Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Cooperative HARQ for IEEE 802.16m: DL Mode**
Date Submitted	**2008-10-31**
Source(s)	Ozgur Oyman, Jerry Sydir, Alexei Davydov Intel Corporation 2200 Mission College Blvd., Santa Clara, CA 95054 U.S.A. E-mail: ozgur.oyman@intel.com Email : jerry.sydir@intel.com
Re:	TGm SDD: Relay IEEE 802.16m-08/040: Call for Comments and Contributions on Project 802.16m System Description Document (SDD)
Abstract	This document describes relay-based HARQ techniques for 802.16m downlink (DL) in order to realize cooperative diversity and power efficiency advantages of cooperative relaying techniques for throughput and reliability improvement. In particular, we propose cooperative hop-by-hop HARQ and cooperative relay-assisted HARQ schemes with dynamic selection of modes based on simultaneous transmissions by multiple cooperating terminals using cooperative relaying techniques such as distributed space-time coding and cooperative transmit diversity.
Purpose	For consideration and adoption into the 16m SDD document.
Notice	*This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups*. It represents only the views of the participants listed in the "Source(s)" field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy	The contributor is familiar with the IEEE-SA Patent Policy and Procedures: <http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>. Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat>.

Cooperative HARQ for IEEE 802.16m: DL Mode

Ozgur Oyman, Jerry Sydir, Alexei Davydov

Intel Corporation

A. Introduction

This document describes relay-based HARQ techniques for 802.16m downlink in order to realize cooperative diversity and power efficiency advantages of cooperative relaying techniques for throughput and reliability improvement. In particular, we propose cooperative hop-by-hop HARQ and cooperative relay-assisted HARQ schemes with dynamic selection of modes based on simultaneous transmissions by multiple cooperating terminals using cooperative relaying techniques such as distributed space-time coding and cooperative transmit diversity.

To overcome fading, wireless networks employ various diversity techniques, e.g., channel interleavers, multiple antennas, frequency hopping, etc. Recently, the concept of cooperative diversity was developed, where multiple transmitting/receiving stations (i.e., either BS and one or more RSs, or multiple RSs) partner in sharing their antennas and other resources to create a virtual antenna array and cooperatively transmit or receive the same data to/from an MS. In relay-assisted cellular networks, exploiting the multiplicity of wireless links and introducing spatial diversity and distributed array (i.e. power efficiency) gains through cooperative diversity techniques is especially beneficial in many practical scenarios.

In a low-mobility environment, we expect to see slow-fading channel conditions (channel coherence time larger than several frame durations). When a deep fade is experienced by a link between a transmitter and receiver under such conditions, simple HARQ-based frame repetition over the same wireless link may not be sufficient to enhance link reliability, since poor channel conditions are likely to be experienced by the initially-sent as well as the subsequent retransmissions, resulting in an increase in the average number of retransmissions required for successful decoding and substantial decrease in throughput. To address this problem, it is of interest to use cooperative transmission techniques, in conjunction with HARQ-based retransmissions, benefiting from simultaneous transmissions by multiple cooperating terminals over multiple independently fading wireless links. This realizes cooperative diversity gains during retransmissions, increasing the likelihood of reliable decoding at the receiver, and reducing the expected number of retransmissions necessary for successful decoding of the transmitted message.

The cooperative HARQ schemes may involve more than one cooperator; i.e. multiple terminals may simultaneously transmit the intended message (message from the source to the destination) under the principles of cooperative relaying. The overall objective in maintaining a cooperating terminal set of size 2 or more is to (i) to achieve higher diversity and power efficiency and thereby improve reliability over the second-hop communication by sending appropriately coded signals across different source and relay antennas during the forwarding and retransmission of a burst to subordinate stations, and (ii) to increase the probability of successful decoding by at least one relay terminal over the first hop in the case of a decoding failure at the destination terminal (to avoid retransmissions by the source terminal).

Downlink HARQ Procedure:

We propose the following two cooperative HARQ schemes, to be used under two-hop relaying:

- **Cooperative Hop-by-hop HARQ for 802.16m** – A fixed two-hop relay protocol involving BS -> {Multiple RSs} -> MS links and no direct BS-MS data link considerations. Different hops execute HARQ independently of each other. In the first hop, a cooperator set is formed from the RS terminals which are able to successfully decode the transmitted signals. In the second hop, the cooperator set uses cooperative relaying techniques to convey the signal to the MS. The logic flow diagram for the cooperative hop-by-hop HARQ scheme is provided in Fig. 1. A multi-hop version of the protocol is left FFS.

