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Error Correction Channel Coding Practices for Wireless Communication Systems - A review

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Abstract: The amalgamation of low-bit-rate data coders into incipient land and satellite mobile communication arrangements presents glitches which aforementioned communication systems have certainly not encountered. One of the utmost important of these complications is the degradation knowledgeable in data quality as a consequence of corruption of the transmitted data information by channel errors. The ambitions of error control mechanisms are to afford and protect the data from errors caused by packet loss due to congestion and link failure. The error control classified into two sorts: Error correction coding and Error detection coding. Error control mechanisms for wireless applications can be classified into four types: forward error correction (FEC), retransmission, error resilience, and error concealment. In this review paper, we provide a survey on the prevailing error control mechanisms, representative error mechanisms systems. We pronounce the encounters and solutions of each error control mechanisms. To end with, we demonstrate the Aspectsupshot in the data quality through transmission over wireless systems.

Keywords: Forward error correction, Channel Coding, Wireless communication, Block codes, convolutional codes, turbo code, reed-Solomon codes, BCH codes, RSC codes, Multiple Antenna System.

I. INTRODUCTION

When transferring or storing information there is always a risk of errors occurring in the process. To increase the possibility of detecting and possibly correcting such errors, one can add a certain redundancyto the text carrying the information, for example, in form of control digits. We shall now give two simple examples.

Example 1.1. *Assume that a sender transmits a text which is divided into a number of six digit binary words. Each such word consists of six digits which each is either 0 or 1. To increase the possibility for a receiver to detect possible errors that might have occurred during the transfer, to each word the sender can add the seventh binary digit in such a way that in each seven digit word there always is an even number of ones. If the receiver registers a word with an odd number of ones, then he will know that an error has occurred and can possibly ask the sender to repeat the message.*

Example 1.2. *If the receiver in Example 1.1 does not have the opportunity to ask for a repetition, the sender can proceed in a different way. Instead of adding the seventh digit he can send every six digit word three times in a row. If the three words are not identical when they reach the receiver, he will know that an error has occurred and could try to correct it at each place by choosing a digit that occurs at the corresponding places in at least two of the received words. He can of course not be completely sure that the erroneous word has been corrected, but if the probability for more than one error to occur is low, then the chances are good.*

One disadvantage of the method in Example 1.2 is that, compared with the original text, the message with the error-correcting mechanism takes three times as long to send. Hence it seems a worthwhile exercise to find more effective methods and this is the purpose of the theory of error-correcting codes. This was started off by the work of Shannon, Golay and Hamming at the end of the 1940s and has since evolved rapidly using ever more sophisticated mathematical methods. Here the theory of finite fields plays a particularly important role.

For writing a text we must have an alphabet. This is a finite set F of symbols called letters. As is common in coding theory, we assume that F is a finite field. When F = Z2, as in the above examples, the code is said to be binary. A word is a finite sequence $x_1 x_2 \ldots x_m$ of letters. We shall here only deal with so called block codes. This means that the words are all of the same length m and can therefore be seen as elements in the vector space F^m . When appropriate, we write the words as vectors x = $(x_1, \ldots , x_m)$ in F^m.

$$E : F^m \rightarrow F^n$$

A coding function E is an injective map from F^m into a vector space F^n of higher dimension i.e. m < n. The image C = E(K^m) is what we call a code. To improve the possibility for detecting and correcting errors, it is useful that the elements of the code C lie far apart from each other in F^n. This to minimize the probability that a sent code word is received erroneously as a different code word.

A. Classical Error Correcting Codes

The coding theory is application of the information theory critical for the reliable communication & thefault-tolerant information storage & processing; definitely, Shannon

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channel coding theorem tells us that we can transmit information on a noisy channel with arbitrarily low probability of error. The code is designed based on well-defined set of the specifications & *protects information only for type & number of the errors prescribed in its design.* A good code:

- Adds a minimum amount of redundancy to the original message.
- Efficient encoding and decoding schemes for the code exist; this means that information is easily mapped to and extracted from a code word.

Reliable communication and fault-tolerant computing are intimately related to each other; the concept of the communication channel, an abstraction for physical system used to transmit theinfo from one place to another place and/or from 1 time to another is at core of the communication, as well as, the information storage & processing.

