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The Autonomous Component Carrier Selection Based on User Scheduling for Femtocell in LTE-Advanced System

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Abstract. To achieve the regulations of the IMT-Advanced, 3GPP utilizes the technology of carrier aggregation (CA) in LTE-A. Besides, 3GPP in the LTE Release-8 also advocates that people in the communications industry establish femtocells to reduce the loading of macrocells. However, HeNB is much more easily leads to the irregular establishment. Thus, this condition will bring about signal interference between base stations and user equipment (UE), which makes the whole carrier utility and throughput speed lower. Therefore, 3GPP proposes the approach of autonomous component carrier selection (ACCS), it would let every base station select the carrier which isn't used by near base stations to avoid the carrier interference caused by the irregular establishment of HeNB. However, the selection rules of ACCS are imperfect and it will result in poor performance of system throughput and carrier utility and lower the connection of UE. In this paper, we propose a new ACCS based on user scheduling under the basic CA selection framework of ACCS. This method when the base station cannot be distributed carrier resources because of the interference, base station would check the current user equipment's interference situation, UEs will be scheduled by interference situation, then the base station select the appropriate carrier distribution for UE in the schedule. Finally, simulation results show that method proposed by this study can raise resource distribution of main carrier to attain more users' connection and simultaneously elevate the resource distribution of sub-carrier to meet the demands of UE bandwidth..

Keywords: ACCS, Carrier Aggregation, Femtocell, LTE-A

1 Introduction

LTE-A (Long Term Evolution-Advanced) was first proposed as a further evolution of LTE technology in 2009 [1]. In order to increase the system bandwidth to serve more UEs, 3GPP proposed Release 8, which adds medium and small power base station to enhance system capacity [2], and then presented Carrier Aggregation (CA) technology for LTE-A system in Release 10 [3] to achieve the need to expand bandwidth.

Carrier aggregation technology is characterized in that multiple component carrier aggregations can be aggregated in a continuous or discontinuous manner to form a huge frequency band to achieve 4G transmission requirements. 3GPP has also developed different carrier aggregation scenarios and aggregation methods [4-5, 14], which makes carrier aggregation more flexible to meet the spectrum requirements of user equipment.

Furthermore, the number of small base stations is large and dense, and the coverage of signals between small base stations is relatively overlapping, resulting in signal interference between base stations or base stations and user equipment, resulting in usable use. Insufficient carrier resources, resulting in lower overall carrier usage and transmission rate [6, 15].

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When the base station selects the aggregated carrier resources to meet the bandwidth requirements of the user equipment, it will cause interference with the neighboring base stations [7], therefore, 3GPP proposed ACCS (Autonomous Component Carrier Selection) [8] on the carrier configuration of small base stations to select aggregate carrier resources. When the base station performs carrier allocation, it will consider the currently configured carrier and avoid configuring the same carrier with the neighboring base station. However, as the number of small base stations grows, the number of interfered UEs becomes more, so that when the base station configures the carrier, even if there is a carrier configurable, it is abandoned to avoid mutual interference of the users, so that some UEs cannot obtain the carrier. Resources and base stations are connected [9, 16-17].

In order to solve the problem that there is no carrier resource could allocate to UE due to mutual interference, and make the new UE cannot be connected to the base station. This study re-schedules the user equipment by considering the user and carrier interference, and configures according to the user's interference level and carrier status, thereby improving carrier utilization and increasing the number of user connections, and improving the overall performance of system.

2 Related Technologies and Research

In this section, the basic Carrier Aggregation (CA) technologies and the related research are presented as follows.

2.1 Carrier Aggregation

Carrier Aggregation (CA) technology is one of the key technologies of LTE-Advanced system. Carrier aggregation is used to create a larger frequency band for the system to meet the IMT-Advanced 4G standard. The carrier aggregation technology is based on the existing carrier of LTE, and the continuous and discontinuous carriers are aggregated to achieve a larger bandwidth for use, and the user can simultaneously use the aggregated CC (Component Carrier) resources. Fig. 1 presents a schematic diagram of a carrier aggregation technology. The LTE UE can only select one of the CCs in the same frequency band, and the LTE-Advanced UE can select the most appropriate Resource Block for resource allocation from different CCs because it aggregates other CCs. [10].

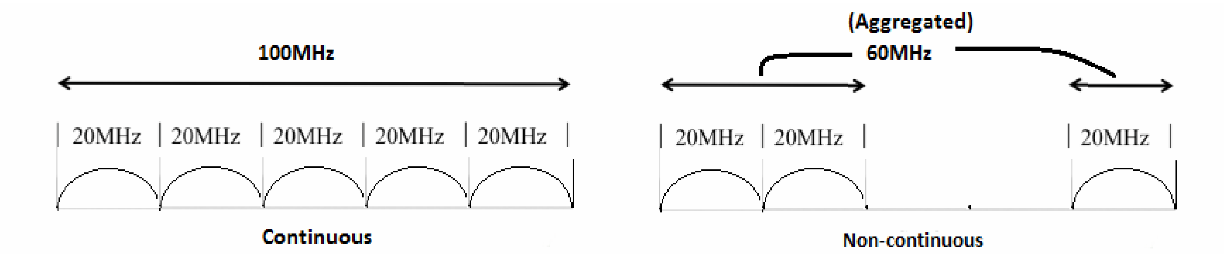


Fig. 1. The schematic diagram of carrier aggregation

Primary Component Carrier (PCC). The carrier acquired by the UE when it is required to connect to the base station is called the primary carrier, and each UE has only one primary carrier.

