Asia University

Department of Computer Science and Information Engineering

Doctoral Dissertation

The Research of Reconfigurable Intelligent Surfaces (RIS) by Using Nakagami-*m* Approach in Cooperative-Non Orthogonal Multiple Access (NOMA) Networks

在合作的非正交多工接取 (NOMA) 網路中使用 Nakagami-m 方法下可重新配置智慧表面 (RIS) 的研究

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Abstract

More apps, including virtual and augmented reality, high-definition three-dimensional video, autonomous driving, and big data analytics, have proliferated in recent years, contributing to the growth of mobile data traffic utilization. Due to this, demand has increased for future wireless communications, such as fifth generation (5G) and cellular communications beyond, as well as for higher communication speeds and greater connectivity. In a cell-free architecture, the proximity of the service antenna to the user equipment (UE) has the crucial side effect of reducing route loss and enhancing network coverage. Cell-free networks are now regarded as a 6G technology because of their nearly uniform performance and simplicity of distribution throughout the EU. Massive cell-free installations, however, come at a very high cost, starting with the frequency spectrum search, installation, and upkeep. The above-mentioned issues might be resolved by the ground-breaking Reconfigurable Intelligent Surfaces (RIS) technology, which employs a low-cost, energy-efficient, and high-power meta-surface. The use of RIS in wireless communication enables network operators to increase the range by regulating radio wave properties such as scattering, reflecting, and refraction. This eliminates the drawbacks of natural wireless propagation. Studying challenging requirements and potential new applications for sixth generation (6G) outside of cellular networks that support the development of cellular connection appears interesting. The concept of changeable smart surfaces is quickly gaining popularity as a key strategy for satisfying the needs of extensive networks. This study discusses the implementation of RIS on the NOMA network. Non-Orthogonal Multiple Access (NOMA) is a technology applied to 5G wireless networks. In this study, the Nakagami-*m* distribution approach was carried out on the fading channel. This approach is used because the Nakagami-*m* distribution has a wider scope than the Rayleigh and Riccian distributions. Furthermore, it is also assumed that all channels are identically independently distributed (*i.i.d*) with perfect channel statistical information conditions (*P-CSI*) and imperfect channel statistical information conditions (*IP-PCI*). The scenario used is a downlink to a half-duplex signal received by two groups of users, namely near-users and far-users, from the base station (BTS) location. Based on these scenarios, a mathematical formulation is derived which is the closest expression of the outage probability for each user. In addition, the closest expression of ergodic capacity was developed for each user.

Based on the results of the simulations carried out in this study, the implementation of the NOMA cooperative network assisted by RIS turns out to be more performant than the conventional cooperative-NOMA network and the OMA-based network in terms of coverage performance and capacity. Thus, the results of this study can prove that the application of the RIS-aided Cooperative-NOMA network can support the development of 5G wireless communication to 6G wireless communication.

Keywords: RIS, NOMA, Nakagami-*m*, 5G wireless communication, 6G wireless communication

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Notations

Notation	Definition
$s(t)$	superpose of the signal that is targeted to Near User (U_1) and Far User (U_2)
P_s	the normalized power of a transmitted signal
P_1	the normalized power of the transmission signal at U_1
a_1 and a_2	the level power of the signal x_1 and x_2, respectively
L and N ,	number of RIS elements
α	the amplitude reflection coefficient with $\alpha \in (0,1]$
θ_l	the adjustable phase applied by the l-th reflecting element of RIS
Φ	The phase-shift matrix, diag(exp(j θ_1), exp(j θ_2), …, exp(j θ_L))
$(.)^H$	Hermitian transpose
β_k	the large-scale fading coefficients of channel *k*
Ω_k	the link power of channel *k*
$\hat{\Omega}_k$	the average connection power of channel *k*
$\hat{h}_k$	average fading coefficient of channel *k*
h_k	the fading coefficient of channel *k*
$\hat{X}_\upsilon$	average gain of fading coefficient by RIS for the υ user
X_υ	gain of fading coefficient by RIS for the υ user
e_k	channel estimation error
$\sigma^2_{e_k}$	variant of channel estimation error
η_k	relative channel estimation error of channel *k*
m_υ	the shape factor of the gamma distribution of the channel at υ
χ	path-loss exponent
d_k	the distance of two points crossed by the channel *k*

