Performance Enhancement of Wireless Systems Using Hybrid RIS Technique

Shaik Karimullah, M. Lalitha, Mounika, S. Mahesh Reddy, S. Mahammad Waseem, and Shaik Mohammad Irfan

Abstract In this, we must characterize statistically and examine the performance of MRCIS—multiple reconfigurable intelligent surface-supported systems. We must first take into account that RIS through varied physical shapes are ordered distributively, the RISs' channels are supposed to be independent yet distributed non-identically, and the system experiences a fading environment. Using the two DMRIS-aided wireless methods, ERA and ORIS-aided, one can calculate the approximations for the OP-outage probability along with EC-ergodic capacity (ORA). In particular, we present a paradigm for putting into practice statistical end-to-end channel characterization. These schemes' end-to-end channel magnitudes can have either a LND—Log-Normal distribution or a GD—Gamma distribution. With these discoveries, we assess the tight approximation formulas for the OP and EC.

Keywords Reconfigurable intelligent surface · Hybrid RIS · Gamma distribution · Ergodic probability · Outage probability

1 Introduction

Reconfigurable intelligent surfaces (RISs) have been envisioned as a new wireless technology capable of dynamic, main objective control of radio signals between such as the transmitter and the receiver, effectively transforming the network resource into a service [1]. The reconfigurable intelligent surface (RIS) is a feasible method for creating future spectral and energy efficient, yet cost-effective wireless networks by cleverly changing the wireless propagation environment, which is typically thought to be random and uncontrollable. IRS can perform a variety of useful operations, such as three-dimensional (3D) passive beamforming, spatial interference nulling as

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well as cancelation, as well as other useful operations, by controlling signal reflection via a large number of low-cost passive elements [2].

The researchers propose a RIS selection method that selects the RIS with the maximum SNR to aid communication in order to achieve low-complexity transmission. The researchers suggest multi-RIS-aided systems both for inside and outside communications in situations in which a shortest link of both destination and source is not available [3]. Though small-scale diminishing was disregarded, effectiveness of the RIS choice technique remained not investigated. Authors investigated the three-dimensional throughput of multi-cell and single systems once multiple RISs remain used for the support of numerous users while attempting to argue with and interference or inter-cell–intra-cell [4]. Future wireless communication systems have been thought to benefit from the upcoming technology known as reconfigurable intelligent surface (RIS). These man-made surfaces have been decided to make of reconfigurable electromagnetic substances that can be exploited and programmed by interconnected electronic devices, potentially improving spectrum and energy efficiencies [5]. When compared to conventional relaying technology, RISs do not require as much expensive gear or overhead to operate. Additionally, RISs have the ability to modify the wireless environment by the utilization of almost reflecting components, giving system inventers complete control over the electromagnetic reaction of the interrupting signals to the surrounding objects [6].

Because of RISs, the definition "smart radio environments" seems to be currently under development. A smart radio environment is a wireless system in which the surroundings are transformed into a smart transportable space that actively engages in information transfer and processing. This is in contrast to today's wireless networks, in which the environment is beyond the operators' control. Smart radio environments essentially expand the concept of software networks. Future wireless networks, in particular, are rapidly evolving more toward a software dependent but also reconfigurable platform in which every element of the network can respond to environmental changes [7]. However, in this optimization process, the environment itself continues to be an unpredictable component because it is blind to the communication process taking place within it.

As a result of their distinct qualities, RISs become one of the fundamental technologies to achieve the futuristic vision of a smart radio environment. Reconfigurable intelligent surface (RIS), which is based on recent meta-materials' developments, is seen as a promising technology for wireless networks in the future, not only for its significant improvements in spectral and energy efficiency but also for its ultimate goal of smart propagation environment control. Particularly, an IRS is made up of inexpensive, essentially passive reflecting components that can change how electromagnetic waves interact with one another [8].

2   Literature Review

According to a review of the technical literature, RIS and RIS-assisted wireless systems have received a lot of attention in terms of design, demonstration, optimization, and analysis. As an illustration, the authors presented a RIS for indoor applications that uses 102 MSs and works at 2.47 GHz [9]. Similar to this, research writers described a RMS-reconfigurable MS with scattering, variable polarization, and focusing controls, and they provided intelligent walls that had frequency-selective MSs [10].

