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Re:	This document is in response to call for technical proposals IEEE 80216-06/027 dated 15 October 2006. This document proposes text regarding signaling for efficient routing for insertion in baseline document IEEE 80216j-06/026.
Abstract	Providing support for a simplified uplink-only relaying mode in the P802.16j context.
Purpose	Adoption of proposed text into P802.16j
Notice	
Release	
Patent Policy and Procedures	

Support for a Simplified Uplink-Only Relaying Mode

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Introduction

The introduction of relaying for IEEE802.16 can serve several purposes, such as range extension, gap filling, and increased data rates near the edge of a cell. As explained in [1] and [2], relaying is especially beneficial for the uplink, since a SS transmits at a much lower power level than a BS. Because of this power difference, the downlink is often interference-limited while the uplink is often thermal-noise-limited even for a reasonable cell radius (e.g., 2 km). Therefore, although the standard must in general be capable of supporting relaying on both the downlink and uplink, there is significant value in including support for a simplified uplink-only relaying mode as well. The main purpose of this contribution is to propose a simplified uplink-only relaying mode for inclusion in the overall 802.16j standard. In this simplified mode, downlink transmissions are not relayed at all, which can significantly reduce the complexity of the relay station, reduce downlink overhead, and simplify route management and handoff.

The solution presented here has the following advantages:

1. The uplink-only RS (U-RS) is a simplified unit that only needs to perform a few layer-one operations and a minimal set of layer-two tasks.
2. One or more U-RS can be deployed in each sector. A particular U-RS does not need to be aware of other U-RS.
3. The BS always remains in control of the transmission, thereby resulting in increased transmission reliability.
4. The architecture still permits hybrid-ARQ (HARQ) to be performed on the uplink.

As a side benefit, the signaling and route selection methods developed for the uplink-only relaying mode may also be used as part of the full two-way relaying mode. In particular, for a two-way relaying scheme that chooses uplink and downlink routes independently, the uplink-only mode described here can be used for managing the uplink part of the relaying. Moreover, if a two-way relay is deployed where downlink relaying would not be particularly helpful, it should be possible to completely turn off the downlink relaying portion of the relay and have it act as an uplink-only relay.

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 RS to be low cost while ensuring robust reliable transmission supervised by a central authority. The cost efficiencies may be realized by reducing RS complexity such that it only focuses on layer-one operations and a minimal set of layer-two tasks.

System Configuration and Operation

Figure 1 depicts the possible communication pathways between BSs, SS, and U-RS. Figure 1a) shows the typical communication paths in a cellular system with the U-RS disabled. A BS coordinates the resources in the cell by distributing control information and arbitrating access requests. In addition, the BS transmits data directly to the SS and receives data directly from an SS. Figure 1b) shows the communication paths with the U-RS 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 data directly to the SS. However, the uplink data from the SS follows a triangular path first being received and detected by the U-RS then re-encoded and transmitted to the BS by the U-RS. Figure 1 c) and d) show two variations on the U-RS configuration. Figure 1c) shows multiple active U-RS simultaneously repeating the SS data to the BS. Figure 1d) shows the simultaneous co-existence of a relayed and non-relayed uplink communication. In accordance with the 802.16j requirements, the SS is completely unaware of the existence of a relay within in the system. Note that in Figure 1, and throughout this contribution, another intermediate RS may play the role of the BS.

