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SPECTRAL EFFICIENCY AND ENERGY EFFICIENCY OPTIMIZATION VIA MODE SELECTION FOR SPATIAL MODULATION IN MIMO SYSTEMS

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ABSTRACT- In this work we consider the multiple-input multiple-output system employing spatial modulation-based transmission in Rayleigh fading channels with known slow varying large-scale fading loss and channel correlations. Observing the system performance is affected by transmission mechanisms and configurations, we propose a framework enabling the selection of the transmission mode for the optimal spectral efficiency (SE) or energy efficiency (EE) while conforming to transmission and error rate requirements with low complexity. In the framework, a closed-form error rate approximation is proposed. It renders the formulated SE and EE-based selection problems solvable via naive exhaustive search method. Besides, we propose to reduce the complexity via using look-up tables.

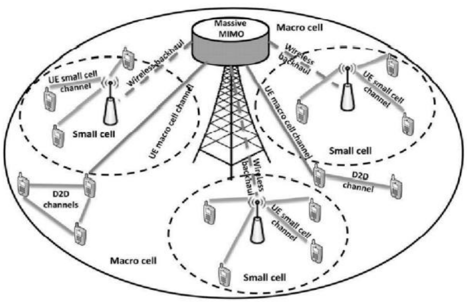

Fig.I Massive MIMO

Computer simulations are provided to evaluate the framework. Spatial modulation (SM) based transmission schemes in multiple-input multiple-output (MIMO) systems utilize both the signal and spatial constellations, i.e., both the conventional amplitude and phase modulation (APM) and the antenna indices, to convey information bits. The distinct feature of SM-based MIMO enhances the utilization ofspatial degrees of freedom (DoF's) with limited number of radios. Frequency (RF) chains, and renders the SM-based MIMO transceiver lower complexity and potentially higher energy efficiency (EE) as compared to the conventional MIMO. To improve the SM-based MIMO, adaptive designs, have been investigated. Here we consider the link adaptive design in which the system adaptively adoptsthe most suitable transmission scheme and configuration. To improve the error rate, approaches in and were proposed to adaptively adjust the construction of the signal constellation. To maximize spectral efficiency (SE) with given symbol/bit error rate (SER/BER), were proposed via adapting modulation orders. As considering energy efficiency (EE) maximization, adaptive modulation designs were proposed without involving circuit power consumption.

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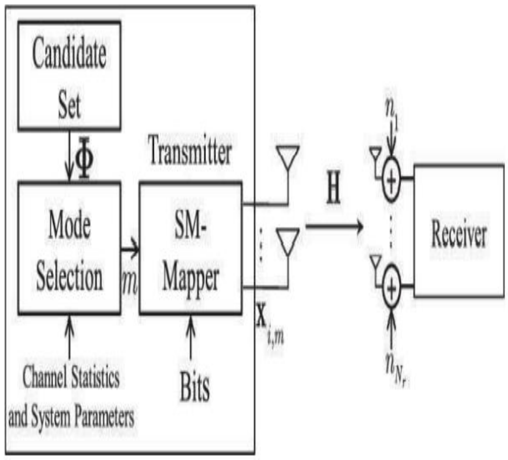

Fig.II System model for the SM-basedMIMO with mode selection

I. INTRODUCTION

1.1 Spatial modulation (SM)

SPATIAL modulation (SM) based transmission schemes in multiple-input multiple output (MIMO) systems utilize both the signal and spatial constellations, i.e., both the conventional amplitude and phase modulation (APM) and the antenna indices, to convey information bits. The distinct feature of SM-based MIMO enhances the utilization of spatial degrees of freedom (DOF's) with limited number of radio frequency (RF) chains, and renders the SM-based MIMO transceiver lower complexity and potentially higher energy efficiency (EE) as compared to the conventional MIMO. To improve the SM-based MIMO, adaptive designs, have been investigated. Here we consider the link adaptive design in which the system adaptively adopts the most suitable transmission scheme and configuration. To improve the error rate, approaches were proposed to adaptively adjust the construction of the signal constellation. To maximize spectral efficiency (SE) with given symbol/bit error rate (SER/BER) were proposed via adapting modulation orders. As considering energy efficiency (EE) maximization, adaptive modulation designs in, were proposed without involving circuit power consumption. Moreover, with circuit power included, optimized EE by switching between the SM-MIMO and conventional MIMO transmission. By our survey, most existing works consider only typical SM- MIMO systems. Besides, there is no existing work focusing on the link adaptive design involving both the SM and its different variants, such as the generalized SM (GSM). Notice that, while one merit of those variants is to provide good trade-offs between SE and EE with different numbers of active RF chains, the link adaptive design involving different variants can provide benefits to the systems.

