PROGRAM

ADVANCED INNOVATION TECHNOLOGY 2026

January 12(Mon)—15(Thu), 2026
Sala Danang Beach Hotel, Vietnam

Organized by KIIS & KSPM

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AI-Based Relay Node Number Estimation Algorithm

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Abstract
In this paper, we propose an artificial intelligence–based approach for estimating the number of participating relay nodes in a barrage relay–based communication environment, using only the statistical characteristics of the received power distribution, without requiring individual relay identification or channel state information.
Simulation results demonstrate that the proposed method can effectively estimate the number of relay nodes in barrage relay scenarios, and further show that it provides meaningful performance even in environments where conventional deterministic estimation techniques are difficult to apply.

Keywords: Barrage relay, artificial intelligence, random phase, received power distribution

1. Introduction

Barrage relay–based communication is a ground tactical communication technique designed for environments where establishing a centralized communication infrastructure, such as a base station, is impractical. In this approach, relay nodes act as forwarding nodes rather than final destinations and retransmit the same signal toward the intended receiver. As a result, the destination node receives a superposition of signals transmitted by multiple relay nodes.
Due to relative timing differences among the received signals, constructive or destructive interference may occur at the receiver. To mitigate packet-level signal cancellation caused by such interference, each relay node divides a packet into multiple time slots and applies a random phase to the transmitted signal in each time slot. In this environment, since multiple relay nodes simultaneously transmit identical signals toward the same destination, it becomes challenging for the receiver to identify the presence or accurately determine the number of individual relay nodes

2. Proposed Work

In this paper, we propose an artificial intelligence–based approach for estimating the number of relay nodes participating in communication by exploiting the distribution of the received power. The proposed method is motivated by the observation that the statistical distribution of the received power exhibits distinct patterns depending on the number of active relay nodes. By learning these distributional characteristics as input features, the trained model estimates the number of relay nodes involved in communication. Consequently, the proposed approach enables relay node count estimation in a barrage relay communication environment using only power information observable at the receiver, without requiring individual relay identification or channel state information.
Fig. 1 illustrates the overall structure of the proposed AI-based relay node number estimation framework. A one-dimensional signal representing the distribution of the received power is used as the input, and the number of relay nodes participating in communication is produced as the output.
Fig. 2 presents the relay node number estimation performance of the proposed method. According to the simulation results, the proposed AI model achieves an average accuracy of approximately 76%in predicting the number of relay nodes. The classification performance for

each node count is summarized as follows.
In the case of single-node communication, the power distribution is clearly distinguishable from those of other node counts, resulting in near-perfect accuracy across all SNR levels. For two-node communication, the classification accuracy improves as the SNR increases; however, the performance saturates beyond approximately 5 dB, maintaining a nearly constant accuracy. In contrast, for three-node communication, the power distribution at low SNR levels is similar to that of the two-node case, leading to degraded classification performance. As the SNR increases, however, the model learns distributional features that distinguish the three-node case from the two-node case, resulting in a consistent improvement in estimation accuracy.

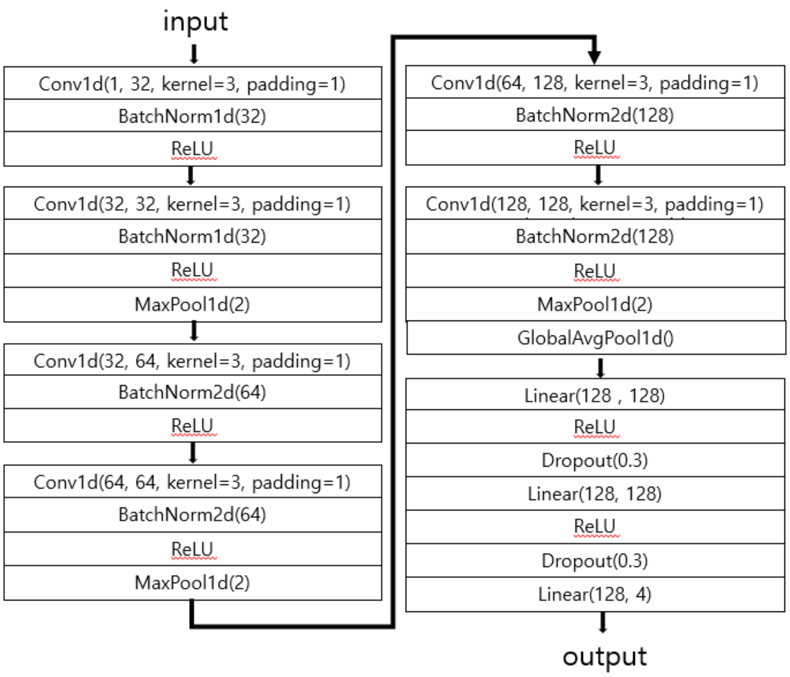

Fig. 1. Proposed Artificial Intelligence Architecture

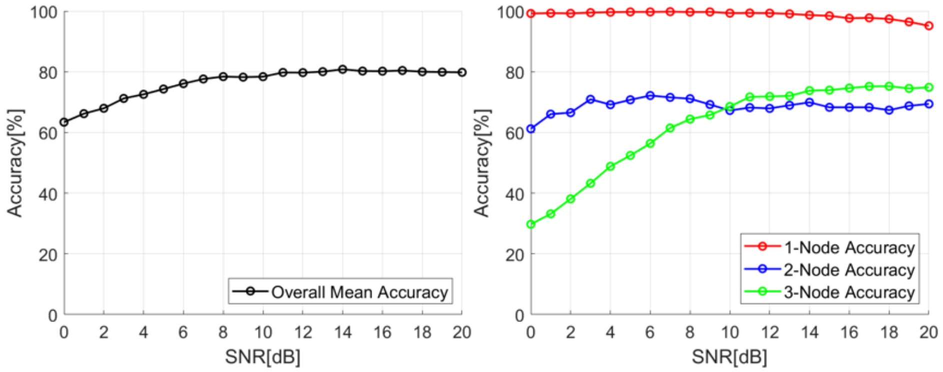

Fig 2. Relay Node Number Estimation Accuracy of the AI-Based Method

3. Conclusion

In this study, we proposed an artificial intelligence–based technique for estimating the number of relay nodes participating in communication in a barrage relay–based communication environment, using only the distributional characteristics of the received power. The primary objective of this work is to enable relay node number estimation solely from power information observable at the receiver, without requiring individual relay identification or channel state information.
Motivated by the observation that the statistical distribution of the received power exhibits distinct patterns depending on the number of active relay nodes, we developed an AI model that learns these distributional features as input representations. Simulation results demonstrate that the

proposed method can effectively estimate the number of relay nodes in barrage relay scenarios. Furthermore, the results indicate that the proposed approach provides meaningful performance even in environments where conventional deterministic estimation methods based on analytical models or thresholding are difficult to apply.

4. References

[1] H. Y. Heo, M. A. Lee, and E. R. Jeong, "OFDM relaying using phase rotation in broadband systems," Proceedings of the Korean Institute of Communications and Information Sciences Conference, Republic of Korea, Feb. 2023, pp. 644-645.
[2] Y. R. Heo, M. A. Lee, and E. R. Jeong, "OFDM relaying using phase rotation in broadband systems," Proceedings of the Korean Institute of Communications and Information Sciences Conference, Republic of Korea, 2023, pp.1686-1687.