Wider Bandwidth In LTE-Advanced System Using Carriers Aggregation

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Abstract:

In order to achieve up to 1 Gbps peak data rate in future IMT-Advanced mobile systems, Carrier Aggregation (CA) technology is introduced by the 3GPP to support very-high-data-rate transmissions over wide frequency bandwidths up to 100 MHz in its new LTE-Advanced standards [1]. This technique makes it possible for multiple spectrum bands to be utilized by the same user in order to satisfy the large bandwidth demand of the service and achieve better performance [2]. This paper provides an overview of carrier aggregation and discusses major technical issues including aggregation structure, scenarios and CA implementation in LTE-Advanced systems [3]. A simulation model of LTE-Advanced in the downlink is developed to investigate the impact of intra-band contiguous CA using up to two Component Carriers (CCs) on the system performance in terms of throughput [4]. The throughput increases from 5.152Mbps to 88.688Mbps when the bandwidth increases from 1.4MHz to 20MHz and when we aggregated two CCs each one with 20MHz, the throughput increased from 88.688 Mbps to 168.816Mbps and the bandwidth because 40MHz. The carrier aggregation is technologically feasible and can be used to significantly increase LTE-A peak data rates.

Keywords: LTE_A, carrier aggregation, component carrier, downlink and throughput.

عرض نطاق ترددي واسع في أنظمة LTE المتقدمة باستخدام تجميع الناقلات

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المستخلص :

من أجل تحقيق زياده في معدل بيانات الذروة لتصل إلى 1 جيجابت في الثانية في الأنظمة المتنقلة لمستقبل الاتصالات المتنقلة الدولية المتقدمة ، 3GPP عرفت تكنولوجيا تجميع الناقل (CA) لدعم الإرسال لبيانات عاليه الذروة جدا عبر نطاقات تردد واسعة تصل إلى 100 ميغاهيرتز في معايير LTE المتقدمه. هذه التكنولوجيا تجعل من الممكن لنطاقات الطيف المتعددة امكانية استخدامها من قبل المستخدم نفسه من أجل تلبية الطلب الى خدمات ذو نطاق ترددي واسع وتحقيق أداء أفضل.هذه الورقة تقدم لمحة عامة عن تجميع الناقل وتناقش القضايا الفنية الرئيسية بما في ذلك هيكلية التجميع، وتنفيذ سيناريوهات تجميع الناقل في انظمة LTE المتقدمة. قد تم تطوير نموذج محاكاة لنظام LTE المتقدم في الوصلة الهابطة لبحث تأثير تجميع الناقلات المتجاورة من خلال تجميع مكونين اثنين من الناقلات ودراسة تأثيرها على اداء النظام من حيث الانتاجية. الزيادات الإنتاجية قد زادت من 5.152 ميغابت في الثانية إلى 88.688 ميغابت في الثانية بزياده عرض النطاق الترددي من 1.4 ميغا هيرتز إلى 20 ميغا هيرتز وبتجميع مكونين اثنين كل مكون 20 ميغا هيرتز، قد زادت الإنتاجية من 88.688 ميغابت في الثانية الى 168.816 ميغا بت في الثاني ة وعرض النطاق الترددي يصبح 40 ميغا هيرتز. ويعتبر تجميع الناقل هو ممكن من الناحية التكنولوجية، ويمكن استخدامه لتحقيق زيادة كبيرة في معدلات بيانات الذروة في نظام LTE المتقدم.

الكلمات المفتاحية: LTE_A، تجميع الناقل، الناقل المكون ,الوصلة الهابطة و الانتاجية.

