

# Efficient Hybrid ARQ Based on Implicit Information

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**Abstract**— This paper introduces the concept of implicit information into the error control scheme of hybrid ARQ and which information is high SNR. This implicit information is inferred from the decrease of error weights in the two consecutive decoded code words. With the implicit information, the performances of hybrid ARQ scheme are improved in both error-correcting performance and throughput efficiency without increasing too much decoding complexity.

**Keywords**— Hybrid ARQ, implicit, error weight, throughput, Hamming distance.

## I. INTRODUCTION

Basically, communications between people are misunderstood by one another most of the time. Hence, repetitions are required for better understanding. Likewise, asking for re-transmission in digital communication is a way to guarantee receiving the correct information, particularly for something that can not be misinterpreted such as money transfer, launching missile, operating nuclear power. However, time is limited in some cases. Hence, many have proposed different kinds of strategy to improve the throughput efficiency of hybrid ARQ (Auto-Repeat Request) schemes using such as reliability accumulation [1]-[3], variable code rate [4]-[6], thresholds [7], cascaded coding [8], criteria[9],[10], decoding failure [11], particular codes [12]-[15], and voting[16], [17]. Unlike those mentioned above, this paper introduces the concept of implicit information into the error control scheme of hybrid ARQ. Such a concept comes from people's linguistic communication which sometimes does not mean exactly [18]. Instead, some information has implicitly revealed on their expressions and emotions. Such an implicit communication has been used in the multi-robot systems based on behaviours from other robots or from environmental changes through sensors [19]-[21]. Moreover, intelligent control with the aid of implicit estimation is implemented as well in [22]. In this paper, a hybrid ARQ based on implicit information from the decrease of error weights for the two consecutive decoded code words is proposed. Both error-correcting capability and throughput efficiency outperform the convectional hybrid ARQ scheme. In the subsequent sections, the implicit information is explained and simulation results are demonstrated to support the reasoning of implicit information. In addition, performances and decoding complexity of the proposed scheme with implicit information are compared with the conventional ARQ scheme and with the one proposed in [16].

## II. IF-HARQ

IF-HARQ is hereafter used in brief for the proposed hybrid ARQ scheme based on implicit information. Basically, Golay code (23,12,7) is used for simulation of the proposed IF-HARQ, where the first number 23 denoted code length, the second number 12 denoted message length, and 7 the minimum distances between code words. Now, consider a convectional ARQ scheme when receiving a word. If errors are detected, system asks for re-transmission until receiving the word with no error detected. It is kind of inefficiency. Some useful information is implicitly embedded in the error messages. For the IF-HARQ scheme, errors are corrected and keep the code word and error weights in memory buffers. Then, system asks for re-transmission. Another word is received. If there is no error, certainly the word is accepted. Otherwise, errors are corrected. At this moment, IF-HARQ scheme compares the current decoded code word with the previous code word in memory buffer. Also, the number of error weights resulting from the previous decoding is compared with the number of error weights from current decoding. If the two consecutive code words are the same one and error weights decrease, IF-HARQ scheme considers the code word as the transmitted one. As stated above, what we mean *implicit information* are implied in the two consecutive code words are the same one in re-transmission and in the error weights associated with the last code word is less than that of the previous one. For example to be more concrete, suppose that  $R_1$  and  $R_2$  are consecutive received words and which decoded to the same code words  $C_1$  by hard decision decoding (HDD) as follows.

$$C_1 = \text{HDD}(R_1) \text{ and } W_1\{C_1 \oplus R_1\} = 3$$

$$C_1 = \text{HDD}(R_2) \text{ and } W_2\{C_1 \oplus R_2\} = 2$$

where  $W\{ \}$  denoted the number of Hamming weights and  $\oplus$  addition of modulus-2.

