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STUDYING THE EFFECT OF INCREASING CAPACITY USING COMP TECHNOLOGY IN LTE-A NETWORKS

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Abstract

Although LTE-A networks support a high-speed data rate, a large increase in capacity leads to a decrease in the level of performance, especially at the edge of the cell. Coordinated Multi-point (CoMP) technology is a fourth generation (4G) technologies that has improved performance at Cell Edge (CE) not only in terms of the throughput but also efficiency and the coverage of the system as a whole. In this paper, a new model of CoMP technology is proposed. The proposed model demonstrates the performance of LTE-A networks at high capacity using 60 users for each sector in downlink transmission. The performance of the user in terms of peak throughput and Spectral Efficiency (SE) is evaluated with the existence and absence of CoMP not only for users at the CE but also for the whole cell as well. This paper also discusses increasing network capacity via varying user numbers up to 60 users for each sector at several Transmission Time Interval (TTIs). The results show the effect of the number of users on the network performance is higher than that of TTI. The comparison between simulation results when using CoMP technology and not using CoMP technology shows that the throughput can be increased by 13.3% in the cell and 11% at the CE besides improving the SE by 8%.

Keywords: Capacity, CoMP, LTE-A, Modelling, Spectral efficiency.

1. Introduction

Third Generation Partnership (3GPP) introduced a new specification called LTE-A to overcome one of the drawbacks of LTE, which is represented by limited capacity within a cell and user performance at the CE, through one of the LTE-A technologies which is the CoMP [1]. CoMP is used in transmission and reception to improve coverage and CE throughput by allowing multiple points to share their antennas in a coordinated manner [2]. Capacity is a measure of the maximum size of the data transmitted between the network sites via a link or network path. Collaborating base stations improve system capacity by increasing signal to interference ratio (SINR), especially for users at the CE. To alleviate interfering signals, which are among the most important negative effects in the cellular network systems at this time, between the transmitted points or to convert the interfering signal to a useful signal, and this serves the user at the CE where the performance is worst [3-5].

This paper is divided into five sections: Section (2) represents related work. Section (3) introduces the principles, techniques, and types of CoMP in the downlink transmission; Section (4) explains the modelling and simulating of the CoMP technique. In section (5) showing and discusses the simulation results. The final section (6) presents the Conclusion and recommendations for further research.

2. Related Work

The researchers balanced the load to save energy and improve SE through the Algorithm Suitability Theory (AST) in LTE-A networks [6]. On the other hand, the implementation of this technique is costly due to the signal processing and linking of the collaborating base stations. However, this problem is resolved by using one or two types of least expensive known as “intra-site,” where the cooperating stations are within the same location, so you do not need to incur a high cost [7-9]. LTE - A added many other features, such as carrier aggregation, spatial multiplexing, CoMP, and relaying [10]. The performance of downlink CoMP technology with joint processing (JP) coordination type in a homogenous network is evaluated in this research. Furthermore, the average users' throughput and the SE at the CE are shown with a varying number of users at different TTI with existence and absence CoMP.

CoMP technique is important in wireless networks and has been the focus of many studies related to this technology in 3GPP for LTE-A. In [11] the authors show the effect of CoMP technology on the 802.16e system through some applications. The model used contains 30 users in each sector only. In [12], an extensive survey on downlink communication with CoMP operation was introduced for LTE-A. It involved CoMP (technique and architecture) for LTE-A standards and the results of the cooperative transmission technique that improved the performance of cellular system spatially for CE users' throughput gain. In [13], the authors used discrete event simulation (DES) of the 4G network with CoMP joint transmission (CoMP-JT). The simulation results displayed extensive gains of the system throughput linked with specific and fixed scenarios. The results showed the use of the CoMP-JT technique on users in areas having low Inter-Cell Interference (ICI) leads to poorer performance than the scenarios with no support at all. Another research [14] presented a proposal for using Radio Resource Allocation (RRA) algorithms to improve peak data rate and throughput at edge cells in LTE networks to serve multiple users up to a maximum of 50 users in each cell. The results indicated that the Exponential Proportional Fair (EXP PF) algorithm is suitable for scheduling real and non-real time flows in LTE networks. The research [10] investigated several CoMP schemes by joining the analysis of flow-level and numerical results from a simulator of the LTE-Advanced network.

Practical CoMP deployment and studies to enhance the SE and SINR were applied for inter and intra-site CoMP situations in [15] which examined the networks of CoMP (ideal and real) in diverse clustering types. The results showed the cumulated number of sectors coordinated with each other in small cluster sizes had SINR compared to larger sized clusters. The downlink-CoMP joint transmission (D-CJT) scheme, which was proposed by [16], shows improvement in the performance of multiple CoMP transmission scenarios. Those good performances proved that the D-CJT structure would be a more suitable application for accurate networks to improve the throughput of the system. The evaluation was based on mean throughput possible in different traffic values and the results showed that intra-site management significantly improves the blind beamforming system, and mainly the enhanced joint transmission system to increase the throughput.