1. Introduction

With an ever increasing demand on wireless broadband services consuming higher data rate and wider bandwidth, the International Mobile Telecommunication-Advanced (IMT-Advanced) system has initiated the standardization process for the fourth generation (4G) mobile communication systems. The3rd Generation Partnership Project (3GPP) has been submitted Long Term Evolution-Advanced (LTE-Advanced) (Release 10 (R10)) to be the standard for the 4G system since it will support high peak data rates for Users Equipments (UEs), up to 1 Gbps in static and pedestrian

environments, and up to 100 Mbps with high mobility speed in downlinks (DL) and 500 Mbps in uplink (UL) [5, 6].
LTE-Advanced system (R10) is seen as the next major evolutionary step in the continuing development of LTE system. The expectation of implementing LTE- Advanced system is to fulfill the requirement of IMT–Advanced requirements. The major components that have been developed in LTE-Advanced system (R10) are a wider bandwidth through aggregation of multiple Component Carriers (CCs), evolved use of advanced antenna techniques with multi-antenna extensions in both UL and DL and Relaying techniques in order to meet the IMT-Advanced targets.
One of the important features of the LTE-Advanced (Release 10) standard is the Carrier Aggregation (CA). CA is achieved by aggregating five CCs over wider bandwidth up to100 MHz, thus improve the system capacity in every cell. Furthermore, LTE-Advanced standards is expected to outperform the requirements of the IMT-Advanced systems in term of peak data rates, transmission bandwidth, high system capacity, peak/average spectrum efficiency, delay performance in control and user planes, mobility and provide maximum flexibility in utilizing the scarce radio spectrum available to operators with very good substantial improvement for cell-edge spectral efficiencies.

2. Carrier Aggregation

A. Concept of Carrier Aggregation:

The basic concept of CA is defined as a set of several operating bands across, which the Base Station (BS) aggregates carriers with a specific set of technical requirements. These operating bands consist of continuous or non-continuous CCs. Both types of CA probably can use the same or different bandwidths to support higher transmission data rate over a wider bandwidth, starting from 20 MHz up to 100 MHz for a single User Equipment (UE) unit in DL or UL between LTE-Advanced evolved Node Base station (eNB) and the UE, while preserving backward compatibility to legacy systems [5, 6, 7].
Continuous CCs is easier to be implemented at the physical layer structure of LTE-Advanced system, thus ease to resource allocation and management algorithms compared to the non continuous CA [6]. However, there is some difficulty to allocate continuous 100 MHz

bandwidth for mobile wireless systems. CA with non-continuous CCs technique provides a practical approach to enable mobile network operators to fully utilize their current spectrum resources, including the unused scattered frequency bands and those already allocated for some legacy systems, such as GSM and 3G systems. But obviously, for non-continuous CA, the deployment of multiple RF receiving units and multiple FFTs is unavoidable in LTE-Advanced UE. Since non-continuous CA supports data transmissions over multiple separated carriers across a large frequency range, the radio channel characteristics and transmission performance, such as propagation path loss and Doppler shift, vary a lot at different frequency bands, and should be fully evaluated and considered in the design of the aggregation algorithms.

In term of spectrum scenarios, CA supports different type of spectrum scenarios: (i) intra-band Contiguous (ii) intra band non-contiguous and (iii) inter-band non-contiguous are some of the spectrum scenarios that have been proposed for CA used in the LTE-Advanced system as shown in Fig.1 [5]. With the development of specific RF requirements, in the DL, both intra – and intre-band scenarios are considered in LTE-Advanced system (R10). But UL is focusing on intra-band scenarios only, due to the difficulties in defining RF requirements for simultaneous transmission on multiple CCs with large frequency separation, considering realistic device linearity.

Furthermore, implementing CA in LTE-Advanced systems (R10) allow fast and seamless connectivity during handover from the source to the target eNBs and also allow smooth network migration and upgrades. Therefore, it is essential to ensure backward compatibility of LTE-A design, so that, UEs for both LTE's (R8, R9) and LTE-Advanced (R10) will be supported by the same carrier that is deployed by LTE Advanced (R10). In CA defined for LTE-Advanced(R10) this is ascertained since each CC is compatible with LTE(R8,R9) and has one of the bandwidths defined in LTE(R8,R9) this would also allow reuse of (R8, R9) RF design and implementation at the eNB and UE [5].

