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Title	**Cooperative Relaying in Downlink for IEEE 802.16j**
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Re:	Call for Technical Proposals regarding IEEE Project P802.16j.
Abstract	The document contains technical proposals for IEEE P802.16j that provides cooperative diversity in relay downlink.
Purpose	This is a response to Call for Technical Proposals regarding IEEE Project P802.16j.
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Cooperative Relaying in Downlink for IEEE 802.16j

1 Introduction

In general, a single time-frequency resource within a frame is assigned to one RS in relay downlink to MS as shown in figure 1. While a relay station is transmitting a packet, other stations cannot transmit using the same time-frequency resource. But, if the transmission timing differences from multiple signal sources are within a CP period, an OFDMA system, which is robust in multi-path channel environment, can take advantage of the signal arrivals from multiple sources to obtain diversity gain. In cooperative relay transmission, by allowing a set of multiple signal sources to transmit using the same time-frequency resource, where the set of signal sources may be composed of a combination of RSs and MMR-BS, we can achieve cooperative diversity gain to improve the performance of the relay network.

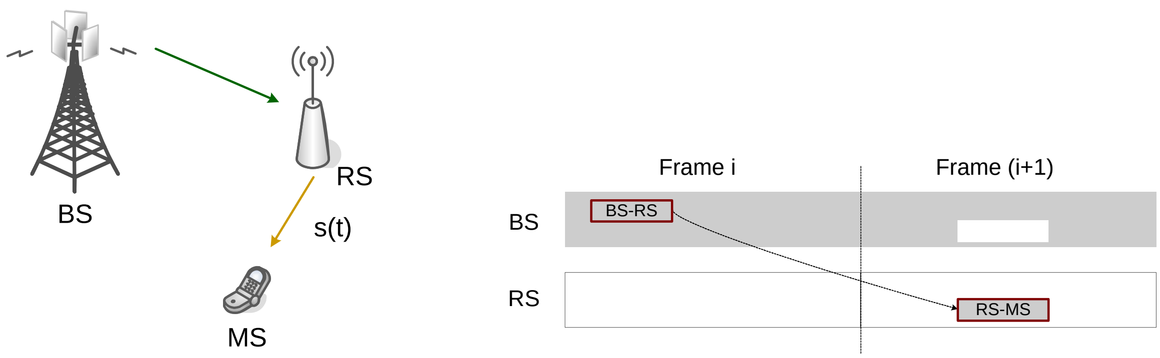


Figure 1. Example of general relay transmission

This contribution proposes to allow virtual MIMO using relay stations by using space-time block codes. For rate 1 codes, using existing modulation methods, there is no increase in backhaul communication compared with standard relaying techniques. By implementing STBCs across different physical transmitting stations, it is possible to achieve diversity.

For this proposal we focus on the rate one codes in 802.16-2004[1]/802.16e-2005[2], such as code A in Sections 8.4.8.1.4, 8.4.8.3.3 for 2 transmit antennas, and code A in Sections 8.4.8.2.3, 8.4.8.3.5 for 4 transmit antennas.

The concept of virtual MIMO has been discussed in previous contributions such as [3]. Virtual MIMO can achieve the following advantages:

- Low complexity and ease of implementation
- Reuse of existing techniques in legacy standard
- Increase in performance (diversity) without sacrificing bandwidth

The following must be ensured:

- Synchronization between RS is imperative to prevent ISI
- For STBC use, power balance (at the receiver) is required for best performance

2 Proposed Solution

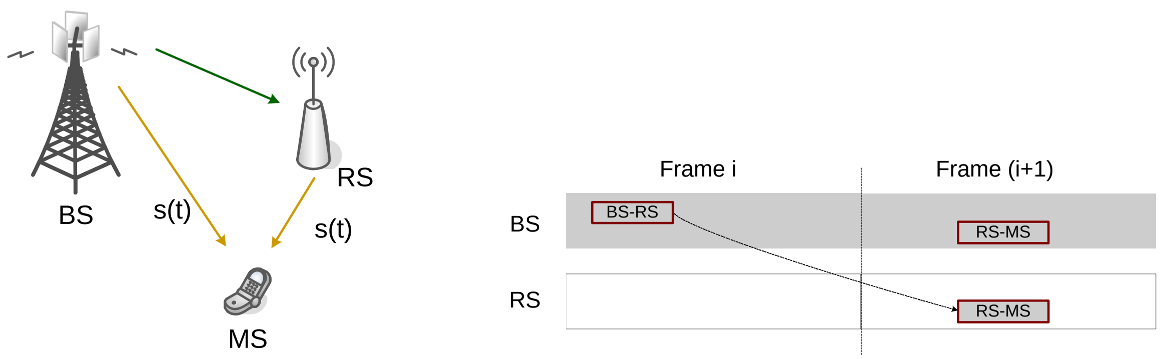
We propose three cooperative diversity schemes:

- Cooperative source diversity: Multiple signal sources simultaneously transmit the *same* signal using the same time-frequency resource.

