Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**	
Title	**HARQ Mechanisms in Multi-hop Relay**	
Date Submitted	**2007-01**	
Source(s)	Wei Ni, Gang Shen, Shan Jin Alcatel, Research & Innovation No. 388, Ningqiao Rd., Pudong Area, Shanghai, P. R. C	Voice: 86-21-50554550 Fax: 86-21-50554554 mailto: wei.a.ni@alcatel-sbell.com.cn
	Fang Liu, Lan Chen, Xiaoming She, Daqing Gu DoCoMo Beijing Lab 7/F, Raycom Infotech Pack Tower A No.2 Kexueyuan South Rd., Haidian District, Beijing, China	Voice: +86-10-82861501 ex.331 Fax: +86-10-82861506 mailto: {liu, gu}@docomolabs-beijing.com.cn
	Fujio Watanabe DoCoMo USA Labs 240 Hillview Avenue, Palo Alto, CA	Voice: 650-496-4726 watanabe@docomolabs-usa.com
Re:	IEEE 802.16j-06_034: “Call for Technical Proposals regarding IEEE Project P802.16j”	
Abstract	Two typical multi-hop HARQ mechanisms, active Multi-hop Relaying (MR) HARQ and passive MR HARQ, are proposed in this document. The active MR HARQ, supporting functions such as high mobility of the RS, CID update and traffic congregation, is a mechanism on the per-hop basis, and fewer resources are required for HARQ retransmissions. The passive MR HARQ is a multi-hop mechanism for simplicity, and the cooperative relay can be implemented with it.	
Purpose	This document is provided as the input for the IEEE802.16j.	
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) 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 and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented	

technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

HARQ Mechanisms in Multi-hop Relay

I. Introduction

In relay based wireless communication systems, the efficiency of HARQ (Hybrid ARQ) mechanism is critical owing to its great impact on the transmission delay and the system capacity [1-2]. The intention of this proposal is to develop efficient HARQ retransmission mechanisms adapted to relay based 802.16j systems and their certain functions by the collaboration between relay stations (RS) and base stations (BS).

As illustrated in Figure 1, two kinds of HARQ mechanisms are proposed for different application scenarios and environments. The first one is the active Multi-hop Relaying (MR) HARQ which is a per-hop mechanism performed over a single hop to compensate for the in-between fast fading and shadowing, and therefore the use of this mechanism allows for the high mobility of the RS, i.e., metro; the second is the passive MR HARQ which is a multi-hop HARQ mechanism performed at the ends of multi-hop links, and in this case, much more stable wireless channels are expected and the design of the RS is relatively simpler than the previous one. In addition, it is easier for RS with the active MR HARQ to perform CID change for the purpose of traffic congregation.

This proposal focuses on mechanisms and implementations regardless of HARQ coding and combining techniques, and both soft combining and Incremental Redundancy (IR) combining are supported. These schemes apply to both uplink and downlink.

