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PERFORMANCE COMPARISON OF TWO ROUTING CODES IN RELIABLE POINT TO POINT TRANSMISSION FOR AD-HOC COGNITIVE RADIO NETWORKS

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ABSTRACT: The familiar technology in wireless communication is Cognitive radio as well known. Usually for transmission all the network has a centralized control, which need the feedback information of each and every node n that network. So collecting all the information about each and every node present in a vast network topology is unscalable and impractical. The recent technology with virtual MIMO is developed, which performs the end to end transmission in CRN. In this paper, we discussed the two codes in the realization of end to end transmission. The performance of Routing Time Theory (RTT) and Routing Permutation Theory (RPT) is greatly analyzed and compared based on the Ad- HOC networking. Where RPT is slightly shows better performance than RTT due to its multiuser scenario. Their BER, SNR and decoding computational complexity comparison is demonstrated.

Index Terms: Cognitive Radio Networks (CRN),Routing Time Theory (RTT), Routing Permutation Theory (RPT), Permutation array [PA], Error rate analysis.

I. INTRODUCTION

A cognitive radio (CR) is an intelligent radio which can be programmed and configured dynamically. Its transceiver is deigned to use the best wireless channels for communication in its vicinity. Such radio automatically detects available channels in wireless spectrum, then along automatically changes its transmission and reception parameters to allow more concurrent wireless communication in a given spectrum band at one location. This mechanism is a form of dynamic spectrum management. So it is considered as a key technology to improve the spectrum efficiency of the future wireless communication. The operation can be explained with a simple realistic example that. first consider or define a link as a transmission phase between two successive nodes and the path is the transmission route between source and destination. This is the end to end transmission [2]. During packet transmission the packet is transmitted from CR through the opportunistic relay path, which then the relay nodes along the path is forward the packets to their next eligible/available relay node[1]. This is the end to end transmission topology for CRNs. Usually CR means that the secondary user makes use of the available chances of unused spectrum left by the primary user [1]. Now to avoid interference of primary user with other user, the relay node must be analyzed about their availability before forwading [1]. If the link is occupied with others user or primary user, the forwading should be queued until the link become free.

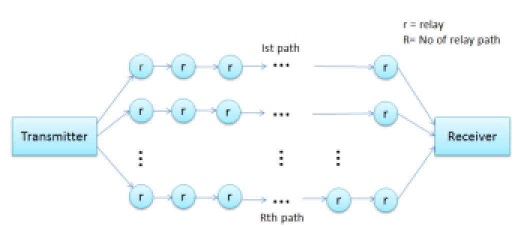

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Fig 1: The topology of end to end transmission between transmitter and receiver in CRN

Rest of this paper details as follows: Section II giving the introduction of two routing theory codes. Section III elaborates the proposed coding schemes with system implementation. Section IV compares and analyzes the superiority of two coding theory. Section V provides the numerical results to validate the analysis and to demonstrate the performance of the proposed end to end transmission. Finally conclusions are drawn in Section VI.

II. ROUTING THEORIES EXTENSION

In this paper we are introducing two routing codes and analyzing which shows better results in Ad-HOC CRN. Here, to achieve the error resilient end to end transmissionwithout the necessity of feedback information[2]. By transmitting multiple codded packets through multiple relay paths. The end to end transmission can then be formulated as Virtual multiple-input multiple-output (MIMO)[1]-[3]. Thus proposing the two routing schemes such as Routing Time Theory (RTT) and Routing Permutation Theory (RPT).

