Adaptive Channel Coding to Enhance the Performance in Rayleigh Channel

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***Abstract*—Rayleigh fading channel model is usually used to model real time wireless mobile communication as it has the potential to emulate the multipath scattering effect, dispersion, fading, reflection, refraction and Doppler shift. Mobility and interferences, will change the channel conditions over the time and so will the error environment and results in variable bit error rates (BER). Fixed channel coding schemes have proven in providing reliability of the data despite of poor channel conditions, but fails to contend with time varying channel conditions. Hence they suffer loss in the information rate during good channel conditions. There is need for adaptive scheme that adapts dynamically to channel conditions improving the overall performance and reliability in communication. An adaptive channel coding technique(ACC) is proposed in this paper which requires a simple statistics from the receiver and switches two channel coding schemes dynamically to the changing environment and makes it different from other schemes which deals dynamic tuning of parameters of one Error control coding (ECC) scheme. This strategy not only guarantees reliability but also spectral efficiency as channel capacity is utilized effectively by switching between two ECCs, less robust (high data rate) Convolutional ECC is used when the channel conditions are good and more robust (low data rate) Turbo ECC is used when the channel conditions degraded. Proposed concept is implemented using MATLAB and results outperforms the conventional fixed ECC schemes, an effective reduction of Eb/N0 requirement is obtained for a target BER compared to the fixed or predetermined ECCs. ACC is tested under various mobile channel environment and proven resilient to varying channel conditions. It is beneficial in providing flexibility in QoS by changing the switching criteria according to the application.**

Keywords—Adaptive error control coding; turbo coding; convolutional coding; bit error rate; throughput; Rayleigh channel

I. Introduction

Rayleigh fading channel model is usually used to model real time wireless mobile communication as it has the potential to emulate the multipath scattering effect, dispersion, fading, reflection, refraction and Doppler shift. In addition to these channel conditions, due to the mobility and interferences, the channel conditions will change over the time and so will the error environment and results in variable bit error rates. The deep fades caused by Rayleigh fading results in discontinuous power levels in the received signal. During deep fades burst error occurs and error free gaps in between [7].

A. Problem Statement

The wireless mobile digital interaction is involved in every activity by the people now a days like in commerce, education, banking, entertainment etcetera. The number of control and communication channel can be introduced unlimitedly by using ultra-wideband UWB channels in wireless mobile systems. Error control coding (ECC) schemes have proven in providing reliable data despite of poor channel conditions. Effective utilization of the channel capacity will result in high speed data. ECC schemes add redundant bits to the encoded data in order to provide reliable communication which stands contradictory in utilizing full channel capacity.

Predetermined ECC scheme is relatively efficient in terms of error performance, but fail to contend with time varying channel conditions. Hence they suffer loss in the information rate during good channel conditions.

Hence there is a need for reliable and high speed communication scheme which is robust to these varying wireless mobile channel conditions.

B. Adaptive Schemes in Wireless Communication

In order to encounter the variation in the channel characteristics and provide overall errorless that is reliable and efficient communication in wireless environment, various research approaches has been carried out.

In accordance with channel variation, some of the adaptation techniques include varying 1) Channel coding rates. 2) Decoding techniques 3) Number of decoding iterations in case of LDPC and Turbo codes 4) Polar adaptive codes 5) Coding and modulation combined techniques 6) Channel estimation schemes 7) Modulation schemes 8) Constellation order of the modulation schemes 9) Transmit powers 10) Levels of channel codes 12) repetition coding and puncturing 13) Interpolation method of channel estimation in STBC codes

The key principle lies in the fact that there exist a metric based on which the adaptive threshold is determined and decisions are made. Some of the examples of these metrics, which reflect the channel variations, include channel state information, Estimated SNRs, mutual information index[4], BERs, link error states, perfect previous state information, phase estimation, fading levels, channel matrix, received packet reliability, instantaneous channel gain, pilot signals and so on.

C. Channel Coding Schemes

The Key challenges in the channel coding schemes are encoding and decoding complexities, memory requirement hardware complexities, parallelism and tradeoffs [6] as summarized below. Block codes such as BCH codes performance depends on the code length, larger the length more capable it is. Hence they are proposed to be used in the smart cities. Also it's not consistent in all scenarios. Hamming codes is more suitable for low error rates and shorter lengths of data compared to larger data blocks. It is used in environmental monitoring. Convolutional codes is a stream coder with consistent error patterns, which costs complex decoding algorithm and redundancy. It is generally used in health care monitoring systems. Reed-Solomon code is basically a non-binary encoder known for its effectiveness for burst errors, computational complexity increases as capability increases. It is used in tracking applications. Another major limitation is that it is inefficient for random errors. Turbo codes are high performance codes but has decoding complexities due to iterative decoding and made suitable for high SNRs in LTE, 4G systems and industrial automation. On the other side LDPC requires parameter tuning for optimal performance and its complexity increases with the block length. Polar codes are used in 5G systems which has less complexity in encoding and in specific applications like wearable devices it has excellent performance but not equally optimal in all cases.