- **Cooperative RS-assisted HARQ for 802.16m** – One or more RSs monitor the HARQ burst transmitted from BS to MS (since RSs know DL-MAP) and multiple infrastructure terminals (BS and/or RSs) are used to transmit data only upon reception of a NACK message from MS regarding transmission over BS -> MS link. In other words, in order to reduce the resource retransmission of HARQ bursts, multiple infrastructure terminals (BS and/or RSs) simultaneously retransmit the HARQ burst instead of BS if one or more RSs have the correct HARQ burst. The logic flow diagram for the cooperative RS-assisted HARQ scheme is provided in Fig. 2.

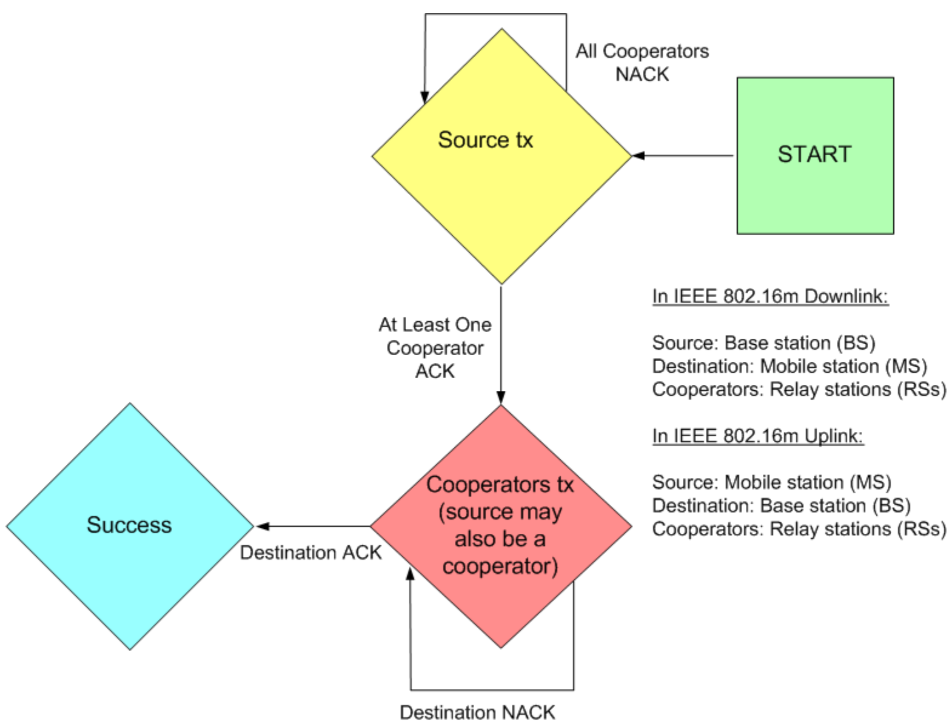

Figure 1 – *Logic flow diagram for the cooperative hop-by-hop HARQ mechanism.*

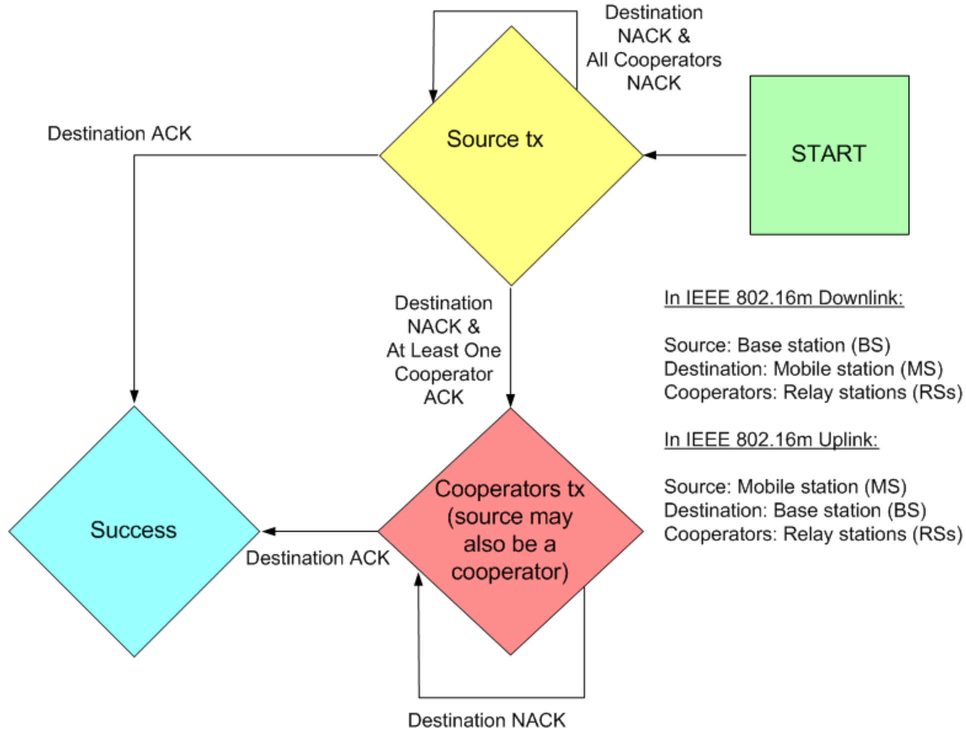

Figure 2 – *Logic flow diagram for the cooperative RS-assisted HARQ mechanism.*

The key difference between cooperative hop-by-hop HARQ and cooperative RS-assisted HARQ schemes is that the latter assumes that the direct data link between BS and MS exists and uses RSs only when the direct link fails, while the former assumes that no data transmission will happen over the direct link and utilizes from RS-assisted multi-hop routing (of at least two hops) regardless of the link quality between BS and MS. Furthermore, RS-assisted HARQ schemes assume that the MS is associated with the BS and hence receives control information (preamble, BCH, DL/UL MAP, etc.) from the BS, while hop-by-hop HARQ schemes assume that the MS is associated with an RS, and receives control information from that RS.