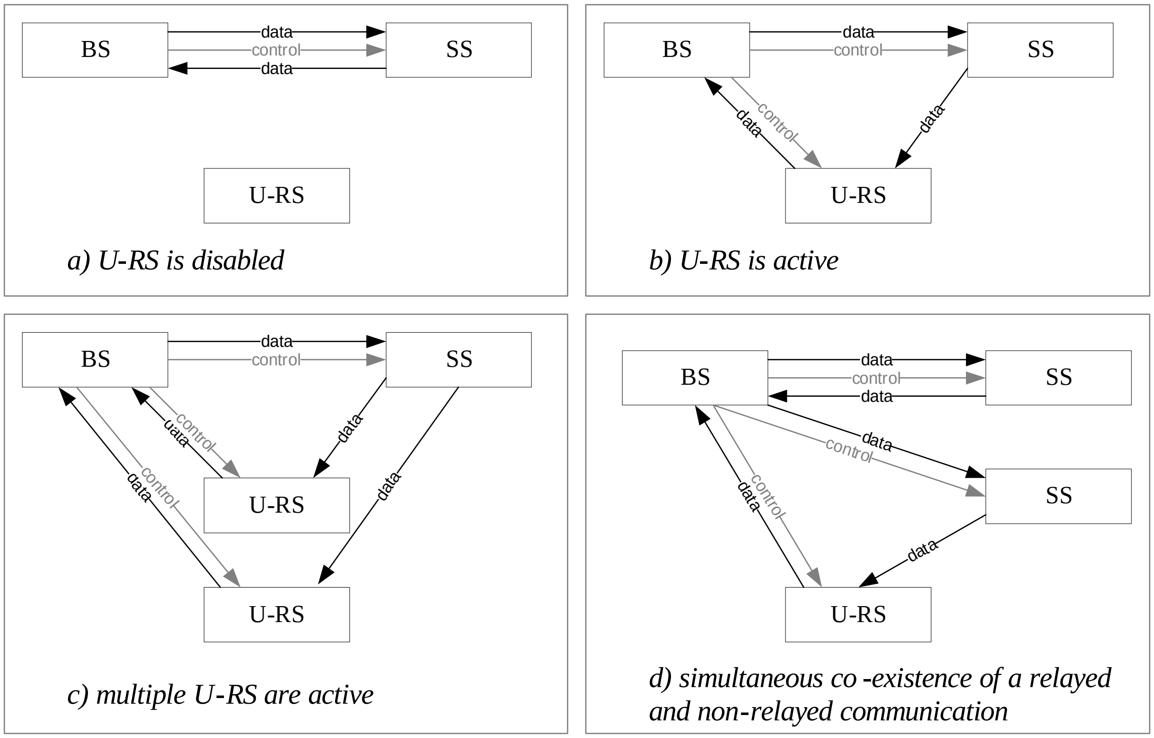

Figure 1 Communication pathways between BSs, SS and U-relays.

In the broadest sense, the above procedure is the minimum required to increase uplink data transmission rates, especially in a noise-limited scenario. Typically, the determination of whether a U-RS is to be employed is made on an average channel quality basis (e.g., taking shadowing but not fast fading into account). The U-RS (more generally, one or more U-RS) is a subordinate relay because the resource allocation for the SS to U-RS link is provided by the BS.

Considering a two-way RS that utilizes the U-RS protocol for the uplink part, the decision of whether to relay both downlink and uplink SS transmissions or just the uplink SS transmissions can be made at the time of the SS network entry and may be periodically re-evaluated as part of regular route maintenance procedures. This decision could be also made on a per-CID basis as a function of the QoS requirements for that flow.

Operations to be Performed

In order to support a U-RS, a link between the U-RS and the BS needs to be established and maintained. An implementation of the various tasks that need to be performed is detailed below.

SS Ranging and Network Entry with U-RS

When the SS ranges, there are two possible scenarios:

1. Both the RS and the BS receive the ranging code at a power level sufficient to perform measurements.
2. Only the RS receives the ranging code with a high enough power.

For case 1, he overall process is summarized in Figure 2 and is described next. Consider the network configuration depicted in Figure 1. It is assumed that a U-RS is aware of the possible CDMA ranging codes as well as the ranging region allocation used at the BS. Two mechanisms are proposed for obtaining this information. The first is for the RS to monitor and decode the BS UCD and UL-MAP transmissions. This is the preferred method since it does not introduce additional overhead. However, as a backup mechanism, a new MAC management message is also defined and can be transmitted by the BS to the RS.

Once the U-RS obtains the BS ranging channel information, both the U-RS and the BS monitor the BS ranging region. Upon detecting a CDMA ranging code, the U-RS creates a RS_RNG_REP MAC Management message (defined in the Proposed Text section) and transmits it to the BS. This message carries the index and other attributes of the ranging code received, and the recommended power and timing adjustments for the SS as measured at the RS. Simultaneously with the U-RS, the BS also possibly detects the ranging code and performs its own RSSI and time-advance measurements.

