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Re:	IEEE 802.16j-06/034: "Call for Technical Proposals regarding IEEE Project P802.16j"	
Abstract	This contribution introduces a RS neighborhood discovery and measurement mechanism, and then proposes the required message and text input for IEEE 802.16j baseline document.	
Purpose	Propose a RS neighborhood discovery and measurement mechanism and the required message and text input for IEEE 802.16j Multi-hop Relay network.	
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# RS Neighborhood Discovery and Measurement for IEEE 802.16j Multi-hop Relay Network

This contribution presents a RS neighborhood measurement mechanism for neighborhood discovery and measurement in IEEE 802.16j Multi-hop Relay network. The fundamental concept of the proposed measurement mechanism will be first introduced, and then an example is provided to show that how MR network can utilize measurement results to predict the received interference or SINR level before reusing [1] or grouping [2] the radio resources (e.g. segment) and configure/reconfigure the MR network topology.

In the proposed mechanism, MR-BS or other coordinator in backhaul network can request a set of the RSs to transmit the reference signals, which has the same format as 16e preamble, over the designated OFDMA symbol offset for the scanning by other stations. After the RSs reporting the scanning results to the MR-BS or the coordinator in backhaul network, it has the full knowledge on how the RSs may interfere with each other. Then various algorithms for segment assignment/reuse, neighborhood discovery, neighbor list establishment and topology configuration can be benefited by this information.

The fundamental concept of RS scanning is almost the same as 16e MS scanning, and the difference is that RS scanning is performed in unit of OFDMA symbol instead in unit of frame duration. It is because all the data transmission of the subordinated stations may be terminated when RS is scanning its neighborhood, therefore, reducing the scanning duration is very critical with respect to MS scanning.

Meanwhile, other contributions [3-5] had also presented how the resource reuse in access links can be operated by utilizing the measurement results obtained by this mechanism.

## I. The necessities of RS neighborhood discovery and measurement

When a RS being deployed into the MR network, it shall scan its neighbor stations and then perform the network entry with one of the neighbor stations. The neighbor discovery and measurement can be performed in advance of network entry in this case, and RS can directly report its measurement results to MR-BS after network entry. However, not every RS in MR network will transmit its preamble (e.g. transparent RS) or transmit its own preamble (e.g. when RSs are grouped [2]), therefore, the RS may still need to scan its neighborhood again after network entry. In addition, this kind of measurement may also be required for adjusting the transmit power of RS [4], or be required after RS power adjust so as to explore the resource reuse possibility. The aforementioned reasons are applicable for fixed, nomadic or mobile RS. The following gives an example to explain the necessity of such automatic neighborhood discovery and measurement mechanism. In the multi-hop relay systems, the coverage extension and user throughput enhancement may be achieved at the expense of system capacity [6,7]. It is because the user data in relay links carries the same information as the data in access links, therefore, all the traffic in relay links can be treated as a kind of overhead. If the capacity improvement led by better signal quality and higher transmission rate cannot compensate the capacity loss due to radio resources consumed by relay links, the overall system capacity will be degraded due to the deployment of the RSs into the network.

In order to increase the system capacity, reusing the radio resources (i.e. sub-channel and symbol time, or segment) in different relay and/or access links has been shown as an efficient solution. Compared with the case without reusing radio resources, the simulation results in Figure 1 shows that the system capacity can be substantially increased [6,7]. Moreover, its capacity is also significantly outperformed with respect to the case without relaying.