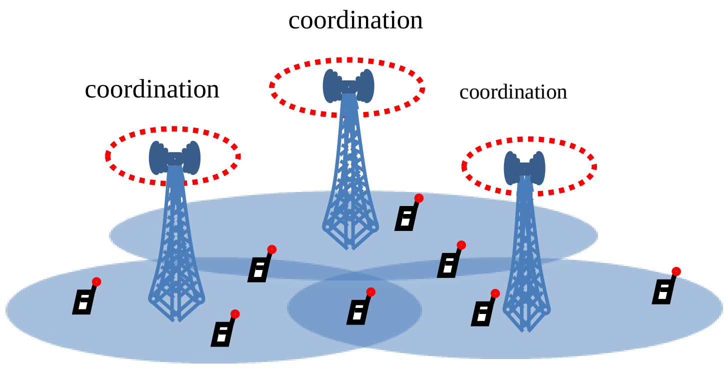
The Vienna Simulator (System-Level (V1.8)) of LTE-A Downlink is used to investigate the effect of schedulers and different spatial deployment situations on performance such as throughput, cell SE and SINR with many small cells [17]. Another research achieved complete estimations in terms of energy efficiency and the overall capacity of the system. The estimation results illustrated that the anticipated algorithm of semi-dynamic cluster division can expand the capacity of the system and the Quality of Services (QoS) of (CE) users and also achieve higher Energy Efficiency (EE) of the network when compared with the algorithm of a static cluster and Non-CoMP methods [3].

The authors in [18] presented a comparison, simulation, and analysis between the two types of coordinated scheduling in CoMP technology. Centralized and decentralized scheduling (CS, DC) in LTE-A networks in downlink transition was performed by changing the bandwidth and number of mobile users to reach (50) user. The results showed Centralized Scheduling (CS) was better than (DC) due to its effectiveness in improving spectral efficiency and providing fairness among users despite increasing their number. Therefore, this type of coordination technology scheduling (CS) is adopted in this paper, with more users (up to 60) per cell.

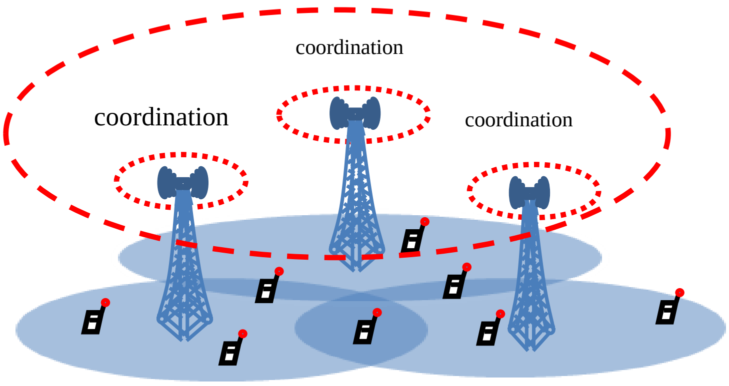
3. Coordinated Multi-Point (CoMP) Principles

CoMP is one of the LTE – A technique with a significant role in reducing the impact of ICI, especially at the CE. In addition to its role in improving the data rate of user in the up and downlink transmission, it increases the throughput of the user and the system as a whole [19]. The principle of this technique is that several points coordinate among one another so that the transmission of the signal among them is not interfered with or the possibility of exploiting this overlap as a useful signal [20]. The CoMP is divided according to the location of the coordination points to either intra-site or inter-site CoMP. The first type is coordination between the sectors that belong to the same base station, while in the second type, the coordinated base stations are in different locations as shown in Fig. 1 [21].

The 3GPP has defined two CoMP schemes, which are detailed in the diagram in Fig. 2.



(a) Intra-site



(b) Inter-site

Fig. 1. CoMP types.

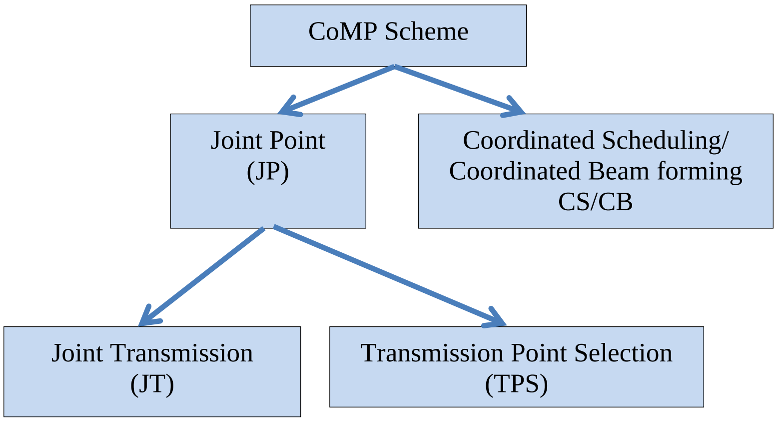
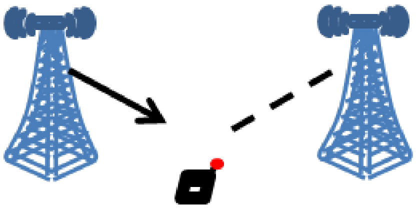
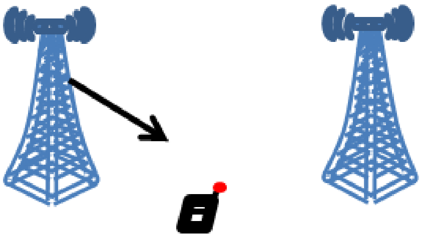


Fig. 2. CoMP scheme classifications.

