國立交通大學

電子工程學系電子研究所碩士班

碩士論文

密集小型基地台與裝置間通訊共存之干擾消除技術

Interference mitigation mechanism for D2D communication in ultra-dense small cell network

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中 華 民 國 一○三 年十月

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摘 要

在小型蜂巢式基地台被電信營運商們廣泛接受之後，布建高密度的小型蜂巢式基地台相關的研究也逐漸被討論。同時裝置間的直接通訊也在 3GPP 也是個熱門的主題，裝置間的直接通訊是個很直觀的概念，藉由直接通訊縮短距離與減少使用骨幹網路的機會 ，同時也減少傳輸路徑的損耗達到提升訊噪比。但在高密度的小型蜂巢式基地台與裝置間通訊共存時，系統效能是會逐漸被影響而下降的。在這篇論文中，我們會針對高密度小型蜂巢式基地台對裝置間通訊在共通道情況下造成的干擾，也提出方案解決不同裝置間直接通訊情境。提出的解決方法包含了不同的方式觸發睡眠模式以及多點傳輸技術幫助一些隱性受害的使用者。在模擬結果部分我們結合了兩種不同的方法並且有效的改善傳輸效能在高密度的小型蜂巢式基地台使用裝置間直接通訊。但還有一點要注意的是，在這邊提供的方法是可以改善干擾問題，但要在這樣的環境下能夠正常的通訊還是必須要有其他的方法來輔助，像是重新分配通道這類的方法，結合不同的方法才能有效提升通訊的品質與問題。

Interference mitigation mechanism for D2D communication in ultra-dense small cell network

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Abstract

After small cell concepts are widely accepted, researches in ultra-dense small cell deployment issues are investigated. At the same time, device-to-device (D2D) becomes a popular topic, discussed by 3GPP. Direct communication is an intuitive concept which can decrease the usage of backbone network and shorten the distance of transmission in order to enhance SINR performance. However, performance degradation will occur while ultra-dense small cells coexist with D2D. In this thesis, we will study the co-channel interference issue for D2Ds initiated in an ultra-dense small cell network. Solutions for solving different D2D transmission scenarios are proposed. The proposed solutions including the trigger of sleep-mode operation and joint transmission under multi-point (CoMP) network for potential victims caused by sleep-mode operation. From simulation results, we will identify the combination of two schemes can significantly enhance transmission performance in ultra-dense small cell network for supporting D2D transmission. However, operating in such an extreme case (co-channel transmission), the network will still require other methods like channel allocation or fractional transmission to meet conventional operation range for real transmission.

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Chapter 1

INTRODUCTION

Device-to-device (D2D) communications have been added to LTE in 3GPP Release 12 [1] . Although cellular network deployments are nearly ubiquitous provide wide range of advance services and solve the increasing subscriber population, exploiting direct communication between nearby mobile devices will still improve spectrum utilization, overall throughput, and energy consumption, D2D-enabled LTE devices can also become competitive for fallback public safety networks that must function when cellular networks are not available, or fail.

3GPP has two group discussing this topic “SA” & “RAN”. [2] has discussed proximity-based service (ProSe) with device discovery, introduction for scenarios, use cases and requirements for discovery of device-to-device(D2D). D2D discovery procedure, discovery signal and LTE-based design.

Usually, operators will focus on increasing deployment cell density. Such as [3] has discussed low-duty operation femto BS. In a dense urban environments, own a short radio links is a traditional way for provide higher bit rates and higher energy efficiency when using small cell. However, deploying larger numbers of small cell occurs interference management problem. We follow 3GPP conference and recent contribution document, D2D have many potential in different domain, such as public safety and commercial usage.

We consider a combinational system include small cell networks and D2D communication, combinational system verifies an advanced network. In this thesis, we will talk about current issue in LTE network and motivation of researcher to develop D2D technique in Chapter 2. Chapter 4 describes two issue briefly and solve two issue with our two proposal, we propose a novel on/off SC control mechanism and add in coordinated multi point (CoMP) since victim appears after we implement on/off control. Chapter 3 formulate the problem and simulation to verify proposal in Chapter 5 and evaluate in worst case. Chapter 6 will give a conclusion and several future work.

Chapter 2

BACKGROUND OF HETNET AND D2D

Heterogeneous networks (HetNet) has been investigated in recent of years, operators realized the requirement of significant increasing of data. To provide significant performance leap in wireless networks and improving spatial spectrum reuse, deploy large amount of small cells overlaying the macro BS has been well known. HetNet unit include mix of macro BS, remote radio head and low-power node such as picocells, femtocells, and relays. After small cell concepts are widely accept by public, D2D have been added to 3GPP Release 12. Although D2D and small cell both offload network, D2D coexist with ultra-dense small cell can get what kind of benefit still need to verify.

2.1 Overview of LTE-A

LTE-A (Long-term-evolution advanced) is a mobile communication evolution from LTE which was formally submitted as a candidate 4G system to ITU-T in late 2009 [4], and was standardized by the 3rd generation Partnership project (3GPP) in March 2011 as 3GPP Release 10. Nowadays, high speed mobile application is ubiquitous, LTE standard expect Downlink 100Mbps/Uplink 50Mbps in 20MHz frequency band with good QoS, even at the cell edge. However, frame structure has two totally different mode, frequency-division duplexing (FDD) and time division duplexing (TDD) [5]. The difference between TDD and FDD is shown as Figure 2-1 from Institute for Information Industry (III).

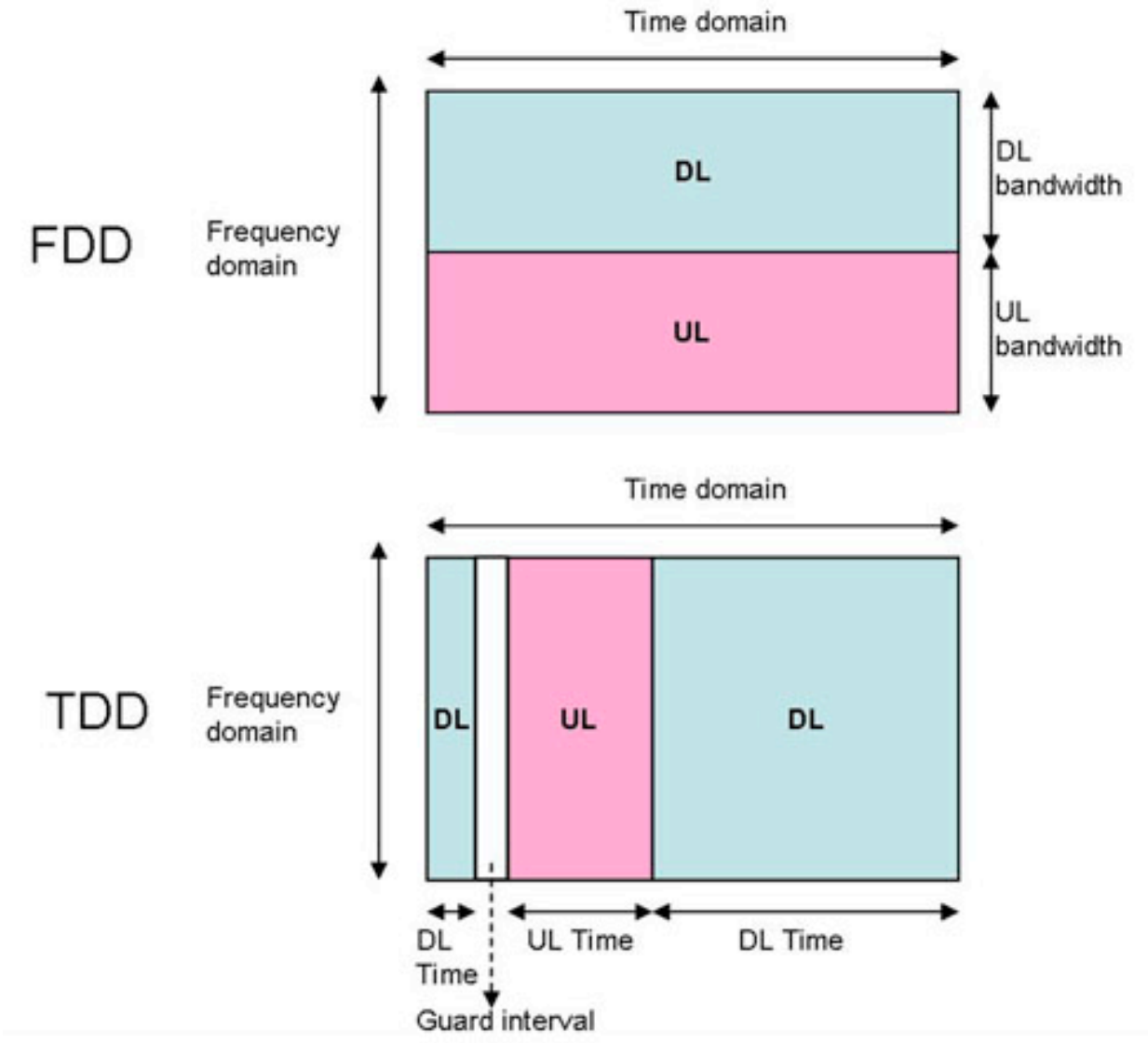


Figure 2-1 Example for TDD LTE and FDD LTE

2.2 Overview of Small Cell Networks

Small cells (SC) are an integral part of LTE networks. SC are low powered radio access nodes that operate in licensed and unlicensed spectrum unlike WiFi APs only in unlicensed band. When mobile operators struggling to fast increasing mobile data traffic, SC appear for more efficient use of radio spectrum and enhance signal strength by providing line-of-sight path or nearer signal source. In dense urban areas, base stations are deployed very close to each other, so small cells overlap with each other, too. Overlapping provide benefits when user (UE) moving due to handover and other reason but also cause interference for those UE who are not the desire receiver , 3GPP has proposed enhanced inter-cell interference (eICIC) for HetNet in

order to mitigate interference by allowing some special subframe called almost blank subframe (ABS) in macro BS frame configurations. Figure 2-2 shows inter-cell interference, consider a dense deploy small cell networks, HetNet will face more challenges due to irregular large amount of small cell.

