Cyclic Triangular-Sic Decoding Scheme For M-Ary QAM Asynchronous-Noma D2D Network

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Abstract- *The complexity of successive interference cancellation at the receiver's end is a challenging issue in conventional non-orthogonal multiple access assisted massive wireless networks. The computational complexity of decoding increases exponentially with the number of users. Further, under realistic channel conditions, a synchronous non-orthogonal multiple access scheme is impractical in the uplink device to-device communications. An asynchronous non-orthogonal multiple access-based cyclic triangular successive interference cancellation scheme is proposed for a massive device-to-device network. The proposed scheme reduces the decoding complexity, energy consumption, and bit error rate of a superimposed signal received in an outband device-to-device network. More specifically, the scheme follows three consecutive stages; optimization, decoding, and re-transmission. In the decoding stage, the data in the optimal interference cancellation triangle is decoded using a conventional triangular successive interference cancellation technique. Next, the remaining users' data are decoded in sequential iterations of the proposed scheme, using the retransmissions from such users. Utilizing the successive interference cancellation characteristics, the performance of the proposed device to-device network is defined in terms of energy efficiency, bit error rate, computational complexity, and decoding delay metrics. Moreover, the performance of the proposed decoding scheme is compared with the conventional triangular successive interference cancellation decoding scheme to demonstrate the superiority of the proposed scheme.*

Keywords- cyclic triangular successive interference cancellation, device to-device network, decoding delay metrics

I. INTRODUCTION

The forthcoming beyond-5G/6G network is expected to provide reliable, error-free, and energy-efficient services with ubiquitous connectivity. On the other hand, the usage of new wireless devices is also increasing mobile traffic by thousand times in comparison to the existing networking systems. In this context, widely used 5G Orthogonal Multiple Access (OMA) schemes such as Orthogonal Frequency Division Multiple Access (OFDMA) and Code Division Multiple Access (CDMA) can support a large number of devices by utilizing the existing network resources effectively. Moreover, in OFDMA, the complete bandwidth of the channel is allocated to all the sub-carriers in such a manner that the interference between each sub-carriers can be minimized. Since the number of sub-carriers within the bandwidth is limited, OFDMA suffers from spectrum limitation issues in public networks.

Non-Orthogonal Multiple Access (NOMA) scheme is included in 3GPP as a multiple access scheme for B5G/6G. This has the potential to enhance the spectral efficiency, by allowing multiple users to simultaneously access the same subcarrier Resource Blocks (RBs). The fundamental concept of NOMA is based on superposition coding and successive decoding where the superposition coding of multiple users' signals can be done over the same subcarrier with different power levels that enables the receiver to decode the signal by using the Successive Interference Cancellation (SIC) technique. At the receiver, the SIC treatment is applied to decode the data of the user having the strongest channel conditions up to the last user in descending order of Signal to Noise Ratios (SNRs). Once the strongest signal is directly decoded, the detected data is passed through to an iterative SIC algorithm. Next, the strongest signal is reconstructed based on the prior knowledge of Channel State Information (CSI) and the modulation scheme used for transmission. Finally, the reconstructed signal is subtracted from the received superimposed symbol to reduce its interference and increase accuracy in decoding the rest of the user signals. However, the SIC decoding scheme is applicable only for time-synchronous transmissions that limits the NOMA scheme performance, due to the negligence of the added interference from the overlapping symbols.

With the trend of connecting an ever-increasing number of devices in the future internet of things (IoT) scenarios, there will exist a large number of devices that are widely deployed in natural environments, who have demand for data uploading, information sharing, etc. In this scenario, energy harvesting (EH) endows cellular communication and device-to-device (D2D) communication with the ability to continuously operate for data uploading, information sharing in areas where the power line is infeasible, thus this reveals a prominent application prospect in practice. Through harvesting energy from the ambient environment, like solar and wind energy, cellular communication, information sharing through device-to-device (D2D) communication can play a crucial part in IoT or other similar purposes in natural environments. In particular, with D2D communication, information can be shared between user equipment (UE) without traversing the base station (BS), where D2D links can reuse the spectrum of cellular users (CU) to improve the spectrum efficiency.

For the prominent advantages in easy deployment and spectral and energy efficiency, EH-powered D2D communication has been invoked into various communication scenarios for IoT services, machinetype communications, etc. While the available energy, which relies on EH, becomes an extra non negligible factor in resource allocation. Except for the transmit power in resource allocation, the spectrum assignment can also be different under various energy levels. Besides, most existing researches that involve D2D communications only consider the D2D communication model with one D2D transmitter (DT) transmitting to the D2D receiver (DR), which is limited in practical implementation for IoT services. In real scenarios, IoT services or other applications like machinetype communications may have substantial demand for multiple access for information collection purposes. Therefore, the limitation of existing literatures in providing more effective multiple connectivity drives us to come up with an effective approach to tackle the multiple access issue for providing IoT services.

