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Title	**Detaining and dropping signaling for HARQ feedback in increasing throughput capability under less necessary HARQ soft buffer requirement**	
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Re:	Re: PHY: HARQ; in response to the TGm Call for Contributions and Comments 802.16m-08/033 for Session 57	
Abstract	This contribution introduces detaining signaling and dropping signaling in reducing necessary HARQ soft buffer.	
Purpose	For discussion and approval by IEEE 802.16m TG	
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Detaining and dropping signaling for HARQ feedback in increasing throughput capability under less necessary HARQ soft buffer requirement

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1 Introduction

This contribution introduces detaining signaling to reduce necessary HARQ soft buffer. Contribution [1] depicts that the necessary soft buffer is large in supporting 100Mbps or even 1Gbps throughput. However, the soft buffer is generally not in use due operating packet error rate=0.1. Low packet error rate implies the vacant buffer, i.e. the buffer is over design. One can reduce the buffer but it causes larger packet dropping rate. Therefore, we introduce a detaining signaling. If the soft buffer is almost in use, each HARQ process can send detaining signaling instead of ACK to halt the process for one RTT or multiple RTTs. Therefore the MS can exploit high throughput and low complexity at the same time.

2 N-Channel Stop and Wait HARQ mechanism

Fig. 1 shows an N-channel HARQ communication system. HARQ incorporates channel coding and CRC code detection. Each virtual channel has one HARQ process. Fig. 2 shows an HARQ mechanism for one HARQ process. This mechanism stores the received packet if the decoded data can not pass the CRC detection. Then receiver stores the received packet in the ith HARQ buffer shown in Fig. 1.

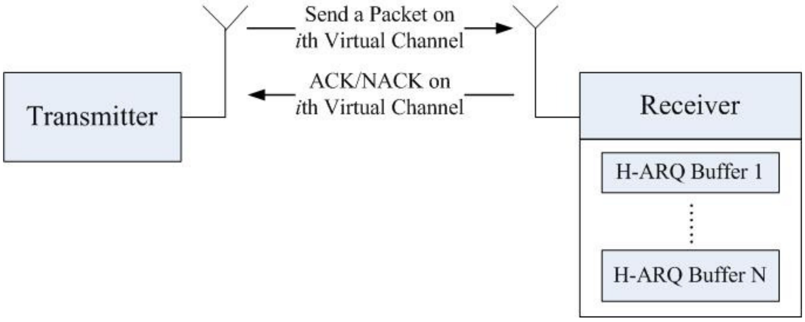

Fig. 1: N-channel HARQ communication system.

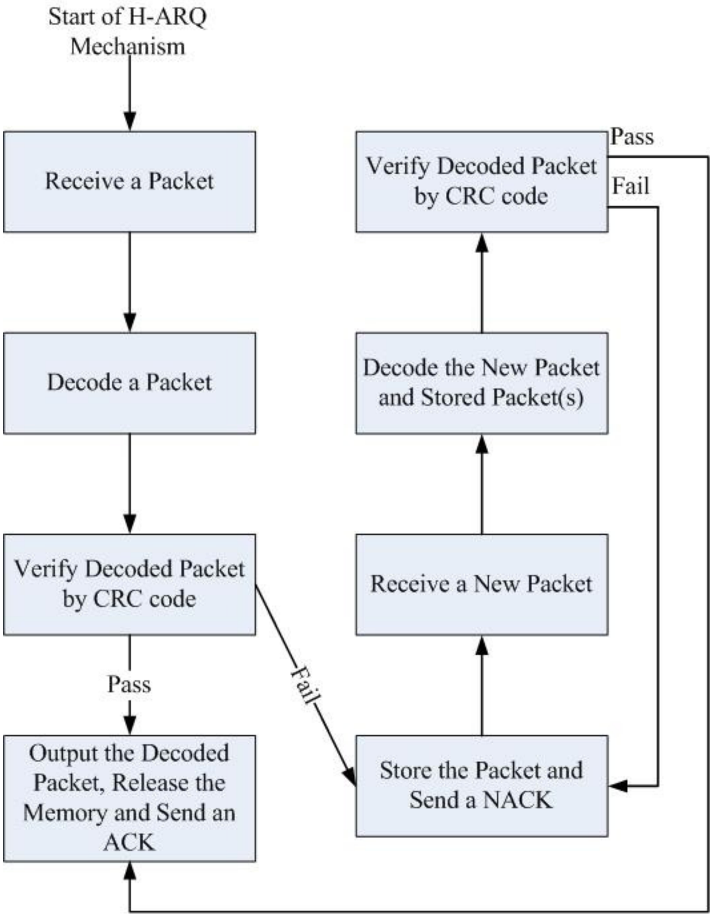

Fig. 2: Hybrid ARQ mechanism.

