BSs is outside the scope of this standard.

To synchronize data transmission for all RSs and MR-BSs in a MBS zone, the MR-BS is required to pre-transmit MBS data to each RS involved in MBS service. When pre-transmitting MBS MAC PDUdata to each RS, MR-BS attaches a frame number to the relay MAC PDU which contains MBS data block to be transmitted at a frame over access link. This frame number indicates the target transmission frame of the MBS dataMAC PDU. RS is required to transmit the MBS MAC PDUdata block at the target transmission frame to MSs over the access link. In addition, the MBS data block is relayed by each intermediate RS to its subordinated RSs in a timely manner to allow synchronized transmission at access link. The relaying of MBS data block is constrained by QoS parameters (such as Maximum latency, etc) for the MBS service flow at each RS. The initial initial QoS parameters for relaying MBS data block at each intermediate RS are determined by MR-BS during MBS connection set up and are sent to each RS through DSA/DSC messaging.

If a RS receives a relay MBS MAC PDU after its target transmission frame or a RS is not able to process the MAC PDU at its transmission time, the RS should ignore the MBS MAC PDU and send a NACK indication Access Link Transmission Status feedback to MR-BS. Included in the NACK indicationfeedback, the RS should inform MR-BS the number of addition frames that MR-BS should pre-transmit the MAC PDU to meet the target transmission time.  In addition, the RS may also optionally send a NACK indicationAccess LinkTransmission Status feedback when a MBS MAC PDU arrives too early at the RS earlier than Early Arrival Report Threshold. The Early Arrival Report Threshold can be configured to RS through REG-RSP message.

When MR-BS receives feedbacks from one or more NACKsRSs, it should re-adjust the pre-transmission time with respect to the target transmission time to ensure all RS successfully transmits MBS data synchronously.

Similarly, when a RS enters or exits the network, MR-BS should re-adjust the pre-transmission time based on RS reporting ~~in SBC-REQ message~~ or the processing of Access Link Transmission ~~NACKs~~ feedbacks received that may be triggered by the RS entry or exit event..

Figure 1 shows an example message for this method. The MBS scheduler shown in Figure 1 is for illustration purpose only. Its functionality and physical location is outside the scope of this standard and not discussed in this contribution.
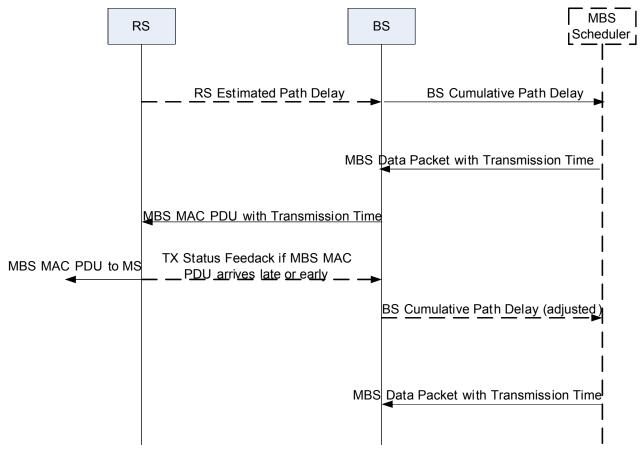


Figure 1 MBS Data Synchronization

Using this method, the MR-BS can adapt to the changes of delay at each RS in a timely manner. When the cumulative delay changes, there is no need to inform each RS of the change. Instead, the RS only needs to transmit the MAC PDU based on the target transmission time specified.

It is proposed that the support of this method and the method currently specified in the baseline document be optional implementation selections for both MR-BS and RS, meaning that to be standards-compliant, an implementation need only provide support for one of the two methods.

## Specified Text Changes
*[Insert new section 6.3.2.2.8 in 6.3.2.2]*

### 6.3.2.2.8 Relay MAC Subheader

Relay MAC Subheaders shall only be included in Relay MAC PDU with Relay MAC PDU header.

### 6.3.2.2.8.1 MBS Subheader

MBS subheader is a per-PDU subheader and shall be included in all MAC PDUs for a MBS transport connections if Multi-BS MBS service is specified for the connection. MBS subheader shall be inserted into MAC PDU immediately following Relay MAC PDU header.

MBS subheader is shown in Table xxx:

| Syntax | Size | Notes |
|---|---|---|
| MBS Subheader{ | | |
| Frame Number | 16bits | Indicates the frame which RS shall transmit the MAC PDU to MS |
| } | | |