Upon receiving the RS_RNG_REP message, the BS compares its RSSI measurement with the RSSI measurement reported by the RS. Based on the comparison, the BS may make the decision to activate the U-RS. However, prior to activating the relay for the SS, the BS first completes the network entry and registration process for the ranging SS. Note that upon completion of the ranging procedure, the identity of the SS is provided to the BS via the RNG-REQ message, which could be used to map the power and timing adjustment parameters reported in the RS_RNG_REP to the specific SS. If the initial ranging procedure takes multiple power and timing adjustment iterations, the U-RS continues to report its ranging measurements in the RS_RNG_REP messages, so that the BS is always in possession of the current timing advance and power adjustment parameters as measured at the U-RS.

At the completion of the registration process, the SS timing advance/power parameters are matched to the BS rather than the RS. If the BS decides to activate uplink relaying for the SS, the BS may then send an unsolicited RNG-RSP message to the SS with new time and power adjustment parameters configured so as to attain the timing advance and power levels reported in the most recent RS_RNG_REP message for that SS. At the same time, BS activates the U-RS as described in the following section.

The RS_RNG_REP message may also be used during periodic ranging once uplink relaying has been activated. That is, the RS continually monitors the ranging region of the BS and reports appropriate timing advance and power level adjustments to the BS in the RS_RNG_REP message. The BS transmits the RNG-RSP message with the parameters configured to obtain the timing advance and power level adjustments specified in the RS_RNG_REP message. If multiple CDMA codes are detected at the RS simultaneously from multiple ranging SS, the power and timing adjustments for these codes are combined into a single RS_RNG_REP message. The RS_RNG_REP message is also to be used by the U-RS to report detection of a BW Request CDMA code to the BS.

Finally, note that in some deployments, the distance between a RS and the BS may be small enough that the SS could keep its timing advance and power parameters matched to the BS rather than the RS. In this situation, part of the cyclic prefix is basically being used to absorb the propagation delay difference between a SS to BS link and an SS to RS link. In such cases, a modest overhead savings can be achieved by eliminating the final unsolicited RNG-RSP transmission of the BS.