D. Adaptive Channel Coding Scheme

There is change in the paradigm, from achieving reliability from predetermined fixed channel codes at the cost of computational complexity, to a simple, less complex and efficient adaptive coding schemes where channel coding computation varies in accordance with the channel conditions adaptively and hence provides a reliable communication as well as efficiency.

E. Proposed Scheme

In our paper, an adaptive channel coding ACC or Adaptive error control coding AECC techniques which is used alternatively in this paper, is introduced where the novelty lies in switching between two different channel coding schemes in accordance with the error conditions of the channel.

This ACC scheme requires a simple statistics from the receiver and adapts to dynamic the changing environment and provide an effective reduction of E_b/N_0 requirement compared to the fixed or predetermined ECCs. In other words its overall performance is improved by achieving trade-offs between capacity and reliability. It shows that the proposed scheme is simple, effective and efficient in reducing overall E_b/N_0 requirement for a target BER by 3dB compared to uncoded and fixed channel coding schemes.

By adaptively switching between a less robust and more robust channel coding schemes result in the increased resilience to the channel variations thereby enhancing the spectral efficiency, error combat, reduced latency and flexibility to the QoS requirements.

F. Organisation of Paper

The rest of the paper is organized this way, the state of art of adaptive channel schemes methods and the research gaps identified in discussed in Section II, followed by channel modelling in Section III which discusses the theoretical implications about Rayleigh channel model and BPSK modulation scheme. A brief summary of the features of Convolutional codes and Turbo codes are discussed in Section IV, their performance are evaluated individually. The proposed system model in explained in the Section V and its implementation details is discussed in Section VI. Finally it is concluded with results which discusses proposed method's advantages and limitations, conclusion and future works in Sections VII and VIII, respectively.

II. State of Art of Adaptive Channel Schemes

There are few researches done on the adaptive channel coding schemes. The authors in [2], [3], [8], [16], proposes a rate adaptive scheme. It adjusts the rate of the channel code (Turbo and RS codes) between each pair of consecutive packets. The protocol responds to dynamic fading and other time-varying propagation losses and BER feedback from the receiver controls the adaptation. However it requires perfect previous state information and channel state information to perform effectively.

The authors in [1], [12], [15] proposes adaptive modulation and coding technique to enhance the energy efficiency of the transmission, it addresses the problem of energy consumption by iterative decoding process and tries to adaptively perform to be based on channel conditions. These techniques and not only achieve reliability but also spectral efficiency as modulation techniques is also been adapting. Results shows 3dB improvement over conventional adaptive methods but requires perfect channel state information, it is an optimization method to existing coding and modulation method that lacks in finding the closed form solutions to solve optimal adaptive Turbo coded modulation schemes.

In [9],[17] an adaptive polar coding for block fading channels are proposed where the bit channels are partially polarized by fading and modulation. Polar codes are constructed by matching code polarization perfectly with modulation polarization and fading polarization hence provide better performance than conventional polar BICM schemes and LDPC codes[22].

Control of adaptation in terms of limiting number of iterations is based on an stop criteria and shows a better performance over fixed number of iteration for Turbo ECCs in indoor wireless environment [10] and in [11] it's based on channel estimation using two estimators on fading amplitudes and accordingly coding rates are adapted. Similarly SNR estimators as proposed in [12],[14] decides the adaption of Turbo code rate and transmit power hence achieve performance within 3 dB of the fading channel capacity.

Most of the research papers estimate the channel condition using various metrics, fix up a threshold condition based on those metrics and decisions are taken at transmitter in adapting different coding schemes based on those values. Most commonly used simple strategy is to simply vary the code rates according to channel feedback.

Channel prediction algorithm, where a finite-state Markov chain model for a Rayleigh fading channel by partitioning the range of the received signal envelope into K intervals is constructed Using this matrix to predict the channel state, adaptive forward error correction (FEC) coding scheme based on this prediction [13]. The major drawback is that it increases the computational complexity.

A. Research Gaps

From the above survey, it is noted that the adaptive algorithms that take the decisions based on the various factors such as channel state information, estimated SNRs, fading coefficients, mutual information etcetera control either coding rates or number of decoding iterations or methods, polarization adaptive codes and so on using any one of the channel coding schemes or even multiple levels channel codes[5],which occupies a constant minimal channel expenses in terms of computational complexity and efficiency. Also very few works in carried on adaptive channel coding for UWB Rayleigh channel using BER information with a combination of channel codes.