1.2 D2D COMMUNICATIONS

DEVICE-to-device (D2D) communications as an underlay to cellular networks has been considered in 5G cellular networks to enhance the spectral efficiency, offload traffic from base stations (BSs), and reduce the transmission delay for user equipment (UE) As the D2D links and conventional cellular (CC) links share radio resources, the mutual interference between them becomes a critical problem which will aggravate both the D2D and CC links without a proper resource allocation and power control (RAPC) mechanism. Authors in have proposed a centralized resource allocation scheme for D2D andCC links to maximize the spatial reuse of radio resources. In order to maximize the system throughput, game theory based RAPC mechanisms were studied in and. However, these works

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have not considered the energy consumption of UEs, which are typically with limited battery capacity and may be quickly out of service if the energy consumption is not managed properly.

1.3 RAPC

There have been some initial efforts in developing energy efficient RAPC solutions for D2D communication. In the energy efficient RAPC schemes were proposed based on convex optimization, combinatorial auction, branch-and bound, or adaptive genetic algorithm, respectively. With the same objective, authors in decomposed the original joint RAPC problem into the resource allocation subproblem and the power control sub-problem, and then designed heuristic algorithms to solve the two sub-problems, respectively. Nevertheless, none of these works has studied the energy saving for UEs with low residual energy to prolong the overall survival time of the cellular network. As the success of certain D2D assisted or enabled applications, such as multichip D2D communications, D2D content sharing, and personal hotspot, relies on the sufficiently long survival of all cooperative devices, we propose to maximize the overall system survival time by jointly optimizing the RAPC for D2D and CC links. We define the overall system survival time as the minimal expected battery lifetime of all transmitting UEs in a cell. Subject to the available sub- channels and transmission 3 rate requirement of each link, we formulate the RAPC problem into a mixed integer nonlinear programming (MINLP) problem, which is NP-hard. In view of this, we propose a game theory based distributed approach to solve the RAPC problem, where the D2D and CC links are considered as non-cooperative players with the overall system survival time as their utility function. We prove the existence of the Nash equilibrium and propose a low complexity algorithm to calculate each player's best response. Performance of the proposed game theory based RAPC approach is evaluatedthrough simulation in comparison with relevant existing schemes. Device-to-Device (D2D) communication has been increasing in recent years, which represents an add-on communication paradigm to the modern 5G wireless cellular networks. Thus, D2D communications reduce the traffic seen by the Base Station (BS), and thus increase the spectral efficiency, energy efficiency, and system capacity. In addition, the quality of service (QOS) in D2D communication is necessary to guarantee high reliability in data transmission. To solve the problem of spectrum scarcity and increase the system capacity, a D2D user can share the licensed spectrumwith cellular users. Moreover, the information data increases proportionally with the number of D2D and cellular users, and therefore the interference caused by these devices will deteriorate the received signal of these data. Therefore, the reduction of aggressive interference and guarantee of reliable transmission have emerged as the key issues in D2D networks. To address such issues, appropriate power control algorithms are needed in both D2D and cellular user devices. In addition, a power control algorithm is necessary for energy efficiency and to increase the battery life of devices. This can be done by ensuring that the most efficient strategy is implemented by selecting the minimumpower level that achieves the

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desired QOS requirement. Power control has been studied in various wireless networks and scenarios, in which the objective was to achieve reliable communication for wireless devices and maintain the QOS requirement. Recently, game theory is exploited to address the problem of power control in modern wireless networks such as cognitive radio (CR) and Femtocell networks. Among all these algorithms, the signal-to-interference-andnoise-ratio (SINR) based on power control is the most well-known. The QoS objective based only on SINR is not appropriate in wireless data networks because the error-free communication had high priority.

