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PERFORMANCE ANALYSIS WITH COORDINATION AMONG BASE STATIONS FOR NEXT GENERATION COMMUNICATION SYSTEM

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Abstract—Next generation communication system, such as Long Term Evolution Advanced (LTE-A), has the advantages of high transmission rate, wide bandwidth and better bandwidth utilization in high mobility environments. However, in such a kind of system when users are distributed sparsely in the base station coverage range the spectrum efficiency becomes worse. The emergence of new technologies such as the coordination among based stations makes the utilization of system bandwidth more efficient. The technology of coordination among base stations has other merits such as reducing noise interference, increasing receiving diversity, improving the system receiving gain, etc. In this paper, the system spectrum utilization and its associated efficiency will be investigated when the scheme of coordination among base stations is implemented.

1. INTRODUCTION

As new wireless communication technologies emerge, the demand for networks applications becomes diversified, and the request for service quantity is also correspondingly increased. Network application has become an indispensable service in human life, and then as system develops, how to select or set the system parameters so that the system will achieve its optimal capacity becomes a vital task. It then incurs the issue of how to properly utilize the network resource anytime and anywhere in its applications. Earlier generations of wireless mobile communication systems are unable to meet the current

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service providers' request that asks for wide bandwidth and high speed data applications and also for the extension of the system coverage range. The new interface standards proposed by Third Generation Partnership Project (3GPP) and IEEE 802.16 m all contain the advantages of high transmission data rate, broad bandwidth and wide coverage area. In this paper, how to implement the coordination scheme among base stations to improve the system capacity will be considered.

As shown in Figure 1, a user is located in the common coverage area of many base stations. After the user is inter-connected by these base stations and through the implementation of the coordination among these base stations, the user's effective receiving gain can be increased, and also the interference among users can be reduced by implementing the techniques such as Coordinated Multi-input Multi-output (Co-MIMO) and Coordinated Multiplexing (CoMP) [1–7].

In this paper, the bandwidth shared among base stations will be analyzed when users are interconnected by many base stations, and it will then determine which is the proper situation to trigger the coordination scheme among base stations to improve the system capacity. As shown in Figure 1, when base station 1 (BS1) and base station 2 (BS2) use different carrier frequencies in their transmissions, the user equipment (UE) can be based on its received signal to noise ratio from each base station to determine which link has better receiving signal quality. On the other hand, when both stations use the same carrier frequency in their transmissions, the UE can enhance its received signal strength by combining receiving signals from both base stations.

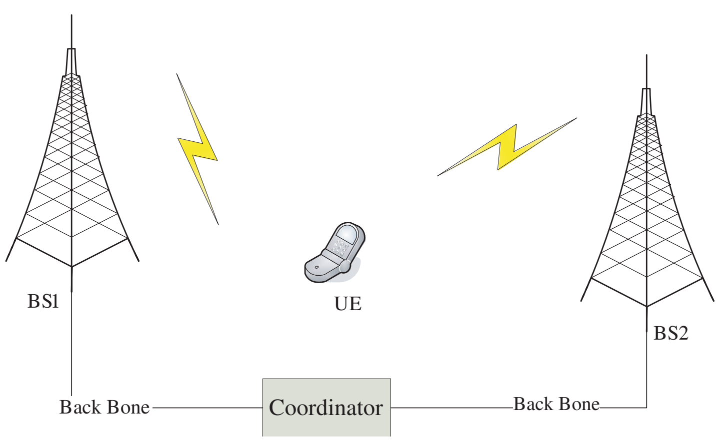

Figure 1. A UE is covered within multiple base stations.

Channel fading [8] plays an important role in the wireless communication. When signal transmits through the channel it will encounter various interferences such as the multipath effect when the signal transmits through the buildings, forests and terrains. The multipath effect will enhance or fade transmit signal to make it impossible at the receiver terminal to accurately determine the transmitted signal; it needs to use statistical description to characterize the receiving signal strength. The channel model in wireless communication is derived through analysis and simulation of channel responses and modified through empirical measurements; many channel models have been proposed [8–19]. Summarily, the received signal strength at the base station/UE can be estimated from the following equation:

$$P(\text{dBm}) = P_t + G_t + G_r - PL \tag{1}$$

where

P_t: Transmitting power of base station/UE (dBm).

G_t: Antenna gain of UE/base station (dBi).

G_r: Antenna gain of base station/UE (dBi).