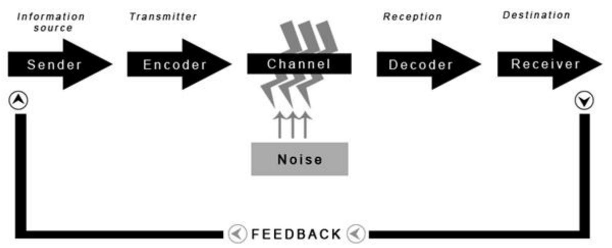


Figure 1.A system model for wireless communication system consist of an encoder and decoder for error correction for noisy communication channel.

It should though be clear that existence of the error-correcting codes doesn't guarantee that the logic operations can be implemented using the noisy gates & circuits. Strategies to build the reliable computing systems using the unreliable components are based on the John von Neumann's studies of the error detection & theerror correction techniques for the information storage & processing.

II. TYPE OF TRADITIONAL ERROR CORRECTION CODES

There are two types of code: block code and convolutional code. Block codes do not depend on previous messages while convolutional codes do.

A. Block Codes

A block code of size k over a finite alphabet with q symbols {0, 1, 2, _, q-1} is a set of k q-ary sequences of length n called code words.A message $u = (u0, u1, u2, \ldots, uk-1)$,and code word $v = (v0, v1, v2, \ldots., vn-1)$

$$v1\infty n = u1\infty k \infty Gk\infty n$$

Where, $ui, vi \in GF(q)$and $v \in GF(q)$, n and v does not depend on past u, memoryless.

There are q^k possible code words of length n, they are called q-ery (n, k) block code.The Code rate is defined as R = k/n.

Example: Binary (7, 4) linear block code

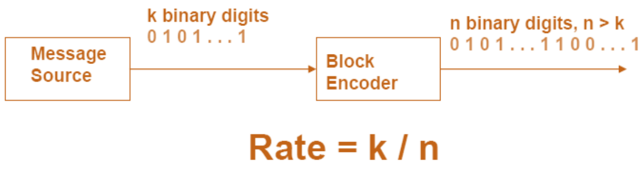
TABLE 1. A Binary (7, 4) linear block code

Messages	*Code Words*
(0000)	(0000000)
(1000)	(1101000)
(0101)	(0110101)
(1100)	(1011100)
(0010)	(1110010)
(1010)	(0011010)
(0110)	(1000110)
(1110)	(0101110)
(0001)	(1010001)
(1001)	(0111001)
(0101)	(1100101)
(1101)	(0001101)
(0011)	(0100011)
(1011)	(1001011)
(0111)	(0010111)
(1111)	(1111111)

The generator matrix $Gk\infty n$ is given by

$$G_{4\infty 7} = \begin{bmatrix} g_0 \\ g_1 \\ g_2 \\ g_3 \end{bmatrix} = \begin{bmatrix} 1101000 \\ 0110100 \\ 1110010 \\ 1010001 \end{bmatrix}$$

Where, g_0,g_1,g_2,g_3 are 4 (=k) linearly independent code words.



B. Convolutional Codes

Message$ui = (ui0, ui1, ui2, \ldots, ui(k-1))$,
code word $vi = (vi0, vi1, v2i, \ldots., vi(n-1))$

$$vi = f\ (ui, ui-1, ui-2, \ldots\ldots, ui-m)$$

v depends on current and last m message units -- memory order of m, sequential logic (n, k, m) convolutional code

$$Code\ rate\ R = k/n$$

Hard decision: the output of demodulator is quantized

Soft decision: the output of demodulator is left unquantized, decoder accepts multilevel or analog inputs, and soft-decision decoding offers significant performance improvement over hard-decision decoding.

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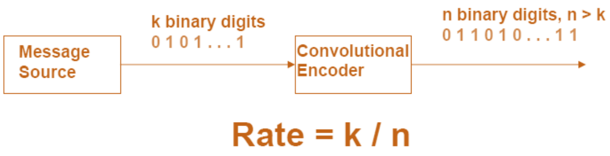

Typical Details about Codes

1)Block Codes:
– Example: (7, 4) Hamming Codes
– General Theory of Binary Group Codes
– Low Density Parity Check (LDPC) Codes
– Reed Solomon (RS) Codes

2)Convolutional Codes & Viterbi Decoding
– Example: Rate ½ 4 State Code
– General Description of Convolutional Codes
– Punctured Codes
– Decoding and the Viterbi Algorithm
– Turbo codes

III. REVIEW OF LITERATURE FOR VARIOUS EFFICIENT CHANNEL CODING SCHEMES

A. Hamming Code

In 1947 R. W. Hamming proposed thesis in which author declared that if a message **M** with the **m** bits is to be transmitted, then, code **C** with **c** bits must be created. Length of **M** is associated to that of **C** with following equation:

$$c = m + p \leq 2^{p} - 1 \quad \ldots..(1)$$

Where **p** is no. of the redundant bits, also called theparity bits [1]. Without the loss of generality, if we take **m** to be equal to **4**, then solving the equation 1 will result in **p** &**c** equal to **3**&**7** respectively.

