Review Paper on Spectrum Sensing Non-Cooperative Cognitive Radio Network based 5G Massive MIMO Systems

Manish Kumar Shrivas [1*], Prof. Abhijeet Gupta [2]
[1]M. Tech. Scholar, Department of Electronics and Communication Engineering, LNCTS, Bhopal,
[2]Assistant Professor, Department of Electronics and Communication Engineering, LNCTS, Bhopal.

***Abstract*—** In a cellular network, the demand for high throughput and reliable transmission is increasing in large scale. One of the architectures proposed for 5G wireless communication to satisfy the demand is Massive MIMO system. The massive system is equipped with the large array of antennas at the Base Station (BS) serving multiple single antenna users simultaneously i.e., number of BS antennas are typically more compared to the number of users in a cell. This additional number of antennas at the base station increases the spatial degree of freedom which helps to increase throughput, maximize the beamforming gain, simplify the signal processing technique and reduces the need of more transmit power. The advantages of massive MIMO can be achieved only if Channel State Information (CSI) is known at BS uplink and downlink operate on orthogonal channels. The studied of non-cooperative cognitive radio network based massive MIMO systems is present in this paper.

Keywords: **- Spectrum Sensing, Cognitive Radio, Non-Cooperative Communication, Massive MIMO.**

I. INTRODUCTION

The demand for wireless throughput has grown exponentially in the past few years, with the increase in a number of wireless devices and number of new mobile users [1]. The throughput is the product of Bandwidth (Hz) and Spectral efficiency (bits/s/Hz). To increase the throughput, either Bandwidth or Spectral efficiency has to be increased. Since increasing the Bandwidth is a costly factor, the spectral efficiency has to be taken into consideration. It can be increased by using multiple antennas at the transmitter and receiver. Multiple-Input Multiple Output (MIMO) antennas enhance both communication reliability as well as the capacity of communication (by transmitting different data in different antennas).

Generally MIMO systems are divided into two categories: Point-to-Point MIMO and Multi User - MIMO (MU-MIMO) [2], [3]. In Point-to-Point MIMO, both the transmitter and receiver are equipped with multiple antennas. The performance gain can be achieved by using the techniques such as beamforming and spatial multiplexing of several data streams. On the other hand, in MU-MIMO, the wireless channel is spatially shared among the users. The users in the cell transmit and receive data without joint encoding and joint detection among them. The Base Station (BS) communicates simultaneously with all the users, by exploiting the difference in spatial signatures at the BS antenna array. MIMO systems are incorporated in several new generation wireless standards like LTE - Advanced, Wireless LAN etc. The main challenge in MU-MIMO system is the interference between the co-channel users. Hence, complex receiver technique has to be used, to reduce the co-channel interference.

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In [4], it is shown that by using an infinite number of antennas at the BS in comparison with the number of users in the cell, the random channel vectors between users and the BS become pair-wise orthogonal. By introducing more antennas at the BS, the effects of uncorrelated noise and intra cell interference disappear and small scale fading is averaged out. Hence, simple matched filter processing at BS is optimal. MU-MIMO system with hundreds of antenna at the BS which serves many single antenna user terminals simultaneously at same frequency and time is known as Massive MIMO system or large antenna array MU-MIMO system [5],[6]. One of the architectures proposed for 5G wireless communication is the massive MIMO system in which BS is equipped with a large number of antennas and serves multiple single antenna user terminals as shown in Fig 1.

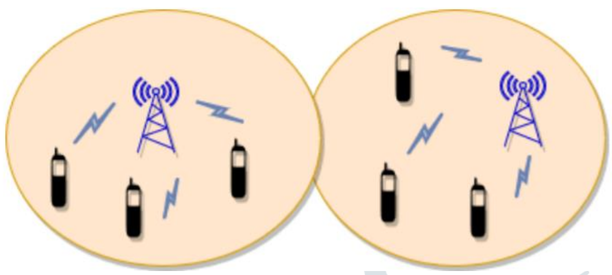

Figure 1: Multi-cell Massive MIMO System

Advantages of Massive MIMO System:-

High energy efficiency: If the channel is estimated from the uplink pilots, then each user's transmitted power can be reduced proportionally to 1/ √ M considering M is very large. If perfect Channel State Information (CSI) is available at the BS, then the transmitted power is reduced proportionally to 1/M [7]. In the downlink case, the BS can send signals only in the directions where the user terminals are located. By using the Massive MIMO, the radiated power can be reduced achieving high energy efficiency.

