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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.
Notice	
Release	
Patent Policy and Procedures	

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 measurement by other stations. After the RSs reporting the measurement 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 leaded 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.

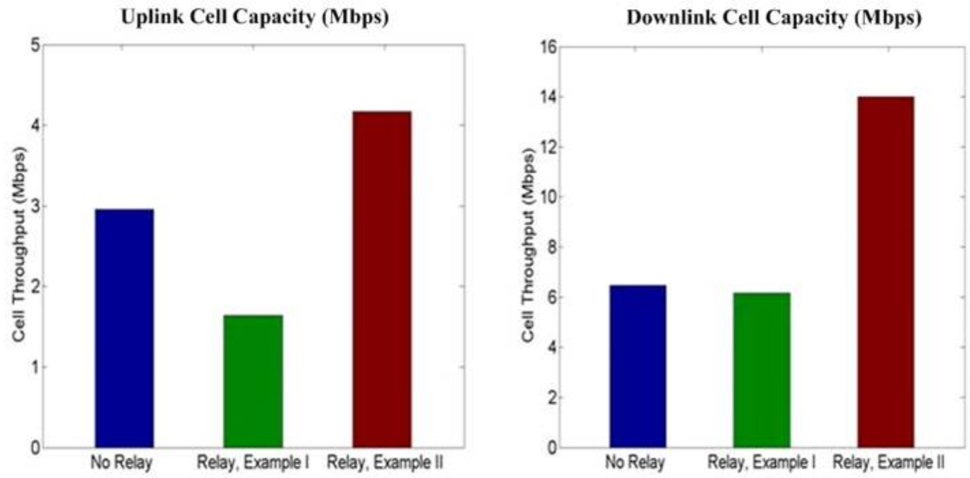

Fig.1 Capacity comparison for different relay scenarios

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?**".

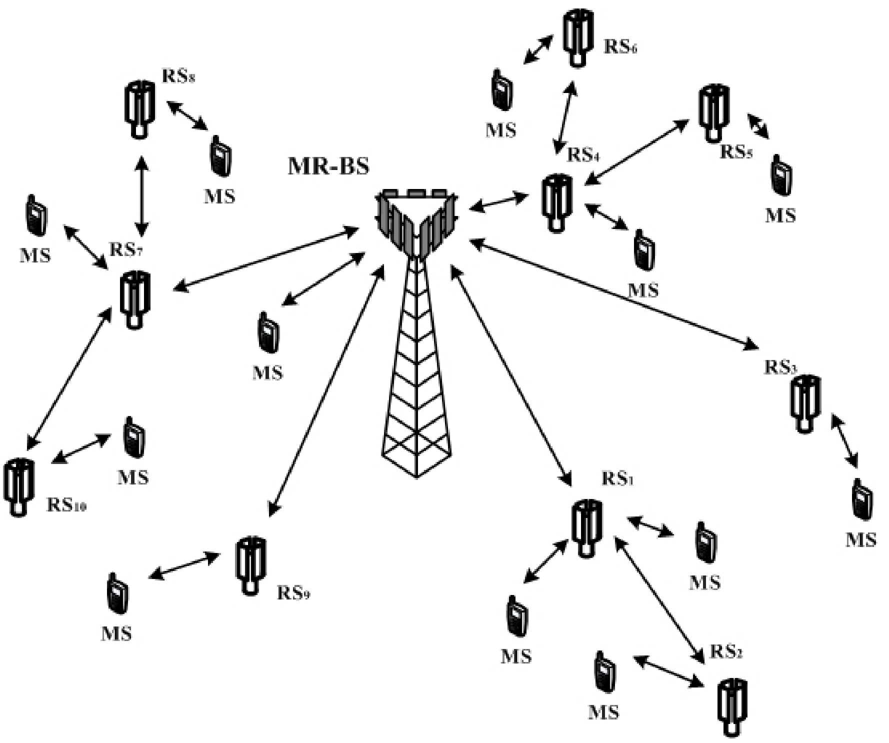

Fig.2 An example of IEEE 802.16j MR network

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.

