Chase Combining HARQ Process in LTE

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Approval Sheet

This thesis entitled "Chase Combining HARQ process in LTE" by Roochika Kalyan is approved for the degree of Master of Technology from IIT Hyderabad.

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Dedicated to

I dedicate this Thesis to my family and friends without them I wouldn’t be here.

Abstract

The purpose of LTE is to bring high data rates and embrace quick data transfer and reliable communication. To achieve reliable communication, LTE has two mechanisms to detect and correct the errors, which are ARQ and HARQ. This thesis describes different types of ARQ and HARQ, as well it was described why it is better to choose particular type of chase combining HARQ. In the implementation of chase combining HARQ, turbo codes are implemented to get "Near Shannon Limit Error-correcting coding and decoding". In this thesis, the procedure for Chase combining HARQ with soft combining, from eNodeB to UE is shown in a block diagram for easy understanding. This thesis shows at what SNR value, what will be the average number of retransmissions required to deliver data correctly at UE side with both AWGN channel and Rayleigh fading channel introduced. It is successfully shown in this thesis that, how number of times of repetitions of Turbo decoding affect the BLER for particular SNR. It is concluded that, for particular signal to noise ratio, what will be the number of repetition required at decoder with what number of retransmission of data, to achieve particular BLER and data rate.

Contents

Chapter 1

Error Detection and Error Correction Techniques

1.1 Error Detection and Correction Techniques

In any transmission system when transmitter send any information to the receiver then some errors will occur. So we have some techniques that basically checks if the information sent by transmitter correctly received by the receiver. These mechanisms to check the errors are known as Error Detection and Correction.

1.1.1 Error Detection Techniques

Error detection is mostly realized using a suitable hash function, that function adds a fixed length bits to a message, which enables receiver to verify the delivered message by recomputing the fixed length bits and comparing it with the one provided.
There are following Error Detection techniques-

1) Repetition code
2) Parity bits
3) Checksums
4) Cyclic Redundancy Checks
5) Cryptographic hash functions
6) Error –correcting codes

1.1.2 Cyclic Redundancy Check(CRC)

Cyclic Redundancy Check is designed to detect accidental changes to digital data in computer networks.

One of the most common method of Error Detection is ‘Cyclic Redundancy Check (CRC)’, where CRC bits are added to a group of information bits.

The CRC bits are generated based on the contents of the information bits. If the information bits are delivered with the error then CRC bits are used to verify and help to recover the degraded information.

It is characterized by specification of what is called a *generator polynomial*, which is used as the divisor in a polynomial long division over a finite field, taking the input data as the dividend, such that the remainder becomes the result.

As per **3GPP TS 36.212 version 10.0.0 Release 10, we used following generator polynomial, as we are using 16 bit CRC**

$g_{CRC16}(D) = [D^{16} + D^{12} + D^{5} + 1]$ for a CRC length $L = 16$.

A cyclic code has favorable properties that make it well suited for detecting burst errors.

If the information bits are delivered with the errors, then CRC bits are used to verify and help to detect the errors.

1.1.3 Error Correction Techniques

Error Correction can be done by following two ways:
Automatic Repeat Request: It is an Error Control technique whereby an Error Detection scheme is combined with request of retransmission of erroneous data.
Forward Error Correction: UE encodes the data using an Error Correcting Code (ECC) prior to transmission. The ECC adds some additional information called as redundant information is used by the receiver to recover the original data.

1.2 ARQ

ARQ stands for Automatic Repeat Request. It is an Error Control method that uses acknowledgements and timeouts for reliable transmission. It uses Cyclic Redundancy Check to determine whether the packet received is correct or not.
If the packet is received correctly receiver send ACK to the transmitter, and if the packet is erroneous than receiver send NACK to the transmitter. After the packet is received NACK transmitter re transmits the same packet again. The retransmission is done for the set of number of times, if it is not successful for few tries then the system will drop the packet.