$P_{(..)}$	outage probability at (..)
n_{U_1} and n_{U_2}	the AWGN at U_1 and U_2, respectively
$d_{SU_1}, d_{SR_1}, d_{RU_1}$	the distances for BS-U_1, BS-RIS, and RIS-U_1, respectively
$d_{SU_2}, d_{SR_2}, d_{RU_2}$	the distances for BS-U_2, BS-RIS, and RIS-U_2, respectively
$h_{D_1}, h_{D_2}, h_l, g_{1l}, g_{2l}$	the coefficients of fading channels
ρ_s	the transmit signal to noise ratio (SNR)
$\rho_{U_2 \to U_1}$	the received signal to interference and noise ratio (SINR) for U_1 to decode signal x_2 of U_2
ρ_{U_1}, ρ_{U_2}	the received SINR for U_1 and U_2 to decode its own signal, respectively
$\rho_{2,U2}$	the received SINR for U_2 to decode signal x_2 for relaying link
$\rho_{U_2}^{SC}$	the received SINR after selection combining (*SC*) at U_2
ρ_{Th_1} and ρ_{Th_2}	target SINR of user u_1 and u_2, respectively
R_1, ζ_1 and R_2, ζ_2	target rate of user u_1 *and* u_2, respectively
P_{U_1} and P_{U_2}	outage probability at U_1 and U_2
τ_1, τ_2 and τ_3	as the *first-comparison –parameter*, the *second-comparison-parameter and* the *third-comparison -parameter*
λ_1, λ_2	interference and noise due to the using of RIS-aided at U_1 and U_2 respectively
δ_1, δ_2	the scale factor of the gamma distribution of the channel at U_1 *and* U_2 respectively

Chapter 1. Introduction

1.1 Background, Motivation, Objective and Scope

1.1.1 Background

Mobile data traffic has exploded in recent years thanks to a growing range of applications, such as virtual and augmented reality, high-definition three-dimensional video, autonomous driving, and big data analytics. This has increased the demand for faster communication speeds and greater connectivity, as well as for future wireless communications such as fifth generation (5G) and beyond cellular communications.

According to recent studies, the capacity need for data traffic is predicted to expand 1000-fold over the course of the next decade, and typical wireless communications using lower frequencies, such as those operating at sub-6 GHz, will not be able to meet this demand. The requirements for reliability and latency for factory automation can be, respectively, 109 packet-loss and 250 s. For virtual and augmented reality applications, which need extremely high data rates (> 1 gigabit per second) and low latency (1 -10 millisecond), high data rate and latency requirements are crucial. Future wireless communications have been encouraged to use promising methods like millimeter wave (mm-Wave) communication, multi-input multi-output (MIMO) techniques, finite block-length coding, intelligent reflecting surface (IRS) techniques, and cell-free networking to satisfy these demands.

The enticing promise of significantly improving network performance in a number of areas, including data throughput, latency, and security, makes mmWave MIMO communications one of the potential underlying technologies for 5G and 6G mobile communications. As opposed to the current radio technology in sub-6 GHz bands, future wireless communication networks should use mmWave due to its abundant spectrum resources and short wavelengths. For example, the current available mobile network bandwidth (fourth-generation (4G) and LTE-Advanced spectrum) is less than 780 MHz, whereas the potential mmWave bandwidth is greater than 150 GHz and has the capacity to sustain multi-Gbps data rates. IEEE 802.11ad operating at a maximum data throughput of 7 Gbps, for instance. Furthermore, large-scale antenna arrays may be crammed into mmWave transceivers of restricted size, producing highly directed signals. This is possible because mmWave radios have substantially shorter wavelengths than sub-6 GHz radios. This strong directivity property can greatly reduce co-device interference and overhearing from eavesdropping and jamming in addition to supporting high antenna gain for rate enhancements. The pathloss and penetration loss of mmWave signals are substantially higher than those of microwave signals due to their short wavelength, which significantly reduces their coverage. For instance, bricks can reduce signals by as much as 40 to 80 dB, while a person's body can reduce signals by as much as 20 to 35 dB. Beamforming and massive antenna arrays are thought to be necessary to improve the SNR in order to combat the high pathloss and support highly directed transmissions. It is demonstrated that the inter-channel interference of multi-user MIMO (MUMIMO) systems could be efficiently avoided with massive MIMO and well-designed beamforming. Full-duplex (FD) relays can also be used in mmWave communications as wireless backhauls in networks made up of small cells to increase coverage and rates.

