Chapter 1

Introduction

1.1 Wireless Communication – An Introduction

In the communication area, wireless communications is a fast growing sector, having high potential speed in deliver with maximum quality of transferring data between the portable devices anywhere on the earth. Since from 1960, because of a confluence of numerous consequences, the tremendous development in wireless communication technology, this has been the subject of research. For starters, the requirement for wireless connectivity has skyrocketed. Secondly, VLSI technology is rapid advancement, which enables complex signal processing and coding methods in small-area, low power devices. Voice and low-volume digital data transmission had enabled by second-generation wireless communication technologies such as CDMA, GSM and TDMA. In third-generation, it provides additional highly developed services to achieve higher capacity by enhanced spectral efficiency [1]. Automated highway systems, smart home appliances, distance learning and video teleconferencing are all examples of multimedia Internet-enabled mobile phones, in an independent sensor networks the possible applications are enabled by this technology. However, there are two major technical obstacles to overcome in order to support these applications. First is fading, channel time variation because of minor-range effects like multi-path fading, major-range effects like path loss because of distance attenuation as well as obstacle shadowing. Next, because wireless transmitters and receivers must communicate over air, they are subject to significant interference. Overall, the difficulties stem from a lack of radio frequency spectrum with complicated wireless time-varying fading as well as multipath environment. Most important intention is increasing transmission reliability and data rate in current wireless communication. To put it another way, as the need increase in data rates maximum, less dropped calls, quality of the service is improvised, increased growth of network capacity and user coverage grows, more wireless communication technologies, such as OFDM and MIMO, are introduced to develop spectral efficiency and link dependability. Multiple antennas have recently implemented in NOMA systems (NOMA-MIMO) which scaled up system throughput with the number of antennas by exploiting spatial freedom [2]. However, the superior performance needs high power consumption and complex computation for signal processing on two ends of transmitter and receiver. In order to control the maximum power utilization, expensive hardware and computational burden while preserving the benefits of MIMO technology, antenna selection techniques are recognized as efficient solution [2][3].

1.2 Multiple Access

In wireless communication system, to provide communication service between multiple transmitters and receivers simultaneously over a single channel by using channelization techniques based on time, frequency or code is known as multiple access. The channels are created by dividing the resources orthogonally or semi-orthogonally. The transmitting power of each transmitter may be different, but the receiver's bandwidth is divided among the users. The principle of multiple access technology is utilizing the available resources like bandwidth and power in an efficient manner while creating minimum or no interference. Generally, when dedicated channel allocation is done to the users, it is called multiple access. It is commonly used in the telephone systems as they use dedicated channel allocation for voice signals. The sharing of bandwidth which requires burst transmissions by using random channel allocation and which do not assure channel access is called random multiple access. The characteristics and compatibility of the system will determine whether arbitrary access or multiple access as well as channelization are utilized. Overall channel capacity is increased by sharing bandwidth [1]. The types of multiple accesses are an orthogonal as well as non-orthogonal type way in [4].

1.2.1 OMA- Orthogonal Multiple Access

OMA- Orthogonal Multiple Access technique scheme divides the available resources (power or bandwidth) of the system equally and then assign to the users through the channels. In this scheme, using different basis functions, the receiver separates unwanted signals to obtain the desired signal [4]. There are different methods to divide the channel like frequency division, time division and code division. Performance of different division technique is different and it depends upon the traffic characteristics of the system. OMA offers a set of desirable benefits, including employing techniques for increasing single user rate using higher order modulation, assigning orthogonal signal sub-spaces to different users to avoid intra-cell interference and it is insensitive to the near-far effect. In packet domain services, the OMA can achieve good system throughput with a simple receiver design [5]. OMA lacks in spectral power efficiency, sensitivity to cross-cell interference and synchronization of frame to maintain orthogonality. The earlier and existing wireless networks OMA has used Frequency Division Multiple

Access (FDMA) and Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) in 3G Orthogonal Frequency Division Multiple Access(OFDMA) is preferred and used in 4G.

1.2.2 OFDMA- Orthogonal Frequency Division Multiple Access

The multi-user communication technique called Orthogonal Frequency Division Multiple Access (OFDMA) that is dependent on OFDM (Orthogonal Frequency Division Multiplexing) and used widely in the wireless broadband network possible to overcome drawbacks of signaling transmission and increase the rate of transmission [6]. It converts channel frequency into several parallel streams and modulates each stream into individual carriers or subcarriers which allows us to divide the total bandwidth into non-overlapping channels and simultaneously transmit data to multiple users. To maintain orthogonality, these subcarriers maintain minimum frequency separation with time-domain waveform. Despite this, the frequency spectra of different subcarriers overlap. As a result, the available bandwidth is effectively utilized. If the OFDM transmitter has access to channel knowledge, it can adjust its signaling strategy to match the channel [7]. The Inverse Fast Fourier Transform (IFFT) can be used to attain OFDM, which allows for a greater number of subcarriers while maintaining low complexity [8]. Due to the sub-channelization, the OFDM system can allocate to the users as more power and low signal to noise ratio (SNR), and less power with more SNR [10]. This technique has turn into trendy for transmission of information over wireless channels and its adoption in many wireless standards like Digital Video Broadcasting (DVB – T) and IEEE 802.11a [9] local area standard [7]. Due to its advances in its computational power and simpler receiver design for higher carrier bandwidth, OFDM technology was selected for 4G [11].

1.2.3 Non-Orthogonal Multiple Access

A competent 5G network multiple access system is NOMA (Non-Orthogonal Multiple Access) [5][12].High spectral efficiencies can be achieved in transmitter and the receiver end by superposition and Successive Interference Cancellation (SIC) respectively. The user who nearer decodes and subtracts the distant user signal while accommodating multiple users at a time. Decoding of signal for distant user without much interference from the near user signal, which is weak. [5][13][14].

The two common classification of NOMA are Power Domain Non-Orthogonal Multiple Access (PD – NOMA) as well as Code Domain Non – Orthogonal Multiple Access (CD –

NOMA). In Code Domain Non – Orthogonal Multiple Access transmission of signals is further classified into several techniques that depend on Low Density Signatures (LDS) as well as Sparse Code Multiple Access (SCMA). LDS method minimizes intersymbol interference (ISI). This LDS consists of sparse spreading codes in which each comprises some non-zero elements. These sparse codes permit generation of more extra-ordinary codewords for the transmission of the signal which in turn permits more users to superimpose non-orthogonally. Users separation can be done at the receiver even when their power levels are of the same characteristics. By using LDS for multiple access and OFDM for multicarrier modulation, we can achieve frequency diversity and overloading due to their orthogonal mapping and sparse spreading. Neverthless this can be expensive and high receiver complexity. In SCMA, the sparse spreading is optimized further by the combination of LDS and Quadrature Amplitude Modulation (QAM) mapping to generate codewords [15]. Due to which, complexity in the receiver is moderate as the codebooks between the transmitter and receiver are transparent [16].