Secondary Component Carrier (SCC). After the UE and the base station obtain the connection, the carrier obtained by the system to improve the transmission performance or require additional radio resource requirements is called the secondary carrier, and the number of secondary carriers can be more than one. If the base station or the above base station allocates the same carrier, it will cause interference, and the base station assigns the primary carrier with higher priority than the other base station's secondary carrier allocation priority [7, 11, 18].

2.2 The Classifications of Carrier Aggregation

In the case of aggregated spectrum, there are three classifications of carrier aggregation [12, 14]:

Intra-band contiguous. as shown in Fig. 2, continuous carrier aggregation in the same frequency band is the most concise of the three spectrum modes. Only a set of baseband signal processing components and a set of RF components are needed, which is easier to perform resource configuration actions, but The complete and continuous frequency band is used, so the frequency band is limited and it is easy to cause the remaining fragmented spectrum after use, which reduces the usage rate.

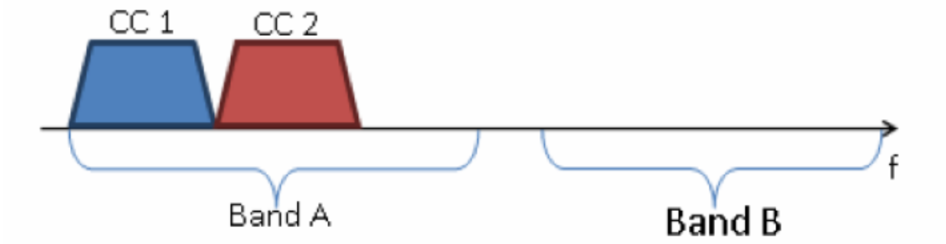


Fig. 2. Continuous carrier aggregation in the same frequency band

Intra-band Non-contiguous. another type is non-contiguous carrier aggregation in the same frequency band, it shown as Fig. 3, which solves the problem of spectrum use efficiency of continuous carriers in the same frequency band, and still retains a single baseband signal processing component and a single RF component. Low-cost features, but the scattered spectrum in the same spectrum is still limited, and may still not meet the demand after aggregation, so there is still the problem of idle waste.

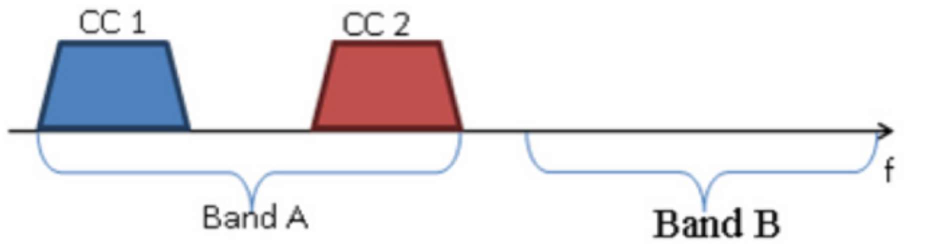


Fig. 3. Non-contiguous carrier aggregation in the same frequency band

Inter-band non-contiguous: the third one shown in Fig. 4, cross-band discontinuous carrier aggregation supports carrier aggregation through resources in other frequency bands, which is more flexible in resource allocation, but has the disadvantage of requiring array of baseband signal processing components and array RF components. The hardware cost and system complexity are high, and the system burden is heavy.

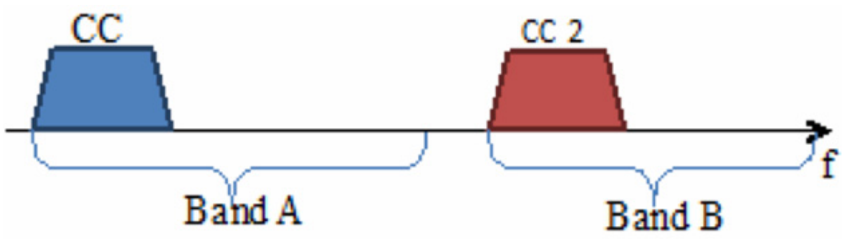


Fig. 4. Cross-band discontinuous carrier aggregation

2.3 E-ACCS

Since the ACCS [8] still causes some UEs to obtain the carrier resources and the base station to obtain the connection [9], T. M. Wang further proposes a new carrier allocation method E-ACCS [13] to increase the number of user connections. When the base station has no carrier resources to be allocated, the neighboring base station is required to release the currently used secondary carrier to connect the user equipment that requires the connection as the primary carrier. This method has the advantage of solving the problem that happened in original ACCS. It is the UE have to wait and can’t connect into system due to there is no carrier resource.

However, the problem still exists in the E-ACCS that the neighboring base station does not necessarily have the secondary carrier that can be provided to the user equipment. If the released secondary carrier is used as the primary carrier of the user equipment, the adjacent base station may cause interference. But it will reduce the connection quality of other users.