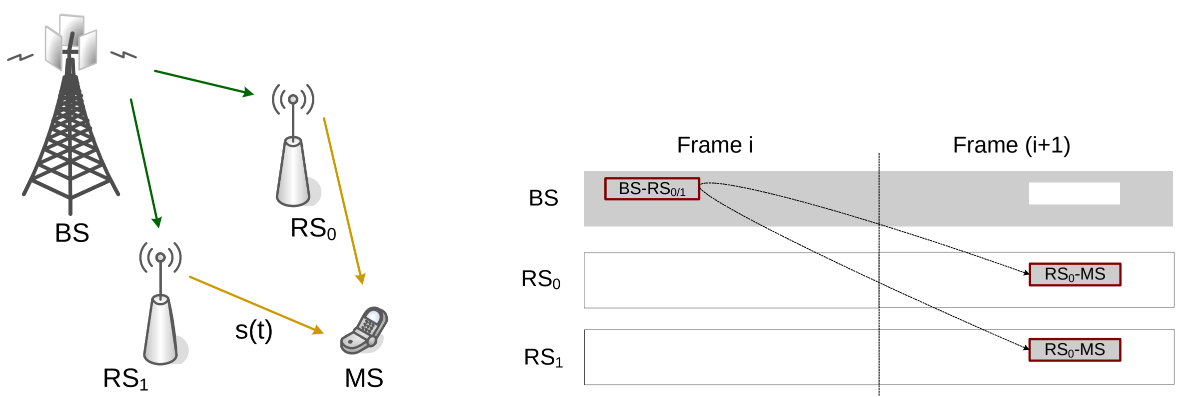
- Cooperative transmit diversity: Multiple signal sources simultaneously transmit *space-time encoded* signals using the same time-frequency resource.
- Cooperative hybrid diversity: A combined diversity scheme of the cooperative source and cooperative transmit diversity.

2.1 Cooperative source diversity

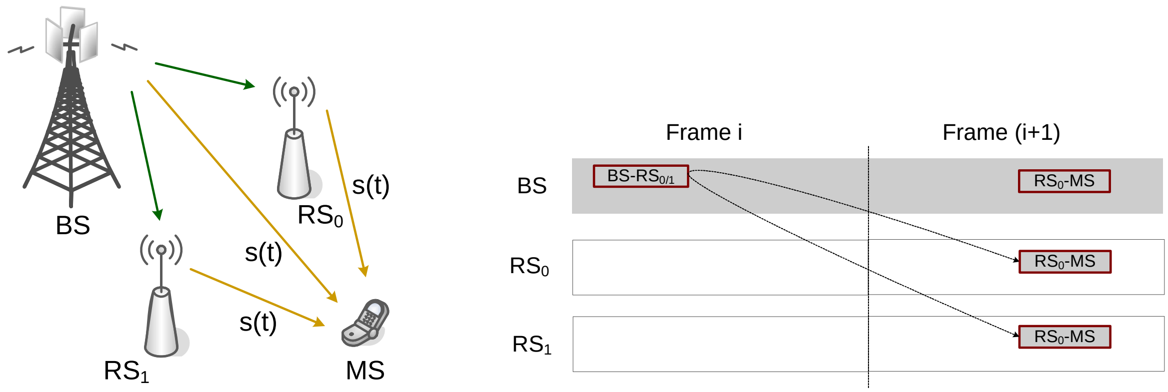
Figure 2 shows examples of cooperative source diversity. In figure 2(a), diversity gain will be obtained by combining the relay transmission from the RS and the transmission from the MMR-BS transmitted using the same time-frequency resource. Figure 2(b) illustrates a source diversity scheme, where multiple RSs transmitting at the same time using the same time-frequency resource. Figure 2(c) describes an example of cooperative source diversity, where signals from two RSs and an MMR-BS are combined. Figure 3 shows the simulation results of BER performance for the example shown in Fig. 2(a). In the simulation, we assumed that the signals arriving at the MS are of the same power, and that the SNR on the relay link is 30 dB. The channel model used in the simulation was SUI-4 model. The signal was transmitted using QPSK modulation with 1/2 convolution code. The same simulation environment was assume for all simulations in this document.