B. CA Scenarios:

Five different deployment scenarios are considered for CA in LTE-A, assuming cells with two different CC frequencies F1 and F2,

and F2 is larger than F1. In Scenario 1, the F1 and F2 CCs are collocated and overlaid. If F1 and F2 are at the same band or the frequency separation is small, it would lead to nearly the same coverage for all CCs. In Scenario 2, the F1 and F2 CCs are collocated and overlaid, but the coverage of them is different due to large frequency separation between CCs, which leads to the different path losses. Only F1 provides sufficient coverage and F2 is used to provide throughput. Mobility is performed based on F1 coverage. Scenarios 1 and 2 are illustrated in Fig. 2 [8]. In Scenario 3 (shown in Fig. 3), the F1 and F2 CCs are collocated and F1 and F2 are typically on different bands. F2 antennas are directed to the cell boundaries of F1 so that cell-edge throughput is increased. F1 provides sufficient coverage but F2 potentially has holes, for example, due to larger path loss. Mobility is based on F1 coverage.

In Scenario 4, one CC provides macrocell coverage and remote radio head (RRH) cells are placed at traffic hotspots for additional throughput by the other CC. Mobility is accomplished based on macrocell coverage. F1 and F2 are generally on different bands in Scenario 4. Scenario 5 is similar to Scenario 2, but frequency selective repeaters are deployed so that coverage is extended for one of the carrier frequencies. It is expected that the F1 and F2 cells of the same eNB can be aggregated where coverage overlaps. Scenarios 4 and 5 are illustrated in Fig. 4 [8].Scenarios 4 and 5 are not supported in LTE-A on uplink operation. Generally, uplink CA is supported for intra band CC configurations with Scenarios 1–3 only. However, all CA scenarios should be supported for the downlink in LTE.

C. Data Aggregation Schemes:

There are two types of aggregation schemes have been proposed to aggregate the CCs in [6]. In first schemes, the CCs are aggregated at physical layer as shown in fig. 5 (a) but one HARQ entity is used for all the aggregated CCs. Also, in this scheme, new transmission configuration parameters should be specified for the entire aggregated bandwidth. In the second scheme, the CCs are aggregated in MAC layer with independently configured transmission parameters for each CC as shown in Fig. 5 (b). Furthermore, this scheme can support more flexible and efficient data transmissions in both uplink and downlink, at the expense of

multiple control channels .In this way, backward compatibility is guaranteed, since the same physical layer and MAC layer configuration parameters and schemes for the LTE systems can be used for the future LTE- Advanced systems compared to the physical-layer scheme.

3. Simulation Results and Analysis:

A. The link level simulation:

In this section, the downlink link level simulations are carried out to evaluate the performances of different bandwidth in LTE where flexible spectrum usage is achieved through this different bandwidth from 1.4 MHz to 20MHz. We investigate the performance of the LTE link level simulator in terms of throughput for different bandwidth. So we have one base station and one user (R8), No CA implemented (we have one CC), with simulation parameters for different bandwidth shown in Table 1. The results obtained as shown in Fig. 6. From the Fig. 6 we noticed that the throughput of the user was increased from 5.152 Mbps to 88.688Mbps when the bandwidth incrased from 1.4 MHz to 20MHz for LTE users with one CC. If we aggregated 2 CCs carriers each one with 20MHz bandwidth in the same band (intra contiguouse CA) ,where CC1 in 800MHz band and CC2 in 800MHz band, the result shown in fig. 7 decleared the throughput inceased with 40 MHz bandwidth from 88.688MHz to 168.816MHz for LTE_A user (R10).

B. The power spectrum of 2CCs aggregation:

Generation of 40 MHz LTE-Advanced contiguous carrier aggregation (Two 20 MHz component carriers) is simulated by the program SystemVue 2013 (product of Agilent Company) [9]. The carrier frequency of the first component equal to 2.59GHz and the second component carrier frequency equal to 2.610GHz.From the Fig. 7 the total bandwidth after aggregated 2CCs is (2670MHz - 2630MHz) 40MHz with sampling frequency equal to 30.72MHz and sampling rate equal to 2x30.72MHz .

