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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. |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

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| | as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>. |

# 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 a interference a 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 the management methods open.

## 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 other than the 802.16e specifications is not the considered approach, provided the fact that the 802.16j specifications shall not un-neccesarily 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.

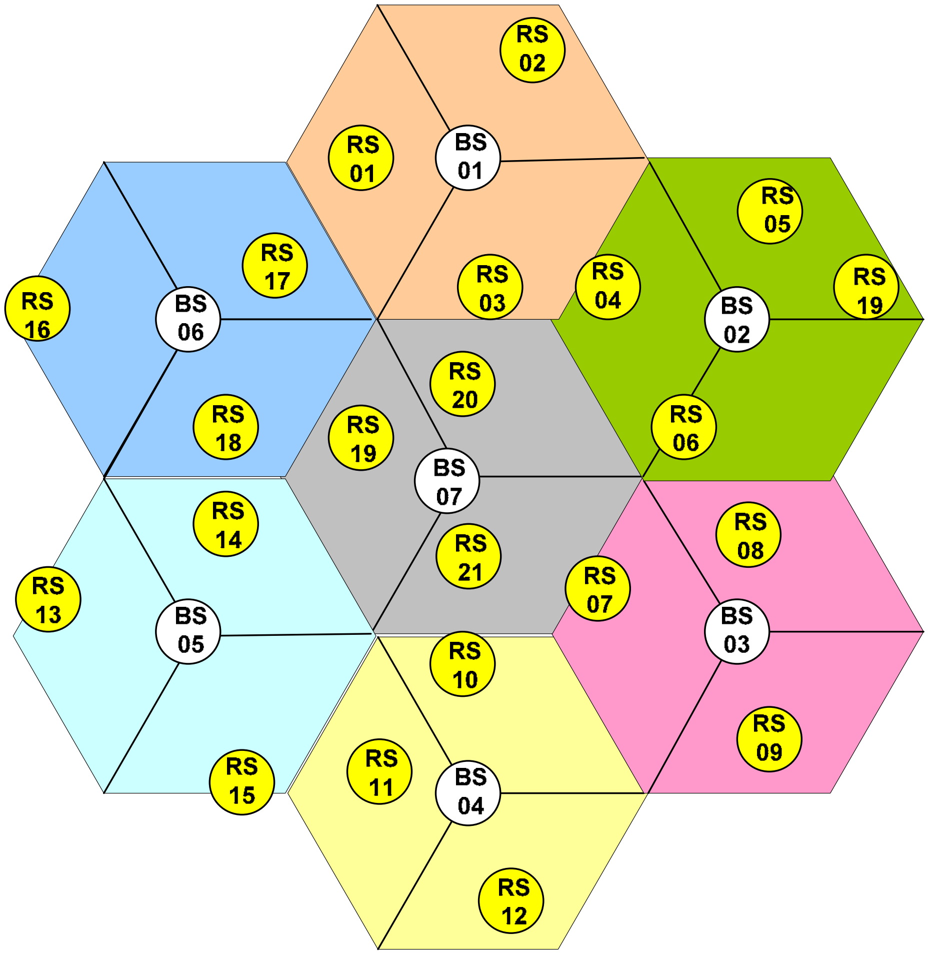


Figure 1 Example of a (1,1,3) network topology.

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 pre 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 a RS to a 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.

## 3. Summary of modifications

In summary, new messaging messages, RS specific are proposed:
RS_NBR-MEAS-REQ: request DL type of interference measurement report (preamble based).
RS_NBR-MEAS-RPT: DL type of interference measurement report (preamble based).
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 new subclause at the end of 6.3.9*

During the RS network registration process, the RS acts as a MS/SS and use REG-REQ message to inform the MR-BS that it has relay capability to MR-BS.

### *Insert new subclause (6.3.2.3.62)*

6.3.2.3.62 RS neighborhood measurement request (RS_NBR-MEAS-REQ) message

| Syntax | Size | Notes |
|---|---|---|
| RS_NBR-MEAS-REQ_Message_Format() { | | |
| Management Message Type = TBD | 8 bits | |
| N_NBR_LIST | 8 bits | Number of neighboring RS/BS in the neighbor list |
| Begin PHY Specific Section { | | |
| For (i=0, i<N_NBR_LIST, i++){ | | |
| Preamble Index | 8 bits | Scan the preamble index and RSSI values in the neighboring list |
| } | | |
| Report Request TLVs | Variable | TLV specific |
| } | | |
| } | | |

The measurement type TLV may include physical CINR or RSSI to allow more flexibility in interference measurement. It shall be determined based on the capability of the RS and the deployed interference management method.

N_NBR_LIST
Number of neighboring RS/BS in the neighbor list.

The RS_NBR-MEAS-REQ shall contain the Report Request TLV (define in 11.11 REP-REQ management message encodings). On receiving RS_NBR-MEAS-REQ, a first hop RS shall measure the interference from the neighboring MR-BSs using the specified methods in the Report Request TLVs.