In this paper an adaptive channel coding scheme with two channel codes is proposed and based on the BER condition of the channel it is switched adaptively for UWB channels. Various threshold can be set based on the application. It uses a simple, less complex (high data rate) ECC techniques for less erroneous channel (good condition) to utilize the complex channel capacity and when the channel is noisy and erroneous (bad condition) an efficient though complex (low data rate) ECC technique is used to cut down the error hence achieving a reliable communication. Compared to block codes, Convolutional codes are less complex at the decoding side and have better performance at low noise conditions. Turbo codes are known for its efficient combat against burst errors which mainly occurs due to deep fades in the Rayleigh fading. It has a high performance compared to other channel code but block length can be traded off with high SNRs. Hence these ECC schemes are used in our proposed method.

III. Channel Model

A. Rayleigh Fading Model

In mobile radio communication system, severe fading is caused by scattering and multipath phenomenon. Fading is statistically divided into long term and short term fading. Long term fading is caused due to small-scale variations in the topography of the propagation path, whereas short term fading is due to various types of signal scatters' reflectivity which are both stationary and mobile and termed as multipath fading. Multipath fading effects are significant in mobile radio communication as most of the communication takes place at ground level between base station and mobile unit.

In mobile radio communication most of the time mobile unit will be moving with some speed and direction in presence of scatterers along the path which contributes to constantly changing environment which leads to reflection, refraction, scattering, power dissipation. This results in multipath and difference in the arrival of signal and results in signal smearing, termed as delay spread. Let us consider three situations where the multipath fading occurs:

Case1: When mobile unit is stationary also is the scatterers.

The received signal is given by

$$r(t)=y(t-\bar{\tau})\exp(j2\pi f0(t-\bar{\tau})+j\emptyset_0) \quad (1)$$

$$\text{Where } y(t)=a_0[\sum_{i=1}^{N} a_i e^{-j2\pi f_0}\, \Delta\tau_i] \quad (2)$$

a_i is the i^{th} path transmission attenuation factor, a_0 is the constant, $\Delta\tau i$ is the additional path delay.

Case 2: when mobile unit is stationary and scatterers (like neighboring vehicles) are moving.

Then equation (1) changes to

$$r(t)=y(t)e^{j\emptyset_0}e^{j2\pi f_0 t} \quad (3)$$

$$\text{Where } y(t)= [\sum_{i=1}^{N} a_i e^{-j2\pi f_0 \tau_i(t)}] \quad (4)$$

Case 3: When mobile unit is in motion it not only experience multipath fading but also Doppler Effect.

The received signal is expressed as

$$r(t)= a_0 e^{[j(\omega_0 t+\emptyset_0-\beta Vt\cos\theta)]} \quad (5)$$

Where $\beta = 2\pi/\lambda$, λ is the wavelength, additional frequency is contributed which due to motion of the mobile unit which is Doppler frequency is expressed as

$$f_d = f_m \cos\theta \quad (6)$$

Where f_m is the maximum Doppler frequency. The f_d can be positive or negative based on the angle of arrival θ. For simplicity let's assume $\theta = 0$.

The multipath fading is also referred to as velocity-weighted fading as is characterizes the mobile unit as if moving with changing velocity. [18]

B. BPSK BER Performance in Rayleigh Fading

Modulation schemes counter effect the time delay spread and multipath fading in mobile radio communications. The received signal will be corrupted only because of fading if the time delay spread is relatively small compared to signaling bandwidth in mobile radio environment.

The coherent binary AM or BPSK has always shown the best performances over other digital modulation schemes. The BPSK detection process is 3-dB improvement over coherent FSK detection process [18]. But as mobile environment are subjected to rapid fluctuations, carrier phase recovery is challenging.

The error rate of each detection system is increased by slow fading. The signal to noise ratio (γ) is proportional to the square of Rayleigh fading envelope(r).here σ is the variance of the distribution.

$$\gamma = \frac{r^2}{2\sigma_n^2} \quad (7)$$

The theoretical probability of error for BPSK in Rayleigh fading is given by

$$P_b = \frac{1}{2}[1-\sqrt{\frac{\gamma_b}{1+\gamma_b}}] \quad (8)$$

Where γ_b is the average signal to noise ratio per bit. [19]

IV. Channel Codes

The detrimental effects of noise in the channel are tried to minimize by error controlling codes, By knowingly adding the redundancy bits during encoding deceives the random noise and dilutes the effect of random noise [20].