Memory size for HARQ buffers determines the throughput of N-channel HARQ communication system. If all HARQ processes fail the CRC detection at the same time, all packets will be stored in the HARQ buffer 1 to HARQ buffer N. Memory size constraints the number of HARQ buffers or the size of each HARQ buffer. Therefore memory size limits the throughput.

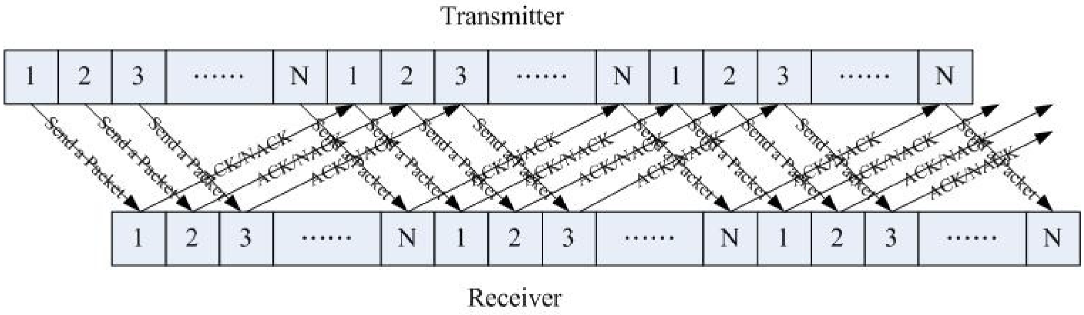

Fig. 3: Time diagram of N-channel HARQ mechanism.

3 N-Channel Stop and Wait HARQ mechanism with detaining feedback

signaling

In general, HARQ operates on packet error rate = 0.1. That all buffers are all in use rarely occurs. For example, if there are 6 HARQ channels and each channel carries one HARQ process, the occurrence of all buffers in use is around 10^{-6} given the packet error rate=0.1 and Table 1 shows the occurrence of number of HARQ buffers in use. The case that two HARQ buffers are in use occupies more than 97%. It implies that half buffers, 3 HARQ buffers, are enough to support HARQ mechanism well-operating in most cases. Therefore, the memory constraint could be relaxed.

Table 1: The occurrence of buffer usage for 6 HARQ channels when packet error rate =0.1.

Number of HARQ buffers in use	0	1	2	3	4	5	6
Occurrence	0.53	0.35	0.098	0.015	0.0012	5.4×10^{-5}	10^{-6}