PL is the path loss in dB and has value as shown in the following Equation (2) as recommended by 3 GPP Rel.9 for Non-line of Sight (NLOS), Macro-urban base station [20]:

$$\begin{aligned} PL = & \; 161.04 - 7.1 \log 10(W) + 7.5 \log 10(h) - (24.37 - 3.7(h/h_{\text{BS}})^2) \\ & \log 10(h_{\text{BS}}) + (43.42 - 3.1 \log 10(h_{\text{BS}}))(\log 10(d) - 3) \\ & +20 \log 10(f_c) - (3.2(\log 10(11.75 h_{\text{UE}}))^2 - 4.97) \end{aligned} \tag{2}$$

where the parameters are:

d: Transmission distance between the base station and the UE, $10\,\text{m} < d < 5000\,\text{m}$.

h: Average building height, $5\,\text{m} < h < 50\,\text{m}$.

W: Street width, $5\,\text{m} < \text{W} < 50\,\text{m}$.

h_{BS}: Base station antenna height, $10\,\text{m} < h_{\text{BS}} < 150\,\text{m}$.

h_{UE}: UE antenna height, $1\,\text{m} < h_{\text{UE}} < 10\,\text{m}$.

f_c: Carrier frequency (GHz).

2. USER'S ENVIRONMENT CASES

When a user is located in different coverage areas of base stations, as shown in Figure 2, three communication environments can be classified

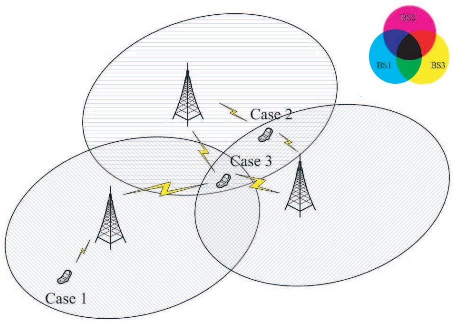

Figure 2. Users environment be depicted with colors.

and are represented by different colors. The bandwidth utilizations of these base stations in different communication environments will be analyzed in the following sections. These three communication environment cases are:

Case 1: The user is covered by one base station.
The user is covered by BS1 with light blue color.
The user is covered by BS2 with pink red color.
The user is covered by BS3 with yellow color.
Case 2: The user is covered by two base stations.
The user is covered by BS2 and BS3 with red color.
The user is covered by BS1 and BS3 with green color.
The user is covered by BS1 and BS2 with blue color.
Case 3: The user is covered by three base stations.
The user is covered by BS1 BS2 and BS2 with black color.

3. SYSTEM PERFORMANCE OF BASE STATION

We perform the system performance simulation of LTE system under various communication environments and make comparison and analysis of the system performances when coordination scheme is implemented or not. The system simulation parameters are listed in Table 1, and the system simulation functional block is illustrated in Figure 3. The system performance simulation procedure can be summarized in the following:

1) Input system parameters into MABLAB program.
2) Use MABLAB program based on certain statistical model to generate the locations of BSs and UEs.

Table 1. LTE parameters.

Duplex Mode	FDD
Carrier Frequency	2 GHz
Bandwidth	10 MHz
Code Rate	1/3
AMC	QPSK, 16-QAM, 64QAM
BS Power	1 W
BS antenna gain	17 dBi
UE antenna gain	0 dBi
UE Power	200 mW
BS Height	35 m
UE Height	1.5 m
Path Loss	Macrocell urban
DL Traffic	128 Kbps
UL Traffic	64 Kbps

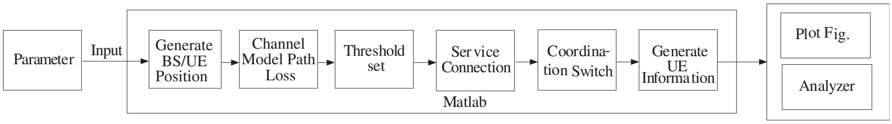

Figure 3. System simulation functional block diagram.

3) Generate the path loss from each pair of BS and UE by using Equation (1).
4) Determine whether to implement coordination scheme.
5) Perform system performance simulation.
6) Analyze and plot the simulation results.