A MS that can rotate an electromagnetic wave that is linearly polarized by 90° has also been described, and a microwave-band MS that is extremely thin and based on phase discontinuities has been proposed [11]. Furthermore, a RIS design that has used varactor-tuned ring resonator to achieve configurable PS by vastly differing the slanted high voltage to the variable resistor was delivered and demonstrated its effectiveness. The final RIS element was RIS elements with PIN diodes attempting to control their EM response. An exponential growth uplink dynamical system making an analysis of RIS-assisted system applications was decided to carry out under Rician fading, but also basic optimization structures for maximizing received RF power throughout RIS-enabled wireless communication schemes were presented underneath the presence of optimization [12].

Additionally, designs for the best precoder which is linear, power distribution, and RIS phase matrix that made use of comprehensive statistics channel awareness and sought to maximize the least SINR present with base station stayed described [13]. Similar to this, the problem of maximizing the weighted sum rate of all users is formulated and solved by jointly optimizing the active precoding matrices at the base stations and the PSs in RIS-assisted multi-user wireless networks, while the joint intensification of the sum rate besides the energy efficiency remained examined for a multi-user downlink scenario [14]. In RIS-assisted systems, the simultaneous wireless information and power transfer optimization problem were also researched. Meanwhile, in a downlink multi-user situation, array antenna base station that can conduct digital beamforming interacts with a variety of users via a finite size [15].

3   Existing Method

The ORA and ERA schemes also utilize multiple RIS, were put out. The statistical characterization of the two methods was our main concern. In order to achieve this, we put up an accurate context to ascertain the circulation with e2e fading medium in each scheme. We go into further detail on the distinctions between the G—Gamma and LN—Log-Normal distributions. When the OP estimated using the G—Gamma and LN—Log-Normal circulations are compared and a slight discrepancy that may be insignificant. The difference at the left tail (the lower tail) of the two distributions, rigorously speaking, is the cause of this minor discrepancy in OP. Let $N(0, 1)$ stands
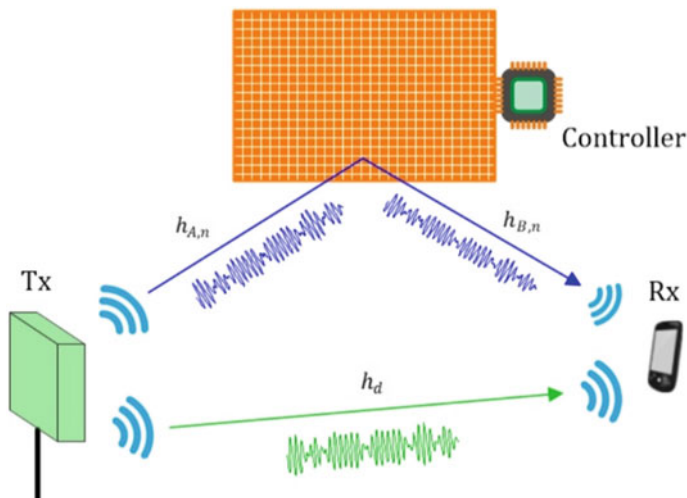
Fig. 1 RIS wireless systems

for a typical RV with a Gaussian distribution. A RV Y with PDF in has a mean given by $E[Y]$ and a variance VAR[Y] of, $Y \sim \alpha \beta 1 + N(0, 1) \sqrt{\alpha}, \alpha \to \infty$.

Both the OP and EC are significantly impacted by the quantity of passive elements deployed at RISs. The reason for this is that under fading medium, each RIS is susceptible to a variable level of fading severity, meaning that the shape and spread parameters of the Nakagami-m distributions between various RISs vary. The ORA procedure is more responsive than ERA system to get element in settings when analyzing performance variations between various element situations. For instance, the transition power of ERA process is required to adjust for the change from element setting L4 to L2, but the ORA scheme needs to compensate for 6.3 dBm to achieve the same OP (Fig. 1).

