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Title	NACK based ARQ Over HARQ in IEEE 802.16m
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Re:	MAC Data Plane
Abstract	Cross-layer design of ARQ and HARQ can result in performance improvements and overhead reduction. The HARQ ACK/NACK mechanism is used to provide internal ACK/NACK information to the ARQ layer facilitating the design of NACK based ARQ mechanism.
Purpose	For discussion and approval by TGm
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NACK Based ARQ over HARQ

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Introduction

A cross-layer design of ARQ and HARQ can result in performance improvements and overhead reduction. We take advantage of the HARQ ACK/NACK mechanism and do not duplicate unnecessarily the same ACK/NACK information at the ARQ layer, thus facilitating the design of a NACK based ARQ in 802.16m.

The NACK based ARQ result in lower overhead compared to the legacy system and ultimately a simpler system, which satisfies the SRD requirements of sections 5.2 and 6.0.

In addition, this ARQ over HARQ mechanism should be extended to MAC management flows to facilitate for a generic framework over which all MAC management state machine retransmissions. In the legacy system, each MAC management state machine, e.g. DSx, HO, etc. has its own retransmission mechanism relying primarily on timers. This results in unnecessary delays since timers must be set sufficiently large to allow the lower layer retransmission schemes to complete first. In addition, the timers must also account for the processing delay at the peer entity.

We propose that in 802.16m the MAC management state machines consider the MAC management connections (basic and primary connections in the legacy system) to be a reliable transport facility with a known and adequate frame error rate performance which meets the MAC management reliability requirements.

Discussion

The following sections describe the DL and UL operation of the ARQ over HARQ mechanism.

The basic idea of the NACK based ARQ is for the transmitter to treat HARQ ACK indication with suspicion since it is susceptible to NACK-to-ACK errors. The transmitter sends an internal ACK indication only after a predetermine time to allow the receiver enough time to detect the occurrence of NACK-to-ACK error and to send a second NACK indication.

DL Operation

The base station is the transmitter; the MS is the receiver. The BS relies on HARQ ACK/NACKs to drive MAC level retransmissions (ARQ). The BS keeps track of MAC PDUs mapping to HARQ packets and whether several MAC flows are multiplex onto the same HARQ packet. The ARQ state machine is advanced based on HARQ ACK/NACK. The window size of the NACK based ARQ is managed using the Fragmentation Sequence Number (FSN) in a manner similar to the BSN of the legacy system.

If the HARQ packet is ACK'ed by the MS, the BS sends an internal ACK to the ARQ state machine for the associated MAC PDU. If the HARQ process is terminated with and unsuccessful outcome (independent of the maximum HARQ retransmission parameter), the BS sends an internal NACK indication for the associated PDUs. Note that HARQ packets can carry multiple MAC flows. In this case, the base station needs to send internal ACK/NACK indications to multiple MAC flows state machines.

Error cases for consideration

- HARQ CRC false positive detection – this failure case cannot be detected; the HARQ CRC must be sufficiently robust so that it meets the QoS requirements of all connections.
- UL feedback NACK-to-ACK detection error
    - Re-TX count < MAX Re-TX
        - MS receives New Packet Indicator (NPI) = 1st Tx when it was expecting a retransmission assignment for the HARQ process ID. MS sends an MAC NACK message for the associated HARQ packet to trigger the ARQ retransmission.
    - Re-Tx count = MAX Re-Tx
        - The New Packet Indicator (NPI) cannot be used to infer NACK-to-ACK detection error;
        - BS sends an internal ACK indication to the ARQ layer after a predetermined time.
        - MS must repeat the NACK indication; two possible alternatives for a repeated NACK indication:
            - MAC level NACK message; the MS sends a UL MAC signalling message to confirm the NACK;
            - PHY level NACK message; the MS gets another HARQ feedback channel, one for the current transmission, if any, and a second to confirm the pervious NACK indications. (Low overhead and fast indications)

The figure below shows the downlink operation with MAC level NACK indication.