An alternative method is to configure the MR network in automatic manner, which means that the RSs can detect and measure the radio signal transmitted from each other, and then report the detection and measurement results to MR-BS (or any other controller) to configure the MR network automatically. Therefore, the MR network can be easily managed in response to time variant traffic distribution or other load unbalance situations. For example, the MR-BS may instruct the permutation scheme of RS_3 to be changed from PUSC to FUSC (or assign more segments), so as to increase the capacity over the specific area.

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

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

II. The concept of the neighborhood discovery and measurement mechanism

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

As a specific example as shown in Figure 3, RS_{10}, RS_8, RS_2 and RS_5 are requested to transmit the reference signals by MR-BS, and the rest of other stations will perform the measurement of the those reference signals.

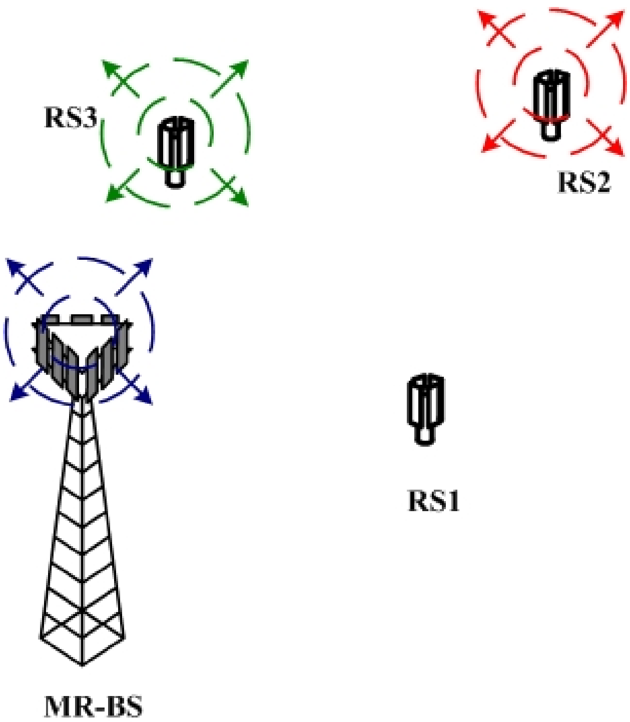

Fig.3 An example of the neighborhood discovery and measurement in MR network

Since the reference signal to be scanned has the same format as 16e preamble, therefore, one possible way to arrange the scanning opportunity is designating multiple stations (i.e. RS_2, RS_3 and MR-BS in Figure 3) transmit its amble over the same time, and ask one RS (i.e. RS_1 in Figure 3) scan those ambles. Therefore, the receiver can identify the transmitter ID and measure the strength if the ambles at the same time.

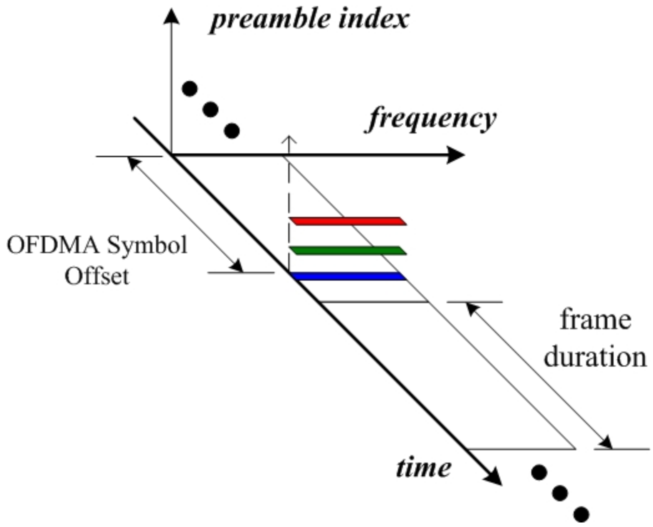

Fig.4 An example to arrange the scanning opportunity over the same OFDMA symbol offset