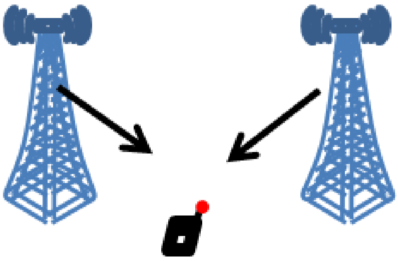
The first category is Coordinated Scheduling/ Coordinated Beamforming (CS/CB). Only the channel status information related to multiple users is effectively shared between multiple points in a Coordinated Scheduling/ Beamforming as shown in Fig. 3(a). The information for each user is available only at one point of transmission and cannot be shared. The users on the CE are given a different amount of a different Resource Block (RB) which has a significant role in reducing interference [1]. It is noteworthy that the maximum RBs allocated to frequencies 1.4, 3, 5, 10, 15, and 20 MHz are 6, 15, 25, 50, 75, and 100 RB, respectively.



(a) Coordinated Scheduling/Coordinated Beam forming (CS/CB).



(b) Transmission Point Selection (TPS).

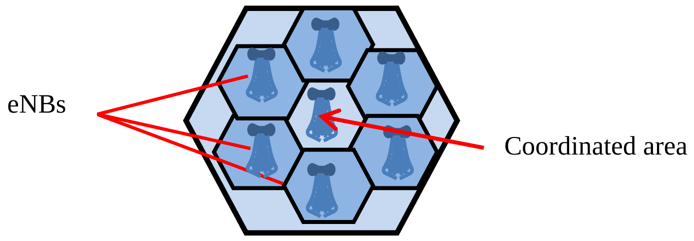


(c) Joint Transmission (JT).

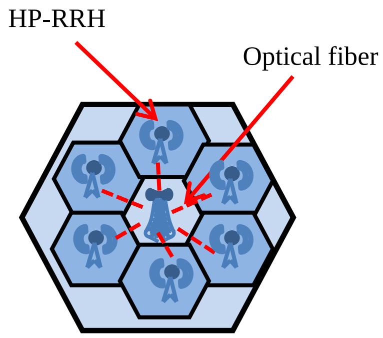
Fig. 3. CoMP classifications.

Joint Point (JP) is the second type in which data are available in multiple Base Stations (BS) and are sent synchronously to a single user to avoid ICI. Based on the configuration of the coordinates that send the data, JP is divided into Transmission Point Selection (TPS) and Joint Transmission (JT). In TPS, the data are sent from one cell as shown in Fig. 3(b). This transmitter point is chosen from among the multiple transmitter points according to certain criteria. The user in the JT type receives data from several BSs with the same radio resources. This type of transmitter also transmits interference signals to a truly desirable signal as shown in Fig. 3(c). This section of CoMP is used in this paper.

3GPP provides different scenarios for CoMP to identify the nature of the work of CoMP in different networks. For example, the homogeneous networks, which are adopted in this paper, the nature of the deployment of CoMP in this particular type can either be intra-site, which uses low power- Remote Radio Head (RRH), or with inter-site, which needs higher power-RRH. In the first type, the cells of the base station cooperate in a coordinated manner in a commonplace. This makes the CoMP performance faster compared to the second type which needs optical fiber to connect RRH with stations. Figure 4 illustrates both types [22].



(a) Scenario (1) Intra-site.



(b) Scenario (2) Inter-site.

Fig. 4. CoMP scenarios.

3GPP also divides the implementation of CoMP based on the presence or absence of a central control unit in the network architecture. In the case of centralized control, this unit is responsible for receiving Channel State Information (CSI) from Users' Equipment' (UEs) of the cooperating cell. Besides, the responsibility for scheduling is assigned to this unit. On the other hand, the absence of the central control unit makes the implementation of CoMP and scheduling uncertain, and CSI is exchanged among the cells. Furthermore, the coordination and scheduling processes take place at each BS individually [4]. The two previous methods mentioned are shown together in Fig. 5.