Cell-free networks, a user-centric network paradigm, have recently been seen as a promising method to increase network capacity and get around the cell-boundary effect of traditional cell-centric networks (e.g., cellular networks). In cell-free networks, several dispersed service antennas that are linked to central processing units (CPUs) serve every user simultaneously on the same time-frequency resource. High multiplexing gain and broad degrees of freedom are both possible in this distributed MIMO network. More crucially, the proximity of the service antennas to the user equipment (UE) in a cell-free design results in reduced path-loss and strong network coverage. Recent research demonstrates that in a variety of real-world situations, cell-free networks function better than small-cell and conventional cellular networks. Due to its near-uniform performance and easy handover across UEs in any location, the cell-free network has been recognized as a 6G technology.

However, deploying more distributed base stations (BSs) will boost the capacity of cell-free networks, but it also will cost a lot and power. Additionally, a cell-free network that uses high-frequency bands (such mmWave bands) may experience significant propagation loss and be more susceptible to obstruction. The innovative Reconfigurable intelligent surfaces (RIS) technology, which uses a low-cost, energy-efficient, and high-gain meta-surface, may be able to solve the aforementioned issues.

RIS is man-made surfaces of electromagnetic (EM) material that are electronically controlled with integrated electronics, have received considerable attention due to their unique wireless communication capabilities. The power of the received signal can be increased by adding the reflected signals constructively at the intended receiver while superimposing them destructively at the unintended receivers to lessen co-channel interference. This is accomplished by properly tuning the phase shifts using an RIS controller. The implementation and operation of RIS reflecting components can be done at orders of magnitude lower hardware and energy costs than conventional active antenna arrays since they just passively reflect impinging signals and do not need any transmit radio frequency (RF) chains.

RIS is an energy-efficient hardware technology to improve performance beyond 5G wireless systems. This system take advantage of spatial diversity not just to boost throughput but also to improve the wireless channel's reliability. Radio signal propagation via man-made intelligent surfaces, on the other hand, has recently emerged as an attractive and sensible way to replace power-hungry active components. By the use of reflective surfaces, smart radio environments with the ability to transmit data without generating new radio waves but instead reusing the same radio waves can be implemented [1-3].

The presence of RIS in wireless communications makes it possible to expand the coverage by controlling the characteristics of radio waves, *e.g.* scattering, reflecting, and refracting, to eliminate the negative effects of natural wireless propagation by network operators. The challenging criteria and possible new usage cases for future 6^{th} generation (6G) beyond cellular networks that contribute to the future of mobile connectivity look promising to study. The idea of reconfigurable smart surfaces is evolving rapidly as a crucial approach to meet the requirements for huge networking, powered largely by the future Internet of Things (IoT) [4].

The use of RIS is particularly advantageous when the LoS link is blocked or insufficiently strong, as additional transmission paths could be provided by utilizing the reflecting elements of a RIS. While it is possible to mitigate the channel's negative effects through the use of relays [5], the hardware cost, power consumption, and latency significantly increase as the signal is actively processed at each relay [6]. Additionally, real-time phase shift control of each RIS element enables optimization of certain system performance indicators, including transmit power, reachable rate, energy efficiency, and received Signal-to-Noise Ratio (SNR) [4, 5]. Besides that, RIS has a full-band response since, ideally, it could work at any operating frequency and could be easily deployed, e.g., on the facades of buildings, ceilings of factories and indoor spaces, human clothing, *etc* [3].