The usage of one of the following cooperative relay modes in conjunction with cooperative HARQ techniques is feasible: (i) cooperative transmit diversity; distributed Alamouti coding, distributed space-time coding, distributed beam-forming, cooperative antenna selection, etc., (ii) cooperative source diversity (pure signal repetition without any space-time processing), (iii) cooperative hybrid diversity, which is a combination of cooperative source diversity and cooperative transmit diversity. Further technical content on cooperative relaying techniques can be found in the following contributions:

[1] O. Oyman et. al., “Cooperative Relaying for IEEE 802.16m”, IEEE C802.16m-08/1277

[2] A. Davydov et. al., “Cooperative Relaying Mode Proposal for IEEE 802.16m”, IEEE C802.16m-08/1280

B. Proposed Text:

[Insert the following text into section 15 of the SDD:]

15.X.3 Cooperative HARQ

Two kinds of relay-based HARQ schemes are used in conjunction with cooperative relaying (i) cooperative hop-by-hop HARQ, and (ii) cooperative RS-assisted HARQ. Cooperative RS-assisted HARQ can be used when there exists a direct data link between BS and MS and when the MS is associated with the BS and hence receives control information (preamble, BCH, DL/UL MAP, etc.) from the BS. Cooperative hop-by-hop HARQ can be used when the MS is associated with an RS and no transmissions occur directly between the BS and MS. Both cooperative HARQ techniques can be used in conjunction with one of the following cooperative relay modes specified in Sections 15.X.1 and 15.X.2.

15.X.3.1 Downlink (DL)

This subsection describes DL HARQ with multi-hop relay support using cooperative transmission techniques. In this context, we will discuss cooperative hop-by-hop HARQ and cooperative RS-assisted HARQ schemes separately.

15.X.3.1.1. *Cooperative Hop-by-Hop HARQ:*

In cooperative hop-by-hop HARQ, the BS transmits data to a set of RSs. The BS then coordinates the RSs in performing a collaborative transmission to the MS. HARQ retransmissions are performed separately on each hop.