Attracted by the great potential of non-orthogonal multiple access (NOMA) technology in improving spectral efficiency as well as providing massive connectivity, come up with the idea of integrating uplink NOMA into D2D communication for providing IoT services. By employing the successive interference cancellation (SIC) technique in the receiver, the NOMA receiver can decode the superimposed signal of multiple users in the same time and frequency following a certain decoding order. For these prominent advantages in spectral efficiency and multiple connectivity, some works begin to implement trials on integrating NOMA with D2D communications. In existing literatures on NOMA-based D2D communications, one DT and multiple DRs jointly form a NOMA group, which is generally called a D2D group. Nevertheless, all those existing researches only consider downlink NOMA in D2D communication, which cannot meet the many-to-one transmission in IoT scenarios. In IoT scenarios, there may exist multiple DTs transmitting to one DR for the purpose of data collection or other IoT services. The cruel reality is that there still lacks work on uplink NOMA-based D2D communications till now. Different from downlink NOMA, where a transmitter transmits to multiple receivers, uplink NOMA enables multiple transmitters to transmit to one receiver at the same time and frequency by employing SIC on the receiver side. In this paper, the power domain NOMA is adopted. Thus how to efficiently accomplish power allocation for multiple uplink NOMA-based D2D users and coordinate the interference in spectrum reusing becomes a new crucial issue.

To investigate the resource allocation issue of EH-powered cellular users (CUs) and D2D groups in the cellular network. In a D2D group, since transmitted signals are superimposed on the same spectrum, there may exist serious internal interference between transmitted signals. Thus how to carefully control the power of DTs in a D2D group, especially in the EH scenario where energy levels can be time-variant, is a fatal issue that determines the gain of NOMA compared with OMA schemes. Besides, how to deal with the interference between D2D and cellular communications is also a crucial issue, and taking the available energy of UEs into consideration to realize more effective resource allocations should also be discussed.

To resolve the above issues, propose to optimize the unilateral energy efficiency of both D2D groups and CUs through resource allocation. With this goal, put forward a two-stage game approach to tackle the energy efficiency maximization problem in a distributed manner. In the first stage, introduce an approximation method to model the power allocation between each potential pair of D2D group and CU as a non cooperative game. In this game, the D2D group and CU are both seen as players, where the D2D group that contains multiple D2D links is approximated as an entity. Through this method, skillfully avoid the complicated combinatorial game and greatly reduce the computational complexity. After obtaining equilibrium in the first stage, use a matching game to obtain a global stable matching result. To sum up, our contributions can be concluded as follows:

1) propose to integrate uplink NOMA with D2D communication to provide access for multiple DTs for IoT service. To investigate this issue, set a target of accomplishing the joint resource allocation of uplink NOMA-based D2D groups and CUs. To our knowledge, the uplink NOMA-based D2D communication issue has been rarely investigated before.
2) Different from most existing works that solve optimization problems in a centralized manner, the optimization of UEs’ energy efficiency occurs in a distributed way in our method. To achieve this goal, put forward a two-stage game approach to deal with the joint

power and spectrum allocation problem, where the computation separately occurs in D2D groups and CUs, where the available energy of UEs is considered during the game.

3) Introduce an approximation method to formulate the first-stage game as a non cooperative game, instead of using a complicated coalitional game with high computational overhead, during the power allocation. With this approach, the computational complexity and signaling overhead can be greatly reduced.
4) Moreover, present an intuitional analysis of the influence of the energy levels under EH on resource allocation, and then propose an energy-aware screening approach on the establishment of preference lists to further reduce computational complexity. Finally, elaborated simulation results are presented to verify the effectiveness of our proposed method

In addition, with the emerging of NOMA technology, researchers start trials on integrating NOMA with D2D communications for multiple access and higher spectral efficiency. Aimed to deal with the delay and interference issue in NOMA-based D2D cooperative communication, and they proposed a two phased tactile internet-driven scheme to resolve the problem. In, the authors formulated a sum-rate maximization problem to accomplish the subchannel and power allocation in NOMA-enhanced D2D communication. Besides considered the NOMA-enhanced D2D association and channel assignment issue in multi-cell uplink NOMA networks. Asides from using NOMA in D2D communication for transmission creatively proposed to exploit NOMA technique to cancel the received interference signal in D2D communications. Although NOMA-based D2D communication is expected to bring improvements on system spectral efficiency performance, the price is the careful design of power allocation schemes. However, rare literatures considered the energy efficiency during power allocation in NOMA-based D2D communication scenarios. Besides, downlink NOMA is mostly adopted in the above literatures, but integrating uplink NOMA with D2D communication to provide access for multiple DTs is still an unexploited issue.

