Chapter 1

Introduction and Literature Review

1.1 Motivation for the Thesis

In the modern wireless communication era, the mobile traffic volume is kept on increasing exponentially due to the huge development of various emerging applications such as mobile broadband to Industry 4.0, virtual reality (VR), Internet of Everything (IoE), three-dimensional (3D) media, and a large number of intelligent products [1]. It may be a predicate that this traffic volume to be 5016 EB[1]/month in the year of 2030 [2]. Foreseen that the fifth generation (5G) is difficult to accommodate such a massive volume of traffic in 2030 and beyond [3]. Therefore, academia and industry have been enthusiastically looking into sixth-generation (6G) wireless networks. According to the white paper of Samsung research [4], 6G mainly focused on the peak data rate of 1Tbps and user experienced data rate of 1 Gbps with an air latency less than 0.1 ms, and the mobility means that the targeted maximum

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[1] 1 exabyte (EB)=1 000 000 terabytes (TB)

speed of 1000km/h. In this context, the present technologies such as multi-carrier signaling, large-scale MIMO systems, relaying, beamforming, reconfigurable antennas, adaptive modulation, and coding are insufficient to achieve the above targets [5]. Moreover, deploying more base stations (BSs), access points (APs), and relays to enhance the coverage area and capacity. Still, it causes to increases network interference, higher energy consumption, and maintenance costs. Thus, radical changes are required in physical layers (PHY) techniques. Therefore, the above mentioned targets can be achieved by using some emerging physical layer techniques such as reconfigurable intelligent surface (RIS), non-orthogonal multiple access (NOMA), and spatial modulation and index modulation (SM/IM) for the next-generation wireless communications.

1.2 Reconfigurable Intelligent Surface

A RIS is also called as an intelligent reflecting surface (IRS) [6] or software-controlled meta-surfaces [7] or large intelligent surface (LIS). RIS is made up of meta-surfaces with integrated electronic circuits, which can be programmed to change the incoming electromagnetic signals to the desired direction. It also has planar structures and is equipped with a large number of passive reflecting elements, which can be fabricated using lithography and nano-printing technologies. Each RIS's reflecting elements can reconfigure the wireless channel environment by smartly tuning the phase of the incident signals constructively. Thus, RIS transforms the fast fading to slow fading and mitigates the co-channel or inter-cell interference. However, it creates a virtual line-of-sight (LoS) between transceivers to bypass the obstacles. Therefore, RIS can overcome the wireless channel's detrimental effects, resulting in higher received signal strength. They also have some distinguishable features such as

- RIS-aided system achieves the same data rate as a full-duplex/half-duplex amplify forward (AF) relay-aided system using more reflecting elements. It is free from antenna noise amplification and self-interference.
- RISs do not require an RF chain like an active antenna since elements of RISs is passive.
- Since RIS is lightweight and low profile, it can easily be deployed on ceilings of factories, roadside billboards, buildings of facades, indoor walls, etc.

Due to these distinctive characteristics, the RIS can enhance the performance of wireless communication performance in terms energy efficiency and coverage area. Moreover, RIS will be compatible with emerging PHY techniques like NOMA and SM/IM can improve the bit error probability and sum-rate performances for the next-generation communications.

1.2.1 RIS-assisted SISO System

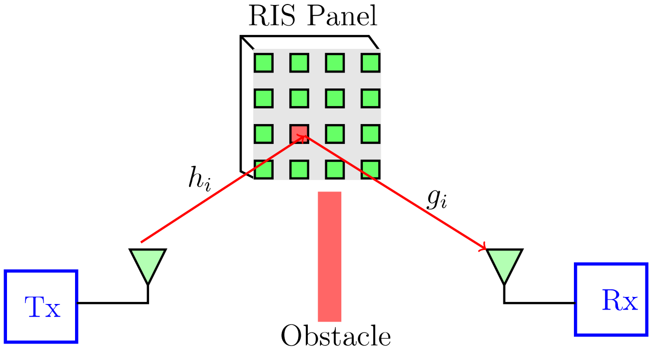

FIGURE 1.1: RIS-assisted SISO system.