A.Introduction of RTT

RTTs aim is to exploiting path diversity to improve the transmission reliability[2]. RTT has some similarities like space time code function in the physical layer. RTT has become more challenging, due to the presence of erasures, especially when time varying erasures if need to be accounted. Its main aim is to transmit multiple codded packets using all the relay paths and to decode them simultaneously[1], [2]. Initially RTT must to be investigated on a channel where the erasures are null. Christo Ananth et al. [4] proposed a secure hash message authentication code. A secure hash message authentication code to avoid certificate revocation list checking is proposed for vehicular ad hoc networks (VANETs). The group signature scheme is widely used in VANETs for secure communication, the existing systems based on group signature scheme provides verification delay in certificate revocation list checking. In order to overcome this delay this paper uses a Hash message authentication code (HMAC). It is used to avoid time consuming CRL checking and it also ensures the integrity of messages. The Hash message authentication code and digital signature algorithm are used to make it more secure . In this scheme the group private keys are distributed by the roadside units (RSUs) and it also manages the vehicles in a localized manner. Finally, cooperative message authentication is used among entities, in which each vehicle only needs to verify a small number of messages, thus greatly alleviating the authentication burden.

B. Introduction of RPT

RPT is very familiar for its several features. It is much suitable for all kinds of Ad-HOC CRNs. For end to end reliable transmission RPT access only one path at a time. This accessed path is selected based on the data sequence in the packets. Specially data packets are encoded in two ways i.e.,by using the transmitted symbols with quadrature amplitude modulation (QAM) and by using a permutation array (PA) consisting of a set of path indices. The term permutationcomes from the fact that the RPT code word comprises these PAs. Consider a toy example of RPT using two relay paths and two time instants. In addition to the bits conveyed by the transmitted QAM symbols, the source node can encode another bit with Pas. Specifically, if the bit ‘0’ is encoded by the PAs, the first and the second relay paths are successively

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selected at the first and second time instants according to the PA. Contrarily, if this bit value is '1', the second and the first relay paths are successively selected at the first and second time instants according to the PA [2]. The destination node then identifies the order of the accessed paths and decodes the transmitted QAM symbols to recover the data packet. The proposed end-to-end PPC transmission enjoys several advantages as follows:

1) **Error resilience**: The RPT code word is dispersed through various time instants, creating the time diversity that allows the data packet to be recovered if a transmission outage occurs at some time instants and/or some relay paths. With reference to the previous toy example, the destination node is able to recover the data even if data is only successfully transmitted through one path. Itfollows that the end-to-end RPT transmission is robust to the presence of randomly available opportunistic links.

2) **High link availability**: Since one relay path is used at each time instant in the context of end-to-end RPT code. Transmission, link availability of the ad hoc CRN in this case is higher than that of the end-to-end RPT transmission where all relay paths in the multipath routing are concurrently accessed.

3) **Multiple access**: With the assigned PAs, multiple CRs can transmit simultaneously, and thus the RPT can be utilized as a multiple access technique in multiuser scenarios.

4) **Low control overhead**: Since only one packet is transmitted at a time, the multiplexing technique or the two step protocol [5]for the transmission at the source node is saved. Also, the control for the synchronization of the arrival of multiple coded packets is avoided.

5) **Low encoding and decoding complexity**: Since the encoding only performs the selection of the relay path, the encoding complexity is low. Decoding the single RPT coded packet which includes the identification of the order of the accessed paths, i.e., the PA, is much simpler than the joint decoding of multiple RPT-coded packets.

III. SYSTEM MODEL AND END TO END RTT AND RPT TRANSMISSION

The ad hoc CRN with multihop multipath route can be viewed as a set of R link-disjoint paths. Each of them comprising Nr − 1, for r = 1, . . . , R, relay nodes.. To describe the virtual MIMO system and for the comparison with the PPC technique, in thissection we review the end-to-end RTT and RPT transmission.

A. End to End RTT transmission

To perform end-to-end RTT transmission, the source node encodes a data packet $x \in \chi^M$using the coding matrix $\tilde{C}_m \in C^{R\times M}$, Where χ denotes the QAM constellation set.The resulting coded packet $\tilde{C}_m x$ is transmitted at time instant m.Let.,$v_m = [v_m,1, . . . , v_m,R]^T$ is the erasure vector of R paths at time b, where $(\cdot)^T$denotes the transposition.$h_m = [h_m,1, . . . , h_m,R]\_ \in C^R$ as the path fading vector at time b.The Schur product of $h_m$and $v_m$as $h_m \circ v_m = [h_m,1 v_m,1, . . . , h_{m,R} v_{m,R}]^T$. The received coded packet at the destination node has the form

$$
\begin{aligned}
y_m &= (h_m \circ v_m)^T \widetilde{C_m} x + \sum_{r=1}^{R} \widetilde{n_{m,r}} \\
&= (h_m \circ v_m)^T \widetilde{C_m} x + n_m, \qquad (1)
\end{aligned}
$$

where $\tilde{n}_{m,r}$denotes the additive white Gaussian noise (AWGN) aggregated from all links in the rth path at time instant b.

