ITERATIVE RELAY RECEIVER FOR PHYSICAL LAYER NETWORK CODED TRANSMISSION

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Abstract : ***Forwarding the packets through relay nodes is an area where many processing techniques can be designed and validated. Physical Layer Network coding (PNC) is an emerging method which exploits the superposition of signals in air. The present work proposes to implement a relay receiver for iterative decoding of turbo coded packet. As an alternate to decoding the message with respect to each source, the present work considers combined decoding of superimposed messages to yield the XOR estimate.***

Index Terms – PNC, Two-way relay channels.

I. INTRODUCTION

When network Coding was initially introduced for wired networks it created a paradigm shift in the way the routing switches were used[1].This breakthrough in the application of the routing switches has led to the concept of network coding in the network layer[2].Further the concept of network coding was experimented at the physical layer[3] which is known as physical layer network coding (PNC).The throughput of a Two-Way Relay Channel (TWRC) was shown to be improved considerably with the advent of PNC, where two end nodes exchange the information via a relay node. The two end nodes send packets in the same time slot to the relay node in a PNC system [1]. The relay node then converts the superimposed packets to a network-coded packet and broadcast back to the end nodes. Each end node uses their self-information to extract the packet of the other end nodes from the network-coded packet [2]. In a two-way relay transmission scheme, communication can take place over four-time slots, where source A communicates with source B in the first two-time slots with source B remaining idle, and source B communicates to source A in the last two time slots with source A remaining idle. This scheme is referred as a four-time slot transmission scheme, and its performance has been well studied in different channel environments and Signal-to-Noise Ratio (SNR) variations at the source and relay. One problem with this transmission scheme is the relatively low maximum sum-rate, due to transmission over four-time slots [3]. Recently, the concept of Physical Layer Network Coding (PNC) has attracted a lot of attention. The basic idea behind PNC is that for a two-way relay channel [4], where the multiple access interference occurring at the relay was exploited so that the communication between the end nodes can be done using a two-phase protocol. Information theoretic studies for the PNC scenario were reported in [5], [6].

Relay-aided communications are widely adopted in cellular networks and ad hoc networks where the end nodes cannot directly communicate with each other [7]. Compared with the store-and-forward relaying method, network coding reduces the necessary number of communication phases and thereby increases network throughput. Physical-layer Network Coding (PNC) employs not only the broadcast nature of wireless channel but also the natural network coding ability derived from the superposition of electromagnetic waves [8], which makes PNC benefit more throughput improvement than Conventional Network Coding (CNC).

Hence PNC is an effective method to embrace the interference in a constructive way but it still has to overcome the effect of channel noise. Link-by-link coded PNC is the method in which not only the two users but also the relay performs channel coding and decoding. Apart from the two transmission time slot transmission the relay has to perform the channel decoding and network coding (CNC) [11] process in which it has to obtain the channel uncoded but network coded (XORed) information from the superimposed channel coded packets.

Iterative algorithms are a viable option for the challenging estimation and detection tasks that face next generation communications receivers. Iterative probabilistic processing for communications receivers originates from the popular concept of turbo decoding discovered in the early 1990s. The concept of an iterative receiver was developed in which probabilistic information about the unknown data and parameters are passed between the blocks of the receiver (e.g., synchronization, equalization, demodulation, and decoding) in an iterative fashion. From a theoretical standpoint the goal is to approximate maximum a posteriori (MAP) symbol-by-symbol detection of the information bits and estimation of the unknown channel or signal parameters.

Since its appearance, turbo decoding has proved to be a powerful decoding algorithm for parallel and serial concatenated codes, allowing performance close to the theoretical Shannon limit. Turbo-codes are designed to enhance the error correcting capabilities of the information. Turbo-codes belong to a group of high-performance linear error correcting codes which find application in satellite communications in deep space and also in mobile communication.

II. Literature Review

The previous works have concentrated on analog network coding such as [2], [11] and some of them have concentrated on physical layer network coding such as [12] [13],[14],[15],[16] using AF and Decode and Forward(DF) protocol. These are discussed as follows.

Cao et al. [13] proposed symbol based PNC(SPNC) which is a combination of Antenna Selection based PNC(AS-SPNC) and signal combining based PNC(SC-SPNC) scheme. The analysis of these two schemes confirm their full diversity performance and also viewed as an effective single-input-multiple-output system, in which AS-SPNC and SC-SPNC are equivalent to the general AS scheme and the maximal-ratio combining scheme. Furthermore, an asymptotic analysis of symbol error rate is provided for SC-PNC considering these that the number of relay antennas is sufficiently large. However this method not applied to practical systems like LTE etc. also this SPNC technique is personalized for MPSK modulation, it is feasible to extend the SPNC to MQAM scenario.

