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Enhancing Reliability of Radio Links in Cognitive Radio Networks

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Abstract

The radio spectrum being an important resource should be used with optimum performance. In Cognitive radio Networks it can be improved by pooling and dynamic allotment of resources. The Radio links performance deteriorates in the wireless channel due to numerous known and unknown disturbances. This problem had been tackled using channel coding techniques of various kind. Proper Channel coding technique can be used in a particular application to make the radio link reliable. This reliability of the radio ink can be further improved by incorporating other coding & decoding techniques, channel processing and nullifying the channel disturbance at receiver and better decoding techniques with advanced algorithms. The reliability of links can be further improved in this case by using higher order modulations as more info is carried within same band width. So the performance of Link reliability model will increase manifold if we use noise cancellation techniques along with these techniques in such model.

Keywords: Cognitive Radio, Networks, Radio spectrum, Link reliability, Coding techniques, Models.

1. Introduction

Cognitive Radio is a license free radio system with capability to manage its resources, processing and parameters owing to its benefit of inbuilt intelligence. The cognitive radio network consists of secondary users only. It allows unlicensed secondary users (SU) to share some of the spectrum allotted to licensed primary user (PU) without interfering them i.e. seeks transmission opportunities in a spectrum when not used by

PU. The cognitive users operate at very low power level to avoid any interference to primary users. But if a PU gets activated in its channel, there is collision of transmissions causing SU data corruption or complete loss. This is referred to as jamming. Various Channel coding techniques have been devised, studied and applied for the recovery of lost packets. The codes yielding complete recovery are termed as powerful anti-jamming codes(2). Cognitive radio has the ability to switch the link among cognitive users to a new channel also. This ability along with anti-jamming codes provides reliability (3) to cognitive user links.

Cognitive Radio system virtually increases the spectrum available by identifying the spectrum holes and arranging them in pools.

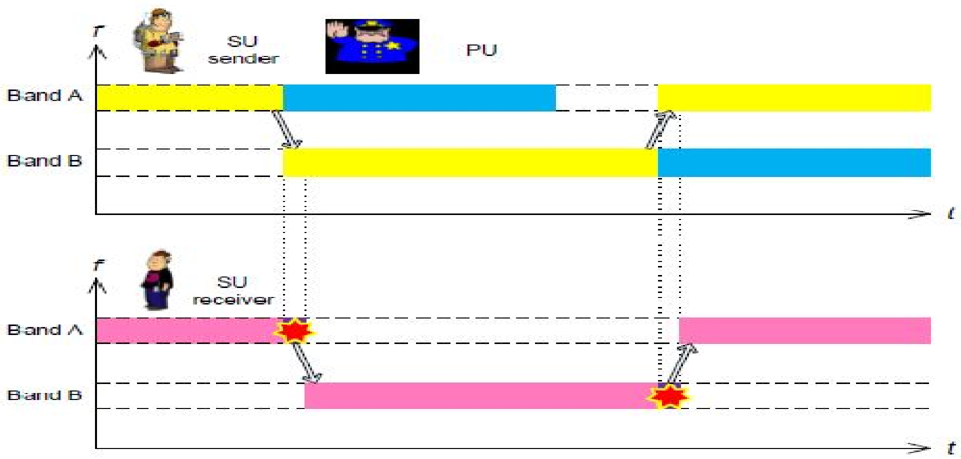


Fig. 1: Spectrum Switching in Cognitive Radio.

Haykin (10), defined cognitive radio as an intelligent wireless communication system that is aware of surrounding environment and adapts to variations in the RF stimuli by making corresponding changes in certain operating parameters (e.g., transmitting power, carrier frequency, and modulation strategy etc) in real-time.

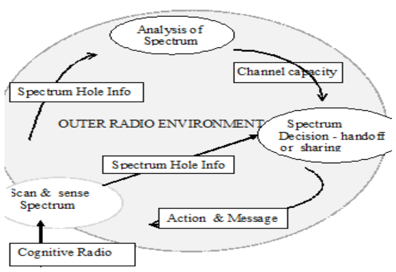


Fig. 2: CR working

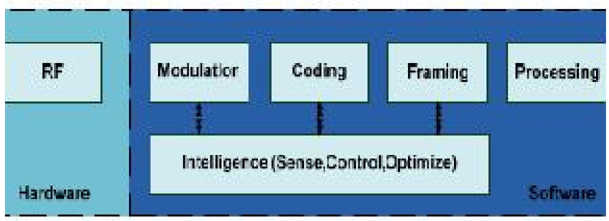


Fig. 3: Block Diagram of Cognitive Radio

The concept of Cognitive Radio (CR) was introduced by Joseph Mitola(9,5) after the concept of Software Defined Radio(4) (SDR- hardware components were replaced by software processing on general purpose processors). In CR intelligence was introduced in the device for parameter selection and the software processing as per network conditions expecting the optimized utilization of RF spectrum and high quality of service for reliable communication.