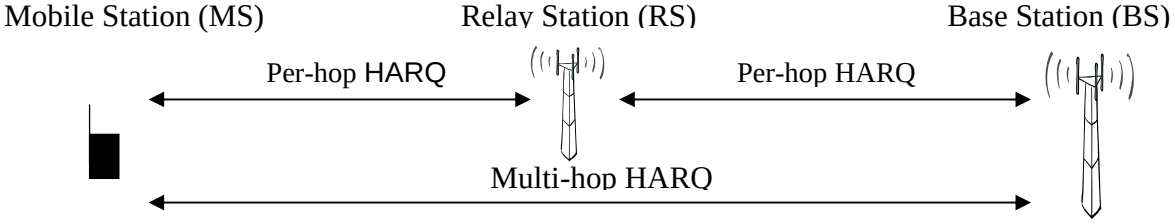


Fig. 1 The per-hop HARQ and the multi-hop HARQ in multi-hop relaying networks

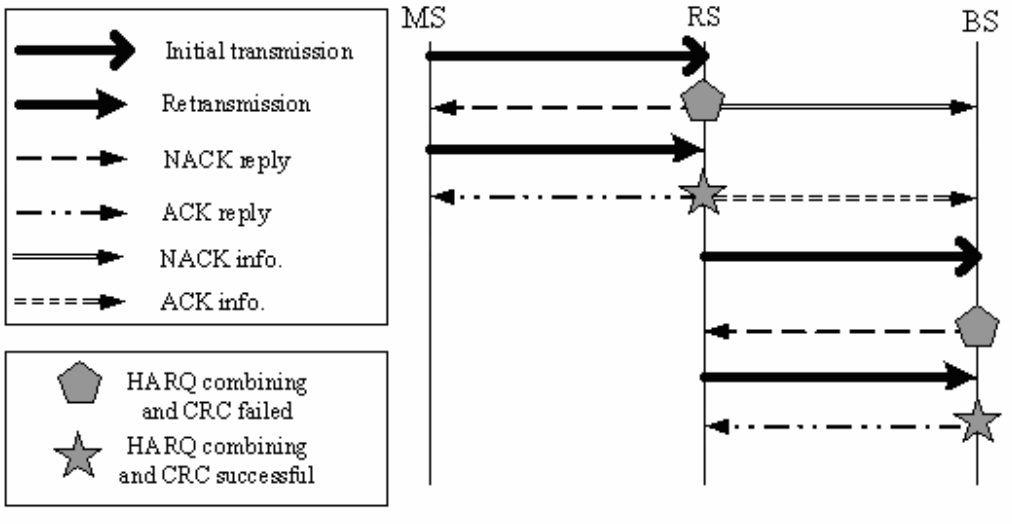
II. System Description

1. Active MR HARQ

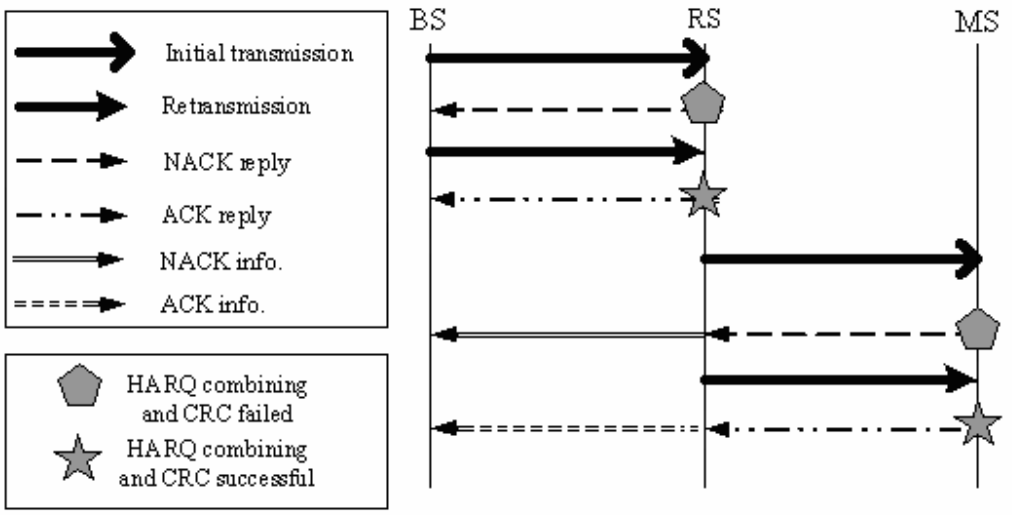
In this mechanism, the per-hop HARQ is performed over each single hop. During each hop, the RS reports to the BS “actively” by a certain message whenever an ACK or a NACK is received, and then the BS correspondingly allocates the resources for the following HARQ retransmission. The principle and procedure of this mechanism is illustrated in Figure 2, where typical 3-hop HARQ procedures in both uplink and downlink are given as examples.

As shown in Figure 2, only the packets which are possibly correct after HARQ combining or whose retransmissions reach their maximum will be forwarded. For example, the RS receives an uplink packet correctly while an “NACK” is received from the BS, that means the errors happened within the hop between the RS and the BS, and then the RS goes on with retransmission and informs the MS of the correct reception with an “ACK”. In this case, it is the BS that allocates the resources for HARQ retransmissions exclusively.