Hamming code is computed using either **even**/**odd** parity. Table 2 displays binary representation of first 7 non-zero decimal digits. Here, first row shows the decimal digits 3, 5, 6 & 7 as subscripts of the column headers for 3rd, 5th, 6th, & 7th columns from right separately. There are no column headers for first, second & fourth columns from right simply because there are not required at this point. Rows 2 through 4 give corresponding the binary representations of these subscripts. Row headers $\boldsymbol{P_1}$, $\boldsymbol{P_2}$&$\boldsymbol{P_4}$ are the 3 parity bits representing Hamming parity **P**.

TABLE 2. Relationship between parity & message bits

Code / Parity	M_7	M_6	M_5		M_3		
P_1	1	0	1	0	1	0	1
P_2	1	1	0	0	1	1	0
P_4	1	1	1	1	0	0	0

We will assume that parity bits are interleaved with bits of message **M**. To compute parity bits, Hamming used respective row for each. Values for $\boldsymbol{P_1}$, $\boldsymbol{P_2}$&$\boldsymbol{P_4}$ are given by following equations where symbol **@** represents ***exclusive or*** operation:

$$\boldsymbol{P_1}=\boldsymbol{M_7}@\boldsymbol{M_5}@\boldsymbol{M_3}@\ \boldsymbol{P_1}\ldots..(2)$$

$$\boldsymbol{P_2}=\boldsymbol{M_7}@\boldsymbol{M_6}@\boldsymbol{M_3}@\ \boldsymbol{P_2}\ldots..(3)$$

$$\boldsymbol{P_4}=\boldsymbol{M_7}@\boldsymbol{M_6}@\boldsymbol{M_5}@\ \boldsymbol{P_4}\ldots..(4)$$

Observe that message bits used for computing the parity bit are column headers of nonzero entries on row represented by that parity bit. If column is without header, it represents the parity bit that is associated with column number. In figure, columns 1, 2, & 4 are without headers, therefore they represent parity bits $\boldsymbol{P_1}$, $\boldsymbol{P_2}$ and $\boldsymbol{P_4}$. Assume initial value of the 0 for each parity bit to permit evaluation of these equations. Obviously, building typical circuit to produce these parity bits would need**9** dual input ***exclusive or*** gates. In next section we will introduce the optimization of Hamming code.

B. Low-Density Parity-Check Codes

Low-density parity-check codes, introduced by Gallager in 1962 [2], have been the subject of much recent experimentation and analysis (e.g., [3-9]). The interest in these codes stems from their near Shannon limit performance, their simple descriptions and implementations, and their amenability to rigorous theoretical analysis [2], [16]–[19], [5], [7-11]. Moreover, there are connections between these codes and turbo codes, introduced by Berrou, Glavieux, and Thitimajshima [12], as the latter can be described in the framework of low-density parity-check codes (see, e.g., [13]). Moreover, the turbo decoding algorithm can be understood as a belief propagation based algorithm [14], [15], and hence any understanding of belief propagation on low-density parity-check codes may be applicable to turbo codes as well.

$Malema, G., et. al,$[20] “Programmable low-density parity-check decoder”, this paper presents programmable semi-parallel architecture for the low-density parity-check (LDPC) codes. The communication conflicts are evaded by the edge colouring code graph & grouping of edges or physical connections by color. Architecture model is easily scalable & programmable for the larger block sizes. Though communication hardware cost is high, model can be easily reconfigured to decrease hardware cost at expense of the flexibility in the code design & the decoding performance. Hardware cost, latency, the code flexibility & the code performance trade-offs can be various over the wide range to suit wide range of the applications.

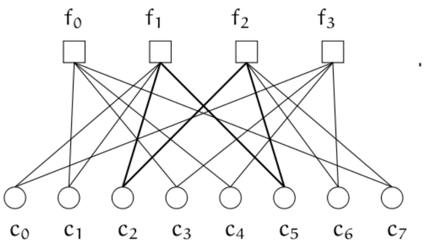

Figure 2. This is a popular way of graphically representing an (n, k) LDPC code. The bits of a valid message, when placed on the T's at the top of the graph, satisfy the graphical constraints.

