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Interference-aware Coordinated Access Control for Heterogeneous Cellular D2D Communication Networks

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ABSTRACT

Device-to-Device (D2D) communications is expected to be a key technology of the forthcoming mobile communication networks because of its benefits in terms of spectral efficiency, energy efficiency, and system capacity. To mitigate frequency collisions as well as reduce the effects of co-channel interference between user's connections, we propose an interference-aware coordinated access control (IaCAC) mechanism for heterogeneous cellular D2D communication networks with dense device deployment of user equipment (UEs). In the proposed network setting, we consider the co-existence of both macro base stations (MBSs) and smallcell base stations (SBSs). In the proposed IaCAC mechanism, MBSs and SBSs are coordinated to perform access control to their UEs while MBSs allocate bandwidth parts dynamically to SBSs based on the interference levels measured at SBSs. Besides, to reduce D2D-to-cellular interference, device user equipments (DUEs) can perform power control autonomously. Simulation results show that the proposed IaCAC can provide higher system throughput and user throughput than those achieved by the network-assisted device-decided scheme proposed in [21]. Moreover, simulation results also reveal that the proposed IaCAC also significantly improve SINR of MUE's and SUE's uplink connections.

Key words: D2D communications, Access control, Channel allocation, Power assignment, Interference mitigation.

1. INTRODUCTION

Future mobile networks may require a huge wireless traffic demand of D2D communications, for example, vehicle to vehicle communications, communications between IoT devices. D2D communications can bring significant benefits in terms of spectrum reuse, traffic offloading, low latency, and system throughput [1]-[4]. However, cellular networks with D2D communications face to many technical challenges such as high signaling load and frequency collisions which may cause the degradation of system performance.

In such cellular D2D communication networks, there are two typical types of connections consisting of cellular connections between base stations (BSs) and user equipments (UEs), and D2D connections between two arbitrary UEs. Under the inband-underlay mode, both cellular and D2D connections share a same frequency spectrum. Thus, D2D connections might cause D2D-to-cellular interferences to cellular connections when they use same channels [5]-[9]. To mitigate D2D-to-cellular interference, an efficient access control mechanism including channel allocation and transmission power assignment processes is needed to handle D2D connection requests.

Channel allocation, transmission power assignment, and interference mitigation are crucial research issues in cellular D2D communication networks. The authors in [9] analyze unavoidable co-channel interferences in the cellular D2D communication network when the device density is high. By joint optimizing channel allocation and power control, and interference mitigation, the system performance can be significantly improved. Power control can be implemented in different approaches, i.e., centralized manner [10] or distributed manner [11]. Centralized power control has high accuracy, but it suffers high overhead as the number of devices increases. By contrast, in distributed power control, D2D users exploit local information of channel states to decide the transmission power. Thus, the overhead can be reduced. Nevertheless, D2D users might use high transmission power which can cause high interference to cellular users due to the lack of global interference information. The work in [12] studies the radio resource management in each sector of an MBS to reduce interference between D2D users and cellular users. Channel reuse technique using OFDM is proposed in [13] where D2D and

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cellular users can share a same spectrum. In the work [14], a joint admission control and resource allocation strategy is proposed to provide QoS support to cellular and D2D communications. The authors in [15] propose a resource scheduling method based on user location. However, in dense networks, processing information of users' locations might cause high computational load. A guard zone based D2D-activation scheme is proposed in [16] in which the exact closed-form expressions for the successful transmission probability of cellular users are proposed under the assumption that D2D users are uniformly distributed within a geographical area. The proposed scheme performs the guard zone's inner radius optimization while maximizing both STP and average throughput. The approach is proved to be efficient for low dense mobile networks.