In order to perform cooperative hop-by-hop HARQ, the BS first selects and notifies the set of RSs which will cooperate to perform the transmission. This selection can be made and signaled for each transmission or on a slower timescale. See section 15.X.3.3 for more details on the selection process. Having selected and notified the cooperators, the BS transmits the burst to the RSs in the selected set using a multicast transmission. It indicates to the RSs that the burst is to be transmitted to the MS using a cooperative transmission. The BS allocates an HARQ ACK channel for each of the RS(s) and receives ACK/NACK signals from each RS separately. The BS may perform retransmissions if not all of the RSs have received the burst correctly. Next the BS determines the specific cooperative transmission mode that should be used to transmit the burst. It schedules an allocation in which the RSs will transmit the burst and notifies them of the transmission scheme and of the allocation (the frame and slots within the frame) (referred to as cooperative transmit allocation, which could be potentially inserted into DL MAP sent over the relay links). Only the RSs which received the data correctly are included for the cooperative transmission to the MS, but the RS to which the MS is associated is always notified of the allocation and is always the RS which transmits to the MS the MAP IE which notifies the MS of the allocation and the specific transmission scheme that will be used. This RS also allocates an HARQ ACK channel for the MS and receives and forwards to the BS the ACK/NACK which is received from the MS. If the burst was not received successfully, the BS schedules another retransmission. This scheme may be extended to operate over paths which are more than two hops. This extension is left for further study.

15.X.3.1.2. *Cooperative RS-assisted HARQ:*

In cooperative RS-assisted HARQ, the BS transmits data to the MS directly and directs a set of RSs to receive the transmission as well. If the MS does not successfully receive the transmission, the BS then coordinates the RSs in performing a collaborative re-transmission to the MS.

In order to perform cooperative RS-assisted HARQ, the BS first selects and notifies the set of RSs which will cooperate to perform the re-transmissions. See section 15.X.3.3 for more details on the selection process. Having selected and notified the cooperators, the BS transmits the burst to the MS and the RSs in the selected set attempt to receive this transmission. The BS allocates an HARQ ACK channel for the MS as well as for each of the RS(s) in the cooperator set and receives ACK/NACK signals from each of them separately. If the MS receives the transmission successfully, no cooperative retransmissions are performed. If the MS has not received the data correctly, the BS determines the specific cooperative transmission mode that should be used to retransmit the burst. It can retransmit the burst itself, or use a cooperative retransmission from one or more of the RSs and optionally itself. The BS schedules an allocation in which the collaborators will transmit the burst and notifies the RSs of the transmission scheme and of the allocation (the frame and slots within the frame) (referred to as cooperative transmit allocation). Only the RSs which received the data correctly are included in the cooperative transmission. The BS transmits the MAP IE which notifies the MS of the allocation and the specific transmission scheme that will be used and allocates an HARQ ACK channel for the MS. If the burst was not received successfully, the BS schedules another retransmission.

An example message flow is depicted in Figure 3 for the cooperative RS-assisted HARQ scheme. Another example for the cooperative hop-by-hop HARQ scheme is depicted in Figure 4.