- **Simple signal processing:** Using an excessive number of BS antennas compared to users lead to the pair-wise orthogonality of channel vectors. Hence, with simple linear processing techniques both the effects of inter user interference and noise can be eliminated.
- **Sharp digital beamforming:** With an antenna array, generally analog beamforming is used for steering by adjusting the phases of RF signals. But in the case of Massive MIMO, beamforming is digital because of linear precoding. Digital beamforming is performed by tuning the phases and amplitudes of the transmitted signals in baseband. Without steering actual beams into the channels, signals add up in phase at the intended users and out of phase at other users. With the increase in a number of antennas, the signal strength at the intended users gets higher and provides low interference from other users. Digital beamforming in massive MIMO provides a more flexible and aggressive way of spatial multiplexing. Another advantage of digital beamforming is that it does not require array calibration since reciprocity is used.
- **Channel hardening:** The channel entries become almost deterministic in case of Massive MIMO, thereby almost eliminating the effects of small scale fading. This will significantly reduce the channel estimation errors.
- **Reduction of Latency:** Fading is the most important factor which impacts the latency. More fading will leads to more latency. Because of the presence of Channel hardening in Massive MIMO, the effects of fading will be almost eliminated and the latency will be reduced significantly.
- **Robustness:** Robustness of wireless communications can be increased by using multiple antennas. Massive MIMO have excess degrees of freedom which can be used to cancel the signal from intentional jammers.
- **Array gain:** Array gain results in a closed loop link budget enhancement proportional to the number of BS antennas.
- **Good Quality of Service (QoS):** Massive MIMO gives the provision of uniformly good QoS to all terminals in a cell because of the interference suppression capability offered by the spatial resolution of the array. Typical baseline power control algorithms achieve max-min fairness among the terminals.
- **Autonomous operation of BS's:** The operation of BS's is improved because there is no requirement of sharing Channel State Information (CSI) with other cells and no requirement of accurate time synchronization.

II. MASSIVE MIMO CONCEPT

A single cell massive MIMO system where BS is equipped with a large number of antennas (M) and serving multiple single antenna User Terminals (K), where (M > K) is shown in Figure 1. The channel matrix of massive MIMO system is modeled as the product of small scale fading matrix and a diagonal matrix of geometric attenuation and log-normal shadow fading. The channel coefficient between the m^{th} antenna of the BS and the k^{th} user h_{mk} is represented by

$$h_{mk} = g_{mk}\sqrt{\beta_k} \tag{1}$$

Where g_{mk} is the small scale fading coefficient. $\sqrt{\beta k}$ models the geometric attenuation and shadow fading, which is assumed to be independent over m and to be constant over many coherence time intervals and known apriori. This assumption is reasonable since the distance between the users and base station is much larger than the distance between the antennas.