The AWGN $n_m$has a time-varying power spectral density, denoted by $N_{0,m}$. The received coded packet from $m = 1$ to $m = M$ can be represented as

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$$y = \begin{bmatrix} (h_1 \circ v_1)^T & \cdots & 0^T \\ \vdots & \ddots & \vdots \\ 0^T & \cdots & (h_M \circ v_M)^T \end{bmatrix} \underbrace{\begin{bmatrix} \widetilde{C_1} \\ \vdots \\ \widetilde{C_M} \end{bmatrix}}_{C} + \underbrace{\begin{bmatrix} n_1 \\ \vdots \\ n_M \end{bmatrix}}_{n}$$

$$= \underbrace{\begin{bmatrix} (h_1 \circ v_1)^T \tilde{C}_1 \\ \vdots \\ (h_M \circ v_M)^T \tilde{C}_M \end{bmatrix}}_{H_{eq}(V,C)} x + n$$

$$= H_{eq}(V,C) + n, \quad (2)$$

Where $C = [\tilde{C}_1^T . . . \tilde{C}_M^T]^T \in C^{RM\times M}$ represents the cascaded $\tilde{C}_m$. With the equation in (2), the end-to-end codedtransmission in ad-hoc CRNs is described by the same mathematicalexpression as a MIMO system, characterized by the equivalent channel matrix $H_{eq}(V,C) \in C^{M\times M}$.

This MIMO matrix incorporates the *RM* Bernoulli random variables modeling the erasures, and can be modified by a suitable choice of the coding scheme.

Equation (2) describing a virtual MIMO system where multiple nodes are coordinated to form multihop/multipath route between a source/destination node pair. The source node encodes the data packet along time and path coordinates. First nodes are collected. Next, since the destination does not have an a priori knowledge of the erasure pattern, joint detection is performed to simultaneously identify the entries of V, i.e., the erasures, and decode the data packet x.

RTT exploits the path and time diversity to increase end to end transmission reliability[1],[2]. For DFT based RTT, the $(k,m)^{th}$ entry of the coding matrix, $C_{k,m}$, takes the form,

$$C_{k,m} = \frac{1}{\sqrt{R}} e^{\frac{-j2\pi km}{RM}}, k = 1, \ldots\ldots, RM, \quad m = 1, \ldots\ldots, M \quad (3)$$

The use of DFT matrix has several disadvantages. The DFT-based RTT allows efficient implementation by Fast Fourier Transform (FFT) architecture, as those widely used in Orthogonal Frequency Division Multiplexing (OFDM) systems.

B. End to End RPT transmission

RPT is a reliable end to end transmission in which only one relay path is accessed at a time and the hopping is among multiple relay paths. End to End RPT transmission implementation is done in OFDM channels. Here virtual MIMO is use for multi user scenario techniques. Some basic formulation such as cyclic prefix also done here for getting information about the previous signals. The detailed explanation of each and every is already discussed in previous chapters. The sample block for implementation is given below.

In this section, end to end transmission in ad hoc CRNs is elaborated upon, including its encoding mechanism and the corresponding virtual MIMO formulation.