II. LITERATURE SURVEY

For the prominent superiorities in energy and spectrum efficiency, Device-to-Device (D2D) communication has become a hot topic among the 5th generation (5G) technologies. However, the widely adopted mode that one or more D2D links reuse one cellular user`s uplink spectrum may lead to severe limitation on D2D communication rate, especially when cellular user's uplink spectrum is very limited. In this method, will face the high rate requirements of D2D pairs (DPs), with the help of carrier aggregation technology, each DP can reuse the uplink spectrum of multiple cellular users when needed. More practically, consider that only statistical channel state information (CSI) of certain communication links is available here. Then, formulate the problem to minimize the total power consumption of the mobile devices to obtain an energy-efficient resource allocation result, including spectrum and power allocation. Meanwhile, the quality of service (QoS) requirements of cellular and high-rate D2D communications are both ensured. The formulated problem is mathematically a non-convex mixed-integer nonlinear programming (MINLP) problem, which is NP-hard. To solve it, first tighten the constraints and deploy transformation methods on it to make it convex. Then, propose a two-layer algorithm, the independent-power greedy-based outer approximation (IPGOA), to solve the transformed problem. Besides, to handle the involved uniform power allocation circumstance in the carrier aggregation process, a uniform-power GOA (UPGOA) algorithm, which can be regarded as a simplified version of IPGOA, is also proposed. The simulation results show that in different scenarios, our proposed scheme is approximately optimal.

Power allocation plays a vital role in coordinating interference between Device-to-Device (D2D) and cellular communications, and when power allocation meets simultaneous wireless information and power transfer (SWIPT), the energy efficiency of D2D communications can be significantly improved. While numerous research studies have been conducted on D2D power allocation, most of these studies do not take the presence of SWIPT into consideration. Toward a remedy for this issue, investigate the problem of D2D power allocation with SWIPT power-splitting architecture, and address it by establishing a novel game-theoretic model. Two power allocation mechanisms are proposed to simultaneously allocate transmit power and choose power splitting ratio for D2D communications. Also develop two pricing strategies for the proposed power allocation mechanisms based on the social utility (sum utility of both D2D and cellular communications) maximization. Simulation results validate theoretical analyses and the effectiveness of the proposed mechanisms. In particular, find through performance comparisons that our developed pricing strategies are light-weighted and energy-efficient, and the distributed power allocation mechanism is responsive to the mobility of D2D users.

Green communication with sustainable energy is being considered for 5G cellular network and Internet of Things (IoT) mainly with focus on energy harvesting (EH) to prolong network lifetime. Moreover, device-to-device (D2D) communication on shared channels is also considered as a promising technology to achieve high data rates, ultralow latency communication, and high spectral efficiency. In this method, investigated resource allocation in EH-aided D2D communication underlying 5G cellular along with enabling IoT services. The objective is to maximize throughput of the network subject to the joint constraints on user performance, number of admitted users for equity and fair usage, mode assignment (cellular or D2D) as per available energy, and transmit power allocation along with EH techniques, which results in a mixed integer nonlinear programming problem. Have proposed a low complexity and efficient algorithm, adaptive resource allocation and energy sentient network (ARA-ESN) using branch-cut, branch-bound, and mesh adaptive direct search (MADs) solutions, where cellular or D2D communication is based on available energy and user performance criteria along with EH through ambient energy and radio frequency (RF) energy transfer techniques. Have applied the outer approximation-based linearization technique that guarantees the convergence to the optimal solution. The results show that ARA-ESN branch-cut outperforms ARA-ESN branch-bound and ARA-ESN MADs. Moreover, have also observed that ambient harvesting increases performance of network due to better acquisition of energy as compared to RF energy transfer.