At this time, non-orthogonal multiple access (NOMA) has become a promising candidate for multi-user scheduling in fifth-generation (5G) cellular networks [7]. Key benefits of using NOMA as a radio access technique for 5G and beyond are high spectral efficiency, massive connectivity, and low latency. NOMA allows multiple users to share the same time-frequency resource by dividing multiple users through different transmission power so that Successive Interference Cancellation (SIC) is required at the receiver side [8].

Based on the benefits of using NOMA network and multi-antenna system RIS, then this paper attempts to explore the outage probability performance of the Cooperative NOMA system with the RIS-aided. This approach is selected because RIS is nearly passive, no need for any dedicated energy source, viewed as an adjoining surface, and ideally, any point can shape the wave impinging upon it (soft programming) [9, 10]. Moreover, it is not affected by receiver noise, since, ideally, no need Analog-to-Digital/Digital-to-Analog Converters (ADCs and DACs), and power amplifiers. As a result, RIS does not amplify nor introduce noise when reflecting the signals and provides an inherently full-duplex or half-duplex transmission. Future wireless communication systems could benefit from using the RIS approach to increase their spectrum- and energy-efficiency (e.g., beyond 5G). Additionally, it has drawn growing study interest in the fields of channel prediction, beamforming, and resource allocation.

1.1.2 Research Motivation

By using reconfigurable intelligent surfaces (RIS) on the cooperative-non-orthogonal multiple access (Cooperative-NOMA) network could increase the efficiency energy that occurs in NOMA. Therefore, the performance of the nearby users (users with better channel conditions) of the base station in carrying out its role as relay decode and forward (DF) could increase system reliability. The Nakagami-m fading model is selected as an assumption because it could handle a wide range of m-orders. This fading channel is used in many types of fading environments ($m = 1$ for Hoyt, $m > 1$ for Rayleigh, and $m < 1$ for Rician) and has better empirical data than the Rayleigh fading channel. Despite this, the Nakagami-m models will struggle to represent transmission situations with line-of-sight (LOS). Another aspect of the Nakagami-m model is that it is more analytically tractable in its mathematical form. However, there has been very little research into evaluating analytical performance especially for implementing RIS on NOMA network, and the number of outcomes is extremely limited. This motivates author to analyze outage performance, which is a measure of the coverage of a network system by implementing the RIS-aided NOMA network system use Nakagami-m as fading channel model.

1.1.3 Research Objective and Scope

Because of there has been very little research evaluating the analytical performance of outages caused by implementing RIS in the NOMA network. Despite the fact that research about this has already been conducted, the number of its outcomes is extremely limited. This thesis aims to investigate the performance of the coverage probability expressed in the form of outage probability in a non-orthogonal multiple access (NOMA) cooperative network assisted by RIS. In addition, the ergodic capacity is also investigated, which is the expected capacity of each user. The author proposes various schematics of the RIS-assisted NOMA cooperative network model for studies on outage probability performance. The author derives the closest expression of the outage probability for each user using channel statistical information (CSI). Moreover, the author also used at the NOMA transmission technique in the mmWave network to enable safe communication and fair user access under the assumption that the fading environment type would be Nakagami-*m* channel. The study of feasible mmWave communication levels from the viewpoint of finite block length information theory is also very interesting since it could provide design recommendations for future mmWave applications that have speed, reliability, and latency constraints. Following are some high-level research topics that sum up the focus of this thesis:

- *RQ1: How to derive the closed-form expression of the coverage performance of RIS-aided NOMA network system by assuming that the fading environment type would be Nakagami-m channel?*
- *RQ2: How to make simulation base on the closed-form expression of the coverage probability which is found and analyze the analytical its performance?*
- *RO3: How to derive the appropriate closest form expression for the probability of attenuation of RIS applied in the wireless Cooperative NOMA system in practice and the creation of a Rayleigh random variable product model that is useful for evaluating performance metrics in several RIS elements with a communication scheme under Ip-SIC conditions simultaneously through Nakagami-m fading channels.*
- *RQ4: How to derive the closed-form expression of the ergodic capacity of RIS-aided NOMA network system?*
- *RQ5: How to make simulation base on the closed-form expression of the ergodic capacity for arbitrary and optimal phase shifts condition?*

1.2 Research Problem

We go into further detail about our research issues in this part based on our research objectives in Section 1.1 and the literature survey in Section 1.2.