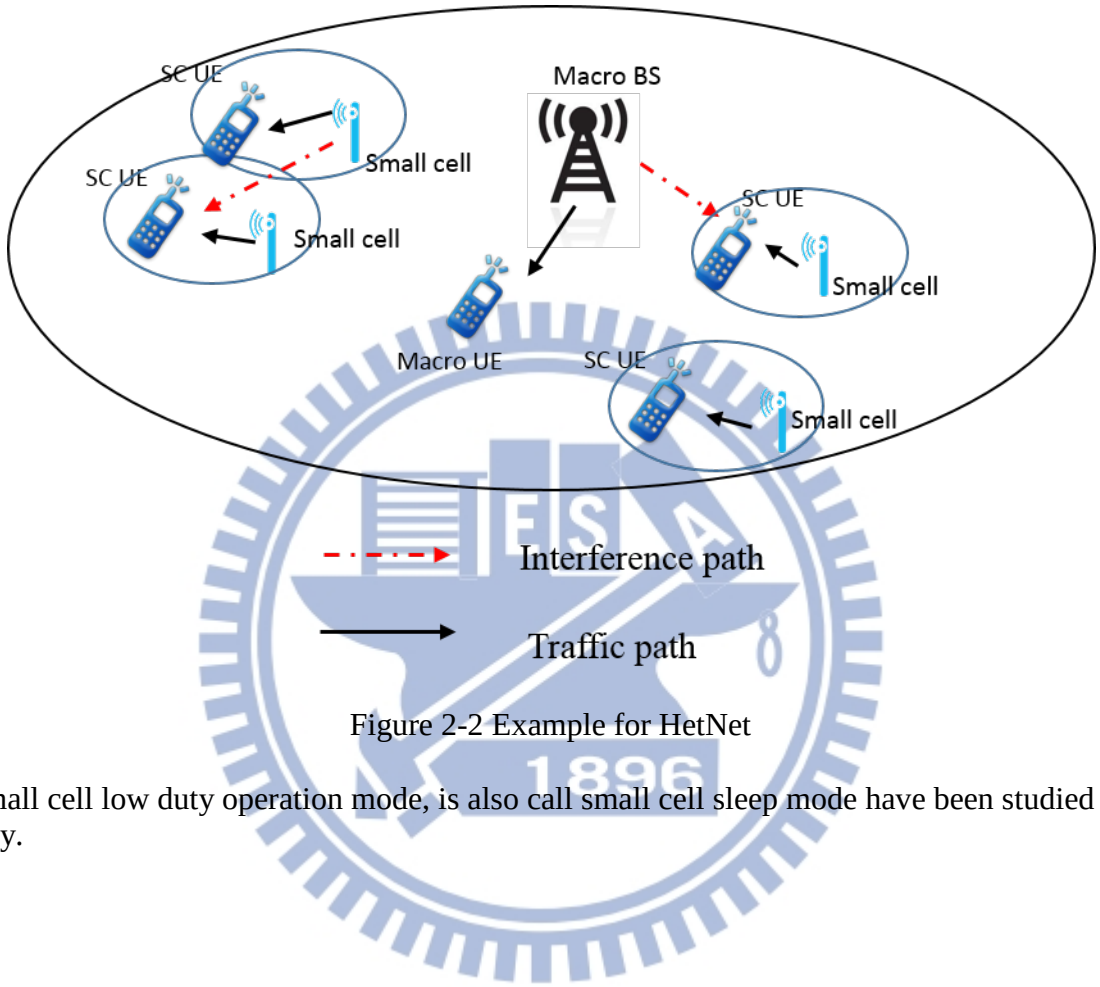


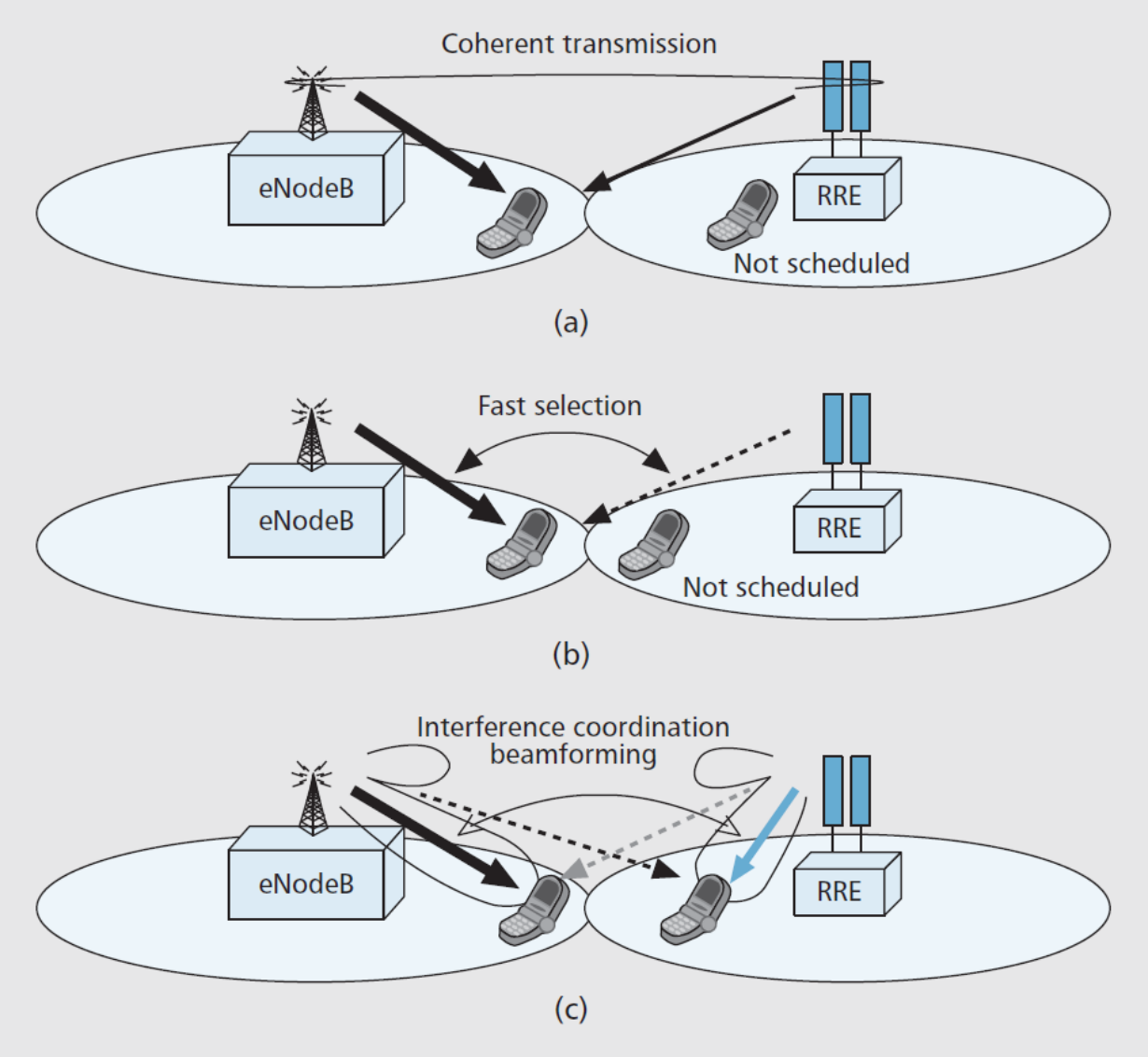
Figure 2-2 Example for HetNet

Small cell low duty operation mode, is also call small cell sleep mode have been studied recently.

2.3 Overview of CoMP

In order to mitigate inter-cell interference cause by dense SC, there are a lot of studies [6] working on this problem such as quasi-static resource allocation schemes. A well-known technique is coordinated multi-point (CoMP) [7] processing which mitigate in-cell interference by coordinating the transmission of several geographically but well synchronized cells. CoMP transmission has two classes: Joint Transmission (JT) and Coordinated Scheduling/Beamforming (CB/CS). JT represent the case where two or more transmission points (TPs) are transmitting signal to a single device on the same time-frequency resource [8] and several studies [9], [7] have verified that JT has better performance than CB/CS, see Figure 2-4, so in this thesis

we include JT CoMP instead of CB/CS. In [8] is also mentioned previous studies for coherent JT but in some research [10] has evidence coherent JT is especially sensitive to imperfections of CSI so it would be premature to include it in the standard in Rel-11; nevertheless, it can still be implement in TDD by channel reciprocity. Non-coherent JT is not able to nullity interference across multiple TPs, the SINR at UE device could be boosted by non-coherent JT, too, but with area splitting-gain, as multiple TPs could instead schedule multiple separate UE devices. Only UE located on the coverage of edge of two TPs are able to get benefit from non-coherent JT.



CoMP transmission in downlink: a) joint transmission (JT); b) dynamic cell selection (DCS); c) coordinated beamforming.

Figure 2-3 Example for CoMP

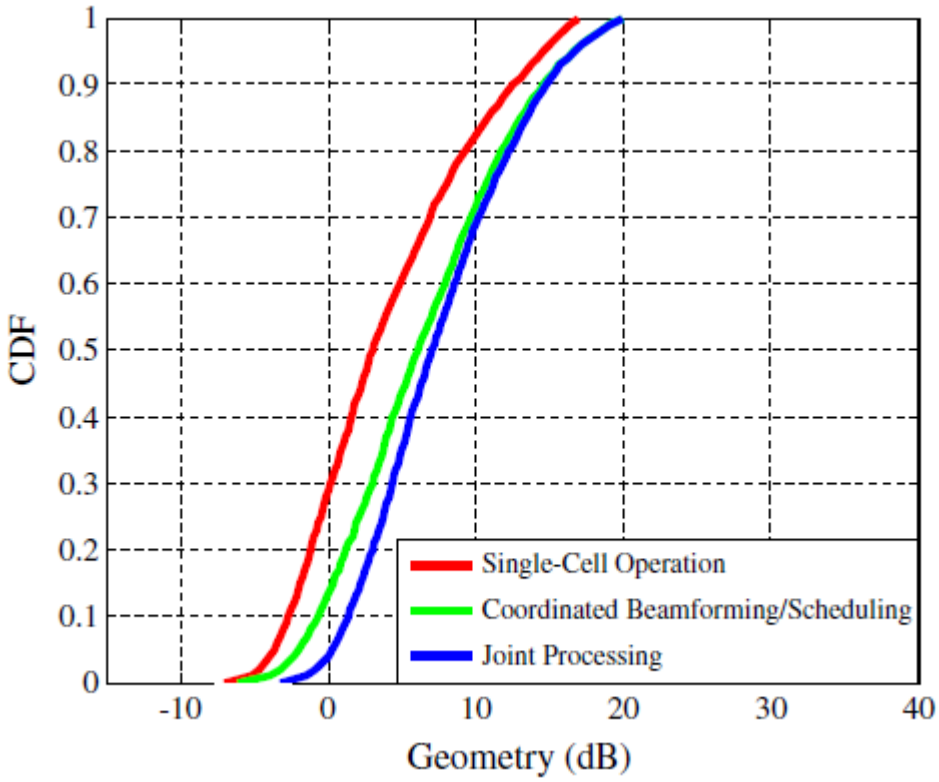


Figure 2-4 Comparison for JT and CS/CB

2.4 Overview of D2D

Mobile operators are struggling to the rapidly increasing of data. As a result, 3GPP is currently investigation possible scenarios for D2D offloading in LTE networks, in [11] has discussed 3GPP LTE traffic offloading onto WiFi direct. In [12], [13] has introduced scenarios, use cases and requirements for discovery of D2D proximity from 3GPP SA and RAN. Corresponding solution options and link budget based on current 3GPP evaluation are also provide. Device discovery and communication are basic two enabling D2D features to fulfill the need for the ProSe. ProSe has also been introduced in [14], [15], it mentions that we can further discuss when UE may use DL resource due to enhance network capacity and throughput. In FDD LTE, DL spectrum is not able for UE, but TDD spectrum, studies of both UL and DL subframes are still open, see Figure 2-5.

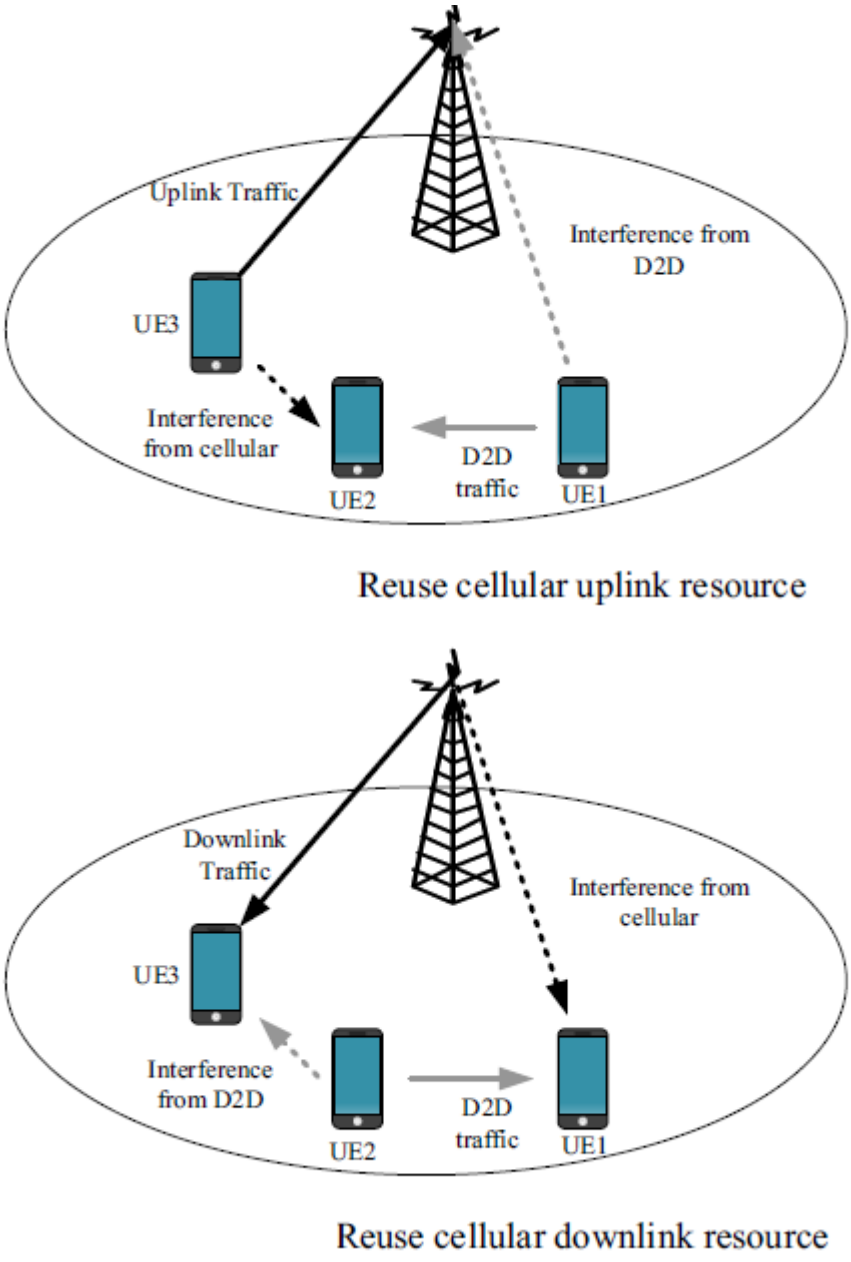


Figure 2-5 Example for D2D UE pairs using both UL/DL resource

Chapter 3

SYSTEM MODEL AND PROBLEM FORMULATION

In this chapter, we talk about the system model for the D2D communication. The design of system model is based on our proposal and the features of D2D communication system, such as enormous amount of UE devices, battery embedded and low mobility. First, the system model is show in 4.1, and the problem formulation is produced in 4.2. In Chapter 3, we provide a combination formula about D2D communication with small cell on/off control mechanism.

3.1 System Model in D2D Communication

The modified system model in D2D communication is show as Figure 3-1. We consider a single macro BS with multiple small cell coexist with several D2D pairs. As the figure shows, D2D communication can establish not only within SC coverage but also happen in macro BS serving range.