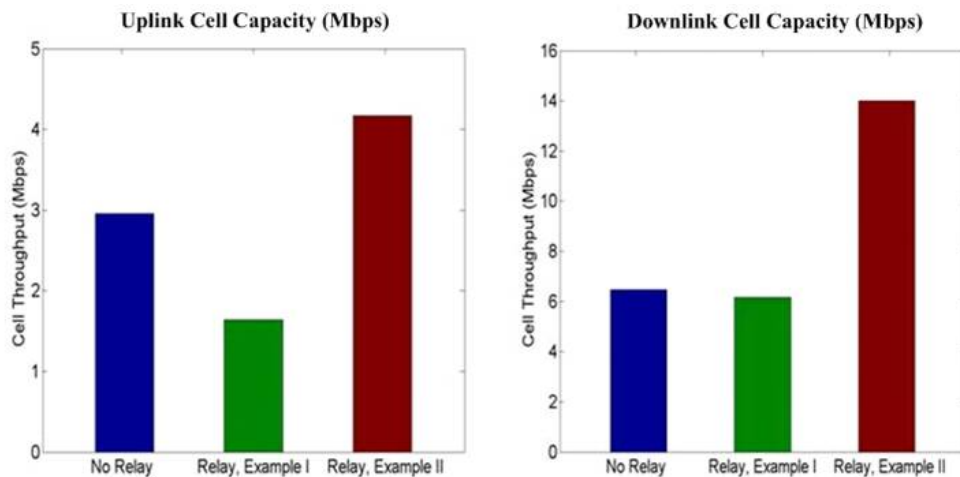


Fig.1 Capacity comparison for different relay scenarios

However, considering an arbitrary MR network as shown in Figure 2, a fundamental problem is: “Which links can reuse the same radio resources without disturbing each other?”.

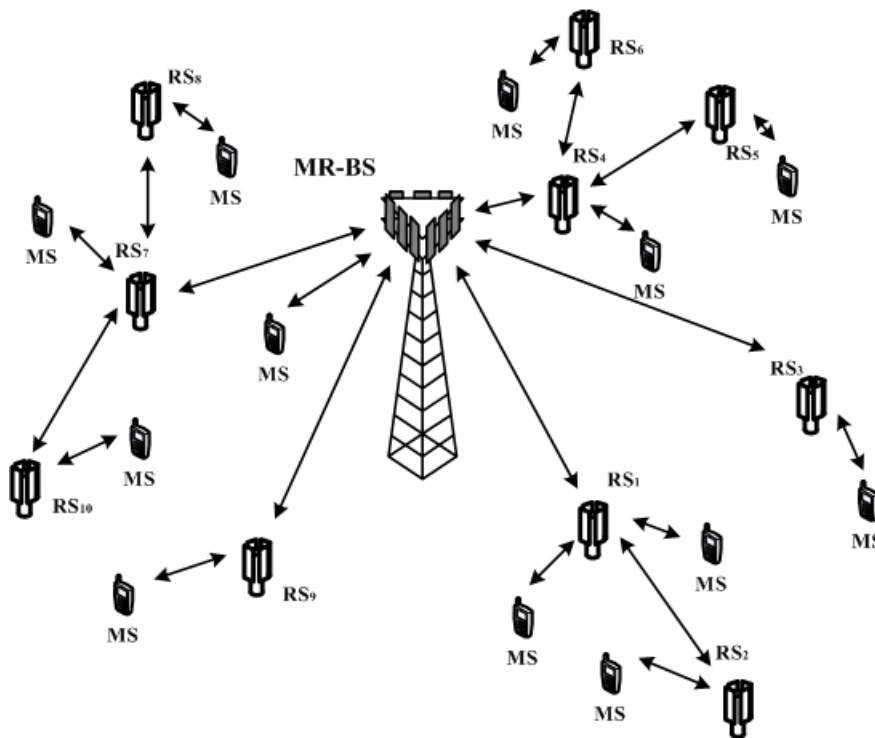


Fig.2 An example of IEEE 802.16j MR network

A traditional method is performing the cell planning when deploying each RS. Therefore, the transmit power, resource assignment and reuse scenario can be manually configured based on the geographical location and the field trial measurement results. However, the geographic location may not be able to reflect the real propagation environment, and the interference measurement can provide better prediction for MR network to explore the propagation environments.

1 An alternative method is to configure the MR network in automatic manner, which means that the RSs can  
 2 detect and measure the radio signal transmitted from each other, and then report the detection and measurement  
 3 results to MR-BS (or any other controller) to configure the MR network automatically. Therefore, the MR  
 4 network can be easily managed in response to time variant traffic distribution or other load unbalance situations.  
 5 For example, the MR-BS may instruct the permutation scheme of RS<sub>3</sub> to be changed from PUSC to FUSC (or  
 6 assign more segments), so as to increase the capacity over the specific area.

