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Re:	IEEE 802.16j-06/027: “Call for Technical Proposals regarding IEEE Project P802.16j”
Abstract	Resource reuse is an essential feature in multihop relay networks to enhance the system throughput. In this contribution, a procedure of measuring interferences between RS is proposed.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
Notice	
Release	
Patent Policy and Procedures	

Estimation of Initial Interference Matrix

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1. Introduction

Resource reuse is an essential feature in multihop relay (MR) networks to enhance the system throughput. Three potential resource reuse scenarios in MR networks are considered [1]: (1) RS⇔SS and RS⇔SS, (2) MR-BS⇔SS and RS⇔SS, and (3) MR-BS⇔RS and RS⇔SS. More aggressive resource reuse could lead to performance improvement. However, interference level increases as well with more aggressive resource reuse. Therefore, it is very important to find a balance between resource reuse and interference control.

In this contribution and [1], we propose a resource reuse and interference management framework to improve overall system capacity of MR networks. The proposed solution includes a workflow to mitigate the interference issues while enabling the resource reuse as much as possible. In this contribution, MR-BS estimates an initial interference matrix to determine whether two RSs within the same MR-cell would interfere with each other based on the collected measurements from all RSs. Then in [1], based on the measurements and feedbacks from SSs, a calibration procedure is proposed to adjust the resource reuse usage and reduce the interference level.

The estimation of initial interference matrix is based on two types of information: (1) static geographical information and (2) dynamic signal measurements. The former information is obtained in the network planning stage while the later information is collected in the initial network establishment stage and succeeding network maintenance stage. The measurement protocol consists of three steps.

- Step 1: The MR-BS sends a REP-REQ message to ask all RSs inside the same MR-cell to report the subsequent measurement results of other RSs. A measurement period is indicated in the REP-REQ.
- Step 2: The MR-BS allocates an exclusive transmission period for an RS using an RS sounding zone Allocation IE and requests all the remaining RSs within the same MR-cell to measure the signal received from the transmitting RS.
- Step 3: After a certain measurement period, the RSs send back the measurement results to the MR-BS. Based on the collected data from all RSs, the MR-BS can construct an interference matrix. The algorithm of determining the interference matrix is implementation specific.

2. Construction of initial interference matrix at MR-BS

To understand the interferences between RSs, the MR-BS may construct an initial interference matrix I, where $I_{i,j}=0$ if communication in RS cell i is guaranteed *not* to interfere with communication in RS cell j; otherwise, $I_{i,j}=1$. The initial interference matrix is determined in the network setup or planning stage and used by MR-BS to determine the initial resource reuse allocation. The matrix I can be also decided either during network design or through in-field measurements. The algorithm of determining the matrix I is outside the scope of this standard. These two methods of providing MR-BS with information to estimate initial interference matrix are described below:

1. Communication range and interference range

The matrix I could be determined off-line based on RSs' static geographical information. Suppose the communication range and maximum interference ranges are defined in advance by taking into account the possible SS location. If the maximum interference range of RS i does not overlap with the communication range of RS j, and vice versa, then $I_{i,j} = 0$; otherwise, $I_{i,j} = 1$. The implementation of the algorithm is outside scope of the standard.

2. Interference Estimation between RSs

The matrix I could be determined dynamically based on RSs' measurement results. The MR-BS allocates an exclusive transmission period for each RS to send sounding signals. All other RSs measure the sounding signals and later report the measurement results to the MR-BS. The detailed protocol is described in the proposed text below.

3. Summary of modifications

In summary, minor modifications of 802.16e-2005 messaging are proposed:

1. REP-REQ: add one new channel type request "RS sounding" and the corresponding TLVs.
2. Sounding zone allocation IE: change one bit "RS sounding".
3. REP-RSP: add two new TLVs "RS Sounding report".

4. Specific text changes

Insert a new subclause 6.3.27.1:

6.3.27.1 Interferences measurement in MR-cell

To understand the interferences between RSs, the MR-BS may construct an initial interference matrix I with entries of $[I_{ij}]$ which indicates if communication in RS cell i interferes with communication in RS cell j or not. The initial interference matrix may be determined in the network setup or planning stage and then may used by MR-BS to determine the initial resource reuse allocation. The matrix I could also be decided either during network design or through in-field measurements. The algorithm of determining the matrix I is outside the scope of this standard.

To understand the interferences between different RSs, the MR-BS needs to collect the interference measurements from RSs. The protocol of interference measurement between RSs consists of three steps. First, the MR-BS sends a REP-REQ message to all RSs inside the same MR-cell on the CID of *ALL_RS_CID*. Besides, the REP-REQ message indicates the TLV of Channel type request is RS sounding (see 11.11). The number of RSs, RSs' CIDs, and the reporting period are also included in the REP-REQ. When an RS receives such an REP-REQ, it expects to hear the Sounding zone allocation IE (8.4.5.4.2) in the subsequent frames until the time indicated in the TLV of report period in the REP-REQ message.