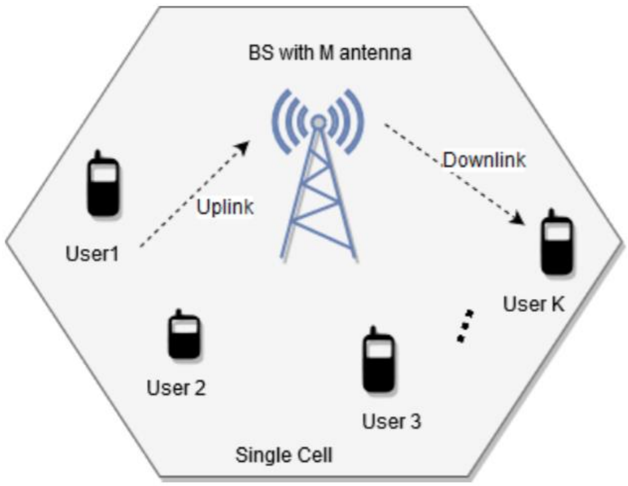

Figure 2: Single cell Massive MIMO System

CHALLENGES

Propagation Model: In most of the Massive MIMO related works, the assumption that made was: as the BS antennas grow the user channels are uncorrelated and the channel vectors become pair-wise orthogonal. But in real time propagation environment, antenna correlation comes into the picture. If the antennas are highly correlated, then the channel vectors cannot become pair-wise orthogonal by increasing the number of antennas. This means that users location is an important factor in Massive MIMO systems.

Modulation: For the construction of a BS with a large number of antennas, cheap power efficient RF amplifiers are needed.

Channel Reciprocity: TDD operation depends on channel reciprocity. There seems to be a reasonable consensus that the propagation channel itself is basically reciprocal unless the propagation is suffering from materials with strange magnetic properties. Between the uplink and the downlink, there is a hardware chain in the base station and terminal transceivers may not be reciprocal.

Channel Estimation: To perform detection at the receiver side, we need perfect CSI at the receiver side. Due to the mobility of users in MU case, channel matrix changes with time. In high mobility case, accurate and time acquisition of CSI is very difficult. FDD Massive MIMO induces training overhead and TDD Massive MIMO relies on channel reciprocity and training may occupy a large fraction of the coherence interval.

Low-cost Hardware: Large number of RF chains, Analog-to-Digital converters, Digital-to-Analog converters are needed.

Coupling between antenna arrays: At the BS side, several antennas are packed in a small space. This causes mutual coupling in between the antenna arrays. Mutual coupling degrades the performance of Massive MIMO due to power loss and results in lower capacity and less number of degrees of freedom. When designing a Massive MIMO system, the effect of mutual coupling has to be taken into account [8], [9].

Mobility: If the mobility of the terminal is very high, then the coherence interval between the channel becomes very less. Therefore, it accommodates very less number of pilots. • Pilot Contamination: Pilot contamination is a challenging problem for multicell massive MIMO is to be resolved. In multicell system, users from neighboring cells may use non-orthogonal pilots that result in pilot contamination. This causes inter-cell interference problem which further grows with the increase in a number of BS antennas.

III. LITERATURE REVIEW

Supraja Eduru et al. [1], in massive Multiple Input Multiple Output (MIMO) systems, spatial correlation is one of the factors, which significantly affects the bit error rate (BER) performance. Therefore, in this paper, linear detection is employed with different decomposition techniques to improve the performance. It is observed that there is 10 dB degradation in channel gain for 10% increment in correlation coefficient. At a BER of 10-3, with Zero Forcing (ZF) using Singular Value Decomposition (SVD), the channel gain is doubled by doubling the order of the MIMO system when compared to Cholesky and QR decomposition. Further, the BER remains unchanged for Minimum Mean Square Error (MMSE) detection irrespective of the type of decomposition techniques used. However, it is also observed that for 32×32 MIMO system, at a BER of 10-3, MMSE provides nearly 10 dB to 15 dB channel gain when compared to ZF.

H. Al-Hraishawi et al. [2], in this paper, the detrimental effects of intra-cell pilot contamination for physical layer secure communication in cognitive multi-user massive multiple-input multiple-output (MIMO) systems with underlay spectrum sharing are investigated. The channel estimates at the primary base-station (PBS) and secondary base-station are obtained by using non-orthogonal pilot sequences transmitted by the primary user nodes and secondary user nodes, respectively. Hence, these channel estimates are affected by intra-cell pilot contamination. Furthermore, a passive multi-antenna eavesdropper is assumed to be eavesdropping upon either the primary or secondary confidential transmissions. In this context, a physical layer security strategy is provisioned for the primary and secondary transmissions via artificial noise generation at the PBS and zero-forcing precoders. For this system set-up, the average and asymptotic achievable secrecy rate expressions are derived in closed-form, and thereby, the secrecy rate degradation due to intra-cell pilot contamination is quantified. Our analysis reveals that a physical layer secure communication can be provisioned for both primary and secondary massive MIMO systems even with channel estimation errors and pilot contamination.

