CROSS-LAYER HYBRID AUTOMATIC REPEAT REQUEST ERROR CONTROL WITH TURBO PROCESSING FOR WIRELESS SYSTEM

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In The Name Of Allah The Most Gracious The Merciful

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ABSTRACT

The increasing demand for wireless communication system requires an efficient design in wireless communication system. One of the main challenges is to design error control mechanism in noisy wireless channel. Forward Error Correction (FEC) and Automatic Repeat reQuest (ARQ) are two main error control mechanisms. Hybrid ARQ allows the use of either FEC or ARQ when required. The issues with existing Hybrid ARQ are reliability, complexity and inefficient design. Therefore, the design of Hybrid ARQ needs to be further improved in order to achieve performance close to the Shannon capacity. The objective of this research is to develop a Cross-Layer Design Hybrid ARQ defined as CLD_ARQ to further minimize error in wireless communication system. CLD_ARQ comprises of three main stages. First, a low complexity FEC defined as IRC_FEC for error detection and correction has been developed by using Irregular Repetition Code (IRC) with Turbo processing. The second stage is the enhancement of IRC_FEC defined as EM_IRC_FEC to improve the reliability of error detection by adopting extended mapping. The last stage is the development of efficient CLD_ARQ to include retransmission for error correction that exploits EM_IRC_FEC and ARQ. In the proposed design, serial iterative decoding and parallel iterative decoding are deployed in the error detection and correction. The performance of the CLD_ARQ is evaluated in the Additive White Gaussian Noise (AWGN) channel using EXtrinsic Information Transfer (EXIT) chart, bit error rate (BER) and throughput analysis. The results show significant Signal-to-Noise Ratio (SNR) gain from the theoretical limit at BER of 10^{-5}. IRC_FEC outperforms Recursive Systematic Convolutional Code (RSCC) by SNR gain up to 7% due to the use of IRC as a simple channel coding code. The usage of CLD_ARQ enhances the SNR gain by 53% compared to without ARQ due to feedback for retransmission. The adoption of extended mapping in the CLD_ARQ improves the SNR gain up to 50% due to error detection enhancement. In general, the proposed CLD_ARQ can achieve low BER and close to the Shannon's capacity even in worse channel condition.

ABSTRAK

Peningkatan permintaan terhadap sistem komunikasi tanpa wayar memerlukan reka bentuk yang efisien dalam sistem komunikasi tanpa wayar. Salah satu cabaran utama adalah mereka bentuk mekanisme kawalan ralat dalam digit hingar saluran tanpa wayar. Pembetulan Ralat ke Hadapan (FEC) dan permintaan Berulang Automatik (ARQ) adalah dua mekanisme utama kawalan ralat. ARQ Hibrid membolehkan penggunaan sama ada FEC atau ARQ apabila diperlukan. Isu berkenaan ARQ Hibrid sedia ada ialah keutuhan, kekompleksan dan reka bentuk yang tidak efisien. Oleh itu, reka bentuk ARQ Hibrid perlu ditingkatkan lagi bagi mencapai prestasi menghampiri kepada kapasiti Shannon. Objektif penyelidikan ini adalah membangunkan Reka bentuk Lapisan-Silang ARQ Hibrid didefinisikan sebagai CLD_ARQ untuk mengurangkan lagi ralat dalam sistem komunikasi tanpa wayar. CLD_ARQ terdiri daripada tiga peringkat utama. Pertama, FEC kekompleksan rendah ditakrifkan sebagai IRC_FEC untuk pengesanan dan pembetulan ralat telah dibangunkan dengan menggunakan Kod Pengulangan Tidak Teratur (IRC) beserta pemprosesan Turbo. Peringkat kedua ialah penambahbaikan IRC_FEC ditakrifkan sebagai EM_IRC_FEC untuk meningkatkan keutuhan pengesanan ralat dengan menggunakan pemetaan lanjutan. Peringkat terakhir adalah pembangunan CLD_ARQ yang efisien termasuk penghantaran semula untuk pembetulan ralat yang mengeksploitasi EM_IRC_FEC dan ARQ. Dalam reka bentuk yang dicadangkan, penyahkodan berlelaran siri dan penyahkodan berlelaran selari digunakan dalam pengesanan dan pembetulan ralat. Prestasi CLD_ARQ dinilai dalam saluran Hingar Tambahan Putih Gaussian (AWGN) dengan menggunakan carta Pindahan Maklumat Ekstrinsik (EXIT), Kadar Ralat Bit (BER) dan analisis daya pemprosesan. Hasil kajian menunjukkan gandaan Nisbah Isyarat-kepada-Hingar (SNR) yang ketara daripada had teori pada BER 10^{-5}. IRC_FEC mengatasi Rekursi Sistematik Konvolusi Kod (RSCC) dengan gandaan SNR sehingga 7% disebabkan oleh penggunaan IRC sebagai saluran pengekodan mudah. Penggunaan CLD_ARQ dapat meningkatkan gandaan SNR sebanyak 53% berbanding dengan tanpa ARQ disebabkan oleh suap balik untuk penghantaran semula. Penggunaan pemetaan lanjutan pada CLD_ARQ meningkatkan gandaan SNR sehingga 50% disebabkan oleh penambahbaikan pengesanan ralat. Secara umum, CLD_ARQ yang dicadangkan boleh mencapai BER rendah dan menghampiri kepada kapasiti Shannon walaupun dalam keadaan saluran yang teruk.