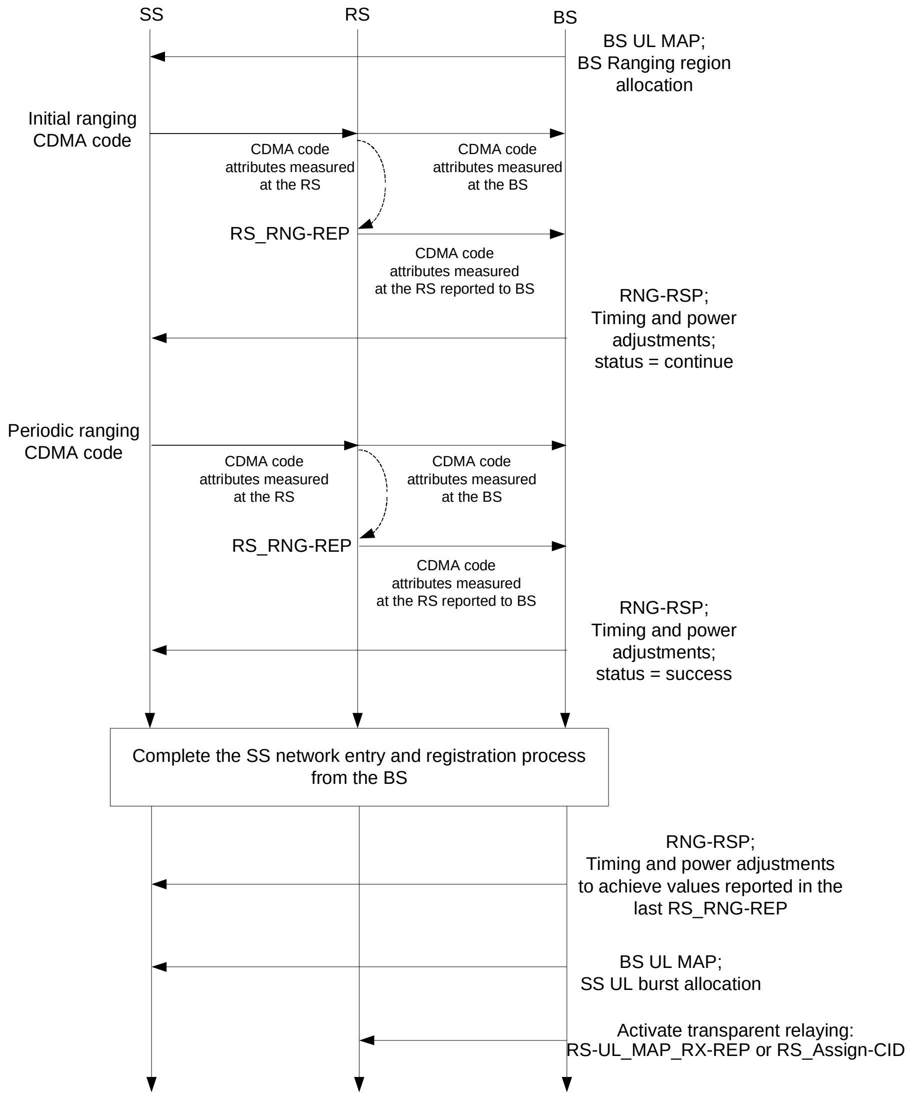

Figure 2. SS network entry process with U-RS when both the U-RS and the BS receive the ranging code..

For case 2 (only the RS receives the ranging code at a high enough power), a very similar process can be employed, and is described in Figure 3.