C. The system level simulation:

The performance are also calculated by using system level simulation where those performance evaluated in term of per-UE average throughputs and cell spectral efficiency with CA deployment

scenarios 1.Deployment scenario 1 is that cells with carrier frequencies of F1 and F2 are overlaid with F1 and F2 in the same band. In this case, almost the same coverage is provided on both carriers due to the similar path loss within a same band.
For CA simulation, system level simulator is set as follows. Seven cells, each of which is divided into three sectors are considered, and 10 users randomly placed per sector. In order to analyze the performances of CA deployment scenarios 1 with different inter-site distances, two CCs with 20MHz bandwidth in 800MHz band and 2100 MHz band respectively are aggregated. Both CC1 and CC2 are simulated in 800MHz band or 2100MHz band in CA deployment scenario 1, the inter-site distances of 500m and 1732m are used. Other simulation parameters are given in Table 2.

i. Single Carrier Results:

When only a single carrier is used, which is called no CA situation hereafter, 800MHz band and 2100MHz band are considered with different inter-site distances (ISDs). Fig. 9 shows the cell spectral efficiency with no CA situation Fig. 10 shows the average UE throughput with no CA situation. In case of ISD=500m, it shows the performance is better in 2100MHz band than in 800MHz band regardless of the scheduler. Due to a larger path loss exponent in 2100 MHz band, less interference from neighboring cells is generated compared to 800MHz band However, in a large inter-site distance case, interference limitation has little effect on both cases, but effect of noise becomes larger, casing noise limited situation. Therefore, in case of ISD= 1732m, the performance is better in 800MHz band than in 2100MHz band owing to a lower path loss.

ii. Carrier Aggregation Results:

In CA deployment scenario 1, both CC1 and CC2 using frequency of 800MHz band (case1) or 2100MHz band (case2). In CA deployment scenario 1, the results show the same trend as in non-CA case. The average user throughput is roughly doubled in this scenario. When using CA in scenario1, no additional gain is obtained except doubled user throughput with doubled bandwidth. It only has advantage of larger bandwidth available. In order to show the effect of CA, Fig. 11 shows average user throughput for inter-site distance of 500m.

4. Conclusion

A comprehensive overview of Carrier Aggregation techniques and scenarios supporting high-transmission data rate over a wider bandwidth in LTE-Advanced system is highlighted and discussed. A simulation has been developed to evaluate the performance of using carrier aggregation in LTE- Advanced systems. Simulation results prove that, implementing CA with higher numbers of CCs improve system performance in term of user throughput.

In the future, the integration between carrier aggregations with Adaptive Modulation and Coding technique that potentially enhance the system performance will be investigated in particular during handover from the source to the target eNBs.

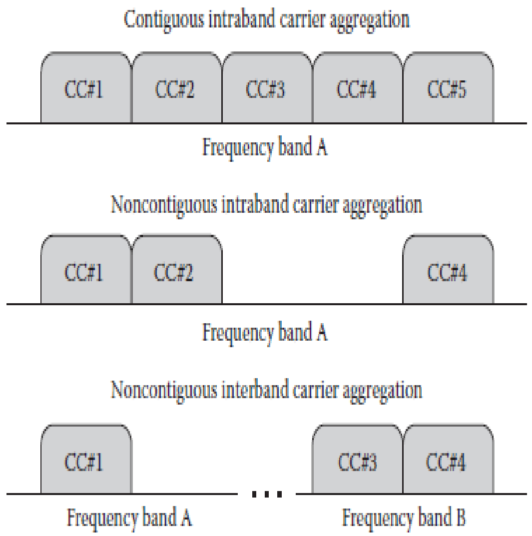


Fig. 1 Carrier aggregation types.

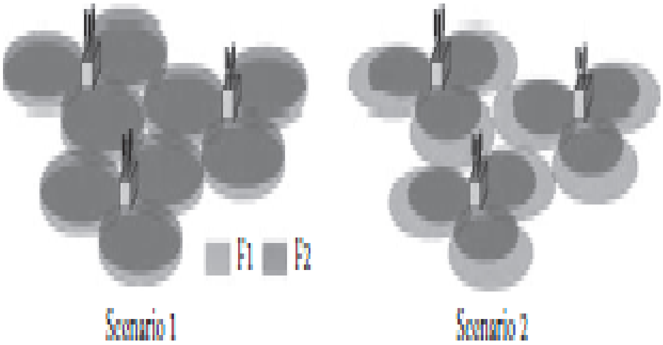


Fig. 2 CCs with overlapping radio coverage.