Second, the MR-BS allocates a Sounding zone allocation IE (an exclusive transmission period) for a RS. In particular, the last bit in the Sounding zone allocation IE is enabled (see 8.4.5.4.2) to indicate the burst is for the RS to transmit a sounding signal. This bit also informs all the remaining RSs within the same MR-cell of measuring the sounding signal from the transmitting RS. In other words, with this bit enabled, the RS Sounding zone allocation IE instructs not only the MR-BS but also all other RSs to listen to the RS sounding signal. The MR-BS uses the same format as UL_Sounding_Command_IE to instruct RSs to send RS sounding signals.

The scheduling of RS Sounding zone allocation IEs by MR-BS is implementation specific. The scheduling of RS Sounding zone shall consider allowances made by an RSTTG and RSRTG in between transmit and receive periods to allow the RS to turn around. The capabilities RSTTG and RSRTG will be provided by the RS during RS network entry (see 11.8.3.7.20).

Third, after the number of frame whose value is indicated in the report period TLV of the REP-REQ message has been passed, all RSs send back the measurement results to the MR-BS.

Based on the collected data from all RSs, the MR-BS can construct an interference matrix. The algorithm of determining the interference matrix is outside scope of the standard.

Since the RS does not communicate with each other, the measured signal is viewed as an approximation to the interference across different RS cells. RS will report a vector of the measurement report to MR-BS, so MR-BS could construct an interference matrix using a pre-determined threshold based on the interference signal strength or CINR.

The matrix depends on the many factors such as the RS position, and the interference range. Note that this matrix is a conservative estimate of interference likelihood as the MS location and movement affect the actual interference.

8.4.5.4.2 PAPR reduction/Safety zone/Sounding zone allocation IE

Change the second to the last entry of Table 289 as indicated:

Syntax	Size	Notes
~~*Reserved*~~ RS Sounding zone	1 bit	~~Shall be set to zero~~ 0 = original value 1 = RS Sounding supported

Insert the following text at the end of 8.4.5.4.2:

RS Sounding zone

When this bit is disabled, only the BS listens to the sounding signal from an SS or an RS. When this bit is enabled, not only MR-BS but also all remaining RSs within the same MR-cell shall listen to the RS sounding signal from the transmitting RS.

11.11 REP-REQ management message encodings

Change fourth row of the second table in 11.11 as indicated:

Name	Type	Length	Value
Channel Type request	1.3	1	0b00 = Normal subchannel, 0b01 = Band AMC Channel, 0b10 = Safety Channel, 0b11 = ~~*Reserved*~~Sounding 0b100 = RS Sounding

Insert the following table at the end of 11.11:

Name	**Type**	**Length**	**Value**
RS sounding type request	1.9	variable	Compound
RS Sounding number	1.9.1	1	number of RSs, N_{RS}, participating in RS sounding measurement
RS CID	1.9.2	N_{RS}	Byte#1 .. Byte#N_{RS}: RS(1) .. RS(N_{RS}) basic CID
Report period	1.9.3	1	RS sends REP-RSP after the number of frames since receiving the REP-REQ
RS Sounding Zone-specific RSSI request	1.10	1	Bit #1: Type of zone on which RSSI is to be reported 0: RS reports RSSI on all subcarriers 1: RS reports RSSI on the subcarriers allocated in the Sound zone allocation IE Bits #1-4: in multiples of 1/16 (range is [1/16,16/16]) Bits #5-7: Reserved, shall be set to zero

Insert the following text at the end of 11.11:

When the TLV of Channel type request indicates the support of RS sounding, TLV of type 1.9 and 1.10 may be included in REP-REQ. TLV of RS Sounding number indicates the number of RSs participate in the interference management. TLV of RS CID carries the basic CIDs of all participating RSs. TLV of report period indicates the period of measurement in the unit of frame number. After this period, all RSs shall report to the MR-BS the collected measurement results. TLV of RS Sounding Zone-specific RSSI requested is needed only when RSs are requested to report RSSI measurements. In particular, RSSI measurement on a subset of carriers may be supported.

11.12 REP-RSP management message encodings

Insert the following rows into the third table as indicated:

REP-REQ Channel Type request (binary)	**Name**	**Type**	**Length**	**Value**
100	RS Sounding CINR Report	2.6	N_{RS}	CINR for each RS

100	RS Sounding RSSI Report	2.7	N_{RS}	RSSI ranging from –40 dBm (encoded 0x53) to –123 dBm (encoded 0x00)

Insert the following text at the end of 11.12:

When an RS received an REP-REQ with the TLV of Channel type request, it shall respond to the MR-BS with an REP-RSP with TLV of Sound reports (type 2.6 or 2.7) after measuring RS sounding signals from other RSs. While RS Sounding CINR Report shall be included in REP-RSP by default, RS Sounding RSSI report is optional and only sent when the REP-REQ carries the TLV of RS Sounding Zone-specific RSSI request.

5. References (if required)

[1] W-P Chen, C. Zhu, G-F Su, and J. Agre, "Resource reuse and interference management mechanism," IEEE C802.16j-06/149, IEEE 802.16 meeting #46, Dallas, November 2006.