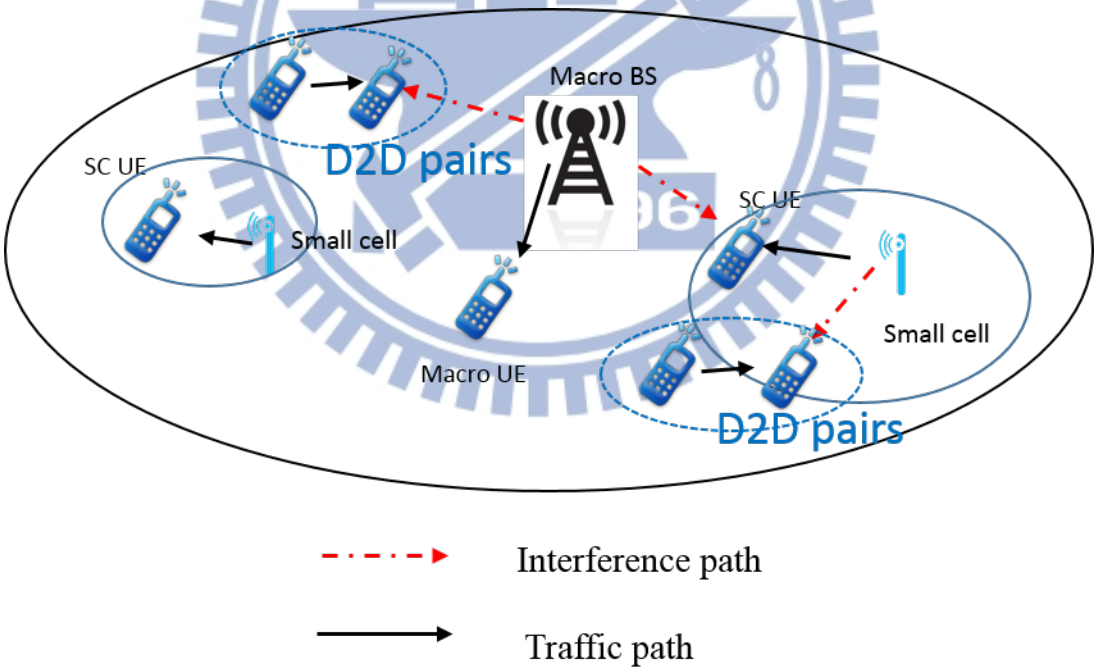


Figure 3-1 System model for HetNet coexist D2D communication

In this system, we assume we have p SC, m macro BS, denote mode space S = $\{n_1, \dots, n_p\}$, U pairs D2D UE, K_P SC UE and K_M macro UE, thus we have total UE = K_P+ K_M + 2U. We can represent Downlink SINR as below

$$SINR_P^j = \frac{P_P|h_{Pqj}|}{\sum_{i=1,i\neq q}^{p} n_i P_P|h_{Pij}| + \sum_{i=1}^{m} P_M|h_{Mij}| + \sum_{i=1}^{U} P_D|h_{Dij}| + N_0}, \quad \text{(4 - 1)}$$

$$\text{j} \in N \; \forall \, j \leq K_P, \text{q} \in N \; \forall \, q \leq p$$

$$SINR_M^j = \frac{P_M|h_{Mqj}|}{\sum_{i=1}^{p} n_i P_P|h_{Pij}| + \sum_{i=1,i\neq q}^{m} P_M|h_{Mij}| + \sum_{i=1}^{U} P_D|h_{Dij}| + N_0}, \quad \text{(4 - 2)}$$

$$\text{j} \in N \; \forall \, j \leq K_M, \text{q} \in N \; \forall \, q \leq m$$

$$SINR_D^j = \frac{P_D|h_{Dqj}|}{\sum_{i=1}^{p} n_i P_P|h_{Pij}| + \sum_{i=1}^{m} P_M|h_{Mij}| + \sum_{i=1,i\neq q}^{U} P_D|h_{Dij}| + N_0}, \quad \text{(4 - 3)}$$

$$\text{j} \in N \; \forall \, j \leq U, \text{q} \in N \; \forall \, q \leq U$$

Where “P” denotes SC, “M” denotes macro BS and “D” denotes D2D UE pairs. P_P, P_M and P_D denote different nodes transmit power. h_{Pqj}, h_{Mqj}, h_{Dqj} denote channel gain for desire signal h_{Pij}, h_{Mij} and h_{Dij} denote channel gain for interference path, N_0 denotes noise. Moreover, considering channel capacity, the achievable rate can rewrite as

$$C_P^j = BW \, log_2\left(1 + SINR_P^j\right) \quad \text{(4 - 4)}$$

$$C_M^j = BW \, log_2\left(1 + SINR_M^j\right) \quad \text{(4 - 5)}$$

$$C_D^j = BW \, log_2\left(1 + SINR_D^j\right) \quad \text{(4 - 6)}$$

Where BW is system bandwidth. With the associate achievable rate, we can calculate system throughput with equation below

$$T_{system} = \sum_{i=1}^{K_P} C_P(i) + \sum_{j=1}^{K_M} C_M(j) + \sum_{k=1}^{U} C_D(k) \quad (4 - 7)$$

3.2 Problem Formulation

Due to total UE K_P+ K_M + 2U = constant and assume we have fix number of D2D pairs, if K_P decrease, K_M increase. Our comparison will based on finding

$$max\{T_{system}\}\ subject\ to\ 1 \le i \le K_P \quad (4 - 8)$$
$$1 \le j \le K_M$$
$$1 \le k \le U$$

Table 4-1 is notation summary in this chapter.

Parameter	Explanation
S	Small Cell mode space
n_i	i_{th} small cell mode
u	Amount of D2D UE pairs
k_P	Amount of small cell UE
k_M	Amount of macro BS UE
$SINR_P^j$	j_{th} small cell UE SINR
$SINR_M^j$	j_{th} macro UE SINR
$SINR_D^j$	j_{th} D2D UE pairs SINR
P_P	Power of small cell
P_M	Power of macro BS
P_D	Power of UE
$\lvert h_{Pqj} \rvert$	Channel gain for q_{th} small cell to j_{th}UE
$\lvert h_{Mqj} \rvert$	Channel gain for q_{th} macro BS to j_{th}UE
$\lvert h_{Dqj} \rvert$	Channel gain for q_{th} UE to j_{th}UE
$\lvert h_{Pij} \rvert$	Channel gain for i_{th} small cell to j_{th}UE
$\lvert h_{Mij} \rvert$	Channel gain for i_{th} macro BS to j_{th}UE
$\lvert h_{Dij} \rvert$	Channel gain for i_{th} UE to j_{th}UE
N	Real and positive integer
BW	System bandwidth
N_0	UE noise figure

C_P^j	Capacity for small cell UE
C_M^j	Capacity for macro UE
C_D^j	Capacity for D2D UE
T_{system}	System throughput

Table 3-1 Notation Summery

Chapter 4

ISSUE & PROPOSED SOLUTION

In this chapter, we talk about the existing problem when D2D communication co-exist with densely deploy small networks, as we mentioned in previous chapter, small cell are deployed very close to each other and D2D UE will using same resource with small cell in order to enhance bandwidth efficiency and throughput.

4.1 Issue & Proposed Solution I

4.1.1 Issue：Unnecessary Small Cell

In dense urban areas, SC are deployed very close to each other and using same resource with D2D pairs to enhance bandwidth efficiency. When there is only single pair UE devices are within the small cell coverage and they start communicate each other. However, in current system, SC still need to turn on its radio radiation power in order to help macro BS no matter offloading heavy traffic or else. Prior work [16] on mitigate interference for D2D focus on power allocation. But in some cases, turn off the SC can benefit system and straight forward. Figure 4-1 to Figure 4-2 shows several scenario.

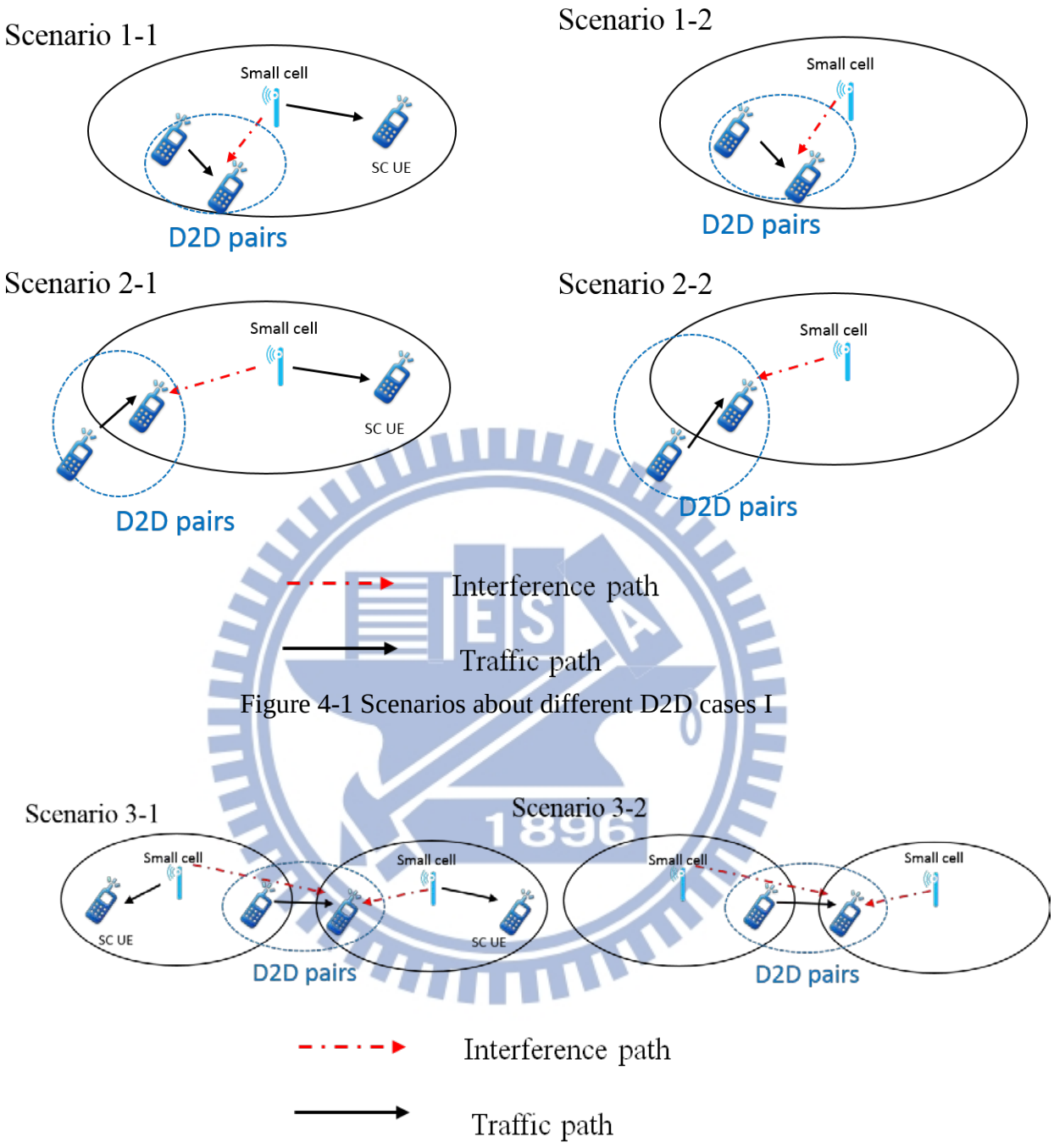


Figure 4-1 Scenarios about different D2D cases I

Figure 4-2 Scenarios about different D2D cases II

4.1.2 Proposed Solution：D2D trigger small cell to sleep mode

To solve the problem of unnecessary SC, we propose the Small Cell D2D State. It's a control mechanism similar to small cell on/off or so call sleep mode see [3] and Figure 4-3. However, sleep mode control is depend on how many UE are close to SC. Our proposal is D2D UE would transmit a beacon before D2D communication establish. After SC or macro BS receive

beacon, if the SC is useless during D2D scenario, SC will turn off its radio radiation power. What kind of scenario is useless will briefly describe in Chapter 5. Figure 4-2 shows some common scenarios, first we can recognize some scenarios such as 1-2, 2-2 and 3-2 SC doesn't have UE in the coverage instead of D2D pairs. It is obvious to realize that scenario 1-2, 2-2 and 3-2 SC should turn off its radio radiation power. However, 1-1, 2-1 and 3-1 are in different situation, we will briefly descript system model and formulate problem in Chapter 3 and justify the result by simulation in Chapter 5. How SC switches mode is shown as Figure 4-4.