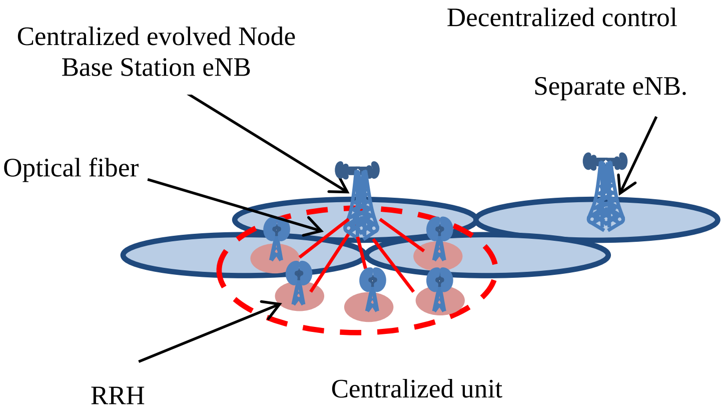
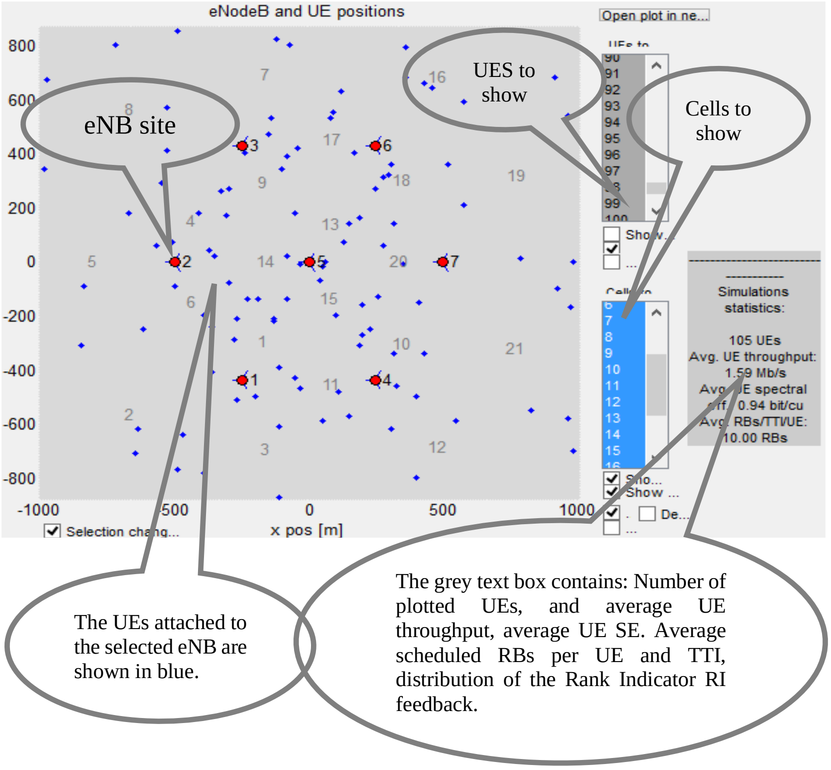


Fig. 5. Centralized and decentralized of CoMP classification.

4. Modeling and Simulating of CoMP Technique

A new model of CoMP technology is proposed using Vienna System-level simulator v1.9 which is licensed by the University of Vienna. This model is used to evaluate the performance in DL transmission. The main page Graphical User Interface (GUI) that represents a new model of CoMP is shown in Fig. 6, which shows the locations of the users, BSs., active and passive users in the network, and the statistical results. The new model has several assumptions such that:

- The homogenous networks are used.
- The proposed model contains seven evolved NodeB (eNB).
- Each eNB carries three sectors. The maximum cells are twenty-one cells. The cell radius is 250m.
- Assumed there is no shadow fading to simplify the model by setting its value at 0dB.
- The maximum number of users in each cell are 60 users.
- Channel speed is maintained.
- This model supported the algorithm of beamforming instead of (v1) mode.
- The transmit antenna ports equal four.
- The received antenna ports equal one.
- 2.14 GHz is the system frequency.
- The number of eNB rings equals one.
- Round Robin (RR) scheduler is used.



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Simulations
statistics:

105 UEs
Avg. UE throughput:
1.59 Mb/s
Avg. UE spectral
eff.: 0.94 bit/cu
Avg. RBs/TTI/UE:
10.00 RBs
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The UEs attached to the selected eNB are shown in blue.

The grey text box contains: Number of plotted UEs, and average UE throughput, average UE SE. Average scheduled RBs per UE and TTI, distribution of the Rank Indicator RI feedback.

Fig. 6. Graphical User Interface (GUI) of Vienna system level simulator.

The new model divides into two parts: The first part represents the traditional LTE-A system while the presence of CoMP technology is the second part. Table 1 shows simulation parameters in the first part.

Table 1. Parameters with no CoMP.

simulation_type	tri_sector_tilted
simSet	[1 1 1]
eNodeB_tx_power	50 Watt
Bandwidth	10 MHZ
Scheduler	round-robin
UE_speed	5/3.6
channel_model.type	TU
UE_per_eNodeB	10-30-40
simulation_time_tti	(200-400-600-800-1000) TTI
nTX	simSet(2)
nRX	simSet(3)
tx_mode	simSet(1)
network_geometry	regular_hexagonal_grid

The maximum power transmission is 50 W at 10 MHz bandwidth according to [8]. This simulation is applied to many users per evolved Node Base station (eNB) randomly distributed through several TTI. The UEs were assumed to be moving at the set speed of 5km/h because the speed effect was not the focus of this research. The UEs' speed was assumed to be 3 km/h in [12]. On the other side, the model assumptions of the second part with the present CoMP are shown in Table 2.