A. Convolutional Codes

Convolutional codes belongs to subclass of tree code, it process stream of input data into smaller sets of data symbols to small sets of codeword which depends on the L previous information frames. L is the size of the shift register to store previous data, called constraint length. It is the code (n_0, K_0) which is linear, time invariant and has finite word length K= (L+1) K_0 where K_0 is the uncoded data length.

The unique property of this code is its reliance(depends on previous input) which gives encoder a finite state machine of $2^{K_0(L-1)}$ states that represents the various possible internal states the encoder can be in, making it to effectively encode information for transmission across noisy channels.

Fig. 1 shows a simple convolutional encoding scheme with n_0=3, K_0=2, L=4 and G is the generator polynomial matrix.

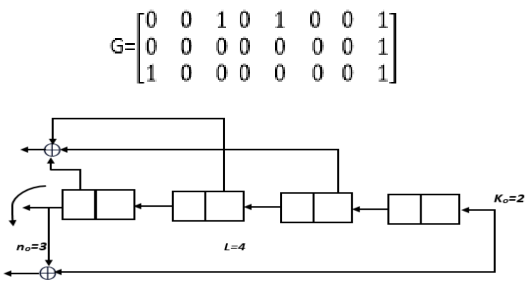

Fig. 1. A convolutional code for n_0=3, K_0=2, L=4 and G is the generator polynomial matrix

Where Coding rate=K_0/n_0, encoding is simply given by

$$c_j(D) = \sum_{l=1}^{K_0} i_l(D).\,g_{l,j}(D) \quad (9)$$

c is the code word, i is the information and g is the generator polynomial also referred as transfer function.

The information frames are encoded into codeword frames of length n_0, the current information frame and previous m information frames is used to obtain the codeword frame, this calls for memory requirement which can retain previous m information frames. This is accomplished by shift registers as shown in the Fig. 1.

Viterbi algorithm is used to decode the encoded convolutional code data because of its ease in implementation, low cost, high speed of operation and high BER performance. Biggest advantage is its fixed decoding time but limited by L. It requires calculations of syndrome polynomial vector. Hard-decision decoding is used where in the Hamming distance is the metric.

$$s(D) = v(D)H(D)^T. \quad (10)$$

H is the parity matrix (n_0-K_0) x n_0 matrix which satisfies G (D) H (D) ^{T}=0, s is the syndrome polynomial.

Crossover probability of the channel and length of the message decides the number of errors in Hard decoding.

B. Turbo Codes

A quasi mix of block codes and convolutional codes are Turbo codes. Turbo code outperforms to convolutional and polar on fading impact, also the other methods when larger length of block used perform close to one another [3]. They require whole block be present stating the encoding process.

Turbo encoder: A typical Turbo encoder is as shown in the Fig. 2, they consist two parallel concatenated convolutional encoders (PCCC) .An Interleaver performs changes in the order of input symbols. If I_k is the input sequence with I= [i_1,i_2, i_3,…i_k], then I.P is the permuted sequence where P is the permutation matrix with single ones in each row and column ,zeroes in other entries. Interleaver^{-1} restores original data by simply transposing the Interleaver matrix P^T. Turbo coders produce high weight code words, suppose I_K is lightweight code and X_k and Y_K^1 may produce low weight code but Y_K^2 will have less probability to have light weight as it follows Interleaver and hence produces a high weight code.

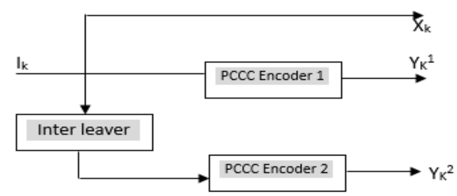

Fig. 2. Turbo encoder

Turbo Decoder: determines the actual performance of the code. Fig. 3 shows block diagram of a typical turbo decoder which generally uses MAP (maximum a posteriori) algorithm. After partial output from the channel X_K and Y_K^1, and passing it to the decoder1 the decoding process begins, Y_K^2 goes to Decoder2 and waits. Decoder1 makes an estimate of the transmitted data, and to match the Y_K^2 and sends it to Decoder2. Decoder2 takes both data from decoder1 and channel and estimates the data. Second process is looped back to decoder 1 where process starts again. It repeats until certain conditions are met, let's say number of iterations and hence the name iterative Turbo decoder.