Device-to-device (D2D) communication is a key enabling technology to facilely realizing the Internet of Things (IoT) due to its spectral and energy efficiencies features. Exploiting the physical-layer network coding (PNC) and energy harvesting (EH) technology, two-way relaying (TWR) D2D communication can achieve significant performance for IoT in terms of data rate and energy efficiency (EE). In this article, investigate the EH-aided TWR D2D communication sharing the uplink (UL) spectrum of the traditional cellular networks. Assume that the D2D transmitters, receivers, and participating relays can collect renewable energy (RE) from natural resources. Also, the relays are considered to be powered by radio-frequency (RF) signals utilizing the power splitting (PS) protocol. Subject to the Quality of Service (QoS), power, subchannel assignment, EH, and maximum practical power constraints, two nonconvex mixed-integer nonlinear programming (MINLP) problems are formulated. The two problems provide a tradeoff on either maximizing the TWR D2D link (TDL) rate or its EE depending on the IoT application needs. Based on the particle swarm optimization (PSO) algorithm, propose the rate and EE tradeoff EH-based algorithm (REET-EH) to deal with these problems. The proposed algorithm can optimally perform the resource allocation (RA), PS factors determination, power allocation (PA), and relay selection processes. The numerical results investigate the performance of the REET-EH algorithm and show its consistency over several parameters. Also, the results illustrate that our proposed algorithm improves the system performance compared with other state-of-the-art algorithms with regard to the D2D link rate and EE.

Integrating mobile edge computing (MEC) into the Internet of Things (IoT) enables the IoT devices of limited computation capabilities and energy to offload their computation-intensive and delay-sensitive tasks to the network edge, thereby providing high quality of service to the devices. In this method, apply non-orthogonal multiple access (NOMA) technique to enable massive connectivity and investigate how it can be exploited to achieve energy-efficient MEC in IoT networks. In order to maximize the energy efficiency for offloading, while simultaneously satisfying the maximum tolerable delay constraints of IoT devices, a joint radio and computation resource allocation problem is formulated, which takes both intra- and inter-cell interference into consideration. To tackle this intractable mixed integer non-convex problem, first decouple it into separated radio and computation resource allocation problems. Then, the radio resource allocation problem is further decomposed into a subchannel allocation problem and a power allocation problem, which can be solved by matching and sequential convex programming algorithms, respectively. Based on the obtained radio resource allocation solution, the computation resource allocation problem can be solved by utilizing the Knapsack method. Numerical results validate our analysis and show that our proposed scheme can significantly improve the energy efficiency of NOMA-enabled MEC in IoT networks compared to the existing baselines.

Investigating the problem of energy efficiency (EE) maximization for uplink multi-cell networks via a joint design of sub-channel assignment, power control, and antenna selection. Study the problem under two practical scenarios. In the first scenario, known as conventional antenna selection (CAS), there is only one radio frequency (RF) chain available at the mobile user and all the sub-channels for each user can be assigned to one of the antennas. For the second scenario, known as generalized antenna selection (GAS), the number of RF chains is equal to the number of antennas and the messages of each user can transmit over its assigned sub-channels via different antennas. The resource allocation design is formulated as a multi-objective optimization problem (MOOP) and then converted into a single objective optimization problem (SOOP) via the weighted Tchebycheff method. The considered problem is a mixed integer nonlinear programming (MINLP) which is generally intractable. To address this problem, a penalty function is introduced to handle the binary variable constraints. In order to obtain a computationally efficient suboptimal solution, the majorization minimization (MM) approach is proposed where a surrogate function serves as the lower bound of the objective function. Furthermore, propose another low-complexity practical algorithm to further reduce the computational cost. Simulation results demonstrate the superiority of the proposed method and unveil an interesting trade-off between EE and SE for two considered scenarios.

Energy harvesting (EH) from ambient energy sources can potentially reduce the dependence on the supply of grid or battery energy, providing many benefits to green communications. In this method, investigate the device-to-device (D2D) user equipments (DUEs) multiplexing cellular user equipments (CUEs) downlink spectrum resources problem for EH-based D2D communication heterogeneous networks (EH-DHNs). Our goal is to maximize the average energy efficiency of all D2D links, in the case of guaranteeing the quality of service of CUEs and the EH constraints of the D2D links. The resource allocation problems contain the EH time slot allocation of DUEs, power and spectrum resource block (RB) allocation. In order to tackle these issues, formulate an average energy efficiency problem in EH-DHNs, taking into consideration EH time slot allocation, power and spectrum RB allocation for the D2D links, which is a nonconvex problem. Furthermore, transform the original problem into a tractable convex optimization problem. Propose joint the EH time slot allocation, power and spectrum RB allocation iterative algorithm based on the Dinkelbach and Lagrangian constrained optimization. Numerical results demonstrate that the proposed iterative algorithm achieves higher energy efficiency for different network parameters settings.