The simple execution control & mapping are other benefits of this model.Behavioural VHDL implementation was developed to confirm functionality of

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architecture.*Yongsoo Hwang*, [21] "On decoding of the non-binary quantum low-density parity check codes", this paper discusses decoding of the non-binary quantum low-density parity check code with the considerations about degeneracy problem in the quantum coding theory.

C. Reed-Solomon codes

We are describing RS coding schemes based on certain applications to handle the digital data as follow:

i. The Digital Audio Disc

It can securely be claimed that the Reed-Solomon codes are most frequently used the digital error control codes in the world. This claim the common condition in present that digital audio disc or the compact disc uses the Reed-Solomon codes for the error correction & the error concealment. Special properties of the Reed-Solomon (RS) codes make sound quality of compact disc as impressive as it is (i.e. signal-to-noise ratio at output exceeds 90 dB). Compact disc system uses pair of cross-interleaved Reed- Solomon codes. However, when Convolutional and Reed-Solomon codes are used in concatenated systems, acceptable coding gains are achievable. A Convolutional code is used as internal code, while a Reed-Solomon code is used to correct errors at the output of the Convolutional (Viterbi) decoder. The most famous application of the concatenated Reed-Solomon system was in Voyager expeditions to the Uranus & to Neptune.

ii. Error Control coding for the Systems with Feedback

Wicker & Bartz examine numerous means for using the Reed-Solomon codes in the applications that permit transmission of info from receiver back to the transmitter. Such applications include mobile data transmission systems and high- reliability military communication systems.

iii. Spread-Spectrum Systems

Reed-Solomon codes can be used in the design of the hopping sequences in spectrum. If these sequences are selected carefully, the interference by unintended users in a multiple access environment can be reduced to great amount.

iv. Satellite Broadcasting or Digital Video Broadcasting (DVB)

Demand for the satellite transponder bandwidth continues to grow, especially in the area of television and IP traffic. Transponder availability and bandwidth constraints have put limits on this growth, because the transponder capacity is determined by selected modulation scheme & the Forward Error Correction (FEC) rate. The BPSK coupled with the traditional Reed Solomon & the Viterbi codes have been used for closely 20 years for delivery of the digital satellite TV.

Construction of Reed-Solomon Codes and Algebraic-Geometric Codes:

Reed-Solomon codes were introduced in the 1960s by Reed and Solomon [22]. They are non-binary block codes constructed from a generator polynomial defined over a finite field [23]. Reed-Solomon codes are widely used in wireless communication and storage systems and are still considered to be one of the most powerful error correctioncodes

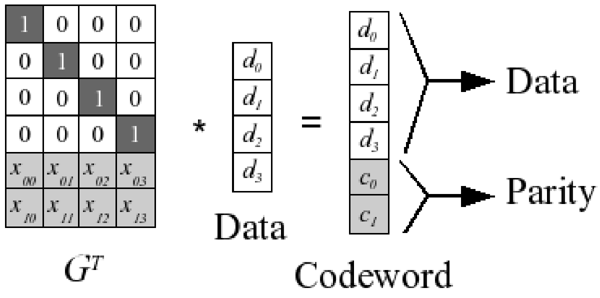

Figure 3. Shows Reed-Solomon coding for k=4 and m=2. Each element is a number between 0 and 2w-1.

Goppa [24] Introduced algebraic-geometric codes in the 1980s. Algebraic-geometric codes are constructed from an algebraic curve defined over a finite field. In fact, Reed-Solomon codes can be considered as a special case of algebraic-geometric codes constructed from a straight line. The Gilbert-Varshamov bound [25, 23] defines a lower bound for a code's code rate r= k/n and its relative minimum distance rate κ = d/n, where k, n and d are positive integers, and they are the dimension, length and minimum distance of the code respectively. Any code with parameters meeting this bound is said to be asymptotically good. Tsfasman, Vladut and Zink [26] presented method to construct asymptotically good algebraic-geometric codes from modular curves that exceed the Gilbert-Varshamov bound.