3.1. Analysis of Communication Environment

It is assumed that users are uniformly distributed in each base station coverage area that is represented within the red zone of Figure 4. Users' locations in various base stations coverage areas can be identified by using different colors as illustrated in Figure 2. Simulated system performances with users location distributions kept the same are plotted in Figure 4 and Figure 5, respectively, for with and without

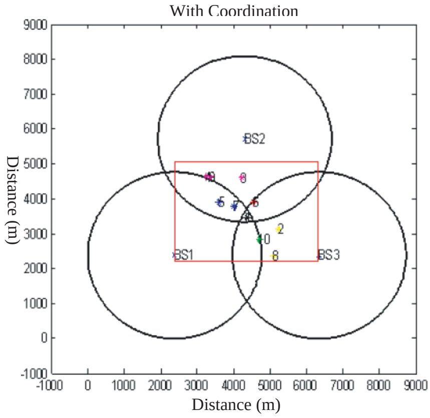

Figure 4. UEs reception statistics: Coordination scheme is implemented.

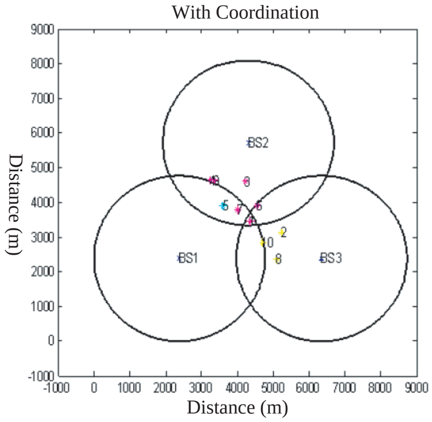

Figure 5. UEs reception statistics: Coordination scheme is not implemented.

the implementation of coordination scheme. In Figure 4 when a user is located in multiple base stations coverage areas, it can receive the information sent from these multiple base stations so that user 1 is marked as black since it can receive three base stations data. Similarly, users 5 and 7 are marked blue, and they can receive data sent from BS1 and BS2. User 6 is red and can receive BS2 and BS3 data. User 10 has green designation it receives BS1 and BS3 information. In Figure 5 it shows the result without implementing the coordination scheme. Each user receives information sent from only one base station, e.g., user 5 receives data from BS1, and user 1, user 3, user 4, user 6, user 7, user 9 each receives data sent from BS2 while BS3 sends data to user 2, user 8 and user 10.

3.2. Analysis of Base Station Spectrum Utilization

When UEs distributions as shown in Figure 4 are considered with coordination scheme implemented, the bandwidth usages in the base stations have the results as shown in Figure 6. On the other hand, when UEs have distributions as shown in Figure 5, the base stations have the bandwidth usages as shown in Figure 7 with no coordination scheme implemented. Comparing the bandwidth usages in the base stations, as shown in Figures 6 and 7, it appears that under the same users' distribution the implementation of coordination scheme will have larger bandwidth usage than that without implementing the coordination scheme.

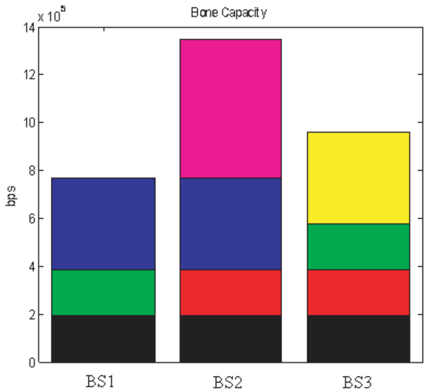

Figure 6. Bandwidth usage with coordination scheme implemented.

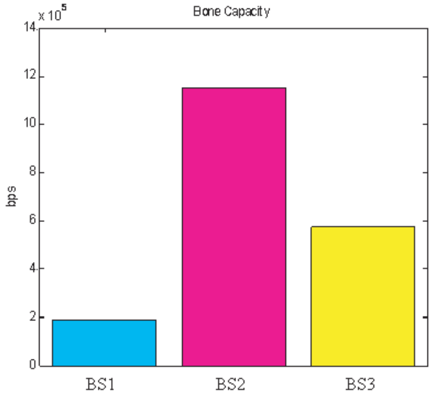

Figure 7. Bandwidth usage without coordination scheme implemented.

3.3. Analysis of Bandwidth Usage

There are many ways defining the bandwidth usage of the base station. We define in this paper the bandwidth usage of a base station as the number of users that the base station has served. From the simulated results as shown in Figure 6 and 7, the ratio of the number of users that the base stations have served with and without coordination scheme implemented is 1.62 : 1.