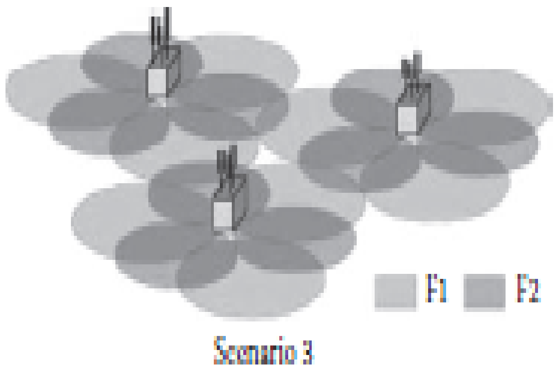


Fig. 3 CCs with different radio coverage.

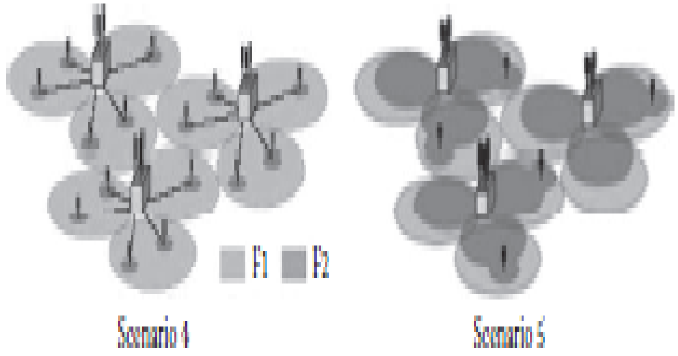
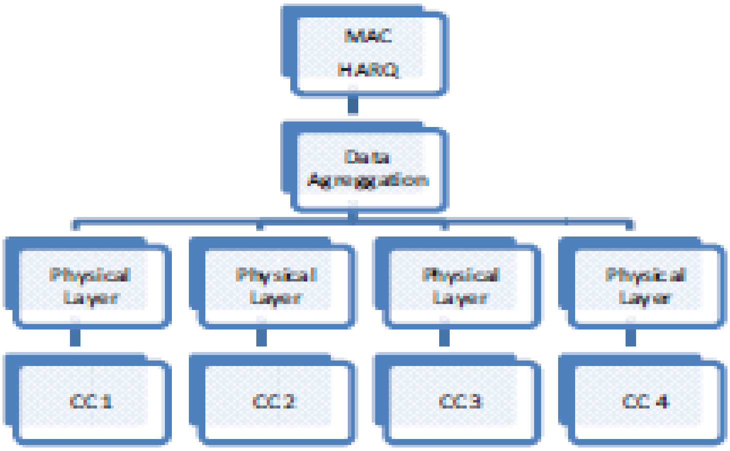
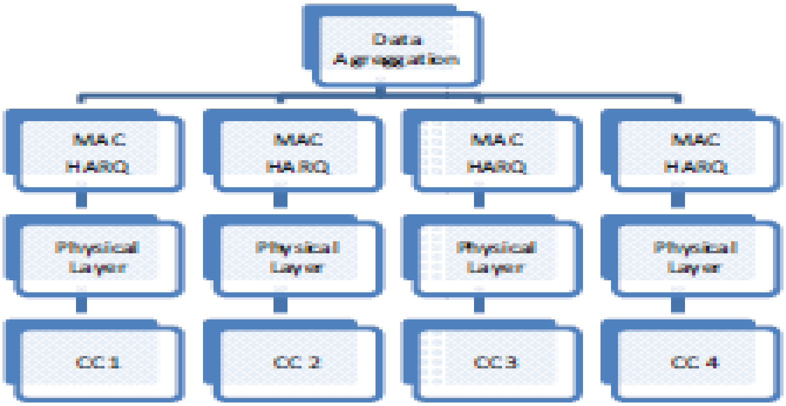


Fig. 4 CCs cooperating with RRHs and repeaters.