(a) Usage of BS and RS transmit source



(b) Usage of multiple transmit source of RSs



(c) Usage of multiple transmit source of BS and RSs

Figure 2. Example of cooperative source diversity

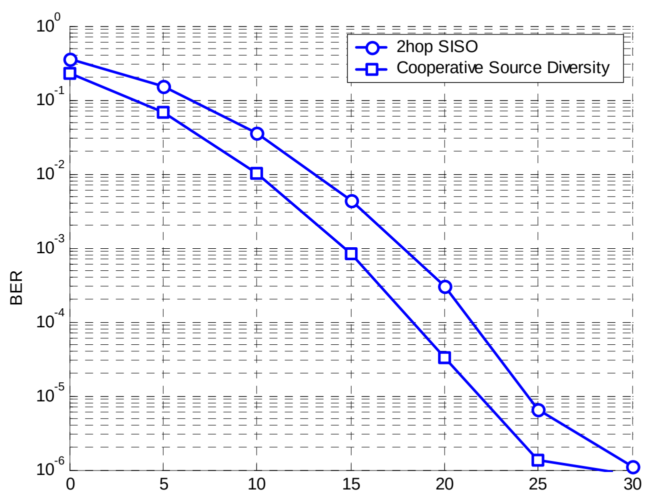


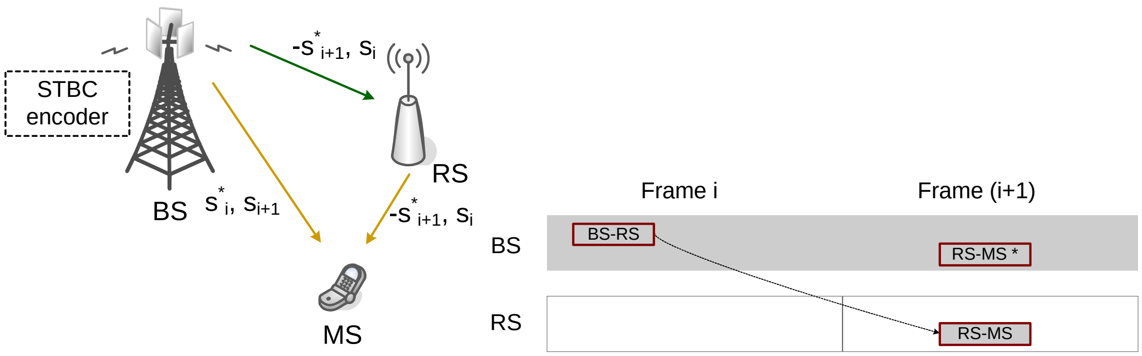
Figure 3. Simulation result of Figure 3(a).

Assumption: 1. Received signal powers from sources are same.