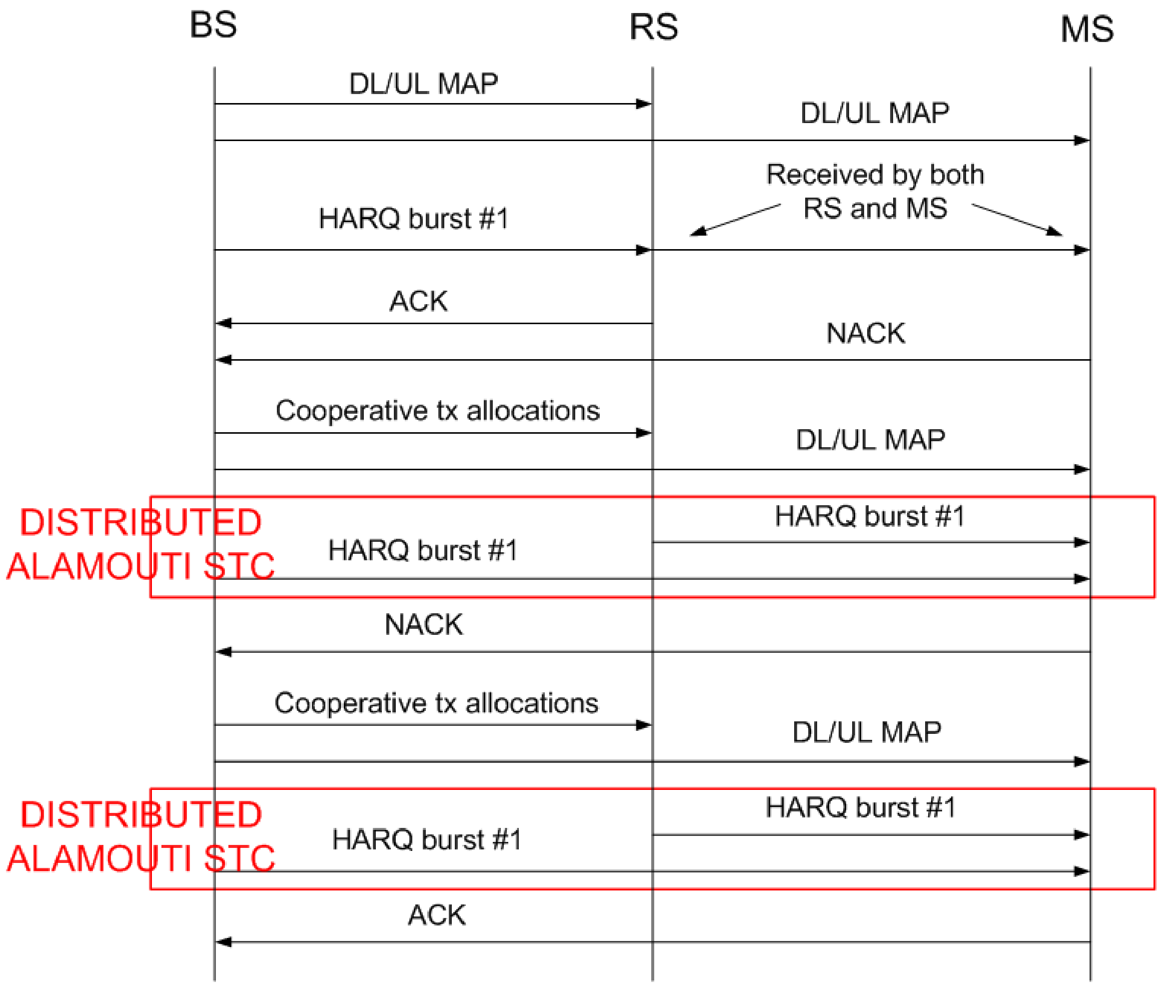

Figure 3 – *An example cooperative RS-assisted HARQ message flow. Here, we assume downlink transmission with a single RS. In the retransmission phase, BS and RS simultaneously transmit using a 2x1 distributed Alamouti space-time code.*

