Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Transparent Uplink Relaying for OFDMA**
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Source(s)	Kevin Baum Brian Classon Mark Cudak [mailto: Mark.Cudak@motorola.com] Philippe Sartori Motorola Labs 1301 E. Algonquin Road Schaumburg, IL 60196
Re:	IEEE P802.16-REVe/D5-2004, Sponsor Ballot
Abstract	Optional signaling methodology to support uplink channel sounding in TDD OFDMA systems.
Purpose	Adoption of proposed changes into P802.16e
Notice	
Release	
Patent Policy and Procedures	

Enabling Transparent Relaying on the Uplink

Kevin Baum, Brian Classon, Mark Cudak, Philippe Sartori
Motorola Labs

1 Introduction

This contribution proposes the introduction of relaying on the uplink for IEEE 802.16e OFDMA. As explained in [1], there is a serious link budget problem on the uplink that drastically reduces the uplink data rates and the system throughput, even for reasonable cell radii (2 km). The solution presented in this contribution enables the seamless introduction of simple one-hop relaying on the uplink to deal with this issue. Downlink transmissions are not relayed at all, thereby drastically reducing the complexity of the relay.
The solution presented here has the following advantages:

- The transparent relay (T-relay) is a simplified unit that only needs to perform a few layer-one operations and a minimal set of layer-two tasks. Moreover, the relay does not need to wired to the network.
- The relaying process is a *transparent* process that requires no changes in the SS and very minimal signaling changes to accommodate the relay enabling process.
- One or more T-relays can be deployed in each sector. A particular T-relay does not need to be aware of other T-relays.
- The BS always remains in control of the transmission, thereby resulting in increased transmission reliability.
- The architecture still permits hybrid-ARQ (HARQ) to be performed on the uplink.

2 General Description

The disparity in PA power between SS and BS suggests that a solution can be tailored to provide the necessary assistance to the uplink while not being involved in the downlink. As a result, cost efficiencies can be achieved by creating a subordinate relationship between relays and the BS allowing the relays to be low cost while ensuring robust reliable transmission supervised by a central authority. The cost efficiencies may be realized by reducing relay complexity such that it only focuses on layer-one operations and a minimal set of layer-two tasks. In addition, control messages do not have to be relayed – only bearer data. Moreover, the transparent relay (T-relay) configuration simplifies system deployment. These T-relays can be deployed in existing cells to address uplink coverage issues without having to re-address cell planning as might be required when adding microcells to achieve the same end.

2.1 System Configuration and Operation

Figure 1 depicts the possible communication pathways between BSs, SS, and T-relays. Figure 1a) shows the typical communication paths in a cellular system with the T-relay disabled. A BS coordinates the resources in the cell by distributing control information and arbitrating access requests. In addition, the BS transmits bearer data directly to the SS and receives bearer data directly from an SS. Figure 1b) shows the communication paths

with the T-relay enabled. In this case, the BS still coordinates resources in the cell by distributing control information and arbitrating access requests. Additionally, the BS continues to transmit bearer data directly to the SS. However, the uplink bearer data from the SS follows a triangular path first being received and detected by the T-relay then re-encoded and transmitted to the BS by the T-relay. Figure 1 c) and d) show two variations on the T-relay configuration. Figure 1c) shows multiple active s-relays simultaneously repeating the SS bearer data to the BS. Figure 1d) shows the simultaneous co-existence of a relayed and non-relayed uplink communication. A key and highly beneficial aspect of the T-relay configuration is that the SS may be completely unaware of the existence of a relay within in the system.

