

# Channel Coding

## Final Report

### ARQ and Interleaver

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2001/6/12

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## ●Part I: Automatic Repeat Request (ARQ)

### 1. Introduction:

- A major concern in data communications is how to control transmission errors caused by the channel noise so that error-free data can be delivered to the user.
- There are two basic categories of error control schemes for data communications: **ARQ** and forward-error-correction (**FEC**).
- ARQ scheme are widely used in data communications systems for error control because they are simple and provide high system reliability.
- However, ARQ scheme has one drawback: the utilization, or the final output of the decoder, is not constant and it falls rapidly with increasing channel error rate.

## 2. Flow Control: Sliding Window Protocol

- Figure 1 is the depiction of the sliding window protocol. The shaded rectangle represents the window frames that may be transmitted. Each time a frame is sent, the shaded portion will shrink; each time a new acknowledgment is received, the shaded portion will grow.

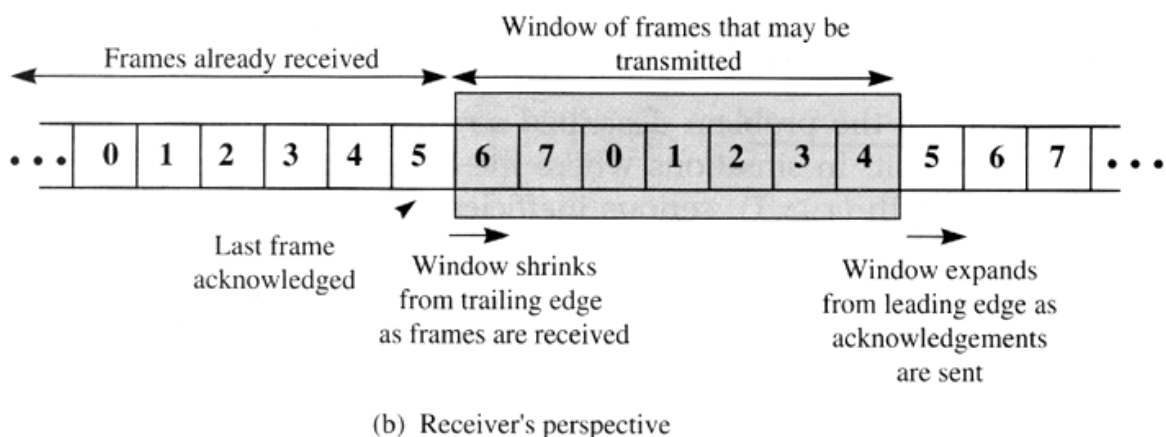
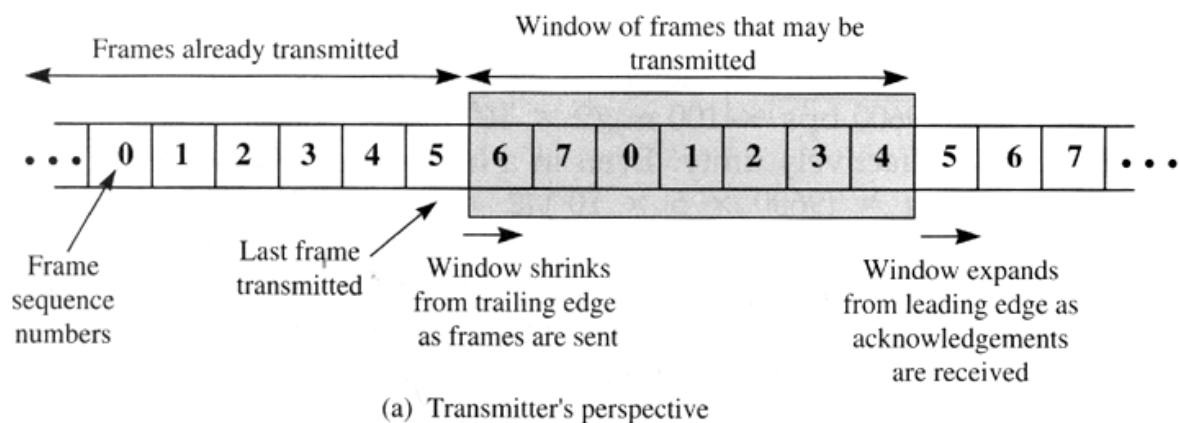