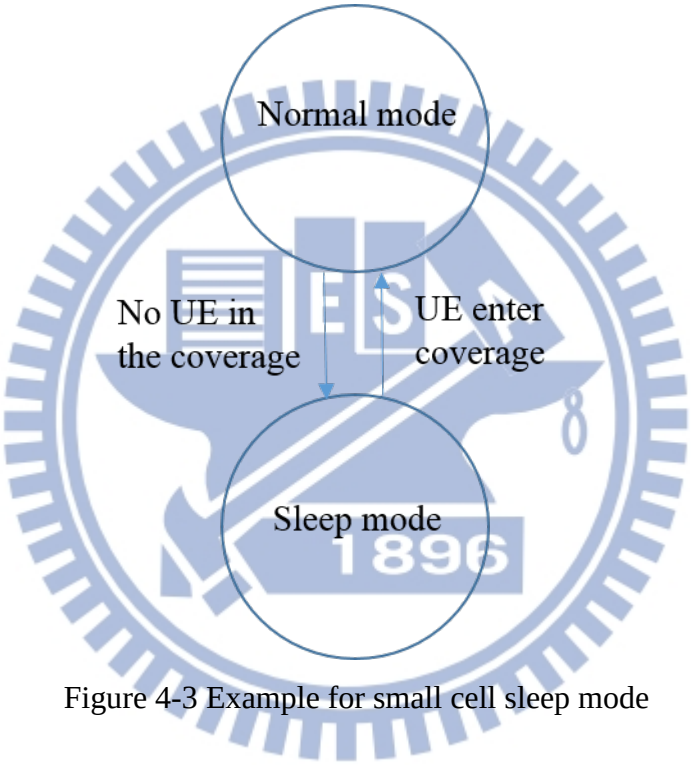


Figure 4-3 Example for small cell sleep mode

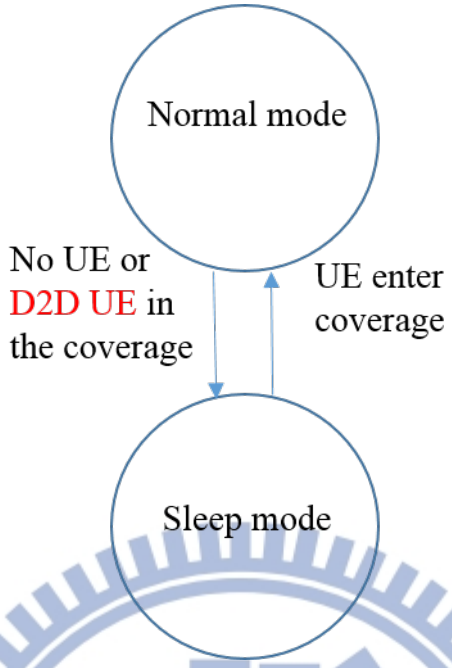
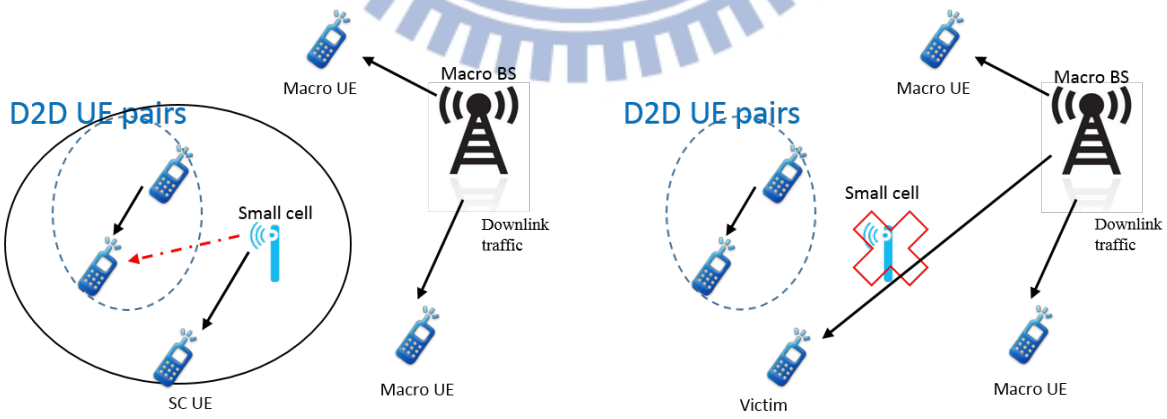


Figure 4-4 Example for proposal D2D trigger to sleep mode

4.2 Issue & Proposed Solution II

4.2.1 Issue：Victim from Small Cell

Another exiting problem happened when SC turn to sleep mode, previous SC UE will handover to macro BS and it is not only increasing loading for macro BS but also wasted UE's battery.



(a) No D2D sleep mode small cell (b) With D2D sleep mode small cell

Figure 4-5 Example for victim appear after small cell turn off

4.2.2 Proposed Solution：Small Cell Grouping and Coordinate

However, in a densely deploy SC networks, SC are very close to each other and we can consider SC as TPs in CoMP technique. We can simply make SCs who is overlap to each other become several group, when there is a group member going to D2D sleep mode, UE in this SC will become victim, and victim could handover to other SC in same group furthermore we could add CoMP to enhance SC UE, detail is related to [7]. We simply make several SC who overlap to each other become a group. Figure 4-8 JT and SC grouping implement to enhance victim receive signal shows after SC turn off, victim handover to neighbor SC and CoMP add to SC group.

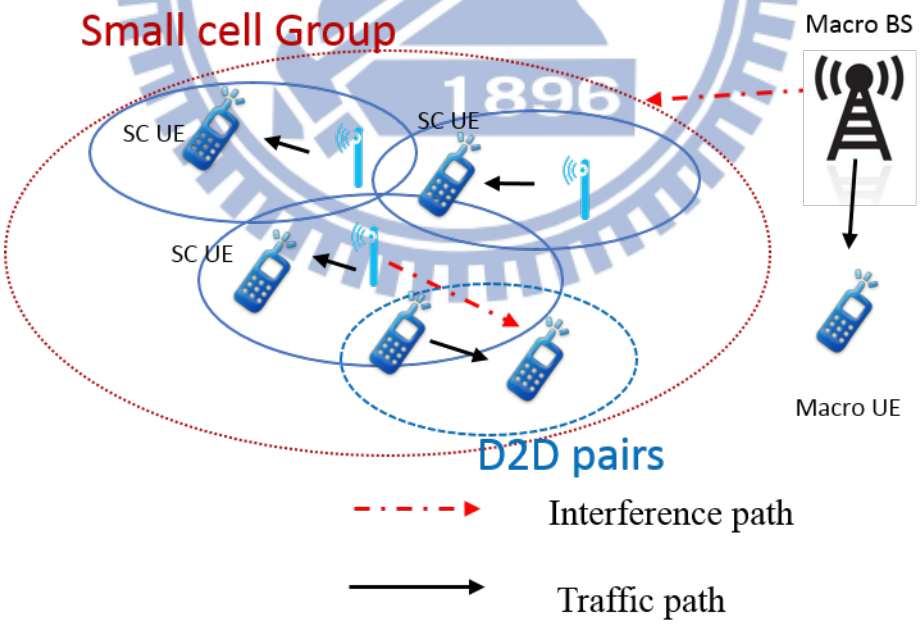


Figure 4-6 JT and SC grouping implement to enhance victim receive signal I

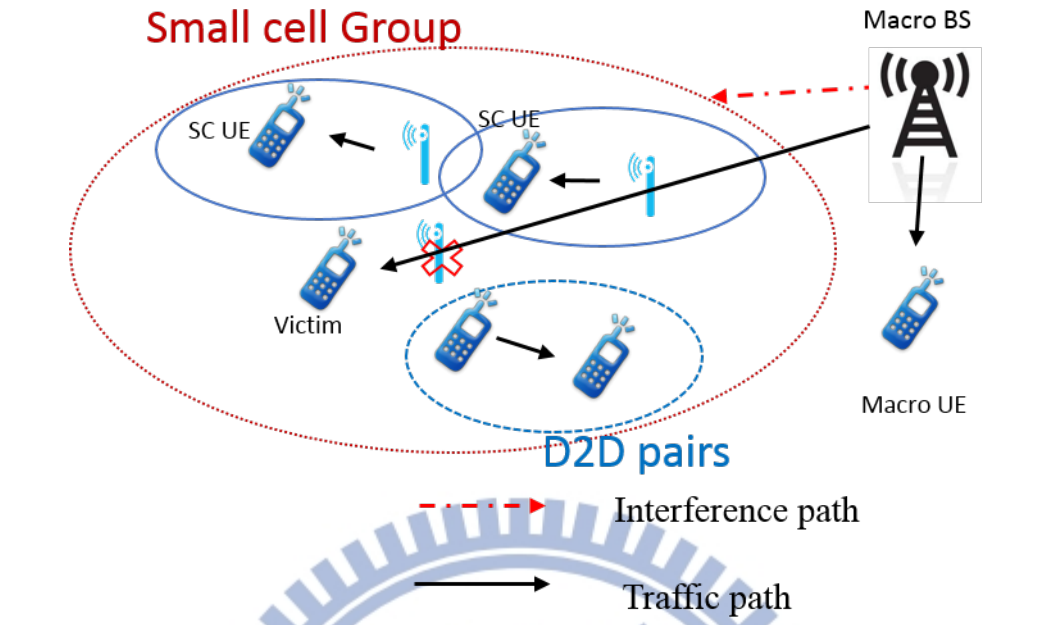


Figure 4-7 JT and SC grouping implement to enhance victim receive signal II

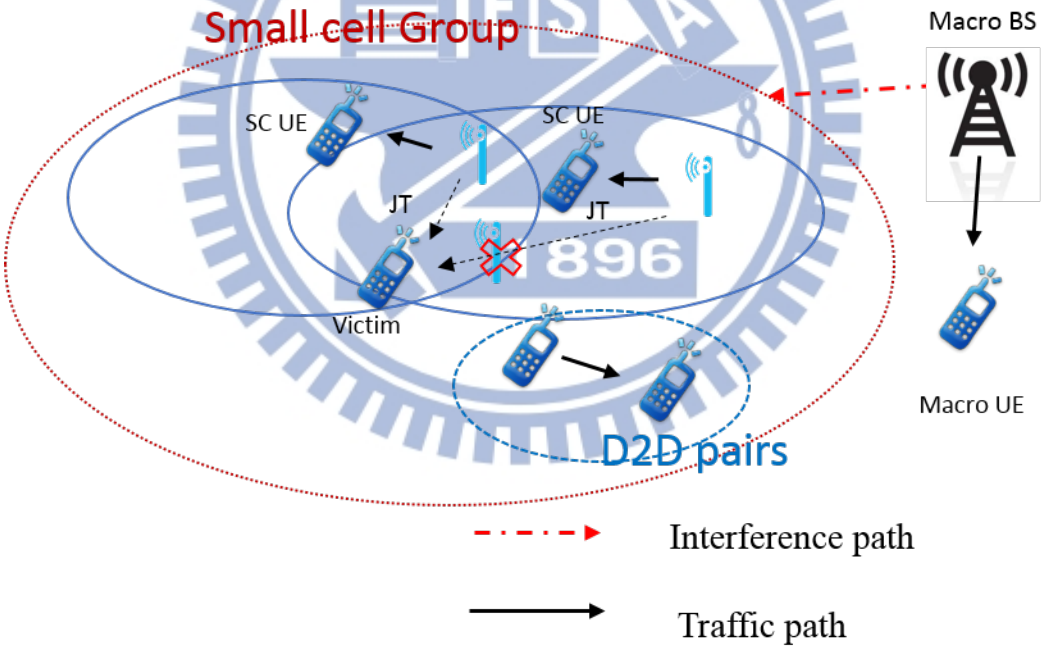


Figure 4-8 JT and SC grouping implement to enhance victim receive signal II

Chapter 5

SYSTEM LEVEL SIMULATION AND EVALUATION

In this chapter, we will talk about simulation detail, parameter setting, usage environment and different condition performance evaluation and comparison. Section 5.1 talk about simulator building, different control mechanism and some assumption will be mentioned in section 5.1, 5.2 and 5.4. Comparison will show in last section 5.3 and section 5.3.

5.1 Simulator building – Initial Setting

5.1.1 Some assumption

Due to we are doing a system level simulation, we have some assumption as shown as below

1. System level simulation – No delay
2. TDD LTE – Explication in previous chapter.
3. Worst case – All UE are DL and UL at the same time.
4. Co-channel – Enhance bandwidth efficiency and throughput.

Some assumption is common in other research such as ignore delay and Doppler shift in low speed, and [17] suggest that in the simulation we can assume all UE devices are in the same up-link-downlink configuration.

5.1.2 Parameter setting

Parameter will follow 3GPP specification [5], standard some BS spec and transmit power and pathloss. D2D is standardize by [13], pathloss model suggest to use Winner + $B1^b$ [18] Table4-1. Additionally, we consider a single macro BS with multiple SC cellular network system, following standard, our simulation are based on 10MHz bandwidth with 2GHz carrier, also we compare different amount of SC and UE. BS parameter is shown as Table 5-1.

	Macro	**Pico**	**UE**
Tx power	46 dBm	24 dBm	23 dBm
Noise figure	5 dB	13 dB	9 dB
Radius	500 m	40 m	N/A
Antenna gain	15 dBi	5 dBi	0 dBi

Table 5-1 Base station parameter

Pathloss between nodes is shown as Table 5-2.

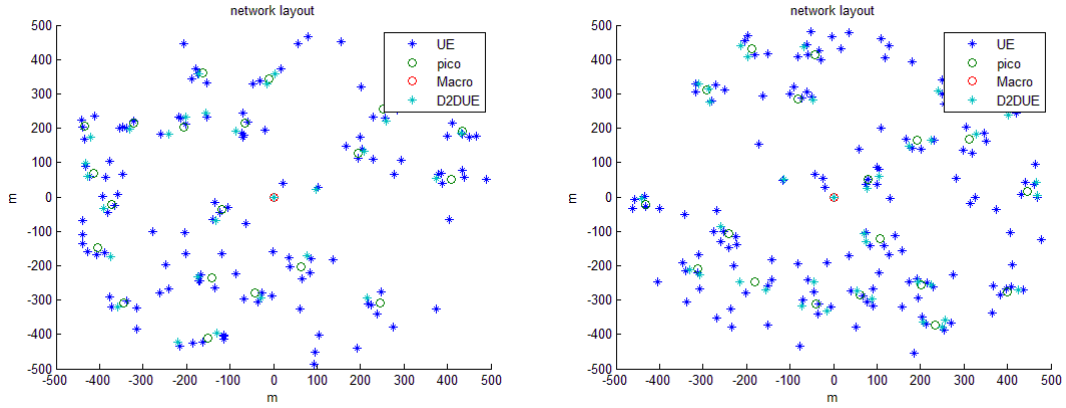
Pathloss case	
Macro – UE	$PL_{LOS}(R)$ = 30.8+24.2log$_{10}(R)$ $PL_{NLOS}(R)$ = 2.7+42.8log$_{10}(R)$ For 2GHz, R in m.
Pico – UE	$PL_{LOS}(R)$ = 103.8+20.9log$_{10}(R)$ $PL_{NLOS}(R)$ = 145.4+37.5log$_{10}(R)$ For 2GHz, R in km
UE – UE	$PL_{LOS}(R)$ = 40.0log$_{10}(R)$ + 7.56 – 17.3log$_{10}(h'_{BS})$ – 17.3log$_{10}(h'_{MS})$ + 2.7log$_{10}(f_c)$ $PL_{NLOS}(R)$ = (44.9 - 6.55log$_{10}(h_{BS})$) log$_{10}(d)$ + 5.83log$_{10}(h_{BS})$ + 18.38 + 23log$_{10}$(f$_c$) ([18]Table 4-1) h_{BS} = h_{MS} = 1.5m, h′$_{BS}$ = h′$_{MS}$ = 0.8m

Table 5-2 Pathloss between nodes

Experiment parameter is shown as Table 5-3, Figure 5-1 to Figure 5-3 shows the distribution of every network.