There are different approaches in optimization solutions of channel allocation and power control for D2D communications. An energy efficient maximization method is proposed the power control algorithm based on Lambert W function and the channel allocation algorithm based on Gale-Shaley algorithms in order to solve the sub-optimal problems of these issues. The proposed algorithms are suitable to improve D2D pair energy efficiency of low density D2D networks. A game-theory based approach has been proposed for distributed channel allocation and power control of D2D underlaid cellular networks where devices select channels and transmission power for their D2D connections by themselves [18]. The method can reduce the computation load of base stations and work effectively in small D2D communications networks. In [19], the authors proposed a joint channel allocation, mode selection and power control scheme for cellular users and D2D users in femtocells during uplink wireless communication. The authors have formulated a non-convex mixed integer programming optimization problem, transformed it to a convex form by relaxing the channel variable and solved the problem by the Lagrangian decomposition method. However, the scheme has limitations in theoretical assumptions such as the same number of channels for femtocells, the same number of cellular users and D2D users in femtocells. In [20], a centralized resource allocation mechanism was proposed which is based on interference control and designed for satisfying SINR of cellular and D2D connections while optimizing system throughput. However, because the mechanism requires fixed and correct positions of all devices when defining interference restricted areas, it is not applicable to mobile networks.

In [21], the authors propose a practical centralized resource management mechanism comprising channel allocation and power control for D2D connections in heterogeneous cellular D2D communications networks. In this mechanism, the MBS cooperate with its UEs. When a source DUE sends a D2D connection request to an MBS, it also sends the list of preferred channels based on channel's link gain. The MBS calculates and allocates the relevant transmission power to each channel subjected to cause minimum interference to macro UE and guaranteeing QoS of cellular connections. This mechanism can significantly improve the system throughput due to the capability of cancelling D2D-to-cellular interference. Although the mechanism has low signaling overhead, it requires high computation load at MBSs and channel measurement at UEs when the numbers of UEs and channels increase.

To our best knowledge, heterogeneous cellular D2D communications networks, where both a macro-cell base station (MBS) and smallcell base stations (SBS) coexist, require a practical access control mechanism instead of complex theoretical solutions. Our research focuses on new constraints of heterogeneous cellular D2D communication networks including high dense deployment of UEs and SBSs, flexible spectrum management (i.e., BWPs) and low signaling load. To deal with the aforementioned requirements, we propose an interference-aware coordinated access control (IaCAC) mechanism for these networks where the MBS and SBSs are coordinated to allocate BWPs dynamically to SBSs. Specifically, MBSs allocate BWPs to SBSs dynamically according to the demand of SBSs. Hybrid access control is then performed by MBSs and SBSs whereas DUEs perform power control autonomously.

The remainder of the paper is organized as follows. The system model and the operation of the proposed IaCAC mechanism are described in Section 2 and Section 3, respectively. Section 4 presents the simulation results and discussions. The conclusion is given in Section 5.

2. SYSTEM MODEL

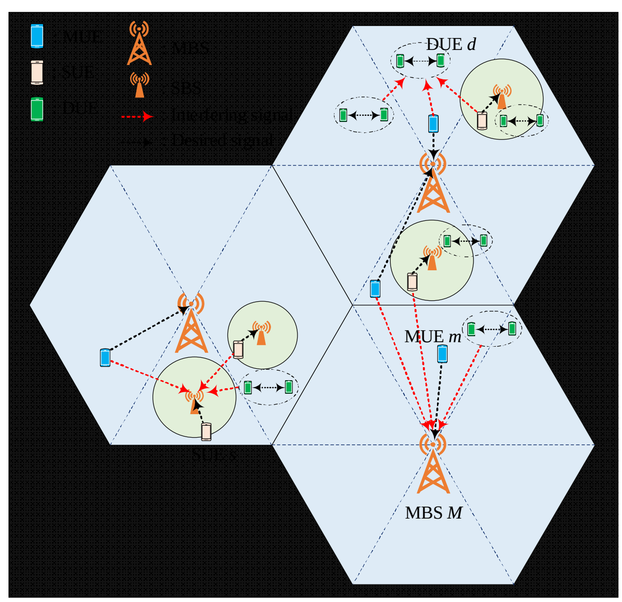


Figure 1: Heterogeneous cellular D2D communications networks.