1.3 OFDM – Orthogonal Frequency Division Multiplexing

OFDM is a digital modulation methodology, where a data stream is splitted into N parallel streams to decreased data rate, everyone is sending on its own subcarrier. This is digital multicarrier communication kind. OFDM has been around for about 40 years as a means of reducing interference between channels with similar frequencies [17]. OFDM has appeared in a variety of applications, including digital audio and video broadcasts and Asymmetric DSL (ADSL) broadband. One of the most widely used wireless communication technologies is OFDM, which has been able to provide high-speed transmission capabilities. Its robust multi-path delay and bandwidth efficiency allow it to handle large data rates. OFDM is a data transmission method for high-speed data transfer over multipath wireless networks that have been proposed. Over the last, four decades, OFDM has grown in popularity as wireless or wired wideband digital communication scheme, with applications including wireless networking, broadband internet access, and digital television and audio broadcasting [18]. Transmitted signals in wireless environments take a variety of paths to reach their destination. Random Phase distortion, delay spread, inter-symbol interference (ISI) and fading occur when these paths are separated from surrounding objects and arrive at the receiver with different propagation delays. For example, the delayed copy of the broadcast signal will interfere with succeeding transmissions, resulting in Inter Symbol Interference. The receiver's delay spread limits the transmitted symbol rate. OFDM is a standard used in wireless LAN, in

United States it isIEEE802.11a. Similarly in Europe it is HIPERLAN/2, as well as in Japan multimedia wireless services it is Multimedia Mobile Access Communications [19]. IEEE standards given for wireless networking transmission, and 802.11 are one of them. They are commonly used in the office, commercial establishments and homes. 802.11a, 802.11b and 802.11g are the various wireless system standards. Here 802.11a standard incorporates 52-subcarrier orthogonal frequency-division multiplexing (OFDM) with a highest data rate of 54 Mbit/s ensuing in practical net achievable throughput in the mid-20 Mbit/s scale. It works in the 5 GHz band and utilises the identical core protocol similar to actual standard. Because the 2.4 GHz band is so heavily used that it is crowded, 802.11a gains a important benefit by using the 5 GHz band. OFDM is also used in the 802.16 and WiMAX networks. The IEEE standard for wireless Metropolitan Area Networks (MANs) also known a WiMAX and wireless LAN [51] is the IEEE standard for wireless MANs. Worldwide Interoperability for Microwave Access (WiMAX) is an acronym and one of the telecommunications technologies that can deliver wireless data in various routes, ranging between point-to-point connections and full mobile cellular access [20].

In OFDM, a data block is transformed to parallel form as well as mapped into every subcarrier in the time domain. The interval between signals is greatly increased when the symbols are transmitted in parallel, effectively eliminating inter symbol interference in time dispersive channels. The signal is the transformed into time domain from frequency domain applying Inverse Fast Fourier Transformation (IFFT). It accepts N symbols at a time, with N indicating the count of subcarriers. The period of every N input symbols are T seconds. The functions of an Inverse Fast Fourier Transformation are N sinusoids which are orthogonal. Every input symbol serves as a complex weight for the sinusoidal basis function. Because the input symbols are not simple, the amplitude and phase of the sinusoid for that subcarrier are determined by the value of the symbol. The summation of all N sinusoids is the IFFT output. As an outcome, the IFFT block makes modulating data onto N orthogonal subcarriers simple. A single OFDM symbol is formed by a block of N output samples from the IFFT [21]. Figure 1.1 depicts the basic structure of an OFDM. The receiver receives the frequency signals. When the frequency signals reach the receiver via the channel the receiver has to achieve synchronization (timing and frequency), demodulation, decoding and channel estimation. The data processing at the receiver end is the inverse of that at the transmitter end, in that the first block is FFT to convert the signal of time- into frequency-domain type at the receiver. Before the

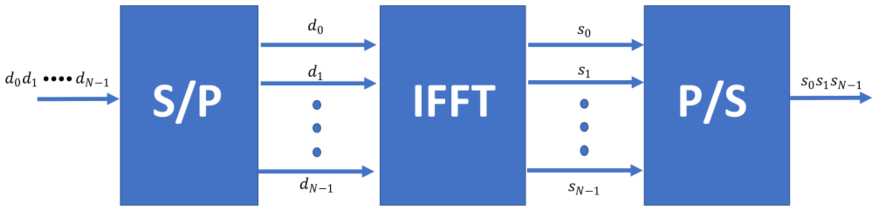

Figure 1.1 OFDM transmitter system

IFFT block, the FFT output should be identical to the transmitted symbols. The symbols will be demodulated and calculated using this data, assuming channel information is available. Figure 1.2 depicts the basic structure of an OFDM receiver. When the transmitter and receiver are connected by several transmission pathways, or the signal which is received will be the sum of numerous version from the signal sent with varied delay, attenuation and multipath effect arises. The ISI effect is the most notable example. Parallel data transmission and cyclic prefix are two methods commonly used in the OFDM scheme to reduce this effect. The cyclic prefix is usually equal to or greater than impulse response to its channel length. The fundamental concept for constructing guard periods can be achieved by copying a piece of the OFDM time-domain waveform from back to front. The duration of the guard period T_g should be more than the target multi-path environment's worst-case delay spread. In Figure 1.3, the structure of cyclic prefix is illustrated [22].

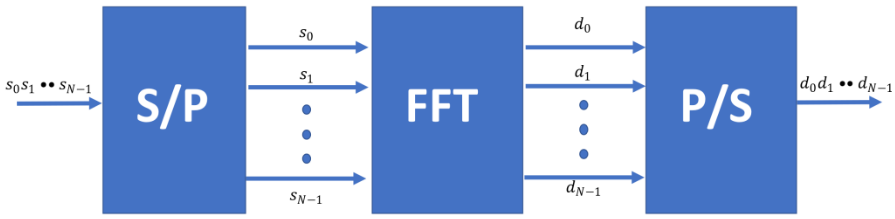

Figure 1.2: OFDM receiver system

Figure 1.3: OFDM signal with cyclic prefix

1.4 Wireless Communication Channel – An Overview

This overview discusses some of the issues that arise during mobile radio propagation, as well as their effects on signal quality. In wireless communications, there are many distortion mechanisms in the communication channels. First, reflections from objects in the surroundings cause multipath effect. There are many replicas of the received signal at the receiving antenna which arrives from distinct paths as well as at dissimilar time, causing multipath fading and inter-symbol interference. At fading and frequency selective fading, it will be explored in depth in the chapter under second section. Secondly, the time varying Doppler Effect occurs when the transmitter and receiver move with a constant velocity relative to each other. Doppler spread is the reason for Quick fading and time-consuming fading. Next, the received power attenuation is strongly influenced by the transmitted signal's path length. At the point when there is enormous landscape among transmitter and beneficiary like slopes and structures, this attenuation is very likely to happen. Finally system noise includes thermal noise in receivers, atmospheric noise, and various types of random noise such as interference among wireless carriers, transmitters as well as systems. These noises are not dependent from the signals during channel transmission and the channel fading. Typically, it is an Additive White Gaussian Noise (AWGN). A detailed description about the impairment methods is given in the following section.