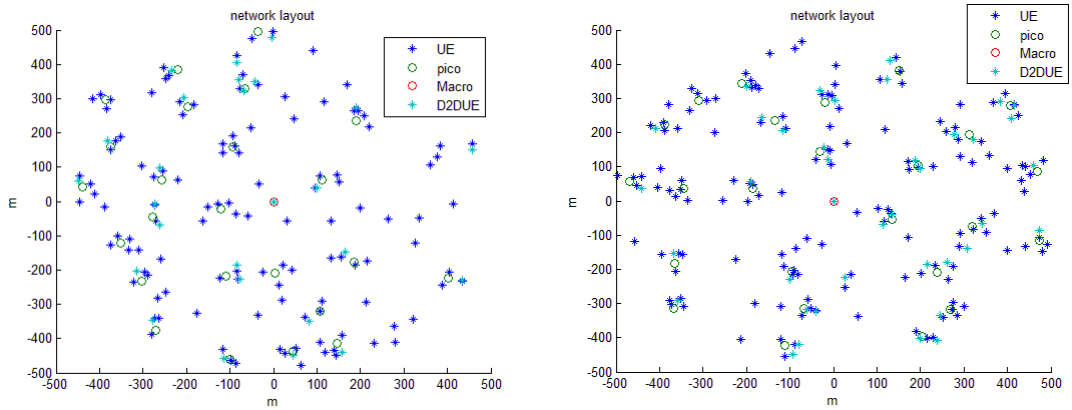
Experiment parameter	**Value**
Amount of UE	150, 180
Amount of pico	20, 25, 30
Amount of macro	1
UE velocity	3 km/hour
System bandwidth (*BW*)	10 MHz
Carrier frequency	2 GHz
System deployment	Urban macro (500m)
UE drop	Hotspot

Table 5-3 Experiment parameter



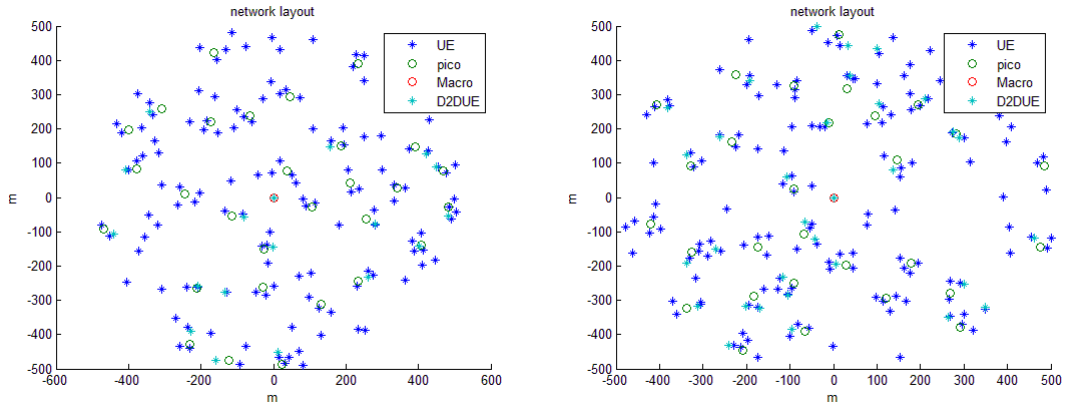
(a) 150 UE (b) 180 UE

Figure 5-1 Network deployment for 20 SCs



(a)150 UE (b) 180 UE

Figure 5-2 Network deployment for 25 SCs



(a)150 UE (b) 180 UE

Figure 5-3 Network deployment for 30 SCs

5.2 Mechanism Evaluation I

In Chapter 4, we have describe problem when D2D UE coexist with SC. For now, we are going to choose which scenario should turn SC off. First scenario 1-2, 2-2 and 3-2 SC should include to D2D state, turn off its radio radiation power. For scenario 3-1 we can simply consider this case as two different scenario 2-1 SC. Remain scenarios is shown as Figure 5-4.

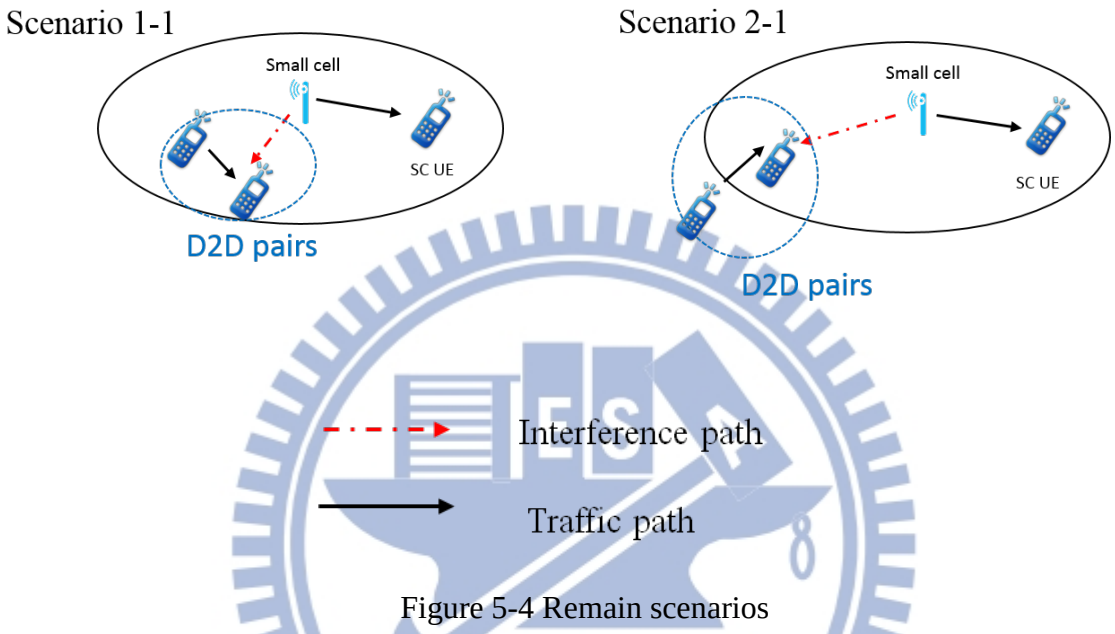


Figure 5-4 Remain scenarios

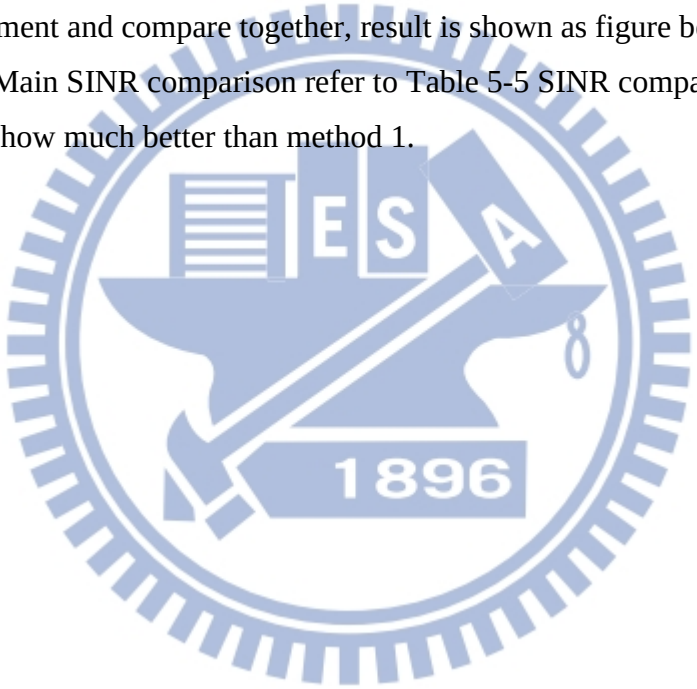
Supposedly, include scenario 1-1 SC to D2D state can get better performance than scenario 2-1 since D2D UE in scenario 1-1 is much closer to SC than other scenarios. As a result, we conclude several method by closing different scenario and it is shown as Table 5-4. Section 5.3 will show comparison about every method in different experiment environment.

Method	Detail
Method 1	Sleep mode only
Method 2	**1-1**,1-2, 2-2
Method 3	**2-1**,1-2, 2-2
Method 4	**1-1, 2-1**,1-2, 2-2

Table 5-4 Method description detail I

5.3 Simulation Result I

In simulation I, we consider whether SC have D2D sleep mode or not, from the result we can also observe sometimes turn off all the SC is not a bad choose but it will not be the best solution. Figure 5-5 to Figure 5-16 shows DL SINR and system DL throughput also compare in different experiment environment. We can recognize that the increasing amount of SC will effects the control method, with higher amount of SC will get more significant performance. Amount of UE effects not only throughput but also effects difference between methods to methods. It is because effect form SC will be obstruct by the increasing of UE amounts. We analysis different experiment environment and compare together, result is shown as figure below, and it conform to our assumption. Main SINR comparison refer to Table 5-5 SINR comparison I and using percentage to show how much better than method 1.