II. LITERATURE SURVEY

To fulfill the objectives of the thesis, thorough knowledge on the concepts of wireless communications, software defined radio, and cognitive radio applications is required. Basic knowledge on OFDM, MIMO systems, software defined radio techniques, cognitive radio technologies, and massive MIMO technologies are dealt by several authors [1]. Basic concepts of all the above technologies are studied and understood. OFDM scheme is used as a digital multi- carrier modulation method for achieving high data rates and permits digital data to be efficiently and consistently transmitted over a radio channel, even in multipath environments (Schwartz M.,2008). MIMO systems are the subject of considerable research effort, due to their efficiency in providing an improved performance without increasing the bandwidth or the emitted power. The most attractive schemes from the stand point of implementation and performance are Alamouti’s transmit diversity scheme [2]. Numerous studies have been performed to investigate their performance and led to the development of several variations [3]. General survey of the spatial modulation design framework as well as of their intrinsic limits are provided. New learning approach based on a new flexible hardware/software defined radio platforms described. Kelly B (2009) proposed the different challenges for new generation of software defined radio. Yeh H.G. and Ingerson P (2010) proposed a software defined radio system with reconfigurable architecture for wireless communications. As an example, adaptable OFDM transceiver for standards, such as IEEE 802.11 was studied. Specifically, the baseband software implementation using a lowpower fixed-point digital signal processor (DSP) was applied to demonstrate the concept of SDRs for different standards and different operational modes. For simplicity, two operational modes, binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK) of OFDM baseband transceivers were implemented. 7 Both the interoperability and adaptability among BPSK and QPSK operational modes of the OFDM systems were discussed. Kleider J. E. et al. (2010) focused on the disadvantages of using co-located MIMO radios such as, inability to provide sufficient antenna spacing for soldier communication frequencies, increased radio size form factors, more complex RF, modem signal processing, and higher digital hardware power requirements. But multiple antenna systems give better performance than the single antenna radios in distributed groups by making use of MIMO virtual arrays created bytransmitter and receiver antennas. Sensing threshold is an important parameter in spectrum sensing. The sensing performance is degraded if the detector does not adjust its threshold properly. A number of approaches based on energy detection were proposed [4]. Several spectrum sensing algorithms such as the matched filter detection [5], the energy detection [6], the cyclo stationary detection [7], the sphericity test-based detection, the generalized likelihood ratio test, the eigen value-based detection and the covariance-based detection [8] have been proposed in the literature. Pros and cons for most of these detectors are elaborated in many studies [9]. The sphericity test-based detection, generalized likelihood ratio test, as well as the eigen value-based detection, implements spectrum sensing via determining whether the eigen values of the population covariance matrix from received signal are all equal or not, i.e., they determine whether the population covariance matrix is a scaled identity matrix or not. However, in some applications for example, in multiple antenna case the noise power among antennas may not be coincident after some array calibration. Then, the performance of these detections will degrade drastically. The covariance-based detection as well as the sphericity test-based detection, the generalized likelihood ratio test and the eigen value-based detection, exploits time and/or spatial correlation of primary user signals without requiring prior information of noise power. Hence, they 8 are non-sensitive to noise uncertainty which always exists in practice [10]. The effect of multiple primary users on spectrum sensing performance is investigated. Emerging standards for cognitive wireless networks targeting the TV white spaces, possible coexistence scenarios, and associated challenges were discussed in (Ghosh C., 2011). Sharma S. K. et al. (2015) provided a comprehensive review of the existing CR approaches by considering practical imperfections including noise uncertainty, channel/interference uncertainty, CR transceiver imperfections, noise/channel correlation, signal uncertainty, etc. Ali A. and Hamouda W (2017) focused on the enabling techniques for interweave CR networks which have received great attention from standards perspective due to its reliability to achieve the required quality-ofservice. Spectrum sensing provides the essential information to enable this interweave communication in which primary and secondary users are not allowed to access the medium concurrently. Several researchers have already considered various aspects to realize efficient techniques for spectrum sensing. Ali A. and Hamouda W (2017) provided a classification of the main approaches based on the radio parameters and the latest advances related to the implementation of the legacy spectrum sensing approaches. Near-optimal spectrum sensing of OFDM signals to achieve reliable detection at low SNR, two asymptotic simple hypothesis test- based detectors were developed for cases with and without time synchronization, and their theoretical performances were analyzed in (Jin M. et al., 2017). Many of the previous researches focused on the mathematical expression of their proposedcost function to design and develop the power allocation algorithm. The famous research in this context was proposed by Koskie and Zoran which aimed to slightly decrease the users' SINR to obtain a significant reduction in their power consumption. They proposed a Nash game model, in which the cost function is defined as a weighted sum of power and square of signal-to-interference-and-noise-ratio (SINR) error. On the other hand, the authors of proposed a new power control game based on the cost function and the target of transmit power, which has been included as well as the target SINR. The cost function in is defined as a weighted sum of the Logarithm of SINR error and the Logarithm function of power error. The algorithm has many 9 advantages, such as fast convergence and better anti-noise performance and capacity compared with the previous algorithm.

III. EXISTING SYSTEM

3.1 Device-to-device communication in 5G cellular networks

In a conventional cellular system, devices are not allowed to directly communicate with each other in the licensed cellular bandwidth and all communications take place through the base stations. In this article, we envision a two-tier cellular network that involves a microcell tier (i.e., BS-to-device communications) and a device tier (i.e., device-to-device communications). Device terminal relaying makes it possible for devices in a network to function as transmission relays for each other and realize a massive ad hoc mesh network. This is obviously a dramatic departure from the conventional cellular architecture and brings unique technical challenges. In such a two-tier cellular system, since the user data is routed through other users' devices, security must be maintained for privacy. To ensure minimal impact on the performance of existing microcell BSs, the two-tier network needs to be designed with smart interference management strategies and appropriate resource allocation schemes. Furthermore, novel pricing models should be designed to tempt devices to participate in this type of communication. Our article provides an overview of these major challenges in two-tier networks and proposes some pricing schemes for different types of device relaying.