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LIST OF ABBREVIATIONS

2D	-	Two Dimension
3D	-	Three Dimension
3G	-	Third Generation
4G	-	Fourth Generation
ACK	-	Positive acknowledgement
ARQ	-	Automatic Repeat Request
ASK	-	Amplitude Shift Keying
AWGN	-	Additive White Gaussian Noise
BCH	-	Bose-Chaudhuri-Hocquenghem code
BCJR	-	Bahl-Cocke-Jelinek-Raviv algorithm
BER	-	Bit Error Rate
BICM-ID	-	Bit-Interleaved Coded Modulation Iterative Decoding
CCC	-	Constellation Constrained Capacity
CCI	-	Co-Channel Interference
CF	-	Compress and Forward
CLD	-	Cross Layer Design
CRC	-	Cyclic Redundancy Check
DAcc	-	Doped-Accumulator
DF	-	Decode and Forward
DVB	-	Digital Video Broadcasting
EM	-	Extended Mapping
EXIT	-	Extrinsic Information Transfer
FEC	-	Forward Error Correction
FSK	-	Frequency Shift Keying
GBN	-	Go-Back-N
HARQ	-	Hybrid ARQ
HSDPA	-	High Speed Data Personal Access

IR	-	Incremental Redundancy
IRC	-	Irregular Repetition Code
ISI	-	Intersymbol Interference
LDPC	-	Low Density Parity Check
LLR	-	Log Likelihood Ratio
LTE	-	Long Term Evolution
MAC	-	Medium Access Control
MAP	-	Maximum A Posteriori
MIMO	-	Multiple Input Multiple Output
MMSE	-	Minimum Mean Squared Error
MUD	-	Multi-User Detection
NACK	-	Negative acknowledgement
NSNRCC	-	Non-Systematic Non-Recursive Convolutional Code
OSI	-	Open System Interconnection
PCCC	-	Parallel Concatenated Convolutional Code
PHY	-	Physical Layer
PID	-	Parallel Iterative Decoding
PSK	-	Phase Shift Keying
QAM	-	Quadrature Amplitude
QoS	-	Quality of Service
QPSK	-	Quadrature Phase Shift Keying
RF	-	Radio Frequency
RSC	-	Recursive systematic convolutional
RSCC	-	Recursive Systematic Convolutional Code
SCCC	-	Serial Concatenated Convolutional Code
SID	-	Serial Iterative Decoding
SISO	-	Soft Input Soft Output
SNR	-	Signal-to-Noise-Ratio
SPC	-	Single Parity Check
SP-ID	-	Serial-Parallel Iterative Decoding
SR	-	Selective Repeat
STC	-	Spatial Turbo Coding
SW	-	Stop-N-Wait
UART	-	Universal Asynchronous Receiver/Transmitter