2.1 System Description

The system model of heterogeneous cellular D2D communication networks is illustrated in Fig.1 in which both macro base stations (MBSs) and smallcell base stations (SBSs) coexist. MBSs form a hexagon layout where there are a number of SBS in the coverage area of each MBS. In Fig. 1, MBS *M* is the central MBS surrounded by up to six MBSs (here only two surrounded MBSs are illustrated due to limited space). There are three typical types of user equipment (UEs) : 1) macrocell UEs (MUEs) served by MBSs; 2) smallcell UEs (SUEs) served by SBSs; and 3) users using D2D communications (DUEs) to create direct connection pairs called D2D pairs. D2D communications allow D2D pairs to exchange their data to each other directly to provide low latency communications. A D2D pair is managed by a SBS when the D2D pair locates in the SBS coverage area. When a D2D pair is not located in any SBS, the D2D pair is managed by the serving MBS. The MBS coverage area has multiple sectors in which the uplink transmissions to MBSs and SBSs, and D2D communications share a same frequency spectrum of N_c channels. The total frequency spectrum is divided to N_{BWP} bandwidth parts (BWPs). A BWP has N_c^{BWP} channels for data transmissions and one reference signal (RS) channel for broadcasting the RS. Each uplink transmission from UEs to MBSs and SBSs utilizes only one channel belonging to a BWP. A D2D connection also consumes one channel of a BWP. When a SBS utilizes a BWP, the SBS broadcasts the predefined RS on the RS channel at a specified transmission power periodically.

2.2 Channel Models

In the literature, various channel models are considered for the D2D communication networks [21]-[24]. In this paper, we adopt the channel models (i.e., Line-of-Sight (LOS) and non-Line-of-Sight (NLOS) models) proposed in [21] for the performance comparison. The pathloss calculations of these transmission models are given below:

- The LOS pathloss model is applied to calculate the pathloss between the MBS and MUEs, the MBS and its DUEs, a SBS and its SUEs, and a SBS and its DUEs. The LOS pathloss is calculated as follows:

$$PL(d) = 127 + 30\log_{10}(d) + \varsigma. \tag{1}$$

- The NLOS pathloss model is applied to the D2D communications and uplink channels between DUEs and MUEs, DUEs and SUEs, and MUEs and SUEs. The NLOS pathloss is calculated as follows:

$$PL(d) = 128.1 + 37.6\log_{10}(d) + \varsigma, \tag{2}$$

where d is the distance between a sender and a receiver in kilometers. ς is the shadowing of log-normal distribution in dB with the mean is zero and the standard deviation is one.

2.3 Performance Metrics

A. Signal to interference plus noise ratio (SINR)

To increase the spectrum efficiency of cellular D2D communications networks, channels are reused in both D2D communications and uplink transmissions in the MBS and SBSs. However, this leads to the degradation of SINR values of all connection types (uplink MBS, uplink SUE and D2D connections) due to the effects of interference that occurs among the connections. Specifically, when a channel is allocated to a D2D connections which is also using by a MUE's uplink connections, it can cause co-channel interference to the MUE's uplink connections. For MUE m using channel k in MBS M, its uplink SINR value is calculated as:

$$SINR_{m,M}^k = \frac{P_m^k G_{m,M}^k}{n_{sub} N_0 \Delta f + \sum_{u \in U_k, u \neq m} P_u^k G_{u,M}^k}, \tag{1}$$

where P_m^k and $G_{m,M}^k$ denote the transmission power of MUE m at channel k and the channel gain between MUE m and MBS M at channel k, respectively. n_{sub} is the number of subcarriers of a channel. N_o is the white noise power density of the subcarrier spacing Δf . U_k is a set of other UEs using channel k. For example in Fig.1, MBS M not only receives the desired signal from MUE m but also receives the set of unwanted signals from other connections in the network. P_u^k and $G_{u,M}^k$ are the transmission power and channel gain of channel k occupied by UE u (i.e., MUE, SUE, or DUE), respectively. SINR of SUE's and DUE's uplink connections can also be calculated in the same way as in the equation (3).

B. User throughput

The user throughput obtained by a UE u (i.e., a MUE, SUE, or DUE) is calculated as follows:

$$C_u = \sum_{k=1}^{N_{ch}^u} \eta_k B_{ch}, \tag{4}$$

where N_{ch}^u is the number of channels used by UE u. B_{ch} denotes the bandwidth of a channel $(B_{ch} = n_{sub}\Delta f)$. The spectrum efficiency η_k of the channel k depends on the SINR value measured at the receiver as shown in Table 1 [21].

Table 1: Matching between the spectrum efficiency and SINR [21].