We first denote *CR* as the PA set which comprises all thepossible *R*! permutations of *R* objects. For example, for *R* = 3,we have 3! = 6 length-three permutations.

$$C_3 = \{123, 132, 213, 231, 312, 321\} \quad (4)$$

Next defining hamming distance matrix D whose (i, j)th component $d_{i,j}$ is the hamming distance between the ith and jth permutations. For example, the hamming distance matrix of $\{123, 132, 213, 231, 312, 321\} \in C_3$ is

$$\begin{bmatrix} 0 & 2 & 2 & 3 \\ 2 & 0 & 3 & 2 \\ 2 & 3 & 0 & 2 \\ 3 & 2 & 2 & 0 \end{bmatrix} \quad (5)$$

a symmetric matrix with null diagonal entries. The minimum Hamming distance of the PA, d_{min}, is the smallest off-diagonal entry of **D**, i.e.,

$$d_{min} = \min_{\substack{i,j=1\ldots k \\ i\neq j}} d_{i,j}, \quad (6)$$

so that $2 \leq dmin \leq R$.

With these notations, let $C_R(K, d_{min}) \subset C_R$ denote a subset of C_R including K PAs with

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minimum Hamming distance d_{min}, which is known at both the source and destination nodes for the encoding and decoding. This PA subset can be assigned off-line and periodically updated. The two parameters K and d_{min}respectively reflect data rate and reliability, since RPT maps a data sequence with length of log2 K bits one-to-one to a permutation in $C_R(K, d_{min})$. The larger K is, the more bits can be encoded by this PA subset, but the value of the minimum Hamming distance may get smaller.,dmin decreases as K increases, which implies that the rate reliability tradeoff. Various permutation subsets and their mapping rules are addressed such as [6],

1.Distance Conserving Mapping (DCM).

2.Distance Increasing Mapping (DIM).

For the DCM, the Hamming distance between any pairs of PAs may be the same or larger than that of their associated demapped binary data, while for the DIM, the Hamming distance between the PA pairs is guaranteed to larger to the distance between the associated demapped binary data.these follows data table [1], which improves the reliability at the expense of lower throughput.

Finally The virtual MIMO system model in (2) of the end-to-end RPT transmission thus simplifies to,

$$y = (h_r \circ v_r)x + n \qquad (7)$$

It should be noted that certain relaypaths may be occupied by the primary users for a long duration. By hopping among various relay paths, the end-to-end RPT transmission can easily overcome this problem. Since only one transmission occurs on a single relay path at each time instant, some control overhead, of the end-to-end RPT transmission can be saved. Additionally, the relay paths do not need to be link-disjoint, because only one path is accessed at a time. The multipath routes can thus be established more easily.

IV. COMPARISON OF RTT AND RPT IN MULTI USER ADHOC CRN

For the conventional multipath end-to-end transmission, e.g., flooding with a repetition code or RTT, CR users concurrently access all relay paths to improve the rate-reliability tradeoff. However, due to the concurrent access of multiple relay paths, the availability of the opportunistic links in the ad hoc CRN decreases, and hence erasures occur more frequently. Even worse, for the case of two CR users sharing the same multipath route, only a single user is permitted to perform the end-to-end transmission when flooding or RTT methods are used. Multiple access techniques, causing undesired control overhead, are needed for multiuser transmission. Contrarily, at each time instant, the end-to-end RPT transmission only accesses one relay path even when multiple relay paths are available. Therefore, the availability of opportunistic links in the ad hoc CRN is higher than with the conventional end-to-end multipath transmission. Moreover, by generalizing the RPT technique, multiple users can concurrently utilize the overlapped multipath routes When the RTT is applied, it can be seen that multiple coded packets are concurrently transmitted through multiple relay paths, thus providing error-resilient end-to-end transmission. However, this mechanism simultaneously occupies R opportunistic links, which implies that the link availability decreases quickly, especially when the number of CR users and/or $R$is large. What is even worse, when CR users with overlapped routes need to transmit simultaneously, multiple-access techniques are required, which introduces undesired control overhead. Unavoidable control overhead also arises from the synchronization allowing multiple coded packets transmitted through different relay paths to arrive at the destination node within the same time frame. RTT is not suitable for

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multiuser scenario. These are such drawbacks occurs while using the RTT codes as while the RPT overcome these draw backs which is considered as a better coding theory for end to end transmission.