VoIP	-	Voice over Internet Protocol
WIFI	-	Wireless Fidelity
WIMAX	-	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

a	-	degree distribution
d	-	Doping ratio of the number of symbol mapped
k	-	constraint length
i	-	index
m	-	number of node degree allocation
n	-	number of bit symbol
rp	-	repeated times
rw	-	error correcting capacity of repetition code
x	-	source signal
C	-	Capacity
B	-	Bandwidth of the channel
J	-	J-function
K	-	number f bits per frame
M	-	modulation index
P	-	doping ratio of doped-accumulator
R	-	code rate
d_v	-	repetition times
d_{min}	-	minimum Hamming distance
l_{map}	-	length of modulation bit
v_n	-	AWGN signal
w_{min}	-	minimum wieght
x_n	-	modulated signal
I_A	-	a priori of mutual information
I_E	-	extrinsic of mutual information
L_E	-	extrinsic LLR
L_A	-	a priori LLR
$L_{A,dem}$	-	a priori LLR of demapper

$L_{A,dec}$	-	a priori LLR of decoder
$L_{E,dec}$	-	extrinsic LLR of decoder
$L_{E,dem}$	-	extrinsic LLR of demapper
$L_{AP,dec}$	-	a posteriori LLR of decoder
P_E	-	error probability of frame
P_r	-	Bit error probability
$n(q)$	-	AWGN signal at time q
$x(q)$	-	transmitted modulated signal at time q
x'_k	-	encoded bit
$x_k^{\sim}$	-	input of rate-1 inner code
$x^{\wedge}$	-	received signal
$y(q)$	-	received signal from channel at time q
$F\_i(k)$	-	frame terminology
$H^{(n)}$	-	matrix H in n index
$H(X)$	-	entropy of X
$I(X,Y)$	-	Mutual information
J^{-1}	-	Inverse J-function
$T(.)$	-	Transfer function
π	-	interleaver
μ	-	mapper
σ	-	Gaussian assumption
η	-	spectrum efficiency
Φ	-	modulation doping
R	-	spectrum efficienfy
π^{-1}	-	de-interleaver
μ^{-1}	-	demapper
σ_N^2	-	noise power
$\Pi(.)$	-	vertical iteration function

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CHAPTER 1

INTRODUCTION

1.1 Background

Telecommunication is a fast changing technology in the current modern world. The technology has achieved great development starting from Morse code until the design of 4G wireless communication system. Since the generation of analogue telephony system in the early 1980's to the current wireless broadband systems such as in Long Term Evolution (LTE) Advanced, the degree of peak data rates has increased tremendously for wireless communication system. During the evolution, significant advanced studies have been made in many aspects to increase the system reliability and efficiency in wireless communication. Some of these advances are related to channel access control mechanisms, modulation methods, efficient signal processing algorithms and error control mechanisms. One of the challenges to the network reliability is to deal with error control mechanism in wireless communication network.

Many research works in the telecommunications field focused on providing efficient and reliable wireless communication network system. Error control is one of the techniques that can ensure and measure the reliability of the wireless network system. Two main error control techniques are forward error correction (FEC) which uses error correcting code, and backward error control which uses an error detecting code with feedback. Error correction code detects error(s) and reconstructs original data to minimize error [1]. Meanwhile, error detection detects error caused by the channel and is used to send feedback for retransmission of data. The error detection technique is also called automatic repeat request (ARQ) that requires a feedback path as a backward error control. However, ARQ has a drawback which the throughput efficiency decreases when the channel error rate increases [2].

Network that does not have feedback channel such as broadcasting network uses error correcting code in FEC to correct transmission errors at the receiving end. FEC is able to detect and correct a limited number of errors without retransmission of information. In FEC scheme, redundancy bits are added to the data for error recovery [1]. The addition of redundant data in the transmission is the primary drawback of FEC that makes it more complex. In order to avoid complexity, retransmission is adopted as used in ARQ. ARQ is the technique that uses retransmission process in transmission system. ARQ is a feedback process to send an acknowledgment to the transmitter whether the retransmission is requested. However, feedback in ARQ incurs delay thus increases the data transmission latency. Since FEC can correct a limited number of errors, retransmission may be deployed to combat the remaining errors. The advantages of FEC and ARQ can be exploited when both schemes applied in one system, thus the possibility of corrected error can be increased. The combination of FEC and ARQ is known as Hybrid ARQ. Hybrid ARQ is an example of an advanced error control technique that ensures reliable data transmission. It is a process of detection and correction of corrupted transmitted data at the receiving end and sending end after acknowledgment or feedback. Hybrid ARQ overcomes the complexity in FEC and a delay in ARQ [3]. In Hybrid ARQ, error detection and correction codes are using either or both FEC and ARQ.