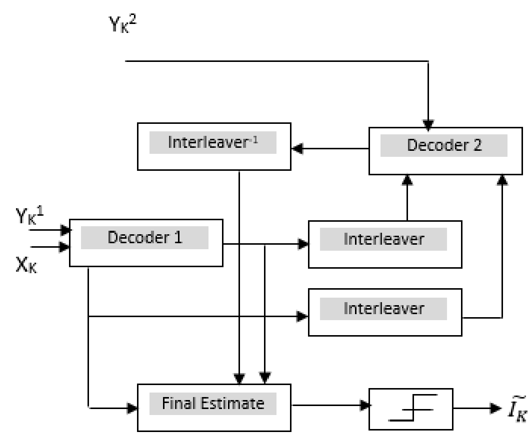

Fig. 3. Turbo decoder

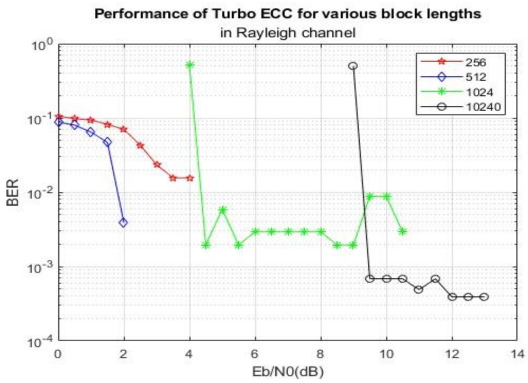

Fig. 4. Performance of Turbo codes under various data sizes for a fixed data rate and code rate

Fig. 4 and 5 shows the performance of Turbo codes and convolutional codes under various data sizes for a fixed data rate and code rate. Turbo codes no doubt has an excellent error performance compared at shorter block length compared to convolutional codes but requires minimum Eb/N0 for larger block lengths to perform well. On the contrary convolutional coding maintains moderate error performance irrespective of block lengths, in addition to this, it is a light weight less robust error control coding scheme which can achieves better throughputs under good channel conditions.

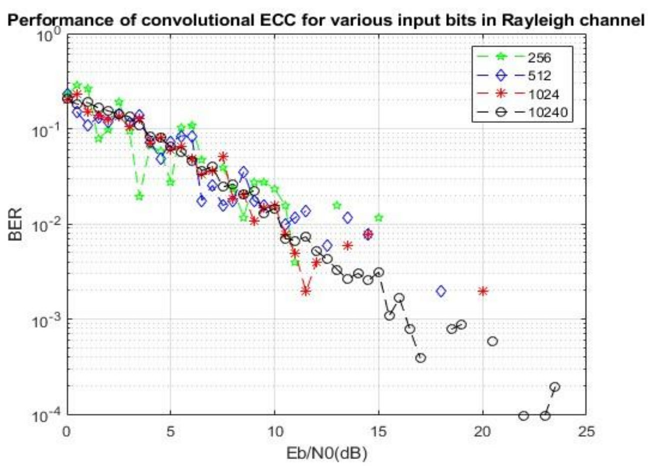

Fig. 5. Performance of Convolutional codes under various data sizes for a fixed data rate and code rate

TABLE. I. COMPARISON OF EXECUTION TIMES OF TURBO ECC AND CONVOLUTIONAL ECC FOR VARIOUS BLOCK LENGTHS

Data Size(bits)	TURBO execution time(s)	CONVOLUTION execution time(s)
1024	3.89846	0.124103
10240	20.536169	1.334816
512	2.827844	0.070872
256	3.305763	0.038528

Table I compares the execution times of various block lengths under Turbo and Convolutional ECC schemes and shows that convolutional ECC is indeed light weight Scheme.

V. PROPOSED SYSTEM MODEL

An adaptive channel coding system based on the feedback from the receiver about the error level of the channel is proposed. Threshold is applied to this based on the behavior of the error control codes at different BER and their corresponding minimum E_bN_0 requirements and can be adjusted based on QoS requirements. So that if the BER value crosses the threshold corresponding ECC will take over hence effectively reducing the SNR requirement compared to individual performance of the ECC codes.

Fig. 6 shows the process flow of the proposed method where in the BER is compared to a threshold value before forwarding the input data to the any of the ECCs. As Turbo Encoders is known for its resilience for the burst errors it is used when the channel is nosier due to the burst errors otherwise a simple Convolutional code which has a simple decoding mechanism compared to other linear ECCs is used in order to increase channel capacity [21]. Execution times of Turbo ECC and Convolutional ECC as it shows Convolutional codes are light weight codes and requires less execution time.