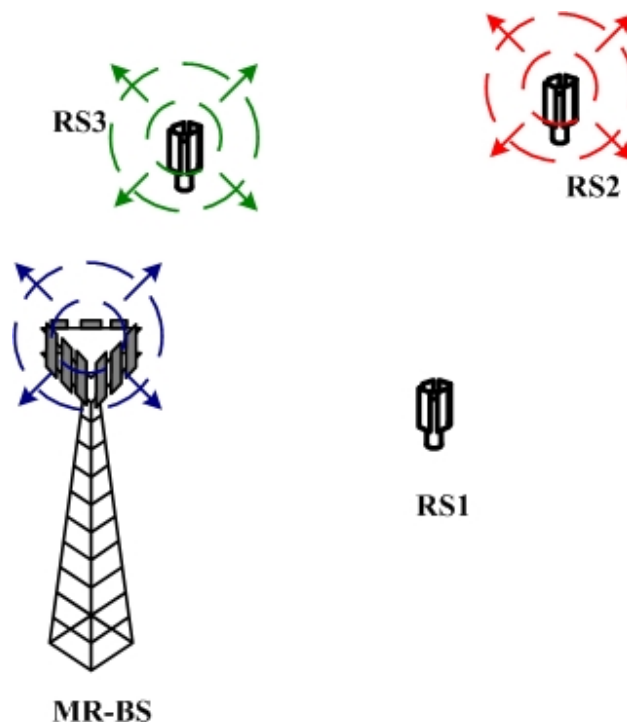
7 In order to make MR network able to automatic configure/reconfigure its reuse scenario, an interference  
 8 measurement and neighbor detection mechanism will be necessary to provide the required information to  
 9 MR-BS.

10 Moreover, the results of interference measurement and neighborhood detection can also be applied to  
 11 compose the neighbor list for each station, and the example presented in this contribution also shows that it can  
 12 also be utilized to determine the topology for MR network.

## 14 II. The concept of the neighborhood discovery and measurement mechanism

16 The fundamental concept of the interference measurement mechanism can be illustrated by Figure 3, which  
 17 includes a MR cell composed by one MR-BS and several RSs. The MR-BS network can designate one or more  
 18 time-frequency regions for specific stations to transmit the reference signals (e.g. same format as 16e preamble),  
 19 and other stations can perform the measurement over the same time-frequency region.

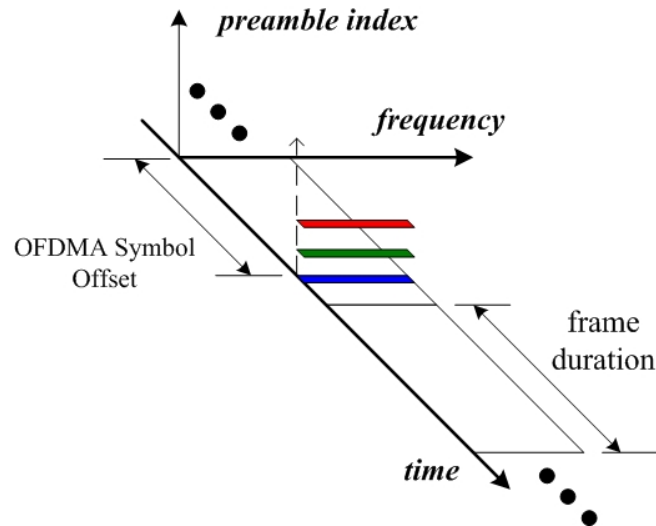
20 As a specific example as shown in Figure 3, RS<sub>10</sub>, RS<sub>8</sub>, RS<sub>2</sub> and RS<sub>5</sub> are requested to transmit the reference  
 21 signals by MR-BS, and the rest of other stations will perform the measurement of the those reference signals.



22 Fig.3 An example of the neighborhood discovery and measurement in MR network

24 Since the reference signal to be scanned has the same format as 16e preamble, therefore, one possible way to

1 arrange the scanning opportunity is designating multiple stations (i.e.  $RS_2$ ,  $RS_3$  and MR-BS in Figure 3)  
 2 transmit its amble over the same time, and ask one RS (i.e.  $RS_1$  in Figure 3) scan those ambles. Therefore, the  
 3 receiver can identify the transmitter ID and measure the strength if the ambles at the same time.



5  
 6 Fig.4 An example to arrange the scanning opportunity over the same OFDMA symbol offset

7  
 8 After the measurement, each station can report the RSSI or the CINR with corresponding transmitter ID to  
 9 the MR-BS or other coordinator in backhaul network.

### 11 III. An example to perform interference and SINR prediction based on the neighborhood measurement 12 results

13  
 14 In Figure 5, an example with 4 stations (1 MR-BS and 3 RSs) is presented to illustrate how we can predict the  
 15 interference and SINR level for different resource reuse scenario and MR network topology. According to the  
 16 aforementioned RS scanning mechanism, each station can transmit an amble for other stations to perform  
 17 measurement and identification. Therefore, the MR-BS can have the knowledge of the RSS (Received Signal  
 18 Strength) from each other, as shown in Figure 5.