Therefore, this research will focus on improving the number of user equipment connections, refer to the E-ACCS carrier configuration method and consider the user equipment (UE) and carrier interference. A new carrier re-distribution mechanism by coordination is proposed. The carrier allocation status between the base stations solves the problem of E-ACCS.

3 The Autonomous Component Carrier Selection Based on User Scheduling

The main purpose of this research is to re-select the carrier configuration when the E-ACCS method is used to disconnect the user equipment due to interference from neighboring base stations. User scheduling is considered in advance for the interference of the user equipment and the current interference of the carrier, and the carrier priority of the user equipment with less interference is improved. Priority is given to finding carrier resources that can be shared without interference, and the carrier with higher interference level is configured to improve the transmission rate, thereby reducing the time for the UE with higher interference to interfere with the adjacent base station carrier.

3.1 Main Flowchart

The method proposed by this paper reconfigures the carrier in the manner of the interfered user equipment scheduling. Fig. 5 is the flowchart of this proposed method, and the process steps are as follows:

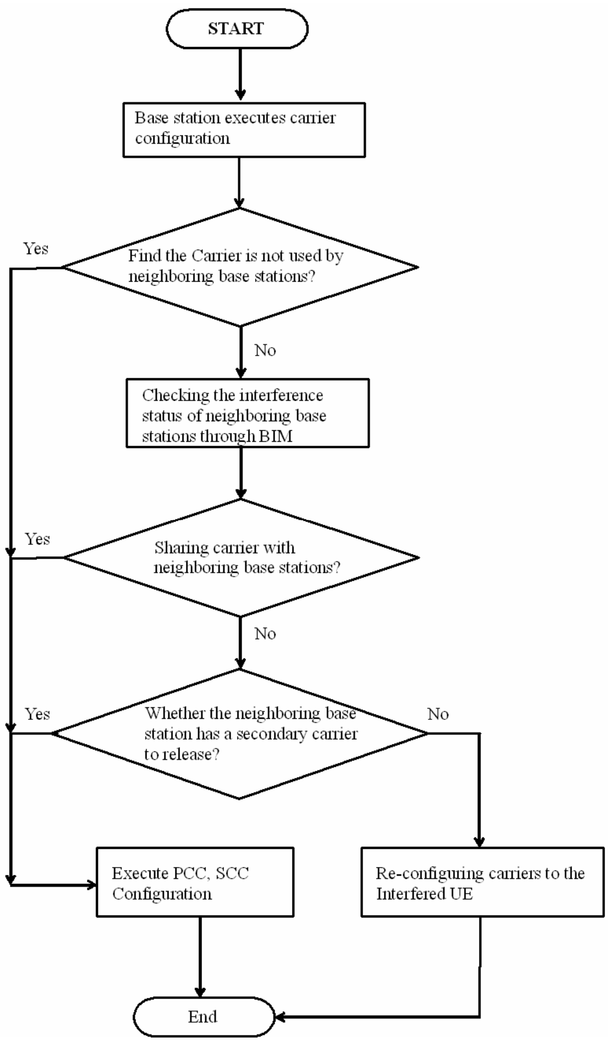


Fig. 5. The main flowchart of proposed method

Step 1. Base station executes carrier configuration. When the base station accepts the user equipment request to connect, it starts to view the current carrier resource list and view the carrier status.
Step 2. Find the Carrier is not used by neighboring base stations?. Checking whether there are carriers that are not used by neighboring base stations can be preferentially configured.
Step 3. Checking the interference status of neighboring base stations through BIM. Examining whether the neighboring base station will cause interference by the information returned by the user equipment
Step 4. Sharing carrier with neighboring base stations?. The interference condition of the neighboring base station is obtained through the BIM to determine whether the shared carrier will cause interference.
Step 5. Whether the neighboring base station has a secondary carrier to release?. Checking whether the neighboring base station has a secondary carrier release, and configure the primary carrier by releasing the secondary carrier.
Step 6. Re-configuring carriers to the Interfered UE. When the primary carrier cannot be configured in the above manner, the carrier configuration is re-performed by the proposed re-scheduling strategy to improve the carrier configuration.

3.2 The Re-scheduling Strategy for the Interfered UE

When the primary carrier cannot be configured by releasing the secondary carrier, the system will start the interfered UE re-scheduling. Relying on the interference level scheduling of the user equipment and the current configuration of the carrier as the criterion for reconfiguring the carrier, so as to improve the problem that the initial configuration carrier does not consider the interference condition of the user equipment. It will Increase the number of user devices and carrier usage at same time. Fig. 6 shows the flowchart of the carrier configuration schedule of the interfered UE.