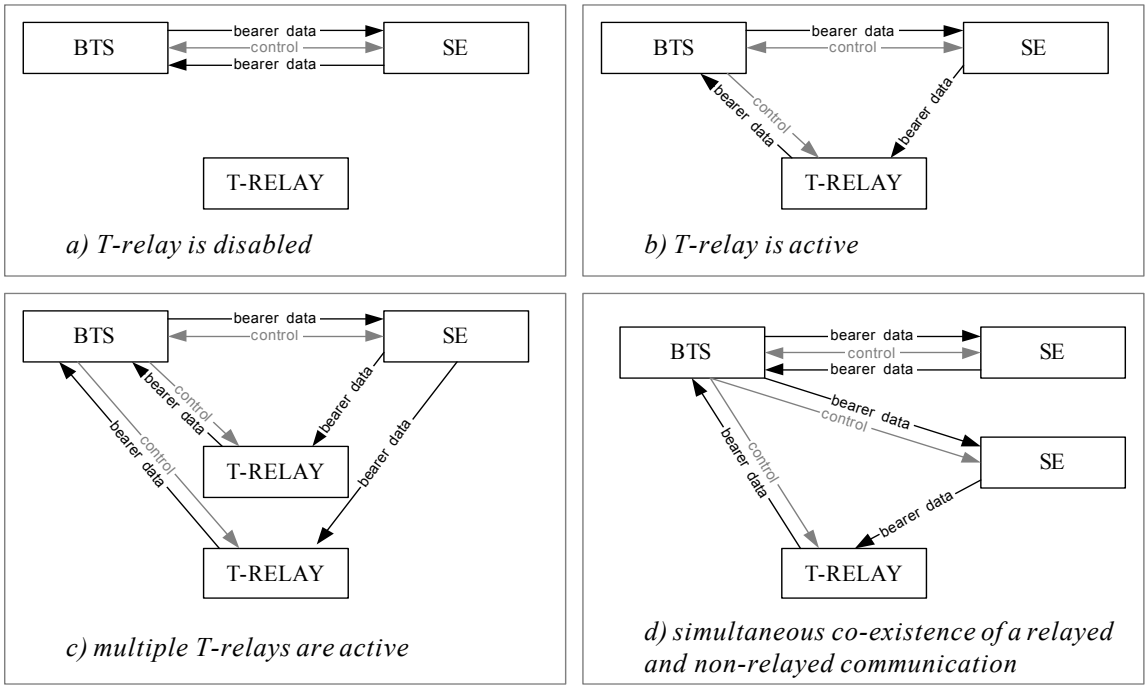

Figure 1 Communication pathways between BSs, SS and T-relays.

In the broadest sense, the above procedure is the minimum required to increase uplink bearer data transmissions rates. If the T-relay cannot be employed, the data rate cannot take into account the relay. If the T-relay can be employed, the data rate can take into account the T-relay and be such that the data rate is much higher. As each data transmission is adaptive to the channel conditions, conditions may be such that even if a T-relay can be employed, it may not be employed if the direct link to the BS is of sufficient quality. Typically, the determination of whether a T-relay is to be employed is made for each transmission, but may also be made on a longer term average channel quality basis (e.g., taking shadowing but not fast fading into account). The T-relay (more generally, one or more T-relays) is a subordinate relay because the resource allocation for the SS to T-relay link is provided by the BS.

2.2 Operations to be Performed

As mentioned earlier, the relaying process is completely transparent to the SS, thereby requiring no additional operations to be performed. However, the link between the T-relay and the BTS needs to be established and maintained. An implementation of the various tasks that need to be performed is detailed below.

2.2.1 Network Entry and Initialization

The network entry and initialization process is the same as for a conventional SS, except that at one point (the registration process), the unit must identify itself as a T-relay.

2.2.2 Relay Assignment to a Connection (listening)

The relay assignment process is done on a frame-by-frame basis. Each T-relay (or group of T-relays) is assigned the CIDs whose transmissions it needs to monitor in the uplink portion of the current frame. Therefore, by decoding the UL_MAP, each T-relay knows every resource it needs to listen to and attempt to detect. Note that a T-relay may monitor one or more connections (e.g., one or more SSs) and may be part of one or more multicast groups. For example, a T-relay may be assigned to monitor two different connections and may be addressed by different CIDs (e.g., a special CID if the T-relay being activated, or even a multicast CID if it is part of a group of relays being activated).

2.2.3 Communication of Relay Assignments (transmitting)

The assignment of resources for the transmission from the T-relay(s) to the BS is also done on a frame-by-frame basis. Each T-relay (or group of T-relays) is assigned resources via the existing UL-MAP_IE message. Each T-relay only relays connections for which it has successfully decoded the data.

3 Proposed Text Changes

---------- Beginning of Text Changes ----------

[In Section 6.1, After third paragraph, add the following paragraph]

Also, in order to improve the uplink data rates, transparent relaying on the uplink may be enabled. Transparent relays (TR) are deployed in a cell in order to break the SS to BS link into a SS to TR link and a TR to BS link on an “as-beneficial” basis in order to provide higher data rates and/or capacity on the uplink, or when the SS to BS link is of unacceptable quality. This process is completely transparent for the SS: it is not aware that it is being relayed.