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

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

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

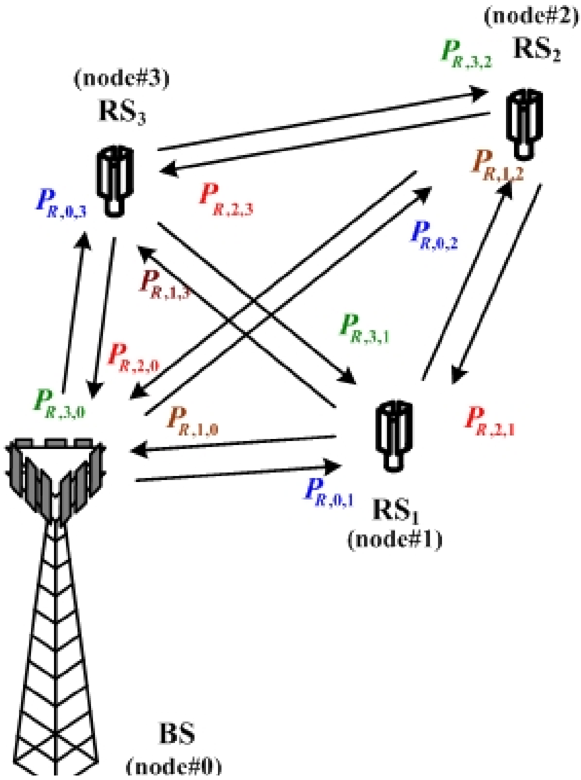

Fig.5 An example to illustrate the interference and SINR prediction

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*.

