Resource Management for an Integrated OFDMA Cellular System with MC-CDMA Based D2D Communications

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***Abstract*—Integration of device-to-device communications (D2D) into cellular networks improves the efficiency and flexibility of the overall system. Besides, D2D can provide partial solutions for some of the inherent problems of cellular systems, such as performance enhancement at cell edges. Similar to cellular systems, interference management is one of the key issues since it greatly affects the system performance. In this paper, we propose a novel and practical resource scheduling scheme for the integrated system. In such a system, multicarrier code division multiple access (MC-CDMA) is used as the multiple access scheme for D2D user equipment (UEs), while orthogonal frequency division multiple access (OFDMA) is used for cellular UEs. The basic idea is to eliminate interference between UEs using different domains (mainly frequency, code and power domains). Furthermore, the combination of resource management, power control, and frequency domain spreading (wideband transmission) leads to an efficient way to realize incell resource reuse between different modes of UEs. Network simulations show that critical interference between different modes of UEs can be well eliminated, while the general SINR performance is acceptable. Spectrum efficiency is improved as well. The proposed scheme provides a simple and practical solution for the integrated system. From both the SINR performance and latency points of view, the solution is robust and promising.**

Keywords—D2D, MC-CDMA, OFDMA, cross mode inter-cell interference (CMICI)

I. INTRODUCTION

Device-to-device (D2D) communication has been studied over two decades [1] [2] and it has been included in some wireless system specifications [3] [4]. Recently it has been proposed as one of the attractive features for 5G and future networks [5] [6]. Essentially, D2D utilizes the advantages of local area (LA) transmissions. From network point of view, efficient resource usage and low power consumption can be achieved. Besides, it provides efficient solutions for some inherent cellular system problems, such as the cell load balance, user equipment (UE) performance improvement at cell edge, and coverage extension (relay). Furthermore, D2D can be used for some specific scenarios, such as D2D based cluster for machine type communications (MTC), and vehicle to infrastructure (V2X) communications [7]. From link level point of view, D2D link provides good channel conditions in general, so that high data rate can be achieved by simple transmitter (Tx) and receiver (Rx) algorithms. The latency can be reduced, due to direct communication between devices and low probability of retransmission.

Interference management is one of the key issues since D2D mode UEs and normal cellular mode UEs may express different characteristics, based on the mode selection criteria used. In the underlay case, the same (licensed) band is shared between different modes of UEs. Therefore, the potential cross mode interference can be critical for some scenarios [8]. Without cell coordination, significant inter-cell interference (ICI) can take place between cellular mode UEs and D2D mode UEs from neighboring cells at cell edges.

Interference avoidance schemes have been investigated from different aspects. Schemes of resource optimization (including incell resource reuse) have been studied in [9-11]. Power control schemes have been investigated in [12] [13]. However, those schemes have some limitations. Some of the algorithms are case-optimized under unrealistic assumptions. Besides, extensive measurements are required by most of the algorithms, which is also difficult to be fulfilled in practice. Furthermore, some centralized algorithms require instant and frequent information (measurement result) exchange between UEs, between UEs and base stations (called eNodeBs or eNBs), and between eNBs. Therefore, most of them require simplification for the practical use.

In this paper, we combine two separate ideas presented in our previous studies [15] [16], considering the reuse of uplink resources of a frequency division duplexing (FDD) based cellular OFDM system for D2D. We use MC-CDMA for D2D mode UEs, and conventional OFDMA for cellular mode UEs. In this case, the D2D transmission is wideband so it obtains the diversity and incell resource reuse in a natural way. Besides, most of the cellular mode UEs can be considered as narrowband interference to D2D mode UEs. Therefore, a D2D mode UE has the capability to endure interference from cellular mode UEs (by CDMA processing gain) in significant extent. However, from [15] we understand that the accumulated cross mode interference can be rather significant without restrictions on UE positions. In this paper, we use the idea in [16] for the integrated system. That is, we use separate resources for D2D UEs in the corresponding resource pool (by CDMA), while resources in the same pool can be used by cellular mode UEs nearby the serving eNB. Applying a strict link budget based mode selection results in a low probability of having D2D pairs near the serving eNB. Therefore, interference between different modes of UEs using this resource pool can be limited and controllable. Normal cellular mode UEs sue another resource pool so that there is no cross mode interference (between D2D mode UEs and normal cellular mode UEs). One of the key advantages of this scheme is that most of the settings (such as resource allocation related and spreading related parameters) can be initialized by eNB and frequent updating is avoided. Therefore, significant overhead (due to measurements and reports) and latency can be avoided.