Because there are not many reflecting elements in total, the Gamma distribution approximation has lower DKL and DKS than LG—Log-Normal circulation approximation, suggesting that it gives greater precision than the LG—Log-Normal circulation. But when the sum of the reflecting elements is large enough, the Gamma and Log-Normal distributions offer equivalent approximation accuracy. The CDF and PDF of the Log-Normal Distribution are given as,

$$F_W(w; \nu, \zeta) = 1 w p 2\pi \zeta 2 e - (\ln w - \nu) 2\, 2\zeta 2$$

$$F_W(w; \nu, \zeta) = 12 + 12 \operatorname{erf} \ln w - \nu p 2\zeta\, 2!$$

The CDF and PDF of the Gamma Distribution are given as,

$$F_Y(y; \alpha, \beta) = \beta \alpha \Gamma(\alpha) y \alpha - 1 e - \beta y, \quad y \geq 0$$

$$FY(y; \alpha, \beta) = \gamma(\alpha, \beta y)\Gamma(\alpha), \ y \geq 0.$$

4 Proposed Method

We provide hybrid RIS systems, which may assess the theoretical foundation and enactment analysis of both ORA and ERA methods of e2e fading medium estimation with a rough distribution. The e2e channel estimation of RISA systems in both structures in relations of OP—outage probability and EC—ergodic capacity are also provided in this work. We may assess the mathematical foundation of the e2e fading channel and performance analysis by merging these two approaches. Ergodic capacity can be determined, and we can assess the effectiveness of these two systems in terms of outage probability. All RISs in the ERA scheme aid in transmission between the source and the destination. When compared to the ERA method, the ORA scheme can handle less reflecting signals.

We demonstrate that true circulation of the size of the e2e medium constant of the ERA structure can alternatively be approximated by the Log-Normal spreading, providing further insights into the fading model of the ERA system. We examine the derived approximation distribution's correctness. The justification between simulated genuine circulation and matched circulation is specifically used to assess the accurateness of the developed arithmetical model (Fig. 2).
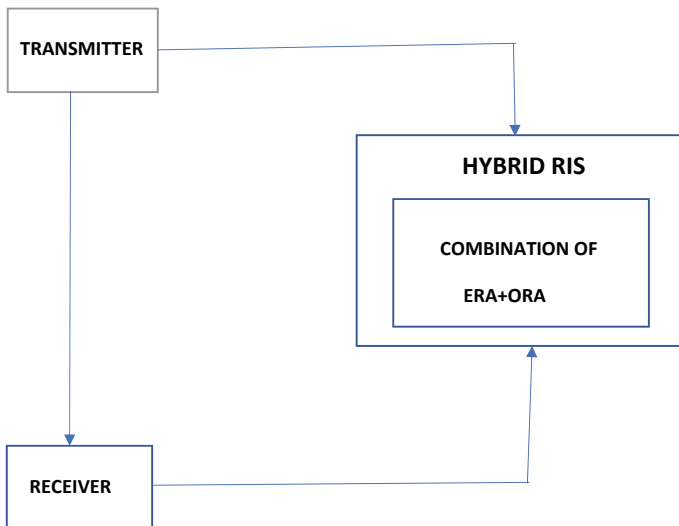

Fig. 2 Block diagram of hybrid RIS technique

4.1 Implementation

The entire analyses is carried out in PC with RAM 8 GB. The operating system used is Windows 10 with an Intel(R) Core i5-8250U CPU @ 1.60 GHz incorporated in it. It is 64 bit operating system. Entire analysis is carried out in MATLAB, which is latest version with more advanced tools. In this MATLAB, tools like communication tools are used.

5 Results and Analysis

See Fig. 3, Tables 1 and 2.

If we observe the above graphs, we can analyze variations of ERA and ORA schemes of transmit power. We can observe that ORA scheme curve started earlier than ERA scheme curve and attains the maximum value earlier than ERA scheme for different RIS values. We can observe that there is an increment of transmit power values with respect to different RIS values. The higher the transmit power, the farther a signal can travel, and the more obstructions it can effectively penetrate (Fig. 4).

If we observe the above graphs, we can analyze that variations of ERA and ORA schemes of energy efficiency. The ORA values start at higher rate when compared to ERA scheme and also ORA scheme attains maximum energy efficiency. It uses less energy to perform the ERA and ORA schemes. The ORA scheme has more efficiency when compared with the Era schemes. By using different RIS values, we analyze that the ERA scheme has less efficiency (Tables 3 and 4).