3.2 Enabling device-to-device communications in millimeter-wave 5G cellular networks

Millimeter-wave communication is a promising technology for future 5G cellular networks to provide very high data rate (multi-gigabits-per-second) for mobile devices. Enabling D2D communications over directional mm Wave networks is of critical importance to efficiently use the large bandwidth to increase network capacity. In this article, the propagation features of mm Wave communication and the associated impacts on 5G cellular networks are discussed. We introduce an mmWave+4G system architecture with TDMA-based MAC structure as a candidate for 5G cellular networks. We propose an effective resource 22 sharing scheme by allowing non-interfering D2D links to operate concurrently. We also discuss neighbor discovery for frequent handoffs in 5G cellular networks.

3.3 A Game-theoretic resource allocation approach for intercell device-to-device communications in cellular networks

Device-to-Device (D2D) communication is envisioned as a promising technology to significantly improve the performance of current cellular infrastructures. Allocating resources to the D2D link, however, raises an enormous challenge to the co-existing D2D and cellular communications due to mutual interference. While there have been many resource allocation solutions proposed for D2D underlaying cellular network, they have primarily focused on the intracell scenario while leaving the intercell settings untouched. In this paper, we investigate the resource allocation problem for intercell D2D communications underlaying cellular networks, where D2D link is located in the overlapping area of two neighboring cells. We present three inter- cell D2D scenarios regarding the resource allocation problem. To address this problem, we develop a repeated game model under these scenarios. Distinct from existing works, we characterize the communication infrastructure, namely Base Stations (BSs), as players competing resource allocation quota for D2D demand, and define the utility of each player as the payoff from both cellular and D2D communications using radio resources. We also propose a resource allocation algorithm and protocol based on the equilibrium derivations. Numerical results indicate that the developed model not only significantly enhances the system performance including sum rate and sum rate gain, but also sheds lights on resource configurations for intercell D2D scenarios. As more and more new multimedia rich services are becoming available to mobile users, there is an ever-increasing demand for higher data rate wireless access. As a consequence, new wireless technologies such as LTE (Long Term Evolution)/LTE-Advanced and WiMAX have been introduced. These technologies are capable of providing high speed, large capacity, and guaranteed quality-of-service (QoS) mobile services. With technology evolution of cellular networks, new 23 techniques, such as small cells, have been also developed, which are able to improve network capacity by reducing cell size and effectively controlling interference. However, most attempts still rely on the centralized network topology, which requires mobile devices to communicate with an evolved Node B (e NB) or access point (AP). Such a centralized network topology can easily suffer from congestion by a large number of communicating devices. Also, the e NB and AP may not have complete information about transmission parameters among devices, which is required to optimize the network performance. As an alternative, the concept of device-to-device (D2D) communication has been recently introduced to allow local peer-to-peer transmission among mobile devices bypassing the e NB and AP Specifically, besides cellular operation, where the user equipment (UEs) can be served by the network via the e NB in the LTE system, some UEs may communicate with each other directly over direct links for proximitybased services. The UE with D2D connections (i.e., a D2D user) is loosely controlled by the e NB. In particular, the e NBs can control the radio resource allocation for the cellular and the D2D links (i.e., the link between UE and e NB and the link between UEs, which we will refer to as cellular and D2D users, respectively). Also, the e NBs can set constraints on the transmission parameters (e.g., transmit power) of D2D users. The purpose of the constraints is to limit the interference experienced by the cellular

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users and satisfy their quality-of-service (QoS) requirements. In this article, we classify D2D communication into two categories: D2D direct and D2D local area network (D2D LAN). D2D direct simply refers to the conventional one-hop (one D2D pair) communication. In multi-hop D2D LAN, network-controlled smart devices can realize cluster-based communication in an ad hoc manner, and meanwhile work over the licensed band to achieve maximal flexibility and performance in a multi-cell scenario. Fig. 1 shows a typical single cell scenario with multiple users consisting of conventional cellular communication, one-hop D2D direct transmission, and D2D LAN for group communication