1.4.1 Multi-path Spread

In traditional wireless communications, the source is one antenna and receiver at the destination is another one. As we previously discussed, this structure can sometimes lead to issues with multipath effects. At the point when an electromagnetic field slams into snags like gorge, slopes, utility wires, structures and the wave fronts disperse then follow multiple paths to contacts the recipient. Multiple waves arrive at delays (phases) which are at random, and different angles and different amplitudes, few problems like fading, cut out and intermittent reception occur [23]. It can slow down information transmission and increase the increment the number of errors in computerized correspondence frameworks like wireless Internet. Figure 1.4 depicts the multi-path effect caused by scattered waves from the transmitter to the receiver, which paved the way for signal distortion and delay which cannot be ignored.

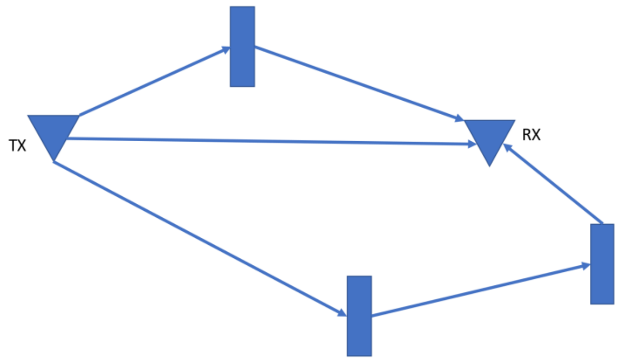

Figure 1.4: Multi-path spread

1.4.2 Types of Fading

When signals transmitted to receivers, fading effects may be in two ways: Flat as well as frequency selective fading. The channel is called at fading when all of the spectral elements of the transmitted signals are impacted by the identical amplitude gains as well as phase shifts. In this scenario, transmitted signal bandwidth may be substantially smaller than the channel's coherent bandwidth. Many wireless environments have at fading channels, which cause deep fades. At fading, the amplitude distribution may be Raleigh or a Ricean distribution. The fading is said to be frequency selective when the spectral components of the sent signals are influenced by various amplitude gains and phase shifts. The transmitted bandwidth surpasses the channel's coherence bandwidth in this scenario. Inter-symbol interference will be generated by frequency selective fading, through using digital processing. To put it another way, consider a single transmitted impulse with a temporal period Tm equal to the time difference in the first and final component which received with the greatest delay spread; thus, the coherence bandwidth f_c is $\frac{1}{T_m}$, T_s is the symbol for time, as we all know. If $T_m > T_s$, then a channel is at frequency selective fading, and if $T_m < T_s$ then called as fading [24].

1.4.3 Rayleigh Fading

Multipath fading with non-line-of-sight is modeled using the Rayleigh distribution (NLOS). When line of sight (LOS) exists, there is possibility of Ricean fading. The Probability Density function of the fading signal of i^{th} path $\propto_i$ is defined through

$$f_{\propto_i}(\propto_i) \ = \frac{2\propto_i}{\Omega_i}\exp\left(-\frac{\propto_i^2}{\Omega_i}\right), \alpha_i \geq 0 \tag{1.1}$$

Where $\Omega_i = E[\propto_I^2]$ and $E[.]$is the expectation of its argument [25].

1.4.4 Doppler Fading

The Doppler Effect is another major concern in wireless communications (shift). As we all know, the relative speed of the elements in the communication system causes this impact. The Doppler Effect is the perception of a wave's frequency/wavelength changing as the observer moves away from the source. As a result, the total Doppler Effect can be caused by either source motion or observer motion.

In this model, the Doppler Effect is corresponding to the magnitude of relative speed with the transporter recurrence commitment. Medium isn't required for waves, for example,

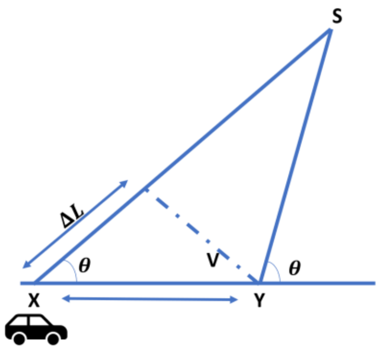

Figure 1.5 Illustration of the Doppler fading effect

light or gravity in extraordinary relativity [26]. The relative distinction in speed among source and onlooker should be tended to. The transporter recurrence shifts when an electromagnetic wave moves towards or away from the recipient in remote correspondence, causing Doppler shift. When both antennas apart from each other, Doppler shift is noticeable. As we can see from Figure 1.5, the phase difference between two transmission paths is:

$$\Delta\phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi\vartheta\Delta t}{\lambda} cos\theta \qquad (1.2)$$

The Doppler shift is:

$$f_d = \frac{1}{2\pi}\frac{\Delta\phi}{\Delta t} = \frac{\vartheta}{\lambda} cos\theta \qquad (1.3)$$

Because the observed frequency increases as objects move nearer to observer, when motion is directed toward the observer, the velocity of the source must be removed. (This is due to the fact that the velocity of the source is in the denominator). When the source moves away, when the motion is gone, the observed frequency drops, therefore the source's velocity is added. A scope of frequencies near the sinusoid recurrence will be received in the event that a pure sinusoid is sent. The basic spectrum in frequency domain spreader then the Doppler shift widens the range of the receiver signal. The impact isn't observable assuming the signal spectrum is enormous in contrast with the spreading. Otherwise, there will be distortion. Investigate BPSK signals in a slow, Rayleigh, and Doppler fading channel with additive white Gaussian noise using one transmitter and one receive antenna. The performance when $f_d = 0$, $f_d = 0.01$, $f_d = 0.05$ are shown in Figure 6 respectively. Because of the effect of Doppler fading, the performance degrades as f_d increases. Because of the effect of Doppler fading, as the size of the sample grows larger, the performance deteriorates. The reception of the transmitted signal can be hampered by multi-path fading and Doppler effects. Inter symbol interference is caused by when numerous ways with various postponements, and co-channel users cause distortion for the target user. Thermal noise, on the other hand, is electronic white noise that must be accounted.