In Figure1.1, consider each transmitter (Tx) and receiver (Rx) having a single antenna and no direct path between them due to blockages. The RIS is consisting of N passive reflecting elements and distance between Tx to RIS is d_1 and RIS to Rx is d_2. According to the free propagation theory, the maximized received power $P_{\mathrm{r}} \propto P_{\mathrm{t}} \frac{N^2\lambda^4}{(4\pi)^2 {d_1}^2 {d_2}^2}$ [5], where P_{t} and λ are the transmit power and wavelength respectively. Moreover, the received signal power is depending up on the reflective elements N^2 and distance of d_1 and d_2, h_i and g_i are Rayleigh flat fading channel between Tx to RIS and RIS to Rx of i^{th} reflective element, respectively and consider the channel phase information known at the RIS. Thus the Rx received signals is expressed as,

$$y = \left[\sum_{i=1}^{N} h_i e^{j\phi_i} g_i \right] x + n \tag{1.1}$$

where, x is modulation symbols which are selected from the constellation points of M-ary phase shift keying (PSK), and n is the additive white Gaussian noise (AWGN) is $\sim \mathcal{CN}(0, N_0)$. Therefore, the maximized SNR is given as,

$$\gamma_{\max} \leq \frac{\left| \sum_{i=1}^{N} h_i g_i \right|^2 E_s}{N_0}, \tag{1.2}$$

where, E_s is average transmitted energy of each modulation symbol. Therefore, the RIS can enhance the bit error rate (BER), sum-rate, spectral and energy efficiencies for the next-generation wireless communications.

1.3 Non-orthogonal Multiple Access (NOMA)

NOMA is an innovative concept for the massive connectivity, ultra latency, and high spectral efficiency (SE) for the next-generation wireless networks [8–13]. Moreover, the NOMA can support more users under the same time/frequency or code domain. The NOMA can be divided into two main categories: code-domain NOMA (CD-NOMA) and power-domain NOMA (PD-NOMA). Moreover, the CD-NOMA has less attention as compared with the PD-NOMA. Since, in CD-NOMA, each user is assigned a pattern vector under the smaller set of resource elements. Thus the multi-user detection is non-linear and more complex. Therefore researchers are focusing on the PD-NOMA.

1.3.1 Power-domain NOMA System

The PD-NOMA concept was first proposed in [14] to improve the spectral efficiency. The PD-NOMA system supports more users at the same time and frequency resource, because the superposition coding is used at the base station (BS). Moreover, multiple users are assigned with different power coefficients according to their channel gain conditions. However, higher power coefficients are assigned to low channel gain users. Furthermore, the successive interference cancellation (SIC) is implemented at receivers to mitigate the interference from the strong users for high channel gain users [15].

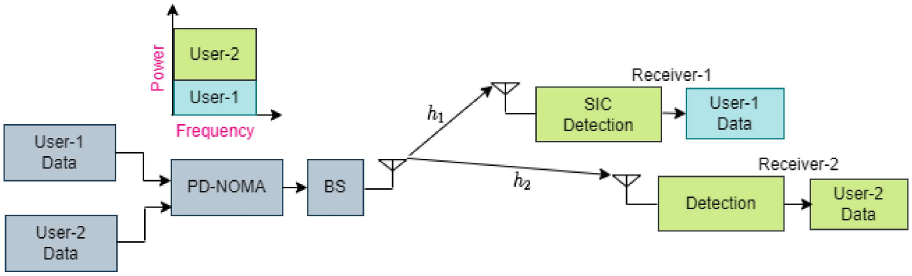

FIGURE 1.2: Two-user downlink PD-NOMA scheme.

The two user downlink PD-NOMA system as shown in Figure1.2, in which BS transmits the superimposed code of two user's information with different power allocation, say $s=\sqrt{\alpha_1 P_\mathrm{B}}x_1+\sqrt{\alpha_2 P_\mathrm{B}}x_2$. The user-1 and user-2 are located at near and far from the BS and corresponding by the power coefficients are assigned as α_1 and α_2 respectively, according to their channel gain $|h_1|^2 > |h_2|^2$. Moreover, the received signals of user-1 is represented as

$$y_1 = h_1\sqrt{\alpha_1 P_\mathrm{B}}x_1 + h_1\sqrt{\alpha_2 P_\mathrm{B}}x_2 + \mathrm{n}_1, \tag{1.3}$$

