최적 재구성 가능한 지능형 표면 배치에 관한 연구

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A Study on the Optimal Reconfigurable Intelligent Surfaces Placement

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Abstract

In the near future, a millimetre wave or Terahertz wave is expected to be widely used. Due to their limited signal propagation distance, it causes a high energy consumption and expense for next-generation communication system construction. Reconfigurable intelligent surface (RIS) is one of the most promising techniques for ironing out these issues. This paper addresses a communication scenario with RIS based on the 5G specification released by 3GPP and various simulation results to verify the optimal placement of RIS.

Ⅰ. Introduction

5G is rapidly expanding to provide needs in diverse areas, and many countries have begun researching 6G technology. According to the Shannon-Hartly theorem, raising the transmitted speed means either expanding the spectrum or improving the signal-to-noise ratio. However, the shorter wavelength brings poorer diffraction and shorter propagation distance. Therefore, 6G, the next generation of wireless communication, focuses on high energy efficiency. Reconfigurable Intelligent Surface (RIS), a nearly-passive surface, is definitely one of the most important technologies to solve this problem.

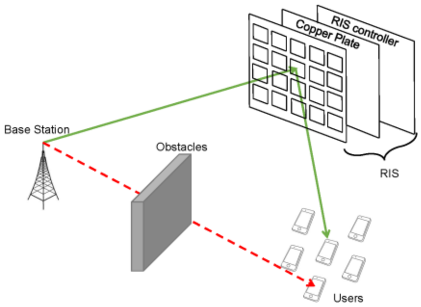


Fig.1 Typical RIS application and its structure.

Broadly speaking, the so-called RIS can achieve a controllable electromagnetic environment [1]. Fig.1 depicts the structure of a RIS. The outer layer of RIS consists of a large number of scattering elements in which each element is with several positive-intrinsic-negative (PIN) diodes and field effect transistors. The ON-OFF status of PIN diodes causes the signal phase change [2]. The following layer is a copper plate designed to prevent signal leaking. Finally, the RIS controller, usually a programmable device like FPGA, adjusts bias voltage to control the ON-OFF status of PIN diodes.

In this paper, we make a comparison between communication systems with RIS and without RIS. It is aimed at obtaining the optimal deployment and energy efficiency of RIS.

Ⅱ. Basic Scenarios and Parameters Setting

1. Basic Scenario

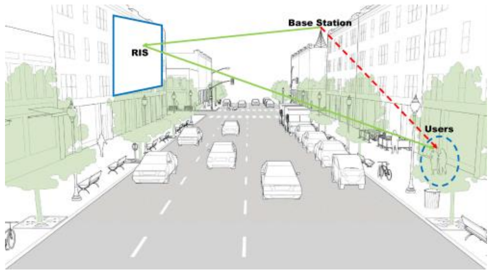


Fig.2 Basic scenario of RIS-assisted communication system.

We begin by introducing and describing details of the basic scenario of the RIS-assisted communication system depicted in Fig. 2. Users are assumed to be on the same side of the base station, while the RIS lean against a building across the road. When users stay directly opposite RIS, the distance of RIS2UE is precisely the width of the road which is also called the minimum distance between RIS and users [1].

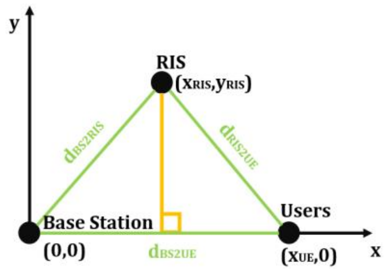


Fig.3 Coordination of the communication system.

Following the aforementioned communication model in Fig. 2, the two-dimensional coordinate system is established in the centre of the base station as the original point, and the distance of the conventional channel from the base station to users is indicated by d_{BS2UE} on the horizontal x-axis, as shown in Fig. 3. Additionally, the distances from the base station to the RIS and from the RIS to users are denoted by d_{BS2RIS} and d_{RIS2UE}, respectively.

In this paper, we consider a four-vehicle-lane road scenario in which the minimum width of a vehicle lane is 2.5m [3]. Hence the minimum distance between RIS and users, as highlighted in the yellow line in Fig. 3, is required to be 10 m which spells y_{RIS} is always valued at 10. Hereinafter, we investigate the RIS deployed at 40 m, 60 m, 80 m and 100 m (i.e., x_{RIS} is equal to 40, 60, 80 and 100, respectively) from the base station against the users distributed from 40 m to 100 m away from the base station. Therefore, x_{UE} is with an interval ranging from 40 to 100.