1.2.1 ARQ Classification

ARQ is divided into three categories-

1) Stop-And-Wait (SAW)

2) Go-Back-N

3) Selective Repeat

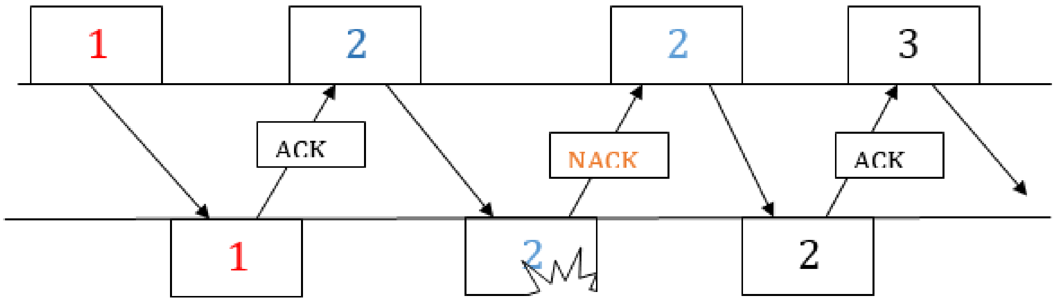

Figure: 1.1 Stop-And-Wait ARQ

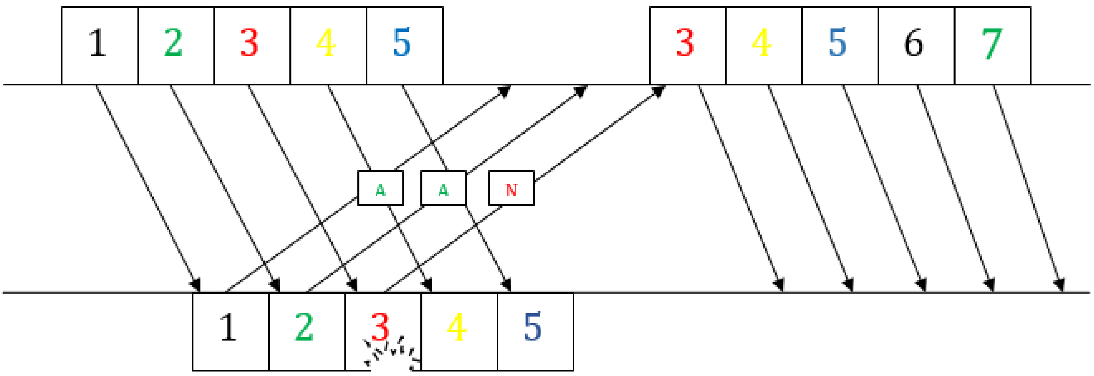

Figure 1.2: Go-Back-N ARQ

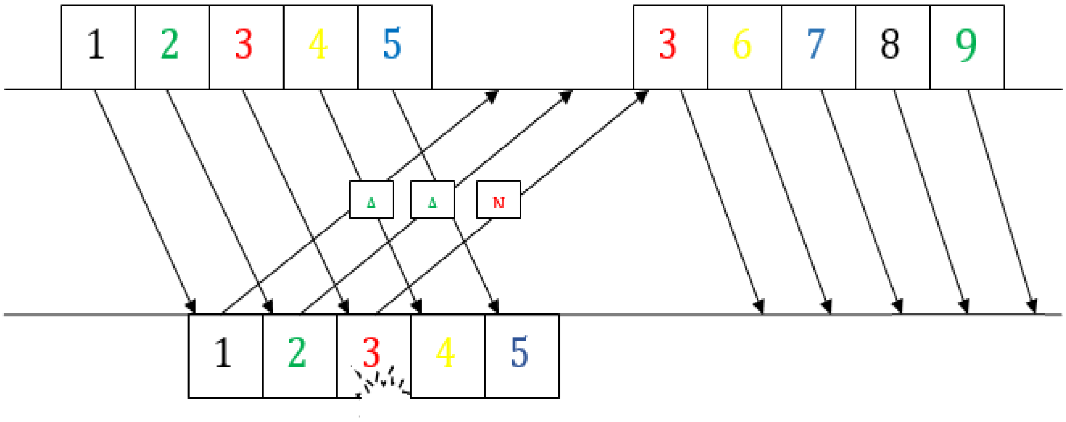

Figure 1.3: Selective Repeat ARQ

1.3 HARQ

HARQ stands for Hybrid Automatic Repeat Request.