Guo et al. [14] propose a new linear vector PNC scheme for spatial multiplexing multiple-input-multiple-output TWRC. The proposed novel typical error event analysis exploits a new characterization of the deep fade events for the TWRC. They derive a new closed-form expression or the average error probability of the proposed scheme over a Rayleigh fading MIMO TWRC. Thus, the analysis shows that the proposed scheme achieves the optimal error rate performance at a high SNR. However, the proposed schemes need to apply networks other than TWRCs, e.g., the multiple-access relay networks or multi-way relay networks.

Toshiaki et al. [17] proposed modulation scheme for the two-way wireless relaying system. The network coding was based on denoise-and-forward (DNF) protocol, consisting of two stages such as multiple access stage and broadcast (BC) stage. The performance evaluations demonstrated that the proposed denoising scheme considerably improves the achievable end-to-end throughput, particularly for Nakagami-Rice fading channels. Furthermore, this study needs to evaluate the design for adaptive modulation and coding based on the channel conditions in DNF two-way relaying systems.

Zhang et al. [2] proposes a non-memory less ANC scheme. In specific, design a soft-input-soft-output decoder for the relay node to process the superimposed packets from the two end nodes to yield an estimated MMSE packet for forwarding back to the end nodes. The analysis shows that the SNR improvement at the relay node is lower bounded by 1/R with the simplest LDPC code. The SNR improvement is also proved by numerical simulation with LDPC code. The experimental results indicate that LDPC codes of different degrees are preferred for lower SNRs.

Ding et al. [15] study the application of PNC to the joint design of uplink and downlink transmissions, where the base station and the relay have multiple antennas, and mobile stations have a single antenna. A new network coding transmission protocol is proposed, where 2M uplink and downlink transmissions can be accomplished within two-time slots. An explicit analytic result has been developed to demonstrate that the multiplexing gain achieved by the proposed transmission protocol, much better than existing time-sharing schemes. To further increase the achievable diversity gain, two variations of the proposed transmission protocols have also been proposed when there are multiple relays, and the number of the antennas at the base station and relay is increased.

Huang et al. [16] consider an irregular repeat-accumulate coded PNC scheme in a Gaussian TWRC. They address the convergence behavior of the iterative receiver of the channel coded PNC at the relay.

Faraji-Dana and Mitran [18] compares the different mappings between FSK and PSK constellation and proves also that many have identical performance in terms of frame error rate (FER). Furthermore, derive a lower bound on the performance of decoding the network-coded combinations. A simulation result shows that the ternary constellation has the best FER performance among all considered cases.

Dong et al. [19] considered Hierarchical Decode and Forward turbo coded PNC on the TWRC and the upper bound on the performance has been given and have emphasized that the performance of binary PNC on the TWRC is less superior compared to a single user end-to-end system when the same turbo code is used as an outer code in both. Joint turbo decoding and PNC at the relay can be performed either by decoding the individual binary messages separately at the relay or by finding an XOR estimate of the transmitted messages by using the superimposed faded signal received at the relay. A softening of the XOR values to improve the overall performance is considered in [20].In this PNC is incorporated in the BCJR decoding process.

Coherent and non coherent PNC form a major research domain where each one of them have performance trade off. In [21] a non coherent Digital Network Coding (DNC) relay receiver capable of non coherent operation using Bit Interleaved Coded Modulation with Iterative Decoding (BICM-ID) and FSK modulation is worked out. The demodulator and decoder are implemented using the Soft Input Soft Output (SISO) algorithm.

Alaa et al. [22] the transmitter based on BICM-ID is considered. The relay receiver is implemented based on the concept of PNC mapping.

Yixin et al. [23] the study on relay based wireless networks from the perspective of complexity has been presented. The complexity of Gaussian Message Passing (GMP)-based schemes in OFDM-based PLNC is considered. The simulation results indicate a considerable improvement in BER since the interference is reconstructed and removed from the received signal based on the decoding result.