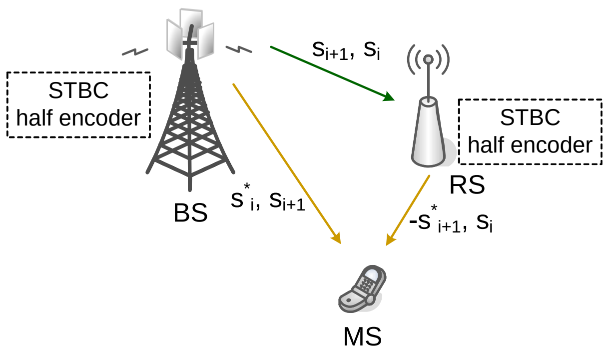
2. SNR of BS-RS is 30dB

2.2 Cooperative transmit diversity

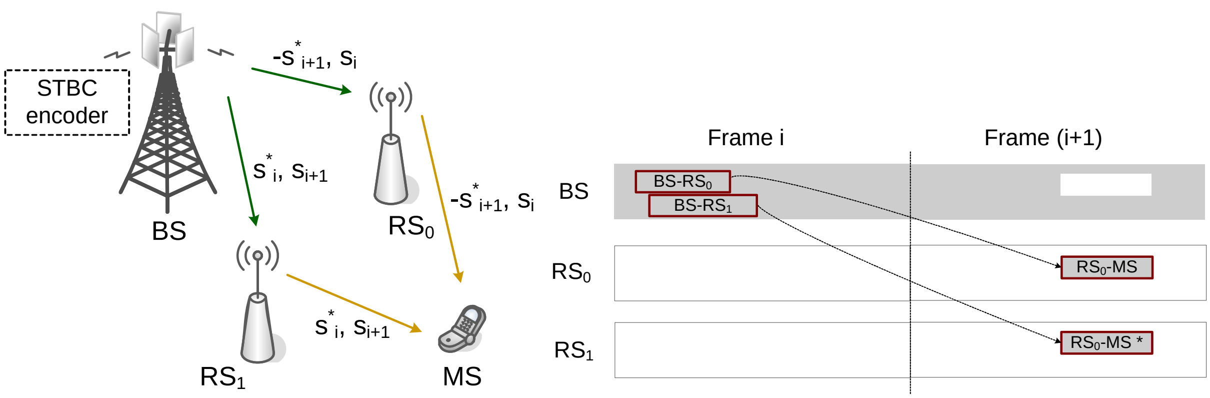
The proposed method is based on MS supporting transmit diversity using STBC. The transmit structures of the cooperative transmit diversity and the cooperative source diversity are identical. However, in the cooperative transmit diversity scheme, the received signals from different sources are different, each signal source playing the role of different transmit antenna in the conventional STBC. If the STBC encoding is performed at the MMR-BS, the RSs simply need to relay the packets. However, if the STBC encoding is performed at the RSs, the channel utilization will be more efficient because the MMR-BS needs to transmit the packet only once in the example illustrated in Fig. 4(d). Figure 5 shows the simulation results of the BER performance of the examples shown in Fig. 4(a) and (b). These examples use rate-1 codes for two transmit antennas (Code A in Sections 8.4.8.1.4, 8.4.8.3.3 in the standard [1,2].



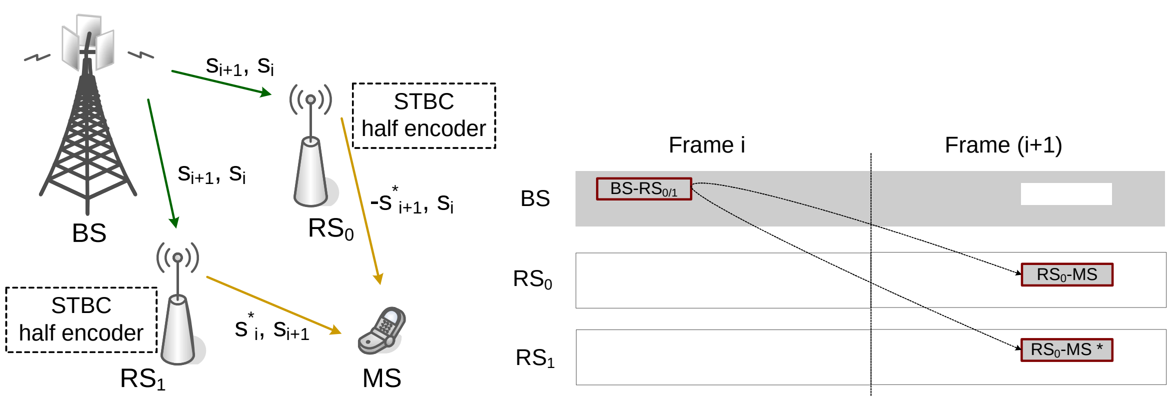
(a) Usage of BS and RS transmit source – full encoding in BS



(b) Usage of BS and RS transmit source – partial encoding in BS and RS



(c) Usage of multiple transmit source of RSs – full encoding in BS



(d) Usage of multiple transmit source of RSs – partial encoding in BS and RS

Figure 4. Examples of cooperative transmit diversity

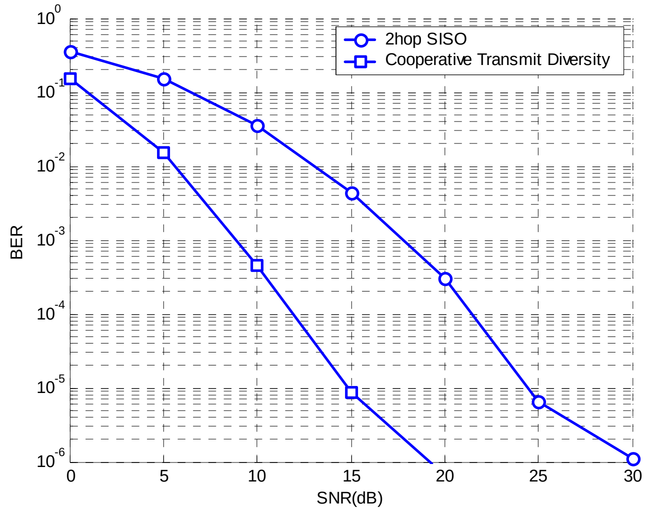


Figure 5. Simulation result of Figure 5(a)(b).