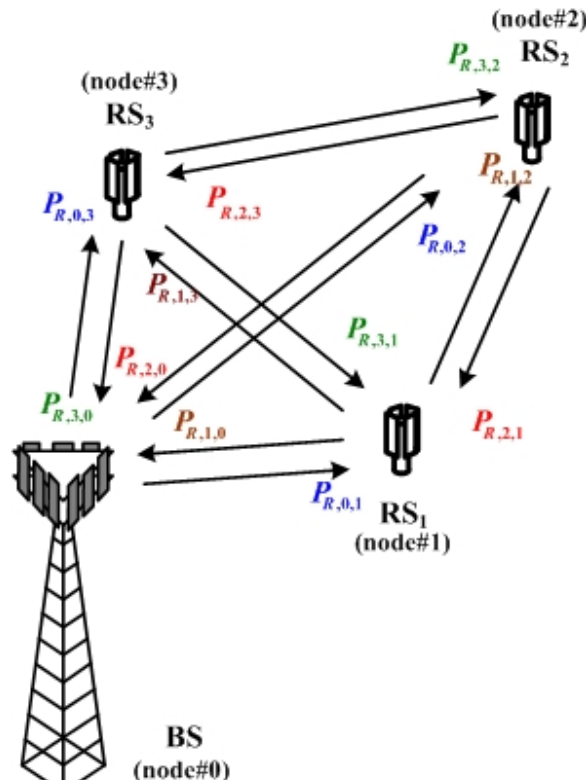


Fig.5 An example to illustrate the interference and SINR prediction

After each station reports its measurement results, the RSS matrix as shown in Figure 6 can be obtained at the MR-BS. Note that the interference generated by the stations which is not involved in this mechanism is considered as the background interference in this example. Therefore, the parameter  $P_{R,i,i}$  is defined as the received thermal noise power plus background interference power by node  $i$ .

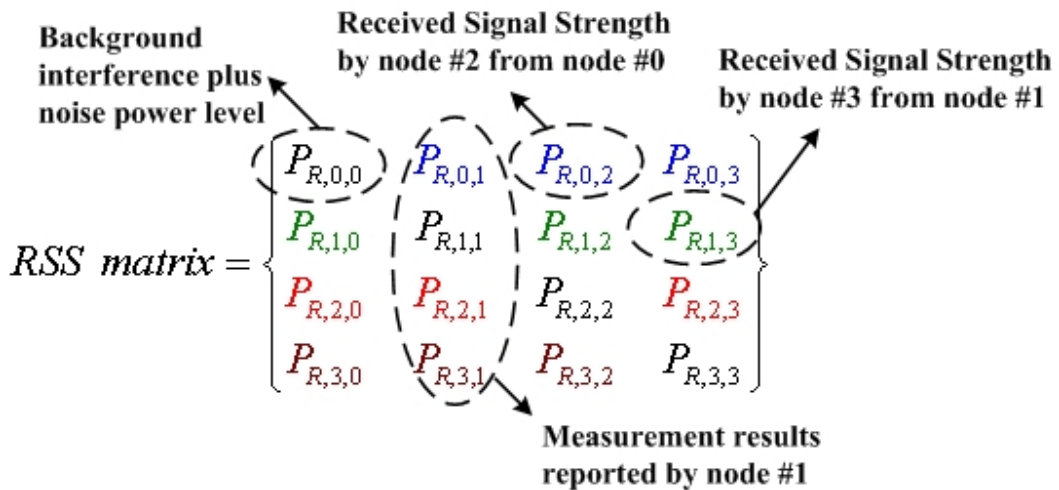


Fig.6 RSS matrix recorded by the MR-BS

According to the RSS matrix presented in Figure 6, the MR-BS or the coordinator can predict the interference and SINR level for each resource reuse scenario and MR network topology, which can be presented as

1 following. Figure 7 represents the first example for the prediction under the topology #1, and here we define the  
 2  $L_{i,j}$  to indicate the radio link from node # $i$  and node # $j$ .