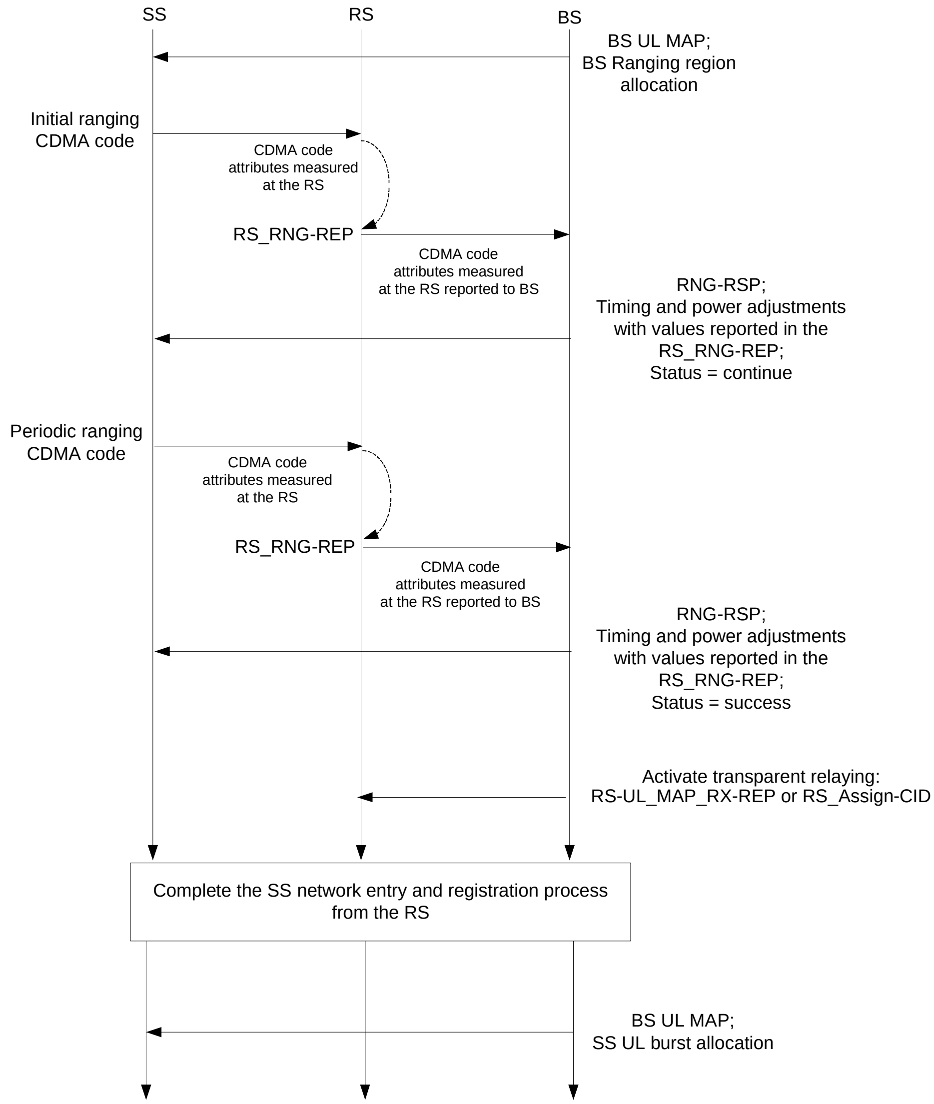

Figure 3. SS network entry process with U-RS when the BS does not receive the ranging code.

Relay Assignment to a Connection

Each U-RS (or group of U-RS) is assigned the CIDs whose transmissions it needs to monitor in the uplink portion of the current frame. Different methods of assignment are possible depending on the frame structure [3]:

The first method is based on the U-RS receiving and decoding the BS UL-MAP. A new BS to RS message, RS_Assign-CID, is defined and is used to instruct the RS which CID assignments are to be monitored and relayed by the U-RS. After receiving the RS_Assign-CID message, the RS determines which resources it needs to receive and attempt to detect on a frame-by-frame basis by receiving and decoding the BS UL-MAP. Note that the RS_Assign-CID message does not need to be transmitted in every frame – it only needs to be transmitted when there is a change in the CIDs that are to be relayed.

The second method is to use a new BS to RS message, RS-UL_MAP_RX-REP, that directly specifies the SS burst allocations to be received and relayed by the RS. This message needs to be transmitted to the RS on a frame-by-frame basis. This method can be used in the U-RS mode, and also enables a full two-way RS to leverage more of the signaling defined for the U-RS mode. In some two-way relaying configurations, the RS may transmit its own SS-directed preamble and control information synchronously with the BS, making it impossible for the RS to receive the BS UL-MAP. In such a case, the RS-UL_MAP_RX-REP message can be used by the BS to specify the burst allocations to be relayed by the RS.

The RS_Assign-CID and RS-UL_MAP_RX-REP messages are also to be used for channel measurements to enable UL route selection for the SS. This is further discussed in [4].

RS-to-BS Resource Assignment

Two options are possible of the RS-to-BS resource assignment:

1. The resources for the RS-to-BS link can be specified using the existing UL_MAP message, where the CID of the allocation is set to the relay's CID. With this method, it is suggested that the RS-to-BS resources be in a separate zone than the direct SS-to-BS transmissions.
2. Another alternative is to provide an allocation for RS-to-BS transmissions in the RS-UL_Zone (UL Relay Zone 2 in [3]) using the RS-UL_Zone_Allocation_IE transmitted from the BS to RS as part of the BS-to-RS DL MAP as described in [3]. This solution is more flexible for supporting both uplink-only relays and two-way relays. Details of this solution are given below.

When a U-RS is provided an allocation for RS-to-BS transmissions with the RS-UL_Zone_Allocation_IE message, the allocation specified in the RS-UL_Zone_Allocation_IE is in-effect until the reception of the next RS-UL_Zone_Allocation_IE. In the RS-UL_Zone, the U-RS initiates all transmissions to the BS. That is, a U-RS autonomously constructs and transmits a burst directed at the BS. This burst is constructed according to the following three rules:

1. The burst is encoded according to the UIUC value specified in the RS-UL_Zone_Allocation_IE.
2. The length of the burst (in slots) may not exceed the length of the U-RS allocation specified in the RS-UL_Zone_Allocation_IE.
3. MAC PDU segmentation at the U-RS to fit the length of the burst to the size of the allocation is not permitted.