The system performances, such as the number of users successfully served and the resulting throughput of each base station, are simulated, with results tabulated in Table 2 and plotted in Figure 8, when a different number of users is served in the system and with or without coordination scheme implemented. Listed in Table 2 are the number of users successfully connected to the downlink and uplink of each base station, the total number of users requested for service and the network bandwidth utilization of each base station, i.e., its throughput. For example, as in Figure 8 from the plot of the number users connected in DL, when we vary the number of users served in the system we find that when the number of users is over 100, as marked by A in the plot, more users can be connected when coordination scheme is implemented than without using coordination scheme.

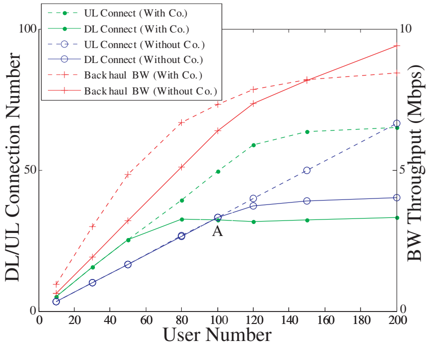

Figure 8. Statistics of service and throughput.

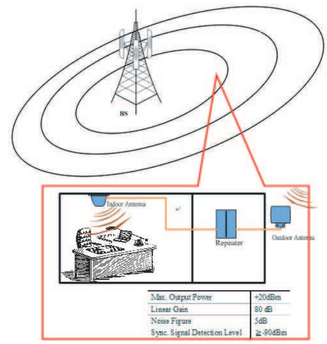

Figure 9. The set up of a repeater and its important parameters [21].

Table 2. Statistics of service and throughput.

DL/UL successfully connected users

Total users requested for services

Base station backhaul network bandwidth utilization

With Coordination																									
UE Number		10			30			50			80			100			120			150			200		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	5.1	5.1	5.1	14.4	14.4	14.4	24.9	24.9	24.9	32.1	38.3	38.3	31.5	48	48	31.9	59.2	59.2	32.5	63.7	66.3	33.3	64.3	98.1
BS2	Connect	4.8	4.8	4.8	16.9	16.9	16.9	26.5	26.6	26.6	34.1	41.5	41.5	33.9	54.1	54.1	33.1	60.9	60.9	32.4	64.7	70.2	33.2	67.1	105.9
BS3	Connect	5.1	5.1	5.1	15.6	15.6	15.6	24.4	24.4	24.4	31.3	38.4	38.4	31.7	46.5	46.5	30.6	56.9	56.9	31.9	62.8	68.2	33.4	64.2	97.2
BS1	Mbps	0.9792			2.7648			4.7808			6.56			7.104			7.872			8.2368			8.3776		
BS2	Mbps	0.9216			3.2448			5.0944			7.0208			7.8016			8.1344			8.288			8.544		
BS3	Mbps	0.9792			2.9952			4.6848			6.464			7.0336			7.5584			8.1024			8.384		
Without Coordination																									
UE Number		10			30			50			80			100			120			150			200		
		DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service	DL	UL	service
BS1	Connect	2.8	2.8	2.8	8.7	8.7	8.7	15.7	15.7	15.7	27	27	27	32.4	32.4	32.4	36.7	36.9	36.9	38.8	48.1	48.1	40.6	66.2	66.2
BS2	Connect	4.5	4.5	4.5	12.3	12.3	12.3	18.9	18.9	18.9	30.6	30.8	30.8	32.2	32.3	32.3	38.1	43.6	43.6	39.1	54.4	54.4	39.7	66.2	66.5
BS3	Connect	2.7	2.7	2.7	9	9	9	15.4	15.4	15.4	22.2	22.2	22.2	35.1	35.3	35.3	37.4	39.5	39.5	38.8	47.5	47.5	40.5	67.2	67.3
BS1	Mbps	0.5376			1.6704			3.0144			5.184			6.2208			7.0592			8.0448			9.4336		
BS2	Mbps	0.864			2.3616			3.6288			5.888			6.1888			7.6672			8.4864			9.3184		
BS3	Mbps	0.5184			1.728			2.9568			4.2624			6.752			7.3152			8.0064			9.4848		

4. ANALYSIS WHEN CERTAIN BS-COMPLEMENTED APPARATUS ARE INDOOR INSTALLED

When users are inside the building or office, they sometimes could not receive the signal transmitted from outdoor base stations due to the signal penetration loss through the building. We propose two options to solve this kind of indoor communication problem. In the first option, repeaters is used to re-transmit the signal that was sent from outdoor base station with power amplification or demodulation-modulation process, while in the other option, femto cells are installed to extend the outdoor base station coverage range andaccomplish the indoor communication requirement.