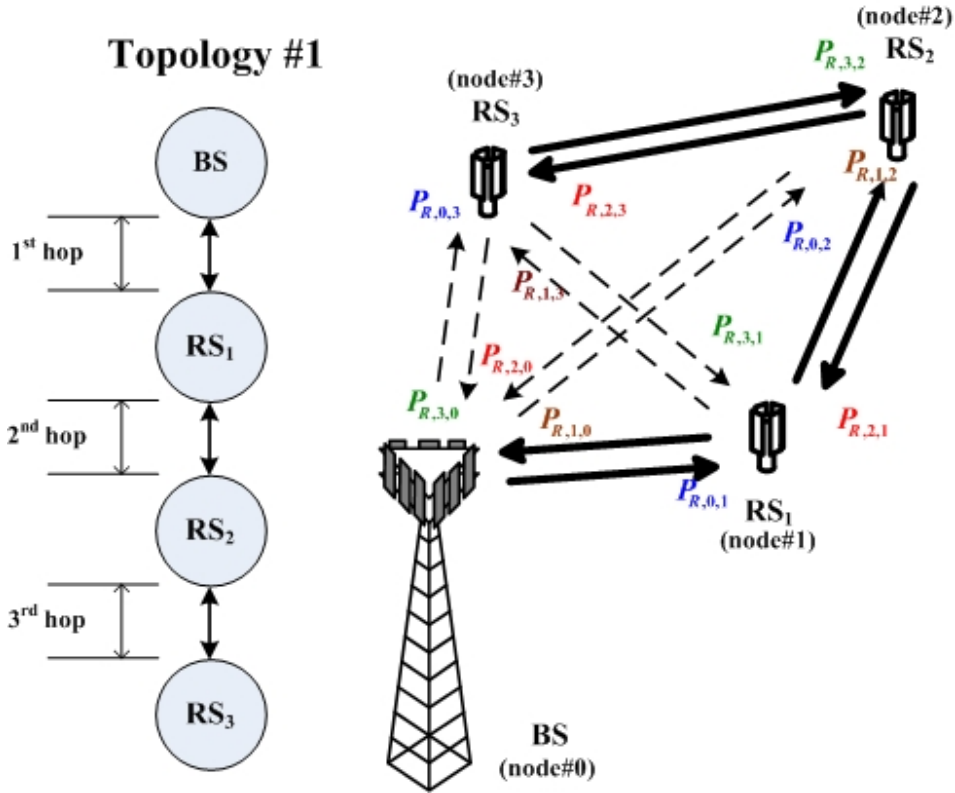


Fig.7 An example for interference and SINR prediction under Topology #1

3  
 4  
 5  
 6 According to the Topology #1, the interference and SINR prediction of each resource reuse scenario is shown  
 7 as Table 1. Note that  $\{L_{i,j}, L_{x,y}\}$  defines that the link  $L_{i,j}$  and the link  $L_{x,y}$  are “reusing the same radio resources”  
 8 but transmitting “different data”, and each station is assumed not able to transmit and receive at the same time.  
 9 Therefore,  $L_{i,j}$  and  $L_{x,y}$  will not interfere each other if they are not reuse the same radio resources (i.e.  
 10  $\{L_{i,j}\}, \{L_{x,y}\}$ ). Note that the following prediction results are represented in linear values (not in dB).

11  
 12 Tab.1 Predicted Received Interference and SINR Level based on the RSS Matrix and Topology #1

Reuse Scenario		Predicted Received Interference Level			
		Node #0	Node #1	Node #2	Node #3
DL	$\{L_{0,1}\}, \{L_{1,2}\}, \{L_{2,3}\}$	Null	$P_{R,1,1}$	$P_{R,2,2}$	$P_{R,3,3}$
	$\{L_{0,1}, L_{2,3}\}, \{L_{1,2}\}$	Null	$P_{R,2,1} + P_{R,1,1}$	$P_{R,2,2}$	$P_{R,0,3} + P_{R,3,3}$
UL	$\{L_{3,2}\}, \{L_{2,1}\}, \{L_{1,0}\}$	$P_{R,0,0}$	$P_{R,1,1}$	$P_{R,2,2}$	Null
	$\{L_{1,0}, L_{3,2}\}, \{L_{2,1}\}$	$P_{R,0,3} + P_{R,0,0}$	$P_{R,1,1}$	$P_{R,2,1} + P_{R,2,2}$	Null
Reuse Scenario		Predicted Received SINR Level			
		Node #0	Node #1	Node #2	Node #3