Figure 1. Sliding window depiction

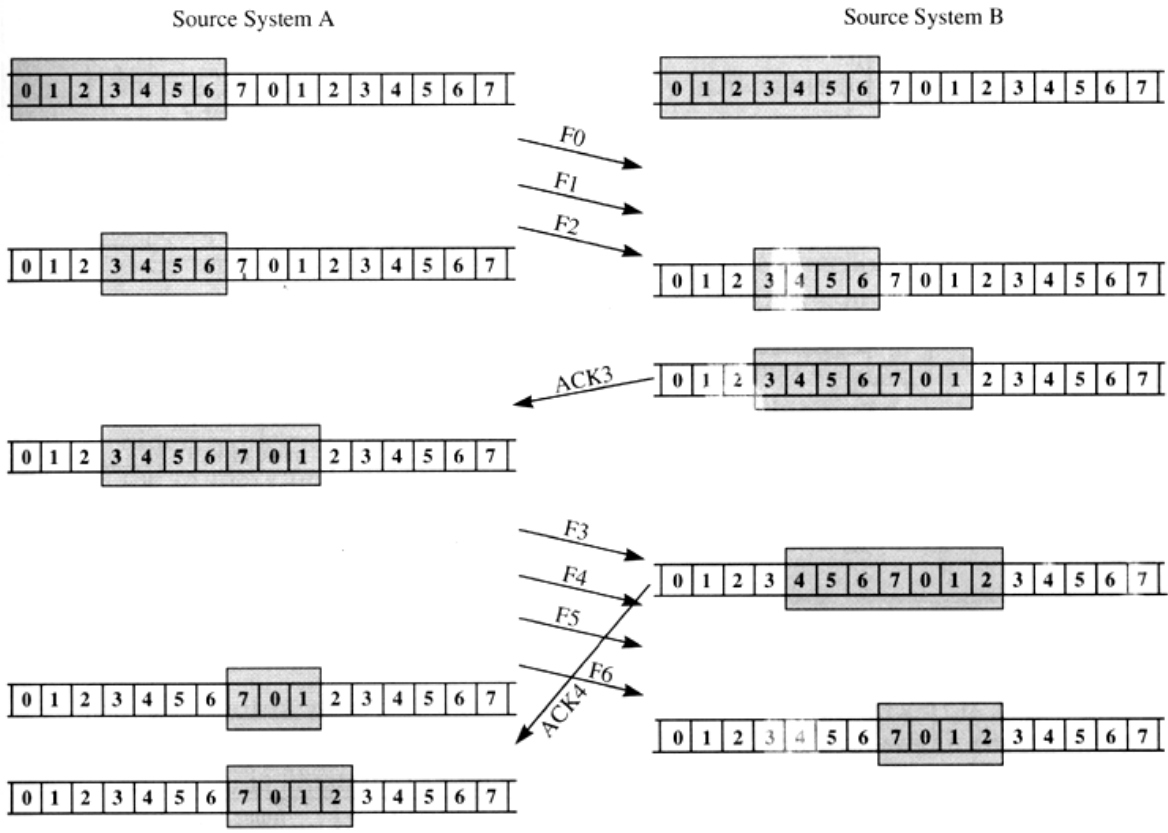
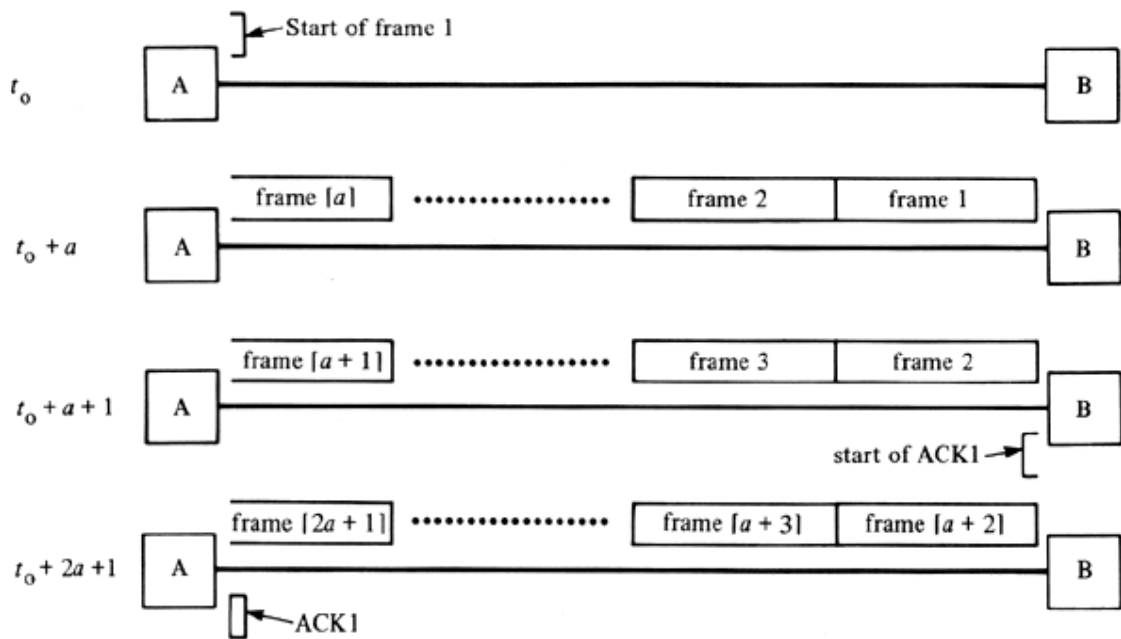
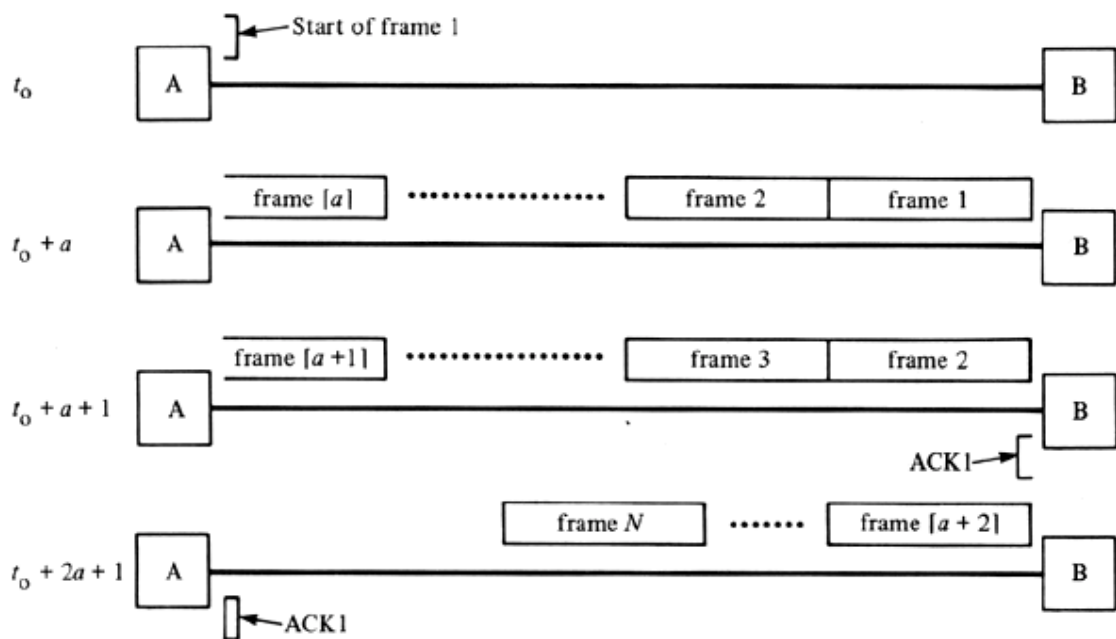