2. Working

The functioning of Cognitive radio includes-
1) Spectrum sensing 2) Spectrum management 3) Actions

Cognitive radio support both central/ distributed networks in three main paradigms(21)

1) Underlay Paradigm: SU and PU coexist till interference to PU is below acceptable level.
2) Overlay Paradigm: PU and SU coexist in a particular band only (lot of site info required)
3) Interweave Paradigm: no concurrent existence/ transmission of PU and SU in a band. This approach being more practical, IEEE 802.22 working group is developing a new wireless standard for cognitive radio based devices in TV broadcast spectrum(16).

3. Channel Coding for CR Networks

The SU channels are considered as non ergodic block erasure channels being low power, may get totally erased due to high power noise or PU interference. The word error probability depends on block diversity (Δ) of a code (7, 6) i.e. block wise Hamming distance. It represents the maximum no. of erased blocks tolerable by a code. For block erasure probability =1, a ML decoder can recover the received coded word correctly in the presence of Δ-1 erasures on such channel. The maximum achievable diversity order is given by the Singleton bound as

$\Delta \leq 1 + \lfloor N(1-R) \rfloor$ where R- code rate, N- number of blocks in coded word.

The codes for which above relation holds good are called diversity wise maximum distance separable (MDS). It is shown in (6) that diversity wise MDS codes achieve outage probability on block erasure channels. Full Diversity Codes achieve the singleton bound for the given rate R . In this case the information outage probability is given by the probability of having all blocks erased.

Rate less codes (Digital Fountain codes)(11) – These can send excess data in channels of unknown characteristics with variable code rate. The number of packets generated from the original data is potentially limitless, transmitter encode and send packets till it receives ACK signal from R_x after successful decoding. The receiver evaluates each received packet, saves valid ones and discards corrupt ones. With enough valid packets, receiver successfully decodes the message and informs the transmitter to stop sending further packets. eg- Raptor codes and LT Codes(17) excellent error correction and decoding depending on design of degree distribution.

$P_n = \binom{N}{n} \epsilon^n (1 - \epsilon)^{N-n} \quad \forall\, n = 1, \dots, N$ and $WEP^{LT} = \sum_{n=M+1}^{N} P_n$ for large no. channels.

LDPC CODES- Low density parity check codes(1,7,6) are capacity achieving linear block codes (k info. bits mapped to n coded bits). Regular LDPC code have parity check matrix with fixed no. of ones in each column and row. Irregular LDPC codes have varying number of 1's in each row and column, specified by their left and right degree distributions. Standard LDPC codes do not achieve outage probability on block erasure channel as they are not diversity wise maximum distance separable (MDS). LDPC codes have full diversity are introduced in (7) as tornado and root-check.

$$P_{out} = \epsilon^N \qquad WEP^{LDPC} = P_{out} = \epsilon^N \qquad \eta^{LDPC} = \frac{K}{N}(1 - WEP^{LDPC}) = \frac{K}{N}(1 - \epsilon^N)$$

They have excellent performance, but code rate R≤ 1/N. For increased number of blocks these are bandwidth inefficient, other problem is specific structure of parity check matrix.

Convolutional Codes- with periodic interleaving result in diversity wise MDS codes(1,2,3), and achieve outage probability. The info symbols are interleaved as L X N matrix by rows, and coded symbols transmitted by columns. Thus all code symbols stored in the same column are mapped to the same sub channel, each sub channel transmits L coded symbols.

$$P_{out} = \sum_{k=0}^{\lceil NR \rceil - 1} \binom{N}{k} (1 \quad \epsilon)^k \epsilon^{N-k} \qquad WEP^{CONVO} \leq \sum_{k=0}^{N-\Delta} \binom{N}{k} (1-\epsilon)^k \epsilon^{N-k} \leq \sum_{n=0}^{N-\Delta} P_n$$

Throughput= k/n (1- WEP^{convo})

4. System Model

We have adopted CORVUS model without spectrum sensing capability, members of a SU Group have a common control channel for signaling, follow unicast communication either between a pair of SUs or between a SU and access point. Direct point-to-point communication between SUs from different groups or broadcast is not supported (1). A spectrum pool with total bandwidth W is divided into N_T sub channels, each with a bandwidth $W_b = W/N_T$. Out of these N_T sub channels, a secondary user is assigned K sub channels to transmit K information blocks and additional M sub channels for redundancy. So SU has N = K + M sub channels. We assume that these N blocks in a secondary user link (SUL) form one data frame.

