Minimum Required Size of RIS for DF Relay based on NOMA with Two Users

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두 사용자 NOMA 기반 DF 릴레이를 위한 RIS 의 최소요구크기

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Abstract

Reconfigurable intelligent surface (RIS) is one of the most promising techniques for ironing out the limited signal propagation of millimetre or Terahertz waves. Additionally, a communication system based on non-orthogonal multiple access (NOMA) technology can achieve optimal energy efficiency. In this paper, we compared the required transmitted power of the NOMA-RIS and NOMA-DF relay communication systems. Based on numerical results, we obtained the minimum number of RIS-reflecting elements needed to outperform the DF relay-assisted communication system.

Ⅰ. Introduction

The mobile communication network will support the thousandfold increase in communication capacity and ubiquitous connectivity for the next decade. Therefore, governments have been accelerating the construction of 5G networks and new infrastructures around the world. Meanwhile, the demand for new services, such as holographic communications and interactive immersive experiences, on communication bandwidth and data rate has been rapidly expanding [1]. It is necessary to develop high-frequency band resources to satisfy a higher data rate. Millimetre waves, Terahertz waves, and even visible light have become an inevitable trend for beyond 5G (B5G) and 6G communication networks as a consequence. However, their fatal weaknesses are the high path loss and the small coverage. Reconfigurable intelligent surface (RIS) is one of the technologies to solve this problem. RIS controls the metamaterial elements via a programmable device to achieve a change in the direction of signal propagation.

Additionally, to improve spectrum efficiency, non-orthogonal multiple access (NOMA) technology is developed. It is noteworthy that the subchannel transmission still adopts orthogonal frequency division multiplexing (OFDM) technology in NOMA. However, a single subchannel is no longer assigned to one user but instead shared by multiple users [2]. Data can be transmitted between users in the same time slot, on the same frequency point, and distinguished by the different power. NOMA thereby becomes one of the leading technology trends for B5G and 6G.

Currently, the decode-and-forward (DF) relay is mainly used to extend cell coverage [3]. Hence, in this paper, we make a comparison between communication systems based on NOMA with RIS and with DF relay. It is aimed to obtain the minimum number of RIS elements to outperform the DF relay.

Ⅱ. Simulation

1. Basic Scenario

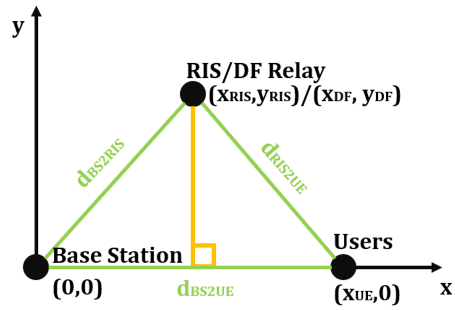


Fig.1 Coordination of the communication scenario.

We start by considering the location of the base station as the origin of the two-dimension coordinate system, whereas the NOMA cluster is distributed on the same side. Consequently, the conventional direct channel lies on the x-axis, and its distance is denoted by d_{BS2UE}. Due to the obstruction, the direct channel is assumed to be a non-line-of-sight (NLOS) channel. The locations of the RIS and DF relay are indicated by (x_{RIS}, y_{RIS}) and (x_{DF}, y_{DF}), respectively. The incident and reflected channels are both considered line-of-sight channels.

2. Parameters Setting

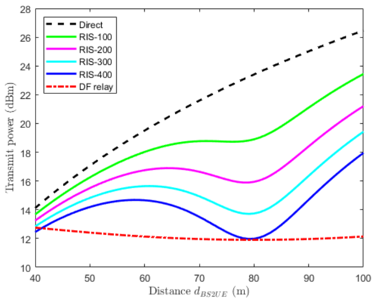
This paper considers the 5G downlink in the urban scenario where the NOMA cluster only contains two users. The 5G parameters of Korean operator LG Uplus are used in the simulation, which a frequency ranging from 3.42 to 3.5 GHz and the channel bandwidth is 80 MHz [4].

According to our previous work, the optimal placement of RIS is 80 m away from the base station on the x-axis [5]. The simulation is used by specifying the parameters shown in Table 1. Significantly, since the reflecting element of RIS cannot amplify signals, the conservative estimate of the gain of the reflecting element is 0 dBi.

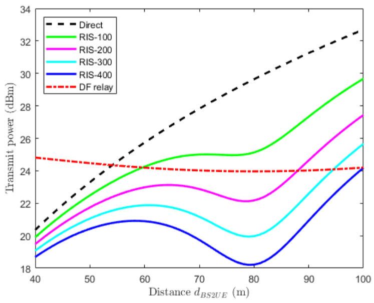
Table 1 Simulation Parameters [6]

Parameters	Value [Units]
Number of Reflecting Elements	100, 200, 300, 400
Achievable Rate	4, 6 [bit/s/Hz]
RIS Element Gain	0 [dBi]
DF Relay Gain	5 [dBi]
Base Station Antenna Gain	5 [dBi]
UE Antenna Gain	5 [dBi]

Ⅲ. Numerical Results



(a) Achievable data rate = 4 bit/s/Hz



(b) Achievable data rate = 6 bit/s/Hz

Fig.2 The transmitted power.

We investigate how the transmitted power varies that is needed to achieve the rate of 4 bit/s/Hz and 6 bit/s/Hz. In this figure, the black dotted line is the result of the communication system without RIS or relay, the red dash-dotted line is the result considering DF relay, and the solid lines exhibit the results of considering RIS, which is with 100, 200, 300, and 400 reflecting elements, respectively.

As shown in Fig. 2 (a), it is found that the required transmitted power of the conventional direct channel is always the highest. The reverse applies to the case of considering the DF relay; the required transmitted power is always at the lowest. For the communication system with RIS, the required transmitted power decreases as the number of reflecting elements increases. After simulation, we obtained that 412 reflecting elements at least should be used in RIS to outperform the communication system with DF relay during d_{BS2UE} = 80 m when the data rate is achieved to 4 bit/s/Hz.

Regarding the data rate being 6 bit/s/Hz, as can be seen in Fig.2 (b), the required transmitted power of considering the DF relay no longer stays at the lowest. Only the distance between the NOMA cluster and the base station is larger than 54 m; the required transmitted power in the case of the relay is lower than in the case of a conventional direct channel. This is due to the limitation of half-duplex transmission. Meanwhile, during the dBS2UE lower than 60 m, the performance of considering RIS is superior to the case of the DF relay. It is found that the communication system with RIS requires at least 136 reflecting elements to go beyond that with the DF relay.

Ⅳ. Conclusion

This paper investigates the required transmitted power with a RIS-assisted and DF relay-assisted NOMA communication system in the urban scenario with two users. For the data rate achieved to 4 bit/s/Hz, the required transmitted power of the DF relay-assisted communication system is the lowest all the time. As the achievable data rate increases, RIS is preferable to cooperate in communication compared to the DF relay. RIS-assisted communication system requires a minimum of 412 reflecting elements to outperform the DF relay-assisted communication system during the achievable data rate is 4 bit/s/Hz, whereas it only needs 136 reflecting elements when the achievable data rate is increased by 6 bit/s/Hz.

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