Cooperative RS Transmission Scheme on IEEE 802.16j

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This proposal is submitted for discussion and adoption in IEEE802.16j

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Cooperative RS Transmission Scheme on IEEE 802.16j

DoCoMo Beijing Labs

Nov. 2006
Introduction

• Cooperative transmission can increase network capacity by using distributed MIMO technologies

• The key problems to implement cooperative transmission in the MMR system
  – How to deal with asynchrony among the transmission from cooperative RSs to the SS/MS
  – How to determine which and how many RSs involved in the cooperative transmission
Using the proposed method, RS1 and RS2 cooperatively communicate with BS and MS 0.

Simultaneously, RS1 also relays for MS1 and MS2; RS2 also relays for MS3 and MS4.

Both BS \(\rightarrow\) RSs and RSs \(\rightarrow\) BS transmissions are synchronized during the registration period.

Directly connected to BS

Connected to RS1

Connected to RS2
Proposed Cooperative RS Transmission

Step 1 (Connection Step):
- Gather information of the received SNR and transmission delay of all possible relay nodes
  1. In the downlink sub-frame add a cooperative indicator (CI)
  2. $\text{RS}_i \rightarrow \text{MS/SS}$ forward the packet at $T_{i0}$
  3. MS/SS records the received time from each $\text{RS}_i$, $T_{i1}$, and measures the received $\text{SNR}_{i1}$
  4. MS/SS $\rightarrow \text{RS}_i$ sends back a control packet at $T_{i2}$ including $\text{SNR}_{i1}, (T_{i2} - T_{i1})$
  5. $\text{RS}_i$ records the received time $T_{iE}$
  6. $\text{RS}_i \rightarrow \text{BS}$ forwards the packet adding $(T_{iE} - T_{i0})$
  7. BS measures the received $\text{SNR}_{i2}$

$$\text{Delay } i1 = \frac{[(T_{iE} - T_{i0}) - (T_{i2} - T_{i1})]}{2}$$

CI: suggested to use 2 bits. (00: No; 11: Yes; 01 and 10 are reserved)
Proposed Cooperative RS Transmission

Step 2 (Selection Step):

- BS makes decision on whether cooperative transmission will be executed and which relay nodes are involved in the transmission

i. Initially select all the RSs that can satisfy

\[
S_1 = \max(SNR_{i1}) \quad S_2 = \max(SNR_{i2})
\]

If the number of RSs selected in i. step exceeds a threshold \(N_R\)

ii. Only \(N_R\) RSs with largest \(J_i\) are finally selected

\[
J_i = \frac{SNR_{i1}}{S_1} \times \frac{SNR_{i2}}{S_2}
\]

A is suggested to be 0.3; \(N_R\) is suggested to be 2
Proposed Cooperative RS Transmission

Step 3 (Information Step):
- All the selected relay nodes are informed with an adjusting table to adjust their downlink transmission timing to be synchronized in the cooperative transmission.

<table>
<thead>
<tr>
<th>Table 1. Adjusting Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS ID</td>
</tr>
</tbody>
</table>

Step 4 (Cooperative Transmission Step):
- More than 1 RSs are used for the transmission between the BS and the dedicated MS. Cooperative transmission is in both uplink and downlink.

Assume \( Delay_{i1} \leq Delay_{i2} \), Adjust delay \( i1 = Delay_{i2} - Delay_{i1} \)

\[ Adjust \ delay \ i2 = 0 \]
Message Flow in Cooperative RS Transmission

BS

Access acquire with QoS requirement from MS 0

Require Cooperative or not

Y

UL Cooperative control packet to BS (T₁₁, T₁₂, T₁₁, SNR₁₁)

Adjusting table

Acknowledgement

Data to MS 0

Data to BS

A

Multicast to A & B

RS 1

Access acquire with QoS requirement from MS 0

T₁₀

DL Cooperative control packet to MS 0

UL Cooperative control packet to BS (T₂₁, T₂₂, T₂₁, SNR₂₁)

Acknowledgement

Data to MS 0

RS 2

Access acquire with QoS requirement from MS 0

T₁₁

DL Cooperative control packet to MS 0

T₁₂

UL Cooperative control packet to BS (T₁₂, T₁₁, SNR₁₁)

T₂₀

DL Cooperative control packet to MS 0

T₂₁

UL Cooperative control packet to BS (T₂₂, T₂₁, SNR₂₁)