Hybrid ARQ can be extended to improve the layering architecture. The layered structure in the TCP/IP network model provides the information encapsulation that enables the standardizing of network communications and makes the implementation of networks convenient in terms of abstract layers. However, compromise of quality of services (QoS), latency, and extra overload are some side effects for encapsulation results. Therefore, to mitigate the side effect of the encapsulation between the abstract layers in the layered structure model, cross layer design (CLD) has been proposed [4]. Cross-layer designs allow information sharing among all of the five layers in order to improve the wireless network functionality, including security, QoS, and mobility [3].

CLD can be categorized in several types which are designed for information sharing between layers [4], merging of adjacent layers such as layer one and layer two, does not need to create a new interface to pair and calibrate across the layers. For an example, Medium Access Code (MAC) layer is a part of data link layer that is responsible for scheduling transmissions and channel access control mechanism. Meanwhile the physical (PHY) layer is a first layer which deal with actual transmission (provide electrical, mechanical and interface procedure including the modulation and encoding performing) and reception of data over the media. In CLD of the physical and MAC layer, both layers interact with each other to get information on each layer conditions. System performance can be improved if the MAC can obtain information from the PHY regarding to the power noise ratio information. Hence, the MAC can schedule transmission during the period of time that noise levels are lower [5]. For ensuring the reliability of the network, Hybrid ARQ as an advanced error control technique can be extended to include CLD approach.

In order to ensure the reliability of higher data transmission, a technique to enhance the error control mechanism is needed. FEC requires higher decoding processing when detecting and correcting huge data. Turbo processing is one of the techniques that able to process reliable huge data through iterative process. Iterative processing revolutionized by Berrou that clarifies the iterative signal processing can be applied efficiently in a communication system [6]. Turbo processing can be used to estimate detection and decoding process blocks that connected together. These blocks basically generate soft information and named as soft-input soft-output (SISO) blocks. The output information in Turbo processing is obtained not only from its own input, but contributed from the feedback and other block. Turbo processing can be applied in other communication systems even with simple FEC coding but its gain high performance likes a Turbo code performance. Turbo code and Low Density Parity Check (LDPC) coding are two examples of channel coding that use Turbo processing to achieve low bit error rate (BER) at low signal to noise ratio (SNR). It uses iterative decoding technique that allows the system to achieve performance very close to the Shannon's capacity [7].

Several methods are used to obtain turbo-like performance by using turbo processing to overcome the weak codes problem. For example, a combination of convolutional code or Reed Solomon as a conventional FEC in Bit-Interleaved Coded Modulation with Iterative Decoding (BICM-ID) [8] based system. BICM-ID as a simple Turbo processing combines with the weak code is an alternative to reduce the complex design as in Turbo and LDPC codes which can achieves the Turbo–like performances as well. Basically, the complexity of FEC coding is due to the decoding process where Turbo codes with Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm is more complex compared to convolutional code with Viterbi Algorithm and repetition code with only simple block decoding [3].

Design of Hybrid ARQ using simple code Irregular Repetition Code (IRC) with Turbo processing introduces a low complexity design with high reliability system design. It also has a high potential to be adopted in various wireless communication standards, especially the standards for commercial wireless communications such as in LTE-Advanced as in [9, 10]. Therefore, it is significant to explore the implementation of Turbo processing in Hybrid ARQ system that exploits the CLD concept where reliability and efficiency in wireless network communication can be increased.

The research work is for generalization purpose and based on the fundamental issue in communication theory where involvement of any specific standard of wireless communication is ignored.

1.2 Problem Statement

FEC is a digital signal processing technique that has been used to enhance data reliability in communication system. Turbo codes are a class of strong code FEC with higher performance codes developed in 1993. Turbo codes are the first practical codes that closely approach the channel capacity [7]. Powerful FEC coding is extremely important in many telecommunication applications because it can reduce the amount of energy required to transmit signals. In addition, it may also increase the range in which the signal can be received. This coding gain can also reduce power consumption for certain portable devices as well as increasing cell capacity for cellular network. Hence, amount of data that can be transmitted is increased with this technology development which significant for telecommunication applications.

