Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**HARQ Mechanisms in Multi-hop Relay**
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Re:	IEEE 802.16j-06_027: “Call for Technical Proposals regarding IEEE Project P802.16j”
Abstract	Two typical categories of multi-hop HARQ mechanisms, active HARQ and passive HARQ, are proposed in this document. The active HARQ, supporting functions such as CID update and traffic congregation, is a mechanism on the per-link basis, and fewer resources are required for HARQ retransmissions. The passive HARQ is more a multi-link mechanism with limited intelligence for simplicity. In addition, the collaborative HARQ is also proposed to introduce spatial diversity/multiplexing gain into the proposed HARQ mechanisms.
Purpose	This document is provided as the input for the IEEE802.16j.
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HARQ Mechanisms in Multi-hop Relay

I. Introduction

In relay based wireless communication systems, the transmission efficiency of the HARQ mechanism is a critical issue since it has great impact on the transmission delay and the system capacity. The intention of this proposal is to develop efficient HARQ (Hybrid ARQ) retransmission mechanisms to be compatible with different designs of relay based 802.16j systems and their certain functions by the collaboration between the relay station (RS) and the base station (BS).

In multi-hop networks, the extra delay possibly is caused by HARQ re-transmissions within multiple hops. Secondly, the physical layer resources are possibly drained due to the assignment for both accessing and relaying. Thirdly, from the perspective of propagation, distinct wireless environments potentially result in the great difference in the performance of HARQ retransmission and combining, which leads to the incompatibility of the transmission rates of different hops and as a result the throughput of the relayed terminal decreases. Consequently as shown in Figure 1, whether the per-link HARQ (that is performed between a single hop to compensate for the in-between the fast fading and shadowing) or the multi-link HARQ (that is performed at the ends of the multiple hops and all HARQ re-transmission resources are allocated by the ends) is more suitable in this multi-hop network need to be found out. Besides, functions and complexity of relay stations should be taken into account.

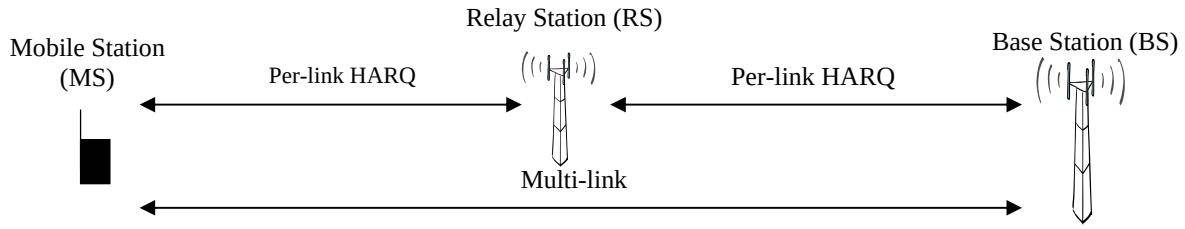

Fig. 1 The per-link HARQ and the multi-link HARQ in multi-hop networks

With a general consideration of the above issues, we propose two main categories of the HARQ mechanisms in multi-hop networks and they are the active MMR HARQ (which can be regarded as a per-link HARQ mechanism) and the passive MMR HARQ (which is a mixture of per-link HARQ and multi-link HARQ). This proposal focuses on mechanisms and implementation regardless of HARQ coding and combining techniques, and both soft combining and Incremental Redundancy (IR) combining are supported.

Besides MMR HARQ mechanisms, the physical layer support of HARQ is also concerned for potential spatial diversity and multiplexing gain. These schemes apply to both uplink and downlink.

II. System Description

1. Active Mobile Multi-hop Relaying (MMR) HARQ

In the active MMR HARQ mechanism, the per-link HARQ is performed within each hop and during each hop, relay stations report to the base station “actively” by a certain message whenever an ACK or a NACK is received and then the base station correspondingly allocates the resources for the following HARQ retransmission. The procedure of this mechanism is illustrated in Figure 2, where a typical uplink HARQ procedure is given as an example.