Yuanyi et al. [24] introduced a type of PNC called link-by-link coded PNC. In this scheme the encoding and decoding is performed at the relay and the source nodes in both the time slots. The advantages of iterative decoding schemes are very well highlighted in this work. In [25] application of non-binary turbo codes is experimented and validated in comparison with the binary turbo codes and it was shown that the non binary turbo codes outperform the binary turbo codes based on the error floor analysis.

The above study indicates that since from the inception of the concept of network coding the relay receiver design has seen a considerable paradigm shift from the simplest Amplify and Forward (AF) to the complex Decode and Forward (DF) and each work has a clear indication that the heart of the PNC lies in how the relay receiver is designed.

The near Shannon limit error correction performance of turbo codes [] and serial concatenated convolutional codes have raised a lot of interest recently to find a practical decoding algorithm for implementation of theses codes. The MAP algorithm which is well known as BCJR algorithm is not much used algorithm for implementation in real systems. The MAP algorithm is computational complexity and sensitivity to SNR mismatch is more prominent. Inaccurate measurement of the noise variance also results in degradation in the system performance.

Hence a low complexity MAP based algorithm with minimal performance penalty is used in the current work. As a result of this motivation the proposed work applies the Simplified Max Log MAP (SMLM) decoder for joint channel decoding and PNC.

I. System Model

We consider a TWRN, where two source nodes, *A* and B, wish to communicate with each other through an intermediate (relay) node *R* .There is no direct link between *A* and B. When PNC is applied at the relay node, the exchange of data between A and B is made in two distinct time slots referred to as the multiple access (MAC) stage and the broadcast (BC) stage. In the MAC stage both *A* and B transmits their signals to the relay node. Due to half duplex constraint the sources cannot listen to any information. The relay node receives the superimposed faded signals from *A* and *B* and estimates the XOR of the original messages. It should be emphasized that no knowledge of each individual message is required for this process. Afterwards, in the BC stage the relay node reencodes the estimated XORed message and, taking advantage of the broadcast nature of the wireless medium, transmits the coded signal back to both *A* and *B* .The system model is depicted in Figure 1.

Relay Node and the two source nodes employ turbo codes to encode their messages. The encoder consists of two identical recursive systematic convolutional (RSC) encoders operating in parallel with an interleaver between them. Assume a turbo code of rate $1/n$. For $i = A, B$, let $u_i = [u_i(1),\ldots\ldots. u_i(N)]$ denote the message vector of length N containing information bits from source A and B, and let $v_i = [v_i(1),\ldots\ldots. v_i(N)]$ be the corresponding coded sequence of length nN bits. Each coded block $v_i = [v_i^1(t),\ldots\ldots. v_i^n(t)]$ is a vector of length n bits and corresponds to the turbo encoder output for the input bit $u_i(t)$ at time t .The coded block v_i is then BPSK modulated to produce x_i ,that is $x_i^j(t) = 1 - 2\, v_i^j(t)$ for $j = 1,\ldots\ldots.n$. We assume that the channels between the source and the relay node are Rayleigh fading channels, The channel from A to R is characterized by the channel coefficients vector ,$h_{AR} = [h_{AR}(1),\ldots\ldots h_{AR}(N)]$ and from B to R is $h_{BR} = [h_{BR}(1),\ldots\ldots h_{BR}(N)]$. The received signal at relay node is given by is given by $y_R = z_R + n$,where $z_R = [z_R(1),\ldots\ldots\ldots z_R(N)]$ contains the superimposed faded signals : $z_R(t) = x_A(t) \circ h_{AR}(t) + x_B(t) \circ hB_R(t)$,and $n = [n(1),\ldots\ldots n(N)]$ is a complex valued Gaussian noise vector with zero mean and variance of σ^2.The received signal at the input of the relay decoder is then given by

$$y_R = z_R + n , \qquad (1)$$

where

$$z_R = x_A \circ h_{AR} + x_B \circ h_{BR}. \qquad (2)$$

The relay has the full channel state information. The relay performs the joint channel decoding and physical layer network coding. The relay outputs an estimate let $u_R = [u_R(1),\ldots\ldots. u_R(N)]$,where $u_R(t) = u_A(t) \oplus u_B(t)$, based on the received signal y_R . Finally, in the BC stage, the estimated XORed bits are re encoded with the same code used in the sources and remodulated by the relay generating a sequence of symbols x_R .This sequence is again broadcast to the sources through the Rayleigh fading channel.