1.2.1 Analysis of the outage performances in the downlink RIS-aided Cooperative NOMA Network through the Nakagami-*m* Channel under the perfect-Channel Statistic Information (*p*-CSI) condition.

Research problem 1 (RP 1): How to derive the closest expression model of the outage probability of each user in the RIS-assisted NOMA cooperative network over the Nakagami-m channel with direct signal from BS to each of users?, How to derive the closest expression model of the outage probability of each user in the RIS-assisted NOMA cooperative network through the Nakagami-m channel with Perfect-Statistic Channel Information (P-SCI)?, Also, how to simulate and the results obtained (location of the closest user placement that acts as a relay, throughput, etc.)?

The system will provide users with various channel advantages according to the NOMA principle. Xianli Gong et al. [55] considered Nakagami-*m* with Imperfect Channel Statistical Information to assess the outage performance of cooperative NOMA networks. This study describes the relationship between outage performance and SNR for nearby users and distant users. In addition, the authors have tested two scenarios: one in which there is a direct signal between BS and the other in which there is no direct signal. Simulations show that NOMA outperforms Orthogonal Multiple Access (OMA), is the ideal place to convey users, and greatly outperforms remote users with direct links in terms of outage performance.

One of the publications discussed above examined the performance of RIS-aided NOMA outages in [70]. The outage performance results from this paper do not provide a comprehensive explanation of the blackout performance. This is demonstrated by the findings of this article, which only provides data on the performance of RIS-aided NOMA and OMA during outages when compared to SNR for throughput, respectively. The outage performance due to the distance between the BS and the nearest user and the outage performance due to the relative error of channel estimation, both of which are significant for network systems using NOMA, are not discussed in this article. This is due to assumptions made by the authors of the paper. The author does not take into account the interaction behavior of signal transmission, both received and reflected by the RIS, assuming the fading channel of the signal reflected from the RIS is the same for near and far users. As a result, U_1 performs better during outages than U_2, which is in contrast to the performance of the NOMA network during outages as shown in the study [55]. In their study [55], the authors applied the Nakagami-*m* assumption and the NOMA principle to test the outage performance of a network with two users. The results of this study indicate that U_2 performs better during a power outage than U_1. This can happen because the authors in this paper assume that the signal transmission behavior received by each user has different characteristics. This is due to the attenuation of the path-loss distance and noise. In addition, using the assumptions on paper [70] also causes difficulties in deriving the closest expression of ergodic capacity.

Regarding the system using a RIS-aided NOMA cooperative network, we propose to create a model system that represents a system using a RIS-aided NOMA cooperative network by considering the direct effect of signals from the base station (BS). Furthermore, based on the model system, we derive the expression for the nearest outage probability for the closest user to U_1 and the remote user to U_2. Then proceed with analyzing the performance of the outage probability with respect to the SNR, the outage probability to the relative channel estimation error, and the outage probability to the position of the closest user and throughput

1.2.2 Outage Probability Analysis of The downlink RIS-aided Cooperative NOMA Network via Nakagami-*m* Channel with Imperfect-Channel Statistic Information (*Ip*-CSI) condition.

Research problem 2 (RP 2): How to derive the closest expression model of the outage probability of each user in the RIS-aided NOMA cooperative network over the Nakagami-m channel with Imperfect- Channel Statistic Information (Ip-CSI) direct signal from BS to each of users?, How to derive the closest expression model of the outage probability of each user in the RIS-aided NOMA cooperative network through the Nakagami-m channel with Imperfect-Statistic Channel Information (Ip-CSI)?, Also, how to simulate and the results obtained.

Non-Orthogonal Multiple Access (NOMA) has emerged as a potential option for multiuser scheduling in fifth generation (5G) cellular networks. By dividing users into separate transmission strengths, NOMA enables many users to share the same period frequency source [11]. Therefore, Successive Interference Cancellation (SIC) is needed at the other end. In comparison to conventional orthogonal multiple access (OMA), NOMA has higher count rates, a lower attenuation probability, and better user fairness [71].