The rest of this paper is organized as follows. In Section II, a short description of the integrated system is first given, followed by a detailed description of the MC-CDMA scheme for D2D mode UEs. The proposed resource management scheme is described in Section III. In Section IV, we present the signal-to-interference-plus-noise ratio (SINR) performance of the proposed system with proposed algorithms, and compare it to the reference system (using conventional OFDMA for all UEs with random resource allocation). Some related issues, such as incell reuse factor selection and effect of system load, are studied in the same section as well. Section V gives the conclusions.

II. System Description

A. D2D integrated MC-CDMA system

The backbone of the integrated system follows the LTE specifications [14]. We use OFDMA for cellular mode UEs, which has the same characteristics with SC-FDMA in all essential respects for this study. If a UE has been switched to D2D mode, MC-CDMA is used. The switching is determined by the eNB. FDD UL band is shared between UEs in the integrated system. Time-division duplexing (TDD) is used for D2D duplexing due to its flexibility. Transmission direction is changed at slot level.

From LTE Release 12 [4], the D2D feature has been included in 3GPP specifications. The UL band can be shared between different modes of UEs by means of FDD or TDD. However, the idea at LTE release 12 is to use D2D for public safety, rather than to use D2D for network efficiency enhancement. So the scenarios (interference models) are different from our studies. From Release 13, more use cases have been investigated (for MTC and V2X) [7]. Based on the LTE roadmap, it seems that D2D will be used for wearable devices in 5G systems and beyond. In this case, the research direction is in line with our studies.

B. D2D related procedures and schemes

Mode selection is link budget based. The link budget is given in dB as

$$G_b = G_{AT} + G_{AR} - L - B_{Loss} . \quad (1)$$

where L is the pathloss between the transmitter and the receiver, G_{AT} and G_{AR} are the antenna gains of the transmitter and receiver, respectively, and B_{Loss} is the total body loss of transmitter and receiver. The decision threshold for mode selection is given as:

$$G_{b\_threshold} = G_{b\_D2D} + G_{SM} \quad (2)$$

where G_{b_D2D} is the minimum link budget for reliable D2D connection and G_{SM} acts as a safety margin. If the link budget of cellular mode (the uplink or the downlink) is larger than the decision threshold (indicating that less Tx power is necessary to compensate the pathloss of the cellular link than to compensate the pathloss of D2D link), i.e., $G_{b\_Cellular} \geq G_{b\_threshold}$, cellular mode is chosen. Otherwise, D2D mode is selected. Since the link budget depends on the pathloss, we use pathloss to make the decisions in simulations. The safety margin is to guarantee the stability of gain obtained by D2D integration. It gives a trade-off of D2D performance and D2D probability. In simulations, G_{SM} is set to 6 dB, at least.

Intracell and inter-cell synchronization is assumed to make sure that most of the effective interferences at the integrated system are roughly synchronized.

The actual parameters concerning spreading can be determined by eNB. To obtain high processing gain and high resource efficiency, the largest available spreading factor is used for D2D mode UEs (equal or close to the size of the D2D resource pool). The spreading factor is fixed for all D2D mode UEs in order to simplify the spreading procedure. Since we assume that significant multi-user interference sources are synchronized, we use Walsh Hadamard (WH) sequences for spreading [15]. The code length is 2^n (the actual length in simulations is 64 at physical resource block (PRB) level). In the D2D pair scenario, the two UEs in a pair share the same sequence, while in the cluster scenario each D2D device has its own UE specific sequence.