4.1. Repeater

The installation of repeaters to improve the receiving quality of indoor users can be referred to Figure 9.

4.1.1. Analysis of Repeater

The signal strength at the indoor antenna output depends on the distance between the base station antenna and the repeater outdoor antenna as shown in Figure 9. Figure 10 shows the indoor antenna output SNR when the distances between the BS antenna and the repeater outdoor antenna is either 500 m or 1000 m.

4.1.2. Performance Analysis in Coordination Environment When Repeaters Are Installed

Figure 11 shows the environment where repeaters are installed when indoor users are unable to receive signals sent from outdoor base station. When signal strengths in 50 houses are measured, their averages are taken after 10 simulation trials. The user's service performance and BS throughput in coordination environment are shown in Figure 12 where users, houses and repeaters are distributed within the red rectangular frame as shown in Figure 4. The simulated throughput is analyzed in Table 3. It shows in Figure 12 that when repeaters are installed the BS provides less available bandwidth than when no repeaters are installed. However, in some cell edges and indoor environments, the efficiency of the throughput is improved when

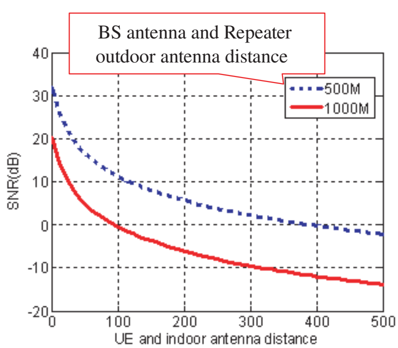

Figure 10. The output SNR of indoor antenna.

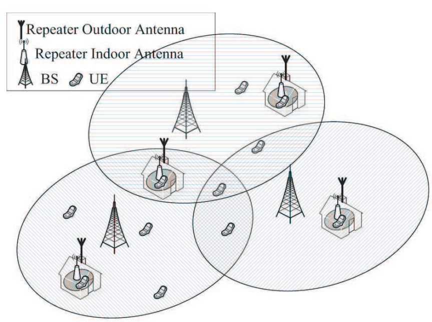

Figure 11. The repeaters installed environment.

Table 3. Users service quality and throughput when repeaters are installed.

Without Repeater																	6
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	3.6	3.6	15.5	15 5	25	25	31.7	40.6	32.6	47.9	32.4	5.65	31 9	63.8	31.6	63.5
BS 2	connect	5.5	5.5	16	16	25 2	25 9	33.6	43.9	33.4	52.3	33	59.9	34.2	66 4	32.2	64.9
BS 3	connect	4.9	4.9	14.9	14.9	24	24	31	36.6	32.5	47	32.4	59.2	31 9	63.9	30.7	61.8
BS 1	Mbps	0.6912		2.976		4.8		6.656		7.2384		7.7632		8.1664		8.1088	
BS 2	Mbps	1.056		3.072		4.8832		7.1104		7.6224		8.0576		8.6272		8.2752	
BS 3	Mbps	0.9408		2.8608		4.608		6.3104		7.168		7.936		8.1728		7.8848	
Total	Mbps	2.688		8.9088		14.2912		20.0768		22.0288		23.7568		24.9664		24.2688	
With Repeater																	
	MS Number	10		30		50		80		100		120		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	5.1	5.1	12.8	12.8	22.6	22.6	31.6	36.7	33.4	42	31.7	53.6	32.3	62.4	32.9	65.6
BS 2	connect	4	4	13.7	13.7	23.7	23.7	32.1	36.7	32.9	47.4	32	55.9	33.2	63.9	34.1	67.1
BS 3	connect	3.9	3.9	12.4	12.4	19.4	19.4	29.9	32.8	32.5	39.2	32.2	50.3	31.6	59.2	32.3	63.7
Indoor	connect	1.3	1.3	3.9	3.9	6.1	6.1	8.5	8.5	12	12	12.5	12.5	18.3	18.3	21.4	21.4
BS 1	Mbps	0.9792		2.4576		4.3392		6.3936		6.9632		7.488		8.128		8.4096	
BS 2	Mbps	0.768		2.6304		4.5504		6.4576		7.2448		7.6736		8.3392		8.6592	
BS 3	Mbps	0.7488		2.3808		3.7248		5.9264		6.6688		7.3408		7.8336		8.2112	
Total	Mbps	2.496		7.4688		12.6144		18.7776		20.8768		22.5024		24.3008		25.28	