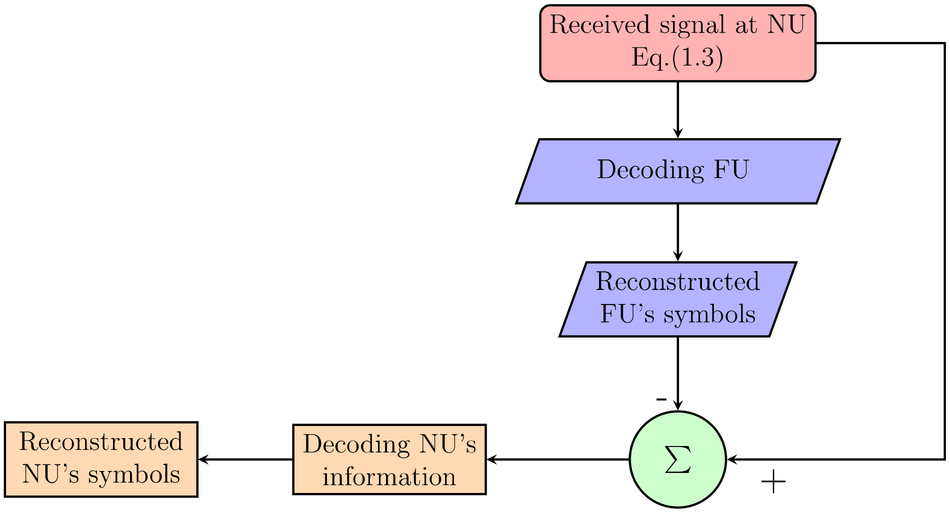

FIGURE 1.3: SIC implemented at NU.

where P_{B} is the available transmitted power at BS, x_1 and x_2 are modulation symbols of user-1 and user-2 with unity energy respectively. Further, the SIC process is implemented at the near-user (NU). Thus, the NU initially decodes strong user signals and removed signal from the received composition signals as shown in Figure1.3 and is expressed as,

$$y_{\mathrm{SIC}} = y_1 - h_1\sqrt{\alpha_2 P_{\mathrm{B}}}\hat{x}_2 \tag{1.4}$$

Further, the received signals at far user (FU) is $y_2 = h_2\sqrt{\alpha_2 P_{\mathrm{B}}}x_2 + h_2\sqrt{\alpha_1 P_{\mathrm{B}}}x_1 + \mathrm{n}_2$, where n_2 is AWGN with $\sim \mathcal{CN}(0, N_0)$ and FU signal is decoded directly by using the optimal detector and it does not perform interference cancellation.

Therefore the NU decodes symbols of x_1 without interference from symbols of x_2 and its sum-rate is expressed as,

$$\mathcal{R}_{\mathrm{D}_1}^{\mathrm{NOMA}} = \log_2\left(1 + \frac{\alpha_1 P_{\mathrm{B}}|h_1|^2}{N_0}\right)\ bpcu.^2 \tag{1.5}$$

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[2] bits per channel user

The sum-rate for FU under the interference of x_1 is expressed as,

$$\mathcal{R}_{\mathrm{D}_2}^{\mathrm{NOMA}} = \log_2\left(1 + \frac{\alpha_2 P_{\mathrm{B}}|h_2|^2}{\alpha_1 P_{\mathrm{B}}|h_2|^2 + N_0}\right) \; bpcu. \tag{1.6}$$

In case of two user uplink NOMA system, both user's information are transmitted to the BS simultaneously under the same time/ frequency resource block. Moreover, the BS is received a superimposed signals of two users and decoded from strong user to weak user and its sum-rate is expressed as [16],

$$\mathcal{R}_{\mathrm{U}_1}^{\mathrm{NOMA}} = \log_2\left(1 + \frac{\alpha_1 P_{\mathrm{B}}|h_1|^2}{\alpha_2 P_{\mathrm{B}}|h_1|^2 + N_0}\right) \; bpcu, \text{and} \tag{1.7}$$

$$\mathcal{R}_{\mathrm{U}_2}^{\mathrm{NOMA}} = \log_2\left(1 + \frac{\alpha_2 P_{\mathrm{B}}|h_2|^2}{N_0}\right) \; bpcu. \tag{1.8}$$