For such a result of decrease in error weights, it implies that the noise going down and SNR going up. So, fewer errors occur at the second received word. Therefore, the *implicit information* is high SNR. The decoded code word is reliable with very high probability. On the other hand, the above outcomes may also be interpreted as noise going up and resulting in more errors.  $C_1$  is probable a result of decoding

error and code word  $C_2$  could be the transmitted code word as below for a code with seven minimum Hamming distances.

$$C_2 \leq (R_1) \text{ and } W_1 \{C_2 \oplus R_1\} = 4$$

$$C_2 \leq (R_2) \text{ and } W_2 \{C_2 \oplus R_2\} = 5$$

However, the point is that noise is random. It is a matter of probability and very unlikely that  $C_2$  is the case. By this kind of reasoning,  $C_1$  is accepted as decoded output and no more re-transmission is necessary. Hence, throughput efficiency can be improved without degradation of error-correcting performance. In addition, simulation results support the reasoning and the error-correcting performance is improved as well for IF-HARQ. For clarity, a simplified flow chart is shown in Figure 1 and decoding steps of proposed IF-HARQ scheme are summarized as shown below, where  $R_i$  denoted  $i$ th received word,  $C_i$  code word resulting from errors corrected in  $R_i$ ,  $W_i$  associated number of error weights in  $R_i$ .

Decoding steps of IF-HARQ scheme:

Step1. No error detected in  $R_i$ ,  $R_i = C_i$ . Jump to Step 6.

Step2. Detect errors in  $R_i$ .

Step3. Correct errors in  $R_i$ . Keep decoded code word  $C_i$  and error weights  $W_i$  in memory buffers.

Step4. Check if  $C_i$  is equal to  $C_{i-1}$  and  $W_i < W_{i-1}$ , go to Step 6.

Step5. Ask for re-transmission  $i=i+1$  and go to Step 1.

Step6. Accept code word  $C_i$ .

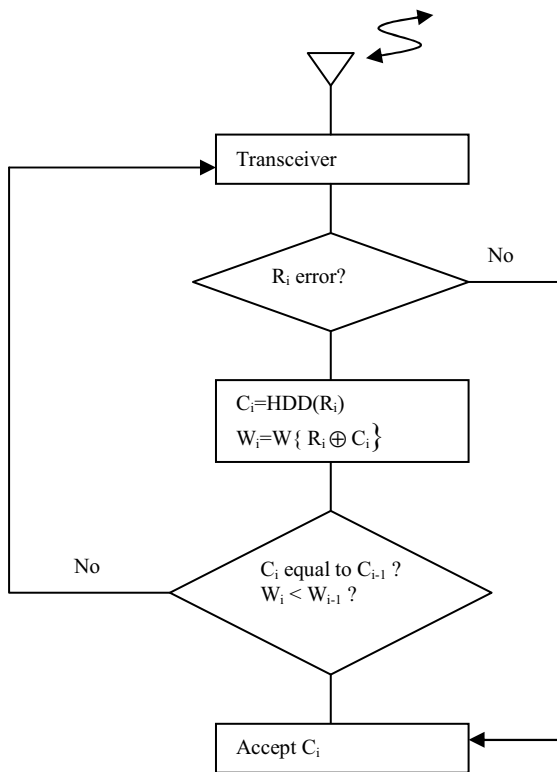


Figure 1. Decoding flow of IF-HARQ scheme

### III. PERFORMANCE ANALYSIS

Referring to simulation result in Figure 2, IF-HARQ exceeds conventional ARQ, which denoted as HARQ60, in

error-correcting performance by around 1 dB coding gain at  $10^{-4}$  block error rate. In addition, throughput efficiency is improved as well by 10% at 1dB  $E_b/N_0$  as shown in Figure 3. Yet, the proposed IF-HARQ scheme is inferior to those of HARQ scheme based on voting of three votes, which denoted as V3-HARQ, no matter in error-correcting performance or in throughput efficiency. However, in respect to decoding complexity, the proposed IF-HARQ is superior to that of V3-HARQ proposed in [16]. The proposed IF-HARQ requires only extra memory buffers for previous code word  $C_{i-1}$  and associated error weight  $W_{i-1}$  instead of more memory buffers to keep all code word candidates during re-transmission for the V3-HARQ scheme. Moreover, finding out plurality code word is necessary for the V3-HARQ scheme and unnecessary for the proposed IF-HARQ. In Table 1, comparisons of performances and decoding complexity are made with the three schemes. To reinforce the reasoning of the proposed IF-HARQ scheme, simulations are also made using non-perfect code BCH(15,5,7). As shown in Figure 4, error-correcting performance of IF-HARQ outperforms the conventional ARQ scheme as well. As expected, the throughput efficiency of IF-HARQ is also higher than that of the conventional one as shown in Figure 5. Such performances for BCH code require one more condition at decoding step 4 for which  $W_i < 2$  must be satisfied.