Hence, the length of the burst could possibly be shorter then the full length of the U-RS UL allocation. The length of the burst is signaled to the BS in a separate RS-UL_BCH (Burst Control Header) message. This message occupies the first slot of the allocation and carries the RS-UL_Burst_Prefix_IE specifying the length of the RS-to-BS burst. Note that multiple MAC PDU received at the U-RS could be packed by the RS into a single burst. This process is the same as the MAC PDU concatenation process described in Section 6.3.3.2 of the IEEE 802.16-2004 Specification. If desired, an ARQ with selective repeat process could be enabled on the RS-to-BS link, wherein the BS provides ACK/NAK feedback for each burst. In that case, each RS-UL_BCH is to carry a sequence number to identify bursts received in error for retransmission. In the case of a NACK, an entire burst (all concatenated MAC PDU) is to be retransmitted from the RS. Note that this RS-to-BS resource assignment scheme is also applicable to the full two-way RS configuration. The structure of the RS-UL_Zone is illustrated in Figure 4.

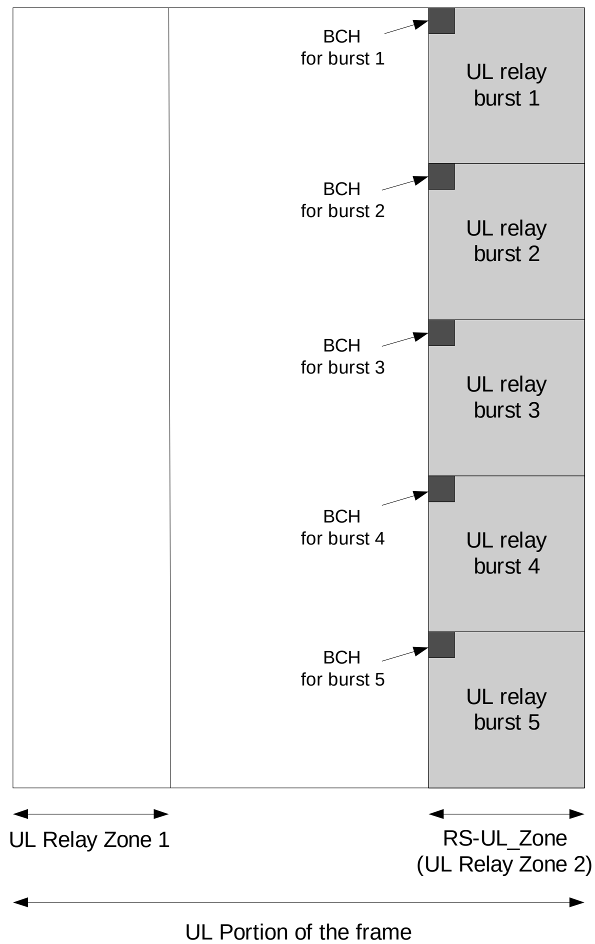

Figure 4. Proposed RS-UL_Zone structure.

References

[1] IEEE C802.16e-04/237, "Link budget on the uplink for IEEE 802.16e," Jul. 2004.
[2] IEEE C802.16e-04/286, "Transparent Uplink Relaying for OFDMA," Aug. 2004.
[3] IEEE C80216j-06_155, "Proposal for Multihop Relay Frame Structure for 802.16j," Motorola, Nov. 2006.
[4] IEEE C80216j-06_159, "Signaling for Efficient Routing," Motorola, Nov. 2006.

Proposed Text Changes

In section 6.1.1, insert the following paragraph

In order to improve the uplink data rates with simplified RS and system functionality, an uplink-only relaying mode and associated RS device class is defined. Uplink-only relay stations (U-RS) may be deployed in a cell in order to break the SS to BS link into a SS to U-RS link and a U-RS to BS link on an "as-beneficial" basis, such as to provide higher data rates, capacity, or coverage on the uplink. This uplink-only relaying process is illustrated in Figure ABC.

The messages defined for the U-RS mode are also used as part of the message set for full two-way RS operation.

An RS with two-way relaying capability shall also have the capability to disable its downlink functionality and operate in an uplink-only relaying mode. When operating in the uplink-only relaying mode, the RS shall operate as if it is a U-RS.