HARQ does not retransmit packet as it is, as done by ARQ technique.

It is a combination of Forward Error Correction and ARQ error control. Minor error are corrected without retransmission and major errors are corrected via a request of retransmission.

HARQ leads to higher efficiency in transmission and error correction. In ARQ, redundant bits are added to data to be transmitting using an Error Detecting Code such as CRC. If receiver detects an erroneous data then it will request for a new message from the transmitter. While in Hybrid ARQ, the original data is encoded with a Forward Error Correction (FEC) code, and the parity bits are sent when the receiver detects an erroneous message.

1.3.1 HARQ Process Classification

In terms of retransmission timing, HARQ process can be classified into Synchronous HARQ and asynchronous HARQ. HARQ process can be further classified as Adaptive and non-adaptive HARQ in terms of managing transmission attributes.

1.3.1.1 Synchronous and Asynchronous HARQ

Synchronous HARQ:

In Synchronous HARQ process, all the HARQ retransmission processes are restricted to occur within certain time period between UD and eNodeB. It does not require HARQ process number for retransmission packets and can be operated with less signaling overhead during retransmissions.

Asynchronous HARQ:

In Asynchronous HARQ, there is no restriction of retransmission timing, that is retransmission may take place at any time after decoding of ACK?NACK signaling. It requires HARQ process number to transmit each retransmission packets and makes possible to have more flexibility in scheduling. But due to this explicit signaling, signaling overhead is increased.

1.3.1.2 Adaptive and Non-adaptive HARQ

Adaptive HARQ:

In Adaptive HARQ operation, transmission attributes such as modulation order, code rate and amount of resource allocation may be changed during retransmissions. By applying these attributes adaptively with varying channel condition, scheduling can be more flexible. So it gives more scheduling gain. And it requires more control signaling overhead because receiver should get information about these transmission attributes at every retransmission.

Non-adaptive HARQ:

In non-adaptive HARQ, the packet format for retransmissions is fixed that is known to both UE and eNodeB, so no further control signaling is required. It is difficult to get scheduling gain in non-adaptive HARQ because of its fixed characteristics in packet formats.

Chapter 2

ARQ and HARQ in LTE

2.1 Need for both ARQ and HARQ

UE and eNodeB sends data to each other in the form of Transport Block, if data receives correctly, ACK is sent otherwise NACK. If UE or eNodeB receives erroneous packet then in LTE two mechanisms HARQ and ARQ are followed to detect and correct the errors.

2.1.1 Implementation of ARQ and HARQ in LTE

HARQ in implemented to correct the error packets in the PHY layer. Furthermore, there might be a chance that some packets are still left with errors and might be acceptable to some applications. Hence, these are passed to upper layers.

ARQ is implemented in the RLC layer which takes care of these residual errors. It either fixes those errors or discards the packets.

PHICH is used to carry HARQ feedback in the downlink direction for the received uplink data. Similarly, PUSCH/PUCCH are used to carry HARQ feedback in the uplink direction for the received downlink data.

2.1.2 Need of two layer Retransmission

The reason for having two level retransmission structure is to achieve both fast and reliable transmission.

The HARQ provides very fast retransmissions which is suitable for high speeds used in LTE. HARQ feedback is fast and frequent to correct transmission errors in a very short period of time so the end-to-end Round Trip Time is low.

The ARQ is responsible for reliability, as HARQ feedback is more susceptible to error as compared to ARQ feedback.

2.1.3 Need of Multiple HARQ Process

UE will not send new data or re-transmit data until it will not get ACK signal from receiver. As, UE is waiting for ACK signal from receiver hence it decreases the Throughput.
To overcome this issue, LTE uses multiple HARQ Process with different process ID.