An encouraging advancement in wireless networks is cooperative NOMA, which has increased spectral performance and accuracy. There are currently two areas of joint NOMA research. One feature is that the person relaying information to the far-off NOMA user is regarded as the nearby NOMA user with the best channel conditions [8, 71, 72].

We looked into the possibility of using a reconfigurable smart surface aided wireless scheme (RIS) in a non-orthogonal dual access (NOMA) system based on the information presented above. RIS may one day be a possibility for additional performance enhancements in 5G or 6G systems as it has the ability to boost the spectrum efficiency of wireless systems including massive MIMO, full-duplex communication, NOMA, mmWave communication, and cognitive radio [72-74]. Even though a lot of research has been done on 6G, it is anticipated that this research will help advance communication technology in mobile communications, which is still in the form of 4G systems and 5G technology. The world's 5G technology is expected to improve as a result of this research [45, 55, 75, 76].

The majority of the existing research on RIS and Cooperative NOMA is in Perfect Channel Statistic Information (p-CSI) conditions via the Rayleigh fading channel, but it is challenging to implement in real-world wireless systems due to channel estimation error [72, 77]. Therefore, we consider the application of RIS to the Cooperative NOMA downlink network with Imperfect Channel Statistic Information (Ip-CSI) through the Rayleigh fading channel. How to correctly obtain the closest form formula for the attenuation probability for RIS, in which the communication scheme under Ip-CSI circumstances is assessed concurrently across the Rayleigh fading channel, is the topic that will be looked at in this work.

To assess performance indicators in various RIS components, it is possible to develop a Rayleigh random variable product model as in the Nakagami-*m* approach. In an Ip-CSI condition, the RIS coverage probability is expressed using the Nakagami-*m* fading channel communication scheme. The scenario is that the base station (BS) sends information to far-users with the assistance of the closest user, which is referred to as DF relaying [36].

1.2.3 Outage Probability and Ergodic Capacity of RIS-aided NOMA with *p*-CSI Fading Channel

Research problem 3 (RP 3): How to derive the closest expression model of the outage probability of each user in the RIS-aided NOMA cooperative network over the Nakagami-m channel with Perfect- Channel Statistic Information (P-CSI) without direct signal from BS to each of users?, Also, how to simulate and the results obtained?, How to derive the *closed-form expression of the ergodic capacity of* RIS*-aided NOMA network system?*, Also, *How to make simulation base on the closed-form expression of the ergodic capacity for arbitrary and optimal phase shifts condition ?*

In order to meet the demand for low latency, affordable devices, and a range of services, 5G will need to handle enormous connection of people and/or devices due to the Internet of Things' (IoT) explosive growth. Data from several IoT devices is often transmitted to a coordinator, who then communicates with a server together with other coordinators [3, 42].

Due to the huge increase in demand, an ultra-dense network is needed to support the 5G network infrastructure, which uses mm-Wave frequencies only to traverse short distances. Because of this, 5G small cell applications will be much wider than before, and a variety of form factors and architectures will be used. However, the operations of acquiring spectrum, setting up, testing, and managing the network, and keeping it up and running all cost more money.

Depending on the location of each 5G small-cell, installing a fiber-optic network is not always practical. As a result, 5G must incorporate wireless network growth. The potential of 5G can provide bandwidth at frequencies higher than six gigahertz allows for the networking required by consumers with devices capable of higher data rates. The high frequency spectrum, on the other hand, is limited, which is why multiple tiny cells are required to cover a large region. The signals could be blocked by trees, buildings, and other objects. Therefore, it necessitates the use of cell towers to avoid signal loss. In addition, NOMA on a 5G basis still requires a reduction in energy requirements in the Amplify and Forward (AF) process [78]. Therefore, a technology other than 5G is needed that is able to reduce the weakness of NOMA. This is what motivated us to develop NOMA as the basis for the 5G system in order to be able to achieve the principles of the 6G system by implementing RIS-aided NOMA.

