Project	IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>
Title	Cooperative RS Transmission Scheme on IEEE 802.16j
Data Submitted	2006-11-14
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Abstract	This document recommends cooperative RS transmission scheme in IEEE 802.16j
Purpose	The contribution is submitted for discussion and adoption in IEEE 802.16j
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Cooperative RS Transmission Scheme on IEEE 802.16j

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1. Introduction

In the mobile multihop relay (MMR) system, the subscriber station (SS)/ mobile station (MS) is possible in the overlap coverage of 2 or more than 2 relay stations (RS). In the meantime, the RSs can also hear from the base station (BS). A cooperative transmission can be established in both uplink and downlink among the RSs, by 'sharing' their antennas in a manner that creates a virtual MIMO system. Then, some of the benefits of MIMO systems can be obtained and the reception performance in both BS and SS/MS can be improved.

In the cooperative virtual MIMO system, it is difficult to achieve perfect synchronization among distributed transmitters. For multiple access MMR system, how many and which RSs should be involved in the cooperative transmission is another key issue to be determined. In this document, a transmission duration based synchronization and SNR based RS selection method is proposed to the cooperative MMR system.

The proposal presented here has the following advantages:

- Realize synchronized transmission among cooperative RSs.
- Balance the received performance and the system capacity.
- No hardware change in MS is required when the proposed cooperative transmission is used.

In this proposal, the relays used for coverage extension are considered. Figure 1 shows the scenario of a cooperative MMR system, where all the stations including RS, MS and SS which are directly connected to BS are synchronized. In other words, we assume that the dual-direction (uplink and downlink) transmission the first hop from BS has been already synchronized, and the uplink synchronization among cooperative RSs is excluded in this proposal. The main aim of this document is to introduce a duration measurement method for downlink transmission, i.e. the cooperative RSs to the destination SS/MS, and then according to all the durations, adjust each cooperative RS's downlink transmission time to make them synchronized to the SS/MS. Another contribution of the document is the cooperative selection scheme according to the received SNR in both BS and SS/MS.

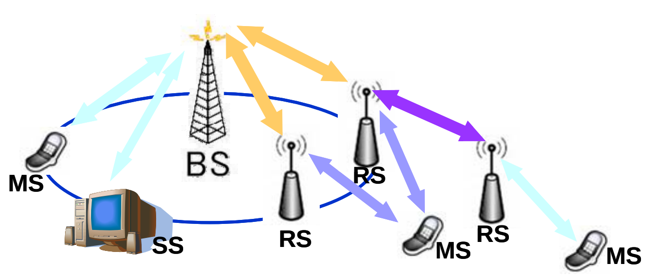

Figure 1. Scenario of cooperative transmission in MMR system

2. Proposed Solution

Figure 2 shows an example of cooperative transmission in the multiple access MMR system. RS 1 relay data packets for MS 1, 2 and 0, and RS 2 also relays for MS 0 except for MS 3 and 4. Thus, RS 1 and RS 2 are cooperative relays for MS 0. In the following part of this chapter, this example will be used for illustration.

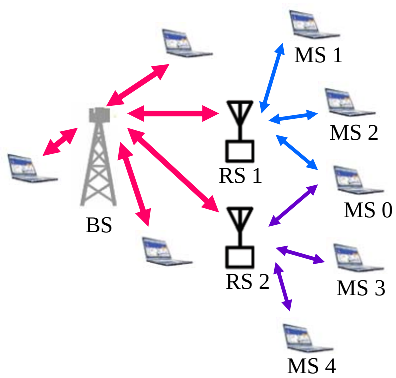

Figure 2. The example of cooperative transmission in the multiple access MMR system

There are totally 4 steps in the cooperative transmission, Connection Step, Selection Step, Information Step and Cooperative Transmission Step.

- **<u>Connection Step</u>**

In the first step, information of the received SNR and transmission delay of all possible relay nodes is gathered by BS. Specifically,

① According to the requested QoS of the destination MS/SS, BS adds a cooperative indicator (CI) into the downlink MAP to initiate a cooperative connection, and transmits a downlink control packet.

② RS i forwards the downlink control packet to MS/SS at T_{i0}

③ MS/SS records the received time of the packet from each RSi as T_{i1}, and measures its received SNR_{i1}

④ MS/SS sends RS i back a uplink control packet at T_{i2} including SNR_{i1},$(T_{i2}$-$T_{i1})$

⑤ RS i records the received time from MS/SS as T_{iE}

⑥ RS i forwards BS the packet by adding information of $(T_{iE}$ -$T_{i0})$

⑦ BS measures the received SNR_{i2}

After gathering all the information, BS calculates the transmission duration from any possible relay node RS i to the destination MS/SS (in figure 2 is MS 0), $Delay_{i1}$ as

$$Delay_{i1} = \frac{(T_{iE} - T_{i0}) - (T_{i1} - T_{i2})}{2} \qquad (1)$$

Here, CI is suggested to use 2 bits to denote. (00: No; 11: Yes; 01 and 10 are reserved)

The frame content illustration in connection step based on frame structure proposed in [1] is in figure 3.

