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Re:	IEEE 802.16j-06/027: “Call for Technical Proposals regarding IEEE Project P802.16j”
Abstract	Implementing Relay Stations in the OFDMA networks as specified by 802.16e-2005, using a low frequency re-use factor triggers an increase of the network interference amount compared with the legacy 802.16e networks. Detecting and measuring the related interference provides the support for increasing the Quality of Service for the supported 802.16j links, as a result of a further network interference control and management which is implementation specific.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
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Interference Detection and Measurement in OFDMA Relay Networks

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1. Introduction

OFDMA networks based on the 802.16e standard, operate in high interference environments, due to the very demanding conditions imposed by the aggressive frequency re-use factors (1:1 or 1:3). In order to increase the related intra-cell QoS per link, Relay Station entities, operating on the same sets of subcarriers as the serving BSs, have been defined, in order to combat poor coverage and improve the related spectral efficiency. While the interference in 802.16e networks concerns this contribution, the means proposed to address the interference related issues are specifically related to 802.16j networks.

In this contribution we target the following issues:
- To propose an interference detection/measurement scheme that provides useful information related to inter BS/RS interference that can be further employed by the interference management schemes. The interference management and control algorithm is considered beyond the scope of this contribution.
- To define the related messaging support for different interference detection and measurement techniques.

This contribution envisions maximum flexibility for the network integrator or a service provider with regards to the interference management, therefore specifying only the related messaging support and leaving the implementation of the management methods as being implementation specific.

2. Interference Detection and Measurements

In order to execute interference measurements, the target intranet interference should be properly detected. The interference measurements shall be normalized in order to be further compared and evaluated and thus allowing the interference management algorithm to take the proper steps to combat the interference.
Based on the above conditions, an accurate detection and measurement of the intranet interference requires specific interference patterns to be evaluated across a given cluster of cells subject to the interference detection and measurements. Generating additional patterns outside the 802.16e specifications is not the considered approach, provided the fact that the 802.16j specifications shall not un-necessarily diverge from the main 802.16e frame work.

Therefore, the following possible symbol structures, defined by 802.16e, could be employed for interference detection and measurements:

1. Access preamble, as defined for the 802.16e Base Stations. This preamble sequence based method is suggested for determining the intrinsic 802.16e DL related interference, in TDD/FDD mode of operation.
2. Relay Station UL interference pattern built on the UL sounding structure. This type of interference detection and measurement method is envisioned for the RS intrinsic interference generated in OFDMA mobile networks. While the definition of such a pattern is mandated by 802.16e being built based on the UL Sounding structure, the detailed specifications of such a pattern are left to the implementation. This symbol structure could be used for the specific RS UL interference measurements in TDD modes of operation, considering the related symmetrical nature of the propagation channel. This interference measurement method should be seen as complementary to the 802.16e intrinsic interference detection.