Table 2. Parameters with CoMP.

simulation_type	tri_sector_tilted
simSet	[6 4 1]
nRX	simSet(3)
nTX	simSet(2)
tx_mode	simSet(1)
eNodeB_tx_power	50 Watt
Bandwidth	10 MHZ
Scheduler	CoMP
CoMP_scheduler	round-robin DB
CoMP_configuration	intra_site
UE_speed	5/3.6
channel_delay	3 ms
simulation_time_tti	200-400-600-800-1000
UE_per_eNodeB	10-30-40
nr_eNodeB_rings	1ring

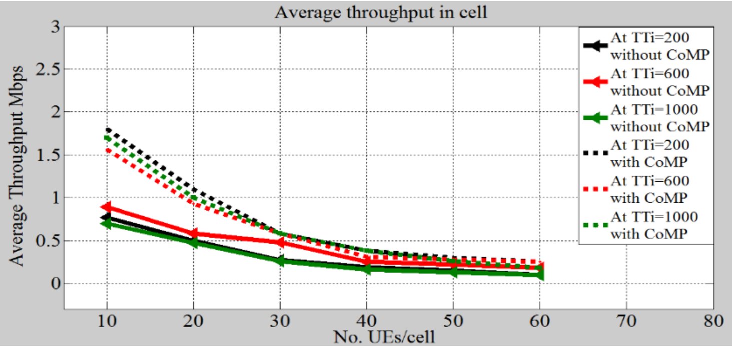
It is worth mentioning that the parameters in Table 2 are almost identical to Table 1, with some differences and additions that are consistent with the CoMP architecture. With CoMP technology, a special parameter describes the type of Round Robin (RR) algorithm behaviour used. Another parameter mentions that the type of CoMP scheme is intra-site. User numbers vary from 10 to 60 users per eNB, while varying the simulation time gives sufficient time to the cooperating stations to coordinate among themselves for maximum benefit from this technique. When the number of users increases, a growing number of users are likely to be on a CE with bad service. The advantages of CoMP technology are highlighted here to improve network operation and thus increase the efficiency and performance of the system, particularly users at CE. The results of the presence and absence of CoMP are shown in the next section.

5. The simulation Results

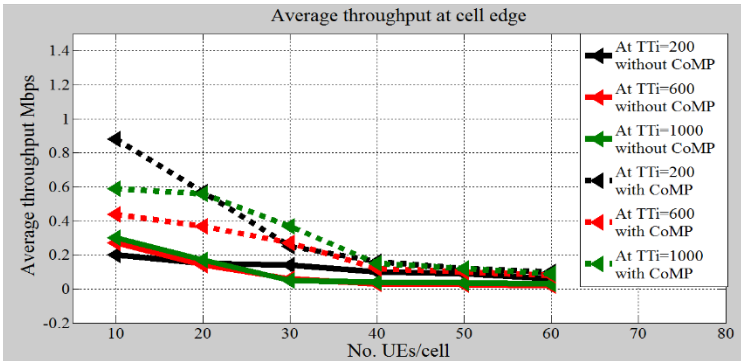
5.1. Average throughput in the cell

Figure 7(a) shows the relation between average throughput of cell and various groups of users per cell (10, 30, 40, 50, and 60) for several TTI (200, 600, and 1000) TTI with and without CoMP in the cell as a whole. On the other hand, Fig. 7(b) shows this relation at CE.

As expected, the average throughput increases with CoMP compared to non-existence. The throughput improvement percentages are (18.75%, 13.3%, and 8%) when user number equals to 30 per cell at 200, 600, and1000 TTI respectively, the irregularity of the curves at 30 users within the cell is due to random movement and distribution of users within the cell. For CE, again the average throughput with CoMP increases compared to non-existence, however at 1000 TTI its improvement reaches 49.15%, 69.64%, 66.6%, 76.4%, 68.33% and 65.55% for 10, 20, 30, 40, 50 and 60 users per cell respectively as shown in Fig. 7(b). The presence of several basic stations collaborating among them contributed to the increase in throughput because of their role in reducing interference in the case of using CoMP technology compared to non-use, which is what the previous results have shown. The reason for decreasing the throughput when increasing TTI is the increase in latency, which increases the likelihood of a collision.



(a) The average throughput of cell with and without CoMP.

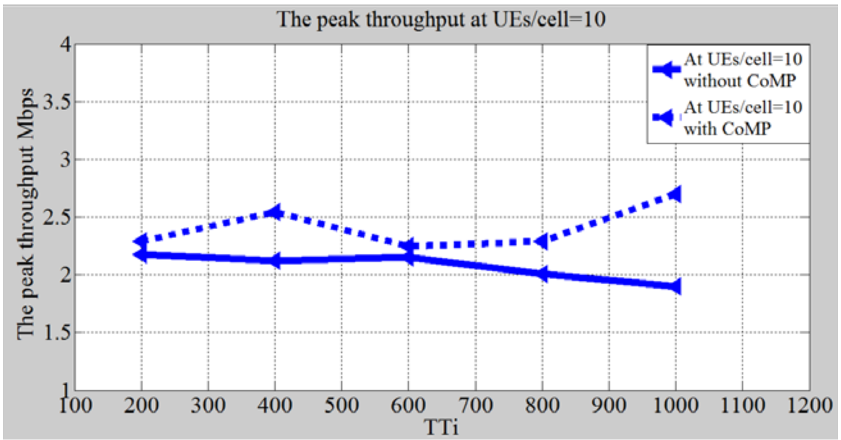


(b) The average throughput at CE with and without CoMP.