IV. PROPOSED SYSTEM

4.1 D2D COMMUNICATION.

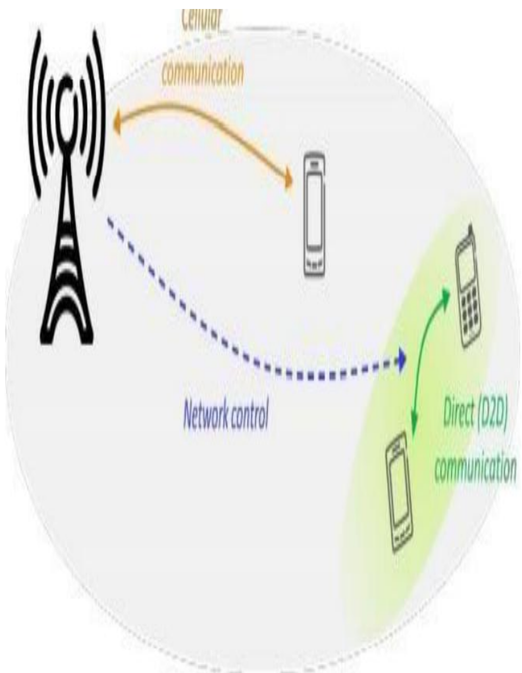

Figure 4.1.1 A simplified D2D communication integrated in a cellular network

Similar to the cognitive radio, D2D communication is among the key technologies that can improve the spectrum utilization and capacity of next generation cellular networks. Due to advent of new multimedia applications, there is an increasing demand to improve the capacity of 4th generation (4G)/beyond 4G cellular networks (i.e., next generation 5G cellular networks). One of the possible solutions to achieve high capacity is small cell networks (e.g., micro-BS, femto-BS). In small cell network, cell size is reduced to increase the spectrum reuse factor. Cellular user and BS are in close proximity to achieve high data rate and lower delay. However, there are issues based on construction and maintenance cost (e.g., the backhaul bottleneck). Recently, the concept of D2D communication has been proposed for cellular networks to avail the high-capacity benefits to cellular users with minimal constraints on maintenance and construction. In a generic D2D framework, two cellular users living in proximity can form a direct link for data transmission without routing it through the base station (BS). However, control or signaling information between the users is still carried out bythe BS. A simplified form of integration of D2D communication in a cellular network is shown. Traditionally, D2D technologies were restricted to short-range communication networks such as Wi-Fi-Direct and Bluetooth working on unlicensed 2.4 GHz band. The unlicensed bands are generally crowded with a large number of

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interferers; thus, traditional D2D technologies do not provide the QoS and security as expected in the cellular networks. Several applications of D2D like proximity-based services, emergency communication, cellular traffic offloading, Internet-of-things (IoT) enhancement, etc. make it a viable candidate for next-generation 4.5G and 5G cellular networks band D2D communication. A schematic view of resource utilization for D2D users is shown. ϖ In band D2D Communication: In in band D2D, a user can share the licensed spectrum of the cellular user either in uplink or downlink of the cellular transmission as shown. In band D2D communication is also referred as LTE direct. A D2D user can access the licensed cellular spectrum either in underlay (also known as nonorthogonal mode) or overlay (also known as orthogonal mode). ϖ Out band D2D communication: In out band D2D, the D2D communication takes place by exploiting the unlicensed spectrum such as industrial, scientific, and medical (ISM) bands (IEEE 802.11) or Bluetooth (IEEE 802.15).

4.2 In terms of network control, the D2D communication is classified

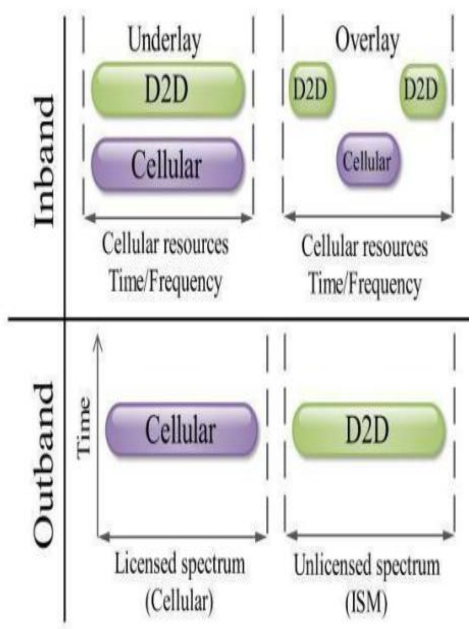

Figure 4.2.1 Resource allocation for D2D communication

ϖ Network assisted D2D: It is also known as infrastructure assisted D2D communication. In this mode, the BS is responsible for D2D discovery, resource allocation, connection setup, security and mobility management.

ϖ Autonomous D2D: In this mode, similar to the Ad hoc network, the BS has no control over D2D communication. Such mode can be esteemed useful during the infrastructure failure.

The most common D2D communication frameworks for the cellular networks are underlay and overlay D2D communication. 5.3 UNDERLAY D2D COMMUNICATION Argument for underlay D2D framework in LTE-A cellular networks. In, the resource sharing between the D2D user and the cellular user is optimized while satisfying the individual power constraints. Distance constrained resource sharing criteria for underlay D2D

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cellular network is considered in. Specifically, authors have formulated an analytical approach to find an optimum distance between the cellular