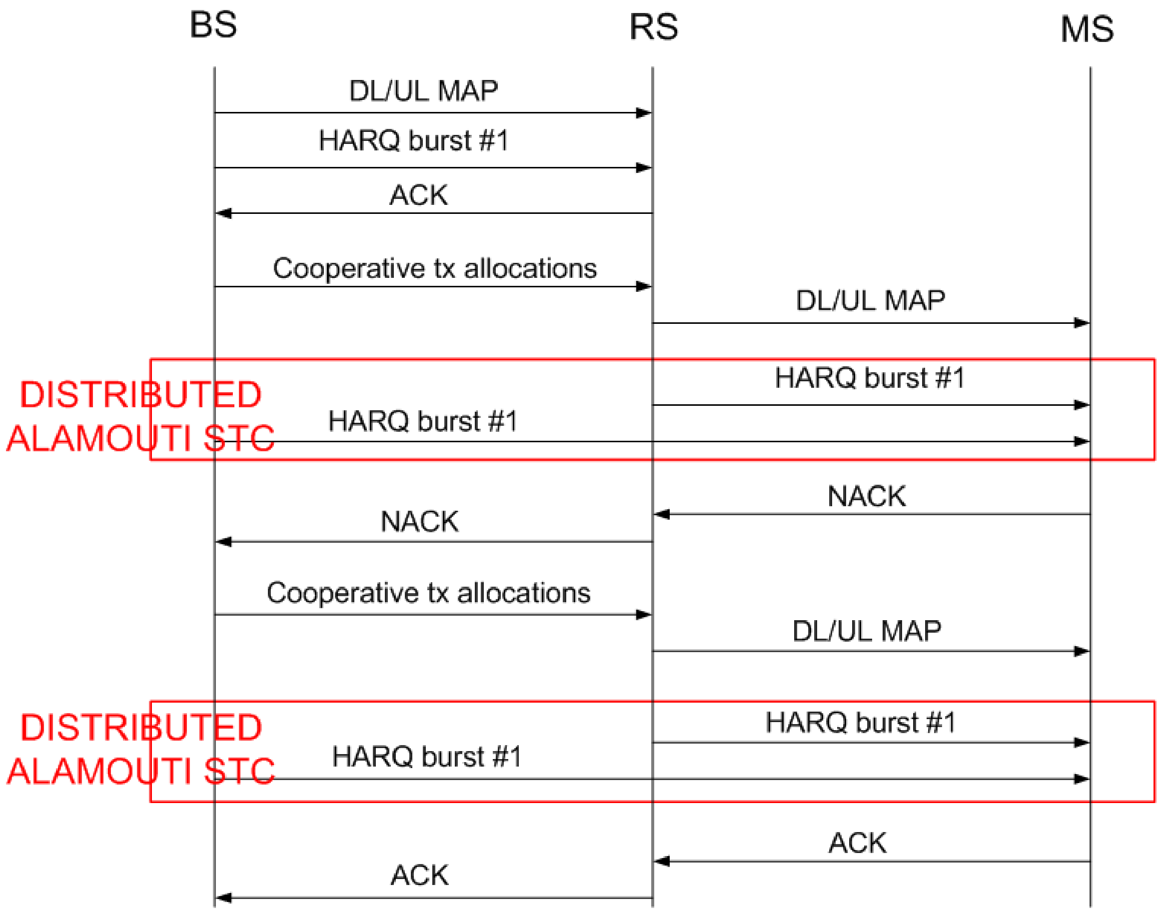

Figure 4 – *An example cooperative hop-by-hop HARQ message flow. Here, we assume downlink transmission with a single RS. In the second hop, BS and RS simultaneously transmit using a 2x1 distributed Alamouti space-time code.*

15.X.3.3. *Selection of the Cooperator Set and Cooperative Relay Modes*

When the BS wishes to perform cooperative transmission it selects the HARQ mode (RS-assisted or hop-by-hop) based on the station with which the MS is associated. Cooperative relay-assisted HARQ is used for MSs that are associated with the BS, while cooperative hop-by-hop HARQ is used for MSs that are associated with an RS. Having selected the HARQ mode, the BS selects the cooperator set and the cooperative transmission mode that will be used.

The BS makes these decisions based on link quality measurements of the relay and access links. It collects the relay link measurements directly and is provided access link quality measurements by the RSs which may participate in cooperative transmissions. The control signaling required to request and provide these measurements is left for further study.

The selection and signaling of cooperative transmission mode is performed dynamically for each cooperative transmission. This decision depends on the channel qualities of the various links as well as on the specific RSs which have successfully received the data which is to be transmitted using collaborative transmission techniques.

The cooperator set can be determined and signaled dynamically for each collaborative transmission or can be determined and signaled on a slower timescale.

i) Dynamic cooperator selection: The BS determines and specifies which infrastructure stations (i.e. RS(s) and/or BS) are selected to form the set of cooperators for every burst transmission. RSs may be notified via MAC messages or as part of the DL MAP.

ii) Static cooperator selection: In static cooperator selection, the chosen set of cooperating terminals remains fixed over the duration of multiple transmission periods. The set of cooperators for every MS are notified by the BS. This notification may be done using MAC messages or as part of the DL MAP. When a cooperative transmission is scheduled it is possible that not all of the collaborating RSs are able to decode the burst correctly. In this case, the BS dynamically adjusts the set of cooperators by pruning RSs which did not receive the burst correctly. It then selects a transmission scheme which is appropriate for the stations which did receive the burst correctly.

An example downlink communication setup under the cooperative RS-assisted HARQ scheme with a single RS is depicted in Figure 5 showing the specific changes in the DL MAP and UL MAP to support cooperative HARQ simultaneous transmissions.