Open loop fractional power control (OFPC) is used for both cellular mode UEs and D2D mode UEs [17].

III. Resource Management Algorithm

It is understood that cross mode interference can be critical in some scenarios [15]. Therefore, we use wideband transmission (MC-CDMA) for D2D mode UEs so that the interference power from cellular mode UEs (per resource block) can be reduced by a factor equal to the spread factor *SF*. Essentially this is also an incell resource reuse scheme. Meanwhile, the accumulated interference is considerable between different modes of UEs without any restrictions. First of all, around a D2D pair there can be multiple cellular mode UEs with high TX powers. Secondly, a cellular mode UE can use a number of RBs so that the effective processing gain can be limited. Therefore, as shown in [15], the performance of MC-CDMA based D2D mode UEs is generally not as good as the performance of OFDMA based D2D mode UEs. In [15], we suggest a location dependent solution to eliminate the critical incell interference. However, it only reduces the interference from its own serving cell, the cross mode inter-cell interference (CMICI) cannot be reduced if there is multiple RB interference (from single or multiple cellular mode UEs in the neighboring cells).

We use the idea from [16] for the integrated system. The proposed resource management scheme does not need coordination between neighboring cells. Cell coordination is only necessary for normal inter-cell interference cancellation (ICIC) schemes. Therefore, the proposed scheme gives a good trade-off between performance, complexity, sensitivity and signaling overhead. The proposed resource management scheme is formulated as follows.

- The available UL resources of a cell are split into two resource pools with fixed sizes, P_{D2D} an $P_{Cellular}$. The resources are allocated to UE with the following rules:

$$R_{D2D} \in P_{D2D}, R_{C\_Cellular} \in P_{D2D}$$
$$R_{Cellular} \in P_{Cellular} \quad (3)$$

where R_{D2D} and $R_{Cellular}$ denote the physical resource blocks (PRBs) for a D2D mode UE and cellular mode UE, respectively. $R_{C\_Cellular}$ are the PRBs for a cellular mode UE located at the central region of the cell. This kind of UE satisfies

$$G_{C\_Cellular} \geq G_{b\_threshold} + G_{Ext} \quad (4)$$

where $G_{C\_Cellular}$ is the (UL) link budget of a cellular UE (near eNB), and G_{Ext} is the link budget extension, which is determined by the eNB, in order to adjust the range of center UEs around eNB. Using two separate resource pools can avoid the possible CMICI (interference between D2D pair and cellular UE from neighboring cells) efficiently.

Within the D2D resource pool P_{D2D}, D2D mode UEs use all the resource blocks for spreading. Walsh Hadamard (WH) sequences are used for spreading with the code length of 2^n, so D2D pool size is adapted to the size of 2^n as well. In our simulations, we assume a 20 MHz bandwidth system, and the size of D2D resource pool is set to 64 PRBs of 12 subcarriers, and the rest of the available resources are for the cellular resource pool. The sizes of the resource pools are the same for all cells.

The advantages of combining the proposed resource allocation scheme and MC-CDMA D2D include;

- The critical cross mode interference (CMI) can be eliminated. D2D mode UEs at cell edge will not use the same resource as the cellular mode UEs so no significant CMICI occurs. D2D pairs near the cell center may receive the interference from cellular mode UEs nearby. However, the TX powers of those cellular mode UEs are limited since they are close to the serving eNB.
- CMI from D2D mode UEs to cellular mode UEs can be avoided. The potential risk is that cellular mode UE links can receive interference from D2D mode UEs if they are close to eNB. However, at the cell center, D2D pair forming probability is low. The actual TX power for a D2D link is low as well, so such a risk is limited.
- It provides the diversity and incell resource reuse naturally for D2D mode UEs. In general, D2D link has a relatively large coherence bandwidth. The orthogonality can be well preserved (especially in case of a D2D cluster) since all the UL channels are similar D2D links. Then multiple access interference (MAI) can be removed efficiently. For the interference from other D2D pairs or cellular UEs, diversity can be obtained since some of heavily interfered resources (chips) can be dropped.
- No measurements/reports are required. That is, most of the parameters, such as spreading related and resource related parameters for UEs are given by eNB initially, and fixed during the data communication period. So no overhead is required for updating the resources. The latency is not an issue as well since there is no feedback required. Local process at the receiver side is sufficient to obtain acceptable results since in most of the cases, the SINR performance of UEs is sufficient for local detection.