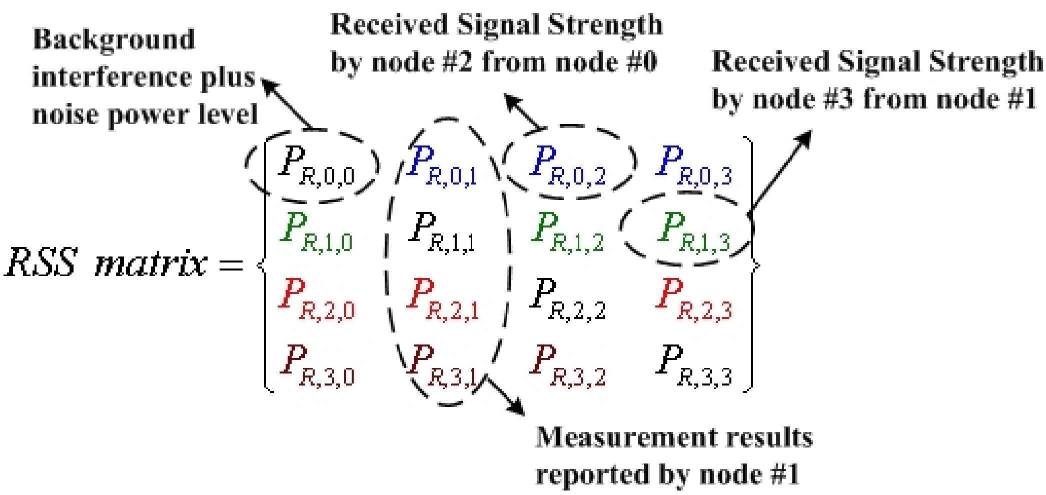

Fig.6 RSS matrix recorded by the MR-BS

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

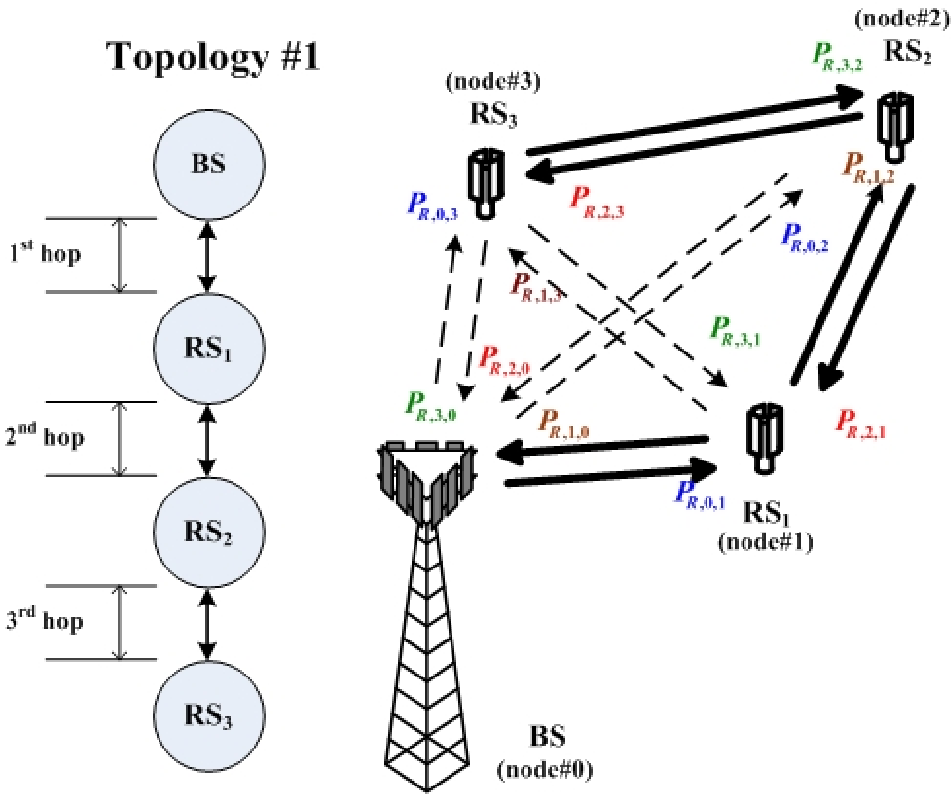

Fig.7 An example for interference and SINR prediction under Topology #1

According to the Topology #1, the interference and SINR prediction of each resource reuse scenario is shown 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" but transmitting "different data", and each station is assumed not able to transmit and receive at the same time. Therefore, $L_{i,j}$ and $L_{x,y}$ will not interfere each other if they are not reuse the same radio resources (i.e. $\{ L_{i,j} \},\{ L_{x,y} \}$). Note that the following prediction results are represented in linear values (not in dB).

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	{ $L_{0,1}$ },{ $L_{1,2}$ },{ $L_{2,3}$ }	*Null*	$\frac{P_{R,0,1}}{P_{R,1,1}}$	$\frac{P_{R,1,2}}{P_{R,2,2}}$	$\frac{P_{R,2,3}}{P_{R,3,3}}$
	{ $L_{0,1}$,$L_{2,3}$ },{$L_{1,2}$ }	*Null*	$\frac{P_{R,0,1}}{P_{R,2,1}+P_{R,1,1}}$	$\frac{P_{R,1,2}}{P_{R,2,2}}$	$\frac{P_{R,2,3}}{P_{R,0,3}+P_{R,3,3}}$
UL	{ $L_{3,2}$ },{ $L_{2,1}$ },{ $L_{1,0}$ }	$\frac{P_{R,1,0}}{P_{R,0,0}}$	$\frac{P_{R,2,1}}{P_{R,1,1}}$	$\frac{P_{R,3,2}}{P_{R,2,2}}$	*Null*
	{ $L_{1,0}$,$L_{3,2}$ },{$L_{2,1}$ }	$\frac{P_{R,1,0}}{P_{R,3,0}+P_{R,0,0}}$	$\frac{P_{R,2,1}}{P_{R,1,1}}$	$\frac{P_{R,3,2}}{P_{R,0,2}+P_{R,2,2}}$	*Null*