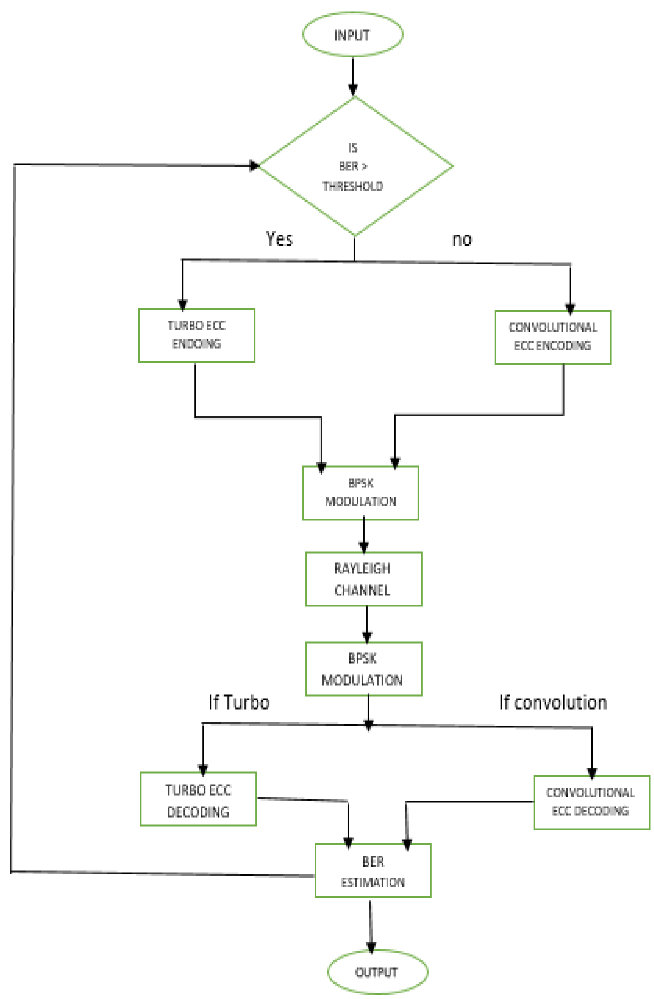

Fig. 6. Process flow of proposed system model of Adaptive Channel Coding scheme

VI. Implementation

Proposed model is as shown in Fig. 7. It is implemented using MATLAB with communication system toolbox. A binary input x with N block size is passed through a Turbo decoder which is the default ECC scheme. For Turbo encoder, a simple trellis is chosen structure is set as (4, [13 15 17], 13), similarly Convolutional encoder with k_0= 2, n_0 = 3, and L = 4 is chosen. Interleaver indices Randperm [N, N] is used as it shows better performance than $[N:-1:1]^{-1}$.

The output of the encoder is subjected to a BPSK signaling to represent coded bits to complex data. This is passed through a channel which is a SISO fading channel with no LOS that is a Rayleigh channel object with Doppler frequency of 0.1Hz (default), as we consider flat fading, there are no multipath, Gaussian Doppler spectrum is chosen.

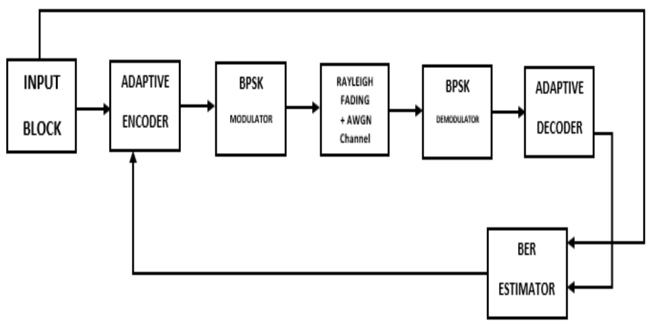

Fig. 7. Proposed system model

AWGN channel noise is added along to add up noise effects along with the fading effects given by the Rayleigh channel, the power level is kept at unity.

$$Rr = h\_doppler.*x + \alpha.*n \quad (11)$$

$$h\_doppler = h.*fd\_ts \quad (12)$$

Where Rr is the channel output, fd_ts is the time varying Doppler frequency, h is the Rayleigh fading envelop which is multiplied with Doppler frequency to give impulse response of overall Rayleigh fading channel. n is the noise weighted by its variance α which is in turn dependent on channel's SNR.

The channel output is subjected to equalizer to get the output r

$$r = rr./h\_doppler \quad (13)$$

At the receiver, we have chosen a turbo decoder with 'TRUE APP' algorithm with 8 optimum number of iterations and Viterbi decoder as a decoder for Convolutional encoder with Hard decision method.

For every N number of input bits, data is encoded, modulated and transmitted, BER is estimated at the receiver and fed back to the transmitter which checks for the threshold condition for switching and switches ECC schemes accordingly for the next N bits based on threshold conditions. The threshold is fixed as 0.001 for an optimal performance to the target BER of 10^{-4} for audio applications.