Energy Harvesting (EH)-based cellular communication has emerged for the merit of simple deployment and continuous energy supply recently. However, the amounts of harvested energy are not always enough to meet the communication requirements of cellular devices. In this method, propose an energy cooperation scheme taking advantage of Device-to-Device (D2D) relaying technology, in which those devices with insufficient energy are aided by others to accomplish data transmission. In this scheme, we study the energy efficiency optimization problem, which involves the D2D relay selection, spectrum reusing and power allocation issues. Mathematically, it is formulated as a Mixed-Integer Nonlinear Programming (MINLP) problem, which turns out to be NP-hard. Thus, make a detailed mathematical analysis to the problem and introduce a two-layer optimization algorithm, and based on which, a suboptimal solution with lower computational complexity is then proposed. The simulation results show that the schemes are valid and can achieve significant improvement in system transmission rate and the satisfaction rate of users' communication requirements.

Device-to-device (D2D) two-hop cooperative communication improves the network coverage and throughput to provide the quality of service and quality of experience to the end users. Nonorthogonal multiple access (NOMA) can be used at the D2D transmitter to improve the spectral efficiency of the network. But, two-hop transmission with NOMA suffers from delay and interference from the neighboring nodes. To resolve the aforementioned issues, in this paper, we propose Tactile Internet (TI) driven delay assessment for D2D communication (DIYA) scheme, which works in two phases. In the first phase, a full duplex communication at relays (intermediate nodes) is used to have the first- and second-hop transmission simultaneously in the same time slot. Then, TI-based communication is used at D2D transmitter to increase the speed of transmission. In the second phase, pricing-based three-dimensional (3-D) matching is proposed to improve the throughput of the cell edge users along with the mitigation of cochannel interference. Also, the power of the D2D transmitter is optimized using successive convex approximation with low complexity, which converts the nonconvex optimization problem of subchannel allocation and power control into convex problem. Numerical results demonstrate that DIYA achieves higher throughput with reduced delay in comparison to other existing orthogonal multiple access (OMA) and NOMA-based schemes.

The 5G cellular network employs non-orthogonal multiple access (NOMA) to enhance network connectivity and capacity, and device-to-device (D2D) communications to improve spectrum efficiency. However, the underlay D2D communications may destroy the execution condition for the successive interference cancellation (SIC) decoding of NOMA cellular networks by introducing the extra interference, which degrades the cellular transmission reliability. Thus, we develop the interlay mode as a special D2D mode for NOMA system, which enables the power domain multiplexing of the D2D pair and cellular users to eliminate the strong interference between them by the SIC decoding. When D2D pair conducts the selection between the interlay mode and underlay mode, the SIC decoding constraint should be satisfied at both D2D receiver and NOMA base station. In order to maximize the system sum rate while meeting the SIC decoding constraint, we propose a joint D2D mode selection and resource allocation scheme with interlay mode, which can be formulated as a combinatorial optimization problem. To tackle the combinatorial nature of mode selection and spectrum assignment, we first prove that the original problem can be reformulated as a maximum weight clique problem, and then propose a graph-based algorithm by applying branchand-bound method to obtain its optimal solution. Finally, simulation results are provided to demonstrate that the interlay mode along with the proposed algorithms can coordinate D2D communications and NOMA cellular network to significantly improve the system sum rate and the D2D access rate.

III. PROPOSED SYSTEM

A D2D A-NOMA signal model and its preliminaries are presented. Hence, an A-NOMA assisted D2D network with $k \in K$ geographically distributed transmitting users, where K is the maximum number of transmitters, and one receiving terminal, RX , within a small neighborhood. It is assumed that there are K NOMA users sharing each subcarrier with N subcarriers, and $K \geq 1$. It is assumed that the transmitted signals are not aligned at the receiver, and hence the channel is symbol asynchronous. Therefore, a power domain A-NOMA scheme assisted decoding method is applied in our proposed work where the waveform technique used is based on Orthogonal Frequency Division Multiplexing (OFDM).