Modulation	Code Rate (Default Repetition=1)	Spectrum Efficiency η (bps/Hz)	Minimum SINR (dB)
QPSK	1/2 (4)	0.25	-2.5
QPSK	1/2 (2)	0.5	0.5
QPSK	1/2	1	3.5
QPSK	3/4	1.5	6.5
16-QAM	1/2	2	9
16-QAM	3/4	3	12.5
64-QAM	1/2	3	14.5
64-QAM	2/3	4	16.5
64-QAM	3/4	4.5	18.5

C. System throughput

The system throughput of a MBS's cell is defined as follows:

$$T_{total} = T_{MBS} + T_{SBS}, \tag{5}$$

where T_{MBS} is total throughput of MUE's and DUE's connections managed by the MBS:

$$T_{MBS} = \sum_{m=1}^{N_{MUE}} C_m + \sum_{d=1}^{N_{D2D}} C_d, \tag{6}$$

where N_{MUE} and N_{D2D} is number of MUEs and D2D pairs managed by the MBS, respectively. T_{SBS} denotes total throughput of SUE and DUE connections served by SBSs which are managed by the MBS:

$$T_{SBS} = \sum_{S=1}^{N_{SBS}} \left(\sum_{s=1}^{N_{SUE,S}} C_s + \sum_{d=1}^{N_{D2D,S}} C_d \right), \tag{7}$$

where N_{SBS} denotes the number of SBSs managed by the center MBS. $N_{SUE,S}$ and $N_{D2D,S}$ are numbers of SUE and D2D pairs in SBS S, respectively.

3. INTERFERENCE-AWARE COORDINATED ACCESS CONTROL MECHANISM

The proposed interference-aware coordinated access control (IaCAC) mechanism has following key functions: i) dynamic BWP allocation to SBSs; ii) co-channel interference mitigation on MUE's connections by setting the maximum allowable transmission power (MAP) of a BWP; iii) hybrid channel allocation and power assignment carried out by MBSs and SBSs; iv) distributed power control of D2D connections.

The operations of the MBSs, SBSs and DUEs are described in detail below:

3.1 MBSs allocate BWPs to SBSs and estimate the MAP of the selected BWPs

When an MBS or a SBS consumes a BWP, it broadcasts the RS channel of the BWP at a predefined transmission power. When a SBS S needs more radio resource (i.e., BWPs), the SBS measures the energy level of RS channels of BWPs which are not consumed at the SBS. Then, the SBS creates a BWP measurement report of energy levels of RS channels and sends the report together with a BWP allocation request to its managing MBS. When the managing MBS receives the BWP allocation request from the SBS S, the MBS performs:

1) Selecting the BWP (denoted as BWP b) which has the lowest energy level in the BWP management report.
2) Estimating the maximum acceptable interference of edge MUEs ($I_{total}^{\max}$) while guaranteeing its SINR target:

$$I_{total}^{\max} = \frac{P_{\max}^{MUE}}{\gamma PL(R)}, \tag{8}$$

where $P_{\max}^{MUE}$ is the maximum transmission power of the MUE. $PL(R)$ is the estimated pathloss of the uplink channel of the MUE where R is the radius of the MBS's cell. γ denotes the target SINR of the uplink transmission of the MUE.

3) Determining the MAP value for BWP b based on the set of SBSs (S_b) which are consuming the BWP b in the same sector of the SBS S as follows:

$$P_b^{MAP} = \frac{I_{total}^{\max}}{\sum_{c \in S_b \cup S} \frac{1}{PL_{c,MBS}}}, \tag{9}$$

where $PL_{c,MBS}$ is the pathloss value between SBS c of the set S_b and the MBS.

4) Informing the SBS S the selected BWP b and the MAP value of BWP b. The MBS also updates all other SBSs of the S_b about the new MAP value of BWP b.

3.2 A SBS allocates channel and assigns transmission power to its SUEs

When a SUE sends an uplink connection request to its serving SBS, the serving SBS performs:

1) Allocating a random free channel of its available BWP b to the SUE.

2) Assigning the SUE an initial uplink transmission power (P_{SBS}^{SUE}) equal to the MAP value of the BWP *b*, (i.e., $P_{SBS}^{SUE} = P_b^{MAP}$).

After the uplink transmission between the SUE and the serving SBS is established, they jointly perform power control to guarantee the SINR target of the SUE while maintaining the transmission power less than the MAP value of the BWP *b*. The SBS measures the SINR value on the allocated channel and sends this information to the SUE. After the SUE received the SINR value, it finds an optimal transmission power which can provides the highest value of SUE throughput while being lower than the MAP value of the BWP *b*.