(a)



(b)

Fig.5 Data aggregation schemes (a) at physical layer. (b) at MAC layer.

Table 1 Simulation Parameters for one CC with Different Bandwidth

Simulation Type	SISO
Number of User Equipments	1
Number of Base Stations	1
Channel Type	Pedestrian B
Number of transmit antennas	1
Number of receive antennas	1
Number of Iterations	100 sub-frames
Scheduling Algorithms	Round Robin
Bandwidths	1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz
CQI	15 (64QAM)
Frame Structure	Type 1(FDD)

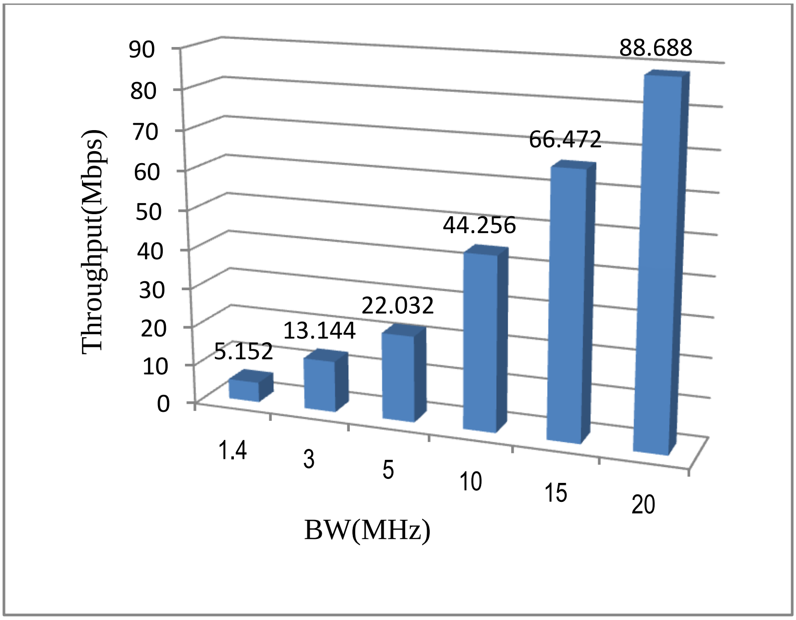


Fig. 6 Throughput for different bandwidth in LTE system

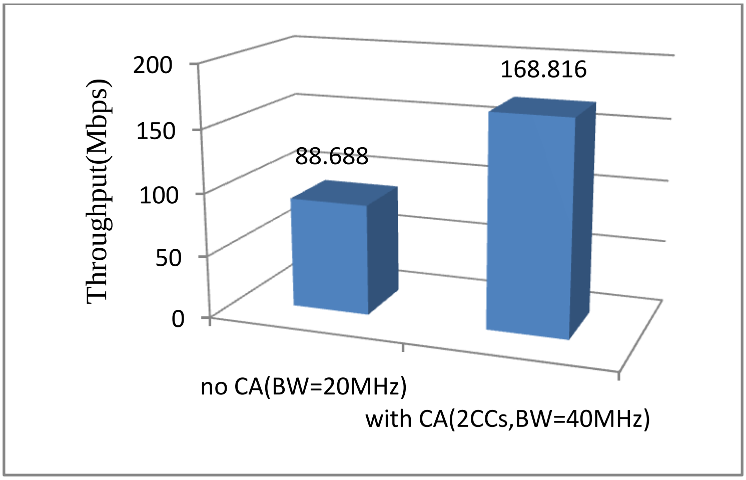


Fig. 7 Throughput for 1CCs in 800MHz band vs. with throughput for aggregated 2CCs in 800MHz band.