IV. Network Level Performance with the Proposed Resource Management Scheme

Network level simulations have been done to investigate the performance of the combination of MC-CDMA based D2D and the proposed resource management algorithm. Signal to interference plus noise ratio (SINR) is used as the main metric for the interference analysis.

A. Main simulation parameters and assumptions

In simulations, we generate the cumulative distribution functions (CDFs) of SINRs of different modes of UEs. A reference system (OFDMA for D2D mode UEs with random resource allocations) has been simulated as well for the performance comparison and validation. The main system parameters in simulations can be found from Table 1. The noise figure for UEs is set to 9 dB, and 5 dB for eNB. The antenna gain for eNB is set to 6 dB, and 0 dB for UE antenna. Fractional open loop power control (OFPC) has been used for both cellular mode UEs and D2D mode UEs [17]. In OFPC, the maximum UE power is 24 dBm, the cell specific path loss compensation factor is set to 0.8. The background noise level is -116 dBm per PRB.

The correlated shadowing pathloss models from 3GPP [17] have been applied for both D2D link and cellular links. For simplicity of discussion, each UE is assumed to use a single PRB. The D2D probability is set manually in simulations such that 50% of UEs are initially in D2D mode. After confirmation, the final probability is slightly lower than 50% (due to the fact that some D2D UEs are out of service range or too close to eNB).

TABLE I. MAIN SIMULATION PARAMETERS.

Item	**Values**
Layout	Hexagonal grid
Inter site distance (ISD)	500 m
Maximum D2D pair distance	ISD/20 = 25 m
UE distribution	Uniform
Carrier frequency	1.9 GHz
Channel model	Indoor [17] for all UEs
Multiple access scheme	MC-CDMA for D2D mode UEs, and OFDMA for cellular mode UEs
Resource allocation for cellular mode UEs	Two pools, random allocation within pools, one PRB per UE
Resource allocation for D2D mode UEs	Use 64 PRBs with fixed WH sequence (SF=64) for each D2D pair.

TABLE II. PERFORMANCE WITH DIFFERENT DISTANCE THRESHOLDS WITH 64 UES/CELL AND D2D PROBABILITY OF 48.5 %.

Threshold (m)	250	167	125	62.5	41.7	31.25
Reuse factor	1	0.55	0.28	0.12	0.075	0.027
Mean SINR (D2D)	-2.50	2.94	5.74	8.30	7.68	8.01
Mean SINR (Cellular)	10.8	18.6	19.9	21.6	21.4	21.57
Mean SINR (All)	4.03	10.6	12.6	14.7	14.2	14.4
Efficiency (bps/Hz)	2.43	2.80	2.62	2.82	2.65	2.52

In Table II, the reuse factor is calculated as the ratio of the number of cellular mode UEs using the D2D resource pool and total number of D2D mode UEs. The resource efficiency is calculated as the ratio of capacity and the number of resources (PRBs) used.

In order to investigate the effects of UE density and D2D probability, we assume that all activated UEs can have their specific resources. For better resource efficiency, SF can be tuned based on the D2D probability (small SF for low D2D probability). In practice, eNB can determine the actual SF (size of D2D resource pool) based on the actual system bandwidth, the estimated D2D probability, and the system load.