Then, consider the second prediction example under the Topology #2, which is shown in Figure 8. In Topology #2, RS_1 and RS_2 are transmitting the same data over the same resource region so that they act like a single station from the receiver's point of view, and they are defined to be within the same cluster (or group) [7] for this example. Therefore, the notation [$L_{i,j}$,$L_{x,y}$] defines that the links $L_{i,j}$ and $L_{x,y}$ are "reusing the same radio resources" and transmitting "**the same**" data over the same resource region, which acts like a virtual station as defined in [8], so that the radio signals of both links are combined over the air from receiver's point of view.

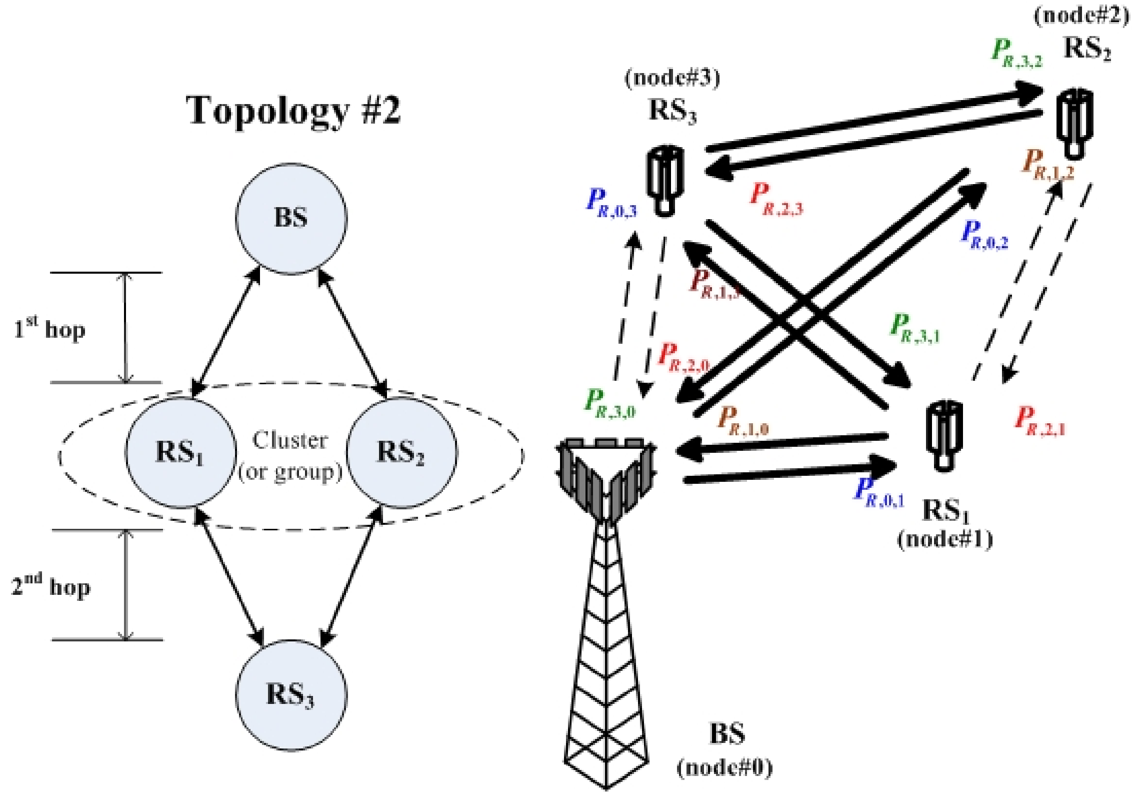

Fig.8 An example for interference and SINR prediction under Topology #2

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 logical link.