2.2 HARQ with Soft Combining.

UE and eNodeB sends data to each other in the form of Transport Block, if data receives correctly, ACK is sent otherwise NACK. If UE or eNodeB receives erroneous packet then it does not discard this data, it combines the packet received in previous transmission with that of later transmission to decode overall packet. This mechanism is known as HARQ with Soft Combining.
The combination of previously erroneously received transmission can give enough information to receiver to correctly decode the original data.

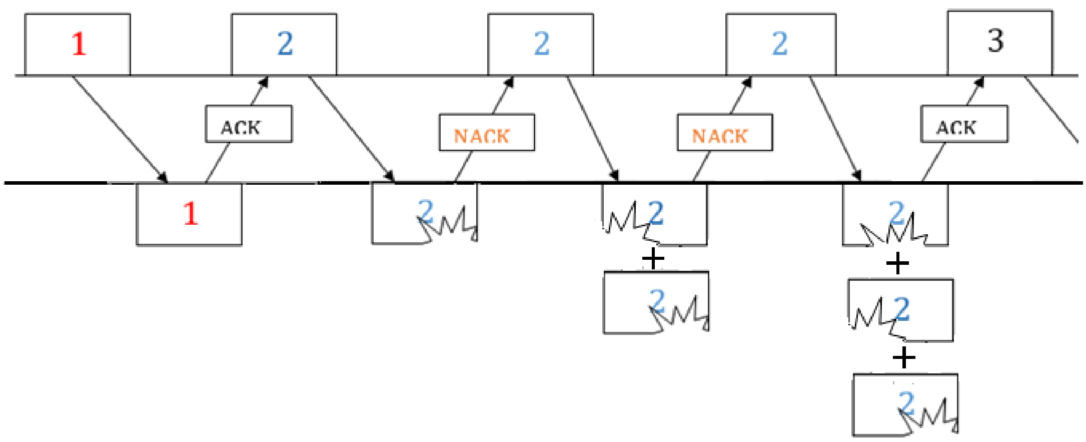

Figure 2.1: HARQ with Soft Combining.

There are two types of HARQ with Soft Combining available-
Chase combing (CC) HARQ Process and Incremental Redundancy (IR) HARQ Process.

2.2.1 Chase Combing HARQ Process

In CC HARQ process every retransmission uses the same information. eNodeB uses maximum-ratio-combining to combine the received bits with the same bits from previous transmissions. At receiver previous packets are stored in a buffer; so that retransmitted packets are summed up with previously received erroneous packets before they are passed to decoder. The technique used at receiver to sum the packets is the simple Maximum Ratio Combining 'MRC' technique.