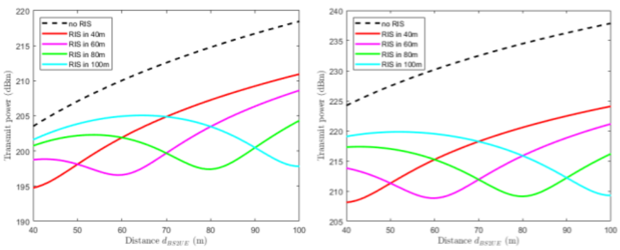
2. Parameters Setting

The simulation only considers the downlink in rural and urban scenarios where all users only receive signals through the transmission of RIS. We anticipate that the reflected signal is equal to the incident signal, i.e., the multiplication of the channel gains of RIS2UE and BS2RIS is equivalent to the conventional channel gain. The conventional channel is a non-line-of-sight (NLOS) channel due to the obstacles, while other channels are line-of-sight (LOS) channels [4]. The RIS is a square array with 64-by-64 reflecting elements. The simulation is used by specifying the parameters shown in Table 1.

Table 1 Simulation Parameters [5]-[7]

Parameters	Value [Units]
Carrier Frequency	30 [GHz]
Channel Bandwidth	100 [MHz]
Number of Reflecting Elements	4096
Peak Spectral Efficiency	30 [bit/s/Hz]
RIS Element Gain	5 [dBi]
Base Station Antenna Element Gain	8 [dBi]

Ⅲ. Numerical Results



(a) (b)

Fig. 4 The transmit power: (a) Rural, (b) Urban.

From Fig. 4 (a) and (b), we can observe that the transmit power declines as the users approach the RIS, and reaches the minimum when d_{BS2RIS} equals d_{BS2UE} on the x-axis. This is because the channel gain of RIS2UE increases as the signal transmission distance between RIS and users decreases. As shown in Fig. 4 (a), in the rural scenario, significant transmitted power savings (up to 9.5%) can be achieved compared to the case without RIS, where no RIS is a scenario where the signal is always carried out from the base station to UEs. The trends in the urban scenario illustrated in Fig. 4 (b) are relatively comparable to the rural scenario. With the communication system deployed with RIS, transmitted power savings of up to 12.1% can be achieved compared to the system without RIS. It is found that deploying RIS can realise a remarkable energy-saving effect regardless of the different scenarios. This justifies that the channels of BS2RIS and RIS2UE with NLOS propagation have low path loss compared to the direct transmission.

Compared to the numerical results of Fig. 4 (a) and (b), it is demonstrated that the urban scenario requires higher transmitted power. This is mainly due to the urban scenario having the characteristics of terrain complexity and plenty of build-up areas. The path loss of the urban scenario is the largest, consequently; it leads to the minimum channel gain. Nevertheless, deploying RIS in the urban scenario can make to maximise energy efficiency.

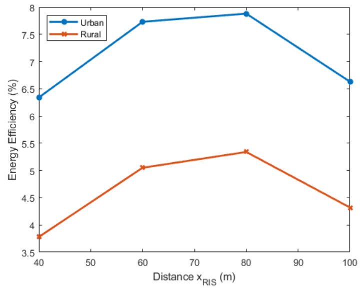


Fig. 5 Energy efficiency as a function of the RIS placement.

As shown in Fig. 5, for the rural scenario, deploying RIS can reach substantial energy savings of around 3.78%, 5.05%, 5.34% and 4.32% at 40m, 60m, 80m and 100m, respectively, away from the base station along the x-axis. Furthermore, it can also indispensably yield the energy-saving efficiency of 6.34%, 7.73%, 7.88% and 6.63%, respectively, in the urban scenario. These analytical results point out that 80m away from the base station on the x-axis is the optimal placement for deploying RIS since the energy-saving efficiency always stands at the maximum in both rural and urban scenarios.

Ⅳ. Conclusion

This paper investigates the required transmitted power with a RIS-deployed communication system in rural and urban scenarios. For the urban scenario, results show significant power savings of up to 12.1% compared to the system without RIS. However, during the rural scenario, the power savings dropped to 9.5%. After the data analysis, it is demonstrated that the ratio of fractional energy saving has been the highest when RIS is deployed at 80m away from the base station.

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