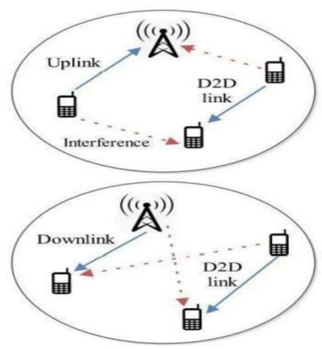

Figure 4.3.1 D2D using cellular uplink and downlink resources

Here, a D2D user shares the uplink resources of the cellular user, thus cellular and D2D transmission causes interference to each other. Specifically, at same time/frequency resource block, a cellular user and D2D Tx transmit their data to BS and D2D Rx respectively. Thus, BS receives interference from D2D Tx, whereas D2D Rx receives interference from the cellular user. Hence in underlay D2D framework,

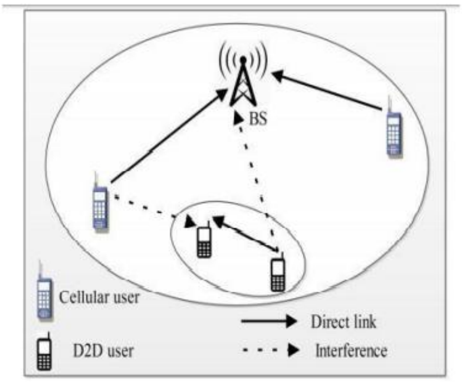

Figure 4.3.2 Underlay D2D communication

V. RESULT

5.1 Base station and user connectivity

A base station serves as a central connection point for a wireless device to communicate. It further connects the device to other networks or devices, usually through dedicated high bandwidth wire or fiber optic connections. Base stations are generally a transceiver, capable of sending and receiving wireless signals; otherwise, if they only transmitted signals out, they would be considered a transmitter or broadcast point. A base station will have one or more radio frequency (RF) antennas to transmit and receive RF signals to other devices.

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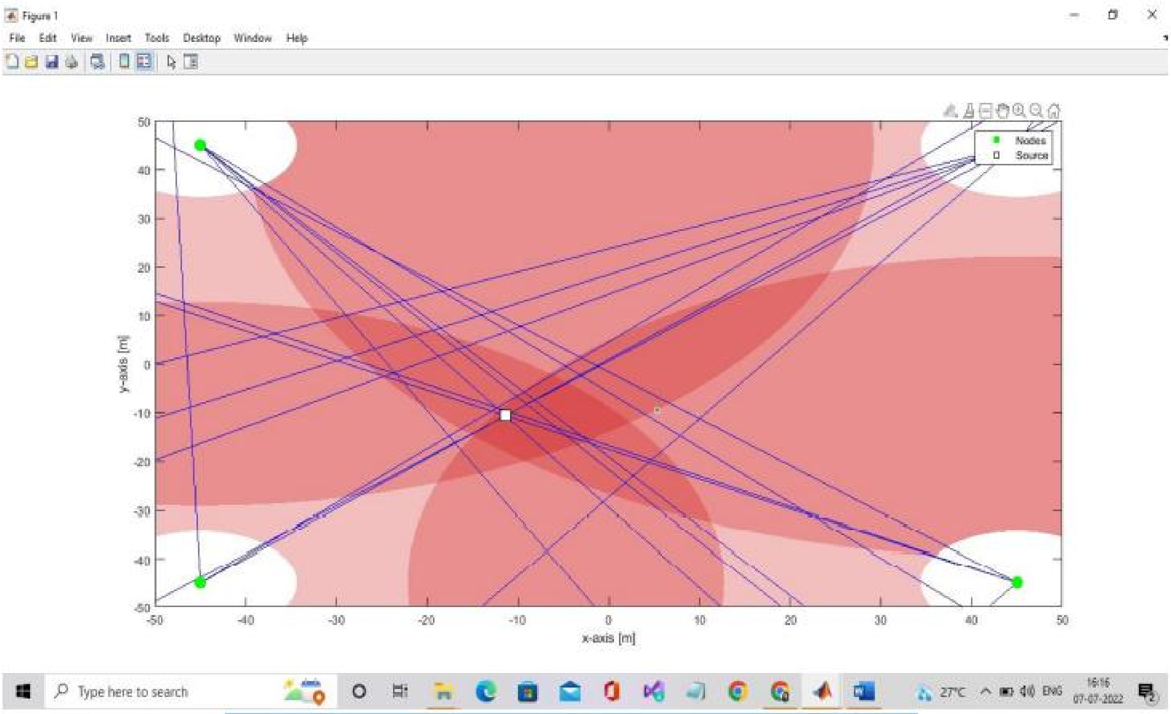

Fig.5.1.1 Output image for base station and user connectivity

5.2 SE based selection for MIMO system

In the figure, we observe that the proposed selection approach can outperform modes without selection, which shows the efficacy of the proposed selection approach. The behavior of proposed EE selection is shown in Fig.5.2.1. From the figure, we can observe the alteration of the number of active RF chains. The reasons are as follows. When the loss is small, the circuit power consumption dominates EE. Hence the number of active RF chains increases only when the increase introduces large benefit. Then as the fading loss increases, the transmit power onsumption starts to dominate.