DL	$\{L_{0,1}\}, \{L_{1,2}\}, \{L_{2,3}\}$	<i>Null</i>	$\frac{P_{R,0,1}}{P_{R,1,1}}$	$\frac{P_{R,1,2}}{P_{R,2,2}}$	$\frac{P_{R,2,3}}{P_{R,3,3}}$
	$\{L_{0,1}, L_{2,3}\}, \{L_{1,2}\}$	<i>Null</i>	$\frac{P_{R,0,1}}{P_{R,2,1} + P_{R,1,1}}$	$\frac{P_{R,1,2}}{P_{R,2,2}}$	$\frac{P_{R,2,3}}{P_{R,0,3} + P_{R,3,3}}$
UL	$\{L_{3,2}\}, \{L_{2,1}\}, \{L_{1,0}\}$	$\frac{P_{R,1,0}}{P_{R,0,0}}$	$\frac{P_{R,2,1}}{P_{R,1,1}}$	$\frac{P_{R,3,2}}{P_{R,2,2}}$	<i>Null</i>
	$\{L_{1,0}, L_{3,2}\}, \{L_{2,1}\}$	$\frac{P_{R,1,0}}{P_{R,3,0} + P_{R,0,0}}$	$\frac{P_{R,2,1}}{P_{R,1,1}}$	$\frac{P_{R,3,2}}{P_{R,0,2} + P_{R,2,2}}$	<i>Null</i>

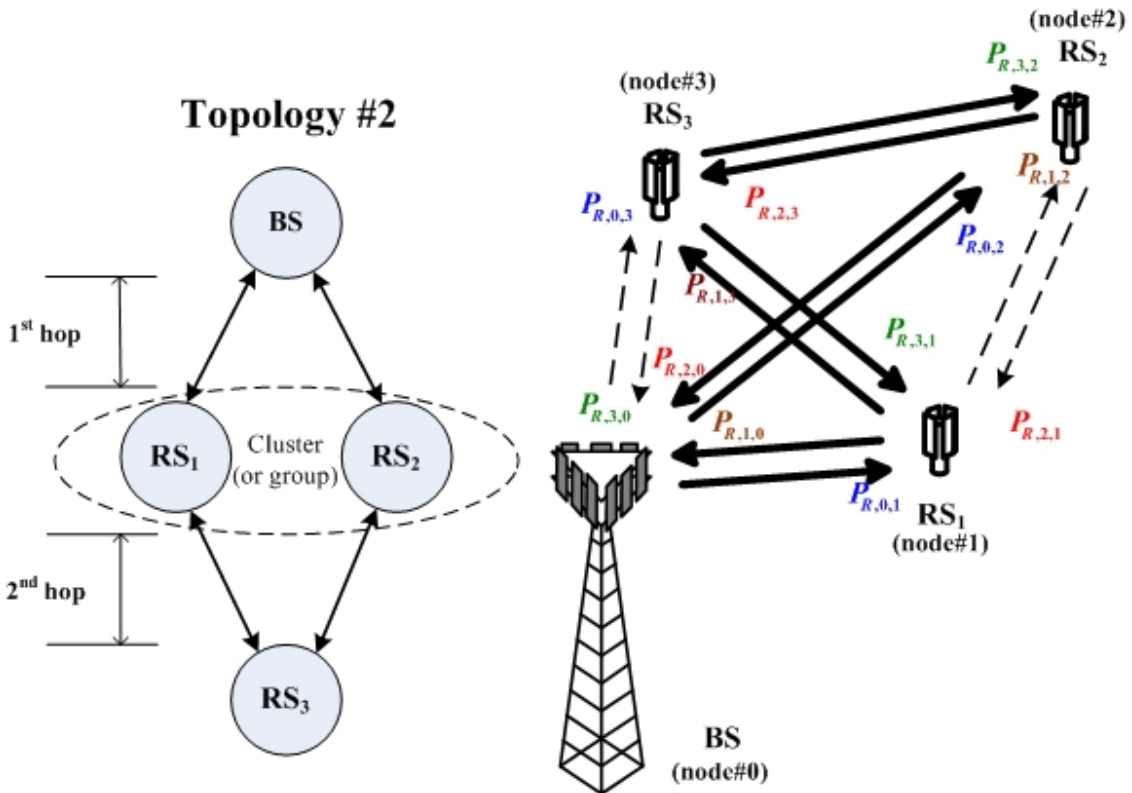


Fig.8 An example for interference and SINR prediction under Topology #2

Therefore, the interference and SINR level for each reuse scenario can be predicted as the results in Table 2. Note that the links with the transmitters which are the stations within the same cluster shall be treated as one