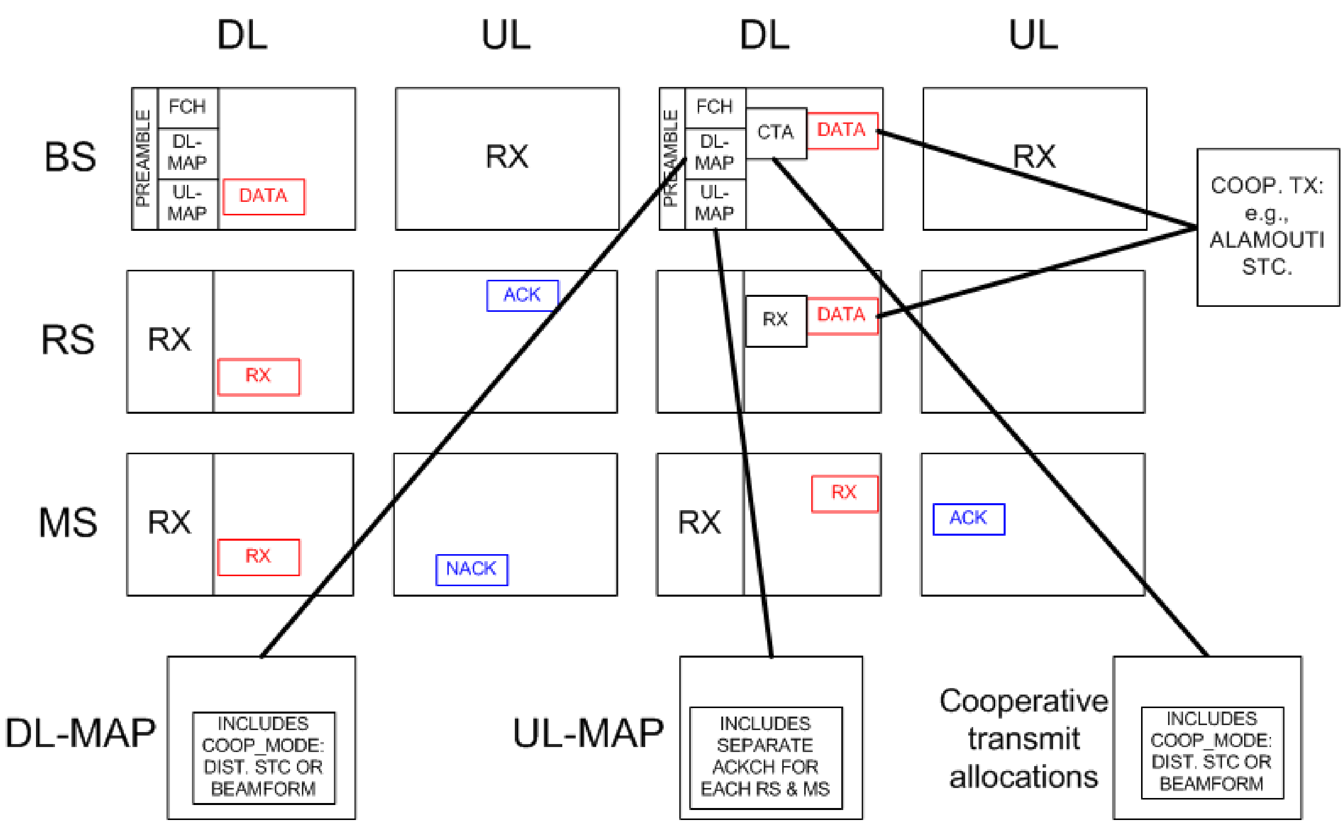

Figure 5 – *An example downlink communication setting in 802.16m with a single RS under the cooperative RS-assisted HARQ scheme. Here, BS and RS cooperate in the retransmission phase and simultaneously transmit to MS based on the cooperative HARQ framework. The changes in DL MAP and UL MAP to support cooperative HARQ are also shown.*

15.X.3.4. *Control Signaling Considerations*

The control signaling details for cooperative HARQ transmissions are left for further study.

The following types of control signaling will be required to support cooperative HARQ transmissions:

- Link quality feedback for access and relay links
- Notification of the cooperator set for a given MS or a given transmission.
- HARQ ACK channel
- Notification of the transmission mode to:
    - RSs which will be transmitting
    - MS which needs to receive