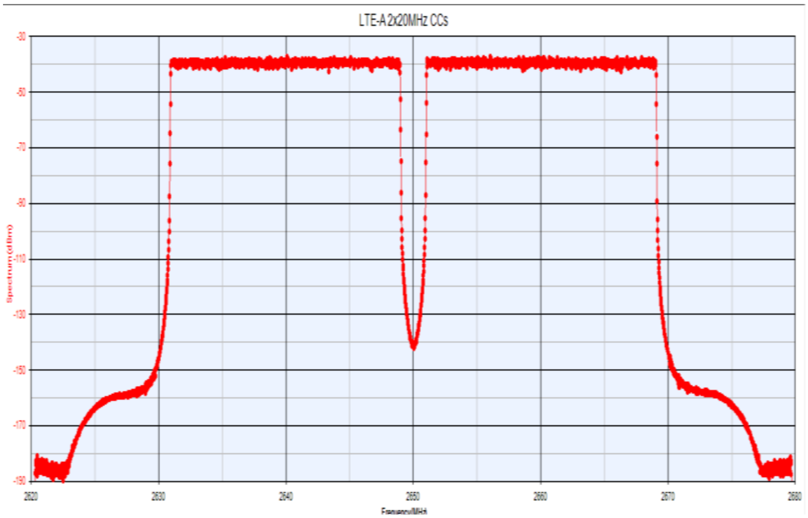


Fig. 8 The power spectrum of the 40 MHz LTE-A DL signal.

Table 2 Simulation Parameters

Parameters	Value
Carrier frequency	800MHz,2100MHz
Bandwidth	20MHz
Network configuration	7cell(site)/3 sector
Number of users	10
Path loss model	TS36942 model
Environment	Urban
Shadowing std	10dB
Transmit power	46dB
Number of Tx/Rx antenna	1/1
Noise figure	9dB
Transmission mode	SISO
Channel model	PedB

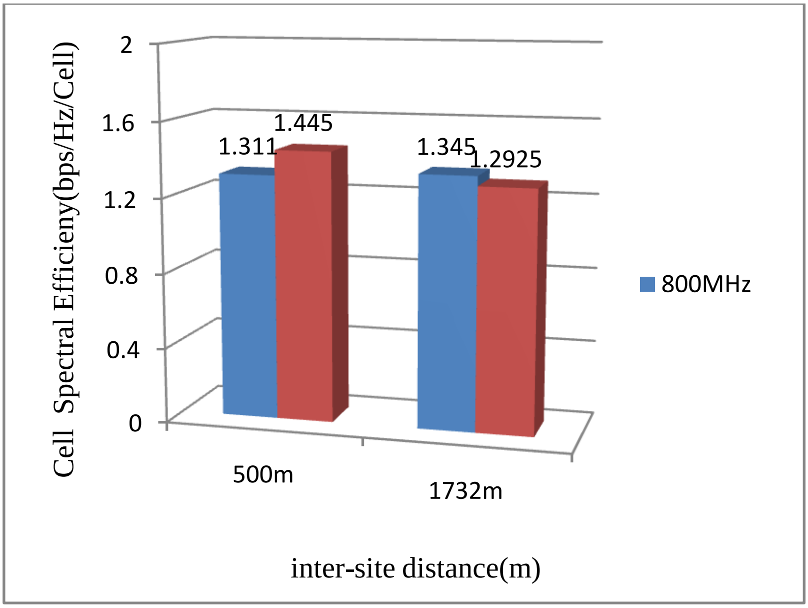


Fig. 9Cell spectral efficiency for inter-site distance and center frequency with no CA.

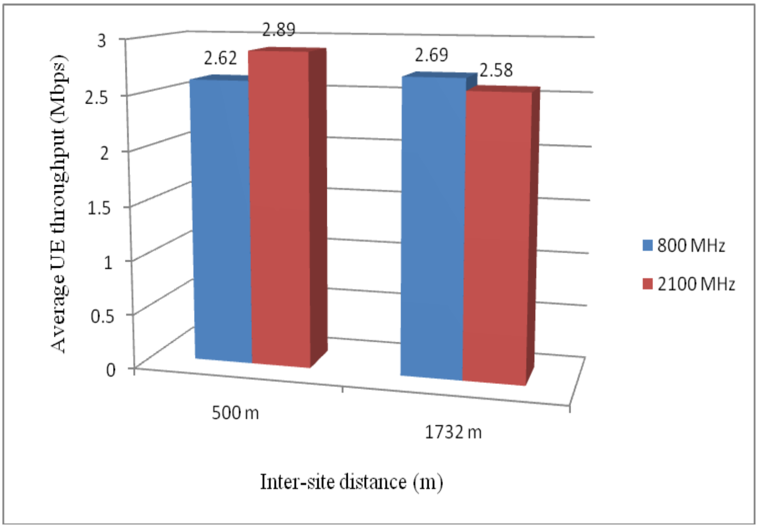


Fig. 10 Average UE throughput for inter-site distance and center frequency with no CA.