3 Tab.2 Predicted Received Interference and SINR Level based on the RSS Matrix and Topology #2

Reuse Scenario		Predicted Received Interference Level			
		Node #0	Node #1	Node #2	Node #3
DL	$\{L_{0,1}\}, \{L_{0,2}\},$ $[L_{1,3}, L_{2,3}]$	<i>Null</i>	$P_{R,1,1}$	$P_{R,2,2}$	$P_{R,3,3}$
UL	$\{L_{3,1}\}, \{L_{3,2}\},$ $[L_{1,0}, L_{2,0}]$	$P_{R,0,0}$	$P_{R,1,1}$	$P_{R,2,2}$	<i>Null</i>
Reuse Scenario		Predicted Received SINR Level			
		Node #0	Node #1	Node #2	Node #3
DL	$\{L_{0,1}\}, \{L_{0,2}\},$ $[L_{1,3}, L_{2,3}]$	<i>Null</i>	$\frac{P_{R,0,1}}{P_{R,1,1}}$	$\frac{P_{R,0,2}}{P_{R,2,2}}$	$\frac{P_{R,1,3} + P_{R,2,3}}{P_{R,3,3}}$
UL	$\{L_{3,1}\}, \{L_{3,2}\},$ $[L_{1,0}, L_{2,0}]$	$\frac{P_{R,1,0} + P_{R,2,0}}{P_{R,0,0}}$	$\frac{P_{R,3,1}}{P_{R,1,1}}$	$\frac{P_{R,3,2}}{P_{R,2,2}}$	<i>Null</i>

4  
 5 In summary, when predicting the interference level based on the RSS matrix, the interference of specific  
 6 receiver node #i can be the summation of:

- 7 1. The thermal noise power and background interference power.  
 8 2. The RSS of the stations which transmit over the same resource region but their target is not node #i.

9 In addition, when predicting the SINR level of specific receiver node #i based on the RSS matrix and the  
 10 aforementioned interference prediction results:

- 11 1. Its denominator can be the aforementioned interference prediction result  
 12 2. Its nominator can be the RSS which transmit over the same resource region and their target is node #i.

13  
 14 **IV. Text proposal**

15 -----Start of the text-----

16  
 17 *Insert new subclause (6.3.2.3.62)*

18  
 19 6.3.2.3.62 RS neighborhood measurement request (RS\_NBR-MEAS-REQ) message

20  
 21 The MR-BS can send a RS\_NBR-MEAS-REQ message to instruct RS neighborhood discovery and  
 22 measurement. When an RS receiving this message with NBR\_MEAS\_MODE=0, it shall measure the reference  
 23 signal over the designated Frame Number Offset and OFDMA symbol offset, and the message shall be sent  
 24 with basic CID. When receiving this message with NBR\_MEAS\_MODE=1, the RS shall transmit the reference

1 signal over the designated Frame Number Offset and OFDMA symbol offset, and the message can be sent with  
 2 either multicast CID or basic CID. Note that the Report Request TLV is defined in 11.11.  
 3  
 4

Syntax	Size	Notes
RS_NBR-MEAS-REQ_Message_Format() {		
Management Message Type = TBD	8 bits	
NBR_MEAS_MODE	1 bit	0: Receive mode 1: Transmit mode
If (NBR_MEAS_MODE==0){		
N_NBR_LIST	8 bits	Number of neighboring stations in the neighbor list
Begin PHY Specific Section {		
For (i=0, i<N_NBR_LIST, i++){		
Frame Number Offset	4 bits	In unit of frames
OFDMA Symbol Offset	8 bits	The location to scan the reference signal
Preamble Index	8 bits	Preamble index corresponds to position of the station in MR_NBR-INFO
}		
Report Request TLVs	Variable	TLV specific
}		
}		
else {		
Frame Number Offset	4 bits	In unit of frames
OFDMA Symbol Offset	8 bits	The location of the reference signal to be transmitted
}		
}		

5  
 6 The Report Request TLV shall include physical CINR or RSSI of the preamble index

7  
 8 NBR\_MEAS\_MODE

9 Instruct the RS to transmit (if NBR\_MEAS\_MODE=1) or measure (if NBR\_MEAS\_MODE=0) the reference  
 10 signal over the designated Frame Number Offset and OFDMA symbol offset

11  
 12 Measurement duration

13 Duration (in unit of frames) where the RS shall transmit/measure the reference signal,

14  
 15 N\_NBR\_LIST

16 Number of neighboring stations in the neighbor list

17  
 18 Frame Number Offset

19 The RS shall transmit/receive the reference signal after waiting this designated number of frames

20  
 21 OFDMA Symbol Offset

22 The location of the reference signal to be transmitted or measured. If NBR\_MEAS\_MODE is set as 0, RS shall  
 23 measure the reference signals over each segment at the designated OFDMA symbol offset.