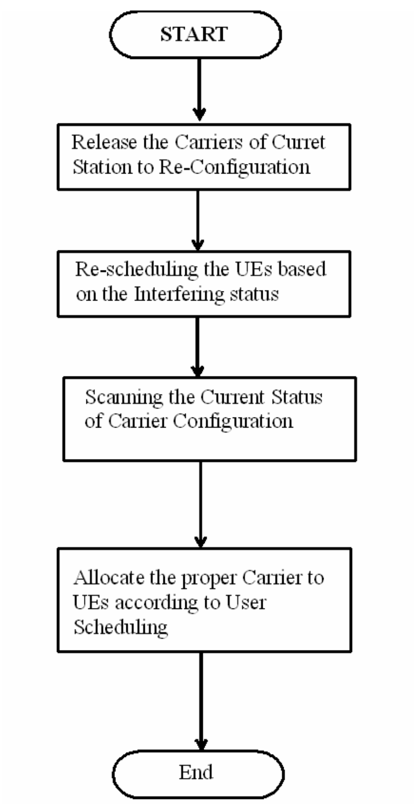


Fig. 6. The flowchart of the carrier configuration schedule of the interfered UE

3.2.1 Considering the Interfering Saturation on UE

The UE periodically measures RSRP values among neighboring base stations and transmitted back to the base station. The background interference matrix (BIM) is established by the information returned by each user equipment to the base station. By obtaining the carrier-to-interference ratio of the neighboring base stations, the user equipment with less interference can preferentially find a suitable shared carrier, and leave better carrier resources to the more interfered carriers.

Fig. 7 is an example of considering the interference state on each UE when reconfiguring the carrier, assume UE 6 wants to configure carrier, but no carrier resources are configurable. In this case, Femtocell A will release carrier resources, and then check the current UE interference state, according to the number of interference from neighboring base stations finally.

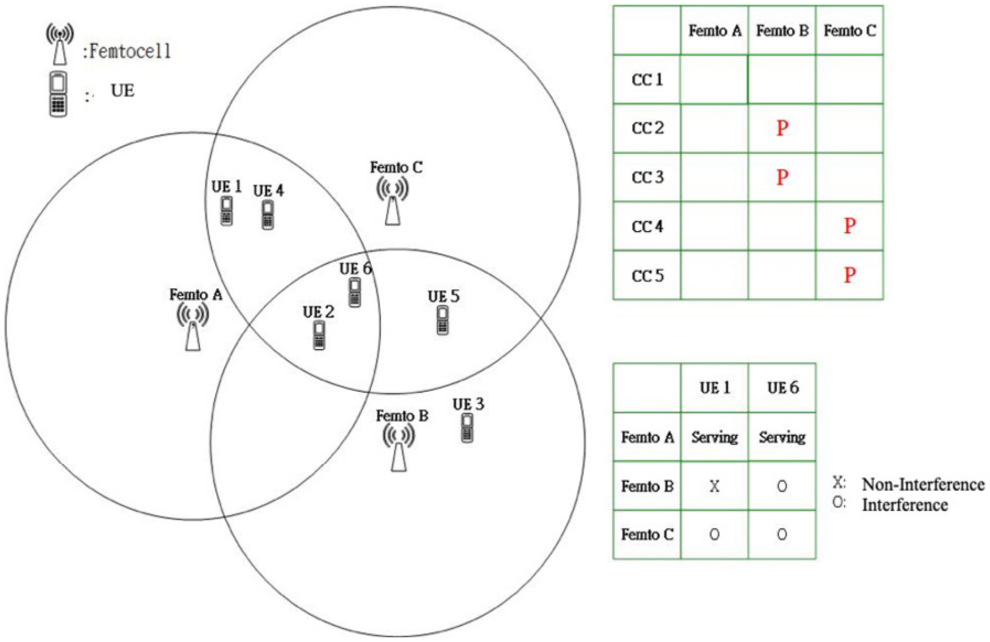


Fig. 7. Example of considering the interference state on each UE

The illustration shows that the originally configured UE 1 will be affected by the neighboring base station Femtocell C, the UE 6 to be configured is affected by both the neighboring base stations Femtocell B and Femtocell C. Therefore, the number of interferences of UE 1 is 1 and the number of UE 6 is 2 from the number of interferences by neighboring base stations. If the number of interferences is the same, then the order of connection according to the requirements of the UE is the second condition. The UE scheduling is performed by recording the interference status of the UE belongs to current base station, and then the suitable carrier configuration is found according to the current carrier configuration of primary carrier. After the primary carrier configuration is completed, the user with more interference is preferentially configured with the secondary carrier to reduce the time that the carrier with large interference continues to affect the neighboring base station.

3.2.2 Considering the Carrier Configuration

When reconfiguring the carrier, in addition to considering the interference of the user equipment under the service base station, it is also necessary to consider the carrier status of the current neighboring base station. Similarly, the most suitable carrier selection can be found on the premise that it cannot interfere with other UEs. The illustration of considering the current carrier status is shown in Fig. 8.

It can be seen from the carrier configuration diagram in the figure that the carrier used by the current neighboring base station is CC 2~CC 5, and CC 2 is configured by Femtocell B to UE 2 as the primary carrier. At the same time, UE 2 is interfered by its neighboring base stations Femtocell A and Femtocell C respectively, so Femtocell A and Femtocell C cannot configure carriers on CC 2. The CC 3 has a Femtocell B configured for the primary carrier of UE 3. However, UE 3 itself is not interfered by other base stations, so it does not affect Femtocell A and Femtocell C to configure carriers on CC 3. Whatever, when Femtocell A and Femtocell C want to configure a carrier, they cannot interfere with UE 3. Otherwise, they cannot be configured because they interfere with their UE.