3.3 A SBS allocates channels and broadcasts the corresponding MAP value to its DUEs

When a DUE (i.e., a source DUE in a D2D connection) wants to establish a D2D communication with another DUE (i.e., a destination DUE), the source DUE sends a D2D connection request to its serving SBS. Then, the serving SBS performs:

1) Allocating a random free channel of its BWP (e.g., BWP *b*) to the source DUE.
2) Sending the selected channel and the MAP value of BWP *b* to the source DUE.

Source and destination DUEs jointly perform power control. The destination DUE measures the SINR value on the allocated channel and sends this information to the source DUE. After the source DUE received the SINR value, it finds an optimal transmission power which can provide the highest value of D2D throughput while being lower than the MAP value of the BWP *b*.

3.4 An MBS allocates an available channel and transmission power to its MUEs

When a MUE u wants to establish an uplink transmission to its managing MBS, the MUE firstly sends a connection request to the MBS. The MBS performs:

1) Allocating a channel for MUE *u*:

- By using directional antenna, the MBS estimates the sector (e.g., sector *j*) where the MUE *u* resides in.

- The MBS finds the BWPs that are being used by other MUEs in sector *j*. If these BWPs still have free channels, the MBS assigns a random free channel in the BWPs for MUE *u*. Otherwise, the MBS selects a new BWP for the sector *j* as following:

  • The MBS finds a set of BWPs (denoted by B_{active}) which have free channels.

  • With a BWP *b* in B_{active}, based on the measurement reports received from SBSs residing in sector *j*, the MBS calculates the interference value (w_b) of BWP *b* in the sector *j* as follows:

$$w_b = \sum_{S \in S_j} p_{b,S}^{RSC}, \tag{10}$$

  where S_j denotes the set of SBSs in the sector *j*, $p_{b,S}^{RSC}$ is the energy level of the RS on BWP *b* estimated at SBS *S*.

  • The MBS selects the BWP having the minimum value of w_b. Then, it allocates a random free channel of the selected BWP to MUE *u*.

2) The MBS assigns an initial transmission power that equal to the maximum transmission power value of the selected BWP to the MUE.

After the uplink transmission between MUE *u* and the managing MBS is established, the MBS and the MUE cooperate to perform power control to guarantee the SINR target of the MUE. The MBS measures the SINR value on the

Table 2: Simulation parameters.

Parameters	Value	Unit
Simulation time	2000	second
Total number of MBS	7	MBS
Macrocell radius(R)	1000	m
Height of MBSs	30	m
Total number of channels	50	channel
Number of Sectors	6	sector
Number of BWPs (N_{BWP})	10	BWP
Number of channels in each BWP (N_c^{BWP})	5	channel
Number of SBSs in each MBS	variabl e	SBS
SBS radius	100	m
Height of SBSs	10	m
Bandwidth of a subchannel	180	Khz
Maximum number of MUEs	50	MUE
Height of UEs	1	m
Maximum transmission power of MUE/device	23	dBm
Mean distance between two devices in a D2D pair	30	m
Target SINR of UEs	18.5	dB
Carrier frequency	2.0	GHz
White noise power density	-174	dBm/Hz

allocated channel and sends this information to the MUE. After the MUE received the SINR value, it finds an optimal transmission power which can provide the highest value of MUE's throughput while being lower than the maximum transmission power.

3.5 An MBS allocates a channel and assigns the MAP value of BWP to DUEs

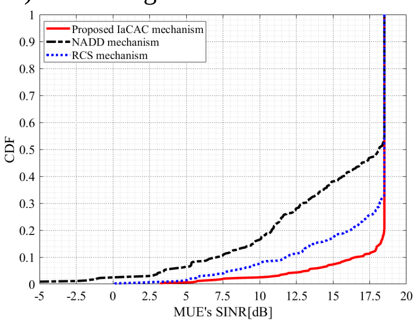
Consider a source DUE s, which resides in the sector *v* of a MBS, wants to establish a D2D communication with a destination DUE. The DUE *s* sends a D2D connection request to the MBS. The MBS performs:

1) Selecting a BWP *b* which is different with the BWPs utilized by other MUEs in the same sector. Allocate a random free channel *k* of BWP *b* to the DUE *s*.