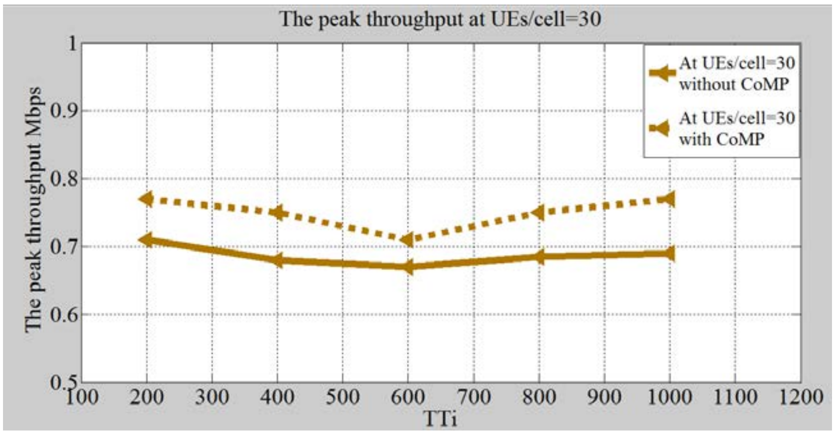
Fig. 7. The relation between average throughput of cell and various groups of users per cell.

5.2. The peak throughput

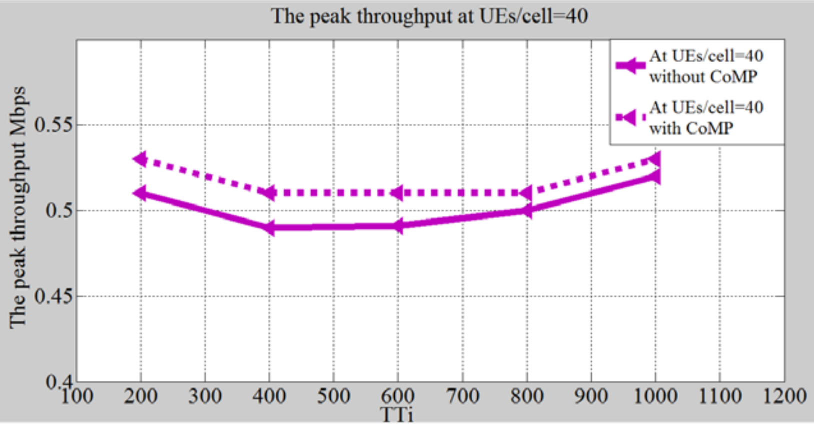
Another result found in this study through one of the statistical results of the cell is the peak throughput. By varying user groups to 10, 30, and 40 per cell in different simulation times (200, 400, 600, 800, and 1000) TTI. Figure 8 shows the relation between the peak throughput of users in the cell and the number of users at different TTI. It also illustrates improved network performance by increasing cell throughput when using the CoMP technique, which makes the average percentage of improvement equal to 9.33%, 4.22%, and 3.92% at users' numbers equal to 10, 30, and 40, respectively.



(a) The relation between a peak throughput in the cell and TTI at UEs/cell=10.



(b) The relation between a peak throughput in the cell and TTI at UEs/cell=30.



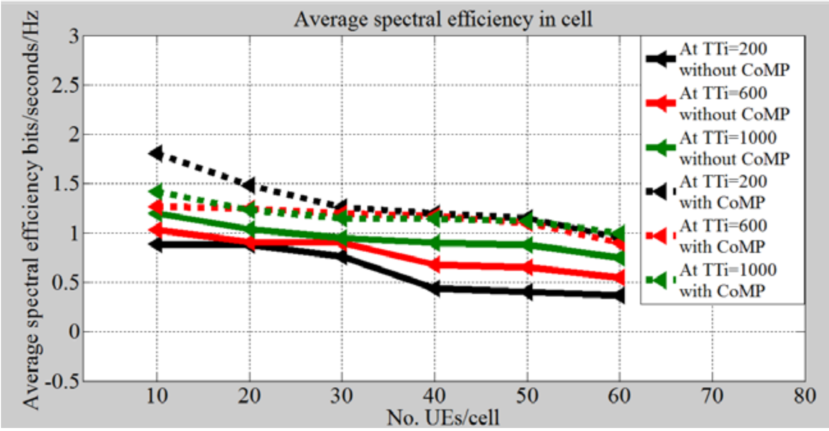
(c) The relation between a peak throughput in the cell and TTI at UEs/cell=40.

Fig. 8. The relation between a peak throughput of users in the cell and number of users at varying TTI.