Buffer Size = No. of coded symbols per coded packet

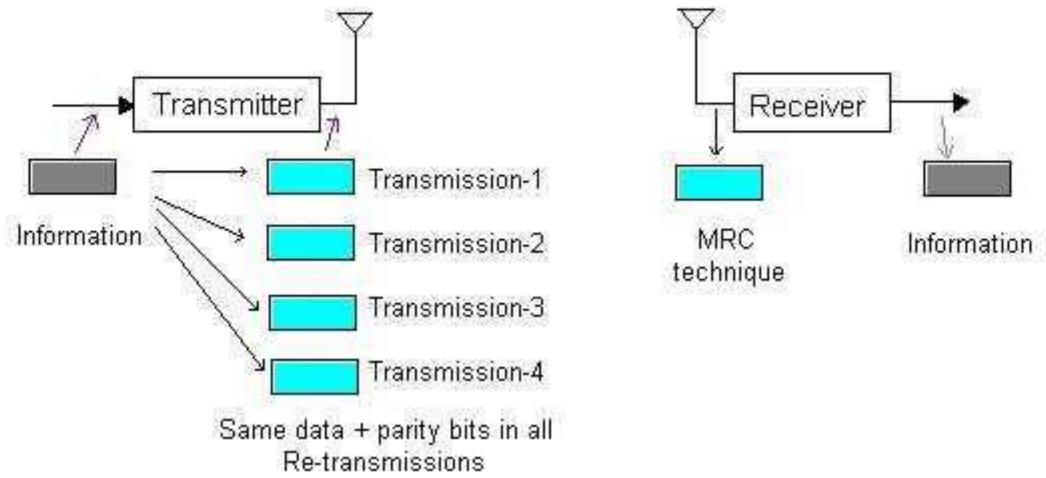

Figure 2.2: Chase Combining HARQ

2.2.2 Incremental Redundancy HARQ Process

Incremental Redundancy (IR) HARQ: In IR HARQ process every retransmission contains different information than the previous one.

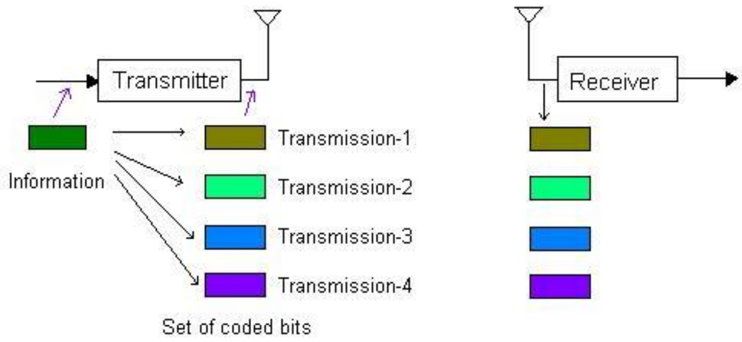

Figure 2.3: Incremental Redundancy HARQ

As shown in Figure 2.3, some additional redundant information bits are transmitted in each re-transmission and receiver needs to decode on each re-transmission. So at every retransmission the receiver gains extra information.

Buffer Size = No. of coded bits of the total transmitted coded packets

Chapter 3

Chase Combining HARQ Process

3.1 Chase Combining HARQ

UE and eNodeB sends data to each other in the form of Transport Block, if data receives correctly, ACK is sent otherwise NACK. If UE or eNodeB receives erroneous packet then it uses soft combing to combine the received bits with the same bits from previous transmissions.
UE sends same information in every retransmission so Chase Combining can be seen as Additional Repetition Coding. Every retransmission adds extra energy to the received transmission for an increased Eb/No.

There are two types of Chase Combining HARQ process:

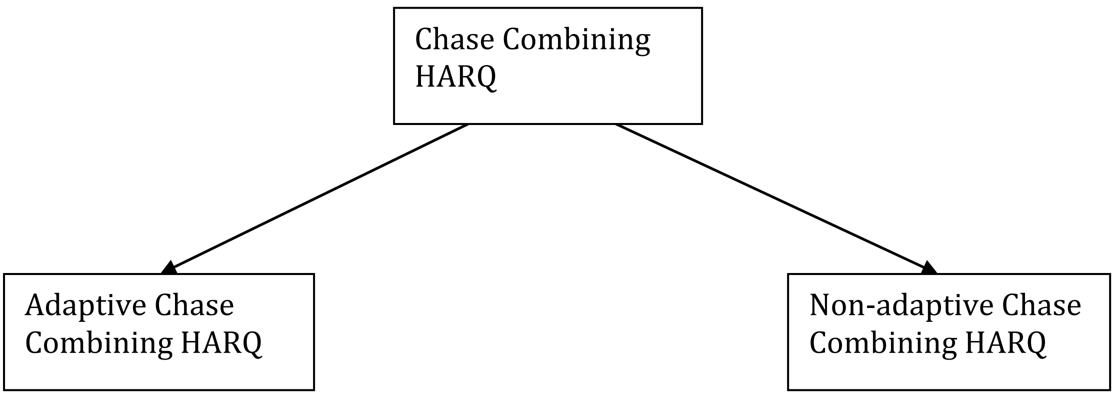

Figure 3.1: Types of Chase Combining HARQ

3.1.1 Adaptive Chase Combining HARQ Process

In Adaptive Chase Combining HARQ process Transport Block size will be varied according to Modulation Channel Scheme and Resource Block size, and MCS and RBs may vary according to CQI-MCS mapping.