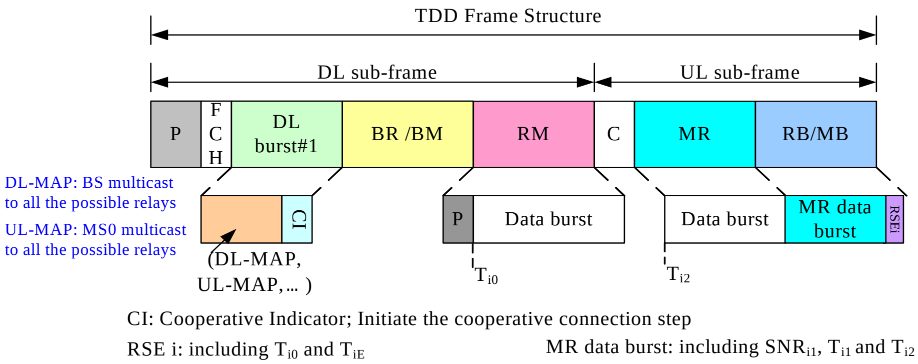

Figure 3. The example of frame content in connection step

- **Selection Step**

In the second step, BS makes decision on whether cooperative transmission will be executed and which relay nodes are involved in the transmission according to the received SNR information gathered in the first step. The selection step includes two sub steps.

① initial selection

Initial select all the RSs that can satisfy the following condition

$$\begin{cases} SNR_{i1} \geq A * S_1 \\ SNR_{i2} \geq A * S_2 \end{cases} \quad 0 < A < 1 \tag{2}$$

where $S_1 = \max(SNR_{i1})$ $S_2 = \max(SNR_{i2})$, and A is a parameter to balance the spectrum efficiency cost and the performance improvement and A is suggested to be 0.3. If the received power difference among the cooperative RSs is huge, the performance improvement is then slight. Thus, it is not worthy scarifying the system capacity to conduct cooperative transmission. In that case, only one RS or even no RS satisfies equation (2), and cooperative relay transmission will NOT conduct then. When there is only one RS satisfies (2), the one will be selected as the relay station of the destination MS/SS; when there is no relay satisfies (2), the RS with largest joint SNR will be finally selected. The joint SNR of RSi J_i is defined as

$$J_i = \frac{SNR_{i1}}{S_1} * \frac{SNR_{i2}}{S_2} \tag{3}$$

We assume that in initial selection, N_I RSs are selected. If N_I exceeds a threshold N_R, the final selection step should be done to re-select N_R RSs out of the N_I.

② final selection

The N_R RSs with largest joint SNR which is defined in equation (3) are finally selected. N_R is another parameter to further balance the overall spectrum efficiency and the received performance of a dedicated user. Here, we suggest that N_R equals 2.

- **Information Step**

After selection step, when more than 1 RSs are selected as cooperative relay stations, BS will calculate the adjust transmission delay for each RS according to all cooperative RSs' transmission duration $Delay_{i1}$ obtained in connection step.

$$D = \max(Delay_{i1}) \tag{4}$$

Without loss of generation, as shown in figure 2, we assume 2 RSs, RS 1and RS 2 are selected as the cooperative RS, and $D = Delay_{11}$. The adjust delay of RS 1is 0 and the delay of RS 2 is $Delay_{11} - Delay_{21}$. And then, all the cooperative RSs are informed with an adjusting table to retract their downlink transmission timing to be synchronized in the cooperative transmission.

Table 1 Adjusting Table

RS ID	Destination MS/SS ID	Total Num. of RS	Order of the RS	Adjust delay i1

where 'Total Num. of RS' and 'Order of the RS' are used for Space Time Code (STC) allocation to form a virtual MIMO transmission among all cooperative RSs. In each of the RS there is a common code book containing STCs with different total number of antennas. The RS firstly finds the set of STC according to 'Total Num. of RS', and then decides the allocated code according to 'Order of the RS'.

- **Cooperative Transmission Step**

In the last step, the cooperative RSs relay the packet using the dedicated STC according to the "adjust delay" in both uplink and downlink transmission. And on the receiver side, all the signals from different

Figure 4 shows an example of frame content in transmission step. And in figure 5 and 6, further illustration is shown for frequency division multiplexing (FDM) and time division multiplexing (TDM), respectively.