1.3.2 Advantages of NOMA

In OMA system, users are orthogonal multiplexing with allocation of bandwidth of λ $(0 < \lambda < 1)$ Hz is assigned for user-1. The remaining bandwidth $(1 - \lambda)$ Hz is allocated for user-2. Therefore, the sum-rate performance of user-1 and user-2 are expressed as,

$$\mathcal{R}_1^{\mathrm{OMA}} = \lambda \log_2\left(1 + \frac{P_{\mathrm{B}}|h_1|^2}{\lambda N_0}\right) \; bpcu, \text{and} \tag{1.9}$$

$$\mathcal{R}_2^{\mathrm{OMA}} = (1-\lambda) \log_2\left(1 + \frac{P_{\mathrm{B}}|h_2|^2}{(1-\lambda) N_0}\right) \; bpcu. \tag{1.10}$$

Therefore, the performance gain of NOMA system is superior than the OMA system under the different channel gains. Moreover, the total sum-rate of NOMA system is expressed as,

$$\mathcal{R}^{\mathrm{NOMA}} = \log_2\left(1 + \alpha_1|h_1|^2\gamma\right) + \log_2\left(1 + \frac{\alpha_2|h_2|^2}{\alpha_1|h_2|^2 + \frac{1}{\gamma}}\right) \; bpcu, \tag{1.11}$$

where $\gamma = \frac{P_{\text{B}}}{N_0}$ is the transmit SNR, and considered as high SNR ($\gamma \longrightarrow \infty$) and FU channel is facing deep fade. Therefore, approximately the sum-rate of NOMA is expressed as,

$$\mathcal{R}^{\text{NOMA}} \approx \log_2\left(1+\alpha_1|h_1|^2\gamma\right) + \log_2\left(1+\frac{\alpha_2}{\alpha_1}\right) = \log_2\left(\alpha_1|h_1|^2\gamma\right) \tag{1.12}$$

On the other hand, the total sum-rate performance of OMA system is given as,

$$\mathcal{R}^{\text{OMA}} = \lambda\log_2\left(1+\frac{\gamma|h_1|^2}{\lambda}\right) + (1-\lambda)\log_2\left(1+\frac{\gamma|h_2|^2}{(1-\lambda)}\right) \ bpcu. \tag{1.13}$$

Specifically, consider deep fading at FU then its approximate sum-rate is expressed as,

$$\mathcal{R}^{\text{OMA}} \approx \lambda\log_2\left(1+\frac{\gamma|h_1|^2}{\lambda}\right) \ bpcu. \tag{1.14}$$

From Eq.1.12, and Eq.1.14, it is conclude that the spectral efficiency gain of NOMA is better than the OMA system. Furthermore, NOMA can serve multiple users (MU) at the same time or frequency resource and it can mitigate the interference by using SIC. Therefore, the NOMA can provide a massive connectivity and high spectral efficiency. Moreover, a huge number of information is transmitted simultaneously via the superposition code (SC), which results low latency. Finally, the NOMA maintain the reliability and quality of service (QoS) by allocating the power coefficients between strong and weak users.

1.4 Cooperative NOMA

The first cooperative NOMA (C-NOMA) system was proposed in [17]. In the C-NOMA system, the near users acts as a cooperative relay, which decodes and forward to the far users, as shown in Figure1.4. Moreover, the data transmission through two phases: broadcasting and cooperative. In broadcasting phase, the BS transmits superposed symbols to the near and far users. The near user received signals are expressed as

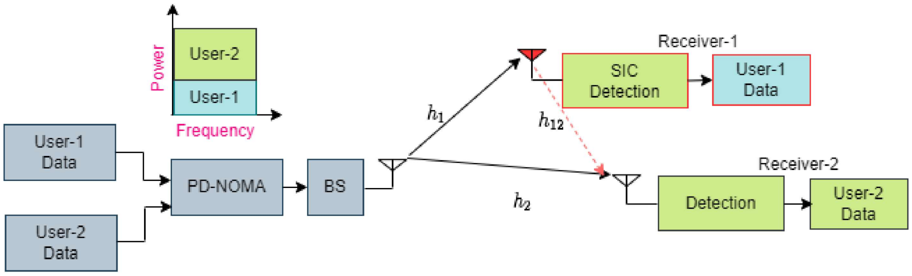

Figure 1.4: Cooperative NOMA system.