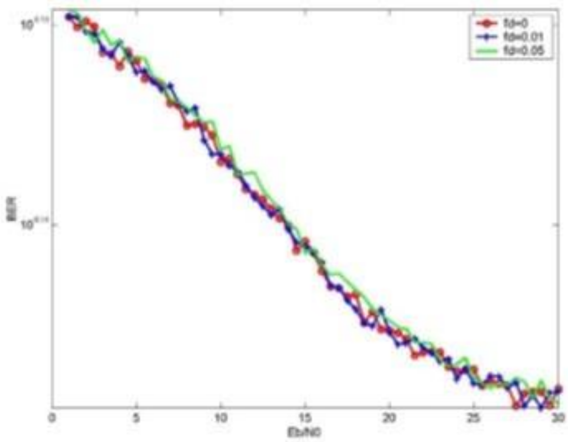

Figure 1.6: SISO simulation under Rayleigh and Doppler fading channel, f_d is Doppler Shift factor

According to [27], diversity is an effective method for improving error rate performance in fading channels. MIMO OFDM is a wireless communication method that uses MIMO provide capacity, array gain, and diversity [28] while also using OFDM to avoid inter symbol interference.

1.4.5 Examples of Doppler Fading

Slow and fast fading are both examples of Doppler spread fading. A channel can be time varying in wireless communication, and these are named as slow or fast fading channels. During the life of a data transmission, the fast-fading channel varies dramatically. When the channel rapidly varies, the amplitude and phase of the symbol are distorted erratically over its interval. Slow blurring happens when the channel changes significantly more leisurely than one symbol duration. It is not necessarily the case that the channel's effects can be ignored, rather, channel changes can be tracked and channel dynamics can be appropriately compensated. The channel's coherence time is the length of time during which the fading process is coupled. The duration of time over which the fading process is associated is referred to as the channel's T_c. T_c is connected to the Doppler spread $f_d$in the following way: $T_c = \frac{1}{f_d}$. Slow fading occurs when the symbol time duration T_s is less thanT_c; otherwise, fast fading occurs [29].

1.5 MIMO

MIMO has been used in wireless systems for a long time. The ground-breaking work of MIMO has been done in Bell Laboratories' by Jack Winters and Jack Saltz [30]. In the mid-1980s, one of the first MIMO wireless communications applications was developed. They use many antennas at the transmitter and receiver to exchange data from the many users on a same frequency/time channel. And since, a slew of researchers and engineers have made significant contributions to MIMO research. Along with its possible applications in digital TV, wireless LANs, MANs, wireless connectivity and MIMO technology has sparked attention. Together under the transmission conditions, MIMO beats the Single-Input-Single-Output (SISO) system. To begin with, the channel capacity of a MIMO system is dependent on the total amount of transmitter and receiver arrays. Secondly, since each signal is calculated using N obtained outcomes, every broadcasting signal is recorded by a complete detector array in a MIMO channel, which inherent range. Through minimizing the effect of ISI (Inter Symbol Interference) as well as channel fading, this increases durability and dependability. To put it another way, spatial diversity generates N unique copies of the broadcast signal. Thirdly, the gain of the array has been raised, meaning that power is being directed in the intended way. The improvement in SNR has indeed been boosted as well [31]. MIMO, on the other hand, is more energy intensive in terms of both transmission and circuit energy consumption. In MIMO research, energy efficiency analysis of MIMO systems is a hot topic.

1.5.1 Multiple Input/Multiple Output (MIMO) Techniques - An Overview

Multiple Input/ Multiple Output (MIMO) is a signal transmission and reception technology that employs multiple antennas. Figure 1.7 depicts the basic MIMO structure, with $T_n$and R_n denoting the nth transmitter and nth receiver antenna. SIMO refers to a system which has single input and multiple outputs in some special cases. Alternatively SIMO refers to a system contains a single input and multiple outputs. Information $(x_1, x_2 \ldots\ldots x_n)$ are broadcasted or sent using N transmitting antenna elements in a MIMO channel. The antenna arrays in the receivers are$M(M >= N)$.Whereas if signal is received by j^{th}antenna is denoted with $r_j(j = 1,2, \ldots\ldots. M)$, therefore the received data just at receivers (see Figure 1.7) could be described simply,

$$\begin{aligned} r_1 &= h_{11}x_1 + h_{12}x_2 + \cdots . + h_{1N}x_N \\ r_2 &= h_{21}x_2 + h_{22}x_2 + \cdots . + h_{2N}x_N \\ &\vdots \\ r_M &= h_{M1}x_1 + h_{M2}x_2 + \cdots . + h_{MN}x_N \end{aligned} \quad (1.4)$$

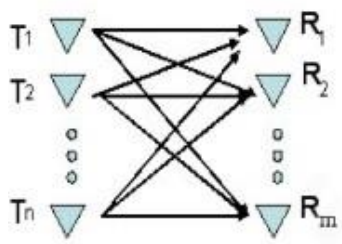

Figure 1.7: MIMO structure

.Where h_{ij} the impact of the j^{th} transmitting signal x_j on the j^{th} receiver signal strength is represented by the weight coefficient. Defining a channel matrix H as:

$$H = \begin{bmatrix} h_{11} & h_{12} \ldots & h_{1N} \\ h_{21} & h_{22} \ldots & h_{2N} \\ \vdots & \vdots & \vdots \\ h_{M1} & h_{M2} \ldots & h_{MN} \end{bmatrix} \quad (1.5)$$

The transmitted signals x_i may be recovered in a MIMO system through computation of channel matrix H as well as signal vector R at the destination.

One of the main advantages of a massive MIMO system is its ability to provide multiple gains, such as spatial multiplexing. However, there are various trade-offs between the two gains. For instance, the larger the gain in spatial multiplexing, the most costly it is for the diversity gain [32]. MIMO employs diversity to combat channel fading. The receiving antenna's signal is much more consistent, and fade may be effectively regulated. Because entire transmitting and receiving antennas gives a signal channel to a destination from the source, and every route transports a same data in real time. Whenever the channel gains across different transmit-receive antennas combinations start to deteriorate on their own, several parallel spatial channels are generated. The data rate is raised by sending separate information streams over the spatial channels in simultaneously. The phenomenon is called as spatial multiplexing [32]. Although diversity provides a reduced error probability, multiplexing provided higher rate; the difference would be that diversity needs delivering identical information, whereas multiplexing demands providing data. Clearly, the disagreements among them imply a basic trade-off among the benefits of diversity and multiplexing.

