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Performance Evaluation for Error Correcting Scheme on Multiple Routes in Wireless Multi-hop Networks

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Abstract

In this paper, we consider the improvement of packet error rate on wireless multi-hop networks. One of the important and interesting techniques for wireless multi-hop networks is multi-path routing. By using multi-path routing, multiple routes can be established from a source node to a destination node. In this paper, we propose the error correcting scheme in which the coded different packets are transmitted using multiple routes on wireless multi-hop networks. Hence, we can achieve a coding gain for multiple routes and expect the improvement of performance. In wireless multi-hop networks, the route loss due to topological change or recognizing failure may be happened. From the above discussion, we evaluate the proposed scheme by packet error rate in consideration of the influence of the route loss.

1. Introduction

A wireless multi-hop network [1] operates without the need of the fixed infrastructures such as base stations. Hence, this network is expected the future-generation wireless network system [2]. A wireless multi-hop network consists of wireless nodes which can communicate directly and mutually. The nodes which are too distant from each other for direct communication exploit multihopping to enable communication. In this network, which wireless nodes relay is determined by routing protocol [3]. There are ad-hoc networks and framework of the cellular network systems[4], as a typical examples of a wireless multi-hop network.

In this paper, we consider the improvement of packet error rate on wireless multi-hop networks. One of the important and interesting techniques for wireless multi-hop networks is multi-path routing. By using multi-path routing [5]-[7], multiple routes can be established from a source node to a destination node. By attending this characteristic, we proposed the error correcting scheme which achieve a diversity gain by combining multiple copies of the same packet that are transmitted along different routes [8]. However, the proposed scheme can be assumed repetition code for multiple routes because of multiple copies of the same packets are transmitted.

In this paper, we propose the error correcting scheme in which the coded different packets are transmitted using multiple routes on wireless multi-hop networks. Hence, we can achieve a coding gain for multiple routes and expect the improvement of performance. In the proposed scheme, we assume that N routes are established by multi-path routing. An information sequence is encoded by turbo code, divided into N sequences at the scrambler and transmitted from the source node to destination node by N routes. The destination node decoded the received packet by SOVA(Soft Output Viterbi Algorithm) [9].

In wireless multi-hop networks, moreover, the route loss due to topological change or recognizing failure may happen. In [10], a path availability model for wireless ad hoc networks was proposed. The route loss does not become a problem so much when the multiple copies of a packet are transmitted. But, in the proposed scheme, the route loss results in reducing a part of coded information. If the route loss is regarded as puncture of code sequence, we can expect the tolerance over route loss by using turbo code. The turbo code could achieve low bit error rate in the case that coded sequence is punctured. From the above discussion, we evaluate the proposed scheme by packet error rate in consideration of the influence of the route loss due to topological change or recognizing failure.

In section 2, we describe the wireless multi-hop network model. In section 3, the proposed transmitter and receiver structure are described. We evaluate the system performance and discuss the results in Section 4.

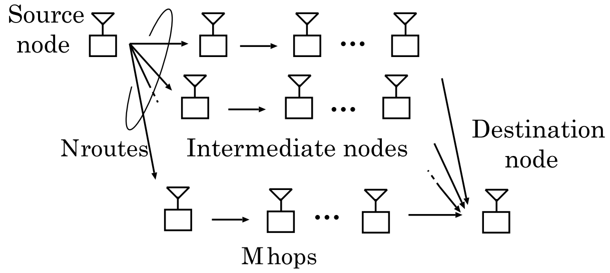

Figure 1: Model of wireless multi-hop network.

Finally some conclusions are presented in Section 5.

2. Wireless Multi-hop Network Model

Figure 1 shows the wireless multi-hop network model. The network consists of the wireless links between the wireless nodes which can be communicated directly. In this model, N routes are established by the multi-path routing. Information sequences are transmitted from a source node to the next intermediate nodes using N routes. The intermediate nodes perform regenerating relay when a node forwards a sub-packet to a next intermediate node. Note that, the intermediate node does not perform error correcting or error detecting. This can mitigate the load of the intermediate node. Finally, information sequences are received at a destination node.