To avoid serious delay due to relaying and retransmission, multiple HARQ retransmissions are proposed to be scheduled within one frame for time diversity if free resources are enough for hops with no MS involved. The support of the BS is expected in this scheme.



(a) The principle and procedure in uplink



(b) The principle and procedure in downlink

Fig. 2: The principle and procedure in the active MR HARQ mechanism

Furthermore, the use of the per-hop HARQ retransmission allows for the different CIDs for the RS and the MS. That means this mechanism can support some special functions of the RS, such as traffic congregation.

2. Passive MR HARQ

Suppose CID is unchanged in the RS, the passive MR HARQ mechanism is expected to be simpler than the active HARQ.

In this mechanism, the number of hops to the destination for the multi-hop HARQ depends on whether the RS correctly receives the initial or combined packet to achieve the flexible and reliable transmission. If CRC is failed at the RS for the initial transmission, the multi-hop HARQ is performed between the source and the destination until the packet after combining at the RS is correct. Otherwise, the multi-hop HARQ is employed between the RS and destination to recover the original data. ACK/NACK message is only initiated by destination, and the RS is responsible to forward the ACK message or invert the NACK to ACK message in

accordance with its CRC verification. No additional messages are required. A 2-hop example of the passive MR HARQ is illustrated in Figure 3.

For the initial transmission of HARQ, the RS performs forwarding regardless of its CRC result. As shown in Figure 3, when HARQ retransmission is received by the RS, it is then combined with the previous receptions. In the case of Chase combining, the combined packet is forwarded no matter whether it is error-free or not. In the case of IR combining the RS forwards this correct packet only if the combined packet is error-free. Otherwise, the original received HARQ retransmission or the combined packet will be forwarded. This procedure continues until the destination correctly receives the packet or the maximum allowed retransmission number is reached.

As a multi-hop HARQ mechanism, the BS keeps requesting the MS to perform HARQ retransmission until its correct reception. Therefore, some resources might be wasted if the correct packet is received in the RS but not received in the BS. However, no extra message is required in this mechanism to inform the BS of the statuses of all intermediate nodes and cooperative relaying can be supported in this mechanism.