Table XXX   MBS Subheader

*[Modify section 6.3.2.1.2.2.1, Table7i, insert a new Feedback Type]*

### 6.3.2.1.2.2.1 Feedback header

| Feedback Type (binary) | Feedback Contents | Description |
|---|---|---|
| 1110 | Early/Late Indication (1bit) Arrival Delta (8 bits) CID (16bits) | This feedback header is sent by RS to MR-BS to provide NACK access link transmission status for MBS data. The feedback is used when MR-BS provides a target transmission time of the MAC PDU and the RS detect any abnormality in transmitting the MAC PDU. The RS may report missed transmission due to late arrival of a MAC PDU or abnormal early arrival of a MAC PDU in respect to transmission time. <br><br>Early/Late Indication: <br>0: Early Indication <br>1: Late Indication <br><br>Arrival Delta: <br>Number of frames RS received frames early or late based on Early/Late Indication. <br>For Late indication, this value is the difference in frame number between the target transmission time and frame in which the MAC PDU arrives at the RS. <br>For Early indication, this value is the difference between the transit delay of the MAC PDU through the RS and the early detection threshold as set by the "Relay |

| | | Data Early Arrival Report Threshold " TLV in the REG-RSP.<br><br>CID:<br>CID of transport~~MBS~~ connection between RS and MR-BS |
|---|---|---|
| ~~1110~~ 1111 | Reserved for future use | - |

*[Modify text in section 6.3.2.3.7:]*

**6.3.2.3.7 Registration request (REG-REQ) message**

When an RS enters the network, the REG-REQ may contain the following TLVs:

RS frame offset(11.7.27)
MBS Data Synchronization Mode Support (11.7.28)
RS Downlink Processing Delay (11.7.29)

*[Modify text in section 6.3.2.3.8:]*

**6.3.2.3.8 Registration Response (REG-RSP) message**

In response to REG-REQ from an RS, the REG-RSP may contain the following TLVs::

RS frame offset(11.7.27)
MBS Data Synchronization Mode Support(11.7.28)
RS Waiting time for MBS (11.7.30)
Relay Data Early Arrival Report Threshold (11.7.31)

*[Modify text in 6.3.23.3:]*

**6.3.23.3 MBS macro diversity Support in MR network**

For MR networks, MBS transmission within an MBS zone shall be synchronized. In Multi-MR-BS-MBS case, MR-BSs should be synchronized in network level as described in section 6.3.23.2.

~~If there is only one RS connecting with the MR-BS, that~~ To facilitate MBS transmission synchronization, RS shall report its processing delay (in unit~~s~~ of ~~a~~ frame), DR, to the MR-BS as a capability parameter in the ~~SBC-~~ REG-REQ message. When an MBS transmission is necessary, the MR-BS shall first send the MBS data over the relay downlink as a pre-transmission.~~, and then after DR frames, the MR-BS and RS shall synchronously transmit this MBS data over the access link~~.

Two synchronization modes are defined that can be supported at MR-BS and RS to provide MBS data synchronization. A RS and MR-BS that supports MBS data synchronization for macro-diversity shall support at least one of the two modes.  The mode(s) supported by a RS shall be provided to the MR-BS during RS network entry via the REG-REQ message and the mode to be used shall be selected by the MR-BS via the REG-RSP message.  If the RS and MR-BS do not support compatible modes, the MR-BS shall not select any of the modes in the REG-RSP message.

*[Insert a new section 6.3.23.3.1 and 6.3.23.3.2 and move the rest of text from  6.3.23.3 to the new*

section6.3.2.23.1 as the following:]

### 6.3.23.3.1 MBS data synchronization with pre-defined relative transmission time

~~If there are multiple RSs in the MBS zone at various hop counts from the MR-BS and/or with different processing delays, each RS shall report its processing delay, DR, to the MR-BS as a capability parameter in the SBC-REQ message.~~ When the capability of MBS data synchronization with pre-defined relative transmission time is selected, ~~T~~the MR-BS shall determine the maximum cumulative delay, DM, of all RSs in the MBS zone based on their positions in the tree and their individual processing delays. The MR-BS shall then calculate the required waiting time, Wi, for each RS based on the value of DM and each RS's cumulative delay and notify each RS of its waiting time via an ~~SBC~~REG-RSP message. If the MR-BS detects that the waiting time has changed for a particular RS, it may send an unsolicited ~~SBC~~REG-RSP message to that RS to update its waiting time. When RS receives a unsolicited REG-RSP message with updated waiting time, it shall send~~s~~ an ACK header [4] to MR-BS as an acknowledgement for the unsolicited REG-RSP message. The MR-BS may retransmit REG-RSP message with the updated waiting time if it does not receive ACK header before the expiration of T49 timer.

~~MR-BS should determine target transmission frame of each MBS MAC PDU based on maximum cumulative delay, DM. In addition, MR-BS shall include relay MAC header and MBS subheader to each MAC PDU sent to RS for MBS data. In MBS subheader, MR-BS shall include frame number of the target transmission frame for the MBS MAC PDU at the RS.~~ When an MBS transmission is necessary, the MR-BS shall forward the MBS data over the relay downlink as a pre-transmission DM frames before transmitting this MBS data over the access link. Each RS in the MBS zone shall forward the MBS data it receives over the relay downlink. Finally, once the MR-BS has waited DM frames and each RS has waited its specified waiting time, Wi, the MR-BS and RSs shall synchronously transmit the MBS data over the access link ~~at target transmission frame~~.