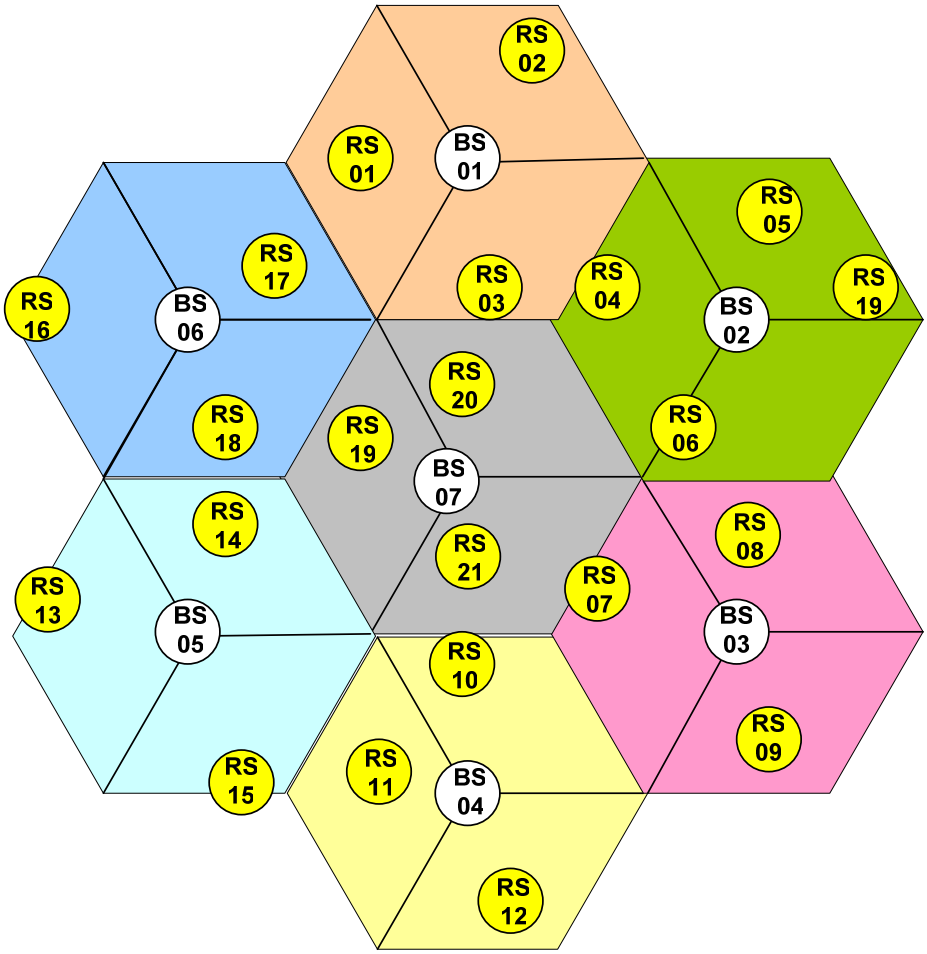

Figure 1 Example of a (1,1,3) network topology.

Based on the example presented in Figure 1 and considering an interference detection algorithm based on interference pattern built upon the UL sounding structure (implementation specific) , as generated simultaneously by one or more first hop Relay Stations, any BS or RS positioned in inside the cluster of cells subject to the interference measurement and management, will receive and attempt to detect the preamble symbol. Further processing will be applied to each request from the BS (e.g. RSSI or SINR), which is implementation specific. These processing results shall be measured by the MR-BS and RS and reported further

to the network management entity, in order to allow further interference management decisions (implementation specific).

Provided the symmetrical nature of the propagation channel in the TDD mode of operation, the interference from an RS to an MR-BS (or another RS) is equivalent to the MR-BS (or RS) to RS interference, assuming equal RF transmission powers. In the case of unequal RF transmission power, the power difference shall be considered when constructing the interference pattern from the channel gain.

The interference measurement schemes based on the preamble and based on UL sounding signals are complementary and their usages shall be determined by the vendors. This contribution is focused on the interference measurement scheme based on using the UL sounding signal.

3. Summary of modifications

In summary, new messaging messages, RS specific are proposed:
RS UL REP-REQ: request UL type of interference measurement report (UL sounding based).
UL sounding zone allocation IE: change one bit “RS sounding”
RS DL REP-RSP: UL type of interference measurement report (UL sounding based)

4. Specific text changes

Insert a new subclause 6.3.27.1:

6.3.27.1 Interferences measurement by RS sounding

In order to predict the interferences between different RS cells, the MR-BS needs to collect the interference measurements from the related RSs and possibly from their associated MSs. The interference can be estimated by having one or multiple RSs or MSs transmit UL sounding signals at specific sounding zones and having the other related RSs and BSs measure the related CINR or RSSI of the received sounding signals. An MR-BS shall construct a multicast group within its MR-cell which uses a multicast CID to represent the group of the RSs that participate in the interference measurement. This group is called RS_interference_measurement group and shall be setup before any measurement of UL sounding signals by the group. The interference measurement procedure is controlled by the MR-BS for intra-MR-cell interference measurement. For interference measurement performed across multiple neighboring MR-cells, a network control entity shall coordinate the measurement activities across the MR-cells.

The interference measurement within an MR cell consists of the following steps.
- Firstly, the MR-BS sends an REP-REQ message to its RS_interference_measurement group. The REP-REQ message includes the TLVs of the reporting period, RS Sounding Zone-specific CINR request, and RS Sounding Zone-specific RSSI request. 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.

- Secondly, the MR-BS sends to its RS_interference_measurement group a UL_Sounding_Command_IE with details of the UL sounding signals to be sent from an RS or multiple RSs. The UL_Sounding_Command_IE shall be sent to the RS_interference_measurement_group as a multicast burst. The MR-BS shall also transmit PAPR_Safety_and_Sounding_Zone_Allocation_IE which matches the sounding zone specified by the UL_Sounding_Command_IE. The CID in the PAPR_Safety_and_Sounding_Zone_Allocation_IE shall be set as the multicast CID of the RS_interference_measurement_group. If an RS belongs to the RS_interference_measurement_group specified by the multicast CID in PAPR_Safety_and_Sounding_Zone_Allocation_IE, the RS shall check whether its own CID is included in the UL_Sounding_Command_IE. When its own CID is included, it shall transmit the sounding signal at the specified symbol and subcarriers as instructed by the MR-BS. Otherwise, the RSs belonging to the RS_interference_measurement_group shall measure the sounding signals if they are not scheduled to transmit sounding signals in the same symbol. The scheduling of RS Sounding zone allocation IEs by MR-BS is implementation specific.

The sounding signal sent from an RS and an MS can be multiplexed in the same sounding zone. This can be done when the MR-BS or RS serving the MS sends to the MS a separate UL_Sounding_Command_IE with instruction of the sounding signal that shall be sent by the MS. The measurement and reporting procedure of the MS UL sounding signal by the RSs in the RS_interference_measurement_group remains the same as the RS sounding procedure.