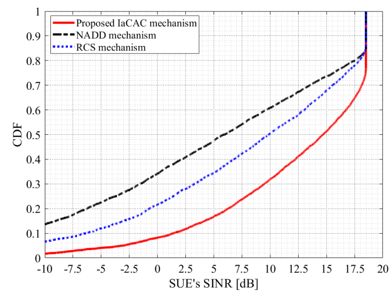
2) Determining the MAP value (P_k^{MAP}) for the selected channel *k* following as:

$$P_k^{MAP} = \frac{I_{total}^{\max}}{\sum_{c \in S_v} \frac{1}{PL_{c,MBS}} + \frac{1}{PL_{d,MBS}}}, \qquad (11)$$

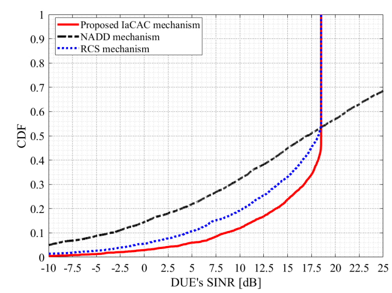
where s_v denotes the set of SBSs using BWP *b* in sector *v*. $PL_{c,MBS}$ is the pathloss value between SBS *c* and the



a) SINR of MUE

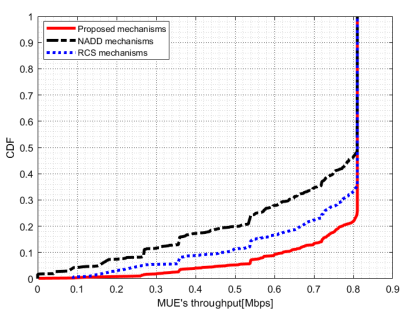


b) SINR of SUE

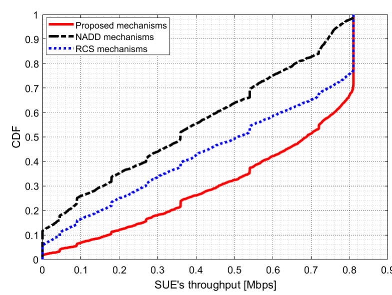


c) SINR of DUE

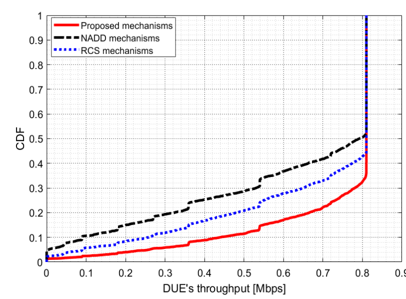
Figure 2. CDF of UE's SINR.



a) MUE's throughput



b) SUE's throughput



c) DUE's throughput

Figure 3. CDF of user throughput.

MBS. $PL_{d,MBS}$ is the estimated pathloss value between the DUE *d* and the MBS. The equation shows the worst case in which all SBSs located in sector *v* use the same BWP *b* and allocate the same channel *k* to its UEs. It causes co-channel interference to the D2D communications.

Similarly, after the connection of the D2D pair is established, they also cooperate to perform power control as described above.

4. SIMULATIONS AND PERFORMANCE COMPARISON

In this section, we conduct discrete event simulations to evaluate and compare the user and system performance in terms of UE's SINR, UE's throughput, and the system throughput achieved by the proposed IaCAC mechanism with those of the network-assisted device-decided (NADD) mechanism proposed in [21] and a random channel selection (RCS) mechanism. In the NADD mechanism, an MBS performs access control for all MUEs, SUE, and DUEs located in its coverage area. For a MUE connections request, the MBS allocates a channel randomly and assigns the maximum transmission power to the MUE. For a SUE/DUE connection request, a SUE (or source DUE) first measures the gain of all channels and selects a number of channels with the highest gains to form its favorite channel list. Then, the SUE (or source DUE) reports the favorite channel list to its managing MBS. The MBS calculates and informs the SUE (or source DUE) the maximum allowable transmission power on each channel in the list. Finally, the SUE (or source DUE) autonomously selects the proper channels and transmission power to enhance the throughput. The NADD mechanism does not perform power control to UEs. In the RCS mechanism, MBSs and SBSs allocate channels randomly to UEs in their serving areas. Power allocation and power control of the RCS mechanism are similar to those of the proposed IaCAC mechanism.