6 Conclusion

In this study, we proposed the ERA and ORA schemes of Hybrid RIS-aided systems. We concentrated on performance enhance of the two approaches. To this purpose, we put forth a mathematical methodology for figuring out how the e2e fading channel is distributed over both approaches. The framework specifically found that the G—Gamma/LN—Log-Normal distributions can roughly approach valid distribution of e2e medium coefficient for the ERA method. We discovered estimated equations for PDF and CDF of e2e channel's enormousness for the ORA scheme. The context also found that a LNG distribution is aided to simulate fading channel in the ORA method. We assessed the fading models produced as a result.
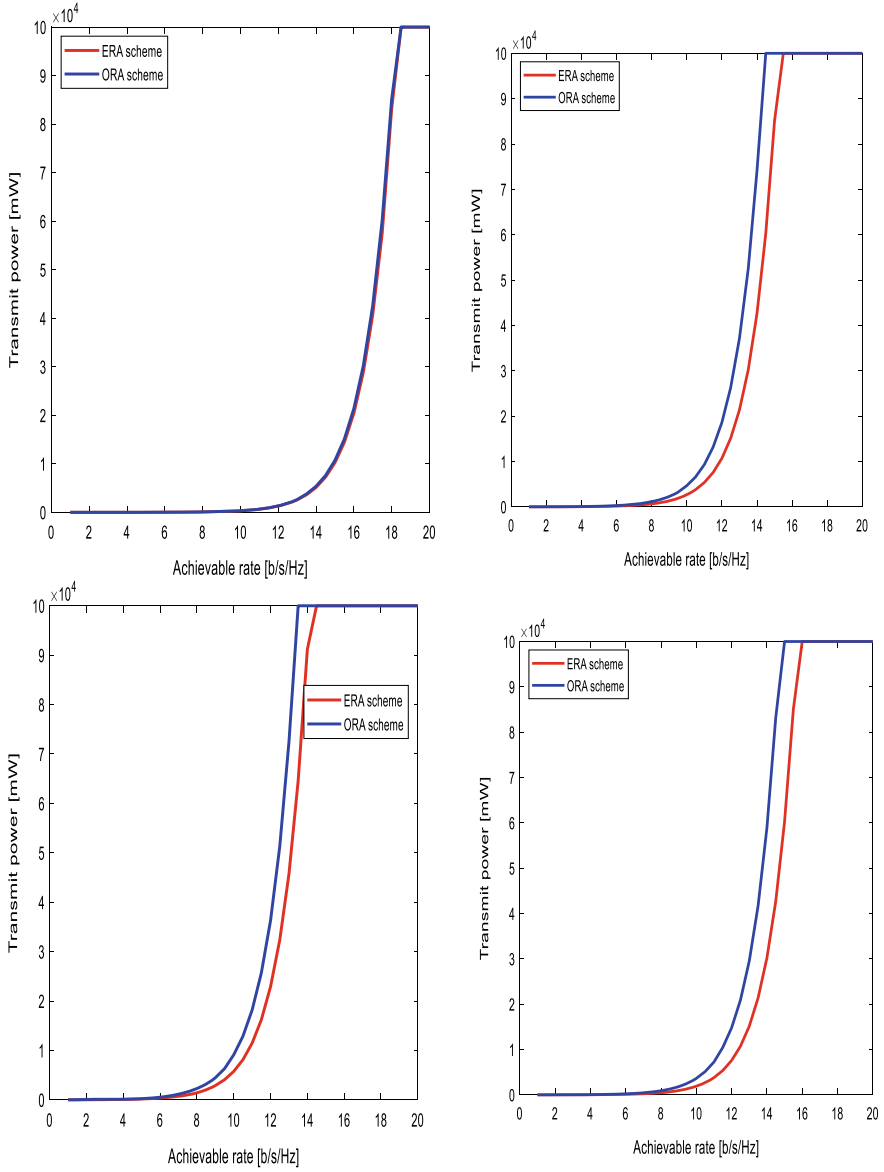
Fig. 3 Transmit power of ERA and ORA schemes