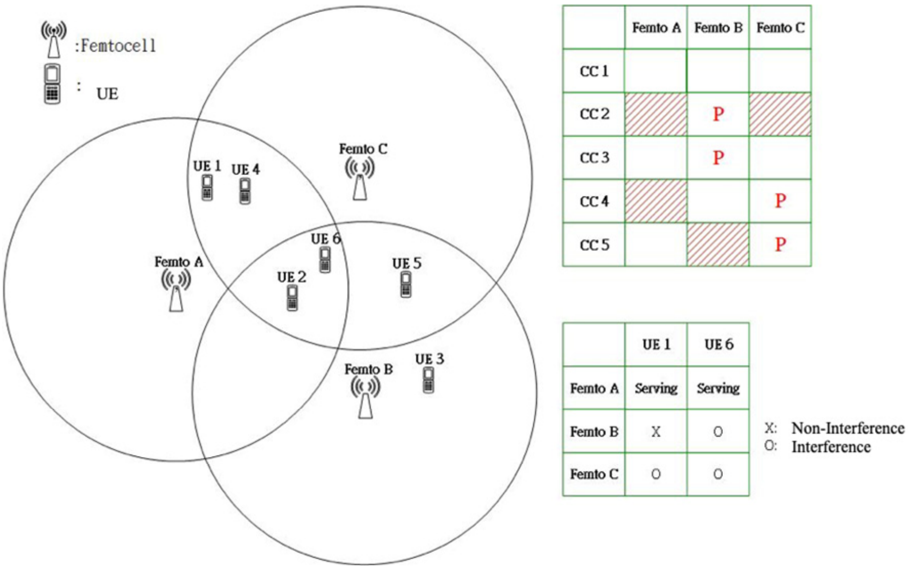


Fig. 8. Example of considering the current carrier configuration

CC 4 and CC 5 can view the interference caused by the current neighboring base station configuration carrier in the same manner as described above. Therefore, when Femtocell A reconfigures the carriers of UE 1 and UE 6, since both CC 2 and CC 4 are unconfigured by neighboring base stations, the suitable carrier without affecting neighboring base stations must be searched from the remaining carriers CC 1, CC 3, and CC 5.

3.2.3 Configuring the Carriers by User Scheduling

After the scheduling of the UE is completed, the shared carrier is preferentially configured according to the current carrier condition. The main purpose is to keep the carrier that is not used by the neighboring base station in the original initial configuration, and find other carrier configurations that can be shared by configuring the carrier that is originally configured to have no other user equipment. The better carrier resources will retain for UEs that are more interfered with scheduling.

Because it is not used by other neighboring base stations, there is no need to worry about the interference from neighboring base stations during configuration. After rescheduling, if there are still user devices that cannot be configured due to interference problems, they will remain in the scheduling and wait for their base station and neighboring base stations to release the carrier. When there is a list of released carrier update carrier resources, it is configurable whether to find a suitable idle carrier. Even the reserved carrier space, although the base station cannot configure the primary carrier, it still enable the neighboring base station to configure the secondary carrier resource and improve the transmission efficiency.

3.3 The Illustration of Carrier Re-configurated Selection

3.3.1 Without Neighboring Base Station Interference

As shown in Fig. 9, for the current Femtocell A, there are no other neighboring base stations nearby. Because, the carrier allocation of Femtocell B and Femtocell C are far away from. It will not affect the carrier selection of Femtocell A. Therefore, it is not necessary for the user equipment to specifically perform the priority scheduling of the interfered quantity, and only need to consider the carrier allocation status of Femtocell A itself.

For example wants to assign the primary carrier, when a user equipment requests connection to Femtocell A. Femtocell A will check whether the current resource allocation table has not yet been allocated. If there is a carrier that has not been allocated yet, the carrier resources are directly allocated to the user equipment as the primary carrier to provide connection. If the carriers have been assigned, the query can be released as a carrier for the secondary carrier allocation. If a secondary carrier can be released, the secondary carrier is released and allocated to the user equipment as a primary carrier.

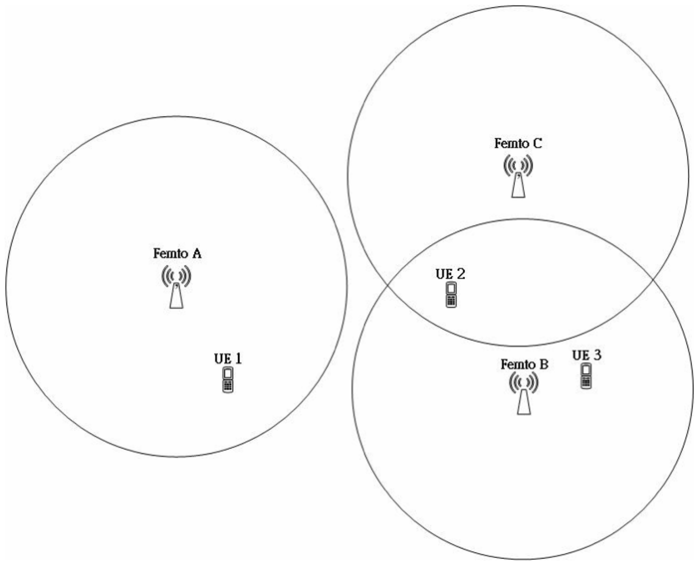


Fig. 9. Example of without neighboring base station interference

3.3.2 With Neighboring Base Station Interference

When the base station wants to configure the carrier and suffers interference from neighboring base stations, it will check firstly from the resource allocation list whether has carriers that are not used by neighboring base stations? If there is a carrier that is not used by the neighboring base station, the carrier is directly allocated to the user equipment as the primary carrier.