T₂₂

MS 0

Data to MS 0

Data to BS

END

END

N

N
Packet Format in Cooperative RS Transmission

Generic MAC header format

- **HT** = 0 (1)
- **EC** (1)
- **Type** (6)
- **ESF** (1)
- **CI** (1)
- **EKS** (2)
- **RSV** (1)
- **LEN MSB** (3)
- **LEN LSB** (8)
- **CID MSB** (8)
- **CID LSB** (8)
- **HCS** (8)

**ESF**: Extended subheader field.
If **ESF** = 0, the extended subheader is absent.
If **ESF** = 1, the extended subheader is present and will follow the GMH immediately.

**ESF** is used to indicate DL cooperative control packet/ UL cooperative packet / DL RS Adjusting table/ UL RS acknowledgement

Extended subheader group format

- **Extended subheader group length** (8 bits)
- **Rsv=0** (1 bit)
- **Extended subheader type I** (7 bits)
  - **Extended subheader body 1** (variable length)
  - **Rsv=0** (1 bit)
  - **Extended subheader type II** (7 bits)
    - **Extended subheader body 2** (variable length)
    - **Rsv=0** (1 bit)
    - **Extended subheader type n** (7 bits)
      - **Extended subheader body n** (variable length)
Packet Format in Cooperative RS Transmission

Table 1 Description of extended subheaders types (DL)

<table>
<thead>
<tr>
<th>ES type</th>
<th>Name</th>
<th>ES body size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>cooperative control packet</td>
<td>1 byte</td>
<td>All reserved</td>
</tr>
<tr>
<td>7</td>
<td>RS Adjusting table</td>
<td>1 byte</td>
<td>Indicate the payload length in bytes</td>
</tr>
</tbody>
</table>

Payload of RS Adjusting table

```
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
```

DID: Destination MS/SS ID  
NRS: Number of RS  
RSID i: i-th cooperative RS ID  
SN i: index of STBC assigned to i-th cooperative RS  
AD i: Retract transmission time of i-th cooperative RS (unit ns)
Packet Format in Cooperative RS Transmission

<table>
<thead>
<tr>
<th>ES type</th>
<th>Name</th>
<th>ES body size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>cooperative control packet</td>
<td>1byte</td>
<td>Indicate the payload length in bytes</td>
</tr>
<tr>
<td>7</td>
<td>RS Acknowledgement</td>
<td>1byte</td>
<td>All reserved</td>
</tr>
</tbody>
</table>

**Payload of cooperative control packet**

1 byte 1 byte 3–6 bytes 2 bytes 2 bytes

<table>
<thead>
<tr>
<th>SID</th>
<th>RSID</th>
<th>SNR</th>
<th>PST</th>
<th>RSE</th>
</tr>
</thead>
</table>

SID: Source MS/SS ID
RSID: ID of the possible RS
SNR: Received SNR of the possible RS
PST: $T_{i2} - T_{i1}$ (unit: ns)
RSE: ReServed for Enhence of the possible RS

Should be added by the possible RS. The content is $T_{iE} - T_{i0}$ (unit: ns)

Where $i$ denotes the ID of RS
Frame Structure in Cooperative RS Transmission

Connection Step:

TDD Frame Structure

DL sub-frame

UL sub-frame

Frame structure in [1] is used for illustrations.

Frame Structure in Cooperative RS Transmission

Transmission Step:

In both uplink and downlink, RS 1 and RS 2 are allocated the same chunk for cooperative transmission and different chunks for other MSs.

Frame structure in [1] is used for illustrations.
Frame Structure in Cooperative RS Transmission

Transmission Step:

The transmission starting time of RS 1 & RS 2 is different.
Frame Structure in Cooperative RS Transmission

Transmission Step:

TDM

TDD OFDMA Frame Structure

Subchannel logic number

DL sub-frame

UL sub-frame

Preamble

UL MAP

DL MAP

FCH

BS ➔ MS

RNG/BW-REQ Sub-channel

The transmission starting time of RS 1 & RS 2 is different

BS ➔ MS

MS ➔ BS

RS 1

RS 2

RS 1 & 2
Merits of the Proposed Cooperative RS Transmission Scheme

• The proposed cooperative RS transmission scheme can
  – Realize synchronized transmission.
  – Balance the received performance and the system capacity.

• No hardware change in MS is required when the proposed cooperative transmission is used