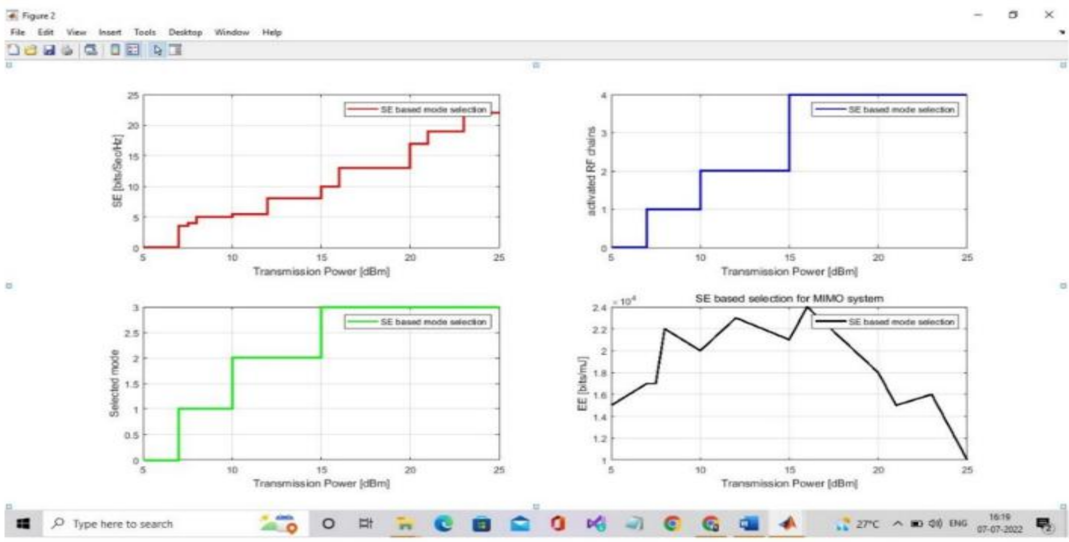

Fig.5.2.1 SE based selection for MIMO system

5.3 Selection comparisons

Selection process strives to maintain the power consumption by activating more RF chains and providing better utilization of spatial DoFs. Finally, as the power consumption continues to grow, the selection approach begins to reduce SE to obtain better EE.

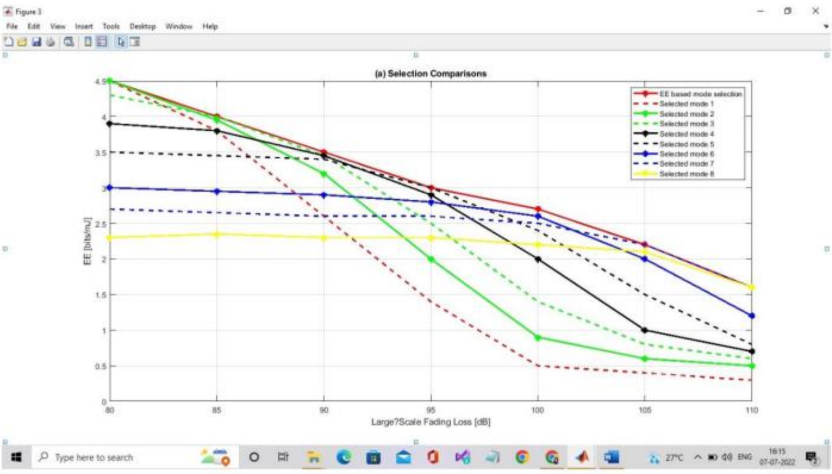

Fig. 5.3.1 output for selection comparisons

5.4 Uncorrelated channels

We propose a mode selection scheme that aims to minimize the transmission power of the D2D transmitter subject to constraints on the minimum required data rate and maximum interference to other cellular users.

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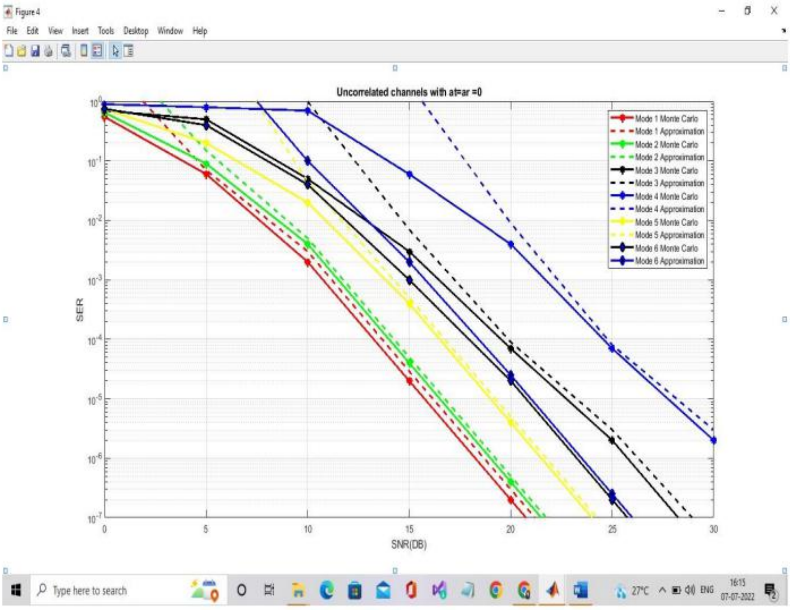

Fig. 5.4.1 Uncorrelated channels with at=ar=0

5.5 Correlated channels

One of the basic properties of spatial channel correlation is that the base station array receives different average signal power from different spatial directions.