B. Simulation results and discussions

1) The effect of incell resource reuse between cellular mode UEs and D2D mode UEs

The criterion for selecting cellular mode UEs to join the D2D resource pool is one of the key issues in the proposed scheme. In (4), $G_{b\_threshold}$ is fairly small in case of using strict mode selection for link reliability. Therefore, G_{Ext} has to be used to balance the probability of incell resource reuse and cross mode interference induced by incell resource reuse. In simulations, it is simplified by using the distance to the serving eNB. That is, a distance threshold is set in such a way that if a cellular mode UE's distance to its serving eNB is smaller than the threshold, it uses the D2D resource pool. Table II shows the effect of using different distance thresholds.

From the table, we understand that unlimited resource reuse will induce a significant cross mode interference between UEs. The performance can be improved significantly with the decreasing of the threshold. However, too short distance will not enhance the performance, but only reduce the reuse factor. Based on our simulation assumptions, 62.5 m seems to be the best choice since it provides acceptable performance with high resource efficiency. It is worth to know that in the proposed system there is no risk of suffering significant CMICI, while in the reference system the potential CMICI is the main bottleneck.

2) General SINR performance

Figure 1 shows the CDFs for the SINRs of D2D integrated OFDMA (LTE UL) system. Here the system load is 64 active UEs per cell, and the overall D2D probability is 48.5%, and it is about the same for each cell. SINRs of cellular mode UEs and D2D mode UEs are plotted separately. In the reference system, random resource allocation (RRA) is used with no resource reuse (NRR). The proposed resource allocation (PRA) is applied for the studied system. Since MC-CDMA is used for D2D mode UEs, resource reuse (RR) is used in a natural manner.

From Figure 1, we find that the performance of D2D mode UEs is improved by the combination of proposed resource scheme and MC-CDMA (for D2D mode UEs), due to the use of separate resource pools and processing gain obtained by spreading. The performance of cellular mode UEs for the proposed system is slightly worse than the reference system, due to the accumulated wideband interference from D2D mode UEs. However, the performance gap is rather small. Figure 1 shows clearly that the main targets of proposed scheme have been achieved. First of all, the risk of having significant CMICI (especially for D2D mode UEs) is eliminated. Therefore, SINRs for all modes of UEs are well balanced and acceptable. Secondly, the overall spectrum efficiency can be improved. It depends on two aspects. The first aspect is that the mean SINR performance of the proposed scheme is better or equal to the performance of reference system since the loss of SINR for cellular mode UEs is controllable, and can be compensated by the gain achieved by D2D mode UEs. The second aspect comes from the incell resource reuse, naturally obtained by using MC-CDMA for D2D mode UEs. Based on the previous results, the PRA scheme is parametrized in such a way that all cellular mode UEs within the radius of 62.5 m (the cell radius is 250 m) share the D2D resource pool, so with the given UE density (64 UEs per cell), about 12% of cellular mode UEs reuse D2D resources. The overall spectrum efficiency (calculated by the overall capacity divided by the effective resources) is improved from 2.47 bps/Hz to 2.8 bps/Hz, i.e., by 13.3%. Naturally, the downlink traffic is significantly reduced compared to the case where all users operate in cellular mode.

3) The effect of system load

Due to the coexistence of narrowband (OFDMA for cellular mode UEs) and wideband (MC-CDMA for D2D mode UEs) operation in the proposed scheme, the accumulated interference effect may be considerable. Figure 2 shows the SINR performance with 2 different loads, 32 UEs per cell and 100 UEs per cell with different D2D probabilities.

Figure 2 shows that with the distance threshold of 62.5 m, the SINR performance of D2D mode UEs is still acceptable. That is, with the reuse factor around 0.1, the number of cellular mode UEs using the D2D resource pool is not increased significantly. However, with high load and high D2D probability, the performance of cellular mode UEs is significantly affected since the number of D2D mode UEs is increased significantly. This can be seen in the 100 UEs/cell case with 50% D2D probability in Figure 2. In this case, we can have two solutions. One solution is to decrease the distance threshold so that the interference from D2D mode UEs is relatively lower. This method reduces the reuse factor. Another solution is to reduce the transmission power of D2D mode UEs. In this case, the performance of D2D mode UEs can be affected negatively.