Moreover, due to the timing offset between users in A-NOMA, inter-carrier interference (ICI) can occur and the resultant OFDM frequency components can get distorted. Such ICI at a subcarrier is formulated as follows. Consider an OFDM signal at time t modeled as:

$$x(t) = \sum_{n=1}^{N} X[n] e^{jw\pi f_n t}$$

Where f_n is the frequency of the n^th subcarrier, $0 \leq t \leq T_N$ and j denotes the complex number. Moreover, T_N is the symbol time, and X[n] is the signal transmitted over the nth subcarrier. Furthermore, the frequency offset due to asynchrony in the A-NOMA signal will introduce a multiplicative timevarying distortion, represented as $\beta(t) = e^{j2\pi\rho\Delta f t}$, where $\rho = \frac{\delta f}{\Delta f}$. As a result, the ICI on the m^th subcarrier is modeled as

$$ICI_m = \sum_{n=1, n\neq m}^{N} \int_0^{T_N} X[N] e^{j2\pi\rho\Delta f t} e^{-j2\pi\wedge\Delta f t} . dt$$

where the $\wedge$ gives the distance of the interfering subcarrier to the desired subcarrier. Meanwhile, in NOMA systems MultiAccess Interference (MAI) given is another interference that can distort the OFDM symbol of the desired user. Also, it is noted that in A-NOMA, the ICI is comparatively lesser than Multi-Access Interference.

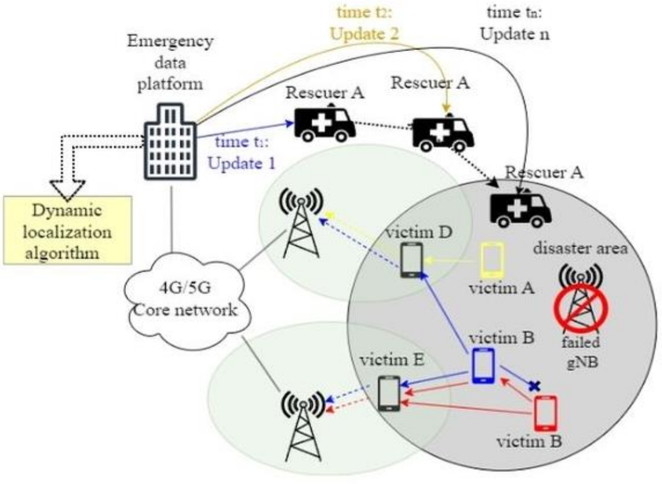


Fig 1 System Model

Hence, for this analysis, the MAI is considered the dominant source of interference, and one subcarrier is focused on for the analysis. The received signal at R_X for the k^{*th} user at the s^{th} symbol is given by

$$Y_{k^*}[S] = h_{k^*} . \sqrt{P_{k^*}} . X_{k^*}[s] + \eta_{k^*}[s] + n_0$$

where $X_{k^*}[s]$ denotes the k* ^th user's s^th data symbol which is complex and output from a M-ary-QAM symbol mapper, and P_{k^*} is the transmit power of $X_{k^*}[s]$, which is same for all symbols of k* ^th user for transmission time duration. Hence, the signal transmitted from the k* ^th user at the sth symbol can be denoted by $\sqrt{P_{k^*}} . X_{k^*}[s]$. The frequency response on one subcarrier for one symbol time period is considered flat and assumed to follow a Rayleigh distribution independently and identically (i.i.d). The symbol time is assumed to be considerably lesser than the channel coherence time. Hence, $h_{k^*}[s]$ is constant for a block of symbols during a transmission period. Further, n0 is the Additive White Gaussian Noise (AWGN) at the receiver side with variance σ^2 and $\eta_{k^*}[s]$ is the total interference to the k* th user's sth symbol

$$\eta_{k^*}[s] = \sum_{i \neq k^*}^{K} \sum_{\varsigma = s-1}^{s+1} \Delta_{k^*}, i[s, \varsigma].X_i[\varsigma].h_i.\sqrt{P_i}.e^{j\theta k^*, i}$$

Where $e^{j\theta k^*,i}$ depicts the i^{th} user's phase mismatch of the signal to the $k^{*\ th}$ and $\Delta_{k^*,i}$ denotes the symbol duration that the i th user's ς symbol overlap with the desired symbol, as a percentage out of the total symbol period, T_{sym}. Moreover, research works have addressed the problem of estimating the time offset, and carrier offset which leads to estimating $\Delta_{k^*,i}$ and $\theta_{k^*,i}$with high reliability in D2D communications using time of arrival measurements.
Following the standard SIC procedure, after subtracting the reconstructed interference, $\hat{\eta}k^*$, i[s, ς], of all overlapping interferes' symbols, the remaining interference cancelled signal for desired symbol is formulated in terms of desired signal, residual interference plus noise as

$$\tilde{Y}_{k^*}[S] = Y_{k^*}[S] - \sum_{i\neq k^*}^{K} \sum_{\varsigma=s-1}^{s+1} \hat{\eta}k^*, \mathrm{i}[s, \varsigma],$$

$$= X_{k^*}[s].h_{k^*}\sqrt{P_{k^*}} + \tilde{\eta}_{k^*}[S] + n_0$$

where the latest residual interference to the desired symbol, k*[s], is modelled as

$$\tilde{\eta}_{k^*}[S] = \sum_{i\neq k^*}^{K} \sum_{\varsigma=s-1}^{s+1} \Delta_{k^*}, i[s,\varsigma].\mathrm{X}_{\mathrm{i}}[\varsigma] - \hat{\mathrm{X}}_{\mathrm{i}}[\varsigma]).\mathrm{h}_{\mathrm{i}}\ \sqrt{P_i}.\, e^{j\theta k^*,i}$$