1  
2  
3 *Insert new subclause (6.3.2.3.63)*

4  
5 6.3.2.3.63 RS neighborhood measurement report (RS\_NBR-MEAS-REP) message

6

Syntax	Size	Notes
RS_NBR- MEAS -REP_Message_Format() {		
Management Message Type = TBD	8 bits	
N_NBR_LIST	8 bits	Number of neighboring stations in the neighbor list
Begin PHY Specific Section {		
For (i=0, i<N_NBR_LIST, i++){		
Preamble Index	8 bits	Preamble index corresponds to position of the station in MR_NBR-INFO
Report Response TLVs	Variable	TLV specific
}		
}		
}		

7  
8 N\_NBR\_LIST

9 Number of neighboring stations in the neighbor list

10  
11 The RS\_NBR- MEAS -REP shall contain the Report Response TLV (define in 11.11 REP-RSP management  
12 message encodings).

13  
14 *Insert a the following text into 6.3.26*

15  
16 6.3.26 Relay station neighborhood discovery

17  
18 When a RS newly deployed into a MR network, it can acts as a SS/MS and scan the preamble transmitted by the  
19 existing stations before network entry. After receiving the MR\_NBR-INFO (see 6.3.x.x), the RS can report its  
20 neighborhood discovery results to MR-BS by RS\_NBR-MEAS-REP (6.3.2.3.63) with corresponding preamble  
21 indexes and the measurement results for initial neighborhood discovery. Since not every RS will transmit  
22 preamble or transmit its own preamble, MR-BS can instruct the RSs to perform complete neighborhood  
23 discovery by RS measurement mechanism.

24 The procedure of RS measurement mechanism is described as following:

25 First, the MR-BS sends a RS\_NBR-MEAS-REQ message to a target RS with the NBR\_MEAS\_MODE set as 0,  
26 and the message is sent by the basic CID of the target RS. Meanwhile, MR-BS can send another  
27 RS\_NBR-MEAS-REQ message to other stations by the either multicast or basic CID with  
28 NBR\_MEAS\_MODE set as 1. Note that the Frame Number Offset and OFDMA symbol offset to instruct the  
29 transmission and measurement of the reference signal shall be synchronized.

30 Second, the neighbor stations transmit the reference signal at the designated OFDMA symbol offset for the  
31 measurement by target RS.

1 Third, the target RS reports the measurement results with corresponding preamble index by  
 2 RS\_NBR-MEAS-REP to MR-BS.

3  
 4 *Insert a new subclause 6.3.27.1*

5  
 6 6.3.27.1 Interference prediction by RS neighborhood measurement

7  
 8 In order to measure the interference from other stations, the MR-BS can instruct the RS to measure the  
 9 preambles or other ambles transmitted from its neighbor stations, and then report its scanning results to MR-BS.  
 10 The procedure to perform RS neighborhood measurement can refer to 6.3.26.

11 In order to predict the interference level if the RS  $\#i$  use the segment  $\#j$ , the prediction result can be the  
 12 summation of:

- 13 1. The thermal noise power and background interference power.
- 14 2. The RSSI of the stations which also use the segment  $\#j$  but they are not transmit the data to RS  $\#i$ .

15 In addition, in order to predict the CINR level if the RS  $\#i$  use the segment  $\#j$ , the prediction result can be:

- 16 1. Its denominator can be the aforementioned interference prediction result.
- 17 2. Its nominator can be the RSSI which also use the segment  $\#j$  and they also transmit data to RS  $\#i$ .

18  
 19 -----End of the text-----  
 20  
 21

22 **V. References**

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- 33 [8] IEEE C802.16j-06/168, "A RS Clustering Scheme for IEEE 802.16j."
- 34 [9] IEEE C802.16j-06/199, "Relay-Station Preamble Segment Assignment/Re-Assignment scheme."
- 35
- 36
- 37