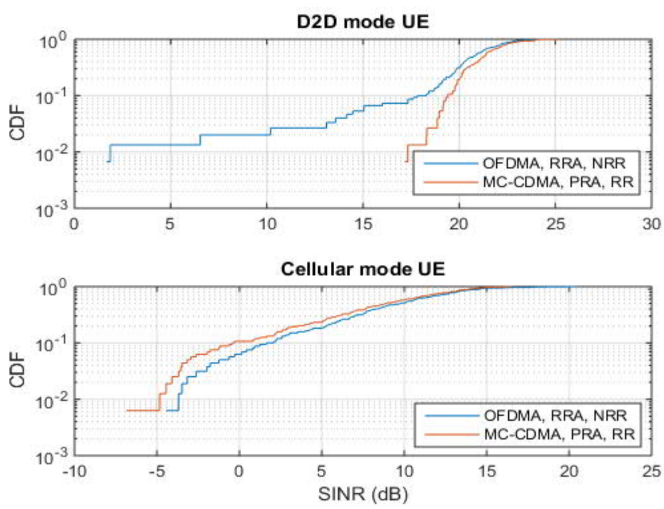

Figure 1. SINR performance of MC-CDMA D2D vs. OFDMA D2D with 64 UEs/cell and D2D probability of 48.5 %.

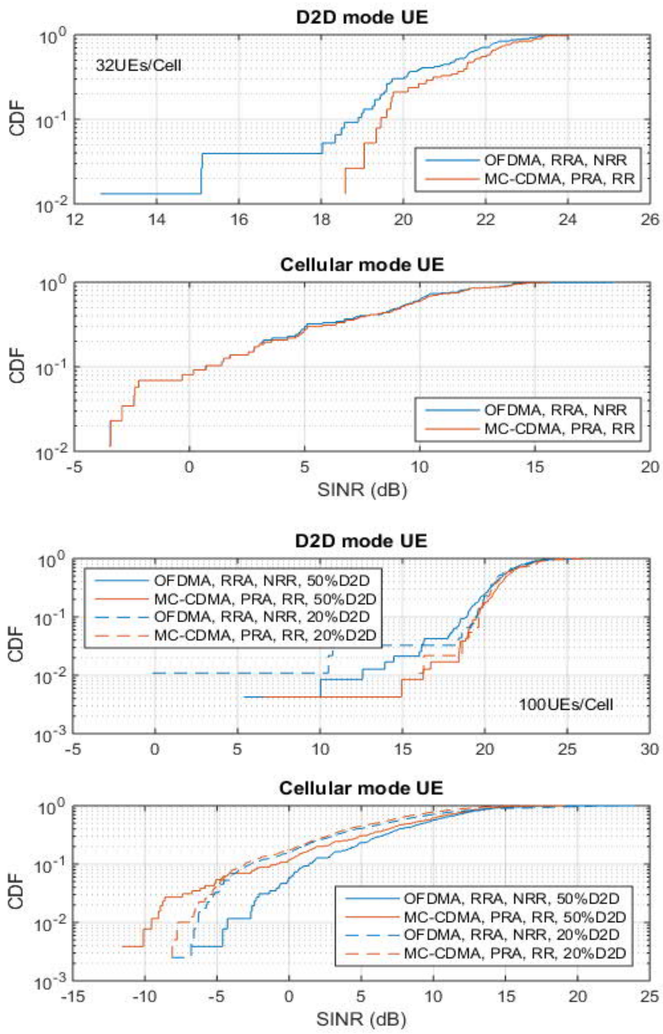

Figure 2. SINR performance with different loads. (a) 32 UEs/cell with 50% D2D. (b) 100 UEs/cell with 20% & 50% D2D.

From the simulation results shown in Figure 1 and Figure 2, we understand that generally SINR performance of D2D mode UEs can be significantly better than the performance of cellular mode UEs. Therefore, the headroom for power tuning is rather dynamic so that power control can be an efficient way to balance the performance of different modes of UEs in the proposed system [18].