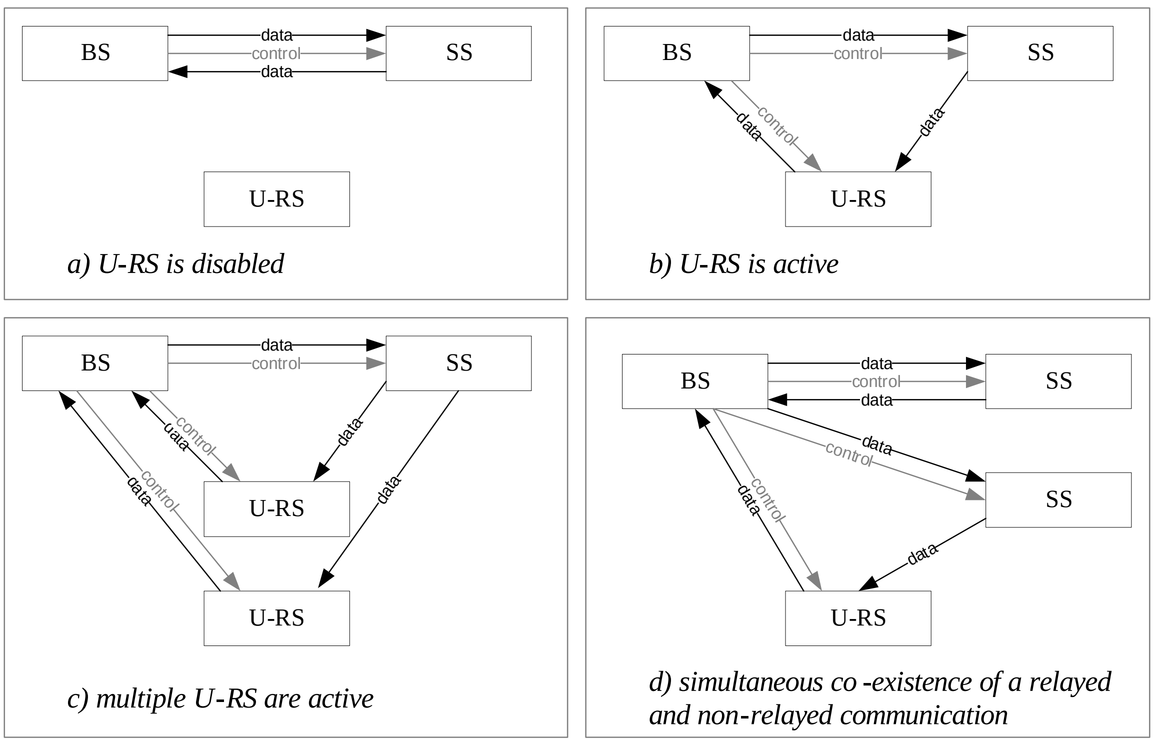

Figure ABC. Communication pathways between BS, SS and U-RS.

Add a new section 6.3.2.3.AA

Section 6.3.2.3.AA Transparent Relay CID Assign (RS_Assign-CID) Message

With the RS-Assign-CID message, the BS will assign one or more CIDs to a U-RS for the purpose of monitoring UL allocations made to these CIDs. The CID may be assigned to only one U-RS or to multiple U-RS. Upon reception, a U-RS will delete all previously assigned CIDs to monitor and adopt those newly assigned. This message can be sent with an empty list of SS CIDs to indicate that this U-RS shall not relay any SS.

Syntax	Size	Notes
RS-Assign-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)
U-RS Primary Management CID.
Transaction ID
Unique identifier for this transaction assigned by the sender.
All other parameters are coded as TLV tuples.
Monitored CID (see 11.20)

Add a new section 6.3.2.3.AB

Section 6.3.2.3.AB Transparent Relay CID Assign ACK (RS_Assign-CID-ACK) Message

This message is sent in response to a RS_Assign-CID message.

Syntax	Size	Notes
RS_Assign-CID-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)
U-RS 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 11.20

Section 11.20 Monitored CID

The value of this field specifies the CID assigned by the BS to a particular U-RS. This field shall be present in the RS_Assign-CID assignment message.