In this network model, for simplification, the number of hops M is equal to each node.

3. Proposed System

3.1. Transmitter Structure

Figure 2 shows transmitter structure of the source node. The transmitter consists of a turbo encoder, a scrambler, a buffer, and a modulator. A turbo encoder which has two RSC(Recursive Systematic Convolutional)encoder is shown in Figure 3. A transmitted information sequence $d(i) \in \{+1, -1\}$ is encoded by turbo encoder, where i is the ith bit of data length L. Encoded sequence is divided into message sequence $c_m(i)$, parity sequence #1 $c_{p1}(i)$, and parity sequence #2 $c_{p2}(i)$ of systematic code. Then, those sequences are inputted into the scrambler. It scrambles the inputted sequences and generates N sequences(called sub-packet) $b_n(i)$, where n is nth route of N routes. The length of sub-packet is $\frac{3 \cdot L}{N}$ because the data length is L and code rate is 1/3. Every sub packet $b_n(i)$ is modulated and transmitted via nth route.

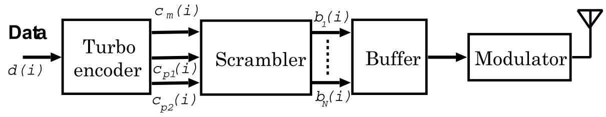

Figure 2: Transmitter structure.

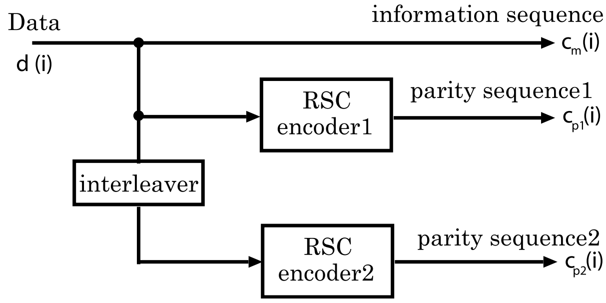

Figure 3: Turbo encoder.

3.2. Receiver Structure

The receiver structure of the destination node is shown in Figure 4. The receiver consists of a demodulator, a threshold device, a buffer, a descrambler, and SOVA decoder. In the destination node, the received sub-packet via nth route is demodulated and decided by the threshold device into the hard-valued sequence $\hat{b}_n(i)$. It is stored at the buffer. After receiving all N sub-packets, the stored sequences are fed into the descrambler. The descrambler outputs three sequences of systematic code $\hat{c}_m(i)$, $\hat{c}_{p1}(i)$, and $\hat{c}_{p2}(i)$. Those sequences are decoded to the decided data sequence $\hat{d}(i)$ by the SOVA decoder.

4. Performance Evaluation

In this section, we evaluate the performance of the proposed system with packet error rate. The packet error rate is the probability that the data sequence $\hat{d}(i)$ is including the error.

4.1. Simulation Conditions

The system performance of the proposed scheme is evaluated by Monte Carlo simulation. The operating parameters are shown in Table 1. The rate of turbo code is 1/3. The constituent encoders of turbo code are RSC code with memory $m = 4$, and the polynomials of those feedback and feed-forward generator are 37_8 and 21_8, respectively. The interleaver in the encoder is the random interleaver with interleaver size 1000. The decoder of turbo code is SOVA, and the number of decoding iterations is 5. The length of transmitted data

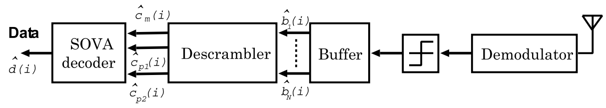

Figure 4: Receiver structure.

Table 1: System and simulation parameters.