[In Section 6.3.2.3.7 Registration request (REG-REQ) message , Just before 6.3.2.3.8 insert the following bolded text]

The REG-REQ may contain the following TLVs:
(…)

Transparent Relay Capabilities (11.7.20)

[In Section 6.3.2.3.8 Registration response (REG-RSP) message, just before 6.3.2.3.9, insert the following bolded text]

The REG-RSP may contain the following TLVs:
(…)
Transparent Relay Capabilities (11.7.20)
[Add a new section 6.3.2.3.43.7.9]

Section 6.3.2.3.43.7.9 Compact_UL_MAP Transparent Relay Monitor

The Transparent Relay Monitor Information Element provides the list of SS CIDs whose transmissions are to be monitored (detected) during the UL part of the current frame and relayed in the next frame..

Syntax	Size	Notes
Compact UL_TR_MONITOR_IE() {		
UL_MAP Type=7	3 bits	
UL_MAP sub-type	5 bits	Encoded as "0"
Length	4 bits	N_CID*2
For (i=0;i<N_CID;i++) {		
CID(i)	16 bits	The CID of the connection to be monitored by the TR(s) in the current frame.
}		
}		

[Add a new section 6.3.2.3.58]

Section 6.3.2.3.58 Transparent Relay CID Assign (TR-CID) Message

The base will assign one or more secondary relay CIDs to a transparent relay for the purpose of sending relay monitor command and allocating resource for a retransmission of the monitored SS(s) data. The relay CID may be assigned to only one transparent relay or multiple transparent relays. Upon reception, a SS will delete all previously assigned relay CIDs and adopt those newly assigned.

Syntax	Size	Notes
TR-CID_Message_Format() {		
Management Message Type=TBD	8 bits	
Transaction ID	16 bits	
TLV Encoded Information	Variable	TLV Specific
}		

Parameters shall be as follows:

CID *(in the generic MAC header)*
SS's Primary Management CID.
Transaction ID
Unique identifier for this transaction assigned by the sender.
All other parameters are coded as TLV tuples.
Relay CID (see 11.16)

Section 6.3.2.3.59 Transparent Relay CID Assign ACK (TR-ACK) Message

This message is sent in response to a TR-CID assignment message.

Syntax	Size	Notes
TR-ACK_Message_Format() {		
Management Message Type=TBD	8 bits	
Transaction ID	16 bits	
Confirmation Code	8 bits	
}		

Parameters shall be as follows:
CID *(in the generic MAC header)*
SS's Primary Management CID.
Transaction ID
Unique identifier for this transaction assigned by the sender.
Confirmation Code
Zero indicates the request was successful. Non-zero indicates failure.

[Add a new section 11.7.20]

Section 11.7.20 Transparent Relay Capability

This field indicates whether the unit is a regular SS or a transparent relay.

Type	Length	Value	Scope
18	1	1 if the unit is a transparent relay 0 if the unit is a SS (default 0)	REG-REQ REG-RSP

[Add a new section 6.3.22]

Section 6.3.22 Transparent Relay Operation

In order to improve data rates on the uplink, relaying some uplink transmission may be advantageous. Relaying on the uplink is performed by fixed entities called Transparent Relays (TR). The BS may allocate one or more TR to relay the data transmissions associated with a particular CID (e.g., a particular SS) on the uplink. The process is shown in Figure AAA. In the UL_MAP, the uplink resource allocations are sent to the transmitting SSs and an UL_TR_MONITOR_IE is included to instruct a TR or a group of TRs to monitor the uplink transmissions associated with one or more SS CIDs. In the uplink, the SSs transmit, and the TRs monitor the transmissions they were assigned to monitor. The monitored transmissions are demodulated and decoded by the TRs so that they can be re-encoded and re-transmitted (relayed) in the next frame. In the next frame, in a second UL_MAP message, each active TR receives its resource assignment for the relaying transmission. This resource assignment is made per TR CID, or for a multicast group TR CID. When the assignment is made per a multicast group TR CID, these are T-relays are expected to simultaneously relay the monitored transmission providing a macro diversity gain.

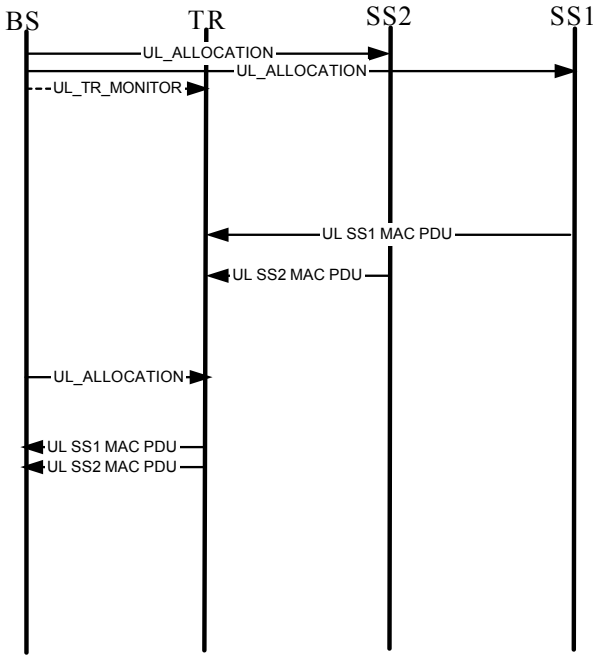

Figure AAA. TR operation.