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

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

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

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

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

IV. Text proposal

---Start of the text--

Insert new subclause (6.3.2.3.62)

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

The MR-BS can send a RS_NBR-MEAS-REQ message to instruct RS neighborhood discovery and measurement. When an RS receiving this message with NBR_MEAS_MODE=0, it shall measure the reference signal over the designated Frame Number Offset and OFDMA symbol offset, and the message shall be sent with basic CID. When receiving this message with NBR_MEAS_MODE=1, the RS shall transmit the reference signal over the designated Frame Number Offset and OFDMA symbol offset, and the message can be sent with either multicast CID or basic CID. Note that the Report Request TLV is defined in 11.11.

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
Measurement Duration	8 bits	Units are frames
Interleaving Interval	8 bits	Units are frames
Measurement Iteration	8 bits	Units are frames
Frame Number Offset	8 bits	In unit of frames
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++){		
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 {		
OFDMA Symbol Offset	8 bits	The location of the reference signal to be transmitted
}		
}		

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

Measurement Duration
Duration (in units of frames) of the requested neighborhood measurement period

Interleaving Interval
The period (in units of frames) which is interleaved between Measurement Durations

Measurement Iteration
The requested number of iterating measurement interval

NBR_MEAS_MODE
Instruct the RS to transmit (if NBR_MEAS_MODE=1) or measure (if NBR_MEAS_MODE=0) the reference signal over the designated Frame Number Offset and OFDMA symbol offset

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

N_NBR_LIST
Number of neighboring stations in the neighbor list

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

OFDMA Symbol Offset
The location of the reference signal to be transmitted or measured. If NBR_MEAS_MODE is set as 0, RS shall measure the reference signals over each segment at the designated OFDMA symbol offset.

Insert new subclause (6.3.2.3.63)

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

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
}		
}		
}		

N_NBR_LIST
Number of neighboring stations in the neighbor list

The RS_NBR- MEAS -REP shall contain the Report Response TLV (define in 11.11 REP-RSP management message encodings).

Insert a the following text into 6.3.26

6.3.26 Relay station neighborhood discovery

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

The procedure of RS measurement mechanism is described as following:

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

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

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

Insert a new subclause 6.3.27.1

6.3.27.1 Interference prediction by RS neighborhood measurement

In order to predict the potential interference or CINR before assigning the segments or allocating the radio resources, the MR-BS can instruct the RS to measure the reference signals transmitted from other neighbor stations and then report the measurement results to MR-BS. The procedure to perform RS neighborhood measurement can refer to 6.3.26.

Before assigning the segment #*j*, the interference that RS #*i* may potentially received can be predicted by the summation of:

1. The thermal noise power and background interference power.
2. The RSSI of the stations which use the segment #*j* but not transmit data to RS #*i*.

Moreover, the received CINR may be predicted by following criteria:

1. The denominator of the CINR may be the aforementioned interference prediction result.
2. The nominator of the CINR may be the RSSI of the stations which use the segment #*j* and transmit data to RS #*i*.

---End of the text--

V. References

[1] IEEE C802.16j-06/169, "Reusing the Radio Resources in IEEE 802.16j Multi-hop Relay System."

[2] IEEE C802.16j-06/234, "Relay Grouping and PUSC Segment Selection for FCH/MAP Transmission."

[3] IEEE C802.16j-06/148, "Estimation of Initial Interference Matrix."

[4] IEEE C802.16j-06/216, "Relay-Station Power Control and Channel Reuse."

[5] IEEE C802.16j-06/225, “Directional Distributed Relay with Interference Control and Management.”

[6] IEEE C802.16mmr-05/041, “System Performance of Relay-based Cellular Systems in Manhattan-like Scenario.”

[7] IEEE C802.16mmr-06/003, “On the Throughput Enhancement of Fixed Relay Concept in Manhattan-like Urban Environment.”

[8] IEEE C802.16j-06/168, “A RS Clustering Scheme for IEEE 802.16j.”

[9] IEEE C802.16j-06/199, “Relay-Station Preamble Segment Assignment/Re-Assignment scheme.”