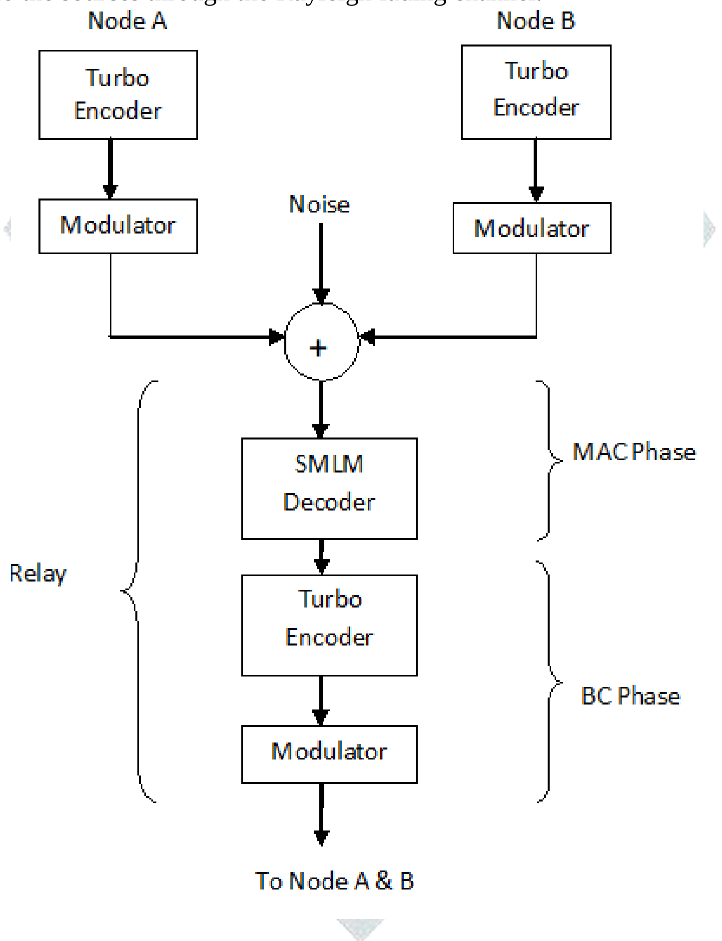

Fig. 1 System model for the proposed decoder scheme

II. SIMPLIFIED MAX LOG MAP DECODER (SMLM DECODER)

Once the relay has received the superimposed faded signal, y_R, the relay tries to recover the XORed sequence $u_R(t)$ using an iterative decoder. We use the Simplified Max Log Map (SMLM) decoder to produce the estimates of the posterior probabilities of $u_R(t)$ based on y_R . Basically the max-log-Map algorithm can be divided into four computation tasks, which are branch metrics generation, forward metrics generation, backward metrics generation and generation of soft output together with extrinsic information.
It is highly desirable that the decoder should avoid complicated arithmetic operations, such as multiplication and exponentiation. Some approximations of the MAP algorithm have been derived, which work exclusively in the logarithmic domain.

$$\wedge(u_R(t)|y_R) = \ln\left(\frac{P(u_R(t)=1|y_R)}{P(u_R(t)=0|y_R)}\right) \quad . \qquad (3)$$

$$\hat{u}_R(t) = \begin{cases} 0, & \wedge(u_R(t)|y_R) \le 0 \\ 1, & \text{otherwise} \end{cases} \qquad (4)$$

$$\alpha_s(k) = \max_{s'}(\alpha_{s'}(k-1) + C_{s',s}(k)) \qquad (5)$$

$$\beta_s(k-1) = \max_{s}(\beta_s(k) + C_{s',s}(k)) \qquad (6)$$

$$L(k) = \max_{s',s:u_k=1} (\alpha_{s'}(k-1) + \beta_s(k) + C_{s',s}(k)) - \max_{s',s:u_k=0} (\alpha_{s'}(k-1) + \beta_s(k) + C_{s',s}(k))$$

Encoder states are given with s and s', k refers to the k^{th} trellis stage and c is the branch metrics. The soft output L is computed with the help of the forward, backward and the branch metrics.

III. SIMULATION RESULTS

The error rate performance of the proposed decoder is compared with the relay that employs simple AF strategy. The error rate performance of the AF relay has been shown in fig.2. The error rate performance of the proposed iterative receiver using SMLM decoder is shown in Fig. 3. We see that the iterative decoding considerably improves the error rate performance compared to AF relay strategy.