Justesen et al [27] presented a construction method for a class of algebraic-geometric codes which require simple algebraic geometry knowledge. FengType equation here. and Rao [28] later also presented simple method for construction of the algebraic-geometric codes from an affine plane curve. Following on, Xing et al [29] presented two constructions of linear codes from a local expansion of functions at a fixed rational point. They showed that their constructed codes have the same bound on their parameters as Goppa's geometry codes. Additionally, they showed linear codes constructed from the maximal curves can have better parameters than Goppa's geometry codes constructed from maximal curves. *Heegard et al* [30] showed how to construct systematic algebraic-geometric codes based on using the cyclic properties of autoOrphisms of the points on the curve. *Blake et al* [31] reviewed how to construct different algebraic-geometric codes constructed from different classes of curves, such as Klein quartic curve, elliptic curve, hyper elliptic curves and Hermitian curves.

D. Orthogonal Space-Time Block Codes

Receive diversity existed as far back as 1960 [32]. However, receive diversity is not suitable for downlink in mobile communications, hence transmit diversity has attracted attention. Alamouti presented basic two transmit diversity scheme [33] and *Tarokh et al.* [34] extended it to general case, called orthogonal space-time block codes (OSTBC). OSTBC have full diversity ($n_T \times n_R$), but have

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little or no coding gain. To provide both diversity and coding gain, one can choose a space-time code that has an in-built channel coding mechanism, for example space-time trellis codes, or one can choose a space-time block code concatenated with an outer channel code. Borran et al. [35] discuss design issues of concatenating channel codes with OSTBC. They show that design issues in maximizing diversity gain, and maximizing coding gain can be decoupled. Due to this simplicity, this structure has been established, for e.g. in WCDMA standard.

Gong and Ben Letaief [36] discuss design of concatenated trellis coded modulation (TCM) and OSTBC, and also show that this scheme outperformsspace-time trellis codes with the same spectral efficiency, trellis complexity and signalconstellation. Bauch and Hagenauer [37] give a new view of OSTBC over fading channel as an equivalent SISO channel. Using this equivalent channel model, they give the analytical evaluation of the error probability, without considering effect of the block fading (i.e. which is typically supposed for linear decoding of STBC). *Uysal & Georghiades* [38] give the error bounds for the MTCM-STBC under the Rician Fading. However, interleaving does not appear in their analysis. *Schulze* [39] gives the union bounds for the channel codes &Alamouti signalling for temporally correlated and i.i.d. channel. But again, the block fading assumption is absent in his analysis. None of the above mentioned works discuss spatially the correlated fading. *Lai & Mandyam* [40] simulate the concatenated convolutional or the turbo codes with 2 temporally & spatially correlated antennas in the framework of WCDMA, but do not provide any analysis.

Another class of space-time codes is trellis based space-time codes (e.g. spacetime trellis codes [41], super-orthogonal space-time trellis codes [42] etc.). These codes incorporate coding and diversity into a single design. Much of the analysis of these systems concentrates on uncorrelated antennas, e.g., the analysis of spacetimecodes in i.i.d. fading in [43] and the analysis of super-orthogonal codes in [44]. In a few isolated cases, attempts have been made to explore the performance of MIMO systems when antennas are correlated.

Damen, Abdi and Kaveh [45] study, via simulations, effect of the parameters like angle spread &the Rician factor on performance of numerous space-time signalling & the detection schemes. Bolcski &Paulraj [46] concentrate on quasi-static channel & find the Cherno bounds that in high-SNR regime link diversity to rank & eigenvalues of correlation matrices. Their analysis yields expressions that are corresponding to, but different from, ones we provide in this work in special case of the quasi-static channel. They also calculate degradation of the average pairwise error probability due to the antenna correlation. Uysal & Georghiades [47] derive the pairwise error probability expressions for the transmit antenna correlation (i.e. with no receive correlation or the temporal correlation).

E. Puncture codes
Coding validity. No evidence on the validity is available from the CSP studies. Study of the laparoscopic cholecystectomy found that 95% of the patients with an ICD-9 code of an accidental puncture or the laceration had a confirmed injury to bile duct or the gallbladder. [48]Though, only 27% hadclinically important injury that essential any intervention; sensitivity of the reporting was not evaluated. Similar study of the cholecystectomies reported that these 2 ICD-9 codes had sensitivity of 40% & the predictive value of 23% in classifyingbile duct injuries. [49] Among the 185 total knee replacement the patients, *Hawker et al.*originate thatsensitivity & predictive value of the codes describing the “miscellaneous mishaps during or as direct result of surgery” (i.e. definition not given) were 86% &55%, separately. [50] Romano et al. recognized 19 of 45 episodes of the accidental puncture, laceration, or therelated procedure using the discharge abstracts of discectomy patients; there was one the false positive. [51]

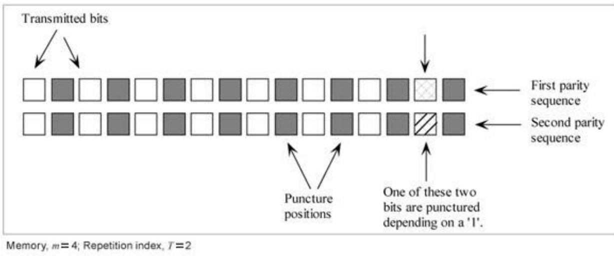

Figure 4. Figure shows the positioning of the puncturing at the transmitter for the dual-repeat-punctured super-orthogonal convolutional turbo codes.