Turbo codes also have long memory and random long enough to perform as a good error control mechanism [11, 12]. However, these codes are complex compared to convolutional codes. Many research works use convolutional code as a FEC in the transmission system such as in [13, 14]. Convolutional code is considered as a weak code but less complexity than Turbo codes. However, many researchers have studied to improve transmission system by using convolutional code with bit interleaved coded modulation (BICM-ID) such as in [15-17]. BICM-ID is introduced by Tuchler as a simple Turbo processing as stated in [18]. Iterative turbo decoding techniques in Turbo processing have been applied to conventional code systems such as Reed-Solomon and convolutional codes with the use of BICM-ID based system in [19, 20]. The complexity design of Turbo codes due to the serial and parallel concatenated and the iterative decoding cycles to reach a given threshold encourages researchers to develop simple Turbo processing with simple FEC coding to maintain the Turbo-like performance. However, the determination of conventional code to combine with Turbo processing is still not sufficient to reduce the complexity of the system design [8, 15, 21, 22]. Therefore, researchers have investigated the use of Irregular repetition code (IRC) as a channel coding code and BICM-ID as a simple Turbo processing for FEC. IRC is much simpler than convolutional code [23, 24], hence a powerful performance with simple FEC coding and simple Turbo processing in CLD is significant to reduce the complexity in the design.

In order to develop a low complexity error control design with simple Turbo processing, a technique that maximizes error detection and correction must be considered although Turbo processing enhances the FEC coding by reducing BER. In fast technology demand, higher order modulation is needed to ensure higher data rate can be transmitted, however researchers faced problem in reducing noise level when higher order modulation is used. In higher order modulation using standard mapping, higher noise level is created when the number of bits per symbol increases. The selection of mapping technique issue is highlighted because previous work shows that certain mapping rearrangement of coded information influence the BER performance such as in [16, 17, 25]. Extended mapping is employed rather than standard mapping technique or other mapping rearrangement to improve the BER performance based on BICM-ID system as in [23, 24, 26]. However, extended mapping has not been used in ARQ and also has never been explored for Hybrid ARQ system. Therefore, to develop efficient Turbo processing in CLD requires rearrangement of the mapping technique to increase the percentage of error detection and correction.

The challenge in wireless communication system is to provide error control mechanisms that can ensure network reliability. Error control consists of error detection and error correction technique [3]. FEC is able to detect and correct a limited number of errors without retransmission of information. In FEC, redundancy bits are added to the data such that the receiver enables the reconstruction of corrupted information [1]. Drawback of existing FEC is the addition of redundant bits and only limited number of errors can be detected and corrected. ARQ is a simple error correction technique via retransmission process but increases the delay due to retransmission in wireless communication system.In order to avoid FEC complexity, retransmission and FEC is combined as Hybrid ARQ system. Hybrid ARQ will request retransmission if FEC cannot correct errors. However, some issues arise to develop efficient Hybrid ARQ system. Many researches work on Hybrid ARQ only focus on the horizontal iteration decoding in BICM-ID. The retransmission process in BICM-ID is insufficient to reduce BER when only horizontal iterative decoding is invoked. In addition, the simplest Hybrid ARQ repeatedly retransmits the same data and discards the error received data. This is inefficient because the data still contain valuable information even there is an error

[17,25,27]. The retransmissions of similar data also may incur link utilization with low goodput. In early 2013, Ade et. al in his article [28] has introduced Turbo Hybrid ARQ system using convolutional code with BICM-ID based system deploying horizontal and vertical iteration at PHY and MAC layers indirectly. The design of Hybrid ARQ improves the possibility for error correction which the vertical iteration only involved when retransmission is requested. Thus, the complex system design and time duration for data transmission can be reduced indirectly. However, the throughput of the system needs to be improved by adopting improved mapping technique compared to standard mapping. Therefore, to ensure the integration system is effective, an efficient Hybrid ARQ system is required to gain low BER at low SNR with the enhancement of error detection and correction technique.

Recently, many research works on CLD use certain parameter from other layer to improve the system and network performance [29-31]. One of the CLD techniques is sharing information between physical and MAC layers to improve the error control in the transmission system such as in [32-34]. CLD at PHY and MAC layer is expected to increase efficiency compared to independent system. FEC works at physical layer while ARQ operates at MAC layer are two error control techniques that work independently. The ability of traditional layered architecture for wireless communication is very limited to the independent modular functions of each layer. The performance of data transmission over wireless communication is limited due to inability of using parameters from other layers. Therefore, there is a need to design the transmission system that takes advantages in CLD to improve the reliability of data transmission over unpredictable communication channel using error control and efficient Hybrid ARQ techniques.