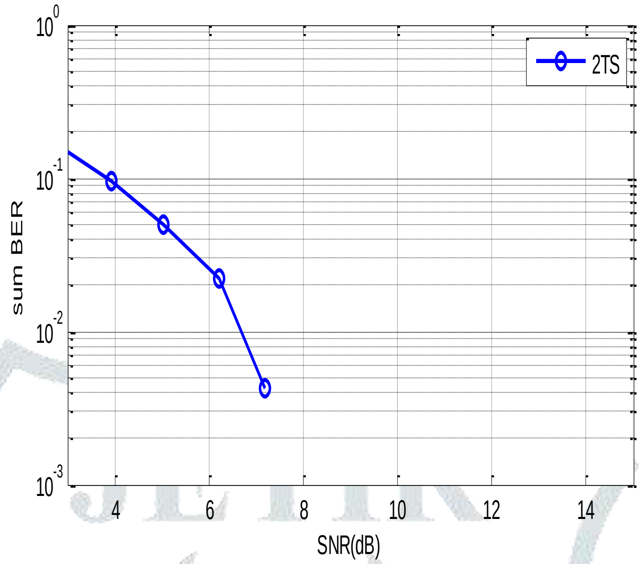

Fig. 2 BER with AF Strategy

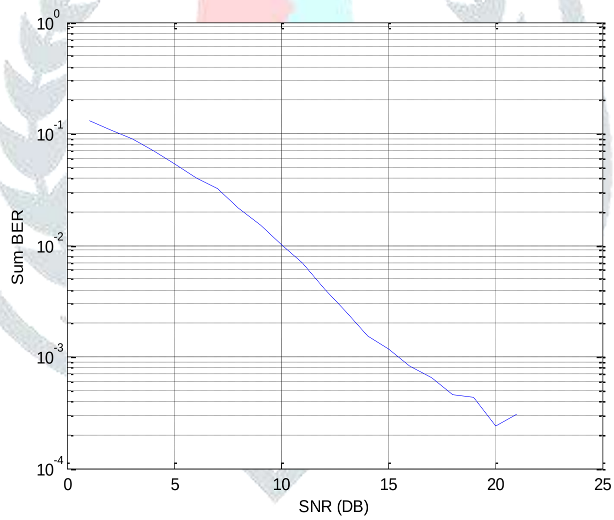

Fig. 3 BER with SMLM Decoder.

In comparison with the fig. 2 we observe that the error rate performance of the iterative decoder using SMLM algorithm is much improved than the AF relay strategy.

VI. CONCLUSION

In the present study, we have considered a two-way relay network with two source nodes A and B, and they connect with one another through the relay node using DF protocol. We have proposed to use an iterative decoder at the relay. The performance of the proposed decoder using SMLM algorithm is compared with the AF relay strategy. Simulation results show that though it is comparatively simple to implement AF relay but at the cost of degraded error rate performance as compared with the DF relay strategy. Also the error rate performance of the DF relay strategy using iterative decoder is superior compared to the AF relay strategy.

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3.1Population and Sample

KSE-100 index is an index of 100 companies selected from 580 companies on the basis of sector leading and market capitalization. It represents almost 80% weight of the total market capitalization of KSE. It reflects different sector company’s performance and productivity. It is the performance indicator or benchmark of all listed companies of KSE. So it can be regarded as universe of the study.Non-financial firms listed at KSE-100 Index (74 companies according to the page of KSE visited on 20.5.2015) are treated as universe of the study and the study have selected sample from these companies.

The study comprised of non-financial companies listed at KSE-100 Index and 30 actively traded companies are selected on the bases of market capitalization.And 2015 is taken as base year for KSE-100 index.

3.2 Data and Sources of Data

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

3.3 Theoretical framework

Variables of the study contains dependent and independent variable. The study used pre-specified method for the selection ofvariables. The study used the Stock returns are as dependent variable. From the share price of the firm the Stock returns are calculated. Rate of a stock salable at stock market is known as stock price.

Systematic risk is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

Consumer Price Index (CPI) is used as a proxy in this study for inflation rate. CPI is a wide basic measure to computeusualvariation in prices of goods and services throughout a particular time period. It is assumed that arise in inflation is inversely associated to security prices because Inflation is at lastturned into nominal interest rate andchange in nominal interest rates caused change in discount rate so discount rate increase due to increase in inflation rate and increase in discount rateleads todecreasethe cash flow’s present value (Jecheche, 2010). The purchasing power of money decreased due to inflation, and due to which the investors demand high rate of return, and the prices decreased with increase in required rate of return (Iqbal et al, 2010).