The simulated cellular D2D communications network consists of 7 MBSs in a hexagon layout. There are 40 SBSs uniformly deployed in the coverage of each MBS. The coverage radiuses of MBSs and SBSs are 1000m and 100m, respectively. New MUE and DUE connections managed by MBSs are generated following the Poisson process with the mean arrival rate of 15 connections/minute for each MBS. New SUE and DUE connections managed by SBSs are also generated by the Poisson process with a mean arrival rate of 2.5 connections/minute for each SBS. When a new connection is created, the corresponding source UE (i.e., MUE, SUE, DUE) is created which has a location randomly distributed in the coverage area of the serving MBS or SBS. The connection duration of UEs is exponent distribution with the mean duration of 180 seconds. The spectrum includes 50 channels divided into 10 BWPs and each channel has the bandwidth of 180 KHz. Each connection consumes only one channel. The maximum transmission power of MUEs, SUEs, and DUEs is set at 23 dBm [25]-[27]. Simulation parameters are listed in Table 2.

Figure 2 shows the cumulative distribution function (CDF) of the average SINR of the UEs (i.e., MUE, SUE, and DUE). The simulation results show that by allocating channels based on interference level of BWPs and applying the maximum allowable transmission power (MAP) value to SUE and DUE uplink connections, co-channel interference is significantly reduced. It results in much higher UE’s average SINR. For example, in Fig. 2a, the average SINR of MUEs achieved by the proposed IaCAC mechanism has highest performance, in which no SINR sample is less than 0 dB and up to 97% of the samples are greater than 10dB. While the NADD mechanism achieves about 3% of samples less than 0dB and only 85% of samples greater than 10dB. Because the RCS mechanism performs the transmission power allocation and power control similar to the IaCAC mechanism, the RCS mechanism outperforms the NADD mechanism with no sample less than 0dB and approximately 93% of the samples greater than 10dB. In Fig. 2b, the average SINR of SUEs when using the IaCAC mechanism is improved by up to 29% and 18.5% comparing to the NADD and RCS mechanisms at 10dB. Moreover, the proposed IaCAC mechanism obtains only 4.5% of the samples less than the outage threshold of -2.5dB, while the NADD and RCS mechanisms have 19.5% and 10.5%, respectively. Fig. 2c shows the CDF of the average SINR for D2D connections in which the IaCAC mechanism has only 2% of DUE's SINR samples less than -2.5dB and up to 92% of the samples greater than 10dB. Meanwhile, the NADD and RCS mechanisms obtain 7.8% and 3% samples less than -2.5dB, and 78% and 85% samples greater than 10dB, respectively. When using the NADD mechanism, up to 60% of samples is greater than 18.5dB. However, it is not necessary because the highest modulation level requires only 18.5dB.

Figure 3 shows a significant improvement in terms of user throughput when using the proposed IaCAC mechanism. Specifically, Fig. 3a shows that the proposed mechanism achieves 91% of samples of MUE’s throughput greater than 0.6 Mbps while the NADD and RCS mechanisms are only 72% and 83%, respectively. Fig. 3b shows the CDF of SUE's throughput in which when considering at 0.6Mbps, the proposed IaCAC mechanism achieves 58% of samples, whereas the NADD and RCS mechanisms obtain only 25% and 41% samples larger than 0.6Mbps, respectively. Similarly, Fig. 3c also shows a significant improvement in DUE's throughput when comparing the proposed mechanism with the NADD and RCS mechanisms.

As a result of the improvement of user throughput, the system throughput of the IaCAC mechanism is greatly improved compared to other mechanisms. The results in Fig. 4 show that the median value of the system throughput when

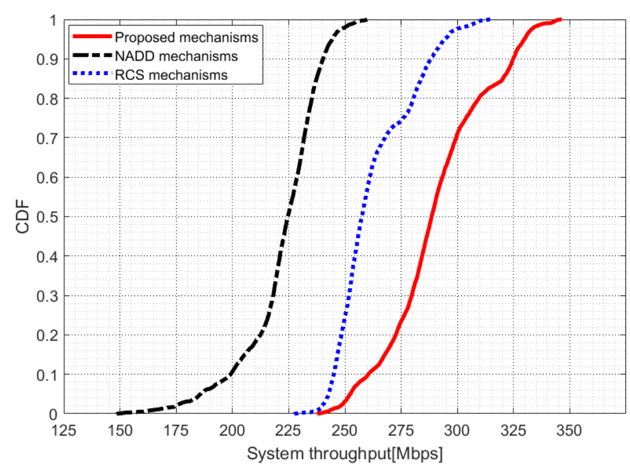


Figure 4: CDF of the system throughput.