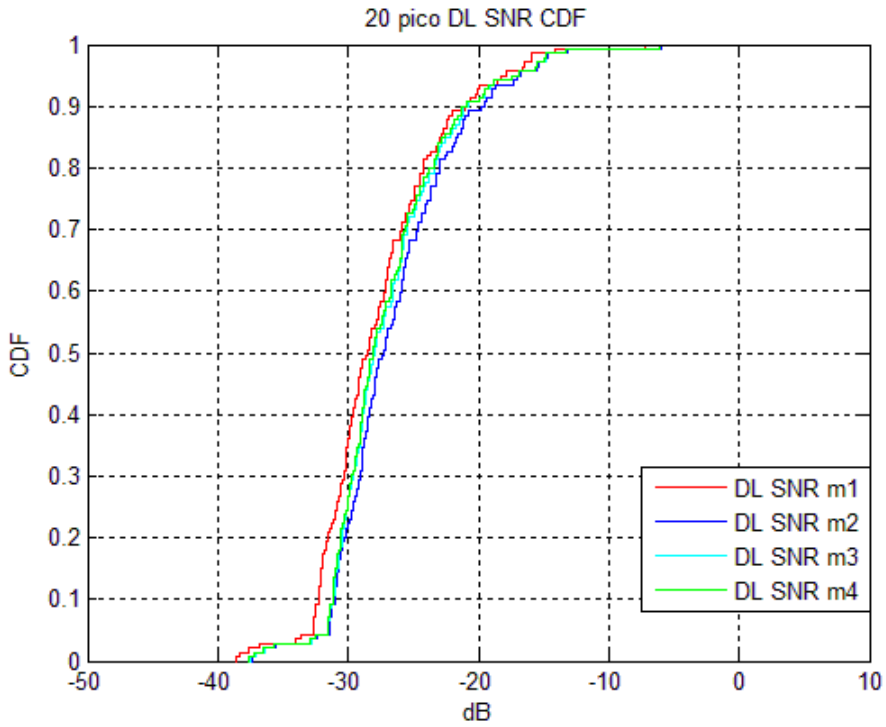


Figure 5-5 20 SC and 150 UE DL SINR

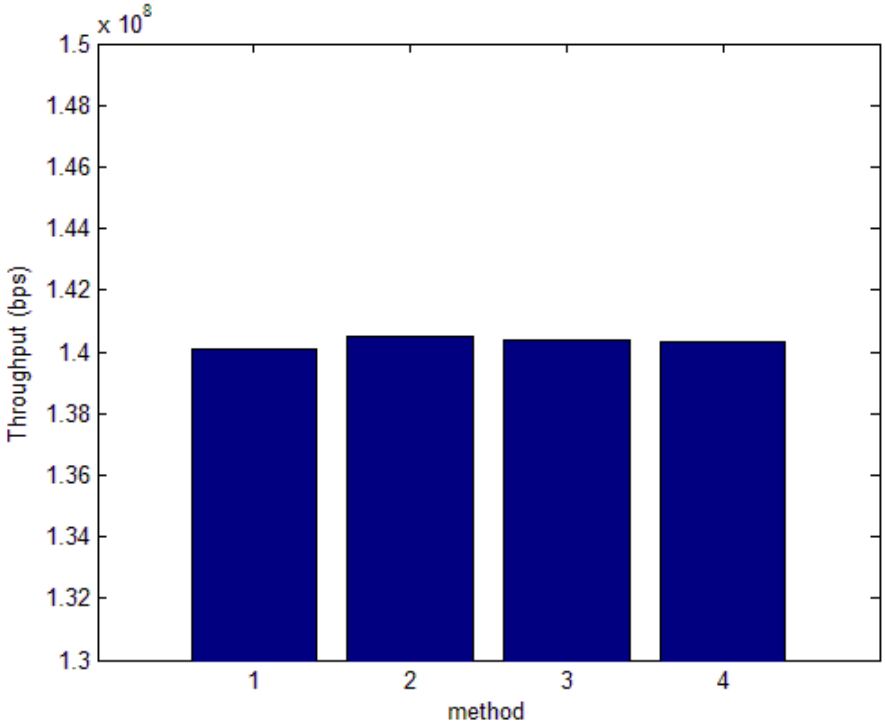


Figure 5-6 20 SC and 150 UE DL throughput

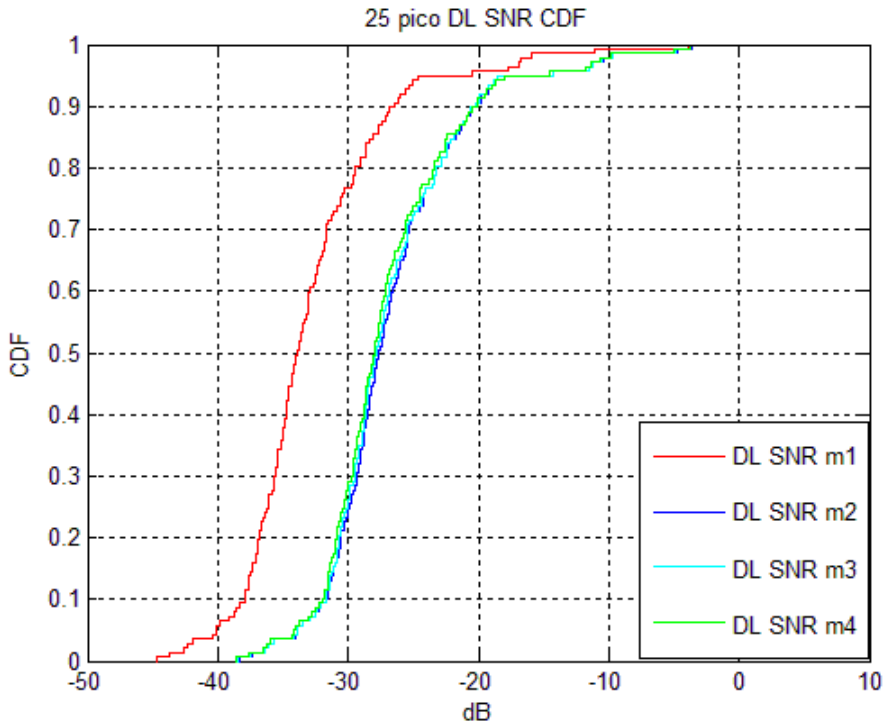


Figure 5-7 25 SC and 150 UE DL SINR

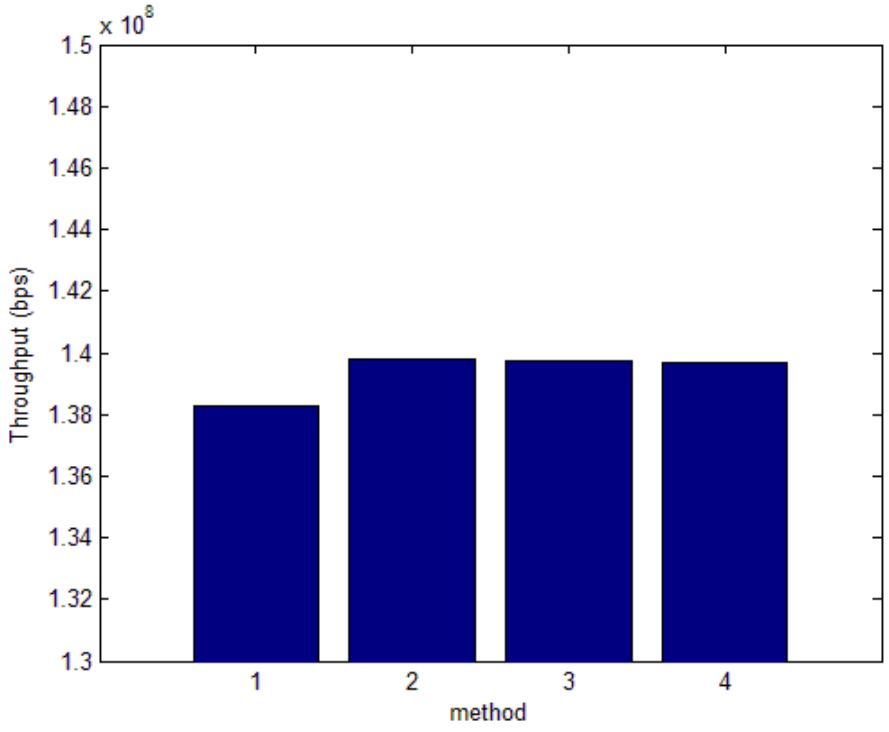


Figure 5-8 25 SC and 150 UE DL throughput

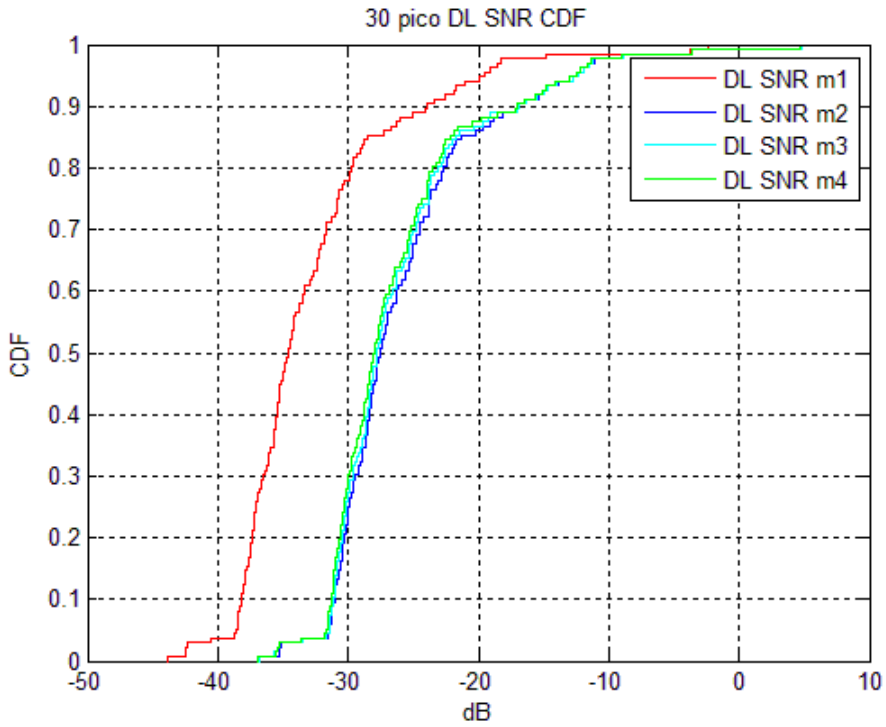


Figure 5-9 30 SC and 150 UE DL SINR

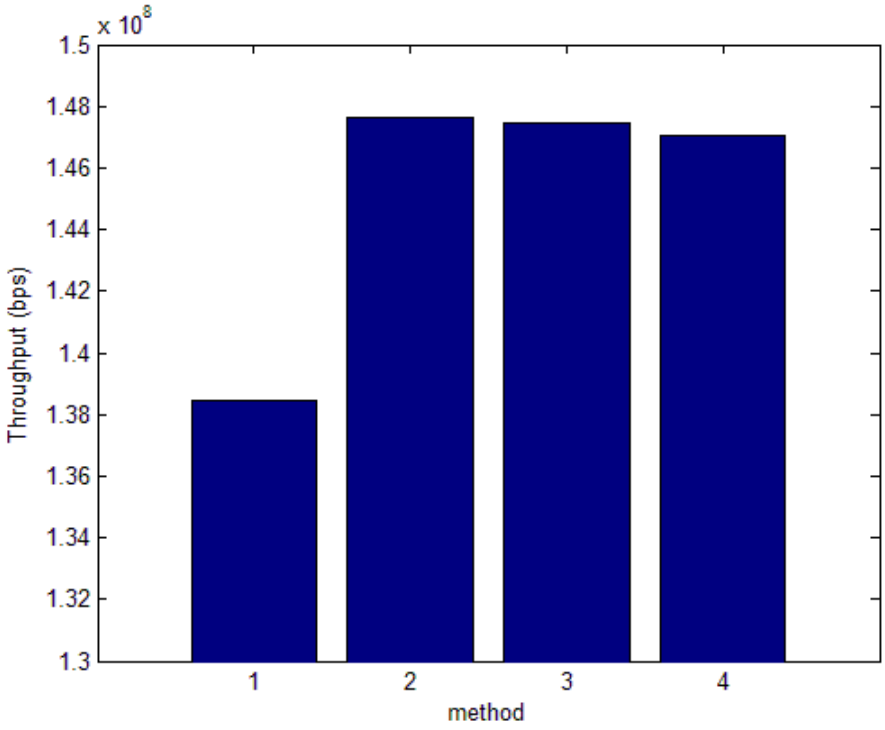


Figure 5-10 30 SC and 150 UE DL throughput

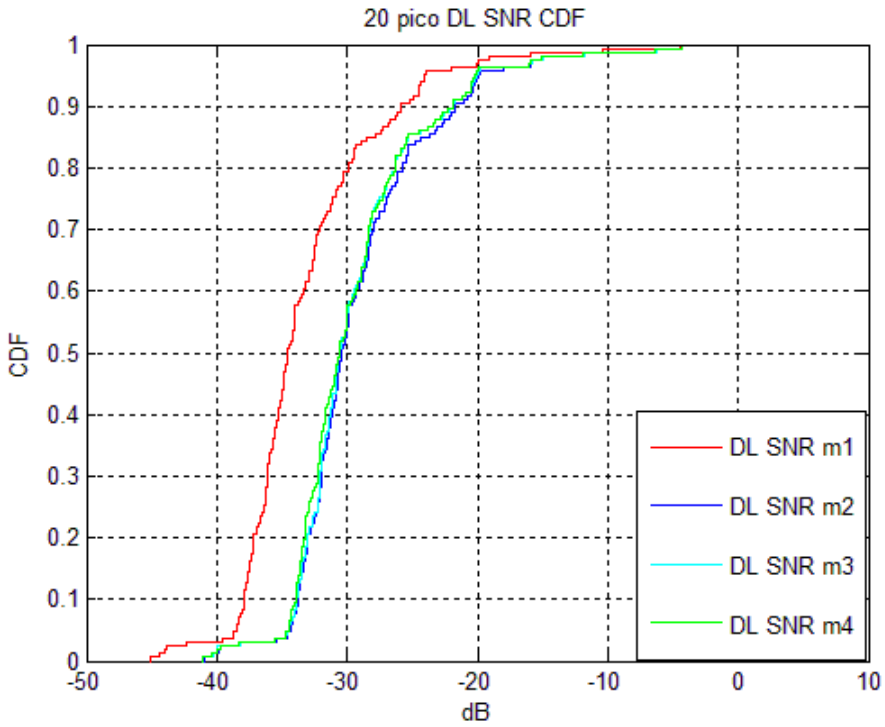


Figure 5-11 20 SC and 180 UE DL SINR

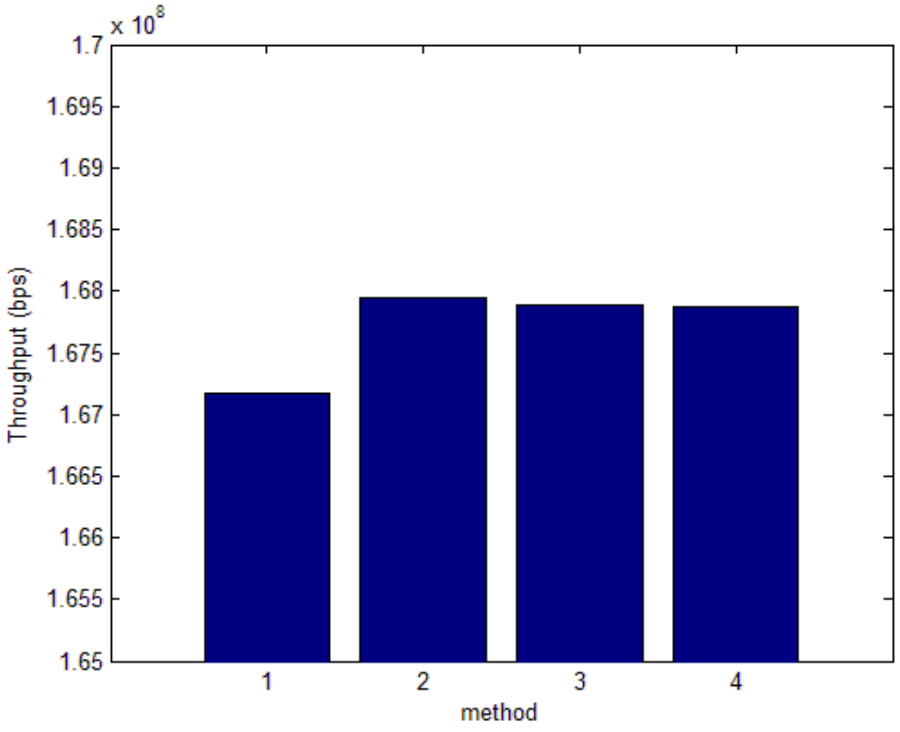


Figure 5-12 20 SC and 180 UE DL throughput

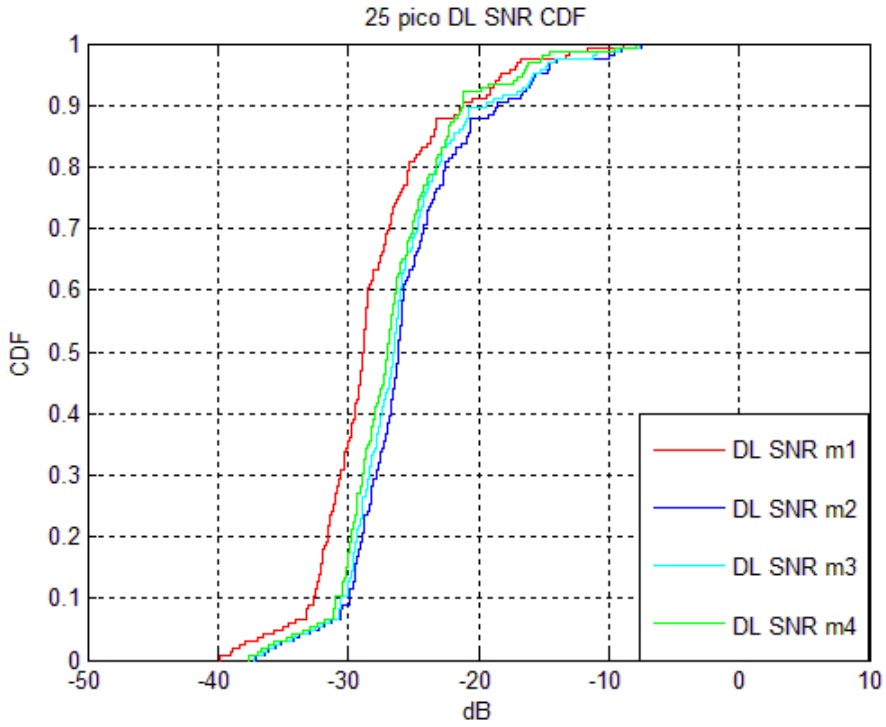


Figure 5-13 25 SC and 180 UE DL SINR

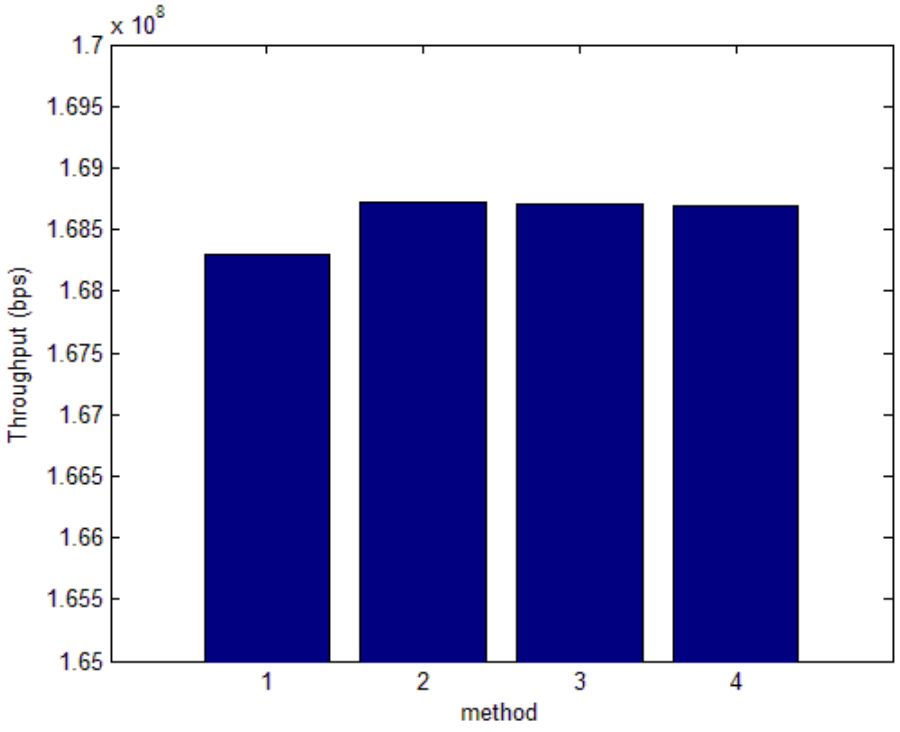


Figure 5-14 25 SC and 180 UE DL throughput

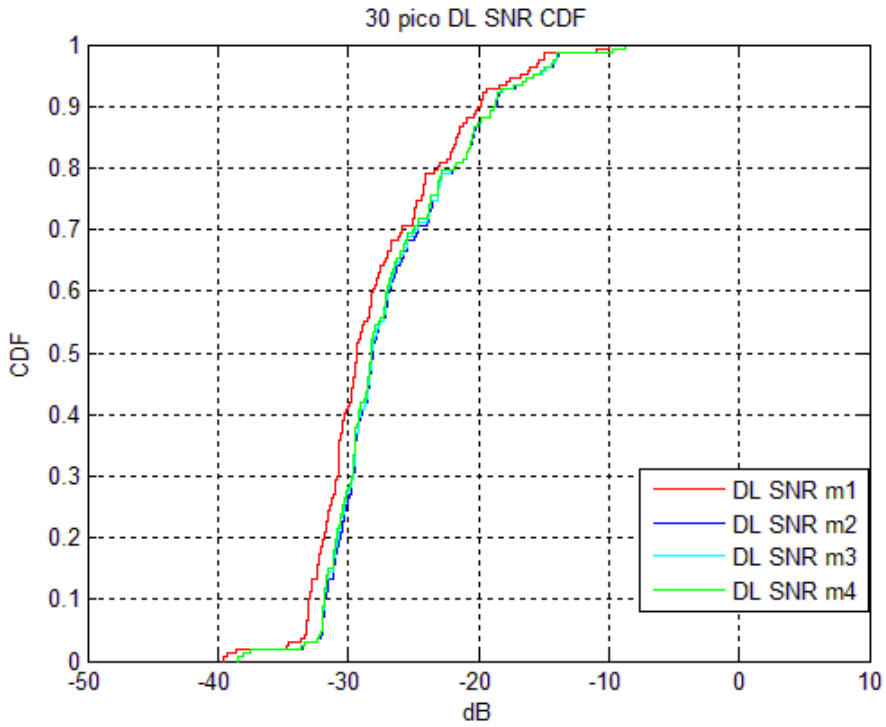


Figure 5-15 30 SC and 180 UE DL SINR

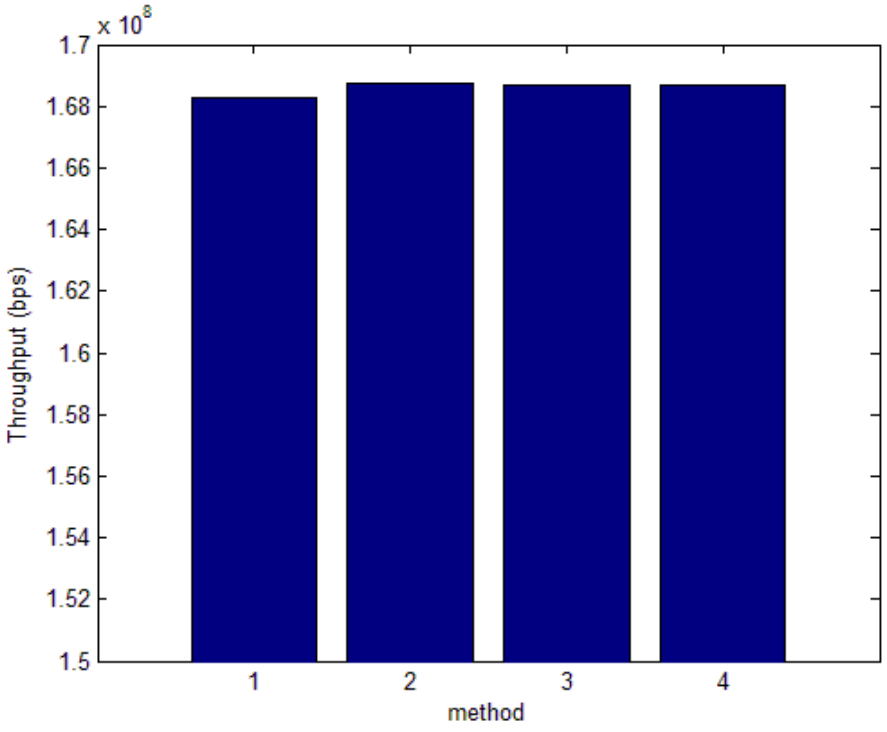


Figure 5-16 30 SC and 180 UE DL throughput

	M1	M2	M3	M4
20SC 150UE		4.72%	2.98%	2.54%
25SC 150UE		19.67%	19.24%	18.55%
30SC 150UE		24.10%	23.24%	22.45%
20SC 180UE		12.76%	12.07%	11.62%
25SC 180UE		10.0%	8.08%	5.52%
30SC 180UE		4.65%	4.38%	4.09%

Table 5-5 SINR comparison I

From Table 5-5 we can observate that SC can work well with D2D on/off state and always better than method 1 and from the result we can sort the performance from high to low is M2>M3>M4. It is because scenario 1-1 D2D devices are both within SC coverage and scenario 2-1 D2D devices are located at SC edge. M4 close both scenario 1-1, 2-1 and it brings more victim than M2, M3. In 30 SC 150 UE case, D2D on/ off control has best performance. In 25 SC 150 UE and 20 SC 180 UE M2 to M4 all have 10% better than M1. M2 win M4 the most at 25 SC 180 UE case.