Source: This indicator was originally proposed by Iezzoni et al. as part of Complications Screening Program, although unlike final PSI, its codes were split between 2 CSP indicators (i.e. CSP 27, “technical difficulty with the medical care,” & “sentinel events”). [52] It was also involved as one component of the broader indicator (“adverse events &the iatrogenic complications”) in AHRQ’s original the HCUP Quality Indicators. [53]The University HealthSystem Consortiumaccepted CSP 27 as an indicator for the medical (#2806) and major surgery (#2956) patients. Miller et al. too split this set ofthe ICD-9-CM codes into 2 broader indicators (“miscellaneous misadventures” & “E codes”) in original “AHRQ PSI Algorithms &Groupings.” [54] Based on the expert consensus panels, McKesson Health Solutions included 1 component of this PSI (i.e. Accidental Puncture or the Laceration) in its Care EnhanceResource Management Systems, the Quality Profiler Complications Measures Module.

F. Turbo code
The turbo coding was invented by Berrou & his colleagues in 1993 [55]. Since its introduction & performance it attained, it involved the considerable research. These researches can be separated into 5 areas:

- The turbo code design & the decoding algorithms,
- An interleaver design,

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- The theoretical performance measures of the turbo codes under variety of conditions,
- The applications of turbo coding in communication systems & other fields, &
- The bandwidth-efficient Turbo coding. The research reported in the dissertation falls in last category.

Original turbo code design incorporated two recursive convolutional encoders & the large non-uniform an interleaver [55]. Decoding is done by two units using iterative decoding algorithm; viz., output from one unit is the fed back tofurther unit & vice-versa. *Chang, et al.*, proposed using error range search to decrease the iteration count of an iterative decoding [56]. *Shen, et al.*, studied numerous puncturing schemes as they are practical in the turbo coding to improve on data rates [57]. *A. cikel* & *Ryan*Proposedthe high rates punctured the turbo codes with the applications to binary or quadric-phase the phase shift keying BPSK or QPSK [58]. Their scheme is restricted to the rates of form k/(k + 1), $2 \leq k \leq 16$. Bingemen & Khandani introduced the symbol based turbo codes where input bit stream is parsed into the n−bit symbols & transmitted instead of the transmitting data as binary bits [59]. *Zhu* & *Alajiji* constructed the turbo codes for the non-uniform memoryless sources & showed that these codes outperform the standard codes for such sources [60].

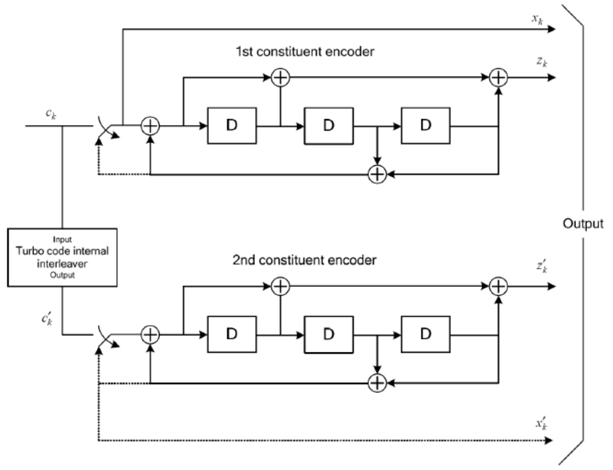

Figure 5. As can be seen in Figure the output of the LTE Turbo encoder consists of three parts, a systematic bit and two parity bits. The systematic bit is the untouched input bit.

While original Turbo codes were based on the convolutional component encoders, there has been study in using the block codes as the components. Pyandiah, et al., proposed using the block codes & the QAM for modulation [61]. They presented performance of their study for the QAM-16 & QAM-64. Noorbakhsh & Mohammed-Pour used the block turbo codes for the equalization in QAM-M [62].