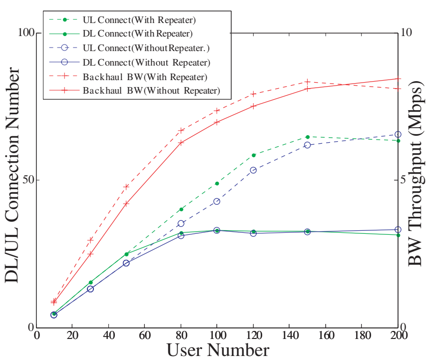

Figure 12. Users service quantity and throughput with and without installation of repeaters.

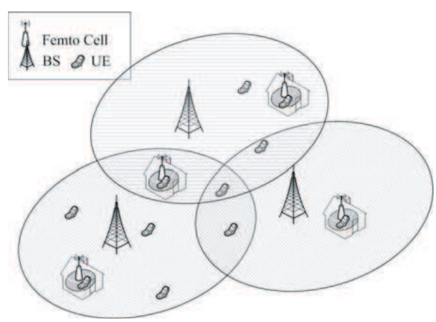

Figure 13. Femto cell environments.

repeaters are installed. From Figure 12, it is concluded that the system with repeaters installed can provide some services to the indoor users so to improve the overall system throughput.

4.2. Femto Cell

Femto cells [20] are installed as shown in Figure 13 when the following situations are encountered such as more users trying to access the system or when the indoor users could not receive good quality of outdoor base station signals, etc.

4.2.1. Analysis of Femto Cells

The parameters relevant to femto cells and the path loss model are listed in Table 4 [20]. When femto cells are installed, their output SNR versus the distance between the transmitter and the receiver has

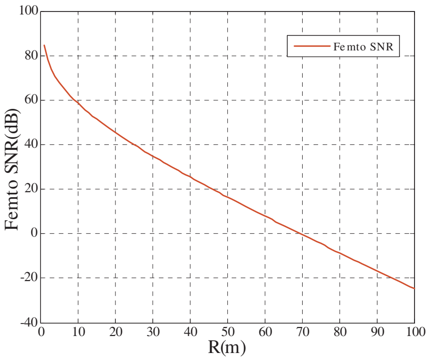

Figure 14. SNR vs. Distance in femto cell.

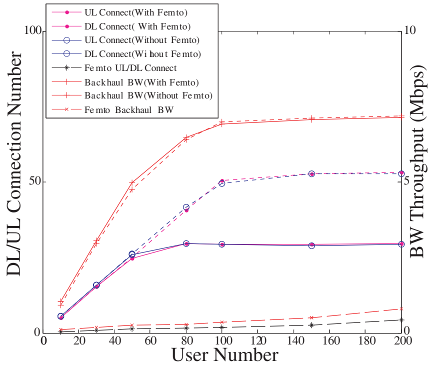

Figure 15. Users connected in the DL/UL and throughput in the base stations and femto cells with and without the deployment of femto cells.

Table 4. Parameters of femto cell.

BS Power	200 mw
BS antenna gain	5 dBi
Path Loss	$PL(\text{dB}) = 38.46 + 20 \log 10R + 0.7d_{\text{2D,indoor}} + 18.3n((n+2)/(n+1) - 0.46) + q * L_{iw})$
shadowing standard deviation	10
q	1
n	
L_{iw}	5 dB

the results as shown in Figure 14.

In the path loss model the relevant parameters are:

R: the Tx-Rx separation distance in meter.

n: number of floors between the femto cell and UE.

q: number of walls between the femto cell and UE.

L_{iw}: building penetration loss.

$d_{\text{2D,indoor}}$: the distance inside the house.

4.2.2. Performance Analysis When Coordination Is Implemented in Femto Cells

After femto cells are installed, we will discuss, in this subsection, the proper situation to exploit the coordination scheme among femto cells, and the bandwidth utilization will also be considered when various numbers of users are served. Listed in Table 5 and shown in Figure 15 are the bandwidth utilizations of femto cells and the system service qualities when 10 femto cells are installed, while entries listed in Table 6

Table 5. Users connection statuses when femto cells are implemented.