5.4 Mechanism Evaluation II

Following chapter 3 propose solution II, adding SC coordinate transmission in mechanism evaluation I method detail shown as Table 5-6 and result will show in section 5.5. In the simulation, JT is related to amount of transmitter and receiver. Every UE devices can use full system bandwidth BW since we consider a co-channel cellular network, so even we consider CoMP bandwidth can still be fully utilized.

Method	Detail
Method 1-1	Sleep mode only
Method 1-2	Same as Method 1-1 and consider CoMP
Method 2-1	**1-1**,1-2, 2-2
Method 2-2	Same as Method 2-1 and consider CoMP
Method 3-1	**2-1**,1-2, 2-2
Method 3-2	Same as Method 3-1 and consider CoMP
Method 4-1	**1-1, 2-1**,1-2, 2-2
Method 4-2	Same as Method 4-1 and consider CoMP

Table 5-6 Method description detail II

5.5 Simulation Result II

Supposedly, consider CoMP should benefit system but the result is not always significant. In the simulation we can observe the amount of SC affects CoMP performance. Figure 5-17 to Figure 5-22 shows DL SINR, throughput and compare to original on/off method. We can see the result from simulation that with amount of SC increase, performance from JT CoMP will become weaker but still get benefit from CoMP in some scenario. In method 4-2, can get better improvement than method 2-2 and method 3-2 since number of victim in method 4-1 is more than method 2-2 and 3-2. However, method 2-2 and method 3-2 still have higher performance than method 4-2 since closing too many SC and without any control still get the worst performance in our simulation result. Main SINR comparison refer to Table 5-7 and using percentage to show how much better than method 1-1.