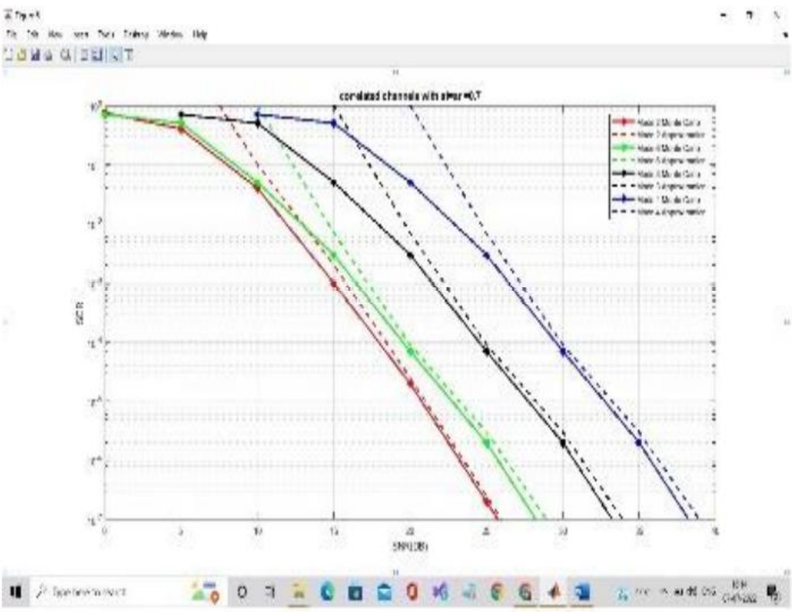

Fig. 5.5.1 Correlated channels with at=ar=0.7

5.6 Selection behaviors

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We note that only small number of modes in Φ are presented in our figures where the system parameters, rate requirement, and spatial correlations are fixed for illustration convenience. While the environmental and system conditions could change for real systems, more modes would be selected and used for transmission.

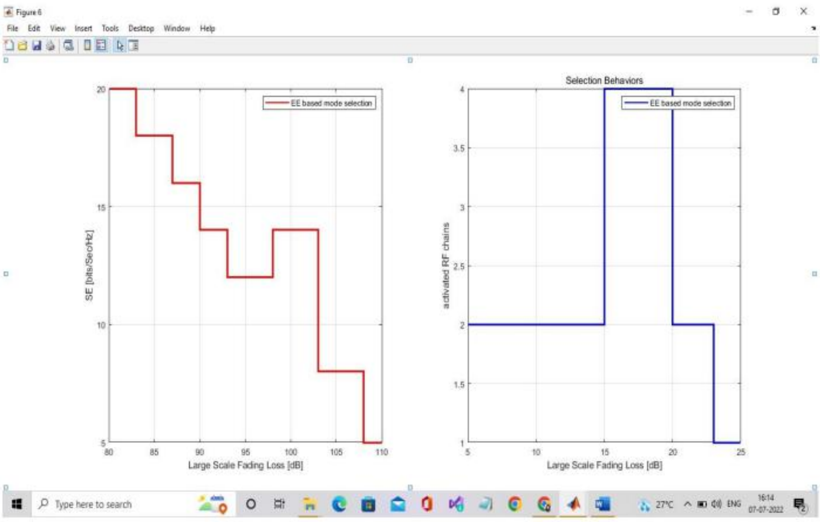

Fig. 5.6.1 output for selection behaviors

VI. CONCLUSION

In this work we propose a framework to select the mode with the best SE or EE while satisfying certain requirements from a pre-defined candidate set. The SER/BER approximation, which replaces the error rate constraint with elegant closed-form expression, is the key to the framework. It renders the selection problems easily solvable via exhaustive search. The framework can include all SM-based schemes without transmit diversity leading to significant improvements. Besides, it is practical with the low complexity and by using merely the slowly varying channel statistics. A possible extension of the framework is to include SM based schemes capable of providing transmit diversity by using the general SER/BER expression in. However, there are still challenges for the extension, such as the simplification of the SER/BER expression and the unification of power model expressions. By resolving these challenges, the performance of the proposed framework can be improved.

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