IAB-based Railway Communication Method for Stable Service Provision

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Abstract **LTE-R (Long Term Evolution Railway) communication problems occur due to high-speed trains, structures around railway tracks, and tunnels. To solve this problem, various studies such as dual system construction and multi-pass are being conducted. However, problems such as cost increase and the occurrence of blockage areas remain issues to be resolved. To solve this problem, in this paper, we intend to apply the IAB (Integrated Access and Backhaul) technology discussed in The 3rd Generation Partnership Project (3GPP) standard to the railway wireless communication network. By installing an IAB node in an area where communication failure is expected, it is possible to provide a stable train communication environment by supplementing the communication failure problem through relay communication between the train and the IAB node.**

Keywords— *NR IAB, V2X Relay, Railway radio communication, Service continuity*

I. INTRODUCTION

Long Term Evolution Railway (LTE-R) constructed by allocating a dedicated railway frequency to LTE technology, in a high-speed train and railroad environment, various studies are being conducted to stably provide the services that passengers in the cabin receive through the LTE-R network as well as control information between the train cab radio and onboard device and the control center. Due to the characteristics of a train moving at high speed, Radio link failure (RLF) occurs as a result of increased service delay due to frequent handovers, a sound range due to tunnel passage, and weakening of signal strength due to surrounding structures, thereby reducing the quality of service [1]. To this end, many organizations are analyzing the cause and looking for ways to solve it. In this regard, a recent 3GPP standards organization is researching a relay technology that enables coverage expansion and constructs a communication network at low cost without adding infrastructure for constructing a backhaul. If this relay technology is properly applied to the LTE-R network to solve the problem of deteriorating service quality, it is expected to provide stable and high-quality service. The rest of this paper is organized as follows. Section II investigates related works and motivation, and section III presents the proposed method in this paper. Section IV introduces the proposed method simulation. The conclusion is given in section V.

II. RELATED WORK

This chapter describes Relay and IAB technologies, which are work items of 3GPP standards organizations.

A. A new Medium Access Control (MAC) protocol

To ensure energy efficiency within resource-limited networks, the new MAC protocol dynamically adjusts the transmission order and transmission duration of nodes. The slot allocation is optimized by minimizing energy consumption of the nodes, subject to the delivery probability and throughput constraints [2].

B. 3GPP Relay Standard trend

Relay technology has been in progress since 3GPP LTE Release 10. The disconnected terminal searches for a neighboring terminal accesses the terminals through an access link and performs backhaul communication with the base station. It was considered as a maximum of two fixed hops, and various items such as backhaul, access link operation, control channel design, and channel synchronization are being studied [3]. In 5G NR (New Radio), the relay specification started in Release 15 and is currently in progress in Release 17. Standardized items for Release 17 are MIMO enhancements, IAB enhancements, Sidelink enhancements, Industrial IoT/URLLC enhancements, NR over NTN (Non-terrestrial networks), and Sidelink relay [4].

C. Integrated Access and Backhaul (IAB) technology

In general, network operators operate the network by constructing additional expensive equipment to expand the network or increase the capacity of the existing network. To solve this problem, in LTE, a relay technology that can be solved at a low cost has been introduced. As the evolution from LTE to NR, a multi-hop-based fixed wireless backhaul concept was added to define the IAB that supports data services through wireless access. IAB is researching various research items such as use cases and deployment scenarios, in-band/out-of-band backhaul, architecture, and topology application, L2/L3 relay application, and protocol layer issues [5].

III. PROPOSED METHODS

This chapter describes how to apply IAB technology to the LTE-R network. For service continuity, a technique that can complement the existing method is described by comparing the existing method with the method proposed in this paper.

A. IAB-based railway communication

The LTE-R network has a requirement to satisfy the requirements of high stability and reliability in railway communication such as task calls, emergency calls, and train control. Various studies are being conducted to improve these requirements. For example, when an error occurs in one device, the backup system is operated to recover the error by operating the spare device. Besides, the introduction of the multiplexing path method uses the Inter-RAT handover method, which frequency switching to the commercial LTE network when a failure occurs in LTE-R network [6][7].

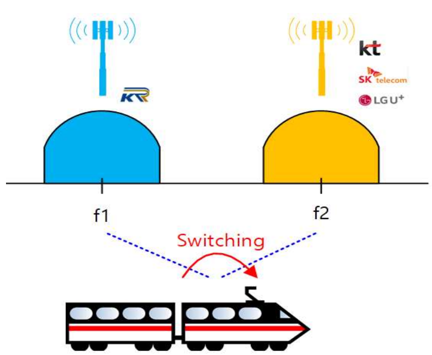

Figure1. Multiplexing path method

However, special environmental factors of railroad communication, such as high-speed trains, frequent tunnels, and elements that can cause blockage, such as structures around railroads, cause communication failures in the cab and service failures in the passenger compartment. It can cause several problems. To solve this problem, IAB is applied to the LTE-R network. The IAB node is installed in the region where both LTE-R and commercial LTE networks are weakly measured for radio wave reception. If it is determined that the radio wave reception state of the connected network is weak while the train is moving, it performs a connection for relay communication with the IAB node and can solve a failure occurring through relay communication between the IAB nodes.