Figure 2. Example of a sliding window protocol

- The efficiency of transmission depends on both  $N$  (the window size) and  $a$  (the propagation time, assuming frame transmission time is 1). Figure 3 illustrates the efficiency of a full-duplex point-to-point line.



(a)  $N > 2a + 1$



(b)  $N < 2a + 1$

$[X]$  = smallest integer greater than or equal to  $X$

Figure 3. Timing of a sliding window protocol

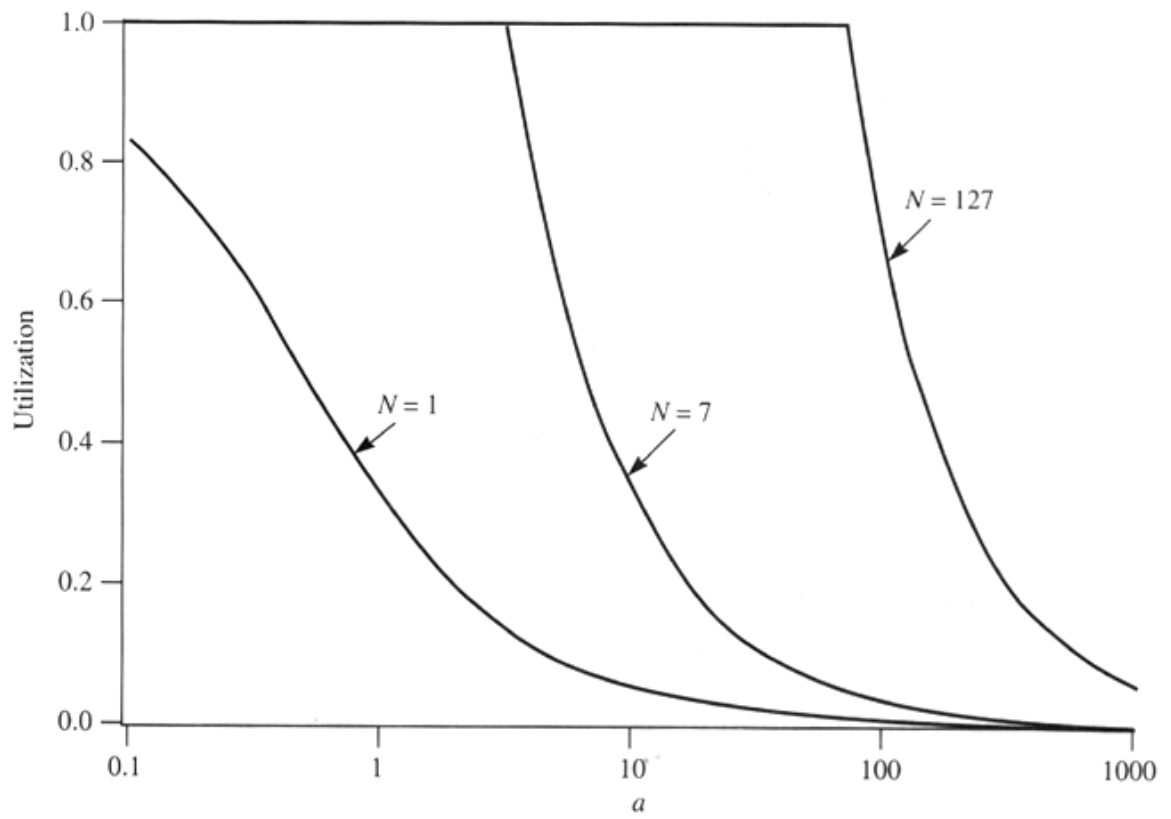


Figure 4. Utilization as a function of window size

### 3. Automatic Repeat Request Schemes:

- Based on retransmission strategies, there are three basic types of ARQ scheme: **stop-and-wait ARQ**, **go-back-N ARQ**, and **selective-repeat ARQ**.
- In a stop-and-wait ARQ error-control system, the transmitter sends a codeword to the receiver and waits for an acknowledgment, as shown in Figure 5. This scheme is simple but inefficient because of the idle time spent waiting for an acknowledgment of each transmitted codeword.

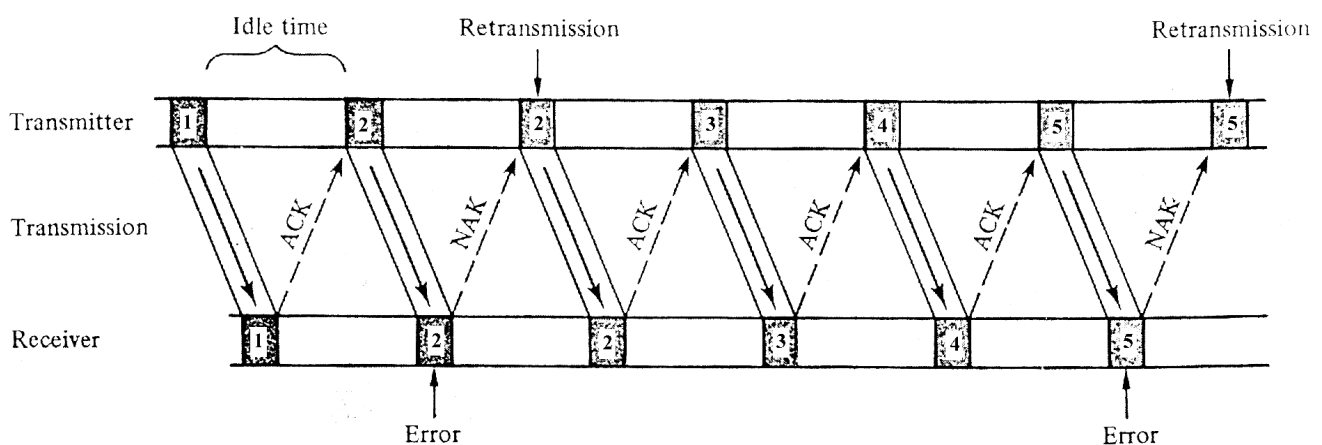


Figure 5. Stop-and-Wait ARQ

- The go-back-N ARQ scheme is illustrated in Figure 6. Whenever the transmitter receives a NAK indicating that a particular codeword  $i$  was received in error. Then it goes back to codeword  $i$  and proceeds to retransmit that codeword and the N-1 succeeding codewords.
- The main drawback of go-back-N ARQ is that, whenever a received word is detected in error, the receiver also rejects the N-1 received words, even though many of them may be error-free.