On the other hand, we find from Figure 2 that even in the 100 UEs/Cell case, the performance gap of cellular mode UEs between the two systems is not significant if the D2D probability is limited, e.g., to 20%. Meanwhile, D2D performance can be improved by applying the proposed scheme. With large number of cellular mode UEs (20% D2D case), the probability of D2D mode UEs suffering from critical CMICI is getting higher, as shown in the figure.

4) MC-CDMA vs. OFDM with proposed resource allocation scheme

In [15], the proposed resource allocation scheme has been investigated for the integrated system using OFDMA only. In fact, with proper choice of distance threshold, the performance of pure OFDMA system with the proposed resource reuse scheme is rather similar to that of the OFDMA/MC-CDMA combined system, as shown in Figure 3.

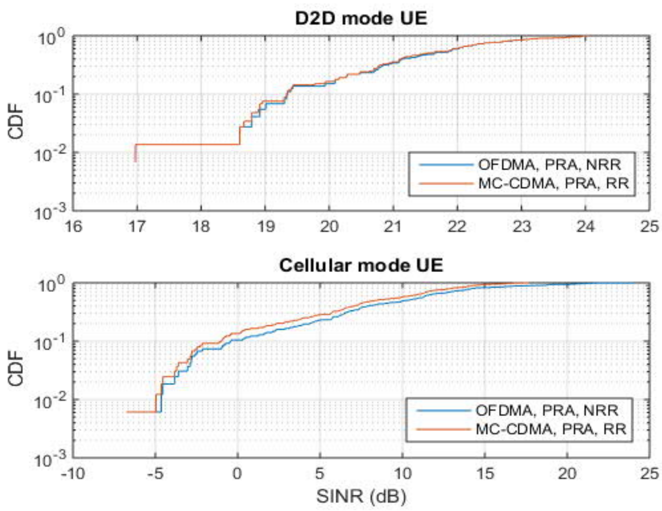

Figure 3. OFDMA vs. MC-CDMA using proposed resource allocation scheme with 64UEs/Cell, 50% D2D.

Furthermore, MC-CDMA based D2D provides a natural way to reuse the resource in the same cell. That is, by simply setting the distance threshold (or G_{Ext}), eNB can well balance the system performance and resource efficiency. For OFDMA D2D system, incell resource reuse is also possible [15]. However, it needs more complicated algorithms and measurements to make decisions. From the resource reuse point of view, MC-CDMA D2D provides a more simple way, which is more easy to use in practice.

V. Conclusions

The performance of the combination of MC-CDMA based D2D and proposed resource allocation scheme was investigated in this paper. The SINR performance was simulated by network simulations. The performance was compared between MC-CDMA based D2D with proposed resource allocation scheme and OFDMA based D2D with random resource allocation.

The basic idea of the combination is to eliminate CMICI, while providing acceptable performance in general. Simulation results show that the critical cross mode interference (CMI) can be well eliminated by separated resource pools and processing gain. Meanwhile, the performance of cellular mode UEs is acceptable, thanks to the proper selection of resource reuse threshold. In fact, in the reuse case, the UE separation is not orthogonal. Therefore, besides the use of wideband signal, power domain (power control) can be used to balance the performance of different modes of UEs.

Another benefit is that MC-CDMA provides diversity and incell resource reuse for D2D mode UEs in a natural way. In general, the large coherence bandwidth of MC-CDMA based D2D ensures near-orthogonality between active D2D pairs or within a D2D cluster UL, and MAI can be removed efficiently. For mitigating the interference from other cellular mode UEs, diversity can be obtained. The incell resource reuse is flexible and simple. eNB can setup the distance threshold (or G_{Ext}) to control the reuse factor, and to balance the system performance and resource efficiency.

In general, the combined scheme provides a simple way to manage the resources between different modes of UEs. Most of the parameters, such as SF, spreading code distribution, resource distribution, and reuse thresholds for UEs are given by eNB initially, and they are fixed during the data communication period. So no large overhead is required for updating the resources, and the latency is not an issue either. Local link level processing at the receiver side is sufficient since in most of the cases, the SINR performance of UEs is sufficient for local detection.