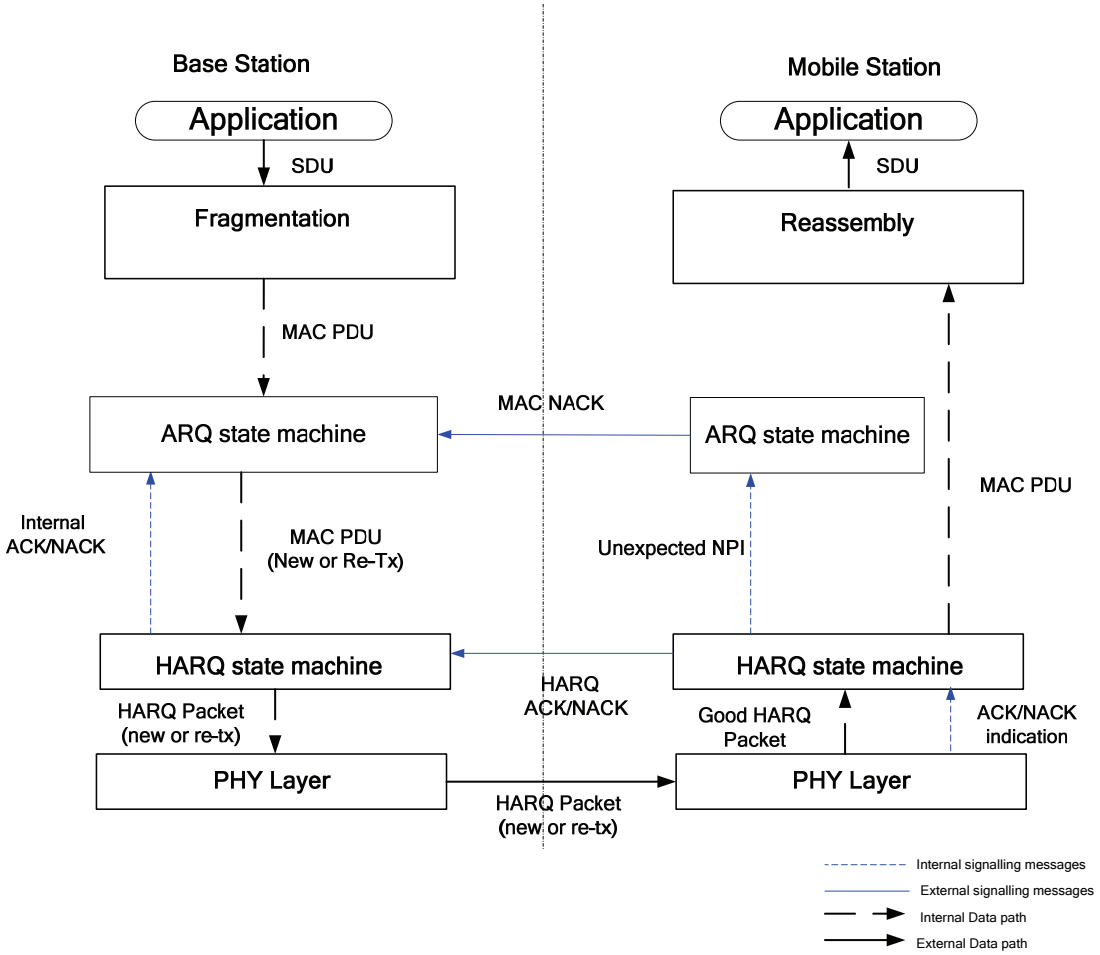

Figure 1: DL ARQ over HARQ operation

UL Operation

The MS is the transmitter; the BS is the receiver. The BS controls the HARQ retransmission operation for both HARQ and ARQ processes. The BS can use an implicit DL HARQ ACK/NACK indication using the New Packet Indicator (NPI). The New Packet Indicator (NPI) signals that the HARQ allocation is for a 1st transmission, or for a Re-Transmission HARQ packet. The transition point (NPI toggles) is interpreted by the MS HARQ as an ACK; NPI is sent as part of the assignment information using the DL control channel.

The MS keeps track of MAC PDUs mapping to HARQ packets. MS assumes that a HARQ packet is implicitly ACKed using the new packet indication (AI_SN toggle in the legacy system) or after the maximum number of retransmission is reached. The MS sends an internal ACK for the associated PDUs after a predetermined time.