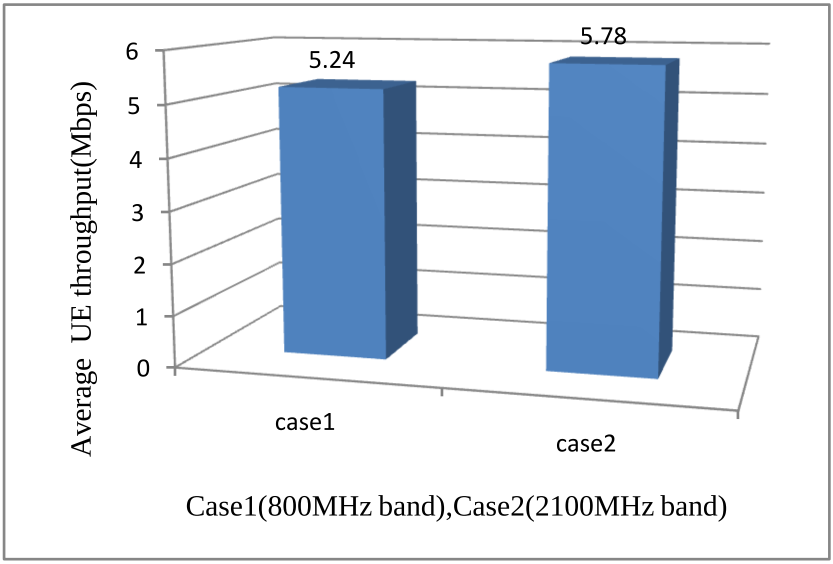


Fig.11 Average UE throughput for inter-site distance and center frequency with CA in scenario 1.

References

[1] AL-Shibly.M.A.M., Habaebi M.H, Chebil J. "Carrier Aggregation in Long Term Evolution-Advanced", Control and System Graduate Research Colloquium IEEE, pp.154-159, July 2012.

[2] Wei W., Zhaoyang Z. and Aiping H., "Spectrum Aggregation: Overview and Challenges", Network Protocols and Algorithms, Vol.2, No. 1, 2010.

[3] Ratasuk R., Tolli D. and Ghosh A., "Carrier Aggregation in LTE-Advanced", Vehicular Technology Conference IEEE, 2010.

[4] Shayea I., Ismail M. and Nordin R., "Capacity Evaluation of Carrier Aggregation Techniques in LTE-Advanced System''. International Conference on Computer and Communication Engineering (ICCCE 2012). pp. 99-103. 3-5 July 2012.

[5] Mikio I., Kamran E., Mo-Han F., Ravi N. and Robert L., "Carrier aggregation framework in 3GPP LTE advanced

[WiMAX/LTE Update]," IEEE Communications Magazine, vol. 48, pp. 60-67, 2010.

[7] 3GPP TR 36.808 V1.7.0, "Evolved Universal Terrestrial Radio Access (E-UTRA); Carrier Aggregation; Base Station (BS) radio transmission and reception (Release 10)", 2011.

[6] Guangxiang Y., Xiang Z, Wenbo W. and Yang Y., "Carrier aggregation for LTE-advanced mobile communication systems," IEEE Communications Magazine, vol. 48, pp. 88-93, 2010.

[8] Xincheng Z. and Xiaojin Z., "LTE-Advanced Air Interface Technology". CRC Press. 2013.

[9] Jinbiao Xu. "LTE-Advanced Signal Generation and Measurement Using SystemVue". Application Note, Agilent EEsof EDA, Agilent Technologies. 2011.