Data length L	1000 bits
Modulation scheme	BPSK
Encoder scheme	Turbo code
Code rate	1/3
Constraint length	5
Decoder	SOVA, 5 iterations
Number of hops M	2 hops
Number of routes N	$1, 3, 6$

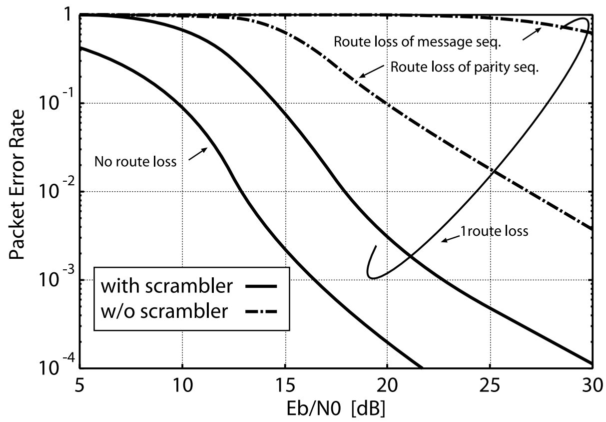

Figure 5: Packet error rate versus E_b/N_0 for $N = 3$ (fast Rayleigh fading).

sequence L is 1000 bits, and the sequence is divided into N sub-packets which include $\frac{3000}{N}$ bits. The number of routes N is 1,3,6. When the number of routes N is 3, scramble algorithm is,

$$b_1(i) = [c_m(1), c_{p2}(2), c_{p1}(3), c_m(4), \cdots]$$
$$b_2(i) = [c_{p1}(1), c_m(2), c_{p2}(3), c_{p1}(4), \cdots]$$
$$b_3(i) = [c_{p2}(1), c_{p1}(2), c_m(3), c_{p2}(4), \cdots].$$

By this scrambling, each sub-packet can hold the equal number of message sequence $c_m(i)$ and parity sequence $c_{p1}(i)$, $c_{p2}(i)$. When the number of routes N is 6, the scramble algorithm is equivalent to $N = 3$. The number of hops is $M = 2$.

We assume that each wireless link is Rayleigh fading channel. In this paper, we evaluate the system performance with two kinds of Rayleigh fading; fast and slow Rayleigh fading. In the fast Rayleigh fading environment, the amplitude differs for every bit. In the slow Rayleigh fading environment, the fading amplitude differs for every sub-packet. So the sub-packet transmitted via each route has the different received power. By using these fadings, we evaluate the tolerance of the bit error in the channel.

As described in Section 1, in wireless multi-hop networks, we can consider that the route loss due to topological change or recognizing failure may be happened and the destination node cannot receive the sub-packets. In this case, we assume that the value of received bits is 0.

4.2. Numerical Results

4.2.1. Under the environment of fast Rayleigh fading

Figures 5–7 show the system performance under the environment of fast Rayleigh fading, where E_b is the energy per bit and $N_0/2$ is two side power spectral density.

Figure 5 shows packet error rate for $N = 3$. So as to evaluate the influence of route loss, the packet error rate curves with and without route loss are shown. Furthermore, we consider the case with and without the scrambler. In the case without the scrambler, $c_m(i)$, $c_{p1}(i)$, and $c_{p2}(i)$ are transmitted as sub-packet. We attend to the case of 1 route loss. In the case of losing the message sub-packet, even if E_b/N_0 becomes large, the packet can be hardly received correctly at the destination node. In the case of losing the parity sub-packet, comparing with the case of losing the message sub-packet, packet error rate performance is improved considerably. Clearly, this means that the message sequence of systematic code is more important than parity sequence. Furthermore, when the scrambler is employed, packet error rate performance is better than the cases without scrambler. As this reason, the scrambler works like an interleaver and distributes the coded bits (both message and parity) over the different routes. Therefore, iterative decoding, which is the feature of turbo code, works more effective than that without the scrambler.