If the BS terminates the HARQ process unsuccessfully, it sends the MS a MAC level NACK. The BS must send the MAC level NACK before the predetermined time expires. The MAC level NACK uniquely identifies the HARQ packet so that the MS may trigger ARQ level retransmission for the associated MAC PDUs. For example, the NACK message may contain the HARQ process ID (ACID in the legacy system) and the frame/sub-frame number the HARQ packet was received.

UL ARQ with Implicit DL HARQ ACK/NACK indication;

- Operation:
  - Regardless of the value of the Re-Tx count, If the MS gets NPI=1st Tx, the MS sends internal ACK indication to the ARQ layer after a predetermined time.
  - If the last HARQ process was terminated unsuccessfully (determined at the BS by CRC check), the BS is required to send a MAC level NACK before the predetermined time to trigger ARQ retransmission; Note that BS MAC level NACK is sent only if the pervious transmission was unsuccessful and the BS toggled the new packet indication. This is done regardless of the maximum retransmission count.
- Possible error cases for consideration:
  - HARQ CRC false positive detection – this failure case cannot be detected; the HARQ CRC must be sufficiently robust so that it meets the QoS requirements of all connections.
  - Loss of subsequent assignment information (assuming async HARQ);
    - MS was not able to decode DL control channel and does not know if the new packet indicator was toggled.
    - MS does not transmit on the designated UL allocation
    - BS detects another NACK (CRC check);
      - Re-TX Count < MAX Re-Tx
        - BS sends another allocation with NPI = Re-Tx
      - Re-Tx count = MAX Re-Tx,
        - BS toggles new packet indication to start a new process and sends an ARQ NACK message to the MS.
        - Note that the BS may not start a new HARQ process because for example the there are no packets queued for the MS. However, the BS is still required to send the ARQ NACK to trigger ARQ level re-transmission.