1.5.2 MIMO OFDM – An Introduction

MIMO OFDM (Multiple Input Multiple Output, Orthogonal Frequency Division Multiplexing) is a wireless transmission technique that combines MIMO and OFDM to overcome the frequency selective channel effect. Because each subcarrier OFDM signal will be able to defeat narrowband fading, MIMO system can then be used in broadband

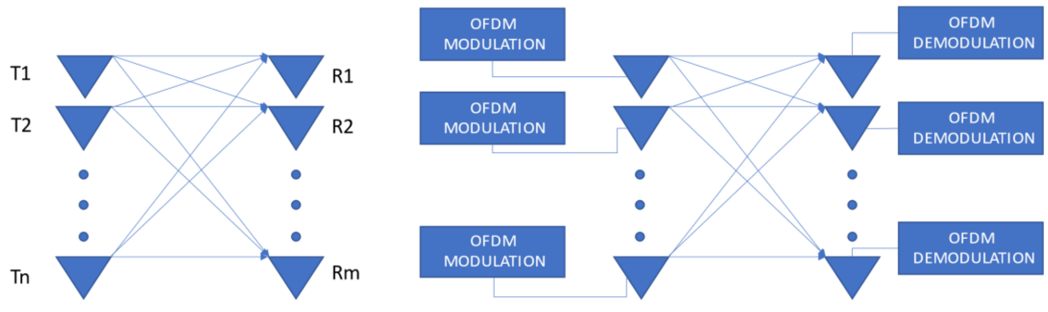

Figure 1.8: MIMO OFDM structure

transmission by combining Multiple Input Multiple Output and Orthogonal Frequency Division Multiplexing technology [33] which helps in transmission of the modulated data simultaneously in a MIMO OFDM system. Following demodulation of OFDM, the signal is retrieved at the receiver from every antenna at transmitter side by decoding each sub-channel [34]. Service providers will be able to deploy a NLOS Broadband Wireless Access (BWA) system using MIMO OFDM. Particularly MIMO-OFDM, multipath having benefits in its property with non-LOS base station antennas, it also provide high throughput and robustness by combining the two techniques. MIMO-OFDM becomes significantly more leisurely in a multiuser situation. Therefore, several users converse with base station or access point called as central station, which gives an additional chance to utilize. The basic arrangement of MIMO OFDM is exposed in Figure 1.8. An OFDM modulator is used to modulate the signals, MIMO system for transmitted and finally recovered by an OFDM demodulator. As a result, MIMO OFDM obtains spectral efficiency, improved throughput, as well as prevention of inter-symbol interference (ISI).

1.6 Massive MIMO

Massive MIMO is the concept of significantly scaling up MU-MIMO systems deploys hundreds or thousands of antennas (transmitter and receiver). The actual number of active participants in these systems determines the number of antennas in base stations. The base station also provides service to all active clients at the same time with almost the same frequency. Due to fading, signal strength in communications systems with some antennas might be quite low. When multiple waves from the same source reach the receiver, they interact destructively. The unique way is to wait for any channel to change therefore that the information is appropriately reached. Latency is the term for the time it takes for a signal to arrive. This strategy will minimize the effects of fading and ensure that the obtained signal is close as expected value. Whenever the base station antennas numbers greatly exceeding the active user's numbers, as shown in [35]. Linear processing is essentially an optimum choice. For instance, if using a maximum-ratio combination or a maximum-ratio transmission, the effects of uncorrelated noise and interference will fade. This is applicable for both downlink and uplink. Therefore, as that the law of averages states that a channel matrix that is desirable for a given user is more than an interference matrix that is ideal for a given user. This also has a lot of angles of liberty, which can be used to make RF amplifiers that are both cheap and efficient [38][39].

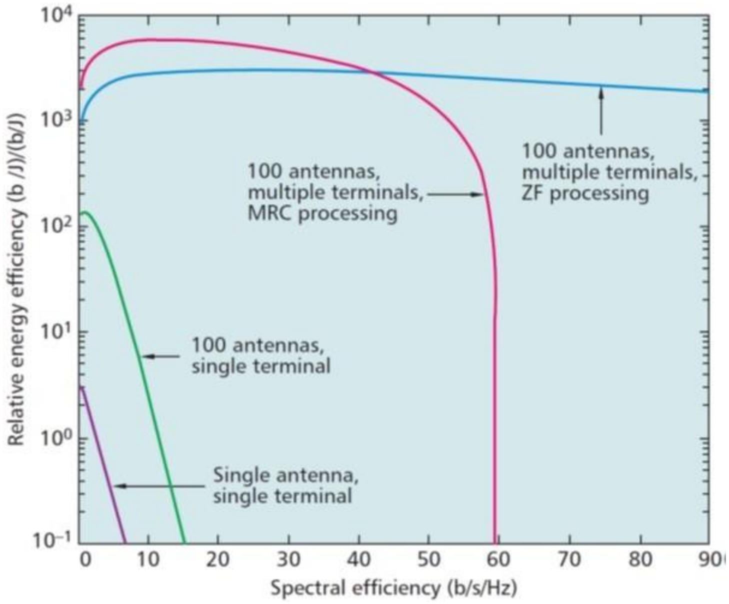

Figure 1.9: Spectral efficiency versus Energy efficiency for multiple access systems [36]

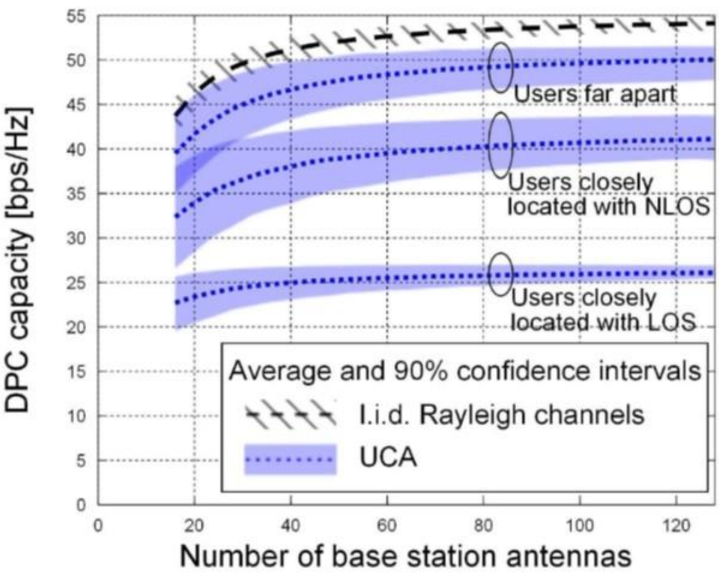

Figure 1.10: Sum-rate capacity with Dirty Paper coding in the downlink for multiple users in intervening scenarios [37]

Massive MIMO offers a upper range of useful energy efficiency compared to earlier generations of wireless systems, as shown in Figure 1.9. As a result of the additional antennas, the base station can use beam forming in the downlink, which improves spatial accuracy while reducing radiated power. In optimal conditions, the transmit power of a network can be reduced by about 3 dB. This strategy can also maintain the same performance while increasing the antennas count installed at the base station. Coherent beam formation creates a higher array in the uplink, allowing each user to transmit with less power, benefitting all mobile devices. This needs on good propagation conditions. Uncorrelated responses to the queries of distinct users can lead to favorable propagation in the downlink channel. When the channel is pairwise or complex, the scattering environment can be minimized. Such kind of model may be used in real channels. According to studies and channel measurements, this system can be performed in various propagation conditions [37]. Figure 1.10 demonstrates the capacity of a 16-user downlink system when the users are far apart but close together.

