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Joint Network-channel Decoding in Wireless Channels with Erasures Channel

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Abstract: Network coding has been receiving much attention recently for its ability to improve network throughput and enhance network robustness. The technology combining channel coding and network coding can effectively resist the influence of multipath fading and improve the system performance. JNCC is a kind of encoding scheme by joint error correction of redundancy network structure and channel error correction. Decoding of JNCC need analyzing received network matrix that may change in the wireless network with erasure channel. This study propose the method to judge redundancy links and linear relation with the received network code matrix in order to joint network-channel decode in wireless erasure channel. The experimental simulation show that the algorithm combining with channel coding and decoding can reduce the bit error rate

Key words: Network code, erasure channel, error correcting code, JNCC

INTRODUCTION

In the wireless communication system, due to the influence from the disturbances including multipath fading and white Gaussian noise in the wireless channel, the realibity of transmission is poor. As a result, various methods are used to improve in wireless communication system. In order to increase the reliability of network, the concept of network code (Ahlswede *et al*., 2000) is proposed and then the network code theory is used in the wireless communication network. During the information transmission process, only transmission mode of network code method cannot resist the failure in network link. For example, if the data package loss due to link failure or break off, the destination node cannot recover the information sent from the information source, the date packet need is sent again in order to recover the information of source. This method commonly leads to delay in network transmission. The scheme of network redundancy coding is used in network error correcting code (Cai and Yeung, 2002). Information is received by broadcast through redundancy coding in middle node. If the some links failure, the lost information can be recovered by other link. This way can increase the network throughput and improve the reliability of network transmission.

In Yeung and Cai (2006); Cai and Yeung (2007), the network error correcting code can corrects the package or link error by redundancy information. Joint network code and channel code can further increase the error correcting ability. Separate Network Channel Code (SNCC) (Chen *et al*., 2006) is a kind of network code communication method, by which the received link of network code in destination node. If the data package is correct by the check, the original information can direct decoding . If the data package is error, we may get source information through joining network code and channel decoding. In the literature (Cai and Yeung, 2006; Zhang, 2008; Rebelatto *et al*., 2011), Joint Network-channel Correction Coding (JNCC) is proposed, by which the network redundancy and channel redundancy are made full use of to correct wrong signal and reduce error rate as far as possible. Low Density Parity Check (LDPC) (Iscan and Hausl, 2011; Sui *et al*., 2009) and Turbo (Li *et al*., 2011) are a kind of the channel code close to Shannon limit which are combined with network code to check the received code for JNCC decoding through iterative method. Previous JNCC decoding is completed based on known network structure. However, in order to avoid the expansion of error information in the network, the received data package need be checked in the middle node. If the received data package is wrong it is deleted. If the received data package is correct, the data packets can be code by network. Therefore, the received transmission matrix at destination node may be different from original network transmission matrix when there is package loss in the network transmission. The received link at destination node may no be redundancy link. As a result, for the network transmission with package loss, the received transmission matrix need be discussed and analyzed before JNCC.

A judgment method for the received link redundancy by the matrix is given in the paper. In the two-source single relay network code structure with Galois field (2), the known network transmission matrix is compared with received link transmission matrix at the destination node and we can judged whether the link has redundancy with JNCC.

Single relay Network Structure In Wireless Coordination

Relay network-channel code structure: In the wireless network , Errors are generated from the change number and location, there are 3 error types: offset error generated from number error in correct location; erasure error generated from error location with correct number; error generated from error location and error number. Package loss in network transmission belongs to erasure error. Joint network-channel code can be presented by product code[n_1, n_2; k_1, k_2; d_1, d_2], n_1: length of code generated from channel linear block code; n_2: number of data packages from network code; k_1: length of code from information source; k_2: number of information sources; d_1: min code distance of channel code; d_2: min distance of network code. A: network code matrix received by destination node.

JNCC coordination network structure is shown in Fig. 1.

JNCC coordination network block diagram is shown in Fig. 2.

The transmission process of the information source to destination node is consisted of 2 parts: channel mode and network mode. Linear block code (n_1, k_1, d_1) is used in channel doe for message code mi in information source MS_1, MS_2, resulting in data packages S_1 and S_2. Middle node R and destination node BS respectively receives the