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REFERENCES

[1] H.-Y. Hsieh and R. Sivakumar, "On Using Peer-to-Peer Communication in Cellular Wireless Data Networks", *IEEE Trans. Mobile Computing*, vol. 3, no.1, pp. 57-71, Jan.-Mar. 2004.

[2] K. Doppler, M. Rinne, C. Wijting, C. Riberiro, and K. Hugl, "Device-to-device communications as an underlay to LTE-advanced networks," *IEEE Comm. Mag.*, vol. 47, pp. 42-49, Dec. 2009.

[3] Wi-Fi Alliance, "Wi-Fi Peer-to-Peer (P2P) Technical Specification v1.1", www .wi-fi.org/wi-fi-peer-peer-p2p-specification-v11.

[4] 3GPP specification, www .3gpp.org/Release-12.

[5] S. Mumtax, K. M. S. Huq, and J. Rodriguez, "Direct Mobile-to-Mobile Communication: Paradigm for 5G," *IEEE Wireless Communications,* pp. 14 - 21, Oct., 2014.

[6] Jian Qiao, Xuemin Shen, Jon W. Mark, Qinghua Shen, and Lei Lei, "Enabling Device-to-Device Communications in Millimeter-Wave 5G Cellular Networks," *IEEE Comm. Mag.*, pp. 200-215, Jan., 2015.

[7] G. Araniti, A. Raschella, A. Orsino, L. Militano, and M. Condoluci, *5G Mobile Communications*, Springer International Publishing, Switzerland, 2017.

[8] H. Xing, and M. Rendors, "Investigation of Filter Bank Based Device-to-Device Communication Integrated into OFDMA Cellular System," in *Proc. ISWCS'14*, 2014.

[9] P. Janis, V. Koivunen, C. Ribeiro, J. Korhonen, K. Doppler, and K. Hugl, "Interference-Aware Resource Allocation for Device-to-Device Radio Underlaying Cellular Networks," in *Proc. IEEE VTC Spring 2009*, pp. 1-5, April 2009.

[10] Z. Liu, T. Peng, H. Chen, and W. Wang, "Optimal D2D user allocation over multi-bands under heterogeneous networks." in *Proc. IEEE GLOBECOM12*, pp. 1339–1344, 2012.

[11] F. Wang, L. Song, Z. Han, Q. Zhao, and X. Wang,"Joint Scheduling and Resource Allocation for Device-to-Device Underlay Communication," in *Proc. IEEE WCNC13*, April 2013.

[12] C.H. Yu, O. Tirkkonen, K. Doppler, and C. Ribeiro, "Power Optimization of Device-to-Device Communication Underlaying Cellular Communication," in *Proc. IEEE ICC09*, pp. 1-5, June 2009.

[13] J. Gu, S. Bae, B. Choi, and M. Chung, "Dynamic power control mechanism for interference coordination of device-to-device communication in cellular networks," in *Proc. IEEE ICUFN'11*, pp. 71-75, June 2011.

[14] 3GPP TS 36.211 V8.2.0 "Physical Channels and Modulation (Release 8)", v 8.2.0.

[15] H. Xing, and M. Renfors, "Multi-Carrier CDMA for Network Assisted Device-to-Device Communications for an Integrated OFDMA Cellular System," in *Proc. VTC2016 Spring Workshop,* 2016.

[16] H. Xing, and M. Renfors, "Resource Management Schemes for Network Assisted Device-to-Device Communication for an Integrated OFDMA Cellular System," in *Proc. PIMRC'15*, 2015.

[17] ETSI TS 36.101 v10.1.1 "LTE; E-UTRA; UE radio transmission and reception," 2011.

[18] H. Xing, S. Hakola, "The investigation of power control schemes for a device-to-device communication integrated into OFDMA cellular system," in *Proc. PIMRC'10*, 2010.