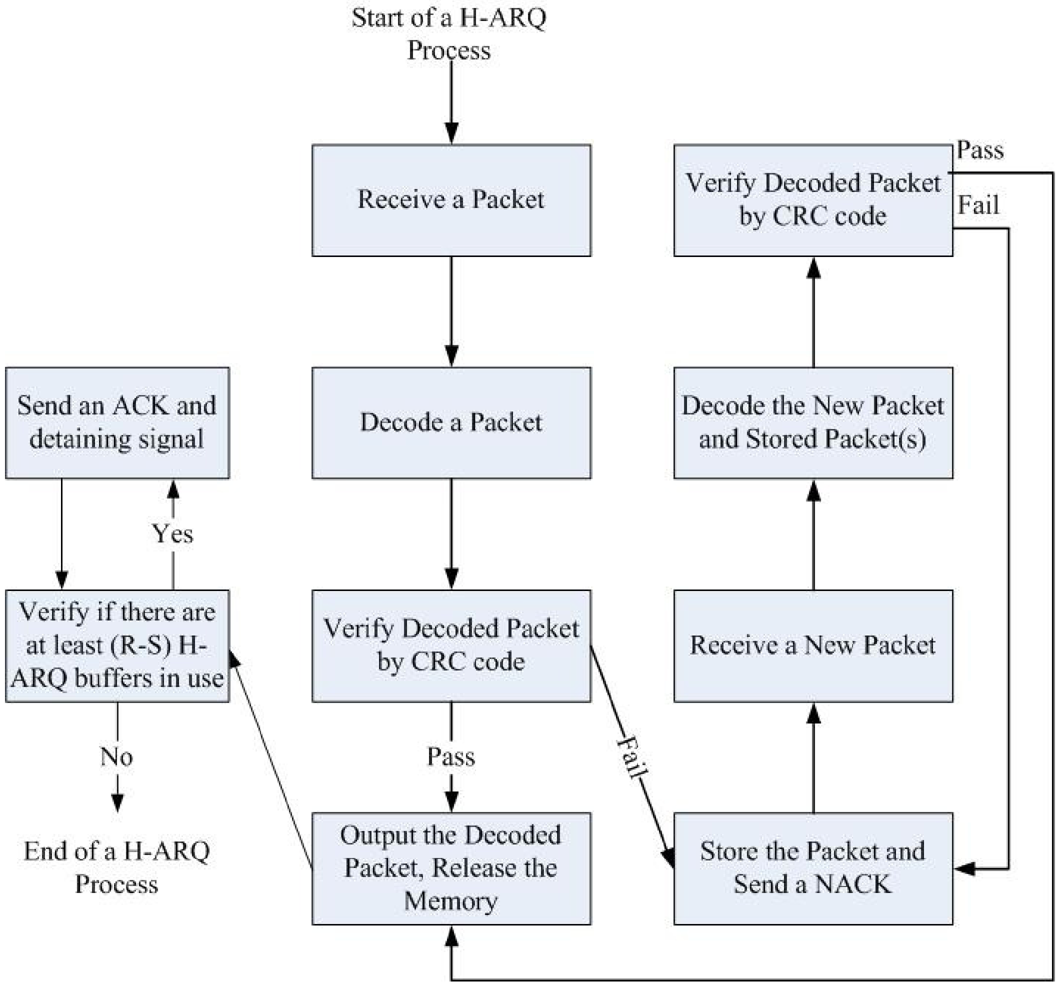

Fig. 4: HARQ mechanism to avoid memory outage.

Fig. 4 illustrates a method which can avoid memory outage. After the decoded packet passes CRC verification, the HARQ process will check if there are at least (R-S) HARQ buffers in use. If there are no more than (R-S-1) HARQ buffers in use, the process will send an ACK and end the process. If there are at least (R-S) HARQ buffers in use, the process will send an ACK and detaining signal. The detaining signal stops the transmitter sending a new packet. The HARQ process will go to the next scheduled time in sending an ACK and check if there at least (R-S) HARQ buffers in use. If there are still at least (R-S) HARQ buffers in use, the process will send an ACK and detaining signal. This process stops until there are no more than (R-S-1) HARQ buffers in use.