In addition, NOMA on a 5G basis still requires a reduction in energy requirements in the Amplify and Forward (AF) process. Therefore, a technology other than 5G is needed that is able to reduce the weakness of NOMA. This is what motivated us to develop NOMA as the basis for the 5G system in order to be able to achieve the principles of the 6G system by implementing RIS-aided NOMA.

We will show that RIS deployment on the NOMA network can increase NOMA's energy efficiency. If adjacent users (those with better channel circumstances) perform well, the base operation's (BO) performance as a relay decode and forward (DF) could increase system reliability. We choose the Nakagami-*m* fading model, where m is the fading parameter in [43, 79], because it provides a wide range of analysis. Despite this, LoS transmission conditions will be difficult for the Nakagami-*m* models to simulate. Another benefit of the Nakagami-*m* model is that it is more analytical.

However, very little study has been done, and there are only a few results, to evaluate analytical performance. We looked at outage performance, a metric for a network system's coverage, using the RIS-assisted NOMA network system with Nakagami-*m* as the fading channel model. In addition, we examine the ergodic capacity of the channels for both near-users and far-users.

1.2.4 Analyzing Coverage Probability of Reconfigurable Intelligent Surface- aided Cooperative NOMA with p-CSI Fading Channel by Using The Others Scenario.

Research problem 4 (RP 4): How to derive the closest expression model of the outage probability of each user in the RIS-aided NOMA cooperative network over the Nakagami-m channel with Perfect- Channel Statistic Information (P-CSI) with other scenario from BS to each of users?, Also, how to simulate and the results obtained?

Reconfigurable intelligent surfaces (RIS), which have the potential to significantly increase communication coverage, throughput, and energy efficiency, have recently gained more attention and are being envisioned as a cutting-edge technology for the beyond fifth-generation (B5G) communication system [8, 71, 72]. According to [55], RIS is composed of a significant number of inexpensive reflecting elements, and the propagation of the reflected signal may be smartly reconfigured by changing the phase shifts of all reflecting elements to meet specific communication objectives. In order to permit dynamic changes in reflections for a range of applications, including the improvement of signal force and interference reduction.

RIS is a planar meta-surface made up of numerous passive components that are controlled by a smart controller. In contrast to conventional methods like active relaying and beam shaping, RIS not only reflects signals in a full-duplex and noise-free manner without introducing self-interference, but it also significantly lowers hardware/deployment costs and energy consumption by using only lightweight passive components. By altering the phase shifts of its passive components, RIS has the ability to artificially boost combined channel strengths and enlarge channel strengths using reflected electromagnetic waves. This motivates us to investigate the cooperative NOMA system with RIS support with another scenario.

Future wireless communication systems may benefit from the development of NOMA, or non-orthogonal multiple access, which can serve several users inside a single resource block [75]. Orthogonal multiple access (OMA) has received a lot of attention, but NOMA has also received a lot of it. In typical wireless networks without RIS, NOMA has shown to be superior to OMA by enhancing spectrum efficiency, balancing user fairness, and expanding network connections. The user of the stronger channel utilizes the successive interference cancellation (SIC) approach to remove the co-channel impedance from the users of weaker channels before decoding the message in the downlink NOMA.

The Gaussian and Rayleigh fading channels are particular cases among the many various channel types that make up a Nakagami-*m* fading channel. Reference [10, 80] examined the effectiveness of a NOMA-based AF relaying network and discovered that NOMA outperformed orthogonal multiple access (OMA) in terms of outage probability and ergodic sum rate, as well as providing superior spectral efficiency and user fairness by utilizing the method of Nakagami-*m* fading channels. NOMA also outperformed OMA in terms of spectral efficiency and user fairness.

Reference [36] examined the downlink NOMA system failure performance of NOMA with fixed power allocation and discovered that NOMA may offer subscribers with higher channel gains across Nakagami-*m* fading channels higher individual rates than OMA. Up till now, the majority of cooperative NOMA investigations have been conducted over *P-CSI* Rayleigh fading channels. However, implementation in actual wireless systems is challenging due to channel estimate inaccuracies. In order to examine the NOMA cooperative network's outage probability performance, our research will apply RIS to it under the other scenario.