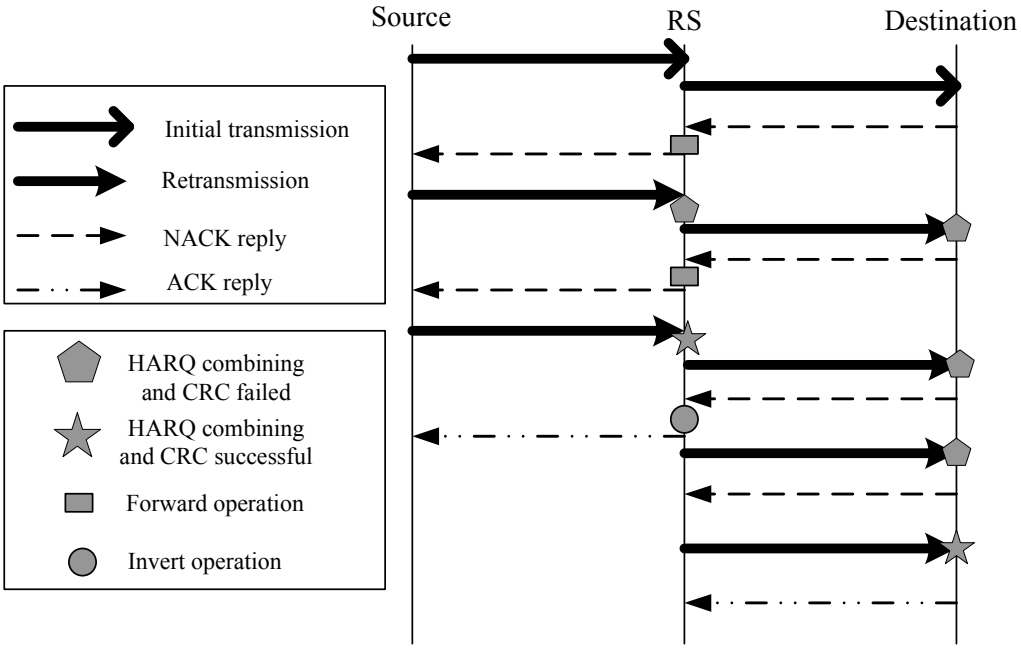


Fig.3: The passive MR HARQ mechanism in uplink

III. Summary

Two complementary multi-hop HARQ mechanisms, active MR HARQ and passive MR HARQ, are proposed for different scenarios and environments. The active HARQ is a mechanism on the per-hop basis to allow for high mobility of the RS and special functions, i.e., CID update and traffic congregation, and fewer resources are required for HARQ retransmissions. The passive MR HARQ is a multi-hop mechanism with limited intelligence, so that the RS is simple and used in the stable environments. In addition, cooperative relay can be implemented with the latter one.

IV. Proposed Text Changes [3]

6.3.2.3 MAC Management messages

[Change the Table 14 as indicated:]

Type	Message name	Message description	connection
67	HQ_INFO	CRC verification result	basic
68-255		*reserved*	---

[Change 6.3.2.3.43.4 as indicated]

Two kinds of HARQ control IE are located in DL/UL MAP_IE. One is HARQ_Control_IE for MS and the other is MR_HARQ_Control_IE for RS. Both formats include encoding/decoding information for HARQ enabled DL/UL bursts, and are presented in the MAC frame.

In MR_HARQ_Control_IE, two HARQ mechanisms, active Multi-hop Relaying (MR) HARQ and passive MR HARQ, are alternative under the indication of Syntax "MHH".

[Insert Table 94b as indicated (note that the original Table 94 is changed to be Table 94a)]

Table 94b MR_HARQ_Control_IE format

Syntax	Size	Notes
HARQ_Control_IE( )	---	---
Prefix	1 bit	0 = Temporary disable MR HARQ 1 = enable MR HARQ
If (Prefix == 1) {	---	---
AI_SN	1 bit	HARQ ID Seq. No
SPID/Reserved	2 bits	Subpacket ID when IR is defined by the FEC mode, otherwise reserved (encoded 0b00)
ACID	4 bits	HARQ CH ID
MHH	1 bit	0 = active MR HARQ is enabled 1 = passive MR HARQ is enabled
Reserved	3 bits	Shall be set to zero
} else {	---	---
Reserved	3 bits	Shall be set to zero
}	---	---
}	---	---

MHH

Indicates which multi-hop HARQ is used, active MR HARQ or passive MR HARQ

[Insert new sub-clause and Table 101f as follows]

Section 6.3.2.3.43.6.10 HQ_INFO message

Table 101f —HQ_INFO message format

Syntax	Size	Notes

HQ_INFO_Message_Format () {		
CID	16 bits	Indicates the link with this CID which is achieved from MS involved within current HARQ retransmission attempt
CRC verification result	1 bit	0 = ACK_Info 1 = NACK_Info
}		

[Insert new sub-clause 6.3.17.4 as follows]

Section 6.3.17.4 HARQ mechanism in multi-hop 802.16j networks

HARQ is performed over each hop based on a stop-and-wait protocol. Two complementary HARQ mechanisms, active MR HARQ and passive MR HARQ, are used on the distinct purposes, but they are compatible to each other in both transparent and non-transparent relays.

[Insert new sub-clause 6.3.17.4.1 and add figures]

Section 6.3.17.4.1 Active MR HARQ mechanism

Fundamentally the active MR HARQ is a per-hop HARQ mechanism which allows for CID update and high mobility of RS. The principle and process of this mechanism are shown in Figure 130ja and 130jb. Its key feature is that besides the "ACK/NACK" reply, the intermediate RS is expected to transmit the associated "ACK/NACK information" to the BS.