1.3 Objective

The main goal of this research work is to develop an error control scheme a for reliable wireless transceiver system using Hybrid ARQ that can achieve low BER at low SNR. In order to achieve the goal, the specific objectives of the work include:

- to propose a low complexity FEC using Turbo processing based system.
- to enhance the reliability of the error detection in the proposed FEC by adopting extended mapping.
- to enhance error control performance through cross layer design ARQ.

The low complexity in the proposed FEC using Turbo processing is due to the use of IRC code as a simple encoding and decoding system. In addition, BICM-ID is deployed as a simple Turbo processing code with serial iterative decoding (SID) process at the receiver. Hence, the proposed FEC is defined as a combination of IRC code and the BICM-ID based-system. The use of ARQ in combination with proposed FEC will be developed to further reduce error with the possibility of retransmission and to closely approach the Shannon's capacity. The proposed efficient cross layer design ARQ is based on four components comprised of deployment of extended mapping, ARQ, SID, and parallel iterative decoding (PID).

1.4 Scope of Work

Error control is designed for wireless communication systems such as LTE network and future generation networks. The proposed work is divided into three stages. The first stage is a development of Turbo FEC defined as IRC_FEC. At this stage, FEC based on Turbo processing using IRC is investigated. Secondly, IRC_FEC enhanced with error detection technique defined as EM_IRC_FEC. Extended mapping (EM) is used in order to enhance the error detection technique.

The last stage is to develop Hybrid ARQ system that utilizes EM_IRC_FEC and ARQ. EM_IRC_FEC detects and corrects error while ARQ provides a feedback in the error control system. The design of Hybrid ARQ defined as CLD_ARQ.

The proposed CLD_ARQ system is based on CLD PHY and MAC layer which involves some iterative processes:

i) Horizontal iteration (SID) process in BICM-ID based-system for FEC in PHY layer for error detection and correction.
ii) Vertical iteration (PID) process for error detection and retransmission system.
iii) Combination of horizontal and vertical process (SID and PID) for error detection, correction and retransmission.

In CLD_ARQ, Doped-Accumulator (DAcc) is implemented as an optimization to improve the performance by eliminating the error floor. There are several assumptions due to the retransmission process in CLD_ARQ design. First, the development of CRC as an error detection scheme is not considered for simplicity work of Hybrid ARQ system. Second, it is assumed that ARQ will be performed when FEC not able to correct the error and selective repeat ARQ is used for multi frame transmission. Thirdly, both SID (i.e. iterative between received frame from the channel and received frame at the decoder) and PID (i.e. iterative between transmitted and retransmitted frame) techniques are invoked in CLD_ARQ system. Then, the acknowledgement feedback (i.e. ACK and NACK) from the receiver to the transmitter for retransmission request is assumed in error-free transmission. It is because of only bit ‘0’ or ‘1’ to indicate the acknowledgement transmission.

Subsequently, to further improve BER due to the limitation in IRC_FEC performance, extended mapping is used to reduce the number of constellation points, thus improving the error detection technique. Extended mapping technique is adopted in EM_IRC_FEC and CLD_ARQ instead of standard mapping in IRC_FEC system.

The development of this research is based on simulation work using MATLAB software. The scopes of the research analysis are limited to analyze the convergence behaviour, BER and throughput performances of Turbo processing-aided Hybrid ARQ. EXIT chart is used to analyze the performance of convergence behaviour of iterative decoding process to detect error through mutual information and correct the error based on the trajectory curve.The convergence behaviour of mutual information in Turbo processing is evaluated using the 2D EXIT and multidimensional EXIT charts.Then, the BER performance is measured for all stages while throughput is analyzed in CLD_ARQ system. Only ARQ protocol on MAC layer is studied in the scope of CLD_ARQ system design. The main difference CLD_ARQ compared to the previous works in [28] is the combination of several components to develop efficient error control system which consists of SID, PID, ARQ and extended mapping deployment.