CQI stands for Channel Quality Indicator, it gives channel quality information. In LTE CQI varies from 1 to 15. CQI value 1 indicates worst channel and CQI 15 indicates best channel.

Modulation Channel Schemes and Recourse Blocks may change as per resources allocated by eNodeB on PDCCH DC10 transmission.

UE does “Adaptive Transmission” if it detects PDCCH (DCI 0). UE does not care about HARQ feedback, it just retransmits based on DCI 0 information.

3.1.2 Non-adaptive Chase Combining HARQ Process

In non-adaptive Chase Combining HARQ process, Transport Block size will be fixed. When HARQ feedback (PHICH = NACK) then UE will use “Non-adaptive retransmission” and uses predefined sequence.

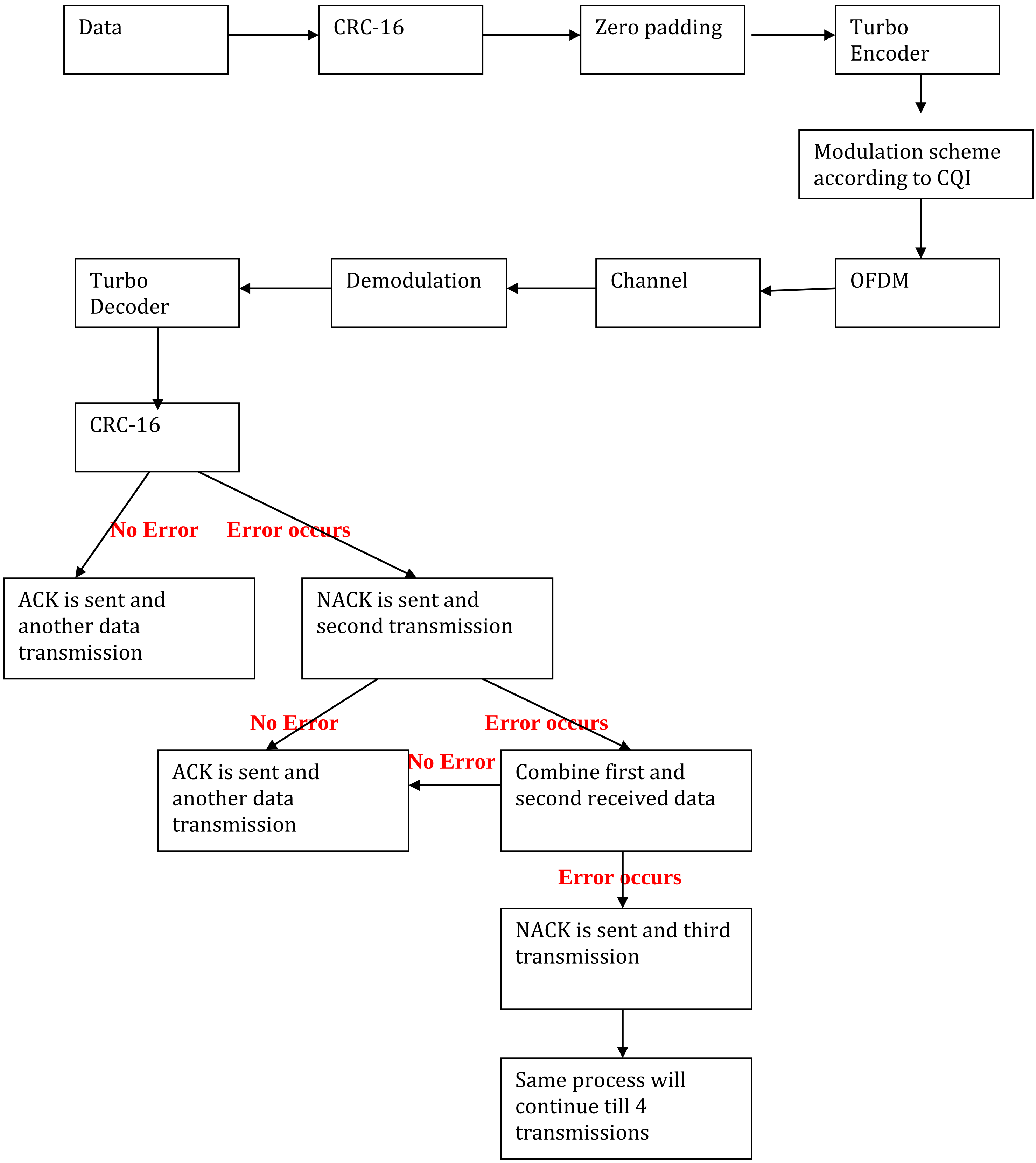