VII. Results

A. *Experiment 1:BER Estimation of ACC Scheme along with the other Fixed ECC Schemes*

A complete communication model with BPSK modulation through flat slow fading Rayleigh and AWGN channel was simulated in MATLAB for various ECC schemes that is for Convolutional, Turbo, and proposed Adaptive channel coding schemes and also without an ECC scheme for a block size of 256 bits. Monte Carlo simulation was carried out for various values of E_b/N_0 dB for a target BER of 10^{-4}.

Audio/speech does not need very strict constraints on BER. With fairly poor BER speech can still be acceptable. For this reason one can use the Adaptive coding scheme to guarantee a certain throughput level for the transmission of speech [15].

The results obtained are as summarized below in Table II.

TABLE. II. Simulation Results and Parameters

Parameters	ACC	CONV CC	TURBO CC	Uncoded
Input block length	256	256	256	256
Code rate	1/5-2/3	2/3	1/5	NA
Data rate	10Mbps	10Mbps	10Mbps	10Mbps
EbNo at 1dB	2.46E-03	1.21E-03	8.20E-04	1.25E-01
EbNo at 3 dB	1.13E-03	1.33E-03	3.13E-04	1.05E-01
EbNo at 5 dB	1.17E-04	5.86E-04	1.17E-04	9.77E-02
EbNo at 7 dB	0	2.34E-04	0	5.47E-02
EbNo at 9 dB	0	7.81E-05	0	3.91E-02

Table II summarizes the BER performances of various schemes as tabulated above. It is inferred that there is a significant reduction in the E_b/N_0 requirement or in other words minimum requirement to achieve desired target BER for about 3 dB by the Adaptive CC schemes as compared to the individual ECC schemes. Even though Turbo is capable of achieving target in much lesser E_b/N_0 value but there is a trade off in execution time and also at higher data size turbo require minimum E_b/N_0 to perform efficiently [7].

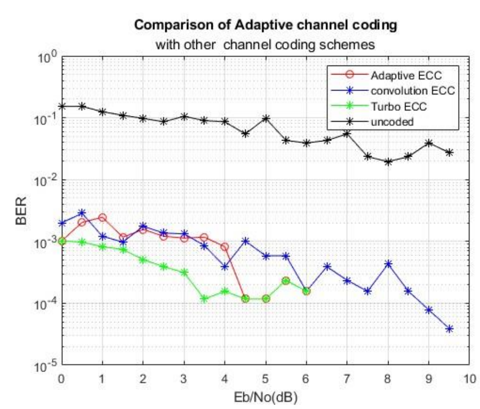

Fig. 8. Performance of proposed Adaptive ECC, No ECC and default fixed ECC

The BER vs. E_b/N_0 performance of proposed Adaptive ECC, No ECC and default fixed encoder is as shown in the Fig. 8.

It is seen that minimum Eb/N_0 value required to achieve target BER of 10^{-4} is reduced for 3dB when Adaptive scheme is used compared with fixed rate ECC.

From Table III The transmitting power requirement with P_r α $(1/d^2)$ is interpreted, example if a device like mobile uses turbo decoding scheme, its battery life will be 13% longer than uncoded device. Similarly using our Adaptive ECC scheme the battery life from 12% can be longer compared to uncoded devices. Hence shows ACC as energy efficient.

TABLE. III. COMPARISON OF TRANSMITTING POWER REQUIREMENT OF NO ECC, CONVOLUTIONAL ECC, TURBO ECC AND ADAPTIVE ECC SCHEMES

Target 10-4 BER(0.000684) N=256	Eb/No dB	Transmitting power requirement for same distance
No ECC	25	1
convolutional ECC	7.5	1/209
Turbo ECC	3.5	1/7.2
Adaptive ECC	4.5	1/6.6 to 1/524

B. *Experiment 2:Throughput Estimation for ACC and Uncoded Schemes*

The throughput performance of uncoded scheme along with fixed and adaptive ECC is plotted as shown in the figure using the formula

$$TP= (1-BER)*Data\ Rate \quad (14)$$

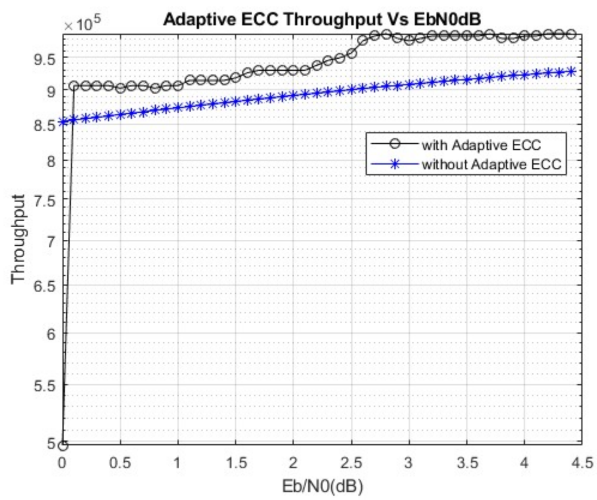

Fig. 9. Throughput performance of uncoded scheme along with fixed and adaptive ECC