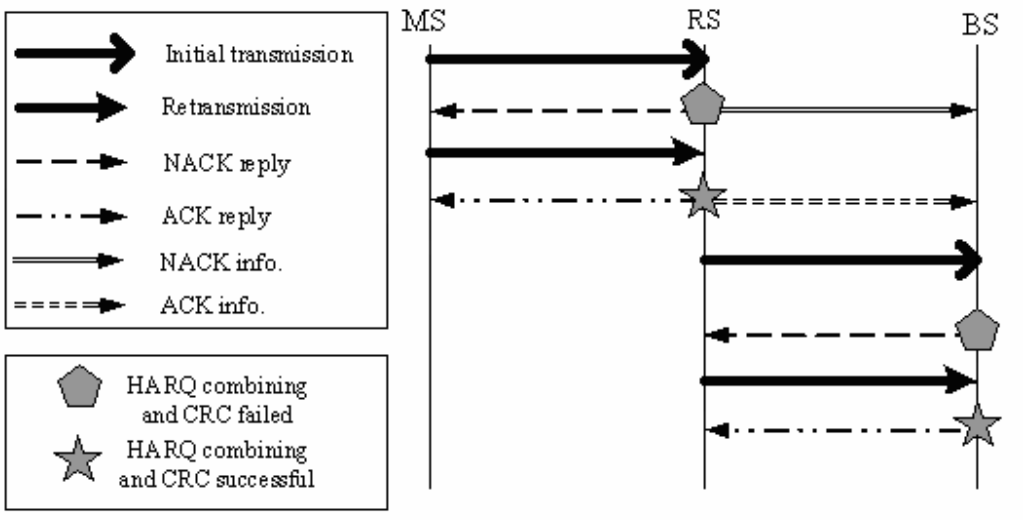


Figure 130ja: The active MR HARQ principle and process in the uplink

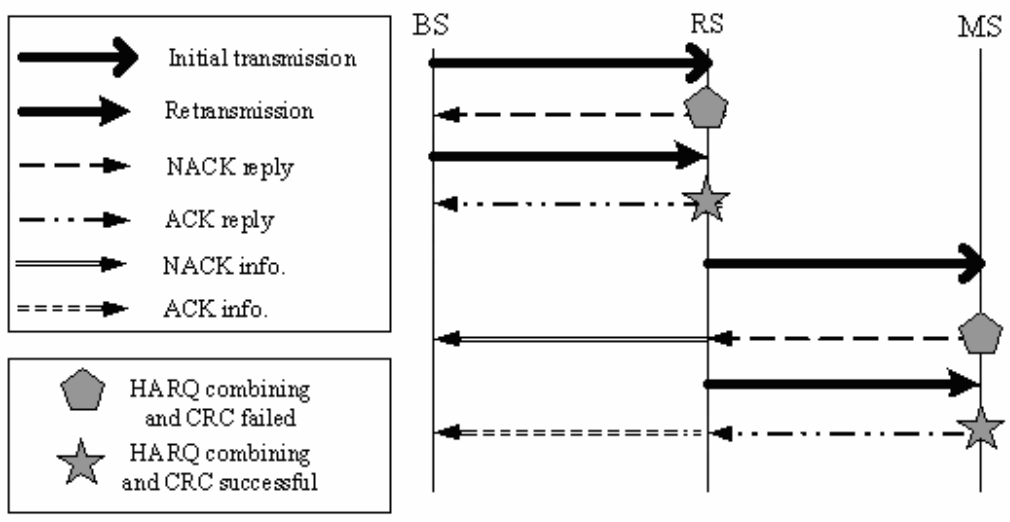


Figure 130jb: The active MR HARQ principle and process in the downlink

In uplink, MS transmits its packet through a certain radio channel which is allocated by the BS and broadcasted in the previous DL-MAP. The RS receives and decodes this packet exclusively if no cooperative relay is taken into account. If the received packet passes the CRC verification after HARQ combining, the S-RS then replies the MS an "ACK" after a fixed delay defined by HARQ_ACK_Delay for UL burst which is specified in DCD message (see Table 358), and meanwhile an "ACK_Info" is forwarded to the BS if there are more than two hops. Otherwise, if this packet fails in CRC verification, a "NACK" is sent to the MS within the duration defined by HARQ_ACK_Delay for UL_burst and an associated "NACK_Info" is then sent to the BS. Due to the stop-and-wait protocol, the retransmissions are only sent after receiving a NACK for the previous transmission or the ACK has not been received within the duration defined by HARQ_ACK_Delay. The similar process happens in the multi-hop links.