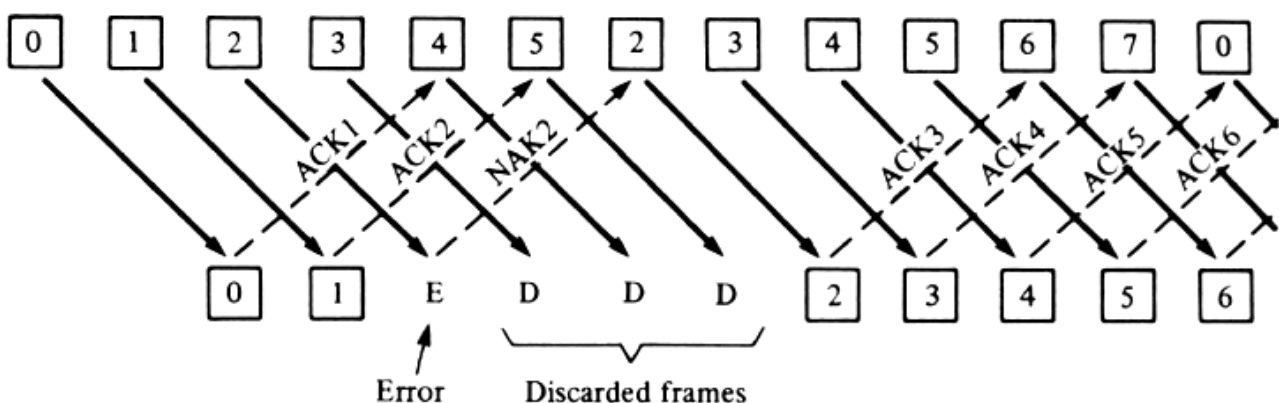


Figure 6. Go-Back-N ARQ

- The selective-repeat ARQ scheme is illustrated in Figure 7. Codewords are also transmitted continuously. However, the transmitter only resends those codewords that are negatively acknowledged (NAK).
- Sufficient receiver buffer storage must be provided in a selective-repeat ARQ system. Otherwise, buffer overflow may occur and codewords may be lost.