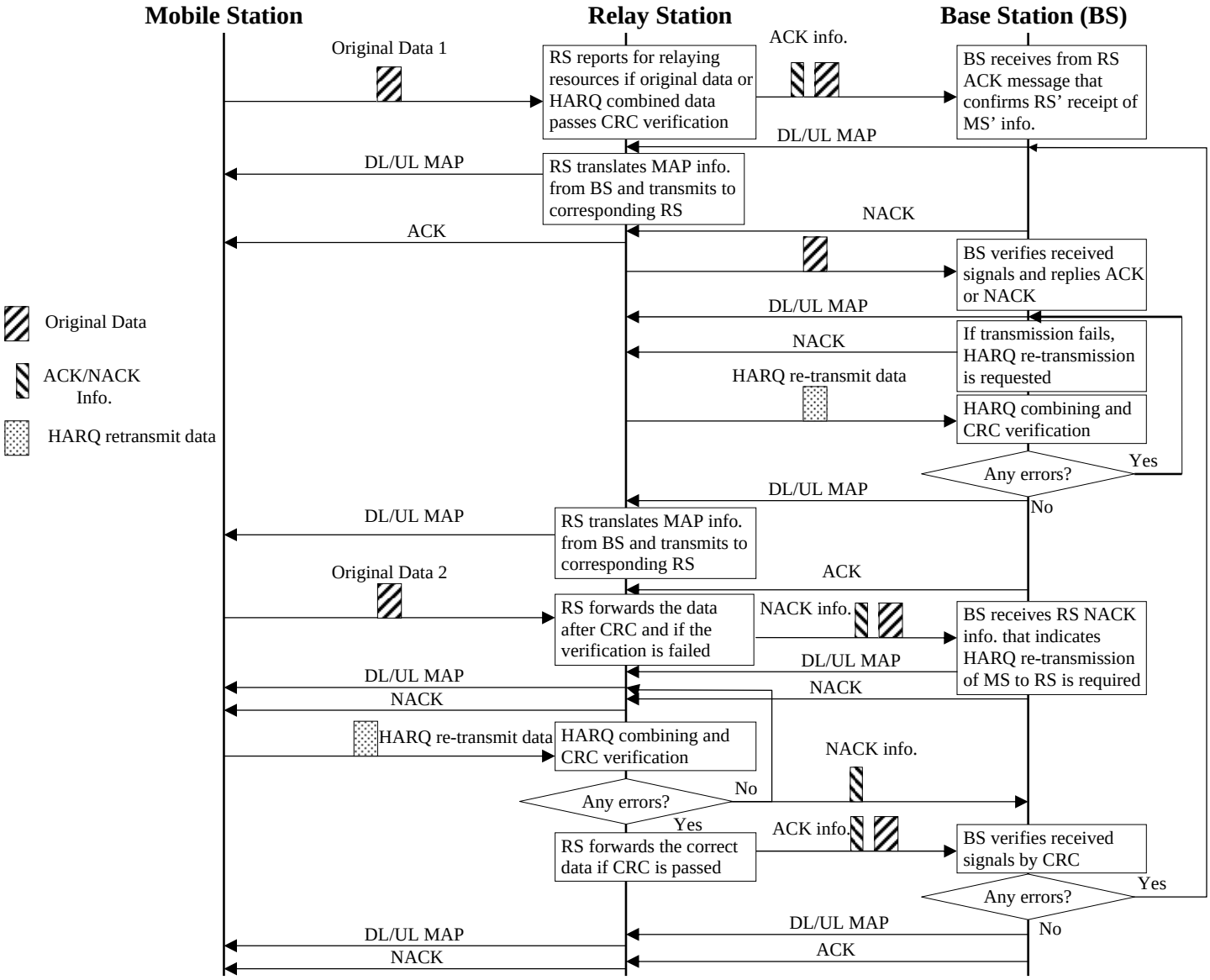

Fig. 2 The uplink example of active MMR HARQ procedure

As shown in Figure 2, the relay station will forward the first transmission of HARQ packet along with its CRC verification result, the "ACK/NACK" information in a defined message, "ACK/NACK info." If the base station receives the first transmission correctly, there is no delay for it and the base station will reply an "ACK". Otherwise, the base station may discard this packet and replies a "NACK" to request HARQ retransmission.

In the other cases, only correct packets (after HARQ combining) will be forwarded. For example, the relay station receives an uplink packet correctly while an "NACK" is received from the base station, that means the errors happen within the hop between the relay station and the base station, and then the relay station goes on with retransmission and informs the terminal of the correct reception with an "ACK".

To avoid the serious delay caused by relaying and HARQ retransmission, multiple HARQ retransmissions are proposed to be scheduled within one frame for time diversity since resources are free due to the silence of previous hops. The support of the base station is expected in this scheme.

As shown in the bottom of Figure 2, if the relay station detects the errors even after HARQ combining, it will actively report to the base station and then since the following frame, the base station will only allocate the HARQ retransmission resources to the terminal and no relaying happens until the correct packet is decoded due to HARQ retransmission and combining in the relay station. In this way, a per-link HARQ is performed and resources are saved.

Furthermore, the use of the per-link HARQ retransmission allows for the different CIDs for the relay station and the terminal. That means this mechanism still works if the relay station changes the CID of the received packets for some purposes, such as traffic congregation.