1.3 Thesis Contribution

According to this research results, it will be gotten the main contribution stated as follows:

- This study fills the gap of research regarding with the using of RIS-aided NOMA in wireless communication. In specific way, this research compares the performance of the RIS-aided NOMA wireless communication system with the conventional NOMA of two users (near users and distant users) with relaying link scenario without direct link from Base Station (BS) and with direct link. This study will derive the closed-form equation of outage probability of each users by using the RIS-aided wireless system as a reflectors and relays. In addition, this study also aims to find out the performance of the outage probability on various Source to Noise Ratio (SNR) values for near user and far user, relative channel estimation error, the distance of near users to base station, and the throughput [81].

- This study will derive the closed-form equation of ergodic capacity of each users by using the RIS-aided cooperative NOMA for arbitrary and optimal phase shifts condition [81].
- This study determines the right closest form formula for the attenuation probability for RIS when the *IP-CSI* conditions of the communication scheme are evaluated simultaneously over the *Nakagami-m* fading channel as a result of generating the RIS coverage probability expression through the *Nakagami-m* fading channel, it also generates a Rayleigh random variable product model to assess performance metrics in a range of RIS elements. In an *IP-CSI* scenario, the base station (*BS*) uses the near-users to relay information to far-users, which is referred to as DF relaying.
- This study will shows that the presentation of a RIS-aided NOMA wireless system by comparing the use of RIS-assisted wireless in near users and far users, which are better than conventional relays, which focus on: system with direct influence from the Base Station (BS) to both near-users and far-users, Imperfect Channel State Information (*IP-CSI*) conditions in propagation are taken into account., using a RIS-assisted wireless system as a reflector, relay, and conventional relay, obtain the coverage probability equation (outage probability) for each condition.
- This study compares the performance of the RIS-aided NOMA-based IoT system to that of a traditional NOMA system with two users (nearby users and distant users) and no direct link to the operator base.
- This study derives the closest-expression of outage probability for each condition using the RIS-assisted wireless system as reflectors and relays. In addition, this study also aims to find out the performance of the outage probability and ergodic capacity at various SNR values for near-users and far-users.
- This study shows that the outage probability and the ergodic capacity in a RIS-aided NOMA wireless network have better performance than in a traditional NOMA wireless network. Our research shows that RIS-aided NOMA-based IoT systems could replace traditional NOMA relay systems. A mathematical model relating to the outage probability and the ergodic capacity performance of each receiver, both near and far from the base station, have been constructed for this purpose

  The RIS-aided NOMA system in downlink achieves NOMA benefits by interacting concurrently with their corresponding destinations via a RIS.

  For the RIS-aided NOMA system, closest-form estimates of outage probability are developed. The effect of each system parameter on the outage probability may be numerically analyzed because they are defined in terms of numerous system parameters. The impact of the number of meta-surfaces in RIS on outage probability, for example, can be assessed to see how the system can improve its performance in practice. The number of meta-surfaces in RIS is shown to have a major impact on the system's outage probability in this study.

- This study aims to reveal that the performance of RIS-aided in the cooperative-NOMA wireless network having a better performance than the conventional cooperative-NOMA wireless communication. Therefore, this study proves that the implementation of RIS-aided in the NOMA wireless can replace conventional NOMA relay systems.

1.4 Thesis Organization

This dissertation is organized into the following sections: The downlink RIS-aided Cooperative NOMA network's outage probability analysis using the Nakagami-*m* channel with perfect-Channel Statistic Information (*P-CSI*) condition is described in Chapter 2. In Chapter 3, we also describe our strategy for the Nakagami-*m* channel with imperfect channel statistical information (*IP-CSI*) condition-based downlink RIS-aided Cooperative NOMA Network outage probability analysis. In Chapter 4, we outline our strategies for cooperative NOMA with p-CSI fading channel supported by Reconfigurable Intelligent Surfaces in the direction of 6G-based IoT. Additionally, in Chapter 5 we demonstrate how to compute the coverage probability of the Reconfigurable Intelligent Surface-aided Cooperative NOMA with p-CSI fading channel, and in Chapter 6 we conclude these works.

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