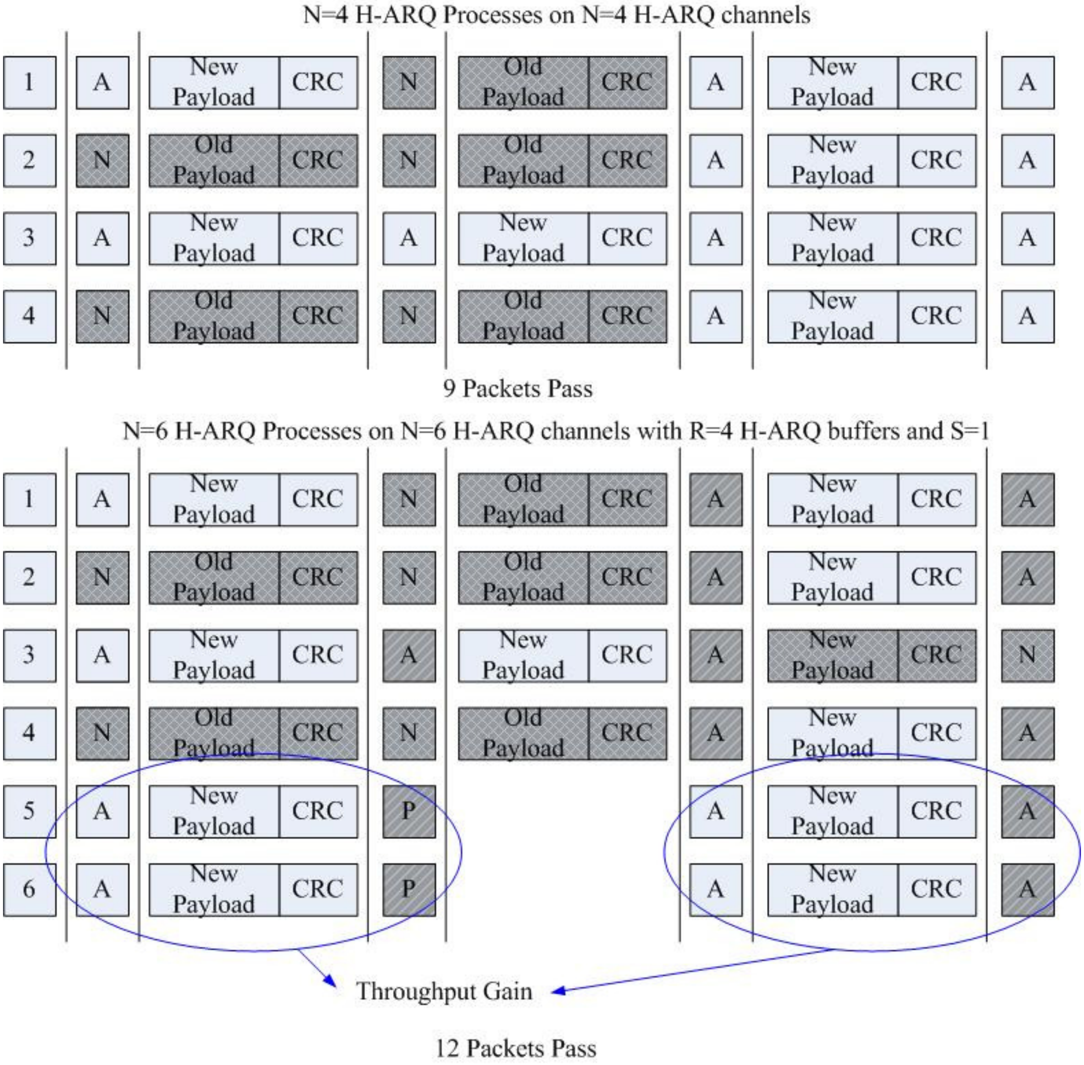

Fig. 5: An example in comparing conventional HARQ and the proposed HARQ mechanisms.

Fig. 5 further illustrates an example to visualize the gain of this method. If we consider there are only four HARQ buffers. Conventional HARQ mechanism only provides four HARQ processes in a communication pair. The proposed method can utilize 6 HARQ processes in communication pairs. In this example, the proposed method can transmit 12 packets but using conventional method 9 packets is transmitted. The proposed methods transmit extra three packets. One can increase the number of HARQ processes to transmit more packets.

4 N-Channel Stop and Wait HARQ mechanism with detaining feedback signaling and multiple sub-processes per channel

Increasing the number of HARQ processes per HARQ channel is the way to reduce memory constraint. Conventional HARQ mechanism carries one HARQ process on one HARQ channel. However, this increases the buffer size requirement if one HARQ process does not pass the CRC verification. If we divide one HARQ process into multiple HARQ processes, e.g. M HARQ processes, the occurrence of all these HARQ processes failing CRC verification decreases. The larger number of HARQ processes per channel, the less memory required to avoid memory outage. Fig. 9 illustrates the associated multiple HARQ processes in a communication system. Each channel carries M HARQ processes and there are N×M HARQ buffers in the system.

Different channel can carry different HARQ processes to acquire flexibility in resource allocation. In other words, we do not constraint all channels apply identical number of HARQ processes.

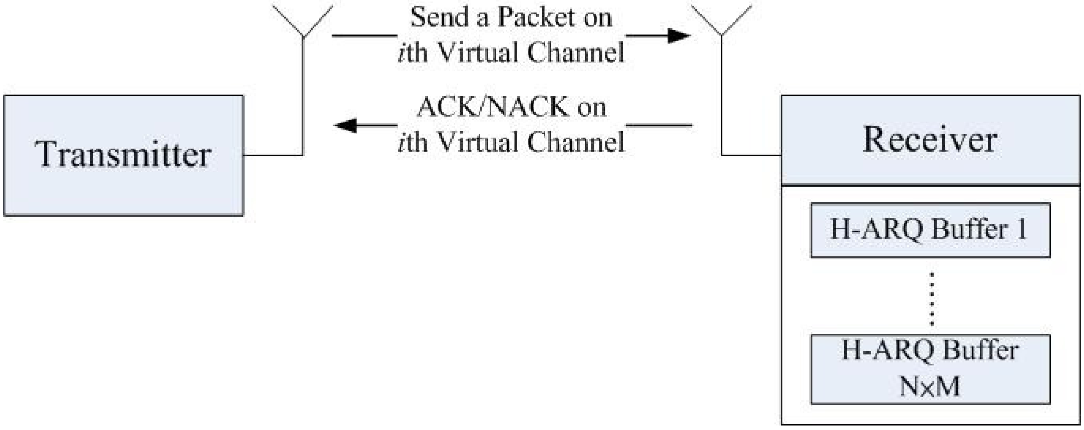

Fig. 6: An example of N channel HARQ communication system with M HARQ processes on one channel.