$$y_1 = h_1\sqrt{\alpha_1 P_{\mathrm{B}}}x_1 + h_1\sqrt{\alpha_2 P_{\mathrm{B}}}x_2 + \mathrm{n}_1, \tag{1.15}$$

The near user first decodes symbols of the far user by considering its own symbols as noise; after that it cancels the far user's symbols using the SIC technique. Next, in the cooperative phase, the near user forwards the far user's symbols. Furthermore, far user received signals from both BS and near user are represented as

$$y_2 = h_2\sqrt{\alpha_2 P_{\mathrm{B}}}x_2 + h_2\sqrt{\alpha_1 P_{\mathrm{B}}}x_1 + h_{12}\hat{x_2} + \mathrm{n}_2, \tag{1.16}$$

where, h_{12} denotes the cooperative channel between the near and far users. Therefore, the C-NOMA system combating with the channel impairments such as fading, shadowing, path loss and improving the reception reliability of the far user.

1.4.1 Advantages of cooperative NOMA

The major advantages of C-NOMA are as follows

- The conventional NOMA is integrated with a relay protocol, and SIC is implemented at the near users. It decodes the far user's information and a forwards to the far user.

- In C-NOMA the reliability of far user is significantly improved, due to it receives signals from source and near user.
- C-NOMA is achieving higher diversity gain, due to far users overcoming the multi-path fading.

1.5 Spatial Modulation for MIMO System

Multiple-input multiple-output (MIMO) technique, which supports higher data rate at high power consumption for the Internet of Things (IoT) application. The capacity of MIMO depends on the transmit and receive antennas, and this lead to enhance the throughput by increasing the transmit antennas. The major drawback of the conventional MIMO system is that it consumes more power. This is due to it activate condition of all RF chains of transmitting antennas and has a power amplifier, filters, synthesizers, mixers, etc. It also facing inter antenna interference (IAI) and inter-channel interference (ICI). In this context, the spatial modulation aided MIMO (SM-MIMO) is used to in enhancing higher energy efficiency by activating one transmit antenna to convey the index information. Furthermore, SM mitigates the IAI and ICI in MIMO system [18].

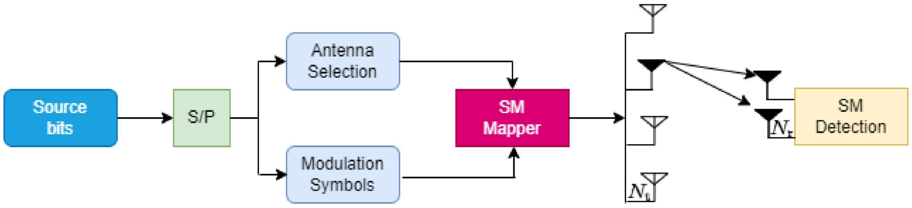

FIGURE 1.5: SM aided MIMO system.

The basic principle of the SM system is the transmit the information bits which are divided into the two parts by using a serial to parallel converter, as shown in Figure1.5. The first part is assigned to transmit or receive antenna index, and the second part is assigned to constellation symbols of binary phase-shift keying (BPSK)