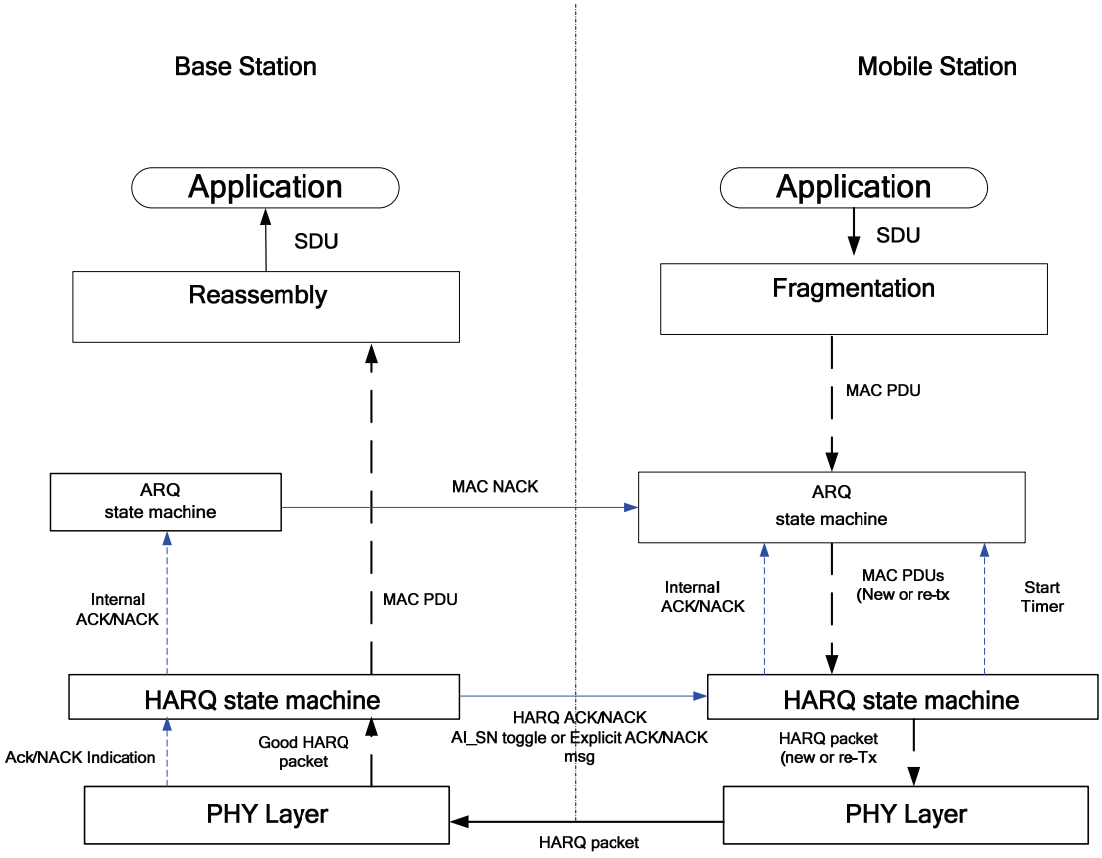

Figure 2: UL ARQ over HARQ operation

Pros and Cons

There are several advantages to NACK based ARQ:

- Overhead savings – ARQ process does not send ARQ ACK indication; with HARQ process performance in excess of 10^{-2} PER, the savings are immediately obvious.
- Faster retransmission since the combined ARQ and HARQ state machine use explicit indications instead of relaying on timers to expire
- Remove the restriction of ARQ block size; ARQ blocks are used in the Legacy system primarily as a way of reducing ARQ ACK overhead, by increasing the granularity from one byte to several bytes. With this NACK based ARQ the NACK granularity is HARQ packet, rather than ARQ blocks.
- Simpler design – no need to coordinate timers between two retransmission mechanisms to ensure that they do not overlap.

Proposed Text

Add the following text to SDD: new Text is shown in blue

10 Medium Access Control

10.x. ARQ

10.x.1 NACK based ARQ Over HARQ

The NACK based ARQ mechanism is extended to both MAC management flows and MAC traffic flows. The MAC management state machines consider the MAC management connections (basic and primary connections in the legacy system) to be a reliable transport facility with a known and adequate frame error rate performance which meets the MAC management reliability requirements.

10.x.1.1 NACK based ARQ DL Operation

The base station is the transmitter; the MS is the receiver. The BS relies on HARQ ACK/NACKs to drive MAC level retransmissions (ARQ). The BS keeps track of MAC PDUs mapping to HARQ packets and whether several MAC flows are multiplex onto the same HARQ packet. The ARQ state machine is advanced based on HARQ ACK/NACK. The window size of the NACK based ARQ is managed using the Fragmentation Sequence Number (FSN) in a manner similar to the BSN of the legacy system.

If the HARQ packet is ACK'ed by the MS, the BS sends an internal ACK to the ARQ state machine for the associated MAC PDU after a predetermined time. If the HARQ process is terminated with and unsuccessful outcome (independent of the maximum HARQ retransmission parameter), the BS sends an internal NACK indication for the associated PDUs. Note that HARQ packets can carry multiple MAC flows. In this case, the base station needs to send internal ACK/NACK indications to multiple MAC flows state machines.

UL HARQ Feedback NACK-to-ACK detection error is overcome by the MS repeating the HARQ NACK indication. The method of repeating this message is FFS. The MS must send repeated HARQ NACK indication before the predetermined time expires.

10.x.1.2 NACK based ARQ UL Operation

The MS is the transmitter; the BS is the receiver. The BS controls the HARQ retransmission operation for both HARQ and ARQ processes. The BS can use an implicit DL HARQ ACK/NACK indication using the New Packet Indicator (NPI). The New Packet Indicator (NPI) signals that the HARQ allocation is for a 1st transmission, or for a Re-Transmission HARQ packet. The transition point (NPI toggles) is interpreted by the MS HARQ as an ACK; NPI is sent as part of the assignment information using the DL control channel.

The MS keeps track of MAC PDUs mapping to HARQ packets. MS assumes that a HARQ packet is implicitly ACKed using the new packet indication (AI_SN toggle in the legacy system) or after the maximum number of retransmission is reached. The MS sends an internal ACK for the associated PDUs after a predetermined time.

If the BS terminates the HARQ process unsuccessfully, it sends the MS a MAC level NACK. The BS must send the MAC level NACK before the predetermined time expires. The MAC level NACK uniquely identifies the HARQ packet so that the MS may trigger ARQ level retransmission for the associated MAC PDUs. For example, the NACK message may contain the HARQ process ID (ACID in the legacy system) and the frame/sub-frame number the HARQ packet was received.