V. SIMULATION ANALYSIS

In this section, the performance of the end-to-end RTT and RPT transmission is evaluated, and the analysis is validated by means of Monte Carlo simulations.To address the performance in a multiuser scenario, we investigatethe sum rate of the end-to-end transmission, and compare RPT with RTT. Since RPT can be realized with low decoding complexity, we use ordered successive interference cancellation (OSIC) for suboptimal RTT decoding as a fair comparison. Let two and three users respectively access the same multipath routes for $R = 5$ and $R = 6$. As shown in Fig. 2, in these two cases, the spectrum efficiencies of the end-to-end transmission using RPT are respectively 3 dB and 6 dB better than that using suboptimal RTT due to the RTT-based multiple access, while both schemes have a low decoding complexity. Even with one path less, the end-to-end RPT transmission still delivers a higher spectrum efficiency. Compared with the end-to-end RTT transmission with optimal but complicated decoding algorithm, the end-to-end RPT transmission achieves a comparable spectrum efficiency for the case of $R = 6$, with lower decoding complexity and control overhead for synchronization and multiple access.For the comparison between the RPT and RTT transmissions, Fig. 3 depicts the BER comparison between the RTT transmission and RPT transmission with different values of $d$min. We can see that, with half of the spectrum efficiency per user, the RPT technique provides slightly better BER performance than the RTT technique. When the spectrum efficiency increases, The BER performance of the end-to-end RPT transmission degrades and becomes worse than that of the end-to-end RTT transmission.

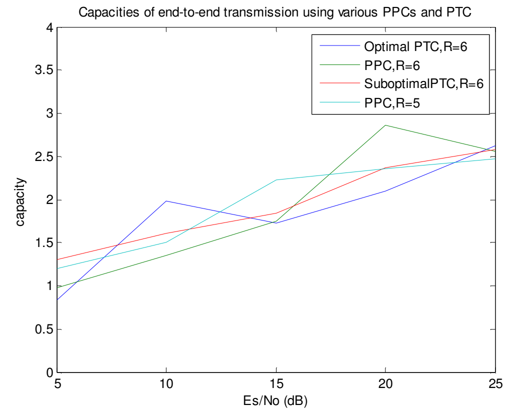

Fig 2: Capacities of end-to-end transmission using various PPCs and PTC under a multiuser scenario with total throughput 4 bits per time instant. For $R = 5$and$R = 6$, two and three users are considered, respectively. For $R = 5$, the end-to-end PPC transmission adopts 64-QAM and $K = 16$. For $R = 6$, two users apply end-to-end PPC transmission.

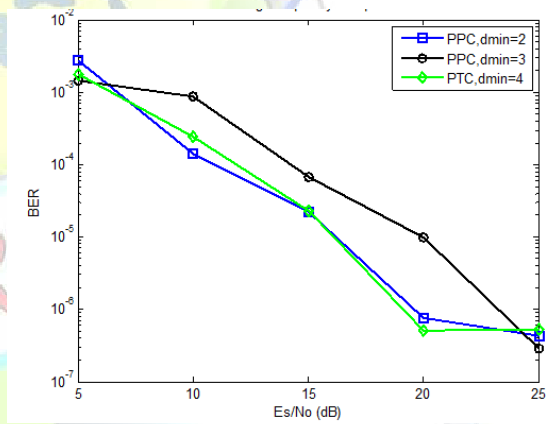

Fig 3: error rate comparisons between the end-to-end PPC transmission and the end-to-end PTC transmission.

VI CONCLUSION

In this paper we have greatly analyzed the performance of two routing schemes RPT and RTT and finalized that the recently proposed RPT is fully fitted for the adhoc cognitive radio networks for end to end transmission. All the two coding schemes carrying same practical implementation process but some of the advanced work in RPT enhances its performance than RTT. It

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can suits to all types of adhoc CRNs. RTT also generates control over head and reduces the link availability which reduces the speed of transmission this does not used in multiuser scenario. Finally RPT delivers higher spectrum efficiency in multi user scenario. The error rate has become tremendously lesser than RTT. Thus we believe that the proposed end to end RPT transmission is suitable for multi user adhoc CRN with simple permutation subsets.

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