Finally, there are improvements in using the Turbo codes alongside the multiple antenna systems. Indeed the Turbo codes are being used in the Multiple Input & the Multiple Output (MIMO) systems [63–68]. They also have been incorporated in the space & time (ST) processing as combination shows the great promise for achieving the better capacity.

Iterative Decoding of Turbo Codes

The definition of turbo codes was given for the first time in [69]. They represent a particular class of parallel concatenation of two recursive systematic convolutional codes. Here we review a few published studies on the performance of turbo codes for AWGN and fading channels, for continuous or short frame transmission systems using the MAP or the Soft Output Viterbi decoding algorithms.

In [69], the first rate half turbo code with memory order 4, generators (37, 21)8, pseudo–random interleaver matrix of 256 by 256, was investigated for an AWGN channel. Using a modified *Bahl et al.* algorithm [70], a bit error rate of 1.0 x 10–5 at Eb/N0 = 0.7 dB was achieved after 18 iterations. This result is based on counting only 80 errors, which is a very small number from a statistical point of view. A very similar performance is claimed to be achieved using a soft output Viterbi algorithm [71], the complexity of which is approximately twice that of the Viterbi algorithm.

In [72], the bit error rate (BER) and the frame error rate (FER) for short frame transmission (192 bits) over an AWGN channel was investigated. The best pseudo–random interleaver from about 800 tested was selected, and a MAP estimator as in [69] with proper termination of the second code was used. A BER of 1.2 x 10–3 and a FER of 2.5 x 10–2, was achieved at an Eb/N0 = 2.0 dB after 10 iterations. These results are reported to be 1.2 to 1.7 dB better than the performance achieved with a non-systematic convolutional code with the same memory order.

In [73] it was concluded that for BER > 10–3 and large FER of 10–2, the effect of the chosen interleaver on the performance of the corresponding turbo code is almost negligible in the case of short frame transmission (192 bits). However for a slightly larger block size (399 bits) the interleaver type can be optimized to double the performance of the turbo code [74].

The application of turbo codes to a TDMA/CDMA mobile radio system was investigated in [75]. Gains of 0.4 to 1.2 dB over non–systematic convolutional codes can be achieved by using turbo codes for the considered mobile radio system using joint detection with coherent receiver antenna diversity. Bad urban and typical urban models specified by COST 207 [76] were used. The complexity of the decoder is increased because it is necessary to determine the variance of the disturbance, arising due to noise and channel estimation errors, at the input of the decoder.

Shows [77] design & implementation aspects of the parallel turbo-decoders that reach 326.4 Mb/s the LTE peak data-rate using the multiple soft-input soft-output decoders that operate in the parallel.

Shows [78]design of novel turbo codes that can achieve the near-Shannon-limit performance. Design criterion for

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the random interleavers is based on maximizingeffective free distance of turbo code, i.e., the minimum output weight of the codewords due to weight-2 input sequences. An upper bound on effective free distance of turbo code has been derived. Review on the multiple turbo codes (i.e. parallel concatenation of the q convolutional codes), which increase so-called \interleaving gain" as q & interleaver size increase, & the suitable decoder structure derived from approximation to maximum a posteriori probability decision rule has been shown. A novel rate 1/3, 2/3, 3/4, & 4/5 constituent codes have been developed to be used in turbo encoder structure.

Shows[79] the development of an application specific design methodology for the low power solutions. Methodology starts from the high level models which can be used for the software solution & proceeds towards the high performance hardware solutions. Effect on the performance due to variation in the parameters such as frame length, no. of iterations, the type of encoding scheme & type of interleavers.

G. Space-Time Coding (STC)

The Space-Time Coding has been studied from early time & the lots of advanced methods have been proposed for implementing the communication technique for the wireless systems. This section of paper discusses related work that was earlier proposed in the literature for the space-time turbo coding.

Alamouti in [80] proposed simple 2 branch diversity scheme. The diversity created by transmitter utilizes space diversity & either time or the frequency diversity. The space diversity is affected byunnecessarily transmitting over the plurality of antennas, the time diversity is affected by the redundantly transmitting at the different times, & the frequency diversity is affected by the redundantly transmitting at the different frequencies. The scheme makes use of 2 transmitter antennas & one receiver antenna. Even then proposed scheme providessimilar diversity order as the Maximal-Ratio Receiver Combining with onetransmit antenna, & 2 receive antennas. The principles of creation are applicable topreparations with more than 2 antennas, (i.e. similarly it was showed) thatscheme can be generalized to 2 transmit antennas & the M receive antennas, it may offer diversity order of the 2M. The most significant advantage of proposed scheme is that it doesn’t need any bandwidth expansion or any feedback from receiver to transmitter. Additionally,computational complexity of proposed scheme is very much similar to the MRRC.