Assumption: 1. Received signal powers from sources are same.

2. SNR of BS-RS is 30dB

2.3 Cooperative hybrid diversity

In case of multiple signal sources, the two cooperative relaying schemes can be combined. If the number of signal sources are greater than the number M in a Mx1 STBC scheme, multiple signal sources can transmit the same STBC encoded signal to implement an Mx1 STBC scheme. Figure 6 shows an example of this hybrid cooperative source and transmit diversity scheme, where three signal sources are cooperating to perform rate-1 space-time coding with two transmit antennas. Figure 7 shows the simulation results of the BER performance of the examples shown in Fig. 6.

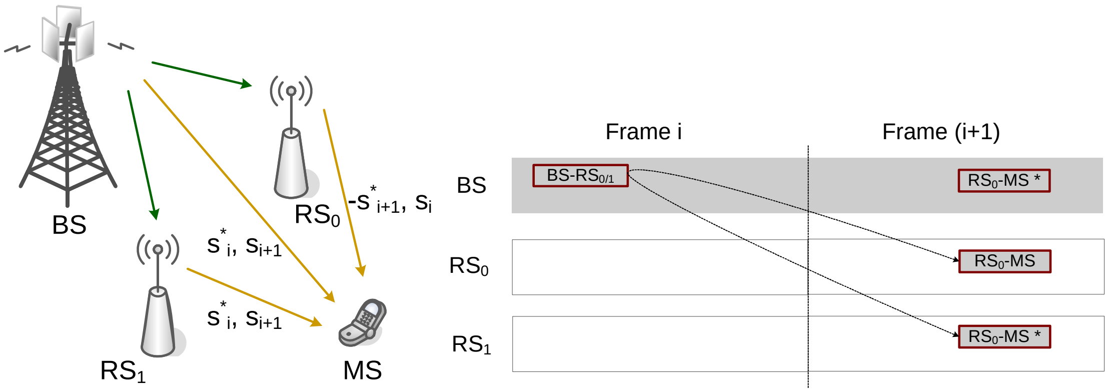


Figure 6. Example of cooperative joint diversity

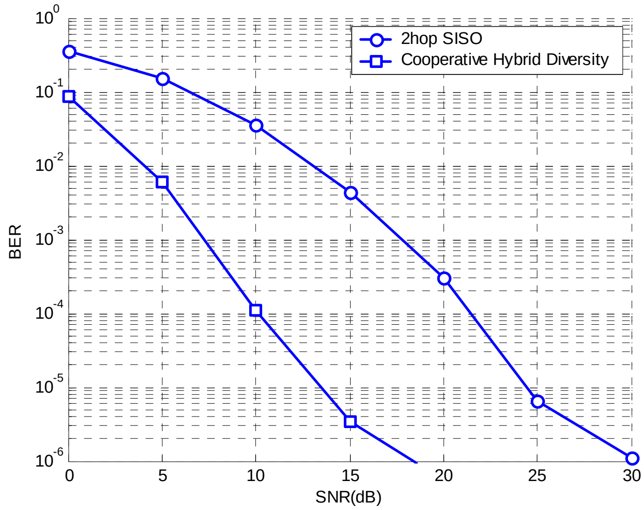


Figure 7. Simulation result of Figure 6.

Assumption: 1. Received signal powers from sources are same.

2. SNR of BS-RS is 30dB

2.4 Use of other space-time codes

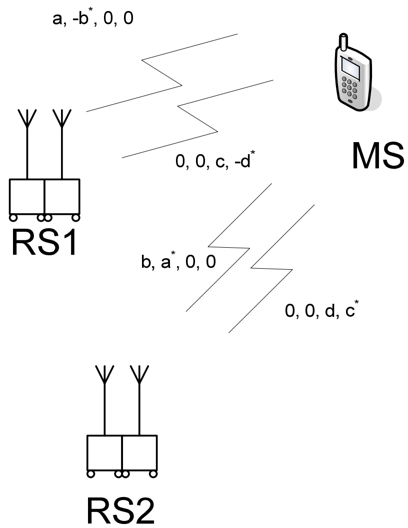


Figure 8. Example of cooperative relaying using rate-1 code for four transmit antennas.