### 6.3.23.3.2 MBS data synchronization with target transmission time

When the capability of MBS data synchronization with target transmission time is selected, MR-BS should determine target transmission frame over access link for each MBS data burst based on maximum cumulative delay, DM and other MR-BS information. MR-BS shall include frame number of the target transmission frame with each relay MBS MAC PDU using MBS subheader. The RS shall remove relay MAC header and subheaders and transmit the MBS data to MS over access link at target transmission frame. The intermediate RS shall relay MBS data to its subordinate RSs based on the constraints of QoS parameters for the RS's relay connection for the MBS data. During MBS connection setup for an MS, if a relay path with suitable characteristics, such as per-hop QoS configuration, is not available to an Access RS, the MR-BS may initiate the creation of a new relay path to the Access RS with the required characteristics, such as per-hop QoS configuration, using DSA* messages. The QoS parameters of any of the constituent per-hop connections on an existing relay path to an Access RS may be changed by the MR-BS via DSC* messages.

If a RS fails to transmit a MBS ~~MAC PDU~~data burst at its target transmission frame, the RS shall inform ~~provide NACK to~~ MR-BS of the failure by sending ~~MBS NACK~~ Access Link Transmission Status feedback header (Feedback type 1110). The RS shall include the duration of late arrival for this MBS data burst~~MAC PDU~~ in unit of frames. In addition, a RS may provide early arrival information to MR-BS by sending Access Link Transmission Status~~MBS NACK~~ feedback header if the RS determines a MBS data burst~~MAC PDU~~ has arrived ~~too early~~earlier than Relay Data Early Arrival Report Threshold ~~to~~for its target transmission frame. With early arrival detection, the RS shall include the number of frames exceeding the threshold that ~~the MBS~~ data burst~~MAC PDU~~ has waited to be transmitted. When Relay Data Early Arrival Report Threshold is set to 0, the early arrival reporting is disabled.

*[Modify section 10.1,add the following at the end of table 42:]*

**10.1 Global values**

| System | Name | Time Reference | Minimum value | Default value | Maximum value |
|---|---|---|---|---|---|
| MR-BS | T49 | Waiting for ACK header from RSs within MR-cell after sending unsolicited REG-RSP to update waiting time | TBD | TBD | TBD |

*[Insert new section11.7.28:]*

**11.7.28 MBS Data Synchronization Mode Support**

This TLV indicates the type of MBS data synchronization method is supported by the MR-BS and RS. A bit value of 0 indicates "not supported" while 1 indicates it is supported.

| Type | Length | Value | Scope |
|---|---|---|---|
| xxx | 1 | Bit#0: MBS Data Synchronization with pre-defined relative transmission time (6.3.23.3.1) <br> Bit#1: MBS data synchronization with target transmission time (6.3.23.3.2) <br> Bit#2-7: Reserved, shall be set to zero | REG-REQ <br> REG-RSP |

*[Move section11.8.3.21 to section 11.7.29 and modify as the following:]*

**11.7.29 RS Downlink Processing Delay**

This TLV is used to report the time delay for a RS to forward a data packet to its subordinate RS.
Except when MBS data synchronization with target transmission time is supported, RS downlink processing delay is defined as a maximum fixed delay time for support delivery of timing-related messages and data at RS, which includes PHY processing delay and MAC scheduling and queuing delay. When MBS data synchronization with target transmission time is supported, RS downlink processing delay is defined as the minimum time duration a RS requires to transmit the MBS data upon receiving of the data without any queuing delay.
.

| Type | Length | Value | Scope |
|---|---|---|---|
| TBA | 1 | ~~RS Downlink Processing Delay (unit: frame)~~ In frames | ~~SBC-REQ~~ REG-REQ |

*[Move section11.8.3.22 to section 11.7.30 and modify as the following:]*

**11.7.30 RS Waiting time for MBS**

| Type | Length | Value | Scope |
|------|--------|-------|-------|
| TBA | 1 | RS waiting time for MBS (unit: frame) | ~~SBC-RSP~~ REG-RSP |

*[Insert new section11.7.31:]*

**11.7.31 Relay Data Early Arrival Report Threshold**

This TLV defines the threshold used by RS to determine when to send Access Link Transmission Status feedback header when one or more MAC PDUs arrives at the RS too early.  When the threshold is included, the RS shall send Access Link Transmission Status feedback header to MR-BS when one or more MAC PDU arrives at the RS earlier than the threshold to the target transmission time. When the threshold is set to 0 or if this TLV is not included, RS shall disable the early arrival reporting.

| Type | Length | Value | Scope |
|------|--------|-------|-------|
| xxx | 1 | In frames. When set to 0, the RS shall not send any Access Link Transmission Status feedback header to MR-BS. | REG-RSP |

Reference:

[1] IEEE 802.16e-2005.
[2] IEEE C802.16j-07/005, "A proposal for synchronous MBS transmission in MR".
[3] IEEE 802.16j-06/026r3
[4] IEEE C802.16j-07/285r1