From the above discussion, we evaluate the effect of iterative decoding for with and without scrambler. Figure 6 shows the packet error rate versus the number of iteration when E_b/N_0 is fixed by $20dB$. In the case of without scrambler, even if decoding iteration becomes large, the packet error rate is kept at almost constant value. In contrast, with scrambler, we can observe that the packet error rate improves by increasing the number of decoding iteration. It proves that the effect of

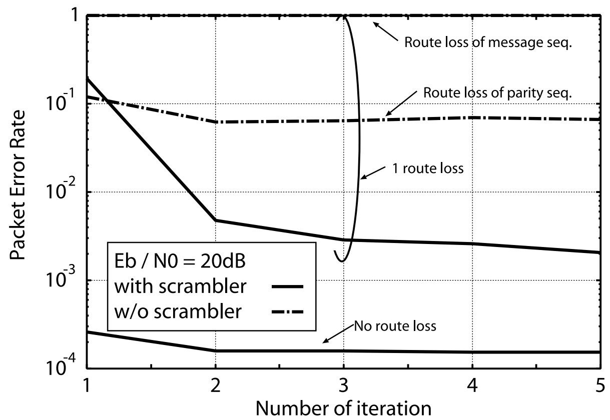

Figure 6: Packet error rate versus the number of iteration for $N = 3$ (fast Rayleigh fading).

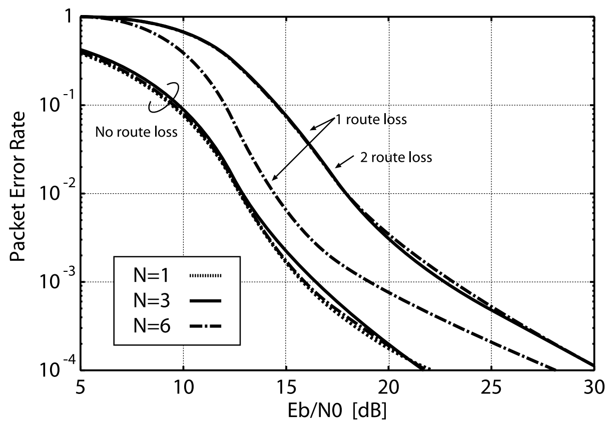

Figure 7: Packet error rate versus E_b/N_0 as a parameter of the number of routes (fast Rayleigh fading).

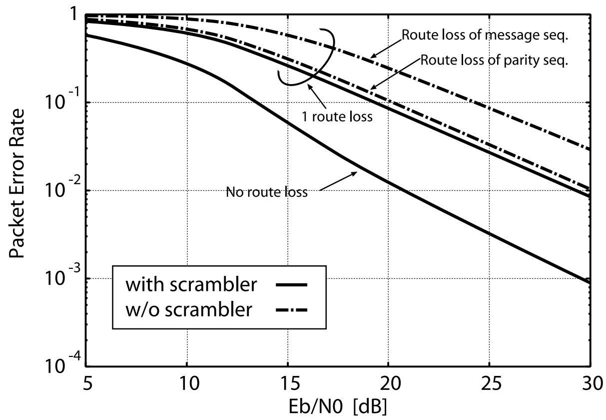

Figure 8: Packet error rate versus E_b/N_0 for $N = 3$ (slow Rayleigh fading).

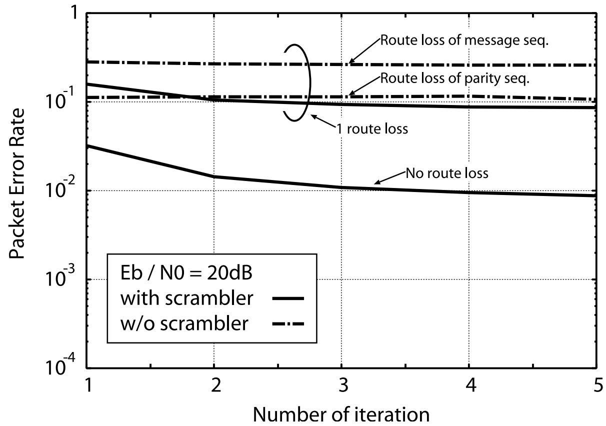

Figure 9: Packet error rate versus the number of iteration for $N = 3$ (slow Rayleigh fading).

iterative decoding can be obtained by using scrambler. The scrambler can reduce the effect of the route loss.