Equations

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I. RESEARCH METHODOLOGY

The methodology section outline the plan and method that how the study is conducted. This includes Universe of the study, sample of the study,Data and Sources of Data, study’s variables and analytical framework. The detailsare as follows;

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Variables of the study contains dependent and independent variable. The study used pre-specified method for the selection ofvariables. The study used the Stock returns are as dependent variable. From the share price of the firm the Stock returns are calculated. Rate of a stock salable at stock market is known as stock price.

Systematic risk is the only independent variable for the CAPM and inflation, interest rate, oil prices and exchange rate are the independent variables for APT model.

Consumer Price Index (CPI) is used as a proxy in this study for inflation rate. CPI is a wide basic measure to computeusualvariation in prices of goods and services throughout a particular time period. It is assumed that arise in inflation is inversely associated to security prices because Inflation is at lastturned into nominal interest rate andchange in nominal interest rates caused change in discount rate so discount rate increase due to increase in inflation rate and increase in discount rateleads todecreasethe cash flow’s present value (Jecheche, 2010). The purchasing power of money decreased due to inflation, and due to which the investors demand high rate of return, and the prices decreased with increase in required rate of return (Iqbal et al, 2010).

Exchange rate is a rate at which one currency exchanged with another currency. Nominal effective exchange rate (Pak Rupee/U.S.D) is taken in this study.This is assumed that decrease in the home currency is inverselyassociated to share prices (Jecheche,2010). Pan et al. (2007) studied exchange rate and its dynamic relationship with share prices in seven East Asian Countries and concludethat relationshipof exchange rate and share prices varies across economies of different countries. So there may be both possibility of either exchange rate directly or inverselyrelated with stock prices.Oil prices are positively related with share prices if oil prices increase stock prices also increase (Iqbal et al, 1012).Ataullah (2001) suggested that oil prices cause positive change in the movement of stock prices. The oil price has no significant effect on stock prices (Dash & Rishika, 2011).Six month T-bills rate is used as proxy of interest rate. As investors arevery sensitive about profit and where the signals turn into red they definitely sell the shares. And this sensitivity of the investors towards profit effects the relationship of the stock prices and interest rate, so the more volatility will be there in the market if the behaviors of the investors are more sensitive. Plethora (2002)has tested interest rate sensitivity to stock market returns, and concluded an inverse relationship between interest rate and stock returns. Nguyen (2010) studies Thailand market and found thatInterest rate has aninverse relationship with stock prices.

KSE-100 index is used as proxy of market risk. KSE-100 index contains top 100 firms which are selected on the bases of their market capitalization. Beta is the measure of systematic risk and has alinear relationship with return (Horn, 1993). High risk is associated with high return (Basu, 1977, Reiganum, 1981 and Gibbons, 1982). Fama and MacBeth (1973) suggested the existence of a significant linear positive relation between realized return and systematic risk as measured by β. But on the other side some empirical results showed that high risk is not associated with high return (Michailidis et al. 2006, Hanif, 2009). Mollah and Jamil (2003) suggested thatrisk-return relationship is notlinear perhaps due to high volatility.

3.4Statistical tools and econometric models

This section elaborates the proper statistical/econometric/financial models which are being used to forward the study from data towards inferences. The detail of methodology is given as follows.

3.4.1 Descriptive Statistics

Descriptive Statics has been used to find the maximum, minimum, standard deviation, mean and normally distribution of the data of all the variables of the study. Normal distribution of data shows the sensitivity of the variables towards the periodic changes and speculation. When the data is not normally distributed it means that the data is sensitive towards periodic changes and speculations which create the chances of arbitrage and the investors have the chance to earn above the normal profit. But the assumption of the APT is that there should not be arbitrage in the market and the investors can earn only normal profit. Jarque bera test is used to test the normality of data.

3.4.2 Fama-Mcbeth two pass regression

After the test statistics the methodology is following the next step in order to test the asset pricing models. When testing asset pricing models related to risk premium on asset to their betas, the primary question of interest is whether the beta risk of particular factor is priced. Fama and McBeth(1973)develop a two pass methodology in which the beta of each asset with respect to a factor is estimated in a first pass time series regression and estimated betas are then used in second pass cross sectional regression to estimate the risk premium of the factor. According to Blum (1968) testing two-parameter models immediately presents an unavoidable errors-in-the variables problem.It is important to note that portfolios (rather than individual assets) are used for the reason of making the analysis statistically feasible.Fama McBeth regression is used to attenuate the problem of errors-in-variables (EIV) for two parameter models (Campbell, Lo and MacKinlay, 1997).If the errors are in the β (beta)of individual security are not perfectly positively correlated, the β of portfolios can be much more precise estimates of the true β (Blum, 1968).