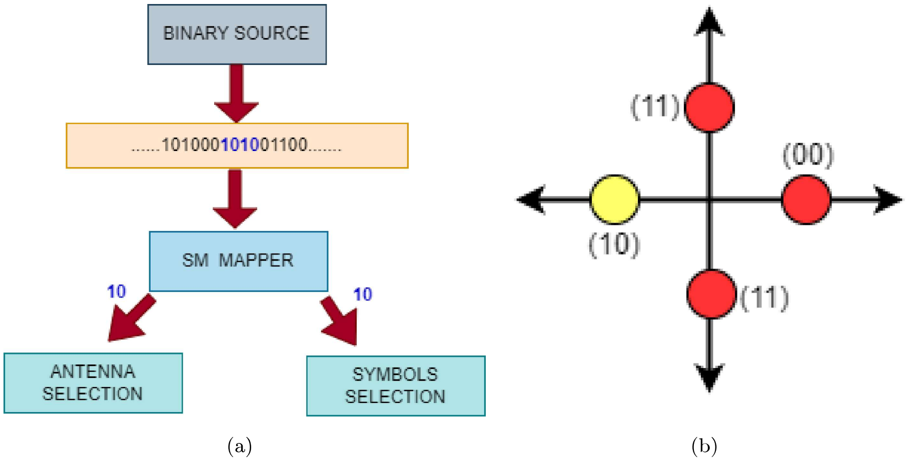

FIGURE 1.6: (a) SM Transmitter (b) Signal Constellation

or quadrature amplitude modulation (QAM). Moreover, the total transmission data rate is, $\log_2(N_t) + \log_2(M)$.

Consider four bits $\{1010\}$ as shown in Figure1.6, and by using SM mapper the first two bits $\{10\}$ are used to activate the second transmitter antenna of BS, and the remaining two bits $\{10\}$ are selected for the constellation symbols and a -1 binary signal is transmitted [19]. The demodulation of SM is done with a two-stage and a maximum likely-hood detector (MLD). Moreover, the two-stage detector is suitable for higher-order modulation like M-ary PSK or QAM, which first determines the index of the active transmit antenna and then demodulates the constellation symbol carried by the active transmit antenna [20]. The complexity of this detector is given as $(O(N_\mathrm{t} + N_\mathrm{r} + M))$. On the other hand MLD is an optimal detector, which jointly detects antenna index and signal-constellation and it's complexity is $(O(N_\mathrm{t}N_\mathrm{r}M))$ [21]. Moreover, channel state information (CSI) is required at the receiver for decoding and the channel estimation.

1.5.1 Advantages of Spatial Modulation

The major advantage of SM over conventional MIMO systems are followed as,

- The SM is avoiding ICI and IAI, which requires a single RF chain. As SM being activating single antenna for data transmission and the remaining antennas are deactivated.
- The data transmission is more, and it increases with a factor of $\log_2(N_\mathrm{t})$ without expansion of bandwidth as compare with SISO system.
- The SM works more efficiently, if ($N_\mathrm{t} > N_\mathrm{r}$), as the diversity of gain is more for a single antenna. Therefore, the SM is more suitable for the downlink communication scenario.
- Finally, the SM is suitable for multi-user scenarios like two transmitters and a single receiver.

1.5.2 Index Modulation

Index modulation (IM) is a promising technology to meet high throughput and energy efficiency, as it is only carrying information about the transmit antenna index. Moreover, transceiver and receiver designs are low complexity. The potential benefits of IM has motivated the author to proposed, a novel IM-aided downlink NOMA system was proposed via RIS, in which cell-edge user is assigned IM, and reaming users are assigned NOMA. Therefore, the transmission data rate is enhanced logarithmically by $\log_2(N_t)$ and improved the energy efficiency. Further, it enhances BER and sum-rate performance of the system by converting reconfigurable the channel environment.

1.6 Literature Review

In this section, works related to NOMA, RIS and some other emerging physical layer techniques are discussed.

Related work on NOMA: Benjebbour et al. [22], have used superposed codes at the transmitter side for transmitting multiple users' information, and implemented SIC at the receivers for extracting the substantial user information, and to show better performance than the OMA. The authors in [23] discussed two users' downlink and uplink PD-NOMA system, to enhance the throughput which outperforms the OMA counterparts. In [24] the performance of downlink NOMA for the SISO system for randomly roaming users was investigated and compared it with the OMA system. In [25] authors addressed the power coefficients optimization problem to maximizing the achievable rate. In [26], user-pairing technique for the uplink NOMA system to enhanced sum-rate performance was proposed. Zhang et al.[27] have investigated the outage probability and sum-rate performance of the uplink NOMA system and verified it by analytically.

