비동기 측정 데이터를 위한 CDF 기반의 스펙트럼 효율 측정 방법론

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CDF-Based Spectral Efficiency Estimation Methodology From Asynchronous Measurement Data

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요 약

This paper studies the estimation methodologies of the mapping between the Signal-to-Interference-plus-Noise Ratio (SINR) and the spectral efficiency (SE) of the currently deployed 5G communication systems. Specifically, SINR is measured and recorded at the measurement device through observing periodic reference signals while the SE is calculated from the data transmitted and the resource assigned by the gNodeB. Consequently, their recording times are inevitably asynchronous which introduces difficulties in defining SINR-SE mapping. To compensate for this shortcoming, we introduce the Cumulative Distribution Function (CDF) mapping method based on the characteristics of SINR and SE values. Through this methodology, we aim to gain a better understanding and estimation of the spectrum efficiency of gNodeBs in 5G networks and provide a more comprehensive understanding and optimization of real-world network performance.

Ⅰ. Introduction

5G networks are among the most widely applied wireless communication technologies with key features, including high data rates, lower latency, and support for more simultaneous connections [1]. While developing new application technologies greatly enhances the service quality of 5G networks, testing and analyzing network performance in real-world scenarios is equally crucial.

For downlink (DL) transmission, the spectral efficiency (SE) supported by a gNodeB is a crucial metric. It is closely related to the gNodeB's modulation method, transmission scheme, the users' channel condition, and the user's reception technology. Among those, the relationship between the channel condition and the corresponding data rate is the main focus of the literature. 3GPP (3rd Generation Partnership Project) measures channel conditions primarily using parameters such as Signal-to-Interference-plus-Noise Ratio (SINR), Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Received Signal Strength Indicator (RSSI) [2]. Previous studies [3] and [4] analyzed the SINR-SE and RSRP-SE relationships, respectively.

When estimating the SINR-SE mapping from field measurements, the SINR is in general measured by the monitoring reference signals while SE values are calculated from the data transmissions assigned by the gNodeB. Form the viewpoint of the measurement device, the recording times for the SINR and SEs could be different. In other words, SINR and SE recording times are not entirely synchronized. In [4], the authors addressed this issue of asynchronous timing by selectively deleting data. In this paper, we propose an alternative approach to tackle this asynchronization problem.

Ⅱ. CDF-Based SINR-SE Mapping Estimation

The Cumulative Distribution Function (CDF) is a statistical tool used to describe the probability that a random variable (RV) takes a value less than or equal to a specific value. It also provides a comprehensive view of the distribution of a variable. Our methodology is based on CDF statistical properties of SINR and SE values.

Let Ω and Φ represent the measurement dataset of SINR and SE, respectively. Based on the dataset collected, the CDF of SINR and SE can be obtained as

$$F_X(x;\Omega) = P\{X \le x;\Omega\},$$
$$F_Y(y;\Phi) = P\{Y \le y;\Phi\},$$

where X and Y represent the RVs of SINR and SE, respectively.

Since it is a common agreement that a higher SE comes from a higher SINR, we can expect that the desired SINR-SE mapping is a non-decreasing function as

$$y = G(x).$$

It is expected that the difference between $F_Y(y;\Phi)$ and $F_Y\big(y;\mathrm{G}(\Omega)\big)$ is minimized if the bias of measurement data collection is small enough.

Suppose that there is a series of SINR values $x_1, x_2, \ldots, x_n$ with increasing order. The corresponding CDF value of the SINR series is $z_1, z_2, \ldots, z_n$. For a SINR value x_i with CDF value z_i, a corresponding SE y_i value can be found such that

$$F_X(x_i; \Omega) = F_Y(y_i; \Phi),$$

which leads the proposed relationship

$$y_i = F_Y^{-1}(F_X(x_i; \Omega); \Phi).$$

With this methodology, a series of SE $y_1, y_2, \ldots, y_n$ can be obtained. Therefore, an approximate relationship between SINR and SE, noted as G^*, can be derived from the obtained set of SINR-SE pairs $\{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$. In practice, the original G function is not known, but an approximate G^* function can be derived from these measured data.

Ⅲ. Experiment Result

We utilized Diagnostic Monitor Logger (DML) and Diagnostic Monitor Analyzer (DMA) of Spiretech to measure the 5G real-time mobile traffic in Gangnam of Seoul for the three major network operators in South Korea. Then, the SINR-SE mapping obtained with our proposed methodology is presented in the following figure.

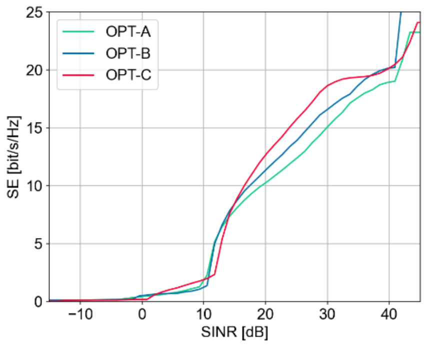

Figure 1. 5G SINR-SE mapping results from measured data in Gangnam area, Seoul.

IV. Conclusion

In this paper, we developed a novel CDF mapping method for SE estimation based on measurement data. This approach overcomes the drawback of relying on time-synchronized data for estimation. By leveraging the CDF statistical characteristics of SINR and SE values, the proposed method enhances the understanding and predictive capabilities of SE in 5G networks.

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