Moreover, such residual interference is utilized in the A-NOMA T-SIC scheme to improve the decoding reliability.

Problem Formulation

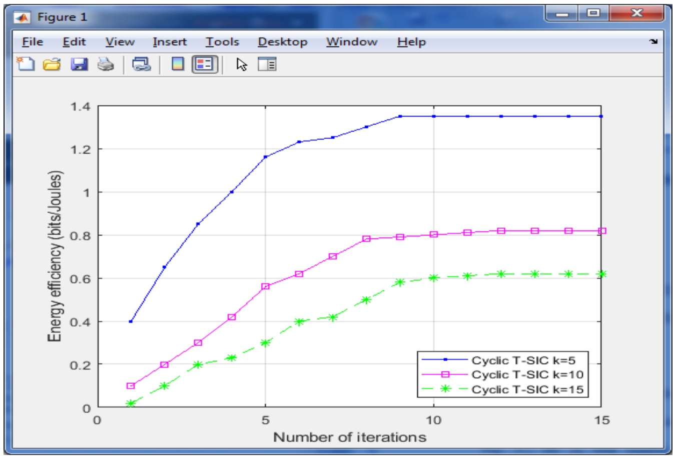
First, the Conventional T-SIC (Conv T-SIC) scheme that can enhance the decoding performance in A-NOMA uplink transmissions is presented. Secondly, a new Cyclic T-SIC scheme that can be applied in A-NOMA D2D networks is proposed.

Conv T-Sic Decoding Scheme

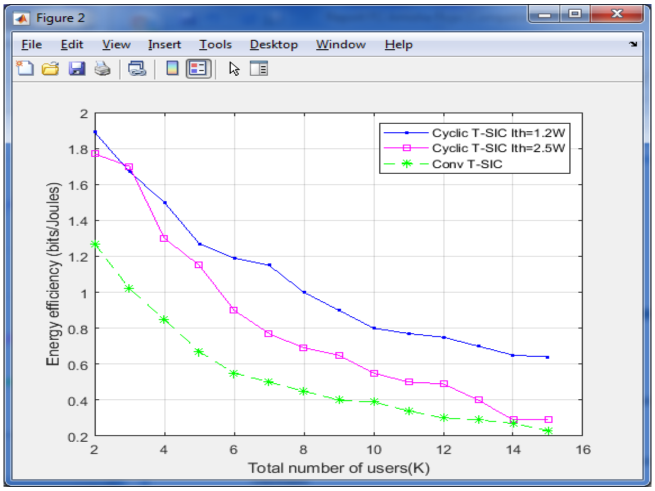
The Conv T-SIC decoding scheme is applicable at the receiver R_X terminal for a communication system containing k ∈ K transmitters. The T-SIC decoding procedure is followed once an asynchronous superimposed signal with misaligned data symbols is received at R_X. First an Interference Cancellation (IC) triangle is constructed by exploiting the triangular pattern of data symbols detected. The weakest symbol received out of such data symbols is added to the IC triangle as the last symbol to be detected. Next, the symbols that overlap with the weakest user's symbol are added to the IC triangle. Then, all the symbols that overlaps the second weakest users' symbols are included to the IC triangle. This procedure is repeated until the strongest users' symbols are entered to the IC triangle. Once such an IC triangle is constructed for n number of transmissions received from k_1 to k_n users, the first symbol of the strongest user, k_1, is decoded. Next the consecutive symbols of k_1 are decoded. Afterwards, the first symbol of the second strongest user, k_2 is decoded by subtraction of prior estimated symbols of k_1. Then, the second symbol of the k_2 user is decoded by subtracting the prior estimated symbols belonging to k_1 and k_2. Next, the first symbol of k_3 user is decoded by subtracting all the prior estimated symbols that belong to both k_1, k_2 from the received signal Y. Similarly, the rest of the symbols of k_3, up to k_n users are decoded by subtracting the prior symbols estimated.