Furthermore, the performance of the NOMA was improved with more antennas on the transmitter side by using a two-stage multi-cast beamforming technique [28], and in which implemented zero-forcing (ZF) beamforming to avoid the cluster interference. Moreover, the NOMA and massive MIMO are vital enabling techniques for massive connectivity. In [29], user-pairing and scheduling algorithms for massive MIMO aided NOMA system was implemented to minimize the outage probability and maximize the sum-rate. In [30], authors have investigated an achievable sum-rate at millimeter-wave (mmWave) for massive MIMO assisted NOMA. Further, the NOMA-aided multicell downlink massive MIMO was proposed in [31], in which designed three transmit power control policies were investigated to maximize the sum-rate.

Related work on Cooperative NOMA: The first cooperative NOMA was introduced in [17], in which the strong user was considered as a relay because it was implemented SIC. In cooperative communications two well known protocols are used namely, decode-and-forward (DF) and amplify-and-forward (AF) [32]. In [33] one source was made to communicated with multiple receivers through the AF relay using NOMA. The above work was also extended to the MIMO system in [34]. A strong channel user to act as DF relay was implemented in NOMA [35], which enhances the cell-edge performance. The physical layer security for cooperative NOMA was investigated in [36], in which both AF and DF protocols are considered. In [37], a cooperative relaying system was proposed for the NOMA system in order to achieve better spectral efficiency than the conventional cooperative relaying system. A cooperative NOMA with near users act as full-duplex was proposed [38], to decode and forward and received far user signals from the near user. In [39] two-stage relay system (RS) was proposed for the cooperative NOMA which achieved minimal outage probability among all possible schemes. In [40], two RS sachems namely are two-stage weighted-max-min (WMM) and max-weighted-harmonic-mean (MWHM) schemes for cooperative downlink NOMA system with fixed and adaptive power allocations were proposed.

Related work on SM: A new proposed a new scheme to modulate constellation points, known as superposition coded modulation-aided spatial modulation (SCM-SM), which was implemented with low complexity detector [41]. In [42] the SM with overlay cognitive radio (CR) networks, in which the primary and secondary networks were considered to work concurrently on the same spectrum band. The low complexity detector based on compressive sensing for SM was proposed in [43]. Furthermore, integrating the SM with NOMA can improve the spectral efficiency without increasing the power consumption. In [44], authors have proposed the integrated NOMA-SM for vehicle-to-vehicle communications, by considering channels are spatially correlated. The SM aided cooperative NOMA was presented in [45], which gave better BER and sum-rate performance with SM-OMA and SM-NOMA and also verified analytically.

Related work on RIS: A RIS has emerged as a promising research topic for next-generation wireless communications to enhance the spectral and energy efficiencies [46–49]. An IRS-aided SISO communication system was proposed in [50], and in which BS was communicated by users via IRS under the Rician fading channel and derived outage probability and ergodic capacity. In [51] a low complexity of cosine algorithm for adapting the phase of a RIS aided MIMO system was proposed. The proposed system was derived from the bit error probability. An IRS-assisted IM for mmWave communications was proposed in [52]. Ertugrul Basar.[53] has proposed RIS assisted space shift keying (SSK) and RIS assisted SM. RIS -SSK/SM schemes enhance the bit error performance and increases data rate by increasing passive reflective elements, which was validated analytically. In [54] large intelligent surface assisted wireless communications with SM (LIS-SM) was proposed, investigated average bit error performance (ABEP). Moreover, the LIS-SM system employing an antenna selection method.

Moreover, researchers are amalgamating RIS and NOMA in order to achieve high spectral and energy efficiencies [55–58]. In [59], RIS aided NOMA system was proposed and investigated both diversity order and outage probability. The outage probability was analyzed for RIS-assisted NOMA system [60] under the hardware impairments. Simultaneously the transmitting and reflecting reconfigurable intelligent surface assisted NOMA Networks (STAR-RIS-NOMA) were proposed in [61], and in which the BS transmitted signals are reflected and transmitted via RIS to nears and far users were calculated the outage probability and ergodic rate for a pair of users under perfect and imperfect SIC. In [62] active and passive beamforming was applied at the BS and RIS, respectively, to enhance the sum-rate of RIS-assisted NOMA.