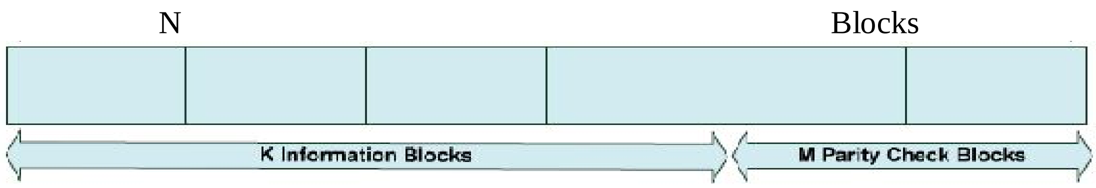
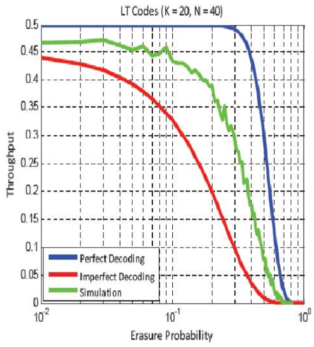


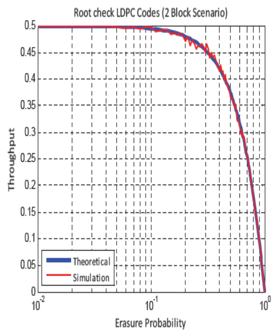
Fig. 4: Frame Structure.

Packets in sub-channel with FEC code protection may not survive strong interference from PU activation. Jamming behavior due to random appearing PU is modeled as block erasure channel, where received packet through sub- channel may be correct or completely lost. Code rate is R= 1/2 and the information bits belong to BPSK alphabet. X_b represent the transmitted symbols and Y_b represents the received symbols. When $Y_b \neq X_b$, there is error.

We have induced channel noise effect and variations due to higher order modulations.

5. Channel Coding Throughputs (1)





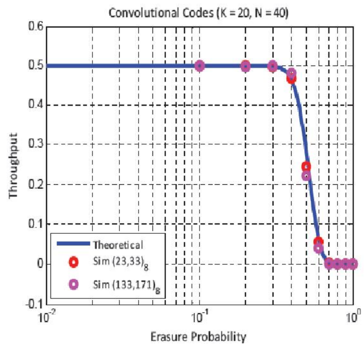
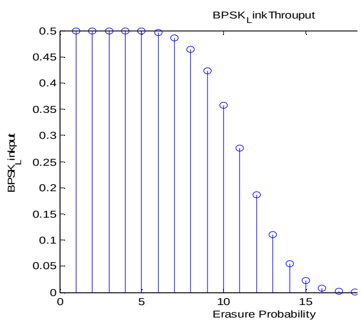
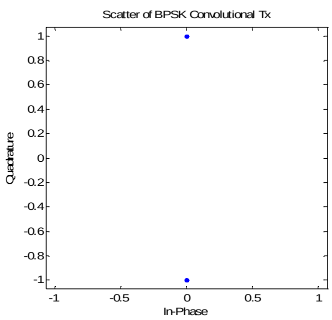


Fig. 5: LT Code Thput **Fig. 6**: Root check Thput **Fig. 7**: Convo. Code Thput





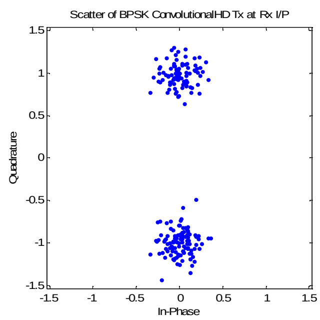


Fig. 8: Convo.Code Thput (Our) **Fig. 9**: BPSK Scatter **Fig. 10**: Noised Scatter BPSK.

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