Fig. 7 illustrates an example in comparing our proposal with and without multiple (2) HARQ processes per channel. For fair comparison, the buffer size for multiple HARQ processes per channel is half of one HARQ process per channel. In this example, the 2 HARQ processes method transmits 29 half packets but the single process method transmits 12 packets; the 2 HARQ processes method transmits extra 2.5 packets. One can increase the number of HARQ processes to transmit more packets.

The multiple processes method also improves transmission rate by half packet passing CRC verification. In figure 7, half packet can pass CRC verification and succeed in transmission for the multiple processes method but the signal process method retransmits whole packet. The multiple process method saves radio resource.

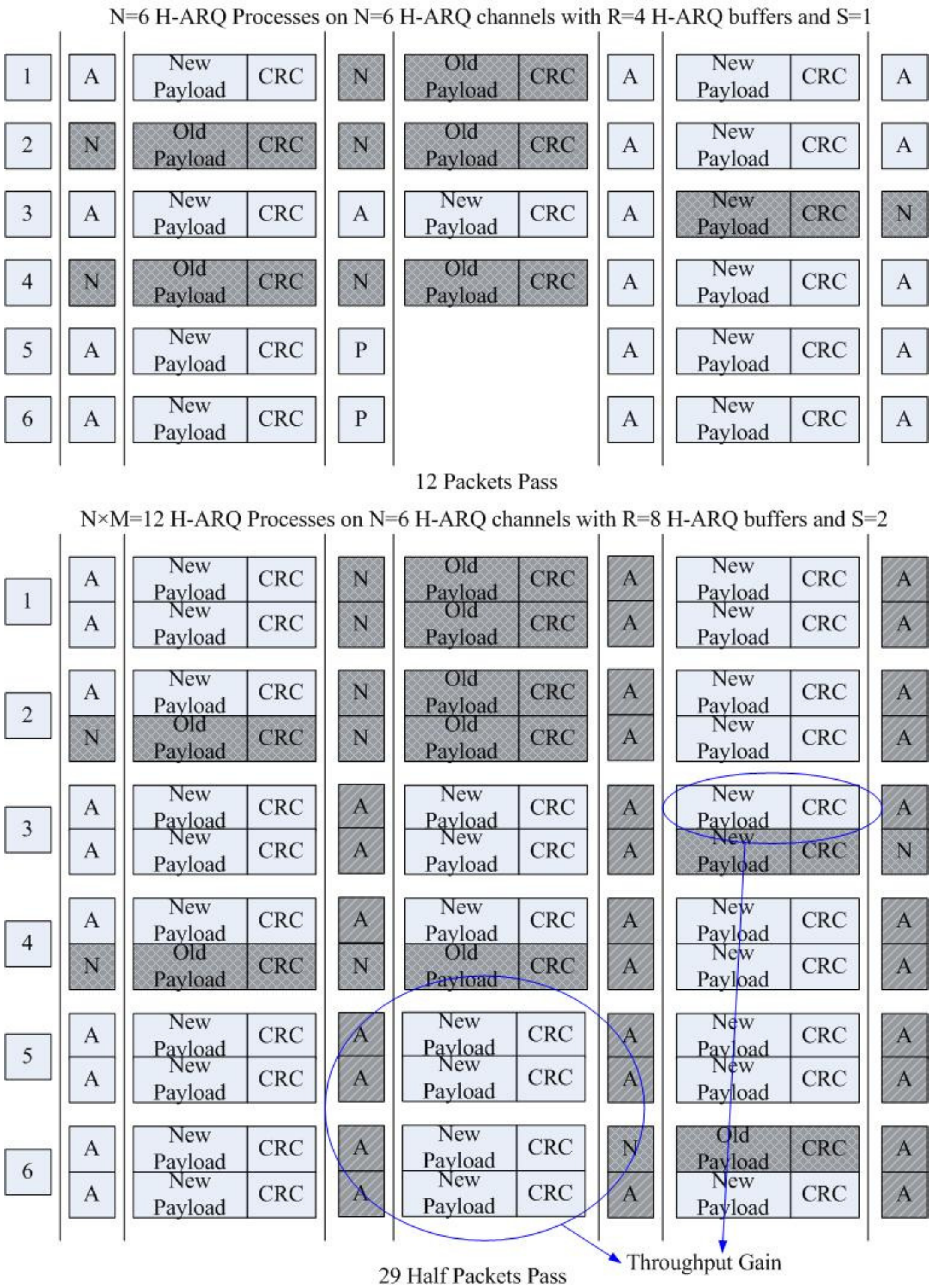

Fig. 7: An example in comparing the proposed HARQ mechanism with and without multiple processes per channel.