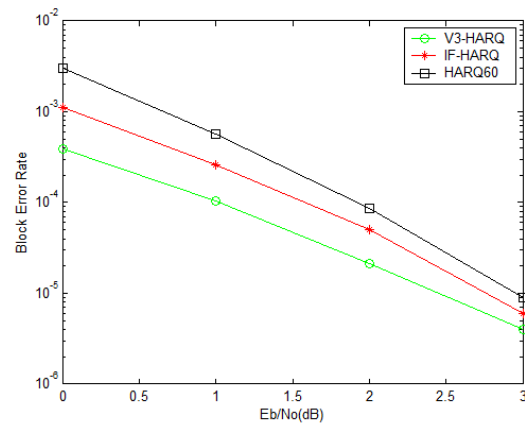


Figure 2. Comparison of error-correcting performance using Golay code (23,12,7)

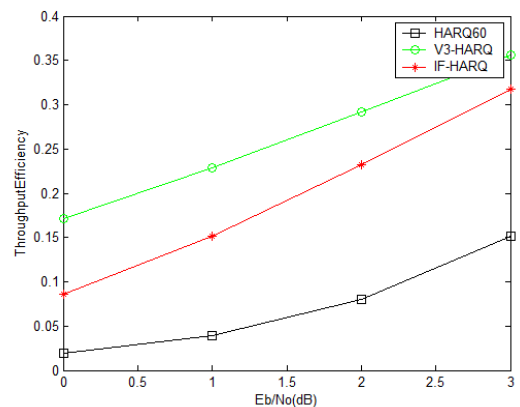
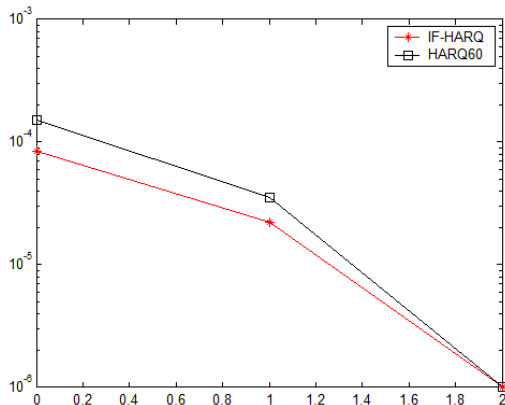


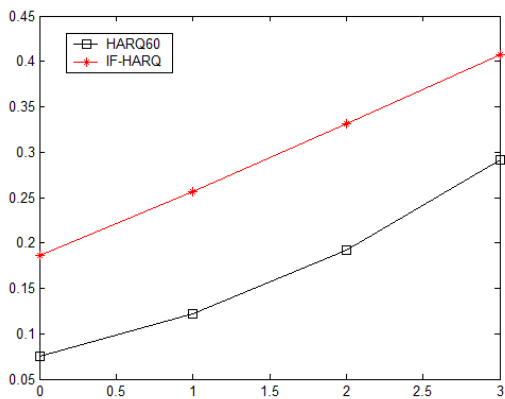
Figure 3. Comparison of throughput efficiency using Golay code (23,12,7)

**TABLE 1.** COMPARISONS OF PERFORMANCES AND DECODING COMPLEXITY USING GOLAY CODE (23,12,7)

| HARQ Scheme | Decoding complexity                                                                                   | Error-correcting | Throughput |
|-------------|-------------------------------------------------------------------------------------------------------|------------------|------------|
| V3-HARQ     | 1. More memory buffers<br>2. error detection<br>3. error correction<br>4. Finding plurality code word | best             | best       |
| IF-HARQ     | 1. Few memory buffers<br>2. Error detection<br>3. Error correction                                    | better           | better     |
| HARQ60      | 1. No memory buffers<br>2. Error detection                                                            | good             | good       |



**Figure 3.** Comparison of error-correcting performance using BCH code (15,5,7)



**Figure 3.** Comparison of throughput efficiency using BCH code (15,5,7)

#### IV. CONCLUSIONS

Referring to Table1, schemes with better performances are at expenses of time complexity and space complexity. Which

one is proper for real implementation depends on case to case. The proposed IF-HARQ scheme outperforms the conventional scheme with only little increase of space complexity and time complexity. Moreover, this is the first time that introduces implicit information into the error control scheme of hybrid ARQ. Such implicit information from decrease on error weights does not depend on perfect code only and may also apply to other systems for improvement. Furthermore, there are maybe some other implicit information with different kind phenomenon rather than error weights in the received information. Hence, searching for other implicit information is a direction for future work.

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