1.6.1 Channel Estimation in Massive MIMO

Spatial multiplexing, a requirement of massive MIMO, calls for accurate channel information on the part of the base station. Users submit uplink training patterns to the ground station, which assesses each user's channel responds. Because the base station requires advance knowledge of the forward channel, obtaining accurate channel response for each terminal will be maximum difficult in a downlink. In time division duplex (TDD) architectures, it is assumed that the reverse and forward channels are identical during a specified coherence interval. For the following forward transmission, the estimated reverse channel answers are applied. As a consequence, channel reciprocity is among the great benefits of TDD systems; however some correction is needed [40].

Closed-loop topologies, but at the other side, are required for frequency division duplex (FDD) designs. To reduce computational necessities and develop capacity of the mobile device battery, the base station estimates the reverse channel using training sequences sent by users. In order to estimate the forward channel in the downlink channel, the base station sends training sequence to the users. This method ensures that the training sequences are identical to the antennas count installed at a given station. Figure 1.11 shows a structure with channel estimate for both the FDD as well as TDD systems, where the time slots with channel estimate are far apart. Despite the fact that FDD is part of the existing LTE standard, implementing it in massive MIMO systems is more difficult due to antenna orthogonality concerns and the enormous number of channel estimations necessary. For optimal estimations, downlink pilots are supposed to be mutually orthogonal. To do so, time-frequency resources are allocated based on antennas count at the base station, resulting in massive MIMO systems requiring more number of resources in huge quantity than standard MIMO systems. There must be fewer orthogonal training sequences than pilots who will use them. Another issue is the number of estimations that the terminals must perform in the shortest amount of time. Each user must estimate a certain number of channel responses, this is related to the antennas count on the base station.

As a result, endpoints had to devote several of times greater resources to providing channels performance rates to the base station, this will be significant disadvantage for cellular phone, and to increases feedback transmission latency. Furthermore, the expected CSI will be affected because of limited channel feedback by quantization errors and obsolete software because of the time among estimates and implementation at the base station. For non-ideal CSI at base stations is investigated in [41], specifically the trade-off between the benefit of FDD systems have a more count of antennas as well as estimation cost of big channel vectors is high. Scaling up large antenna arrays once again introduces two new issues that were not previously considered.

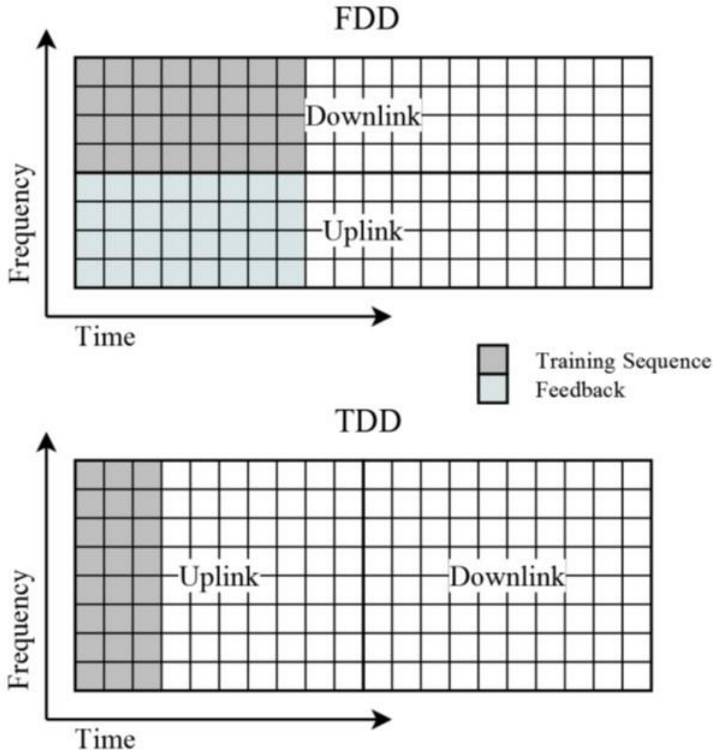

Figure 1.11: Time slot for FDD as well as TDD systems with channel estimation

The system can either function in the TDD or FDD mode. In the former, it can rely on channel reciprocity, while in the latter, it can use the accuracy of the base station's CSI. Since the number of antennas does not affect the pilot resources, the system can operate in FDD mode. Because of needed pilot resources, it is independent of count of BS antennas, this is the typical technique employed in huge MIMO systems [42].

1.6.2 Pilot Contamination

As a multicellular system, massive MIMO is discussed across numerous cells, because it is intended to be a realistic cellular network. To eliminate intra-cell interference, each terminal has a corresponding training sequence for channel estimation. Furthermore, channel estimation is required during each coherence interval. The training sequences should be less compared to total count of elements in every coherence interval. This ensures that the training sequences are reapplied in the cells that have the most coherent time-frequency components. This restriction can cause pilot contamination since the receiver might receive the same signal from different sources. This issue can lead to erroneous channel estimation as shown in Figure 1.12. As a result, non-cooperative MU-MIMO systems' performance is limited by pilot contamination [36]. For the reason that the base station calculates the necessary channel replies inaccurately, the precoding completed in the transmit signal is also wrong. The SINR of the entire transmission is significantly reduced by incorrect precoding. In an MRT precoding scheme, the base station performs beam forming. Because of estimated channel values, the signal power is misplaced, resulting in the required user receiving a low power signal. With the same training sequence, the power is sent as interference to other undesired users. As the quantity of transmit antennas increments, the number of training sequences may not be long enough due to the short duration of coherent intervals, to accommodate all users. This issue can also affect the system's performance. To ensure that the data transmission is performed efficiently, the number of terminals should be lowered. In a massive MIMO environment, pilot contamination can occur due to the number of base station antennas. This issue can also cause SINR saturation since the number of antennas is increasing [43].

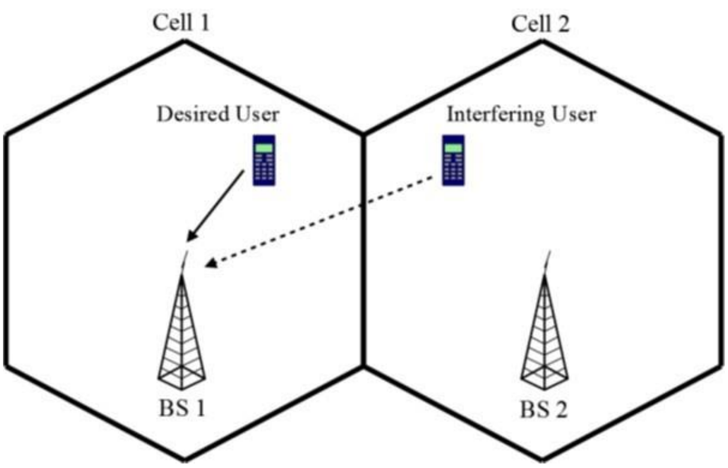

Figure 1.12: Pilot contamination example when both users transmit mutually Non-orthogonal training sequences

1.6.3 Channel Estimation Techniques

For the development of 5G networks, one of the keying technologies is Massive MIMO. It is energy-efficient, also able to reach high spectral efficiency by increasing antenna numbers at the base station with Multi User-MIMO transmission method. Only if the channel replies are properly known then spatial multiplexing be performed in massive

MIMO, the availability of precise channel state information (CSI) is a critical limiting constraint.