The multiple processes method divides one HARQ process into multiple HARQ processes. For high throughput communication, one packet is generally composed of multiple codewords. If one of the codewords fails decoding and all codewords can be transmitted again. We take M as the number of HARQ processes per channel. Therefore, the multiple processes can decreases the frame error roughly to 1/M because the packet length of the M processes methods is 1/M of the packet length of the single process method.

The throughput of these HARQ methods can be calculated by following equations. p denotes packet correct rate, D_{size} denotes the packet size, and T_{ms} denotes HARQ round trip delay.

N channel HARQ processes:

$$\begin{aligned} & \mathit{Throughput} \\ &= \sum_{i=0}^{N} (N-i)P(i)D_{size} / T_{ms} \\ &= \sum_{i=0}^{N} (N-i)C_i^N p^{N-i}(1-p)^i D_{size} / T_{ms} \end{aligned}$$

N channel HARQ processes with R memory buffers and S:

$$\begin{aligned} & \mathit{Throughput} \\ &= \sum_{i=0}^{R-S} (N-i)P(i)D_{size} / T_{ms} \\ &= \sum_{i=0}^{R-S} (N-i)C_i^N p^{N-i}(1-p)^i D_{size} / T_{ms} \end{aligned}$$

N channel HARQ processes with R memory buffers, S and M HARQ processes per channel:

$$\begin{aligned} & \mathit{Throughput} \\ &= \sum_{i=0}^{R-S} (N \times M - i)P(i)D_{size} / M \times T_{ms} \\ &= \sum_{i=0}^{R-S} (N \times M - i)C_i^{N \times M} p^{N \times M - i}(1-p)^i D_{size} / M \times T_{ms} \end{aligned}$$

Table 2 shows the performance comparison for these mechanisms. 4 HARQ buffers is used for these mechanisms. Conventional HARQ mechanism applies 4 HARQ channels and processes. The proposed methods apply 6 HARQ channels with and without 2 HARQ processes per HARQ channel. HSDPA and IEEE 802.16e are compared in this table. p=0.9 is used in this example and generally used for system design. D_{size}=16,384 bits for IEEE 802.16e. T_{ms}=10ms for IEEE 802.16e respectively. The proposed method provides around 50% throughput gain. In other words, the buffer size can be reduced to 2/3 (33% buffer reduction) under the same throughput. The gain is significant.

Table 2: Performance comparison for these HARQ mechanisms.

	IEEE 802.16e
4HARQ processes	Throughput= 2.95Mbps
6HARQ processes with detaining signaling and R=4, S=1	Throughput= 4.36Mbps
	Throughput gain=47.8%
	Buffer saving under the same throughput=32.39%
12 HARQ processes with detaining signaling and R=8, S=2, M=2	Throughput= 4.48Mbps
	Throughput gain=51.86%
	Buffer saving under the same throughput=34.25%

5 N-Channel Stop and Wait HARQ mechanism with detaining feedback

signaling and dropping signaling

Extra dropping signaling can be introduced to reinitiate a new HARQ process to prevent buffer outage. There is still a case that all HARQ processes can not pass CRC check and no detaining signaling. In this case, dropping signaling can be used to indicate some of HARQ processes to reinitiate. Furthermore, these HARQ processes would be further detained. The dropping signal will be send when the HARQ process does not pass CRC check and the buffer is not enough. Since the signal is introduced, ARQ mechanism is not needed to recover packet dropping due to lack of HARQ buffer and extra ARQ-introduced delay is avoided. Fig. 8 shows an example of HARQ mechanism with dropping signaling.