## *Insert new subclause (6.3.2.3.63)*

6.3.2.3.63 RS neighborhood measurement report (RS_NBR-MEAS-RPT) message

| Syntax | Size | Notes |
|---|---|---|
| RS_NBR-MEAS-RPT_Message_Format() { | | |
| Management Message Type = TBD | 8 bits | |
| N_NBR_LIST | 8 bits | Number of neighboring RS/BS in the neighbor list |
| Begin PHY Specific Section { | | |
| For (i=0, i<N_NBR_LIST, i++){ | | |
| Preamble Index | 8 bits | Record the preamble index and RSSI values from the neighborhood discovery |
| Report Response TLVs | Variable | TLV specific |
| } | | |
| } | | |
| } | | |

N_NBR_LIST
Number of neighboring RS/BS in the neighbor list.

The RS_NBR-MEAS-RPT shall contain the Report Response TLV (defined in 11.11 REP-RSP management message encodings). $RSSI_{burst}$ (or $\mu_{RSSI_{burst}}$ ) measured in the segment shall be used when reporting the RSSI in a segment.

## *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 first hop RSs, the MR-BS needs to collect the interference measurements from the related RSs. The interference protocol measurement between MR-BS and RSs consists of three steps.

- Firstly, the Network Management Entity schedules the related MR-BSs to send a REP-REQ message to all sub-ordinated RSs inside a given cluster of cells, subject to interference analysis. 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 a BS 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 related MR-BSs that service the designated cluster of cells or a part of them, subject to the interference analysis allocate a Sounding zone allocation IE (an exclusive transmission period) for each sub-ordinated RS operating within that particular cluster of cells. Depending on the implementation, a few or all the the related RSs operating in that cluster of cells could perform the interference detection/measurement method. 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 a given RS to transmit a sounding signal. This bit also informs the other BSs, within the same cluster of cells under interference analysis, through the network backbone of measuring the sounding signal from the transmitting RS or RSs. Depending on the implementation, one or more BSs could be instructed to listen to the given interference patterns (implementation specific). Depending on the implementation, one or more RSs could be instructed to listen to the given interference patterns (implementation specific), transmitted by their subordinated RSs. Therefore the method could be used for RS to/from BS, within a given cluster of cells under interference analysis or for RSs to/from subordinated RSs. In other words, with this bit enabled, the RS Sounding zone allocation IE could instruct not only the all the MR-BSs, operating in the given cluster of cells but it also could be expanded to other RSs within the same cluster of cells (implementation specific), to listen to the transmitting RS interference pattern (implementation specific) based on the sounding signal. The MR-BS uses the same format as UL_Sounding_Command_IE to instruct the designated RSs to build and transmit the RS sounding signals.

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The entire interference detection/measurement and management procedures should be driven by a network management interference entity or under the control of the MR-BS and thus to be limited to only one cell, if chosen (implementation selectable). Under this particular case, the method could be applied to MS to/from RS interference measurement. A subset of this application becomes then the intra-cell interference measurement.

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 RS-TTG and RS-RTG in between transmit and receive periods to allow the RS to properly switch between transmit and receive mode. The capabilities RS-TTG and RS-RTG will be provided by the RS during RS network entry.

- Thirdly, after the number of frame whose value is indicated in the report period TLV of the REP-REQ message has been passed, all MR-BSs and/or the master RSs have to send back the measurement results to the network management entity. More than one continuous or intermittent round of measurements may be allocated by the network management entity. An averaging of all the subsequent measurements may be executed at the MR-BS level or at the network management entity level, being implementation specific. Since the RSs may not communicate directly with each other, while performing the related measurements, 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, being implementation specific.

### 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<br>1 = Sounding Zone Allocation |
| Reserved<br>RS Sounding zone | 1 bit | Shall be set to zero<br>If Sounding_Zone=1 |

| | | |
|---|---|---|
| | | 0 = MS UL sounding<br>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 could be 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 listens to the sounding signal from an MS or a sub-ordinated 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 sub-ordinated RS. In particular, the RSs involved in RS Sounding can be indicated by the CID of UL MAP IE which contains the Sounding zone allocation IE.

11.11 RS 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,<br>0b01 = Band AMC Channel,<br>0b10 = Safety Channel,<br>0b11 = ~~*Reserved*~~Sounding<br>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 | $N_{RS}$*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])<br>Why do we limit this to 1/16 steps? Why shouldn't we specify this in symbols (max 21 symbols for the entire UL subframe)?<br>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<br>0: RS reports RSSI on all subcarriers<br>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])<br>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 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 [1] 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 sub-ordinated 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. 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, a 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:

$$RSSI_{burst} = 10^{\frac{G_{rf}}{10}} \frac{6.2835\times10^{3}V_c^2}{(2^{2B})R}\left(\frac{1}{K}\sum_{k=0}^{K-1}\sum_{n=0}^{N_{sc}-1}\left|Y_I[k,n]\right| + \left|Y_Q[k,n]\right|\right)^2 mW,$$

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,

$Y_{I\ or\ Q}[k,n]$ 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 -40dBm (encoded 0x53) to -123 (encoded 0x00). Values outside this ranged shall be assigned to the closed value within the range.

## 5. References

[1] IEEE802.16e-2005