If all the carriers are used by neighboring base stations, continue to query the BIM to check the interference situation of the neighboring base stations to the user equipment, and consider using the same carrier as the neighboring base station. When there is no unused carrier and the carrier cannot be shared with other base stations, then the neighboring base station is searched for whether the secondary carrier can be released, and the primary carrier is configured.

When the above procedures cannot configure the primary carrier, the presented method of this research is started to perform re-scheduling, and the carrier configuration is improved. So that the user equipment can configure the primary carrier that follows up the previous description of the proposed method. The mechanism to reconfigure the carrier, as shown in Fig. 10.

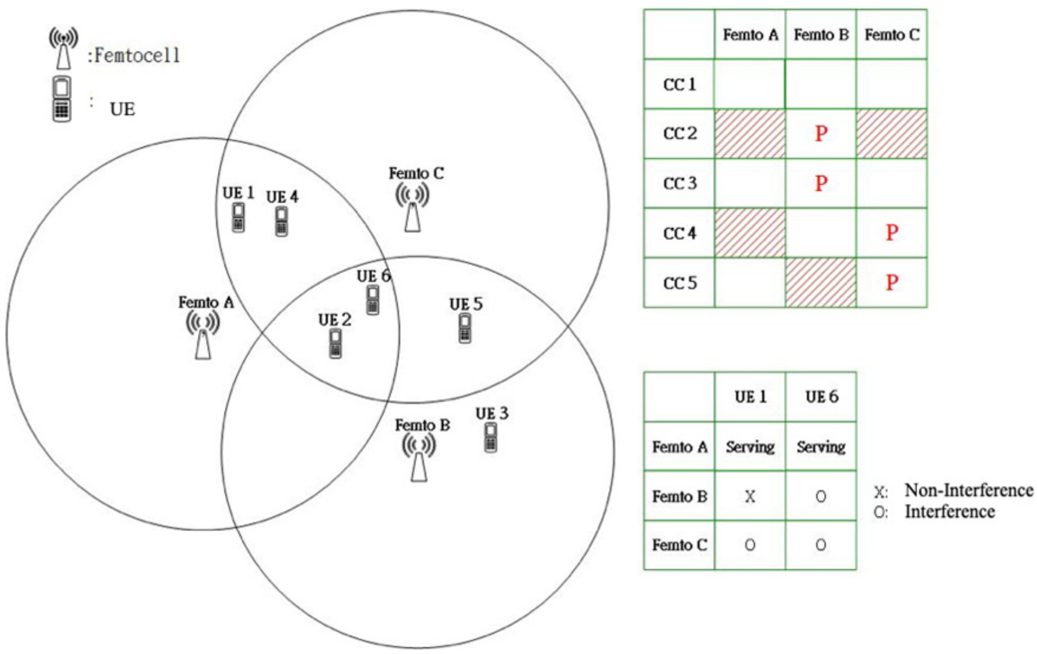


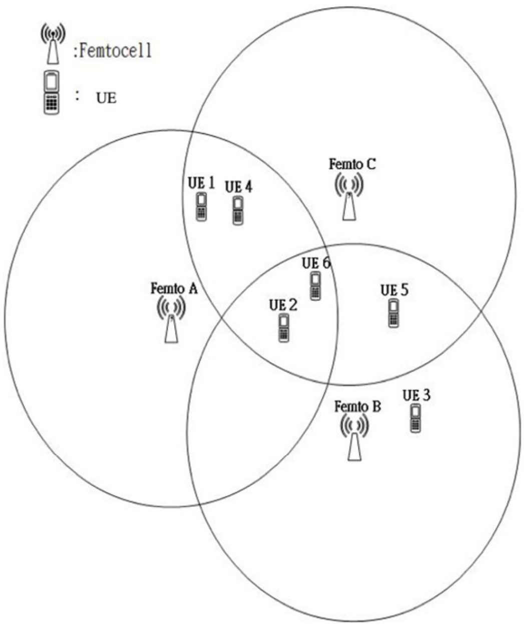
Fig. 10. Example of carrier configuration from interference by neighboring base station

First, Femtocell A will release all carriers for all user equipment to re-schedule, and then view the user equipment that is currently required to configure the carrier to be connected to the Femtocell A base station. The BIM is queried to check the interference status of the UEs that are currently connected to the neighboring base stations. After the interference condition of the UE is queried, the current UE 1 is affected by the neighboring base station interference number 1 and the UE 6 is 2. Therefore, the UE 1 preferentially performs carrier configuration. At this time, the Femtocell A checks the current carrier configuration to find a common carrier suitable for the UE 1. If no other carriers can be shared, the carrier that is not adjacent to the base station is selected. Thereby, better carrier resources can be reserved for the user equipment with greater interference, so that it is less likely to be able to configure the carrier due to interference with neighboring base stations. Therefore, the UE 1 configurable carrier has CC 1, CC 3 and CC 5, but UE 1 itself is affected by the neighboring base station Femtocell C. If Femtocell A configures UE 1 in CC 5, it will receive Femtocell C interferes with each other's user equipment signals.