Tarokh et al. in [81] described the space-time code that is applicable for the high data rate the wireless communications. Usually it is well known that the Space-time coding is bandwidth & the power efficient method of the communication over fading channels that realizes remunerations of the multiple transmit antennas. The precise codes have been constructed using the design criteria consequent for the quasi-static flat Rayleigh or the Rician fading, where the channel state information is accessible at receiver. It is apparent that reasonableness of the space-time codes will be significantly enhanced if derived design criteria continue to be relevant in absence of the perfect channel state info. It is even more desirable that design criteria not be disproportionately sensitive to the frequency selectivity & toDoppler spread.

Performance of the space–time block codes which providednovel standard for the transmission over Rayleigh fading channels using the multiple transmit antennas was recognised by Tarokh et al. in [82]. They consideredthe wireless communication system with ‘n’ antennas at base station & ‘m’ antennas atthe remote. Main purpose of their paper is to approximation performance of space–time block codes created them in the earlier work & to offer details of the encoding & decoding procedures. They supposed that the transmission at base-band employs signal constellation. The maximum likelihood decoding of any space–time block code can be attained using only the linear processing at receiver. Figure 6 shows system block diagram of the space-time coding.

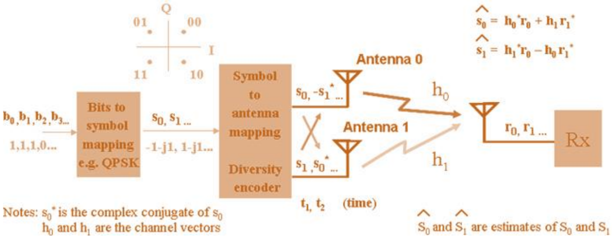

Figure 6. System block diagram of Space time coding Scheme

Sandhu & paulraj in [83] presented Space-time block codes as remarkable modulation scheme discovered recently for multiple antenna wireless channels. They have well-designed mathematical solution for providing the full diversity over coherent, the flat-fading channel. In addition, they necessitate very simple encoding & decoding at transmit antenna & receive antenna respectively. They showed that even though scheme provided the full diversity at the low computational costs scheme incur a loss in its capacity.

Foschini et al. in [84] presented paper that was importantly motivated byessential for the fundamental understanding of the ultimate limits of bandwidth efficient delivery of the higher bit-rates in the digital wireless communications & to also freshman to appearance into how these limits might be advanced. They inspected development of Multi-Element Array technology, which is processing spatial dimension to improve the wireless capacities in certain applications. Completely, they presented the quantity of needed information theory results that guarantee the great advantages of using the MEAs in wireless LANs & building to building the wireless communication links. Case where channel characteristics is not available at transmitter butthe receiver tracks characteristic which is subject to the Rayleigh fading has been explored in the presented paper.

IV. CONCLUSION AND DISCUSSION

In this paper, we have described the error control mechanisms for video application, which can reduce the packet loss in order to provide good data quality. Existing

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error control mechanisms can be classified into four types, namely, forward error correction (FEC), retransmission, error resilience, and error concealment. The first two are in channel coding and the latter two are in source coding.

FEC is to add redundant bits on compressed source bits to enable error detection and correction. Advantage of FEC is its small transmission delay, but the FEC is ineffective if there are more than N-K consecutive packets lost. FEC schemes can be classified into three categories: **a)** Channel coding, **b)** Source coding-based FEC; and **c)** joint source/channel coding.

In the retransmission the receiver notifies the sender which packets were received / lost and the sender re-sends lost packets. Retransmission includes delay-constrained retransmission so it is ineffective for interactive real-time video applications. Error-resilient coding schemes are developed to mitigate the effect of packet losses or to prevent error propagation from compression perspective. The error-resilient composed of resynchronization marking, data partitioning and data recovery. Error resilient source coding may use the optimal mode selection for each packet or multiple description coding (MDC).

Error concealment is a post-processing technique executed only by decoders / receivers. The error concealment mechanism performs some forms of Spatial / temporal interpolation to estimate the lost information from the correctly received data. Any researcher working in the error control mechanisms to provide good efficient transmission with minimum errors has to concentrate in of the following factors source coding, receiver coding and channel (path) to achieve good performance.

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