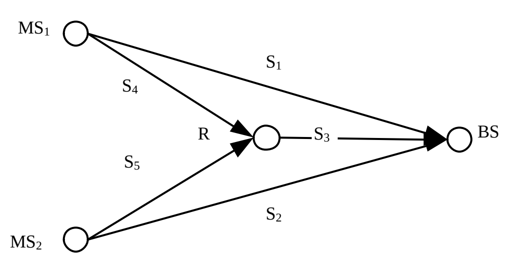

Fig. 1: Two-source single relay network model in wireless coordination

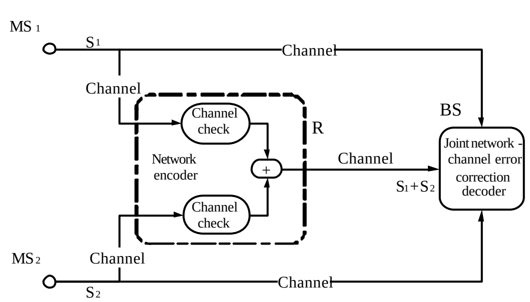

Fig. 2: JNCC work block diagram

broadcasted data packages S_1 and S_2. Received S_1 and S_2 are checked in middle node. If the data package is correct, the linear block code leads to S_1+S_2.

The network code transmission matrix A is reflecting the linear relation between network links from Fig. 1. So the fixed network code structure matrix is:

$$A = \begin{array}{c} \\ S'_1 \\ S'_2 \\ S'_3 \end{array}\begin{array}{c} S_1 \quad S_2 \\ \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \end{bmatrix} \end{array} \quad (1)$$

where, S_i is the send link in MSi, s'_3 is the received link in BS node. The rank of code in network code is 2. So the distance of code in network code is d_2 = 2.

Judgment on received network code matrix structure In the network transmission, due to data jam, the middle node cannot receive the data package or cannot decode correct data package. Such phenomenon is the package loss in the network transmission. This error is also named erasure error. That is to say, the error location is known but the date cannot be corrected.

Example: In the network structure of Fig .1, if there is no error in transmission process, the network transmission matrix is (1). The receiving matrix is equal to fixed network code structure matrix. If the data package loss during the transmission process, the network transmission matrix received by BS node is different from fixed network code structure, leading to (2):

$$B = A\text{-}A' \quad (2)$$

B: Difference of matrixes.

There is no data package loss when B = 0.

If B≠0, there is package loss in the middle node or BS node during network transmission.

Example 1: If the network transmission matrix received by BS node through link is:

$$\hat{A} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \quad (3)$$

From (1) - (3) , (4) is:

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 1 \end{bmatrix} \quad (4)$$

B≠0: There are package loss during the transmission process. Element (3,1) and Element (3,2) are 1 and others are 0 in matrix B. Lost data package is S_1 and S_2 in s'_3 of BS. In the network transmission Â matrix , thecoefficient between S_1,S_2 and S'_3 of BS node is 0. Namely, S'_3 is unrelated to S_1 and S_2. Data package of S_1 and S_2 is not received. It can be judged that the middle node loses the code information of data package S_1+S_2. In matrix Â, the coefficient between S_1 and S_1 and the coefficient between S_2 and S_2 are 1. Therefore, the destination node receives the link S_1S_2. According to (4), received data package is S_1S_2. There is no linear relation in the matrix line.

Matrix order is 2:

$$\hat{A} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

and n_2 = 2. There is no redundancy link. The distance of network code is 0. There is no correction ability in network level. If the received data package S_1S_2 is correct, 2 correct information sources can be decoded. Or else, there is no redundancy data package and no correction ability. Correct information source cannot be decoded:

$$\hat{A}_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 0 \end{bmatrix} \quad (5)$$

(1)- (5) = (6)

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \quad (6)$$

If B≠ 0, there is package loss in transmission process. Element (3, 2) is 1 in B and others are 0. Lost data package is S_2 in S'_3 of BS. Link received by destination node is $S_1S_2S_1$. Matrix $\hat{A}_2$ has 3 lines with matrix order of 2. According to the judgment, Line 1 and Line 3 are linearly related with redundancy seen in (2). However, n_2 = 2, μ = 0. Redundancy link can only be corrected in Line 1 .

It is assumed that the structure of Fig .1 is fixed network code with known transmission matrix A. A is the matrix with matrix order of 2 and no linear relation. A' is the network code matrix with package loss. Compare A and A':

- 1: If A = A', there is no data package loss in transmission process, leading to certain redundancy. Error can be corrected in the network level
- 2:If A≠A', there is data package loss. Judge whether rank (A') is equal to 2;
- 3:If rank (A') <2, in the transmission process, the information source message is lost, the message cannot be decoded
- 4:If rank (A') = 2 and n = 3 in matrix A', judge whether the line in A is linearly related. If there is linear relation, same data package is received, leading to certain link redundancy. Error can be corrected in the link level. Or else, n<3, a link is lost in the transmission process with no redundancy and no error collection ability in network level

JNCC

The network structure condition of JNCC is that the destination node should receive the link with certain linear relation and redundancy. The destination node A in network structure of Fig. 1 is known. Network transmission matrix A' is received by the destination node through the link. Whether the link is related to each other and the code coefficient is represented by 0 and 1.