From Fig. 9, it is seen that the Adaptive ECC shows overall improvement in throughput compared to fixed ECC schemes. It is inferred that channel capacity is efficiently utilized by ACC scheme and hence the overall capacity of the network is enhanced as more users can be accommodated in the same frequency spectrum.

C. *Experiment 3: Study of Mobility Effect in Channel on the Adaptive Channel Coding*

We study the performance of both ECCs in the mobile communication scenario where Doppler Effect is also taken into consideration. We consider three scenarios where the effective Doppler frequency is estimated using equation (6) for a mobile channel which is stationary (0mph), pedestrian velocity (3mph) and vehicles velocity in a freeway (60mph) assuming carrier frequency to be 900MHz.

The performance of ACC, Turbo codes and Convolutional codes under these conditions are evaluated and is as shown in the Fig. 10.

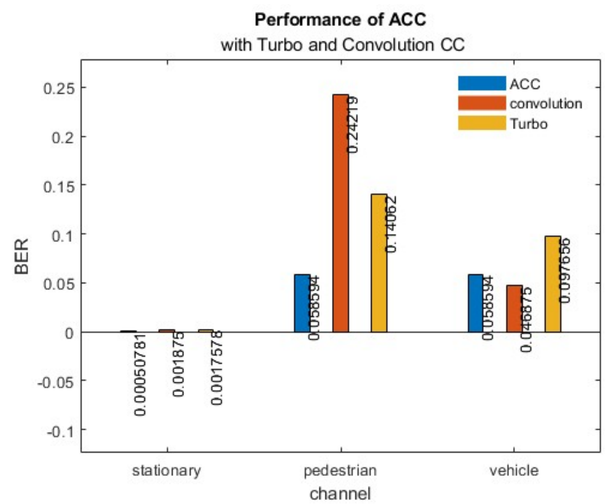

Fig. 10. Performance of ACC for various mobile environment compared to fixed schemes

All ECCs are simulated under various Doppler frequencies for an input block size of 256 at a fixed E_b/N_0 of 1.5dB. It is seen that the Turbo coders are more sensitive to Doppler frequency, even slightest change in the frequency results in more severe the effect of fading on the turbo decoding performance [16]. Even through E_b/N_0 requirement is higher in convolutional codes it fluctuates less significantly compared to Turbo coder.

ACC outperform both of these methods and results relatively better than Turbo and Convolution encoders.

VIII. CONCLUSION AND FUTURE WORK

A. *Consolidated Implications of the Proposed Work*

1) *Advantages*

a) Energy Efficiency: At BER 10-4, comparing the difference between Eb/N0, at different ECC schemes with different coding rates, the transmitting power requirement with Pr α (1/d2) is interpreted, example if a device like mobile uses turbo decoding scheme, its battery life will be 13% longer than uncoded device. Similarly using our Adaptive ECC scheme the battery life from 12% can be longer compared to uncoded devices. Hence shows ACC as energy efficient.

b) Bandwidth Efficiency: There is a significant increase in the throughput by ACC scheme indicating efficient utilization channel capacity so that more number of users can be accommodated resulting in bandwidth efficiency.

c) Resilence to Channel Variations: It is seen that ACC scheme outperforms other fixed schemes for various mobile channel environment. This indicates the coding scheme's resilience against channel variations.

d) Flexibility in QoS: As we have the freedom to change the switching threshold conditions to balance tradeoffs, this scheme offers flexibility in tuning the parameters according to the application satisfying QoS requirement.

2) Limitations

a) Implementing ACC scheme requires additional algorithms thereby increasing the complexity .

b) It adds additional computational overhead.

c) Prediction errors, feedback errors may result in decrease in efficiency.

d) Standardization for wide networks is a problem , so is the scalability ands security issues.

e) It may also result in fluctuations in throughput and QoS.

B. Future Scope

The proposed work can be further extended for various ECCs and various mobile channel environments. An extensive study can be made on Turbo decoders for higher block sizes as good decoding depends on the ability of the decoder. This work can be extended to security [23], vehicular communication and satellite communication. Further this work can be extended for security enhancement of the systems, AI and machine learning concepts can be applied to effectively realize the functionality. It can be realized for distributed networks as well.

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