Figure 7 shows the packet error rate versus E_b/N_0 as a parameter of the number of routes $N = 1, 3, 6$. In the case of receiving all sub-packets at the destination node without losing the routes, the performances of the packet error rate for $N = 3$ and $N = 6$ are the same. This means that the packet error rate is independent of the number of the routes, because each bit in the sub-packet suffers the influence of fading independently under the environment of fast Rayleigh fading. The packet error rate of losing 1 route for $N = 3$ and that of with losing 2 routes for $N = 6$ are also equal. This because the number of losing bits is equal both cases. Transmitting routes $N = 6$ is superior to that of the number of transmitting routes $N = 3$.

4.2.2. Under the environment of slow Rayleigh fading

Figures 8–10 show the system performance under the environment of slow Rayleigh fading.

Figure 8 shows packet error rate for $N = 3$. This figure shows the packet error rate curves with and without the route loss and also shows those with and without scrambler. As we attend to the case of 1 route loss, all packet error rate curves are almost the same. This means that the effect of the scrambler is not obtained so much. That is, we can consider that the effect of iterative decoding cannot be obtained by using scrambler.

Figure 9 shows the packet error rate versus decoding iteration when E_b/N_0 is fixed by $20dB$. This figure shows that all packet error rate curves can be hardly improved even if the number of decoding iteration becomes large. Therefore, under the environment of slow Rayleigh fading, the advantage of decoding iteration can be hardly obtained.

Figure 10 shows the packet error rate versus E_b/N_0 as a parameter of the number of routes. We can ob-

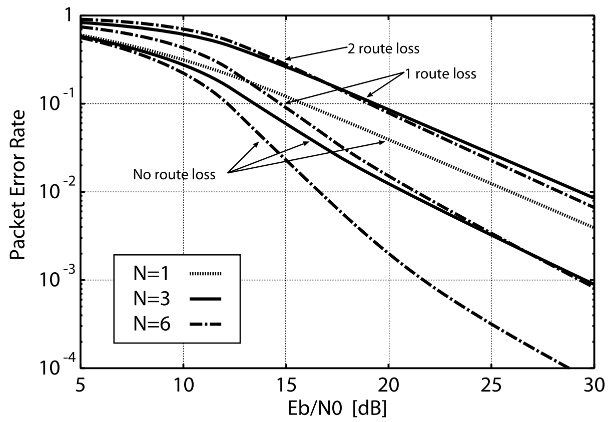

Figure 10: Packet error rate versus E_b/N_0 as a parameter of the number of routes (slow Rayleigh fading).

serve that the packet error rate curves without route loss are improved so that the number of transmitting routes increases. This means that the diversity gain becomes large by increasing transmitting routes. The packet error rate of losing 1 route for $N = 3$ and that of with losing 2 routes for $N = 6$ are almost the same. This is because the number of losing bits is equal both cases. We can observe that the packet error rate without route loss for $N = 3$ and that with losing 1 route for $N = 6$ are almost equal. This means that proposed scheme can complement the route loss by increasing transmitting routes.

5. Conclusions

In this paper, we have proposed the error correcting scheme in which the coded different packets are transmitted using multiple routes on wireless multi-hop networks. Furthermore, we consider the influence of route loss due to topological change or recognizing failure. In the proposed scheme, the route loss results in reducing a part of coded information because of transmitting a part of coded information to each route. We evaluate the proposed scheme by packet error rate in consideration of the influence of the route loss. Under the environment of fast Rayleigh fading, the packet error rate is improved by using scrambler. When the scrambler is employed, the advantage of decoding iteration can be obtained. By using multiple routes, tolerance over route loss can be given by the proposed scheme. Under the environment of slow Rayleigh fading, as increasing the transmitting routes, the packet error rate curve can be improved. Different from fast Rayleigh fading, the scrambler does not improve the packet error rate performance.

Acknowledgments

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