As a result, channel estimation is an important topic to discuss in wireless communications systems, especially as the industry's future is likely to involve large-scale antenna arrays. During the channel estimation procedure, three types of assumptions are made: (i) Blind and Semi-blind, (ii) Fully blind assumptions and (iii) perfect Channel State Information (CSI). When channel information has not known a prior, blind and semi-blind assumptions used in a practical wireless communication system, else the pilot symbols are utilized which is known to the receiver. Though, the spectrally efficient system, limiting the number of transmitted pilot symbols is always desirable. As a result, this method is most popular and has been comprehensively researched in the literature. Training sequence (TS), also known as training symbols or training blocks in semi-blind (SB) channel estimation (CE) terminology, a pilot signal is a continuous stream of known symbols superimposed on the data signal, or a pilot signal is a limited consecutive series of known symbols [44] A typical wireless communication system representation is given in Figure 1.13, and diagram below shows at which stage channel estimations occur.

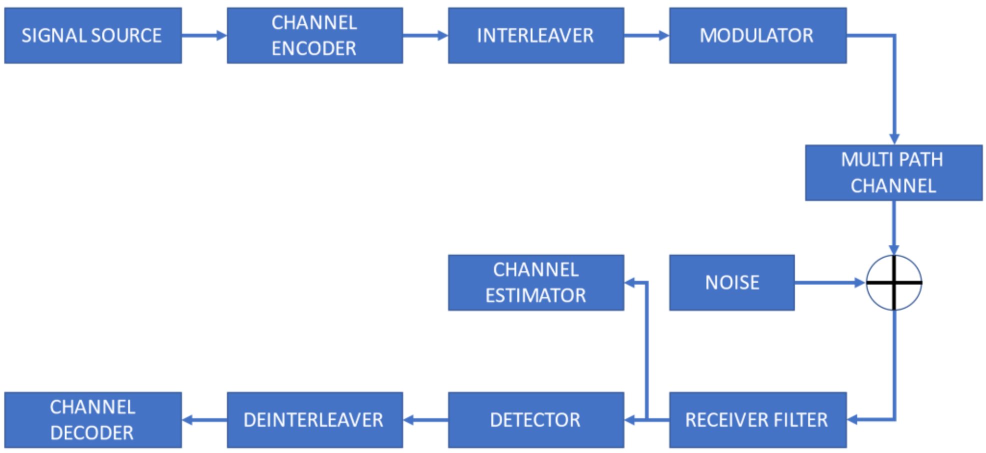

Figure 1.13: Typical Block Diagram for Telecommunication System

1.6.4 Estimation Techniques

Almost every engineering and science discipline employs estimation theory. Karl Fridederich Guass is the progenitor [45] of what is now known as the Estimation Theory, having created least square methods to predict the movements of planets. Other scholars like Rudolph E. Kalman and Norbert Wiener were tried with new algorithms and techniques, which is using now a days in modern signal processing thanks to Karl Gauss's foundation. In the subsections as followed, by looking at different linear estimators for estimating channel parameters for block fading channels through training-based approach. The fundamental proposal behind linear estimation is to find the best linear estimator W for the channel matrix in H given the realizations of Y[46]:

$$\widehat{H} = WY \quad (1.6)$$

1.6.5 Minimum Mean Square Estimator(MMSE)

In MMSE, for a function F [46] where F and $\widehat{H}$ is related as in 1.7, so H is close to the true channel realization H as possible

$$\widehat{H} = F(Y) \quad (1.7)$$

In other words, we try to minimize the mean square error of H for a given realization of Y, the mean square error is specified in 1.8 and the argument to minimize it is given in 1.9.

$$E_{HY}\left[\left\|H - \widehat{H}\right\|^2\right] \quad (1.8)$$

$$min_{\widehat{H}}\ E_{H/Y}\left[\left\|H - \widehat{H}\right\|\right] \quad (1.9)$$

The key advantage of the MMSE is that it uses channel and noise covariance knowledge to try to discover the best trade-off among contribution of the mean squared norm of bias as well as the variance of the estimator.

1.6.6 Least Square (LS) Estimator

The training-based least square (LS) estimator is the most common and basic estimation method. The LS estimator uses the following equation to estimate the channel parameters for a regular MIMO channel:

$$\widehat{H} = arg_H \min\|y - H_s\|^2 \quad (1.10)$$

1.7 Non–Orthogonal Multiple Access (NOMA)

NOMA is an efficient 5G network multiple access technique [5] [12]. It addresses a number of important issues, including high data rates, low latency, and widespread connectivity. At the transmitter, superposition coding is used, and at the receiver, successive interference cancellation (SIC) is used, high spectral efficiencies can be achieved. The nearest user decodes and subtracts the far user signal. The far user's signal can be decoded without much interference from the nearby user's weak signal [5].

NOMA is divided into two types: Power Domain NOMA (PD-NOMA) and Code Domain NOMA (CD-NOMA). In CD-NOMA transmission of signals is further classified into several techniques that depend on low density signatures (LDS) and sparse code multiple access (SCMA). LDS technique minimizes intersymbol interference. This LDS consists of sparse spreading codes in which each comprises some non-zero elements. These sparse codes permit generation of more unique codewords for the transmission of the signal which in turn allows more users to superimpose non- orthogonally. Users separation can be done at the receiver even when their power levels are of the same characteristics. By using LDS for multiple access and OFDM for multicarrier modulation, we can achieve frequency diversity and overloading due to their orthogonal mapping and sparse spreading. Nevertheless, this can be expensive and high receiver complexity. In SCMA, the sparse spreading is optimised further by the combination of LDS and Quadrature amplitude modulation (QAM) mapping to generate codewords [15]. Due to which, complexity in the receiver is moderate as the codebooks between the transmitter and receiver are transparent [16].
Over current orthogonal multiple access (OMA) systems, NOMA is known to provide optimized resource allocation, user selection, and clustering strategy [46].