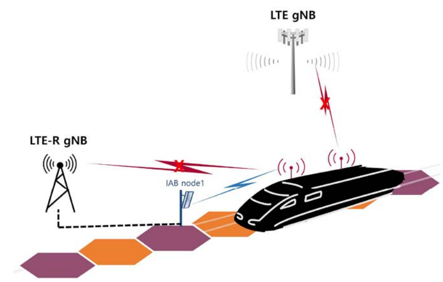

Figure2. Relay communication using IAB node

Figure 2 shows the connection to the IAB node when communication between the train and LTE-R and commercial LTE networks is disconnected.

IV. SIMULATION

The simulation environment is as follows. The radio wave environment was actually measured in the section of the KTX Gangneung Line (Manjong-Gangneung) where the LTE-R network was constructed, and the simulation was performed by applying the measurement result to the OPNET simulation environment. A total of 9 LTE-R base stations were constructed at intervals of 1km, and commercial LTE base stations were constructed at intervals of 500m. The train speed was set to 350km/h and 250km/h. As a result of radio wave measurement, three base stations with the highest handover failure rate and RLF occurrence rate were selected, and IAB nodes 1, 2, 3 were constructed in the selected area. A total of 100 simulations were performed for each 350km/h and 250km/h, and it was verified that service continuity is guaranteed by relay communication through the IAB node when RLF occurs.

Figure3. Relay communication using IAB node

Figure 3 shows the OPNET simulation environment. The simulation result is analyzed by comparing the service continuity index before applying the relay and the service continuity index after applying the relay. The formula representing service continuity is as follows.

$$Service\ Continuity = \frac{Hs - Rt}{\mathrm{Ht}} + \frac{Tr - Rf}{\mathrm{Ht}}$$

Ht is the total number of handovers, Hs is the number of successful handovers, Rt is the number of RLFs, Tr is the total number of RLFs, and Rf is the number of recoveries. The results below show the service continuity results in two situations. The first is the result of not applying the IAB, and the second is the result of applying the IAB proposed in the paper. Each point represents the average of 10 attempts.

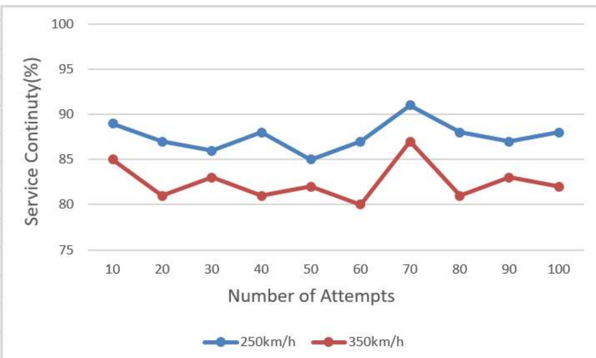

Figure4. Service continuity without IAB applied

The handover failure rate was higher at 250 km/h than 350 km/h. As the speed increases, the handover failure rate is expected to increase.

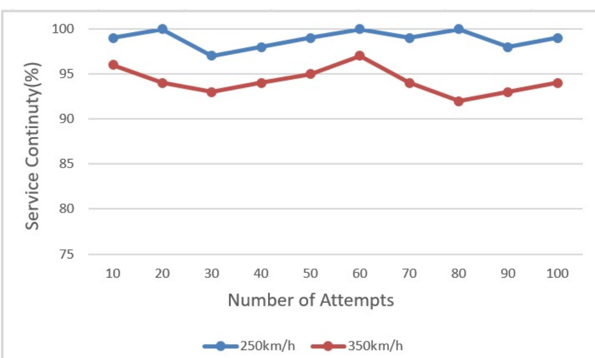

Figure5. Service continuity with IAB applied

As a result of applying IAB, it was confirmed that the performance was better, and this result also confirmed that the higher the speed, the lower the performance.

V. CONCLUSION

In the LTE-R network where reliability and stability are required, when handover failure and service disconnection due to RLF occurs, it is confirmed through simulation that continuous service can be provided if relay communication through the IAB node is applied to railway communication. In future studies, we consider scenarios that can cause more various communication failures, such as structures around railroads, seasonal environment changes, temperature, and crossover between trains, as well as handover failure and RLF cases. So, it should be able to provide service continuity by installing the IAB node in an appropriate area. Besides, due to the characteristics of a train moving at high speed, and optimization study between the train and the IAB node should be conducted to compensate for handover failure and service disconnection.

ACKNOWLEDGMENT

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