When interference across different MR-cells needs to be estimated, the above UL sounding procedure shall be conducted with the coordination of a network control entity which controls multiple BSs. In this case the network control entity shall coordinate the multiple BSs to send PAPR_Safety_and_Sounding_Zone_Allocation_IE and UL_Sounding_Command_IE to their respective RS_interference_measurement_groups and MSs for conducting UL sounding measurement across MR-cells. When the RS sounding signal is to be sent by an RS in one of the MR-cells, the same PAPR_Safety_and_Sounding_Zone_Allocation_IE and UL_Sounding_Command_IE shall be duplicated and sent in the other MR_cells, so the RSs in these other cells will conduct measurement on the UL sounding signal.

- Thirdly, after the number of frame whose value is indicated in the report period TLV of the REP-REQ message has been passed, the RSs in the RS_interference_measurement group 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. The measured signal strength between RSs can be viewed as an approximation to the potential interference between different RS cells. The measurement between RSs can be enhanced by measurement results collected by the RSs on the UL sounding signal sent by the selected MSs in a RS cell. MR-BS could estimate the potential interferences between RSs by receiving a vector of the measurement report from each RS. In the case of inter-MR-cell interference measurement, after an MR-BS receives the REP-RSP from all the RSs in its RS_interference_measurement_group, it shall forward it to the network control entity.

11.11 RS REP-REQ management message encodings

Insert the following table at the end of 11.11:

Name	Type	Length	Value
RS sounding Rreport period	1.9	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: averaging parameter 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: averaging parameter 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:

TLV of report period indicates the period of measurement in the unit of frame number. After this period, the designated MR-BSs shall report to the Network Management Entity the related measurement results (implementation specific). TLV of RS Sounding Zone-specific CINR requested is needed only when RSs are requested to report CINR measurements (implementation specific); TLV of RS Sounding Zone-specific RSSI requested is needed only when RSs are requested to report RSSI measurements (implementation specific).

11.12 RS REP-RSP management message encodings

Insert the following rows into the third table of 11.12 as indicated:

REP-REQ Channel Type request (binary)	Name	Type	Length	Value
11	UL Sounding CINR Report	2.6	N	CINR for each of the N RS or MS UL sounding signal in the sounding zone
11	UL Sounding RSSI Report	2.7	N	RSSI for each of the N RS or MS UL sounding signal in the sounding zone

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 or MS sounding signals. 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. The CINR or RSSI report shall be measured on the UL sounding burst.

Insert the following text as of 8.4.11.2.1

8.4.11.2.1 Burst-specific RSSI measurement

RSSI can also be measured an indication of received signal strength in one particular burst or several bursts. For example, an MR-BS or RS may need to measure and report the received signal level in a UL sounding burst or in a segment (all the bursts in the segment). Because the measured bursts may share the same symbol with other bursts, the regular RSSI measurement in the time domain does not apply. This requires measurement of RSSI in the frequency domain. One possible method to estimate the RSSI is given by the following equation:

$$RSSI_{burst} = 10^{\frac{G_{rf}}{10}} \frac{6.2835 \times 10^3 V_c^2}{(2^{2B})R} \left(\frac{1}{K} \sum_{k=0}^{K-1} \sum_{n=0}^{N_{sc}-1} |Y_I[k,n]| + |Y_Q[k,n]|\right)^2 mW ,$$

Where

B is ADC precision, number of bits of the ADC,

R is ADC input resistance [Ohm],

V_c is ADC input clip level [Volts],

G_{rt} is analog gain from antenna connector to ADC input,

$Y_{I \text{ or } Q}[k,n]$ is the n-th subcarrier in the burst (I or Q-branch) within k-th symbol of the measurement,

N_{sc} is the number of subcarriers in the burst.

K is the number of symbols in the burst used for the current measurement.

$RSSI_{burst}$ can also be measured from preambles which can be considered as a special burst utilizing 1/3 of the subcarriers. When the $RSSI_{burst}$ is measured from regularly transmitted burst of the same dimension (for example, the preamble of a particular segment), its mean should be used instead of individual measurement results. The mean $RSSI_{burst}$ statistics (in mW) shall be updated using the following equation.

$$\mu_{RSSI_{burst}} = \begin{cases} RSSI_{burst}[0], l = 0 \\ (1-\alpha_{avg})\mu_{RSSI_{burst}} + RSSI_{burst}[l], l > 0 \end{cases} \text{ mW}$$

Where

l is the measurement index (started from 0),

$RSSI_{burst}[l]$ is the RSSI measurement from the l–th burst.

$RSSI_{burst}$ and $\mu_{RSSI_{burst}}$ shall be reported in the units of dBm.

Other burst RSSI measurement implementations are possible, but the related measurement uncertainty shall be located in the +/-1 dB range referenced to the real value.

When being reported, $RSSI_{burst}$ shall be quantized in 1dB increments, ranging from -24dBm (encoded 0x67) to -123 (encoded 0x00). Values outside this ranged shall be assigned to the closed value within the range.