1.7.1 NOMA System Model

Considering a Non Orthogonal Multiple Access for a Multiple Input Multiple Output system as shown in the Figure 1.14,this system model consists of a Base Station BS with $N_s$transmit antennas which communicates with User equipments $UE_1$with N_1 receive antennas and with UE_2 with N_2 receive antennas. In this system, we deploy TAS technique at BS to transmit signal and selection combining technique at$UE_1$and UE_2 to combine the received signals. Since TAS is utilized at BS and SC is applied at UE_s, a single antenna is used for transmission at BS which provides a maximum value of the instantaneous SNR is selected for transmission and similarly single antenna which

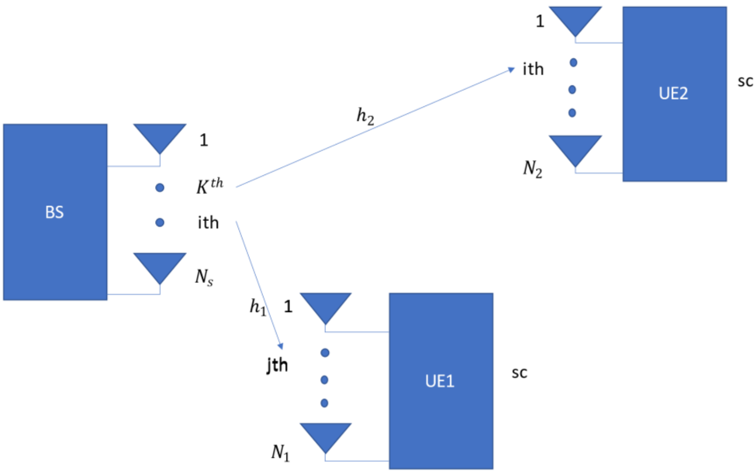

Figure 1.14: NOMA-MIMO system model

maximizes the SNR is selected at both the users. The BS applies NOMA to transmit signals to both the users simultaneously. The superposition coding at BS can be formulated as

$$x = \sqrt{P_s \beta_1 x_1} + \sqrt{P_s \beta_2 x_2} \quad (1.11)$$

where $x_1$and x_2 are the signals with unit power that BS transmits to UE_1 and UE_2, respectively, i.e.,$|x_1|^2 = |x_2|^2 = 1$. Further, P_s is the total transmit power of BS distributed with power allocation coefficients $\beta_1$and β_2 to x_1 andx_2, respectively and β_1= $1 - \beta_2$.

Assume that i^{th}antenna at the BS is selected to transmit the signal to UE_1 and $j^{th}$is the selected antenna to receive at UE_1 from BS. Therefore, h_{ij} is the channel coefficient between selected transmitting antenna and selected received antenna at UE_1 that maximize the SNR at UE_1 .The received signal at UE_1 is expressed as

$$y_1 = h_1 x + n_1 \quad (1.12)$$

$$y_1 = h_1 \left[\sqrt{P_s \beta_1}\, x_1 + \sqrt{P_s \beta_2}\, x_2\right] + n_1 \quad (1.13)$$

$$y_1 = \left[\sqrt{P_s \beta_1}\, h_1 x_1 + \sqrt{P_s \beta_2}\, h_1 x_2\right] + n_1 \quad (1.14)$$

Here, $n_1$denotes the Additive White Gaussian Noise (AWGN) at $UE_1$with zero mean and varianceN_0. Similarly, assume that l^{th} antenna at the BS is selected to transmit the signal to UE_2 and k^{th} is the selected antenna to receive at UE_2 from BS. Therefore, h_{lk} is the channel coefficient between selected transmitting antenna and selected received antenna at UE_2 that maximize the SNR at UE_2. The received signal at UE_2 is expressed as

$$y_2 = h_2 x + n_2 \tag{1.15}$$

$$y_2 = h_2\left[\sqrt{P_s \beta_1}\, x_1 + \sqrt{P_s \beta_2}\, x_2\right] + n_2 \tag{1.16}$$

$$y_2 = \left[\sqrt{P_s \beta_1}\, h_2 x_1 + \sqrt{P_s \beta_2}\, h_2 x_2\right] + n_2 \tag{1.17}$$

Here, n_2 denotes the Additive White Gaussian Noise (AWGN) at UE_2 with zero mean and variance N_0.

1.8 Motivation of the Present Work

The channel estimation performance must be improved to meet the needs of the future communication system. A novel channel estimation method aimed at striking a good balance between channel estimation performance, spectral efficiency, computational complexity, and overall communication system burden. A thorough examination of channel quality characteristics motivates all of the proposed methods. The research highlights of the project are listed below.

1. To acquire channel knowledge, the base station requires channel state information, and estimating channel parameters is one of the vital requirement. As a result, a blind channel estimation method that combines training-based techniques and massive MIMO. It can estimate the channel parameters of the conventional and massive MIMO systems.

2. To obtain channel parameters, an effective compressed sensing (CS) method based on priority is proposed, which takes into account the channel's sparse nature and considers the channel with few dominant taps. The recommended method is estimated as BER and SNR with already existing approaches like least square (LS) and minimal mean square mistake (MMSE). The simulation findings demonstrate that compressed sensing out-performs LS and MMSE approaches.

3. The power allocation strategy is utilized to foster the NOMA technique, where the modulation occurs as for time and power. The said form of design increases energy efficiency and allows remote users to obtain data bits. The greatest threat comes from the fading noise that has been introduced to the channels. Estimating of channel is done using this proposed method, which aids in achieving spectral efficient wireless communications. Error Correcting Block (ECB) based on hamming code provide better

results.

4. For the problem of channel estimation in an OFDM-based NOMA system, an iterative algorithm is proposed. The results of simulations show that using NOMA, a greater number of signals can be transmitted at once. The findings show that using an iterative approach improves efficiency and overall system performance.

1.9 Research Objectives

The main objective is to analyse the performance of channel estimation techniques of MIMO OFDM systems

1. To analyse the performance of conventional MIMO with Massive MIMO
2. To analyse the performance of traditional Least square and Minimum Mean Square Error algorithms with compressed sensing algorithms for channel estimation
3. Performance of MIMO OFDM with the combination of NOMA through the fading channels. In addition hamming code is implemented to ensure error free transmission in channels.
4. Iterative algorithm implementation for both OFDM and NOMA is performed and channel estimation is done with and without the presence of NOMA

1.10 Thesis Organization

This thesis deals with the performance of MIMO systems. The thesis is organized as follows:

1. In Chapter 1, a detailed introduction about wireless communication, multiple access, OFDM, wireless communication channel, MIMO, massive MIMO and channel estimation techniques has been discussed.

2. Chapter 2 gives a detailed literature survey on wireless communication, OFDM, MIMO-OFDM and massive MIMO till recent work.

3. Chapter 3 stress upon performance comparison of massive MIMO and conventional MIMO using channel parameters and the simulation results are given. Followed by, compressed sensing MMSE channel estimation with conventional LS and MMSE comparison is done and the simulation results are also presented.

4. In Chapter 4, performance of fading channels in non-orthogonal multiple access is

presented along with the simulation results. In the same line a novel iterative algorithm for MIMO OFDM NOMA System is implemented. Simulation results for the iterative algorithm for MIMO OFDM NOMA System are shown to demonstrate the superiority of the proposed work.

5. Chapter 5 gives the conclusions about the proposed work discussed in Chapter 3 and 4.
6. Finally, Chapter 6 gives the scope of the work to be carried out in future.