Table 1 Transmit power of ORA scheme

Achievable rate	Transmit power			
RIS	2	3	4	5
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0.00002	0.00003	0.00001
10	0	0.0001	0.00012	0.00005
14	0.00005	0.0008	0.0009	0.0003
18	0.001	0.001	0.001	0.001

Table 2 Transmit power of ERA scheme

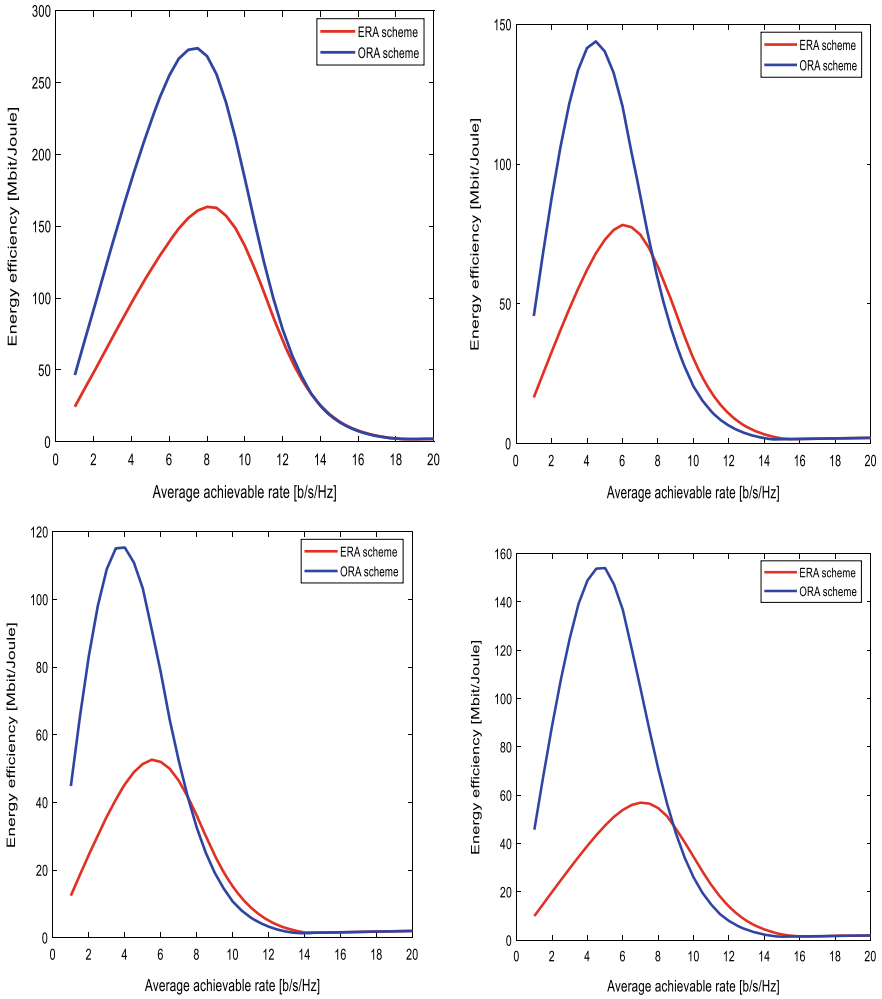| Achievable rate	Transmit power			
RIS	2	3	4	5
2	0	0	0	0
4	0	0	0	0
6	0	0	0	0
8	0	0.00001	0.00002	0
10	0	0.00003	0.0001	0.00003
14	0.00005	0.0004	0.001	0.0004
18	0.001	0.001	0.001	0.001

Fig. 4 Energy efficiency simulation of ORA and ERA schemes

Table 3 Energy efficiency of ORA scheme

Average achievable rate	Energy efficiency			
RIS	2	3	4	5
2	75	60	58	50
4	150	110	100	90
6	250	135	90	130
8	220	70	30	60
10	130	30	20	20
12	80	10	10	9
14	30	5	4	3
18	0	0	0	0

Table 4 Energy efficiency of ERA scheme

Average achievable rate	Energy efficiency			
RIS	2	3	4	5
2	40	25	20	15
4	75	60	45	35
6	125	80	56	50
8	170	70	45	42
10	140	35	30	20
12	75	20	7	15
14	30	10	3	5
18	0	0	0	0

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