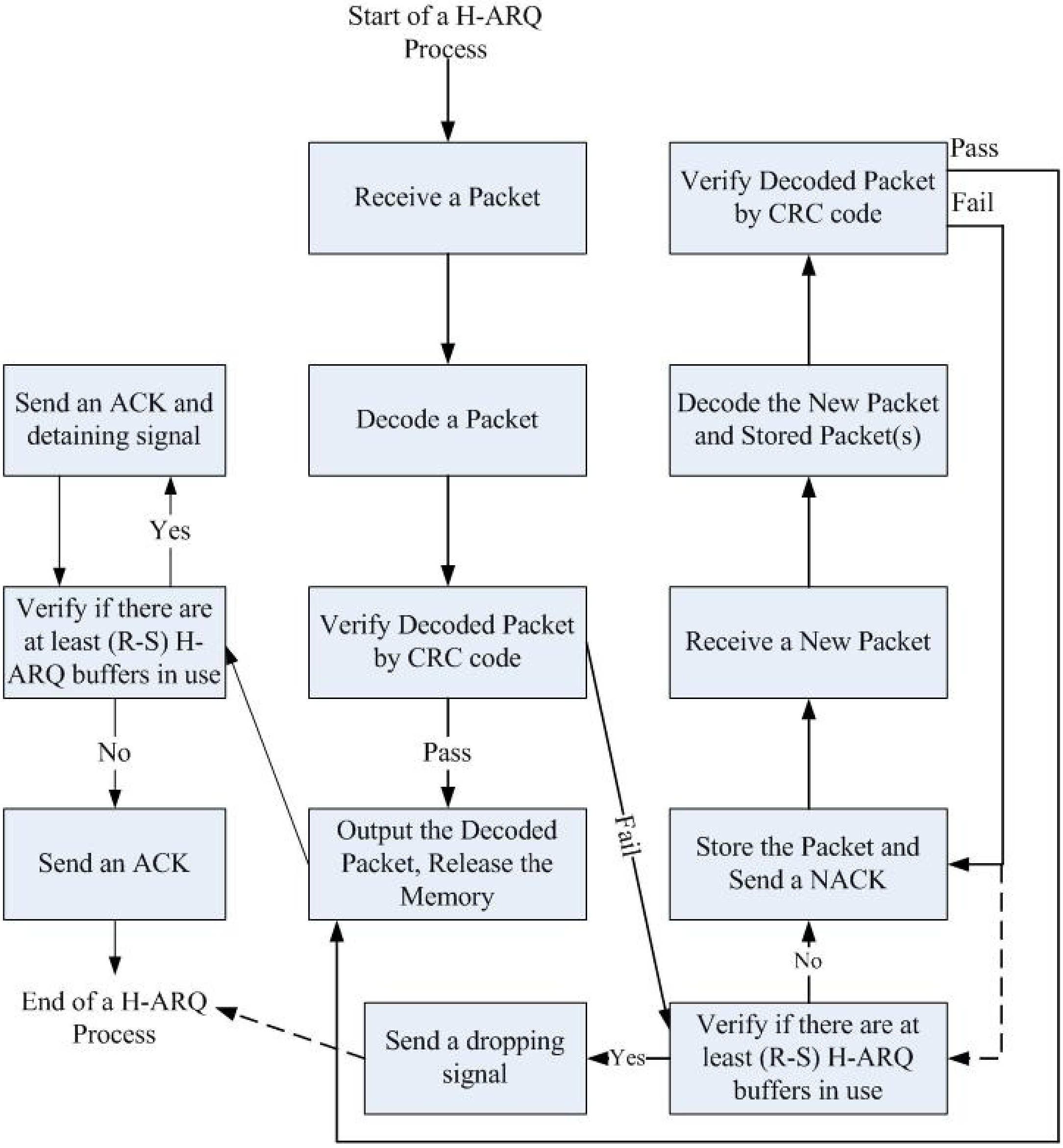

Fig. 8: HARQ mechanism to avoid memory outage with dropping signaling

6 Conclusion

A detaining and dropping feedback signaling are introduced. With these feedbacks, the receiver can implement N-Channel stop and wait with less soft buffer. An example is shown to demonstrate the capability of this feedback. If the number of channels becomes larger, larger throughput can be provided and the buffer outage occurs rarely. If the buffer is really busy, dropping signal would restart overall HARQ process. In system requirement document [2], “IEEE 802.16m should minimize complexity of the architecture and protocols and avoid excessive system complexity.” The proposed method reduces the receiver complexity.

References

[1] IEEE C802.16m-08/585r1, “Hybrid ARQ buffer issues,” ITRI, July 2008.
[2] IEEE 802.16m-07/002r4, “IEEE 802.16m System Requirements,” IEEE 802.16 TGm, October, 2007.

============================== TEXT Proposal ==============================

11.x.1 Channel coding and HARQ

11.x.1.1 Channel coding

11.x.1.1.1 Block diagram

11.x.1.1.2 Partition into FEC blocks

11.x.1.1.3 FEC encoding

11.x.1.1.4 Bit selection and repetition

11.x.1.1.5 Modulation

11.x.1.2 HARQ

11.x.1.2.1 HARQ type

11.x.1.2.2 Constellation re-arrangement

11.x.1.2.3 Adaptive HARQ

11.x.1.2.4 Exploitation of frequency diversity

11.x.1.2.5 MIMO HARQ

11.x.1.2.6 HARQ feedback

There are four kinds of HARQ feedbacks, ACK, NACK, detaining signaling and dropping signaling. ACK signaling indicates a successful transmission. NACK signaling indicates an unsuccessful transmission. For the purpose of soft buffer complexity, detaining signaling and dropping signaling are introduced to avoid the buffer outage and maintain the link reliability with economic size of soft buffer. Detaining signaling indicates a successful transmission and transmitter will halt for a period, e.g. one or two RTT until the unfinished HARQ processes finish their transmission and there are enough a fixed amount soft buffers left. Dropping signaling reinitiate a new HARQ process and indicates that received burst can not be decoded and the soft buffer is full. An example of HARQ flow chart is shown in Fig. XXX.