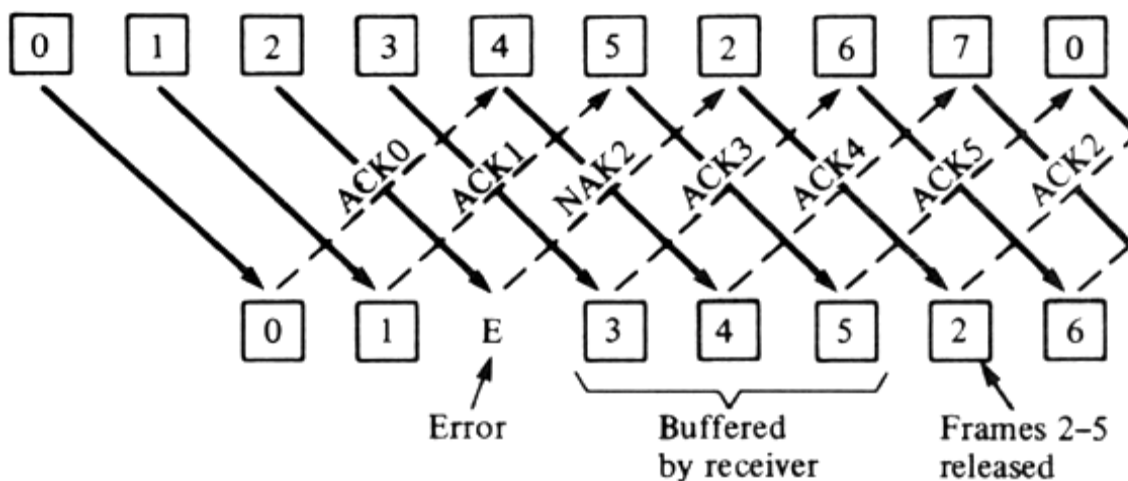


Figure 7. Selective-Repeat ARQ

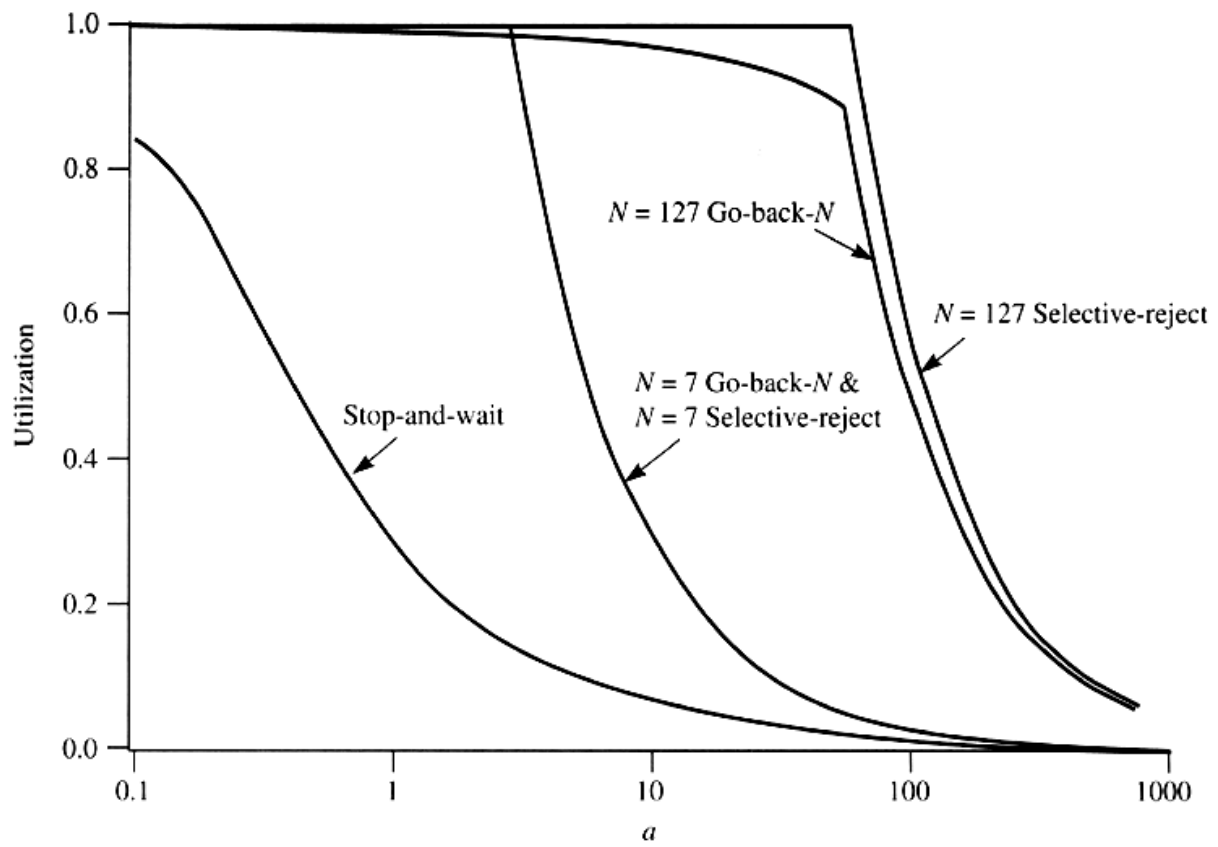


Figure 8. Utilization for various error-control techniques

## ●Part II: Interleaver

### 1. Introduction:

- Most of the block codes is random error correcting. It can correct up to  $t$  symbol errors per codeword , regardless of the placement of those errors. But a problems arises with these codes whenever the channel is **bursty**.
- So is convolutional codes , the performance of convolutional codes is also sensitive to **bursty** channel.
- Much effort has gone into the development of codes or coding techniques that can specifically deal with channel-burst errors. Such codes include the RS codes. Another technique is ARQ. But if no return channel is available, the combination of FEC with interleaving, as shown in Fig 9, is a common solution to combat burst errors.

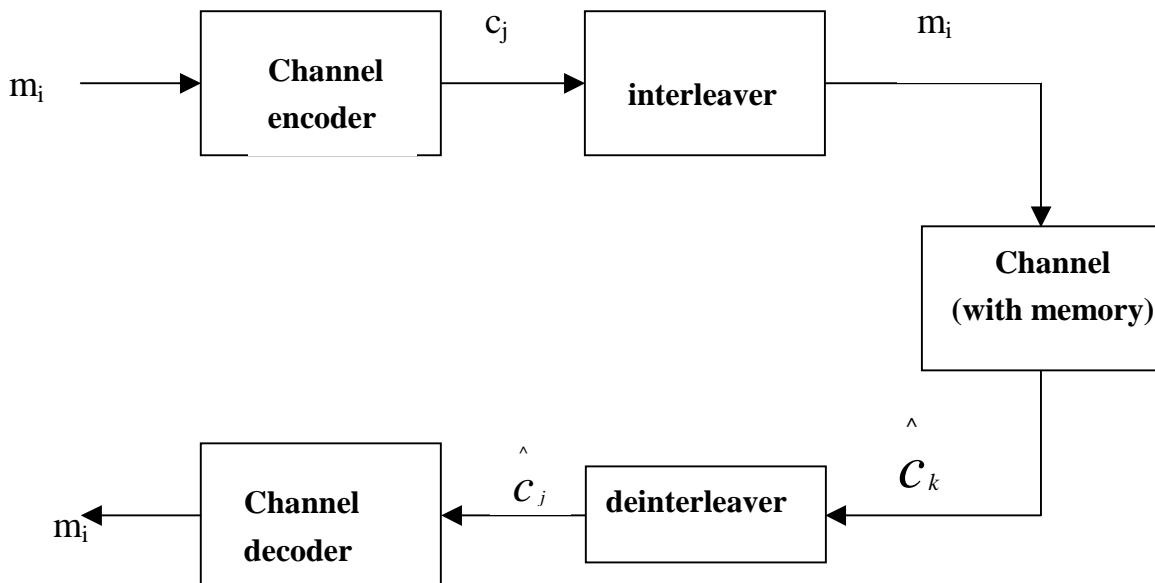


Fig.9 A FEC scheme with interleaving

## 2. Two principle classifications of interleavers:

- **Periodic:** low complexity ,smaller memory requirements than pseudo-random types.
- **Pseudo-random**
- Two commonly used types of periodic interleavers:**periodic block** interleaver and **periodic convolutional** interleaver.

### 3. Definitions of interleaver parameters:

- The usual type of interleaver belongs to the class of  $(I,N)$ interleavers(see fig.10),where  $I$  is called the *interleaver depth*,and  $N$  is called the *interleaver constraint length* or *length*.
- $(I,N)$ interleaver and deinterleaver have the following properties(fig.10):
  - ◆ Each symbol in the input sequence appears only once in the re-ordered output sequence of the interleaver.
  - ◆ Two symbols in the input sequence,which are separated by less than  $N$  symbols,are re-ordered in such a manner that their minimum separation at the interleaver output is  $I$  symbols.This implies that a single burst of  $b < I$  errors,affects only the output symbols which sre separated by at least  $N$  symbols after the inverse re-ordering

by the deinterleaver.