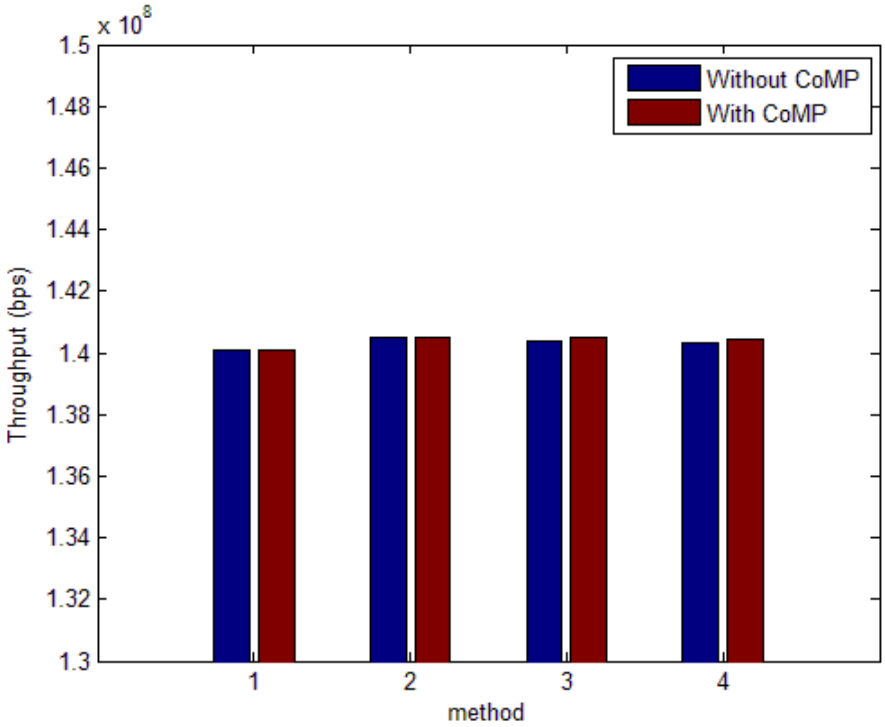


Figure 5-17 20 SC and 150 UE DL throughput

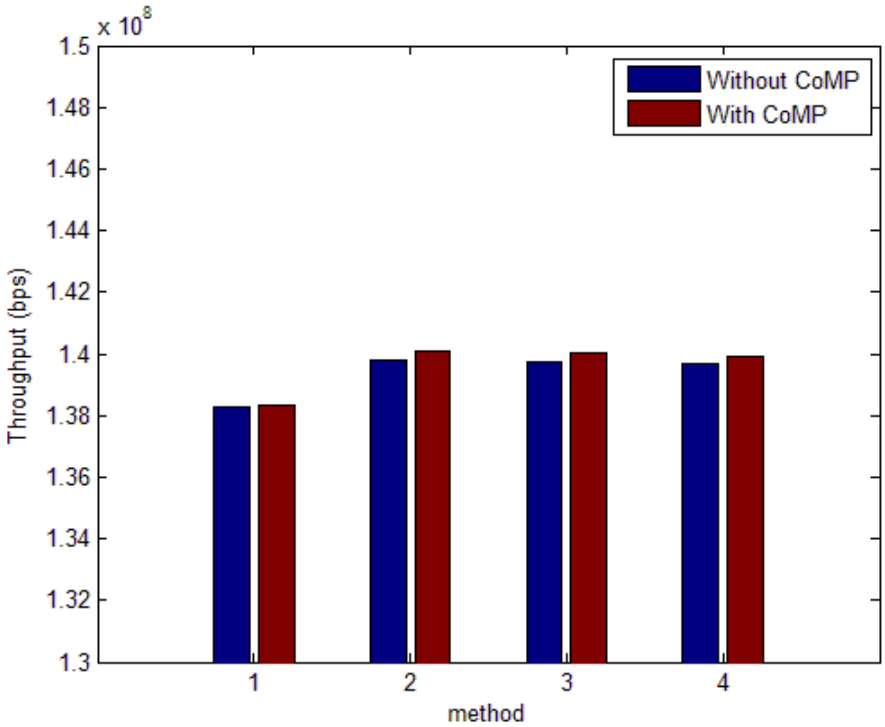


Figure 5-18 25 SC and 150 UE DL throughput

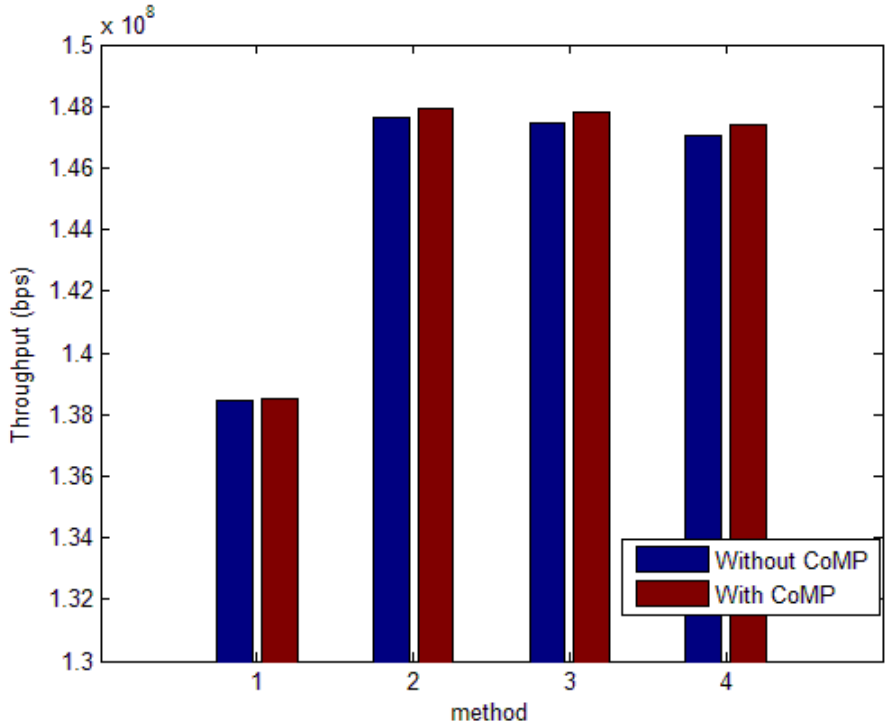


Figure 5-19 30 SC and 150 UE DL throughput

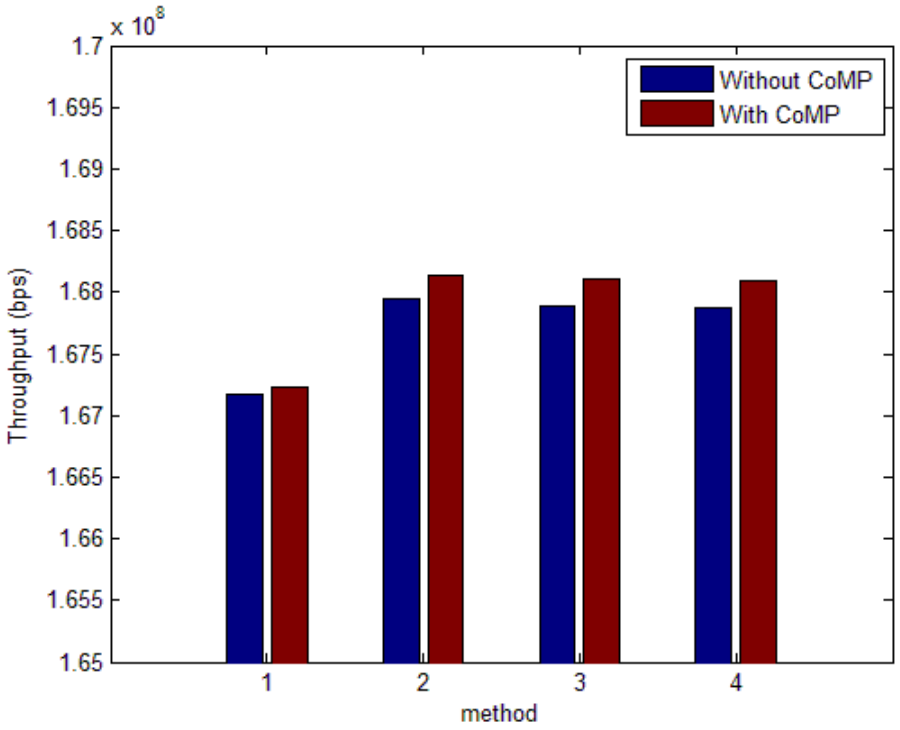


Figure 5-20 20 SC and 180 UE DL throughput

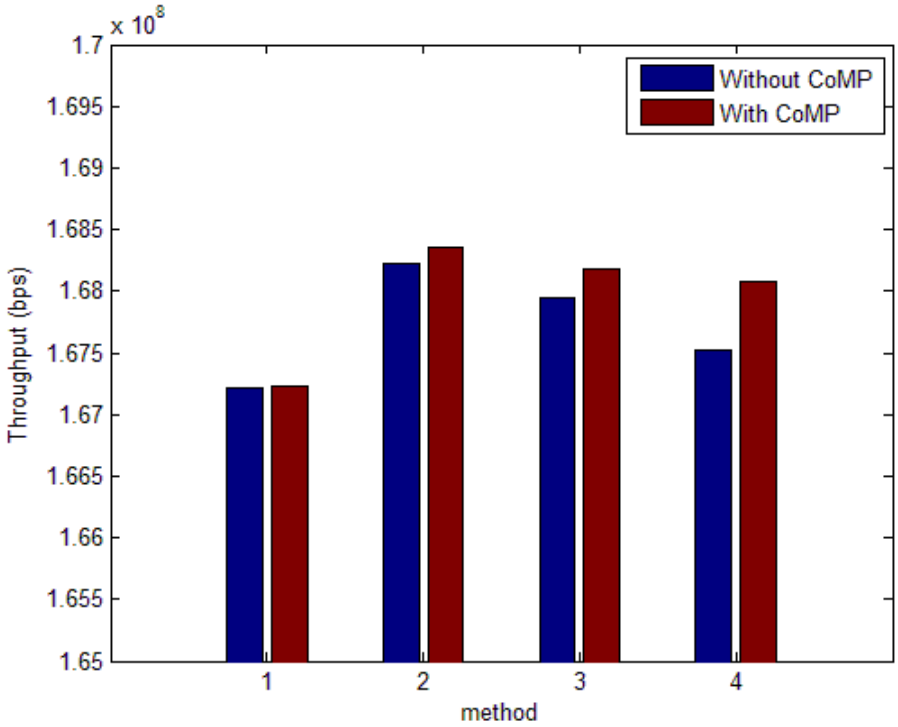


Figure 5-21 25 SC and 180 UE DL throughput

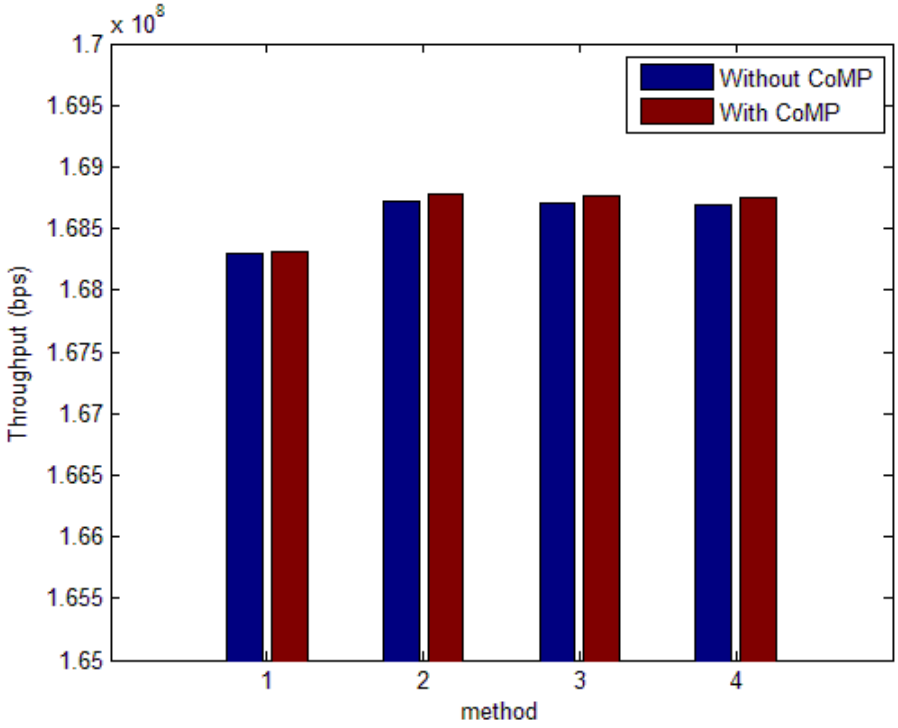


Figure 5-22 30 SC and 180 UE DL throughput

	M1-1	M1-2	M2-1	M2-2	M3-1	M3-2	M4-1	M4-2
20SC 150UE		0.11%	4.72%	5.20%	2.98%	4.83%	2.54%	4.60%
25SC 150UE		0.20%	19.67%	20.22%	19.24%	20.0%	18.55%	19.44%
30SC 150UE		0.27%	24.1%	24.64%	23.24%	24.47%	22.45%	23.99%
20SC 180UE		0.16%	12.76%	13.21%	12.07%	13.04%	11.62%	12.85%
25SC 180UE		0.44%	10.0%	10.50%	8.08%	9.86%	5.52%	8.45%
30SC 180UE		0.86%	4.65%	5.09%	4.38%	4.99%	4.09%	4.94%

Table 5-7 SINR comparison II

From Table 5-7, M1-1, M2-1, M3-1 and M4-1 is same as Table 5-5 M1, M2, M3 and M4. M1-2, M2-2, M3-2 and M4-2 are results about CoMP add to M1-1, M2-1, M3-1 and M4-1. In M4-1 and M4-2, numbers of victim is more than other method. As a result, M4-2 will have better performance than M4-1 and more significant than other method in all of the experiment parameter. Gain in M2-2 and M3-2 is not significant, it is because the victim number is less than M4-2. And in some situation we have target to achieve, for example, assume we need 5 % better performance than M1, we can consider M2-2 in our system. CoMP performance is not as significant as usual since the environment is different. Traditionally, CoMP has 9% to 10% enhancement in TDD LTE but situation is different in ultra-dense SC networks. Transmitters are ubiqueious and signal sources are near each other. Therefore, after D2D state add in CoMP can be improved and more suitable in this situation.

Chapter 6

CONCLUSION

In this thesis, we consider a novel on/off SC control mechanism depends on D2D transmission, D2D communication is very popular in various 3GPP group, companies propose a lot of documents and protocol. Moreover, D2D has been include to Release 12 and related conference is still holding. In our research, we focus on interference problem and solve by our proposal "SC D2D sleep mode" also we solve victim problem by coordinate SC transmission "CoMP", came from previous research and studies.

For interference-limited system, interference management is always an important event, we analysis various D2D scenarios and chose whether the scenario should turn off SC to mitigate interference. Some obvious scenarios we should always turn off SC, SC with single pair D2D device scenarios is not difficult to recognize, but current small cell networks appears earlier than in band D2D so it has not been consider before. As a result, Chapter 3 provide a combination formula about D2D communication with small cell on/off control mechanism, therefore we can verify two kind of mechanism mix together and simulation in Chapter 5. Following 3GPP contribution and their document, we built a LTE simulator and adding D2D devices in our experiment.

D2D proposed to solve network loading, so we select an extreme environment, co-channel and every UE are transmitting data at the same time. In the simulation we can recognize that with increasing amount of SC the more interference we get. As a result, control SC wake up or not will become a more important in a densely deploy SC network.

In issue 2, we select CoMP to handle victim since the research about CoMP is almost ubiquitous and well known. Performance about CoMP has been evaluated, with the increasing of victim the performance become more significant. In method 1-1 and 1-2, throughput enhance from CoMP is the worst in whole research, it is because method 1-1 and 1-2 did not make any interference management also these two method have least victim. Method 4-1 and 4-2 have largest victim, however, without good management can't get highest performance.

Basically, on/off control is an extreme power control mechanism, so future work can further consider SC DL power control implement in coexist D2D networks. Different power control algorithm may provide different performance or enhancement but 3GPP has discuss DL power

control in current conference, and detail algorithm hasn’t been done yet. Therefore, in such an extreme environment we still suggest on/off control and we can handle victim UE by CoMP. Still, we need another algorithm support channel allocation.

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