The previous examples use the Rate-1 transmit diversity codes for two transmit antennas. It is possible to use other rate-1 codes, such Code A in Sections 8.4.8.2.3, 8.4.8.3.5 in the standard [1,2]. This can be used in cells with four single-antenna transmitters, or two dual-antenna transmitters, for example. For this particular code, only two transmit antennas are on at any given time. This contribution proposes to have these active antennas in separate locations. Since a rate-1 code is used, the resources for the backhaul does not increase if compared to the standard relaying mechanism. Multiple RSs can listen to these transmit antennas during the backhaul.

It is possible to use other, higher-rate codes. However, there is a tradeoff between the resources required for the backhaul links, the rate achieved by the forward link to the MS, and the performance (packet error rate) of these links.

3. Text Proposals

6.3.2.3 MAC Management messages

[Change Table 14 as indicated]

67	RS-CDC	Cooperative diversity configuration for RS message	basic
~~67~~68-255		*Reserved*	–

[Insert new subclause 6.3.2.3.62]

6.3.2.3.62 Cooperative diversity configuration for RS (RS-CDC) message

An RS-CDC is sent by a MR-BS to an RS to configure the cooperative diversity mode.

Table 109z—RS-CDC message format

Syntax	Size	Notes
RS-CDC_Message_Format() {		
Management Message Type=67?	8 bits	
Transmit Diversity	2 bits	0b00=No Transmit Diversity 0b01=STC using 2 antennas 0b10=STC using 4 antennas 0b11=FHDC using 2 antennas
Matrix Indicator	2 bits	Antenna STC/FHDC matrix (see 8.4.8) 0b00=Matrix A 0b01=Matrix B 0b10=Matrix C (applicable to 4 antennas only) 0b11=No encoding (applicable to source diversity only)
Antenna Assignment	4 bits	Bit#0: Antenna #0 Bit#1: Antenna #1

		Bit#2: Antenna #2 Bit#3: Antenna #3
}		

An MR-BS shall generate RS-CDC message in the form shown in Table 109z, including the following parameters:

Transmit Diversity

Indicates the cooperative relaying mode to be used.

Matrix Indicator

Indicates the STC matrix for cooperative relaying.(see 8.4.8.1.4)

Antenna Assignment

Indicates which antenna the corresponding RS should play the role of. For example, if this field is a 0b1000, the relay station shall be playing the role of Antenna #0. As another example, in case the RS has two antennas and this field is 0b1100, each antenna of the RS shall be playing the role of Antenna #0 and #1, respectively.

[Insert new subclause 8.4.8.10]

8.4.8.10 Cooperative Relaying

Cooperative relaying can be achieved within an MR-BS cell with BS and RS transmit cooperation, in the same manner as macro diversity with neighboring BS. It is possible to achieve spatial and time diversity by sending correlated signals across different BS and RS transmit antennas during the transmission of a burst to a particular MS. The three modes of operation are cooperative source diversity, cooperative transmit diversity, and cooperative hybrid diversity.

In the following description, the transmission considered is the final transmission from the multiple antennas at the BS/RS to the MS. For cooperative source diversity, the antennas simultaneously transmit the same signal using the same time-frequency resource. The cooperative transmit diversity mechanism uses STBC-encoded signals across the transmitting antennas using the same time-frequency resource (refer to Section 8.4.8 for a list of valid STBCs). Cooperative hybrid diversity uses a combination of source and transmit diversity.

These mechanisms can each be further subdivided into two categories describing the processing requirement at the RS. The relayed data at the RS may not require processing (during the backhaul hop, the BS transmits the exact signals for the RS to relay). Alternately, the relayed data at the RS may require some local processing (the backhaul hop contains uncoded data, and the RS decodes and re-encodes the data according to the STBC in use). In this last category, each RS shall be notified of its virtual antenna number(s).

4. References

[1] IEEE 802.16-2004, “Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems”.

[2] IEEE 802.16e-2005, “Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1”.

[3] IEEE C802.16j-06/006r1, “Cooperative Relay in IEEE 802.16j MMR”.