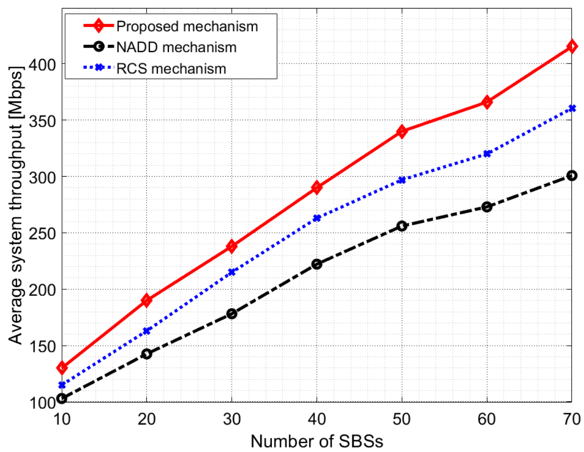


Figure 5: System throughput comparison with different number of SBSs.

using the proposed mechanism is 288.5 Mbps whereas that of the NADD and RCS mechanisms is 225 Mbps and 258 Mbps i.e., the improvement is up to 28.2 % and 11.8%, respectively.

Figure 5 shows that when the number of SBSs increases, the IaCAC mechanism also has a higher average system throughput than that of other mechanisms. For example, when there are 20 SBSs in each MBS, the system throughput is about 190 Mbps, 145 Mbps and 165 Mbps in the IaCAC, NADD and RCS mechanisms. In general, the proposed IaCAC mechanism can improve about 31% and 15% in the system throughput comparing with that of the NADD and RCS mechanisms, respectively.

Finally, we study the impacts of mean arrival rates of SUE to the system throughput illustrated in Figure 6. The proposed IaCAC mechanism can significantly increase the average system throughput which achieves up to 490 Mbps when the mean arrival rate is 2.5 connections per minute. Meanwhile, the average system throughput achieved by the NADD and RCS mechanisms are only 340 Mbps and 430 Mbps, respectively.

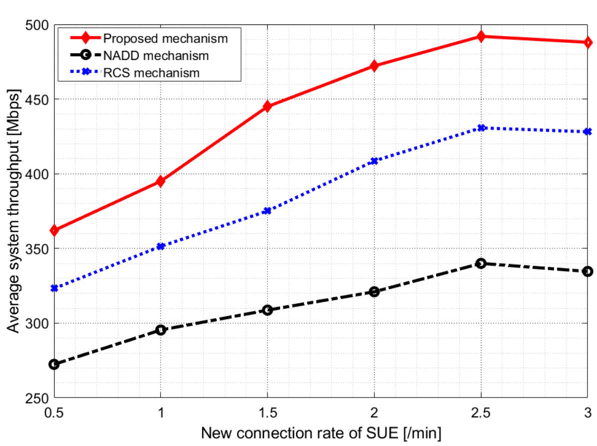


Figure 6. System throughput comparison with different connection rate of SUE.

5. CONCLUSIONS

In this paper, we have proposed the interference-aware coordinated access control (IaCAC) mechanism for heterogeneous dense cellular D2D communication networks where both macro base stations and smallcell base stations (SBSs) coexist. The IaCAC mechanism has been designed under the considerations of new constraints of dense device deployment, flexible spectrum management and low signaling load requirements, aiming to mitigate D2D-to-cellular interference and enhance system throughput. Specifically, in the proposed mechanism, MBSs allocate BWPs to SBSs dynamically according to the demand of SBSs. Hybrid access control is performed by MBSs and SBSs whereas DUEs perform power control autonomously. Simulation results have proved that the proposed IaCAC mechanism can provide higher SINR, system throughput, and UE's throughput than those achieved by other mechanisms. In future works, we consider a more practical scenario which performs the transmission power optimization of mobility UEs.

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