Type	Length	Value	Scope
TBD	2	CID	RS-Assign-CID

Add a new section 6.3.2.3.AC

Section 6.3.2.3.AC RS-UL_MAP_RX-REP

To enable UL reception of the burst a the RS, the BS send this message to the RS to indicate the particular UL burst allocation made to the SS. This message is to be sent on the RS Primary Management CID.

Syntax	Size	Notes
RS-UL_MAP_RX-REP_Message_Format() {		
Management Message Type=TBD	8 bits	
N_Assignments	4 bits	Number of assignments to relay
For (i=0;i<N_Assignments;i++) {		
UIUC	4 bits	
OFDMA symbol offset	7 bits	
Length	4 bits	Length of the SS uplink zone
Permutation	2 bits	
PUSC UL_IDcell	7 bits	
First slot in zone	10 bits	First slot of the allocation for the SS
Length	10 bits	Length of the allocation for the SS
}		

Add a new section 6.3.2.3.AD

Section 6.3.2.3.AD. RS Ranging Report (RS_RNG-REP) Message

This message shall be sent by an RS to the BS in an unsolicited manner following detection of a CDMA ranging code in the BS ranging region, and/or measuring on the RNG-REQ message transmitted from SS and/or measuring in UL transmission from SS.

Syntax	Size	Notes
RS-RNG-REP_Message_Format() {		
Management Message Type=TBD	8 bits	
Downlink Channel ID	8 bits	
REP_IND	2 bits	Bit#0: Report on CDMA code (initial and periodic) Bit#1: Report on UL_Burst
If(Report on CDMA Code==1)		
N_CDMA_Code	5 bits	Number of ranging codes reported
For (i=0;i<N_CDMA_Code;i++) {		
TLV Encoded Information	Variable	TLV Specific
}		
}		
If(Report on UL_Burst){		
N_Burst	5 bits	Number of reports on UL_MAP-IE
For(i=0;i<N_Burst;i++){		

CID	16 bits	Basic CID of SS appears in UL_MAP_IE
TLV Encoded Information	Variable	TLV Specific
}		
}		
}		

A RS shall generate RS-RNG-REP including the following parameters:

Primary Management CID (in the generic MAC header)

The RS-RNG-REP message may include the following parameters encoded as TLV tuples:

Timing Adjust (11.6)
Power Level Adjust (11.6)
Offset Frequency Adjust (11.6)
Ranging code attributes (11.6)

Add a new section 8.4.5.4.30

Section 8.4.5.4.30 RS Uplink Zone Allocation IE (RS_UL_Zone_Allocation_IE)

This IE is to be transmitted from the BS to the RS as part of the UL_RS-MAP. It indicates an uplink allocation for the RS in the RS-UL_Zone. The RS shall use this allocation for all subsequent frames until reception of the next RS_UL_Zone_Allocation_IE.

Syntax	Size	Notes
RS_UL_Zone_Allocation_IE () {		
CID	16 bits	RS primary management CID
Sequence Number	8 bits	
UIUC	4 bits	
OFDMA symbol offset	7 bits	
Length	4 bits	Length of the RS uplink zone
Permutation	2 bits	
PUSC UL_IDcell	7 bits	
First slot of the zone	10 bits	First slot of the allocation for the RS
Length of the zone	10 bits	Length of the allocation for the RS
}		

Add a new section 8.4.4.8.AA

Section 8.4.4.8.AA. RS-to-BS Burst Control Header

The first slot of every RS UL allocation begins with a RS-UL_BCH to enable decoding of the RS burst at the BS. The Burst Control Header carries the RS_UL_Zone_Prefix specifying the length and encoding of the burst. This information is sufficient to enable decoding of the RS burst at the BS. The Burst Control Header is encoded using the convolutional coding scheme with rate ½ and QPSK modulation, and a repetition factor of three.

Syntax	Size	Notes
RS_UL_Zone_Prefix_Format(){		
Burst length	8 bits	Length of the burst in slots
UIUC	4 bits	Modulation
Coding_Indication	3 bits	Encoding scheme
Reserved	1 bit	
}		