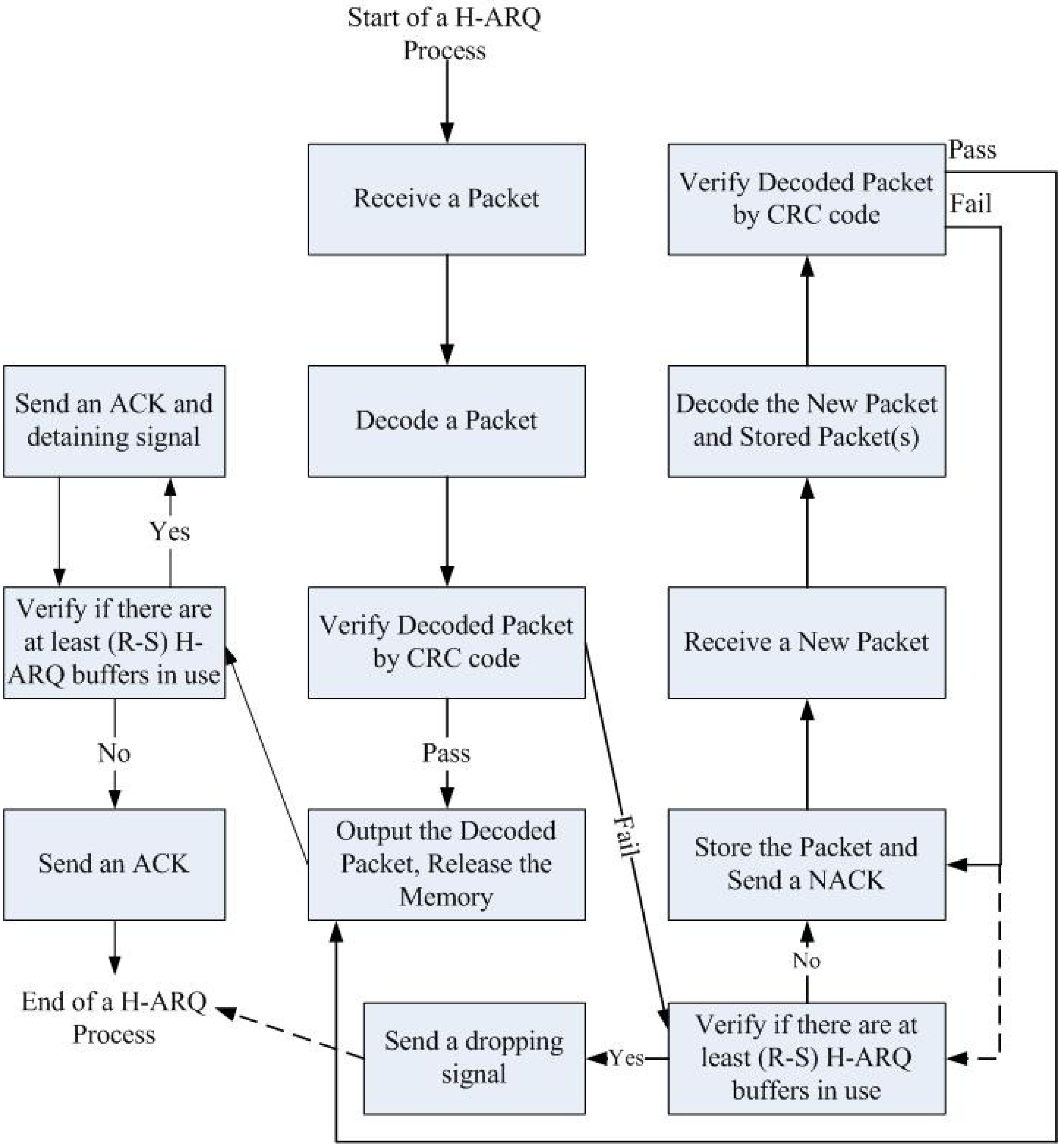

Fig. XXX: The HARQ mechanism with detaining and dropping signaling.