The MAC PDUs are transmitted from a TR in exactly the same relative order as they were received and are modulated and coded with the Modulation Coding Scheme (MCS, based on the UIUC) specified in the UL_MAP_IE addressed to the TR. The MAC PDUs of each respective SS are encoded separately as if the BS had sent separate allocations for each SS that is being relayed. If the TR did not correctly decode the data from a particular user (CID), it does not relay that data and leaves this portion of the assignment empty.

An example of TR resource allocation is given in Figure AAB. In the example described, the TR has to relay three transmissions: MAC PDU S1, MAC PDU S2, MAC PDU S3, whose assignments appeared in this same relative order in the previous frame. The TR receives its resource allocation (in an UL_MAP_IE) for relaying the three transmissions with 64-QAM R=1/2 and the necessary amount of subchannels to perform the relaying operation. The first PDU to be relayed, MAC PDU S1 is modulated and encoded with the new MCS and

mapped onto the first resources. The TR was not able to receive correctly MAC PDU S2, therefore it does not transmit anything for S2, but leaves blank the portion of the assignment resources where it should have relayed this PDU. Resources for relaying MAC PDU S3 are assigned after the resources that were provisioned for MAC PDU S2. This TR resource assignment process enables the BS to know where to find the relayed data for each MAC PDU even though the relay uses a different MCS than the SSs. Macro-diversity is also provided when multiple TRs are assigned to relay the same CIDs.

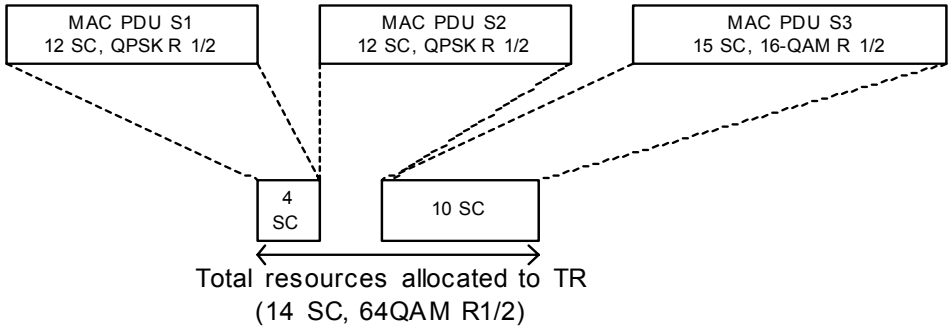

Figure AAB. TR resource allocation. SC denotes subchannel.

[Add a new section 8.4.5.4.23]

Section 8.4.5.4.23 UL_MAP Transparent Relay Monitor

The Transparent Relay Monitor Information Element provides the list of SS CIDs whose transmissions are to be monitored (detected) during the UL part of the current frame and relayed in the next frame.

Table XYZ-OFDMA UL-MAP Transparent Relay Monitor IE format

Syntax	Size	Notes
UL_TR_MONITOR_IE() {		
Extended UIUC	4 bits	0x07
Length	4 bits	N_CID*2
For (i=0;i<N_CID;i++) {		
CID(i)	16 bits	The CID of the connection to be monitored by the TR(s) in the current frame.
}		
}		

[Add a new section 11.19]

Section 11.19 Transparent Relay CID Assign

The value of this field specifies the CID assigned by the BS to a particular transparent relay. This field shall be present in the TR-CID assignment message. The BS shall use the assigned value in the UL_MAP Transparent Relay Monitor IE and Compact_UL_MAP Transparent Relay Monitor IE to instruct the relay to monitor particular uplink allocations. The BS shall use the assigned value in UL_MAP IE to allocate resources for the retransmission of monitored SS data.

Type	Length	Value	Scope
[145/146].2	2	CID	TR-CID

---------- End of Text Changes ----------

4 References

[1] IEEE C802.16e-04/237, “Link Budget on the Uplink for IEEE 802.16e,” July 2004.
[2] IEEE C802.16e-04/298, “Transparent Uplink Relaying for OFDMA,” September 2004.