Therefore, for UE 1, only CC 1 and CC 3 are configurable, and the base station will choose to configure CC 3 for UE 1 to share carrier with neighboring base stations. The better carrier resource CC 1 is reserved for the remaining UEs with large interference conditions, so that the UE with large interference condition is more easily configured without being affected by the neighboring base station. After the UE 1 finishes configuring the primary carrier, the remaining CC 1 and CC 5 of the UE 6 are configurable.

However, if configured in CC 5, it will cause the same problem as UE 1. Therefore, UE 6 can only select CC 1 to configure the carrier, and CC 1 is the carrier that is not used by the neighboring base station, so there is no need to worry about the carrier being configured by the neighboring base station with mutual interference problem.

Finally, it can be found that by reconfiguring the carrier, the UE 6 that could not be configured can also be configured to be connected, as shown in Fig. 11.



	Femto A	Femto B	Femto C
CC 1	P_{UE6}		
CC 2		P_{UE2}	
CC 3	P_{UE1}	P_{UE3}	
CC 4			P_{UE4}
CC 5			P_{UE5}

	UE 1	UE 6
Femto A	Serving	Serving
Femto B	X	O
Femto C	O	O

X: Non-Interference
O: Interference

Fig. 11. Example of carrier Re-configuration from interference by neighboring base station

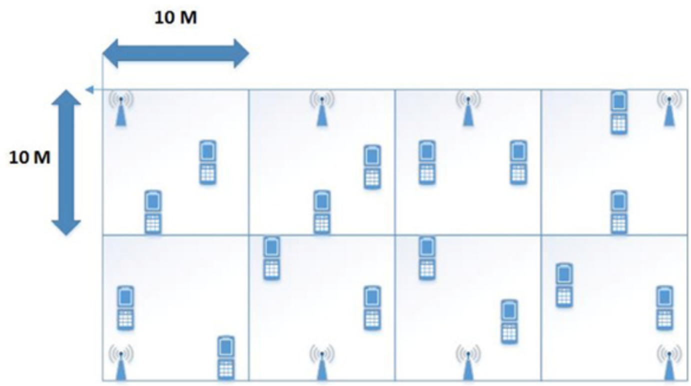
After all the primary carrier configurations are completed, the secondary carrier is preferentially configured according to the user equipment with a greater degree of interference to reduce the time of interference with the neighboring base station user equipment. Even if the user equipment is still re-scheduled, the main carrier cannot be configured due to the serious interference situation. However, by reconfiguring the carrier, the user equipment can increase the number of configured secondary carriers, increase the overall system output, and reduce the time that the user equipment occupies the carrier.

4 Simulation Analysis and Comparison

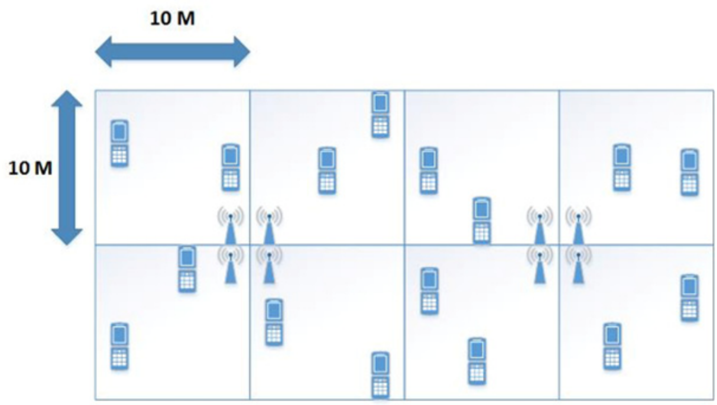
In this section, the proposed method is simulated and the simulation results are used to verify the feasibility of the proposed method.

4.1 Simulation Environment and Parameters

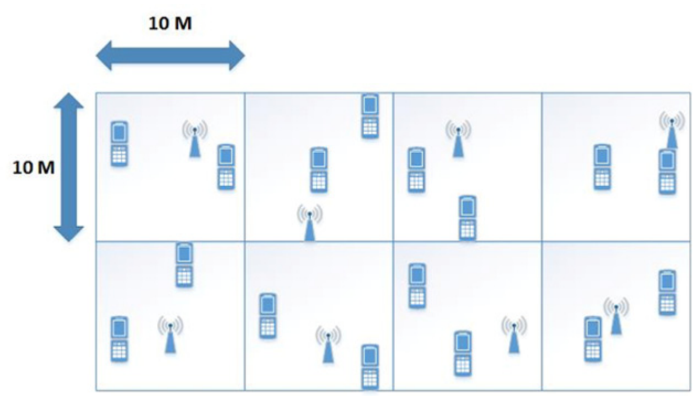
This paper simulates indoor spaces and is a closed user group environment. In 2x4 indoor places, each indoor place is 10m x 10m, shown in Fig. 12. The following assumptions were made for the simulation environment:



(a) Decentralized allocation



(b) Centralized allocation



(c) Random allocation

Fig. 12. Simulation environment

(1) There is only one Femtocell base station in each indoor location,
(2) There are two user equipment (UE) in each indoor location,
(3) The location of the Femtocell base station may be decentralized, centralized, or random,
(4) The location of the UE is randomly distributed in each indoor location,
(5) The sequence of carrier resources required by the user equipment is randomly selected.,
(6) There are five carrier resources per base station,
(7) Regardless of user device movement and hand-over issues,
(8) Do not consider the delayed propagation saturation,
(9) Carrier interference occurs in overlapping coverage areas of user equipment bits between base stations.