V. D. Nguyen et al. [3], in this paper, we propose a cooperative approach to improve the security of both primary and secondary systems in cognitive radio multicast communications. During their access to the frequency spectrum licensed to the primary users, the secondary unlicensed users assist the primary system in fortifying security by sending a jamming noise to the eavesdroppers, while simultaneously protect themselves from eavesdropping. The main objective of this paper is to maximize the secrecy rate of the secondary system, while adhering to all individual primary users' secrecy rate constraints. In the case of active eavesdroppers and perfect channel state information (CSI) at the transceivers, the utility function of interest is nonconcave and the involved constraints are nonconvex, and thus, the optimal solutions are troublesome. To solve this problem, we propose an iterative algorithm to arrive at least to a local optimum of the original nonconvex problem. This algorithm is guaranteed to achieve a Karush-Kuhn-Tucker solution. Then, we extend the optimization approach to the case of passive eavesdroppers and imperfect CSI knowledge at the transceivers, where the constraints are transformed into a linear matrix inequality and convex constraints, in order to facilitate the optimal solution.

R. Zhao et al. [4], this paper investigates the physical layer security problem of cognitive decode-and-forward relay networks over Nakagami-m fading channels. We consider the relaying communication between one secondary user (SU) source and one SU destination by using an opportunistic relay selection from multiple SU relays and sharing the licensed spectrum of multiple primary users (PUs) in the underlay network. While the transmission between the SUs imposes interference on each PU, the relayed transmission is intercepted by one SU eavesdropper. In the absence of the eavesdropper's channel state information, the relay selection is based on the largest channel gain of relay-to-destination link, which is assumed to be outdated due to feedback delay. We derive the exact probability of non-zero secrecy capacity and the exact secrecy outage probability (SOP) in the closed form. Furthermore, we derive the asymptotic SOP in two different cases, and explicitly show the effects of system parameters on the secrecy diversity order and the secrecy diversity gain, respectively. Both asymptotic analysis and simulation results show that the secrecy performance can be improved by increasing either the number of relays or the Nakagami parameter of the legitimate relay channels, whereas the secrecy diversity gain deteriorates as the number of the PUs increases.

W. Zhu et al. [5], in future practical deployments of massive multi-input multi-output (MIMO) systems, the number of radio-frequency (RF) chains at the base stations (BSs) may be much smaller than the number of BS antennas to reduce the overall expenditure. In this correspondence, we propose a novel design framework for joint data and artificial noise (AN) precoding in a multiuser massive MIMO system with limited number of RF chains, which improves the wireless security performance. With imperfect channel state information (CSI), we analytically derive an achievable lower bound on the ergodic secrecy rate of any mobile terminal (MT) for both analog and hybrid precoding schemes. The closed-form lower bound is used to determine optimal power splitting between data and AN maximizes the secrecy rate through simple 1-D search. Analytical and numerical results together reveal that the proposed hybrid precoder, although suffering from reduced secrecy rate compared with the theoretical full-dimensional precoder, is free of the high computational complexity of large-scale matrix inversion and null-space calculations and largely reduces the hardware cost.

W. Wang et al. [6], in this letter, the issue of security for device-to-device (D2D) underlaying cellular networks is considered. The cellular communication is overheard by randomly distributed eavesdroppers. By sharing the spectrum between D2D users and cellular users, the interference generated by D2D users is used as a source of jamming to confuse the eavesdroppers. We first derive the connection probability of the D2D links and the secrecy outage probability of the cellular link based on stochastic geometry tools. We then propose a joint guard zone and threshold-based access control scheme for the D2D users to maximize the achievable secrecy throughput. Moreover, when only the selection threshold is considered, a closed-form expression of the optimal selection threshold is derived. Simulation results show that improved secrecy throughput can be achieved by allowing the transmission of the D2D users.