Figure 7 shows the whole message flow for cooperative relay transmission. The flow starts from connection step to transmission step.

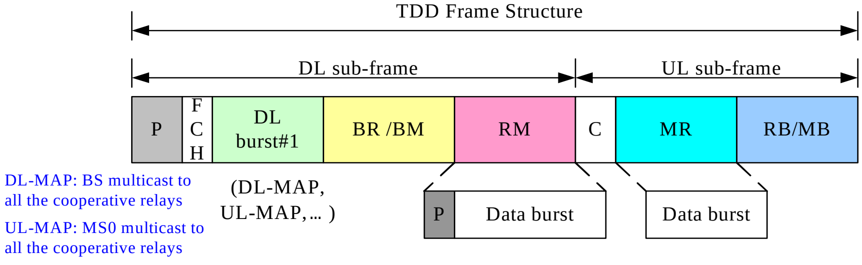

Figure 4. The example of frame content in transmission step

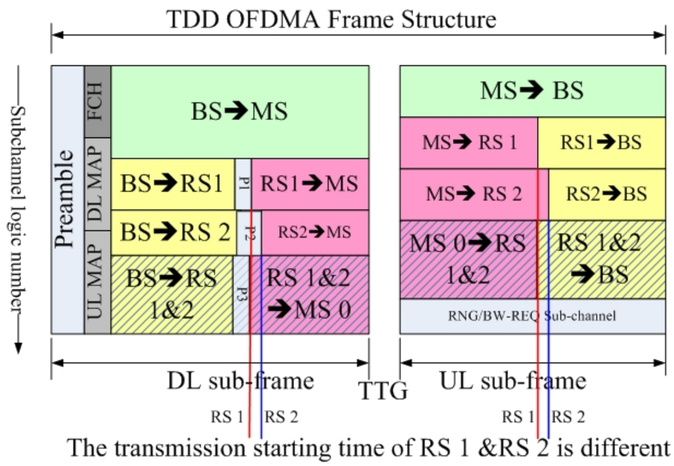

Figure 5. The example of frame content in transmission step for FDM

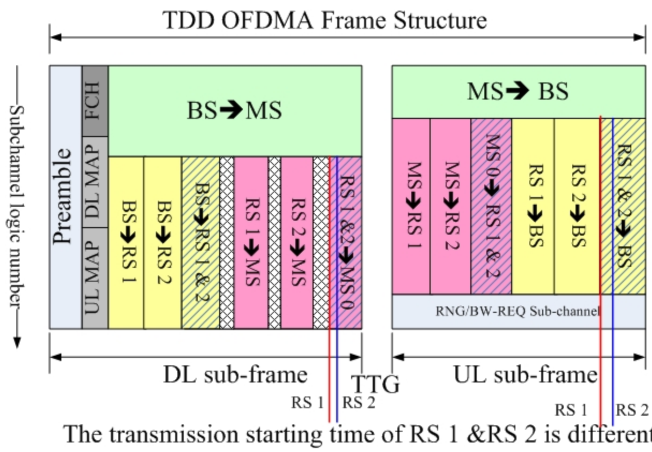

Figure 6. The example of frame content in transmission step for TDM

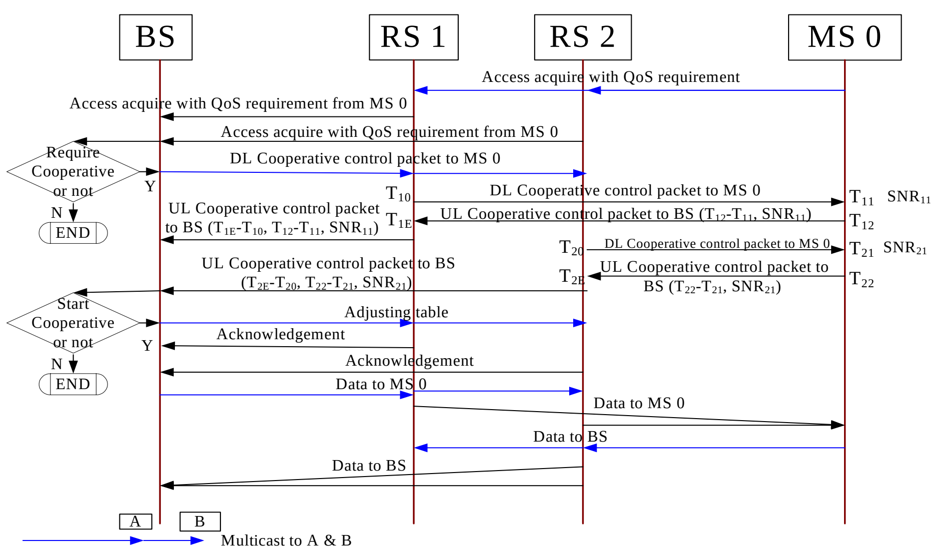

Figure 7. Message Flow for cooperative RS transmission in the MMR system

3. Proposed Text

Chanege the text in Table 13b in subsection 6.3.2.2.7 as indicated:

Table 13b—Description of extended subheaders types (DL)

ES type	Name	ES body size	Description
0	SDU_SN extended subheader	1 byte	See 6.3.2.2.7.1
1	DL Sleep control extended subheader	3 bytes	See 6.3.2.2.7.2
2	Feedback request extended subheader	3 bytes	See 6.3.2.2.7.3
3	SN request extended subheader	1 byte	See 6.3.2.2.7.7
4	PDU SN(short) extended subheader	1 byte	See 6.3.2.2.7.8
5	PDU SN(long) extended subheader	2bytes	See 6.3.2.2.7.8
6	Cooperative Control Packet subheader	1 byte	See 6.3.2.2.7.9
7	RS Adjusting Table subheader	1 byte	See 6.3.2.2.7.10
8–127	*Reserved*	—	—

Chanege the text in Table 13c in subsection 6.3.2.2.7 as indicated:

Table 13c—Description of extended subheaders types (UL)

ES type	Name	ES body size	Description
0	SDU_SN extended subheader	1 byte	See 6.3.2.2.7.1
1	DL Sleep control extended subheader	3 bytes	See 6.3.2.2.7.2
2	Feedback request extended subheader	3 bytes	See 6.3.2.2.7.3
3	SN request extended subheader	1 byte	See 6.3.2.2.7.7
4	PDU SN(short) extended subheader	1 byte	See 6.3.2.2.7.8
6	Cooperative Control Packet subheader	1 byte	See 6.3.2.2.7.9
7	RS Acknowledgement subheader	1 byte	See 6.3.2.2.7.11
5, 8–127	*Reserved*	—	—

Insert new subclause 6.3.2.2.7.9:

6.3.2.2.7.9 Cooperative Control Packet subheader

In downlink, initiate the cooperative connection; in uplink, convey the transmission duration and received SNR information. The value of 11111111 in the downlink Cooperative Control Packet subheader indicates that cooperative control packet is contained in the frame. Other values are reserved. The uplink Cooperative Control Packet subheader indicates the length of the uplink cooperative control packet. The payload of the uplink Cooperative Control Packet is described in figure XX1.

1 byte	1 byte	3~6 bytes	2 bytes	2 bytes
SID	RSID	SNR	PST	RSE

Figure XX1. Payload of the uplink Cooperative Control Packet

SID: Source MS/SS ID

RSID: ID of the possible RS

SNR: Received SNR in the source MS/SS of the downlink Cooperative Control Packet relaying by the relay with RSID

PST: ProceSsing Time in the source MS/SS, i.e. the uplink transmission time minus the downlink received time, with the unit of ns.

RSE: ReServed for Enhance. This part is written by the relay with RSID. And the content is the round time of the relay, i.e. the uplink received time minus the downlink transmission time, with the unit of ns.

Insert new subclause 6.3.2.2.7.10:

6.3.2.2.7.10 RS Adjusting Table subheader

The uplink RS Adjusting Table subheader indicates the length of the RS Adjusting Table packet. The payload of the uplink RS Adjusting Table Packet is described in figure XX2.

1 byte	1 byte	1 byte	1 byte	2 bytes		1 byte	1 byte	2 bytes
DID	NRS	RSID 1	SN 1	AD1	...	RSID N	SN N	AD N

Figure XX2. Payload of the RS Adjusting Table Packet

DID: Destination MS/SS ID

NRS: Number of RS; indicates the total number of RSs involved in the cooperative transmission

RSID i: indicates the ID of i-th cooperative RS

SN i: indicates the code index of STC assigned to i-th cooperative RS

AD i: indicates the transmission retraction time of i-th cooperative RS, with the unit of ns.

Insert new subclause 6.3.2.2.7.11:

6.3.2.2.7.11 RS Acknowledgement subheader

The value of 11111111 in the RS Acknowledgement subheader indicates that RS Acknowledgement is contained in the fr ame. Other values are reserved.

4. Reference

[1] C80216mmr-05_005r2, A Recommendation on PMP Mode Compatible Frame Structure