The study follow Fama and McBeth two pass regressionto test these asset pricing models.The Durbin Watson is used to check serial correlation and measures the linear association between adjacent residuals from a regression model. If there is no serial correlation, the DW statistic will be around 2. The DW statistic will fall if there is positive serial correlation (in worst case, it will be near zero). If there is a negative correlation, thestatistic will lie somewhere between 2 and 4. Usually the limit for non-serial correlation is considered to be DW is from 1.8 to 2.2. A very strong positive serial correlation is considered at DW lower than 1.5 (Richardson and smith, 1993).

According to Richardson and smith(1993) to make the model more effective and efficient the selection criteria for the shares in the period are: Shares with no missing values in the period, Shares with adjusted $R^2 < 0$ or F significant (p-value) >0.05of the first pass regression of the excess returns on the market risk premium are excluded. And Shares are grouped by alphabetic order into group of 30 individual securities (Roll and Ross, 1980).

3.4.2.1 Model for CAPM

In first pass the linear regression is used to estimate beta which is the systematic risk.

$$R_i - R_f = (R_m - R_f)\beta \qquad (3.1)$$

Where $R_i$isMonthly return of thesecurity, R_f isMonthly risk free rate, R_m isMonthly return of market and βis systematic risk (market risk).

The excess returns R_i - R_f of each security is estimated from a time series share prices of KSE-100 index listed shares for each period under consideration. And for the same periodthe market Premium R_m - $R_f$also estimated. After that regress the excess returns R_i - R_f on the market premium R_m - $R_f$to find the beta coefficient (systematic risk).

Then a cross sectional regression or second pass regression is used on average excess returns of the shares and estimated betas.

$$\hat{R}_i = \gamma_0 + \gamma_1\beta_1 + \epsilon \qquad (3.2)$$

Where λ_0= intercept, $\hat{R}_1$is average excess returns of security i,$\beta_1$isestimated be coefficient of security I and Є is error term.

3.4.2.2 Model for APT

In first pass the betas coefficients are computed by using regression.

$$R_i - R_f = \beta_i f_1 + \beta_{i2} f_2 + \beta_{i3} f_3 + \beta_{i4} f_4 + \epsilon \qquad (3.3)$$

Where Ri is the monthly return of stock i,R_f is risk free rate, β_i is the sensitivity of stock i with factors and ϵ is the error term.

Then a cross sectional regression or second pass regression is used on average excess returns of the shares on the factor scores.

$$\hat{R} = \gamma_0 + \gamma_1\beta_1 + \gamma_2\beta_2 + \gamma_3\beta_3 + \gamma_4\beta_4 + \epsilon_i \qquad (3.4)$$

Where$\hat{R}$ is average monthly excess return of stock I, λ = risk premium, β_1 to β_4 are the factors scores and ε_i is the error term.

3.4.3 Comparison of the Models

The next step of the study is to compare these competing models to evaluate that which one of these models is more supported by data.This study follows the methods used by Chen (1983), the Davidson and Mackinnon equation (1981) and the posterior odds ratio (Zellner, 1979) for comparison of these Models.

3.4.3.1 Davidson and MacKinnon Equation

CAPM is considered the particular or strictly case of APT. These two models are non-nested because by imposing a set of linear restrictions on the parameters the APT cannot be reduced to CAPM. In other words the models do not have any common variable. Davidson and MacKinnon (1981) suggested the method to compare non-nested models. The study used the Davidson and MacKinnon equation (1981) to compare CAPM and APT.

This equation is as follows;

$$R_i = \alpha R_{APT} + (1-\alpha) R_{CAPM} + e_i \qquad (3.5)$$

Where$R_{i=}$ the average monthly excess returns of the stock i, $R_{APT=}$ expected excess returns estimated by APT, $R_{CAPM=}$ expected excess returns estimated by CAPM and α measure the effectiveness of the models. The APT is the accurate model to forecast the returns of the stocks as compare to CAPMif α is close to 1.