- ◆ Interleaver and deinterleaver introduce an additional overall symbol delay  $D$  into the communication and require a total memory of  $S$  symbols.

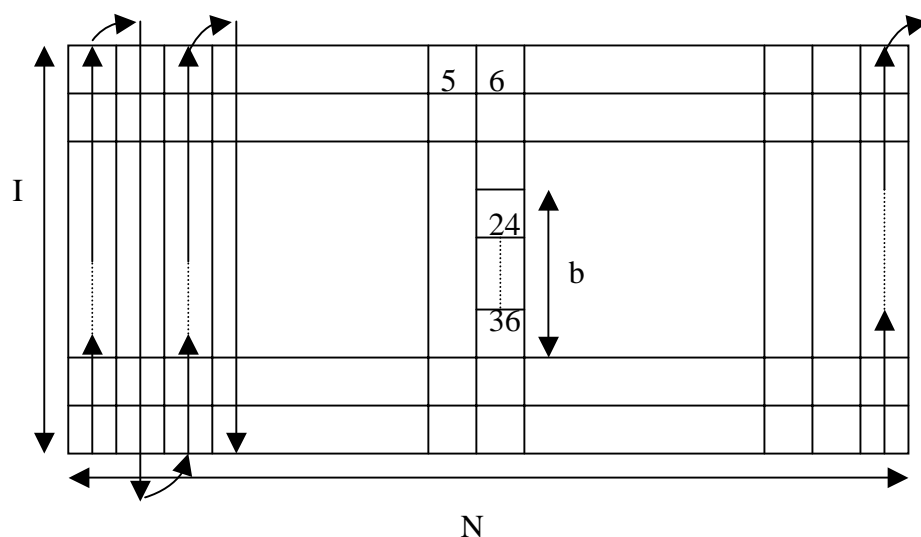


Fig.10

- The parameters  $I$  and  $N$  are often selected :
- ◆  $I$  should be selected to be larger than the length of the longest expected error burst.
- ◆  $N$  should be larger than the codeword length of the block code used for correction or larger than

the constraint length of the convolutional code.

#### **4. Periodic block interleaver:**

- Symbols are *written columnwise* into the matrix and then *read out by rows*. This column and row interleaving process is performed periodically.
- A block-wise synchronization is required to achieve a correct deinterleaving. So the start of each interleaver block must be known.
- In  $(I,N)$  block interleaver, any two adjacent symbols at the input are separated by  $I-1$  other symbols at the output.
- A burst of  $b$  symbol errors causes a maximum of  $\lfloor b/I \rfloor + 1$  symbol errors in each codeword. Therefore, for a  $t$ -error correction block code, the maximum correctable burst length  $b$  is  $b_{\max} = I \cdot (t-1) + 1$ .
- Memory requirements in symbols are  $I \cdot N$  for interleaver and deinterleaver.

Thus the overall memory is  $2 \bullet I \bullet N$ .

- Resulting overall delay for both interleaving and deinterleaving process is  $2 \bullet I \bullet N$ .

## **5. Periodic convolutional (B,N)interleaver:**

- Symbols to be interleaved are arranged in blocks of N.
- Ith symbol in each block is delayed by  $(i-1)NB'$  time units through a  $(i-1)B'$  stage shift register clocked once every N symbol times, where  $B' = B/N$ . (A time unit corresponds to the transmission of a block of N symbols).
- At receiver, groups of N symbols are reblocked, and the ith symbol in each block is delayed by  $(N-i)NB'$  time units through an  $(N-1)B'$  stage shift register.

- We call this a  $B \times N$  interleaver. And correspondingly there exists a similar but inverse  $B \times N$  deinterleaver. (show in Fig.11)

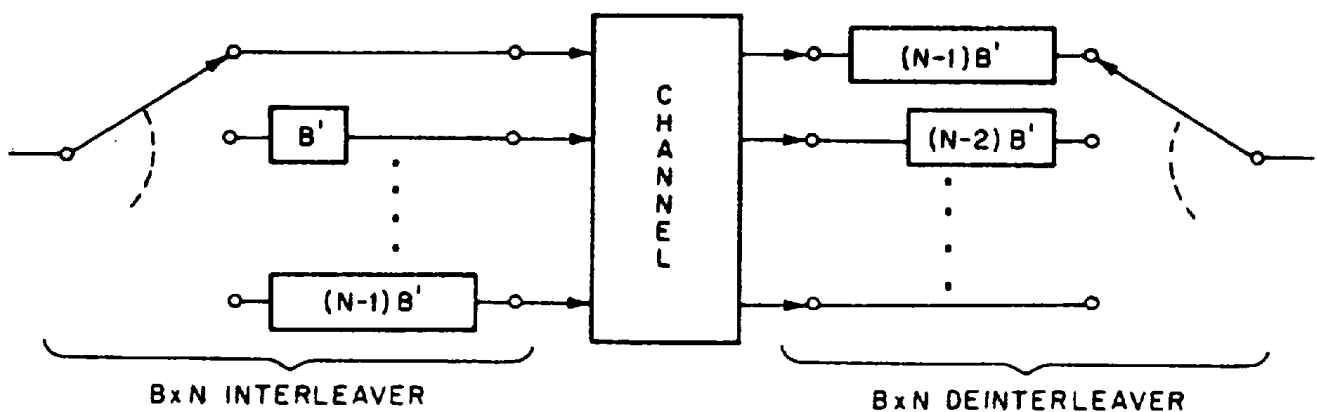


Fig. 11 Periodic interleaver and corresponding deinterleaver ( $B' = B/N$ ).