Then, the JNCC procedure is as follows:

- **Judge whether rank(A') is 2:** Based on the received network transmission matrix A', judge whether rank (A') is equal to 2. If rank(A') <2, the message code of 2 information sources cannot be decoded. Data package should be sent again rank(A')<2:Based on the received network transmission matrix A', judge whether rank (A') is equal to 2. If rank(A') <2, the message code of 2 information sources cannot be decoded. Data package should be sent again.When order of A' is 2, if 2 = A' = A, SNCC is used to decode the data package with error fewer than and equal to 1. JNCC is used to decode data package with errors more than 1
- **A≠A:** When A'≠A', judge whether there is all 0 element in the line. If there is all 0 element in the line, linear relation and channel code of network code is used to decode the correct data package to find the code of information source. However, there is no link redundancy, so error cannot be corrected in the network level. If there is an error in the error data package, the data package shall be sent again

When there is no all 0 element in the line of received matrix: 2 lines with linear relation are found to judge whether the received data package is correct. When the data package with no linear relation in matrix A has error, the decoding is impossible, so the data package shall be sent again. If there is no error in the data package corresponding to line with no linear relation in matrix A, the data package corresponding to line with linear relation has 1 error. SNCC can be used to decode the information source. When there is error in 2 data package, JNCC is used to correct the error and decode the information source.

EXPERIMENT

MATLAB is used for the simulation test on JNCC. Joint network code of JNCC is [31,3; 21, 2; 5,2]. The channel code here is (31, 21, 5) linear block code with min distance $d_1 = 5$; network code (3,2,2); min distance $d_2 = 2$. BPSK is used for modem. Whit Gaussian noise and Rayleigh channel information is used to decode the received network code matrix A' and find the source signal. Direct Transmission (DT), error rate of SNCC and JNCC and relation of error package rate are compared under the same signal to noise ratio. DT is directly between two sources with no passing through middle node relay.

Through the simulation, the curve for relation between Bit Error Rate (BET) and signal to noise ratio (SNR) Fig. 3:

Seen from Fig. 3, when SNR is low, JNCC, SNCC and DT have almost the same BER because there are too much error symbol in data package. Therefore, 3 methods almost have the same error rate. When the SNR>6dB, JNCC compared with SNCC. BER of JNCC decreases much faster, at average 25% more than that of SNCC.

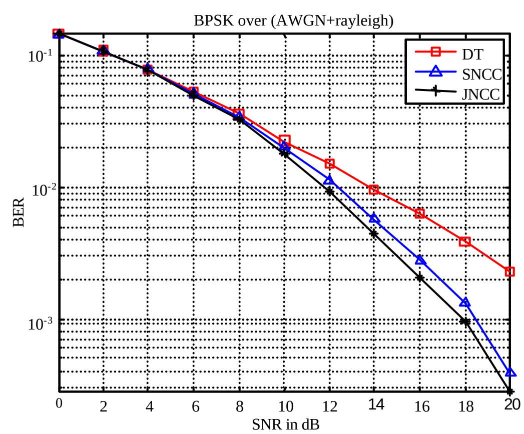

Fig. 3: Curve for relation between BER and SNR

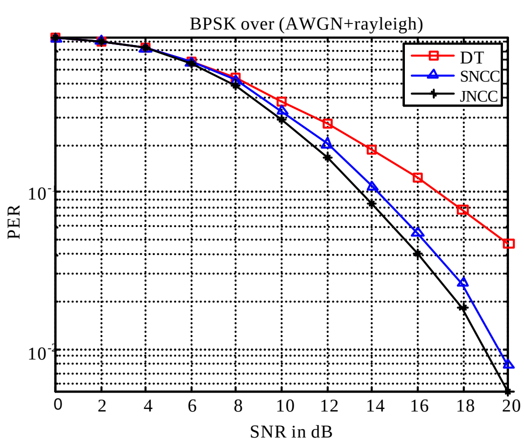

Fig. 4: Curve for the relation between SNR and PER

Through the simulation, the curve for relation between error package rate and SNR, Fig. 4 is given.

In Fig. 4. that package error rate with JNCC under low SNR is nearly the same with SNCC and DT. When SNR increases, the decrease speed of package error rate decreases faster which is average 30% of decrease in SNCC and 50% of decrease in DT.

CONCLUSION

Seen from the above analysis, through the comparison between network transmission matrix and fixed network transmission matrix, the structure of received network link can be judged to find the redundancy. Combining with channel code, JNCC is used to reduce the error rate and error package rate in the network and increase the quality of network communication.

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