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Re:	IEEE C802.16j-06/034, “Call for Technical Proposals regarding IEEE Project 802.16j.”
Abstract	This contribution proposes a MAC layer interference measurement and report mechanism to enable RS sounding in IEEE 802.16j Multi-hop Relay system.
Purpose	This proposal introduces an interference measurement and report mechanism for RS sounding in Multi-hop Relay network and proposes the required text input for IEEE 802.16j standard.
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Interference Measurement by RS Sounding in MR Networks

1. Introduction

Resource reuse is an essential feature in multi-hop relay (MR) networks to enhance the system capacity. In IEEE 802.16j Multi-hop Relay system, radio resources (ex. segments [1]) may be reused among different relay links or among different access links [2], which leads to the improvement on system capacity and spectrum efficiency. However, more aggressive resource reuse may results in interference increment, which should be carefully controlled to prevent disturbing the existing radio links. Therefore, it is very important to find a balance between resource reuse and interference increment. In this contribution, an interference measurement and report mechanism is proposed for the concept of RS sounding in MR network to estimate the potential interference level among MR-BS and RSs, so as to designate the resource reuse scenario for each relay or access link. Then in [3], based on the measurements and feedbacks from SSs, an example was proposed to adjust the resource reuse usage and reduce the interference level. Note that this information may also be applied for other purposes, and the measurement for access links is possible but not within the scope of this contribution.

The following is a simple example how to utilize the interference measurement results, where an interference matrix is considered to indicate whether two RSs within the same MR network would severely interfere with each other if they reuse the same radio resources. The estimation of initial interference matrix can be 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 the RSs inside the same MR-cell to report the subsequent measurement results of other RSs. A measurement period is indicated in the REP-REQ to ensure the RSs will report the measurement results after designated period of time.
- Step 2: The MR-BS allocates an exclusive transmission period for an RS using an "RS sounding zone Allocation IE" and requests the other RSs within the same MR-cell to measure the received signal strength 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 results from the RSs, the MR-BS can construct an interference matrix. The algorithm of determining the interference matrix is implementation specific.

2. An example on the construction of interference matrix at MR-BS

In order to introduce how to utilize the interference measurement results, an example is presented to illustrate how to construct a interference matrix to understand the interferences between RSs. For example, the MR-BS can construct an interference matrix ***I***, where $I_{i,j} = 0$ if communication in RS cell *i* can be guaranteed *not* to interfere with communication in RS cell *j*; otherwise, $I_{i,j} = 1$. The interference matrix can be 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 through the proposed interference measurement mechanism. Nevertheless, the algorithm of determining the matrix ***I*** is outside the scope of this standard.

The two abovementioned methods of providing MR-BS with information to estimate initial interference matrix are described in more details below:

1. Communication range and interference range

The matrix *I* could be determined off-line based on RSs' static geographical information, i.e. MR-cell planning result. 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. Note that it is insufficient to determine the interference patterns simply based the static information of stations' locations as the channel gain is determined by many factors and could be changed constantly.

Note that having this kind of interference matrix at MR-BS or not is implementation issue, various resource reuse algorithms can be developed based on the results obtained by the proposed interference measurement mechanism.

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 by RS sounding

In order to estimate the interferences between different RSs, the MR-BS needs to collect the interference measurements from RSs. The protocol of interference measurement between MR-BS and RSs consists of three steps. First, the MR-BS sends a REP-REQ message to all RSs inside the same MR-cell. 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 and the RS shall send the measurement results in REP-RSP to MR-BS after the time indicated in the TLV of report period in the last REP-REQ message.

Second, the MR-BS allocates an exclusive transmission period to an RS via a Sounding zone allocation IE with the RS's basic CID. 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 a set of 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 the set of the RSs to listen to the RS sounding signal. The set of RSs participating in RS sounding process is listed in the last REP-REQ message. The MR-BS uses the same format as UL_Sounding_Command_IE to instruct RSs to compose 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 switch between transmit and receive mode. The capabilities RSTTG and RSRTG will be provided by the RS during RS network entry.

Third, after the number of frame whose value is indicated in the report period TLV of the REP-REQ message has been passed, the set of RSs participating in RS sounding process have to send back the measurement results to the MR-BS. More than one round of measurements may be allocated by MR-BS. In this case, the average measurement results are reported. Since the RSs may not communicate with each other when performing the measurement, the measured signal strength can be treated as an approximation or a prediction of the potential interference between different radio links if they reuse the same radio resources. Therefore, the MR network can be configured or reconfigured based on this measurement results.

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
Sounding Zone	1 bit	0 = PAPR/Safety Zone 1 = Sounding Zone Allocation
~~*Reserved*~~ RS Sounding zone	1 bit	~~Shall be set to zero~~ If Sounding_Zone=1 0 = MS UL sounding 1 = RS Sounding

Insert the following text at the end of 8.4.5.4.2:

RS Sounding zone

When Sounding_Zone is set 1 and RS sounding zone is 0, this sounding zone is defined for MS UL sounding operations; when Sounding_Zone is set 1 and RS sounding zone is set to 1, this sounding zone is defined for RS sounding. In the former case, only the BS or an RS listens to the sounding signal from its subordinate SS or RS. In the later case, not only MR-BS but also the designated RSs within the same MR-cell shall listen to the RS sounding signal from the transmitting RS. In particular, the RSs involved in RS Sounding process are indicated in the last REP-REQ message. An RS in RS Sounding process shall check all sounding zone allocation IEs even if an IE is not addressed to itself, and shall use the RS Sounding zone bit to decide whether it needs to perform UL sounding measurement.

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	1.9	variable	Compound

type request			
RS Sounding number	1.9.1	1	number of RSs, N_{RS}, participating in RS sounding measurement
RS CID	1.9.2	N_{RS}*2	RS(1) … RS(N_{RS}) basic CID where NRS is the number of RSs participating in the RS Sounding measurements
Report period	1.9.3	1	RS sends REP-RSP after the number of frames since receiving the REP-REQ
RS Sounding Zone-specific CINR request	1.10	1	Bits #0-3: in multiples of 1/16 (range is [1/16,16/16]) Bits #4-7: Reserved, shall be set to zero
RS Sounding Zone-specific RSSI request	1.11	1	Bit #0: 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 #2-5: in multiples of 1/16 (range is [1/16,16/16]) Bits #6-7: 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, the designated RSs shall report to the MR-BS the measurement results. TLV of RS Sounding Zone-specific CINR requested is needed only when RSs are requested to report CINR measurements; 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. The reporting time is indicated in REP-REQ. A vector of N_{RS} measurement results of all participating RSs is reported by each RS. Moreover, an RS reports CINR or RSSI or both information dependent on whether the corresponding TLV (type 1.10 or 1.11) appears in REP-REQ.

5. References

[1] Peter Wang et al, “Fixed/Nomadic Relay-Station Preamble Segment Assignment Scheme,” IEEE C802.16j-07/xxx.

[2] C. Zhu et al, “Frame Structure to Support Relay Node Operation,” IEEE C80216j-06/233r8.
[3] W-P Chen, C. Zhu, C-F Su, and J. Agre, “Resource reuse and interference management mechanism,” IEEE C802.16j-06/149, IEEE 802.16 meeting #46, Dallas, November 2006.