Li Mei et al. [7], Spectrum sensing to facilitate Cognitive Radio emergence and improve spectrum deployment is complex. Confined spectrum sensing technique does not always assure an acceptable presentation due to noise improbability as well as channel fading. For example, a CRN user may be unable to sense the signal from a licensed transmitter shadowed by a large construction and it might cause interference to the licensed users. Introducing spatial diversity will bring down the possibility of detection error when several users work together in spectrum sensing. The essential detection instant on some individual Cognitive Radio user might also reduce.

P. Mukunthan et al. [8], one of the approaches to the above-mentioned design is censoring, in which only the most essential data is disclosed. However, it is not easy to choose a definite amount of local sensing data, in a reporting bandwidth, such as that mentioned above. Moreover, coordination which is a mandate among users utilizes the limited bandwidth resource. A type-based distributed detection method has been proposed in. This approach mainly requires sending several waveforms at the same time to map different outputs. But this implies that when the number of quantization regions for local outputs increases, there is an increase in channel consumption. To mitigate the performance loss with the assumption of synchronous sensing, a descending window algorithm is specified in that employs only the latest reports inside an inspection window for asynchronous supportive sensing. Meanwhile, SNR diversity has been exploited in, to allow the conclusion to be complete with no information from the Cognitive Radio users with low SNRs in such circumstances.

IV. PROPOSED METHODOLOGY

The implementation of system model in MATLAB software, with the main block described below. We generated a random binary signal in serial manner. To analyze a signal in the serial to parallel converter then applied IFFT (inverse fast fourier transform) and convert it from parallel to serial OFDM signal. The OFDM signal is add cyclic prefix (CP) because the remove interference between OFDM symbols. We then feed this signal through an Additive White Gaussian Noise (AWGN) channel. At the receiver site, the OFDM signal is CP removed and signal converted from serial to parallel then applied FFT (fast fourier transform). Received the output of FFT signal then signal converted from parallel to serial converter to each symbol for analysis in the frequency domain is received. After demodulation the signal is cross correlated with that a time shifted in demodulation signal.

Finally, the received signal is compared to a threshold value (ʎ) following the SNR or determines whether the signal is absent or present; if the received signal is greater than the threshold value, there will be detection, otherwise not:

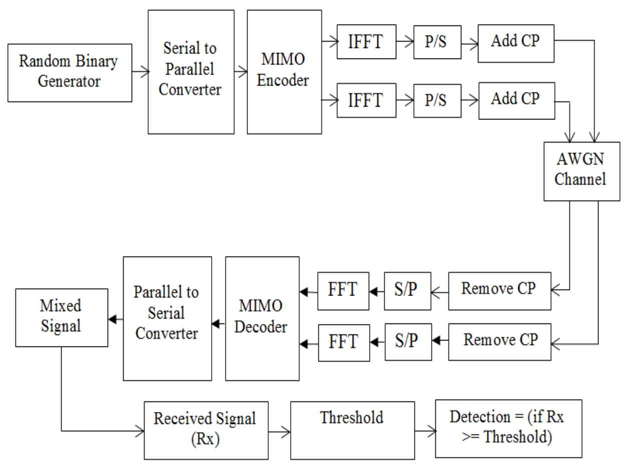

Figure 4: Design of MIMO-OFDM System using Matched Filter Spectrum Sensing Cognitive Radio Network

V. Conclusion

A matched filter, also known as optimal linear filter, is a spectrum-sensing method that detects the free portion of the primary user's spectrum and allocates it to secondary users. It derives from cross-correlating an unknown signal with known ones to detect the unknown signal's presence based on its SNR. In matched-filter detection, the dynamic threshold is used to improve the spectrum-sensing efficiency and provide better performance in cases of lower SNR.

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