With femto															
	MS Number	10		30		50		80		100		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	5.3	5.3	15.9	15.9	25	25.2	29.8	42.3	28.9	49.3	29	52	30.1	53.4
BS 2	connect	5	5	16.7	16.7	26.2	26.6	30.3	43.6	30.1	53.4	30.3	54	30.1	54
BS 3	connect	4.8	4.8	13.7	13.7	22.9	22.9	28.7	36.1	29.3	48.6	28.5	52.1	28.7	52
Total Femto	connect	0.4	0.4	0.9	0.9	1.3	1.3	1.5	1.5	1.9	1.9	2.6	2.6	4.2	4.2
BS 1	Mbps	0.7	0.3	2.04	1.02	3.2	1.61	3.81	2.71	3.7	3.16	3.71	3.33	3.85	3.42
BS 2	Mbps	0.6	0.3	2.14	1.07	3.35	1.7	3.88	2.79	3.85	3.42	3.88	3.46	3.85	3.46
BS 3	Mbps	0.6	0.3	1.75	0.88	2.93	1.47	3.67	2.31	3.75	3.11	3.65	3.33	3.67	3.33
Total femto	Mbps	0.1	0	0.12	0.06	0.17	0.08	0.19	0.1	0.24	0.12	0.33	0.17	0.54	0.27

Table 6. Users connection statuses when no femto cells are implemented.

Without femto															
	MS Number	10		30		50		80		100		150		200	
BS No.		DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL	DL	UL
BS 1	connect	5.3	5.3	15.8	15.8	24.2	24.4	30.8	41.8	29	51.1	27.7	51.6	27.3	49.4
BS 2	connect	5.2	5.2	16.2	16.2	27.6	28.3	29.7	41.7	28.3	50.3	31.2	55.2	31.2	54.9
BS 3	connect	5.8	5.8	15.7	15.7	25.7	26.1	28.4	41.5	30.5	47.2	27.8	51.2	29.6	53.9
BS 1	Mbps	0.7	0.3	2.02	1.01	3.1	1.56	3.94	2.68	3.71	3.27	3.55	3.3	3.49	3.16
BS 2	Mbps	0.7	0.3	2.07	1.04	3.53	1.81	3.8	2.67	3.62	3.22	3.99	3.53	3.99	3.51
BS 3	Mbps	0.7	0.4	2.01	1	3.29	1.67	3.64	2.66	3.9	3.02	3.56	3.28	3.79	3.45

are the results when no femto cells are installed. When femto cells are installed, their bandwidth occupancies are analyzed in Table 5. In the table, the term 'Total Femto' is the total bandwidth utilization by summing the overall bandwidth utilizations from all femto cells.

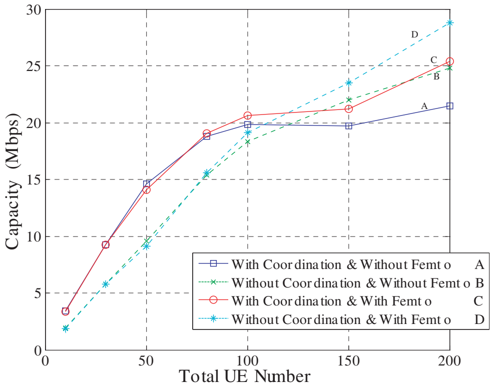

Figure 16. System capacities with or without coordination scheme and with or without femto cell installed.

5. CONCLUSION

As analyzed and simulated in this paper for next generation wideband communication system, the system spectrum efficiency could be increased, and signal quality could be improved with the implementation of the coordination scheme among base stations. When femto cells were installed in the system and with coordination scheme exploited, the system performance was improved in the indoor communication, and consequently the overall system performance was improved. System bandwidth utilization is also studied for four cases, with and without the installation of femto cells and with and without the implementation of coordination scheme. The simulation results are shown in Figure 16. From this figure, we get the following conclusions:

- For less than 100 users, the bandwidth utilization with coordination scheme (line A and C), whether femto cells are installed, is better than that without adopting coordination scheme.

- For more than 125 users, the system with femto cells installed but without implementing coordination scheme has the best bandwidth utilization (line D) while the system with coordination scheme implemented but without installing femto cells has the worst bandwidth utilization (line A).

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