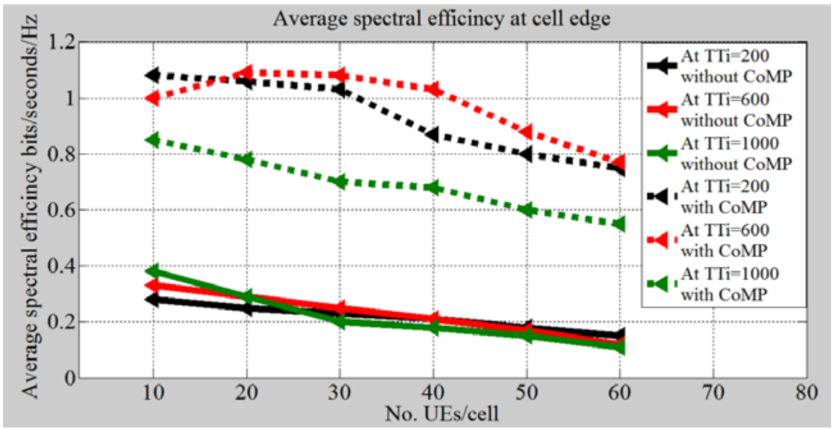
The value of throughput decreases with the increasing number of users. This result is expected because the number of resource blocks (RB) is limited.

5.3. The spectral efficiency

The SE result for 10, 20, 30, 40, 50, and 60 number of users per cell at the simulation time with 200-600 and 1000 TTI values are shown in Fig. 9. Part (a) of this figure shows the average SE for all users within the cell while part (b) shows that of the users at the cell edge.



(a) The average SE for all users in the cell.



(b) The average SE for all users in the CE.

Fig. 9. The relation between a SE and the number of users for varying TTI.

For 30 users per cell, the simulation results show an average SE percentage increase of 30.5%, 23.96%, and 14.28% at 200-600 and 1000 TTI values, respectively. CoMP has a significant effect on increasing SE by reducing interference. The presence of some cooperating base stations will increase the data and thus increase the probability of transmitting information with the same radio sources (time and frequency). In this case, interference will be reduced, and SE will increase. However, the change of TTI does not have a clear effect on SE results because it is not considered to have a significant effect as much as other factors such as SINR and the amount of information sent at each TTI when CoMP is applied, the reason for the irregular change in some of the SE results being the random movement of users within the cells of the cooperating base stations.

6. Conclusions and Future Work

A new model of CoMP is proposed. The effect of CoMP JT on the performance of downlink transmission for LTE-A cellular networks is evaluated by a new model. This evaluation was done using the Vienna system-level simulation (V1.9) to show the enhancement in system performance through the application of CoMP technology. With and without CoMP, when either TTI or number of users is increased, the average throughput and the average SE are reduced in the cell and its edge. However, the effect of the number of users on the network performance is higher than that of TTI. The results show the performance improvement of the cellular network when using CoMP technology, especially users at CE for the possibility of this technology to reduce the impact of interference. The simulation results show an increase in average throughput of up to 13.3%. With the same approach, the percentage of increase in peak throughput reaches up to 9.33% with SE improvement of 30.5%. In future work, it is possible to estimate the effect of increasing the bandwidth on the system performance (the average throughput, SE, and RB allocation per user at a given time) when the CoMP is considered.

Acknowledgment

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Abbreviations

3GPP	Third Generation Partnership
AST	Algorithm Suitability Theory
BS	Base Stations
CB	Coordinated Beamforming
CoMP	Coordinated of Multipoint
CoMP-JT	Coordinated of Multipoint -Joint Transmission
CS	Centralized Scheduling
CSI	Channel State Information
D-CJT	Downlink-Comp Joint Transmission
DES	Discrete Event Simulation
DS	Decentralized Scheduling
EE	Energy Efficiency
eNB	Evolved Nodeb
EXP PF	Exponential Proportional Fair
GUI	Graphical User Interface
ICI	Inter-Cell Interference
JP	Joint Processing
QoS	Quality of Services
RB	Resource Block
RI	Rank Indicator

RR	Round Robin
RRA	Radio Resource Allocation
RRH	Remote Radio Head
SE	Spectral Efficiency
SINR	Signal to Interference Ratio
TPS	Transmission Point Selection
TTI	Transmission Time Interval
UEs	Users' Equipment