1.5 Contributions

CLD_ARQ system is developed in the proposed system which combines error correction and detection as an error control in the system. Three main techniques involved which are Turbo processing, FEC and ARQ in the system. The simple coding and simple Turbo processing are applied using IRC as channel coding and BICM-ID based-system as Turbo processing. The proposed design of efficient CLD_ARQ comprised of deployment of extended mapping and the integration of SID and PID techniques to improve error detection and error correction with retransmission process. The main contributions in this research work include;

i) Low complexity error control technique using Turbo processing.
ii) Improved reliability of error detection in the proposed FEC using extended mapping.
iii) Improved BER and throughput performance using CLD_ARQ on reliable error detection and correction mechanism.
iv) Spectrum efficiency improvement using Doped-Accumulator by eliminating error floor in the CLD_ARQ system.

1.6 Significance of Work

The proposed CLD_ARQ error control system is developed using Turbo processing which involves the SID and PID. CLD_ARQ enhances the physical layer transceiver design where the performance purposely to achieve closely near the channel capacity. CLD_ARQ is significant to be designed to achieve performance closely to a new class of convolutional codes called Turbo codes whose performances in term of BER are very close to the Shannon's limit [7]. The low complexity of FEC with Turbo processing in CLD_ARQ system can be possibly used in all mobile device transceiver designs.

CLD_ARQ provides error control that can ensure network reliability. It can allow reconstruction of the original information and asks for retransmission to detect and correct error. In CLD_ARQ, extended mapping is used to improve error detection technique. Error detection and error correction in CLD_ARQ can be extended to be used in software define radio (SDR) system to improve the channel capacity.

ARQ in the CLD_ARQ system plays important roles where system in CLD_ARQ minor errors are corrected with FEC and major errors are corrected via ARQ. The CLD_ARQ with Doped-Accumulator has been optimized to the system when the error floor can be eliminated; hence low BER can be achieved in worse channel condition. The error floor elimination will improve the spectrum efficiency of the system, thus closely approached to the Shannon's capacity. CLD_ARQ can be applicable in wireless wide area network (WWAN) communication system such as satellite communication, LTE, High Speed Data Personal Access (HSDPA) and 5G system as well as in other application that needs to reach reliable transmission over the network. This system design is applicable in wireless local area network (WLAN), relay network and co-operative ARQ which provides high speed data transmission for mobile phone network [4].

1.7 Thesis Outline

This thesis consists of seven chapters. The contents of each chapter are described and summarized to give an overview of the stages of work. A brief introduction to the proposed system and its applications to various communication systems are presented in Chapter 1. This chapter explains the problems that need to be solved and the objectives of this research. Then, the significant and scope of this research are also elaborated.

In Chapter 2, several of previous related research works are presented and discussed. The related research works are according to turbo processing, coding, mapping technique, EXIT chart analysis, CLD and Hybrid ARQ for retransmission system. All this research topics are discussed in this chapter.

Then, the discussion on the methodology of the system design is provided in Chapter 3 which gives a brief description and explanation to the proposed CLD_ARQ system. This chapter briefly explain the flow of work in every stage and the overall system design that has been done in this research work.

After that, the first stage of this research work briefly described in Chapter 4 where the process of Turbo processing using iterative decoding for IRC_FEC system model is explained. This process presents the performance of IRC codes based-on BICM-ID system as Turbo FEC that has been used in IRC_FEC system. Then, the EXIT and BER performances are analysed for IRC_FEC system.

Chapter 5 presents the second stage of this research work which clarifies the enhancement of IRC_FEC system. Extended mapping is applied replacing standard mapping in the IRC_FEC system and it is defined as EM_IRC_FEC system. The extended mapping that described as an error detection scheme enhancement also discuss in this chapter. EXIT and BER analyses have been measured and presented for EM_IRC_FEC performance.

Next, the integration EM_IRC_FEC and ARQ called CLD_ARQ system is presented in Chapter 6 as a third stage of work. SID and PID technique have been involved in CLD_ARQ development. The significant of this stage is the integration of ARQ and turbo processing in CLD_ARQ system design. The performance of EXIT analysis, BER and throughput of the system are presented in this chapter.

Finally, conclusion and recommendation are clarified in Chapter 7. This chapter expresses the achievement of the proposed system according to the objective and scope of research work. Some topics to be considered as a future work in order to enhance the proposed system also recommended.

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