In downlink, the process is similar to that of the uplink case except that it is the sender that transmits the HARQ_result_message (HQ_INFO) which comes from the received ACK or NACK. Therefore, the BS is kept monitoring the HARQ processes of each hop and consequently allocates the resources for HARQ retransmission.

[Insert new sub-clause 6.3.17.4.2 and add figures]

Section 6.3.17.4.2 Passive MR HARQ mechanism

The passive MR HARQ is a multi-hop mechanism in which the forward is performed at RS no matter whether the correct packet is received or not in the intermediate RS. This mechanism is dedicated for data forwarding with/without CID change along the route. Both the transparent and non-transparent relay can be supported by this passive MR HARQ mechanism.

The principle and process of the passive MR HARQ is illustrated in Figure 130jc.

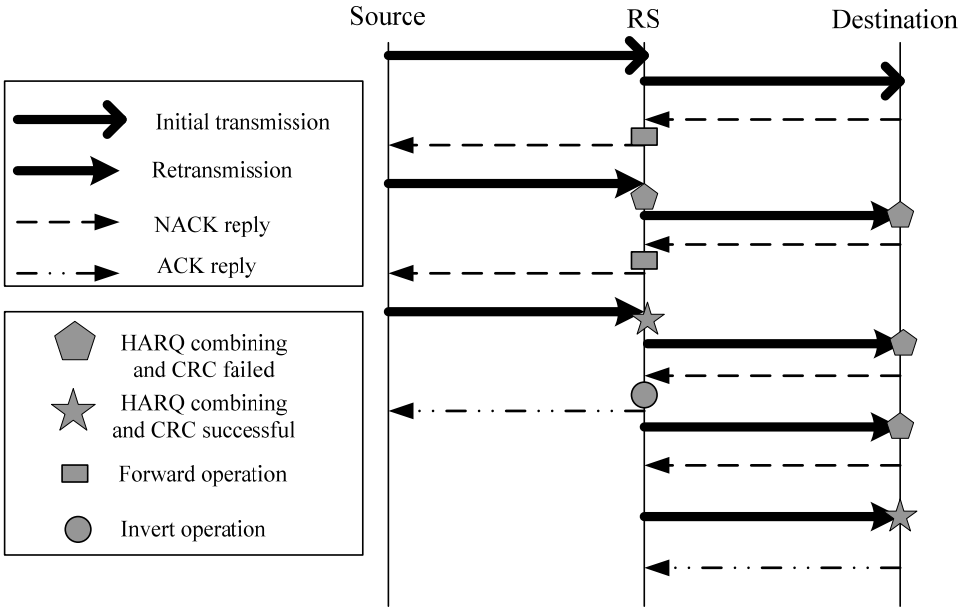


Figure 130jc: The passive MR HARQ mechanism

In both uplink and downlink, the source transmits its packets to RS. The RS forwards the packet to the destination. ACK is sent back to the source via hops from the destination after a fixed delay defined by HARQ_ACK_Delay for UL or DL burst which is specified in DCD message, if the received packet succeeds in the CRC verification. Otherwise, NACK signal is transmitted. Those intermediate RSs simply forward ACK/NACK replies.

Only when a NACK is received for the previous HARQ attempt or an ACK is not received properly, the retransmission is conducted by the source. The intermediate RS performs HARQ combining and CRC verification. If the combined packet passes the CRC verification, the associated RS will play the role of the source in the following HARQ retransmission attempt to send the error-free packet, and also reply ACK signal to the source. Otherwise, the combined packet is forwarded to the next hop for Chase Combining, and the original received HARQ retransmission or the combined packet is forwarded to the next hop for Incremental Redundancy.

The use of the passive MR HARQ mechanism allows for the implementation of cooperative relay even within the intermediate hops.

Reference

[1] C80216mmr-05_028 Open problems in Mobile Multi-hop Relay System.

[2] C80216j-06-029 Usage scenario considerations for 802.16 relay.

[3] IEEE Std 802.16e-2005, IEEE standard for local and metropolitan area networks Part 16: Air Interference for Fixed and Mobile Broadband Wireless Access Systems.