Moreover, the conventional T-SIC is repeated iteratively between users for a fixed number of times, $N_{T\text{-}SIC}$. Specifically, the conventional T-SIC not only utilizes strong user signals to decode weak user signals but also uses weak user signals to decode strong user signals iteratively. In the Conv T-SIC scheme, the N_{TSIC} is within the range $1 \leq N_{T_{SIC}} \leq N_{T_{SIC_{MAX}}}$, where it is used primarily to improve the T-SIC accuracy in terms of BER. Furthermore, Conv T-SIC may not be optimal for decoders, particularly in massive D2D communication networks with energy-limited nodes. In the forthcoming section, a Cyclic T-SIC decoding scheme is proposed for A-NOMA to improve its decoding efficiency in terms of factors such as energy consumption, reliability, complexity, and delay is proposed.

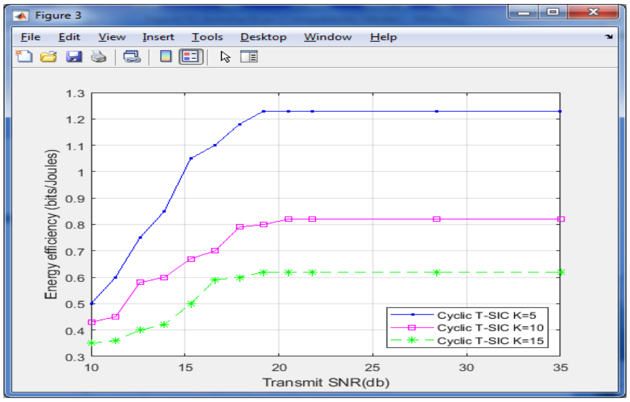
IV. SCREEN SHOTS



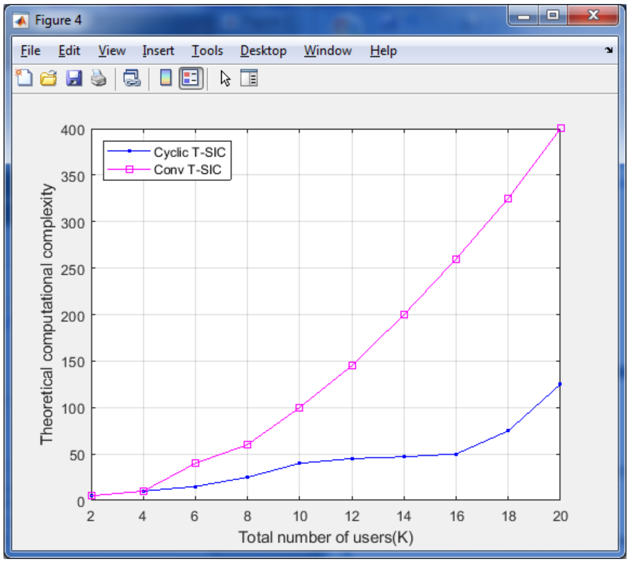
Convergence of EE Cyclic T-SIC scheme against the number of iterations



EE vs total number of users under varying interference threshold constraints



BER and EE analysis of the proposed Cyclic T-SIC



Computational complexity of proposed Cyclic T-SIC

VI. CONCLUSION

Thus, the complexity of successive interference cancellation at the receiver's end is a challenging issue in conventional non-orthogonal multiple access assisted massive wireless networks. The computational complexity of decoding increases exponentially with the number of users. Further, under realistic channel conditions, a synchronous non-orthogonal multiple access scheme is impractical in the uplink device to-device communications. An asynchronous non-orthogonal multiple access-based cyclic triangular successive interference cancellation scheme is proposed for a massive device-to-device network. The proposed scheme reduces the decoding complexity, energy consumption, and bit error rate of a superimposed signal received in an outband device-to-device network. In the decoding stage, the data in the optimal interference cancellation triangle is decoded using a conventional triangular successive interference cancellation technique. Utilizing the successive interference cancellation characteristics, the performance of the proposed device to-device network is defined in terms of energy efficiency, bit error rate, computational complexity, and decoding delay metrics. Moreover, the performance of the proposed decoding scheme is compared with the conventional triangular successive interference cancellation decoding scheme to demonstrate the superiority of the proposed scheme.

Furthermore, a convergence in EE and BER in the Cyclic T-SIC was observed when $\nu \geq 5.0$ and the transmit SNR $\geq$ 23 dBm due to the thresholds in the optimization algorithm which limits the kopt decoded per iteration. As a future direction, investigating the performance of the proposed scheme for 5G Ultra-Reliable Low Latency Communications (URLLC) is an interesting extension to this work.

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