Further, some recent works on RIS-assisted NOMA have maximized the sum-rate performance by joint optimization of active and passive beamforming at BS and RIS in [63]. Furthermore, NOMA assisted backscatter communication system with IRS [64], RIS-assisted two cell downlink NOMA network. Furthermore, the summary of the literature survey is presented in Table 1.1.

Table 1.1: Summary of literature survey

Ref.	Classification	System Model	Design Objective	Main Finding(s)
[65]	SSK-NOMA	Three users	Derived BER and SR	Proposed system outperform to conventional NOMA
[45]	SM-CNOMA	Two users	Derived BER and SR	The proposed schemes outperform SM-OMA and conventional NOMA
[66]	SM-NOMA	K-users	Enhance spectral efficiency and derive the MI for MU	The proposed SM-NOMA scheme is capable of achieving considerable performance gains over conventional OMA.
[67]	PSM-NOMA	K-users	Enhance spectral efficiency and derive the MI for MU	The proposed NOMA-PSM scheme is capable of achieving considerable performance gains over conventional OMA
[68]	SM-mNOMA	K-users	SER derived	An efficient power allocation scheme was proposed for achieving further performance improvement.
[53]	RIS-IM (MISO)	Single users	Derived BEP	Proposed system outperform to conventional IM
[69]	RIS-NOMA(MISO)	K-users	Derived outage probability	Improved cell-edge performance and compare with SDMA.

1.7 Research Objective

The objective of this thesis is to enhance the spectral and energy efficiency of next-generation communications.

To this end, the literature survey focuses on the derivation of outage probability, mutual information for multi-users, and maximization of SINR for sum-rate performance under low transmit power, as well as joint active and passive beamforming optimization problems.

The research task carried out for this thesis are as follows:

- The first objective is to enhance cell-edge performance and massive connectivity by using cooperative NOMA and implementing precoded spatial modulation to mitigate inter-user interference and increase data rate transmission.
- RIS-assisted IM-NOMA has been proposed for higher spectral and energy efficiency. The assigned spatial domain improved the cell-edge users' performance.
- Multiple RISs-assisted NOMA has been proposed to enhance coverage area in highly scattering environments.
- RIS-assisted user-pairing hybrid NOMA has been proposed for more users at the cell edge than at the cell center. Here minimized the transmit power and maximized the beamforming via join optimization.

1.8 Organization of the Thesis

The thesis is organized as follows: In Chapter 2,a precoded SM-aided cooperative NOMA for the downlink MIMO transmission is proposed. It has two phases namely:

the broadcast and the cooperative NOMA phase. The symbol error rate (SER) and MI under IUI were calculated. The main work focus is on more connectivity and enhanced cell-edge user performance. The impact of multiple transmitting and receiving antennas is analyzed and validate the theoretical results by using simulations. The proposed system compare with conventional NOMA and conventional cooperative NOMA.

In Chapter 3, a RIS-assisted downlink IM-NOMA system is proposed for the next-generation wireless networks to achieve higher spectral and energy efficiencies with low latency. Further, the diversity order and upper bound on the probability of error were computed. The achieved BER at a low SNR range of the proposed model and is also verified analytically. The proposed system performance is compare with the conventional IM-NOMA system and derived the sum-rate over Rayleigh fading channels.

In Chapter 4, a multiple RISs-assisted downlink NOMA is investigated to enhance the spectral and energy efficiencies and network coverage. An upper bound of bit error probability under Rician fading channels is derived, and also the BER performance for two different deployment strategies of RIS-assisted NOMA system is investigated. Further, zero-forcing beamforming technique at the BS and passive beamforming at the RIS was implemented. The sum-rate performance is calculated and compared it with a RIS-assisted OMA, like TDMA and FDMA systems.

In Chapter 5, more users are distributed at the cell edge than at the cell center scenario is considered and implemented with a RIS-assisted users-pairing hybrid NOMA system for the practical imperfect SIC. In this work, a joint optimization of transmit antennas beamforming and reflecting elements phase at the BS and RIS, respectively, using SDR and AO techniques are implemented. The sum rate of RIS-assisted systems with different transmit beamforming schemes is calculated and compared with RIS-assisted conventional NOMA and OMA system.

In Chapter 6, the summary of the work embodied in the present thesis and conclusion are present. The limitation of the present work is discussed to bring out promising future research directions.