2. Passive Mobile Multi-hop Relaying (MMR) HARQ

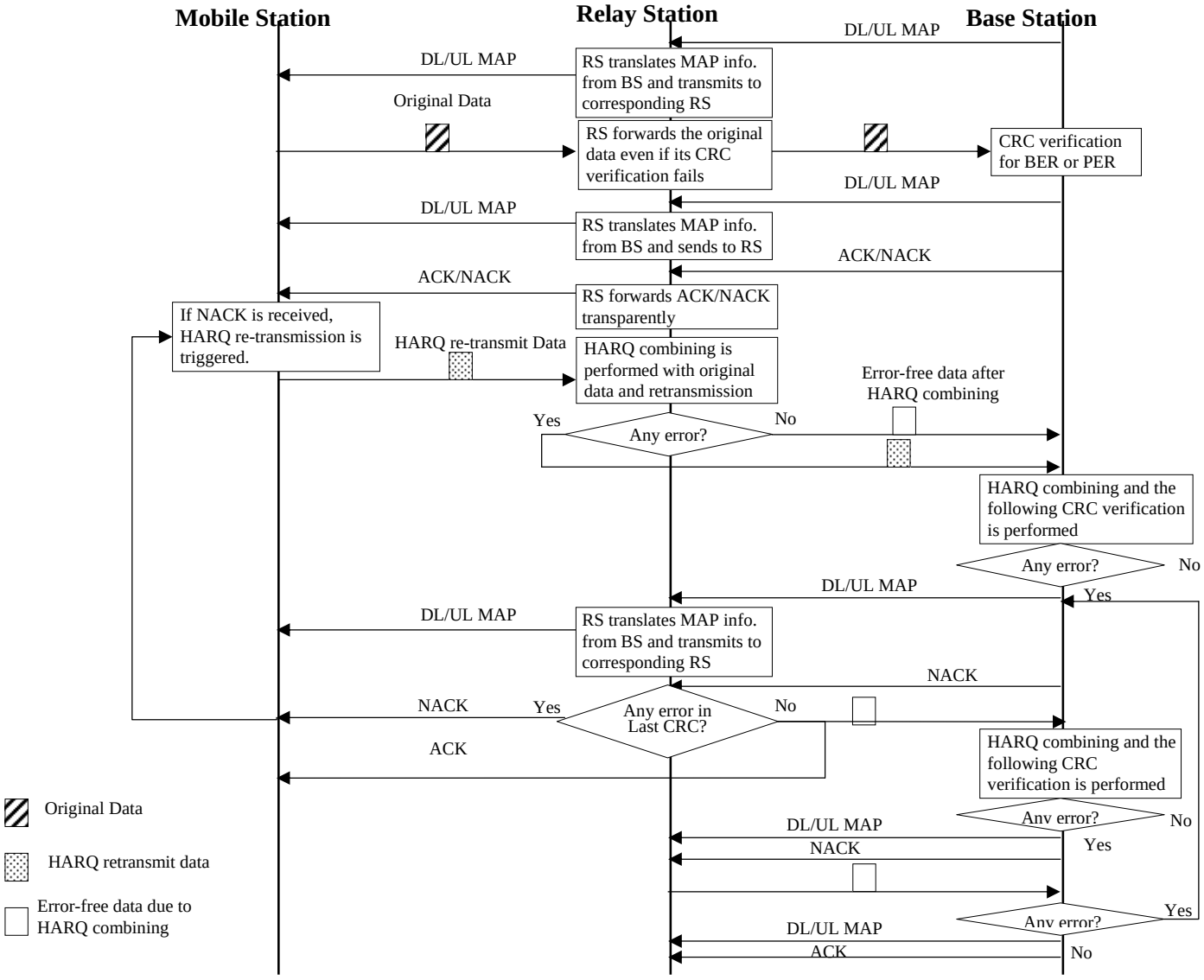

Fig. 3 The example of passive MMR HARQ procedure

Supposing the CID is unchanged in the relay station, the passive MMR HARQ mechanism is expected to be dumper and simpler than the active HARQ. In this case, no additional message is required. As for the "ACK/NACK" reply, relay stations only forwards passively without or with simple process. An example of the passive MMR HARQ is illustrated in Figure 3.

For the first transmission of HARQ, the relay station performs forwarding no matter whether errors are detected or not. It is the two ends of the multi-hop link, the base station and the terminal that reply the “ACK/NACK” after performing the HARQ combining. As shown in the example of Figure 3, when the HARQ retransmission is received by the relay station, it is then combined with the previous receptions in the relay station. If the combined packet passes the CRC verification without errors, the interim relay station forwards this correct packet. Otherwise, the original received HARQ retransmission will be forwarded to avoid error spreading.

In the case that the correct packet is received (after HARQ combining) in a relay station while errors happen in its following hops, the passive MMR HARQ is designed to invert the received “NACK” from the reverse link to an “ACK” in this relay station and then transmit it to its previous hops.

Therefore, the passive MMR HARQ is more a multi-link HARQ mechanism. The base station keeps requesting the terminal to perform the HARQ retransmission until its correct reception. In this case, some resources might be wasted if the correct packet is received in the relay station but not received in the base station. However, no extra message is required in this mechanism to inform the base station of the statuses of all intermediate nodes. Furthermore, cooperative relaying can be supported in this mechanism.

III. Summary

Typically two categories of multi-hop HARQ mechanisms, active HARQ and passive HARQ, are proposed along with the collaborative HARQ which is the physical layer support of multi-hop HARQ for spatial diversity and multiplexing gain. The active HARQ is a mechanism on the per-link basis and relay functions such as CID update and traffic congregation can be supported, and fewer resources are required for HARQ retransmissions. The passive HARQ is more a multi-link mechanism with limited intelligence, so that relay stations are expected simpler and furthermore cooperative relay can be implemented since CIDs of terminals keep unchanged through multiple hops. The collaborative HARQ introduces space-time process into the HARQ mechanisms with gains and can be integrated in the proposed HARQ mechanisms without invalidation.