References

1. Neyja, M.; Mumtaz, S.; and Rodriguez, J. (2017). Performance analysis of downlink CoMP transmission in Long Term Evolution-Advanced (LTE-A). *Proceedings of 7th International Conference on Advances in Cognitive Radio.* Italy, 37-42.
2. Haddadi, S.; and Ghasemi A. (2017). Coordinated multi-point joint transmission evaluation in heterogeneous cloud radio access networks. *Proceedings of 25th Iranian Conference on Electrical Engineering, ICAEE Press*. Iran, 1938-1943.
3. Kong, Q.; Ma, M.; and Lu, R. (2017). Achieving Secure CoMP Joint Transmission Handover in LTE-A Vehicular Networks. *Proceedings of 86th Vehicular Technologies conference.* Toronto, Canada, 1-5.
4. Cantor, O.D.R.; Belschner, J.; Hegde, G.; and Pesavento, M. (2017). Centralized coordinated scheduling in LTE-Advanced networks. *Journal of Wireless Communications and Networking (EURASIP),* 2017(1), 1-14.
5. Abdal-Kadhim, A.; and Leong, K.S. (2018). Application of thermal energy harvesting in powering WSN node with event-priority-driven dissemination algorithm for IOT applications. *Journal of Engineering Science and Technology,* 13(8), 2569-2586.
6. Fall, H; Zytoune, O; and Yahyai, M. (2018). Theory of algorithm suitability on managing radio resources in next generation mobile networks. *Journal of Communications Software and Systems,* 14(2), 180-188.
7. Ayoob, S.A.; and Hammodat, A.N. (2018). Modelling and simulating of Coordinated Multi-Point (CoMP) technology in LTE-A. *Journal of International Journal of Computer Applications,* 182(17), 34-39.
8. Martinez, A.B.; Grieger, M.; Festag, A.; and Fettweis, G. (2015). Sectorization and intra-site CoMP: Comparison of field-trials and system-level simulations. *Proceedings of Global Communication Conference, IEEE Press.* San Diego, USA, 1-7.
9. Alsharbaty, F.S.; Ayoob S.A.; and Allawzi M.J. (2020). Compensation the noisy channel of 802.16E system in downlink using CoMP technique. *Journal of Engineering Science and Technology (JESTEC),* 15(2), 805-819.
10. Khlass, A.; Bonald, T.; and Elayoubi, S. (2015). Analytical modelling of downlink CoMP in LTE-Advanced. *Proceedings of Vehicular Technology Conference, IEEE Press.* Glasgow, UK, 1-6.
11. Alsharbaty, F.S.; Shee, Y.S.T.; and Alshorbaji, M.A. (2019). Influence of coordinated multipoint transmission on the traffic of 802.16e system.

Proceedings of 6th International Conference on Electrical and Electronics Engineering (ICEEE). Istanbul, Turkey, 139-143.

12. Ali, M.S. (2014). On the Evolution of Coordinated Multi-Point (CoMP) transmission in LTE-Advanced. *International Journal of future Generation Communication and Networking,* 7(4), 91-102.
13. Artuso; M.; and Christiansen, H. (2014). Discrete-event simulation of coordinated multi-point joint transmission in LTE-Advanced with constrained backhaul. *Proceedings of IEEE 11th International Symposium on Wireless Communication Systems, IEEE Press.* Barcelona, Spine, 106-110.
14. Ambreen, A; Beg, M.T.; and Ahmad, S. (2015). Resource allocation algorithms in LTE: a comparative analysis. *Proceeding of the IEEE India International Conference INDICON IEEE.* New Delhi, India,1-6.
15. Muqaibel, A.H.; and Jadallah, A.N. (2015). Practical performance evaluation of Coordinated Multi-Point (CoMP) networks. *Proceeding of the 8th GCC Conference and Exhibition, IEEE Press.* Muscat, Oman, 1-6.
16. Sun, H.; and Yang, T. (2015). Performance evaluation of distributed scheduling for downlink coherent joint transmission. *Proceeding of 82nd Vehicular Technology Conference, IEEE press.* Boston, USA, 1-5.
17. Olaifa, J.O.; and Arifler, D. (2016). Using system-level simulation to evaluate downlink throughput performance in LTE-A networks with clustered user deployments. *Proceedings of 1st International Workshop on Link- and System Level Simulations, IEEE Press.* Vienna, Australia, 17-22.
18. Abdullah, B.S.; Magla, M.R.; Asaduzzaman, M.; and Hossain, M.F. (2018). Performance of Coordinated Scheduling in Downlink LTE-A under User Mobility. *Proceeding of the 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT).* Bangladesh, 215-220.
19. Karmakar, R.; Chattopadhyay, S.; and Chakraborty, S. (2018). a learning-based dynamic clustering for Coordinated Multi-Point (CoMP) operation with carrier aggregation in LTE-Advanced. *Proceedings of 10th International Conference on Communication Systems & Networks, IEEE Press.* Bengaluru, India, 283-290.
20. Li, Z.; YuqP, L.; Yu, Z.; and WeP, W. (2016). Downlink CoMP Resource Allocation Based on Limited Backhaul Capacity. *Journal of China Communications, IEEE Press,* 13(1), 38-48.
21. Shang, P.; Zhang, L.; You, M.; Yang, Y.; and Zhang, Q. (2015). Performance of uplink joint reception CoMP with Antenna selection for reducing complexity in LTE-A systems. *Proceedings of Wireless Communications and Networking Conference, IEEE Press.* New Orleans, USA, 977-982.
22. Qamar, F.; Dimyati, K.B.; Hindia, M.N.; Noordin, K.A.B.; and Al-Samman, A.M. (2017). A comprehensive review on coordinated multi-point operation for LTE-A. *Journal of ELSEVIER journal,* 123(2017), 19-37.