Figure 3.2: Flow Diagram of Chase Combining HARQ Process

3.2 Simulation Results:

AWGN CHANNEL:

SNR (in dB)	2	3	4	5	6	7	8	9	10
Avg no of Rx	**7.9060**	**6.040**	**4.8990**	**3.8670**	**3.2050**	**2.8760**	**2.540**	**2.1860**	**1.9690**

RAYLEIGH CHANNEL:

SNR (in dB)	7	8	9	10	11	12	13	14	15
Avg no of Rx	**7.300**	**5.100**	**4.800**	**2.500**	**2.200**	**2.000**	**2.000**	**1.600**	**1.100**

Table 3.1: Results of Non-adaptive CC HARQ with AWGN and RAYLEIGH CHANNEL

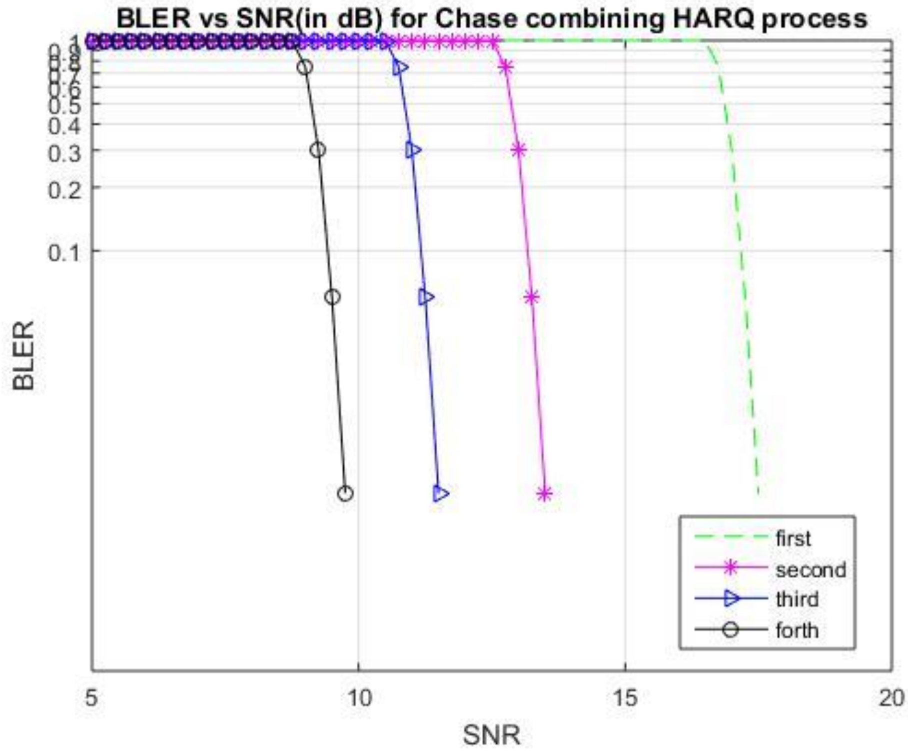

Fig: 3.3 Results of Non-adaptive Chase Combining HARQ

In Fig. 3.3 the results with Chase combining are shown in terms of the slot error rate versus the SNR.

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