- Convolution interleaver has the following properties:
  - ◆ All symbols receive a total delay of  $(N-1)B'$  time units, or  $N(N-1)B' = (N-1)B$  symbol times.
  - ◆ The memory requirements at the transmitter and receiver are  $N(N-1)B'/2$  or  $N(N-1)B' = (N-1)B$  total.

- ◆ A single channel burst affecting  $B'$  blocks or fewer, at the deinterleaver output it affects one of the  $N$  deinterleaver output streams at a time.(see fig.12)
- ◆ A channel burst affecting  $kB'$  or fewer blocks affects no more than  $k$  of the  $N$  deinterleaver output streams at a time.(see fig.13)

IEEE TRANSACTIONS ON COMMUNICATIONS TECHNOLOGY, OCTOBER 1971

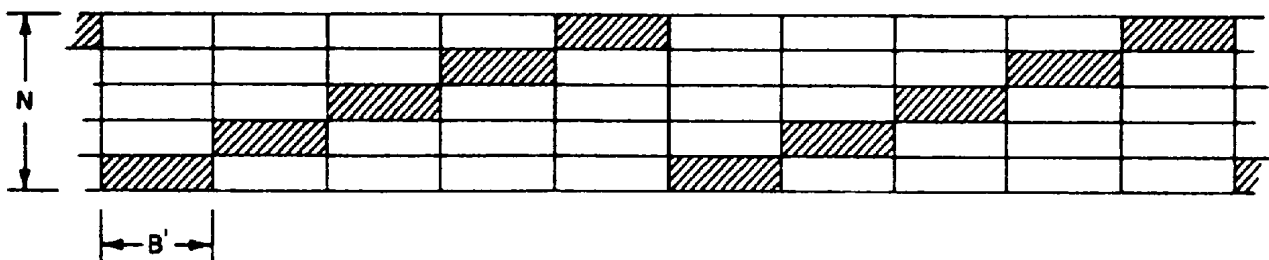


Fig. 12 Appearance of bursts of  $B'$  blocks separated by guard spaces of  $(N - 1)B'$  blocks in  $N$  deinterleaver output streams.

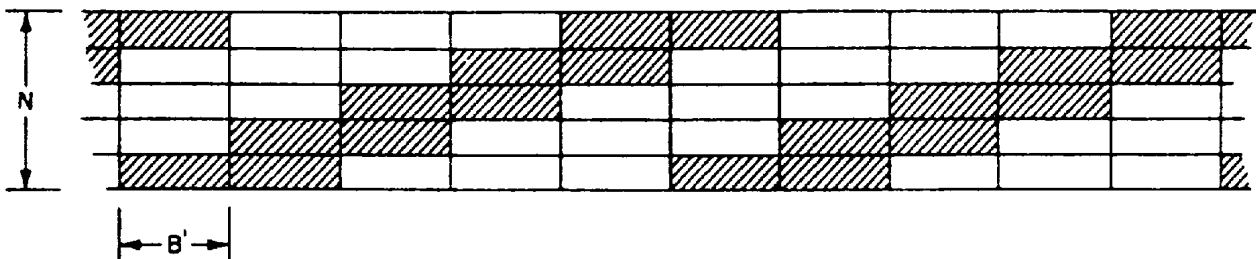


Fig. 13 Appearance of bursts of  $kB'$  blocks separated by guard spaces of  $(N - k)B'$  blocks in  $N$  deinterleaver output streams.

- ◆ For example, the rate-1/2 binary (24,12) Golay code corrects up to 3 bit errors. With this code and a Bx24 interleavers we can correct all bursts of length approximately 3B.

## **6. Comparision of the two interleavers:**

- Convolutional interleaver has the following general advantages over block interleaver:
  - ◆ Minimum overall system delay.
  - ◆ Minimum memory requirements.
- Both of them the synchronization of the interleaver and its deinterleaver is necessary.

## ● Conclusion

- In this presentation, we discuss about the sliding window protocol for flow control and three different types of ARQ schemes for error control.
- And we explain how the three different ARQ schemes operate, and compare their efficiency in data communications.
- In the second part, we discuss the interleaver scheme. We introduce two periodic interleaver and its characteristic.
- Although interleaving/deinterleaving process introduce a delay, but it provide a good performance to combat burst errors.

## ●Reference

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