3.4.3.2 Posterior Odds Ratio

A standard assumption in theoretical and empirical research in finance is that relevant variables (e.g stock returns) have multivariate normal distributions (Richardson and smith, 1993). Given the assumptionthat the residuals of the cross-sectional regression of the CAPM and the APT satisfy the IID (Independently and identically distribution) multivariate normal assumption (Campbell, Lo and MacKinlay, 1997), it is possible to calculate the posterior odds ratio between the two models.In general the posterior odds ratio is a more formal technique as compare to DM equation and has sounder theoretical grounds (Aggelidis and Maditinos, 2006).

The second comparison is done using posterior odd radio. The formula for posterior odds is given by Zellner (1979) in favor of model 0 over model 1.

The formula has the following form;

$$R = [ESS_0/ESS_1]^{N/2} N^{K_0 - K_1/2} \qquad (3.6)$$

WhereESS_0iserror sum of squares of APT, ESS_1iserror sum of squares of CAPM, Nisnumber of observations, $K_0$is number of independent variables of the APT and K_1 isnumber of independent variables of the CAPM.As according to the ratio when;

R> 1 means CAPM is more strongly supported by data under consideration than APT.

R < 1 means APT is more strongly supported by data under consideration than CAPM.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

Variable	Minimum	Maximum	Mean	Std. Deviation	Jarque-Bera test	Sig
KSE-100 Index	-0.11	0.14	0.020	0.047	5.558	0.062
Inflation	-0.01	0.02	0.007	0.008	1.345	0.510

Exchange rate	-0.07	0.04	0.003	0.013	1.517	0.467
Oil Prices	-0.24	0.11	0.041	0.060	2.474	0.290
Interest rate	-0.13	0.05	0.047	0.029	1.745	0.418

Table 4.1: Descriptive Statics

Table 4.1 displayed mean, standard deviation, maximum minimum and jarque-bera test and its p value of the macroeconomic variables of the study. The descriptive statistics indicated that the mean values of variables (index, INF, EX, OilP and INT) were 0.020, 0.007, 0.003, 0.041 and 0.047 respectively. The maximum values of the variables between the study periods were 0.14, 0.02, 0.04, 0.41, 0.11 and 0.05 for the KSE- 100 Index, inflation, exchange rate, oil prices and interest rate.

The standard deviations for each variable indicated that data were widely spread around their respective means.

Column 6 in table 4.1 shows jarque bera test which is used to checkthe normality of data. The hypotheses of the normal distribution are given;

H_0 : The data is normally distributed.

H_1 :The data is not normally distributed.

Table 4.1 shows that at 5 % level of confidence, the null hypothesis of normality cannot be rejected. KSE-100 index and macroeconomic variables inflation, exchange rate, oil prices and interest rate are normally distributed.

The descriptive statistics from Table 4.1 showed that the values were normally distributed about their mean and variance. This indicated that aggregate stock prices on the KSE and the macroeconomic factors, inflation rate, oil prices, exchange rate, and interest rate are all not too much sensitive to periodic changes and speculation. To interpret, this study found that an individual investor could not earn higher rate of profit from the KSE. Additionally, individual investors and corporations could not earn higher profits and interest rates from the economy and foreign companies could not earn considerably higher returns in terms of exchange rate. The investor could only earn a normal profit from KSE.

FiguresandTables

Placefiguresandtablesatthetopandbottomofcolumns.Avoidplacingtheminthemiddleofcolumns.Largefiguresandtablesmayspanacrossbothcolumns.Figurecaptionsshouldbebelowthefigures;tablecaptionsshouldappearabovethetables.Insertfiguresandtablesaftertheyarecitedinthetext.Usethe abbreviation**"Fig.1"** in the text, and "**Figure 1**" atthebeginningofasentence.

Use10**pointTimesNewRoman**forfigurelabels.Usewordsratherthansymbolsorabbreviationswhenwritingfigure-axislabelstoavoidconfusingthereader.Asanexample,writethequantity "Magnetization",or "Magnetization,M",notjust "M".

Table 1 Table Type Styles

Table Head	**TableColumnHead**		
	Tablecolumnsubhead	**Subhead**	**Subhead**
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VI. Acknowledgment

Thepreferredspellingoftheword "acknowledgment" inAmericaiswithoutan "e" afterthe "g".Avoidthestiltedexpression, "Oneofus(R.B.G.)thanks..." Instead,try"R.B.G.thanks".Putapplicablesponsoracknowledgmentshere;DONOTplacethemonthefirstpageofyourpaperorasafootnote.

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