This simulation experiment uses a single-floor closed user group to set up the environment on the Femtocell base station, assuming that the indoor space is 10 meters x 10 meters. The entire system has five carriers, each with a bandwidth of 20MHz. There is only one base station in each indoor place, and the base station is built in three model - decentralized, fixed and random, for separate experiments. Transmission mode uses multiple antennas to achieve multi-output multi-input technology. The location of the user equipment will be randomly located in the respective indoor location, and only the connection to the indoor venue base station is required. The order in which the user equipment requests the carrier resources from the base station is randomly selected. At intervals of 30 seconds, a user equipment requests the base station to connect and simultaneously allocates the primary carrier. After the user equipment obtains the primary carrier, it can request the secondary carrier to be configured again. Regardless of the size of the packet and the delay of signal transmission, and simulate each deployment mode to simulate the configuration status and quantity of the carrier configuration for 50 times.

The system parameters are presented on Table 1.

Table 1. The system parameters of simulation environment

Parameter	Value
Room Size	10m×10m
Cellular Layout	Single-floor dual strip
Carriet frequency	2G Hz
Number of CC	5
Bandwidth per CC	20 MHz
Number of Femto Enb	8
Femto eNB Location	Fix or Random in Room
Femto eNB Type	Closed Subcriber Group
Transmission Model	Transmit diversity
UE Connect Interval Time	30 sec
Number of UE in each room	2
UE Location	Random in each Room
UE Mobility	0

4.2 Evaluation Issues for Simulation

This study will focus on three different carrier allocation methods for ACCS and E-ACCS and the proposed method in this paper, under different base station construction environments. As discussed in Fig. 12 above, the carrier number configuration is discussed. Decentralized and centralized construction environment is a deliberately created extreme environment. In a decentralized environment, each user equipment is subject to the least chance of interference, while in a centralized installation environment, each user equipment is subject to the highest probability of interference. The random type is built in accordance with the natural construction. Evaluation issues are focused on the following:

Carrier allocation as the number of main carriers (user equipment connection number). Determine the impact of different carrier allocation methods on increasing the number of user equipment connections.

Total number of carrier allocations. Determine the carrier usage of the different carrier allocation methods for the whole.

Carrier capacity. It is equivalent to the overall system output after the carrier allocation successfully transmits data. The formula to calculate the carrier capacity is as follows.

$$Throughput = \sum_{k=1}^{CC\_all} CS_k * Packet\_size \quad (1)$$

CC_all: Total number of Carrier
CSk: Carrier is configured successfully and transmitted data
Packet_size: the unit is Mbps

4.3 Simulation Results and Analysis

4.3.1 Comparison of the Decentralized Model

When the base station position is decentralized, the final average number of configurations in the simulation experiment is shown in Fig. 13. Since the proposed method in this study will configure one more primary carrier than E-ACCS in the same environment, the shared carrier is preferentially selected and the good carrier resources are left. Therefore, the UE with greater interference has a higher chance of being configured to the carrier, so the effect is better than ACCS and E-ACCS.

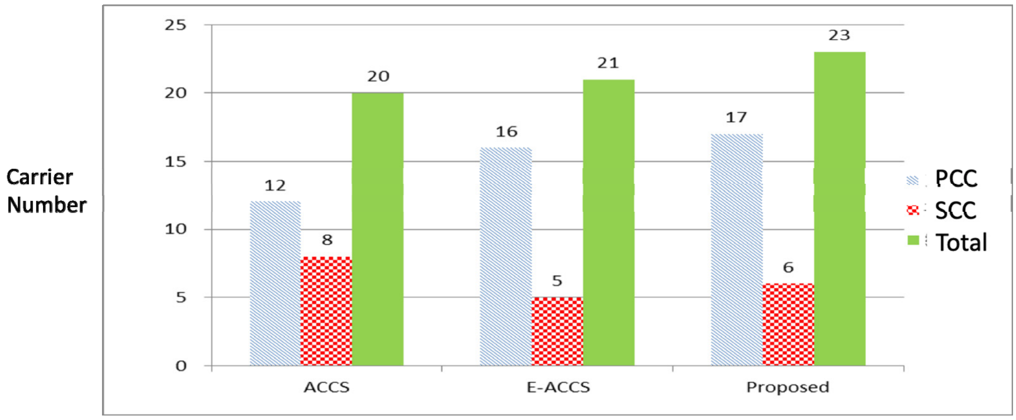


Fig. 13. The carrier usage in decentralized model

4.3.2 Comparison of the Centralized model

When the base station is in a centralized deployment, Fig. 14 shows that the method will be reconfigured after releasing the secondary carrier. And re-enable the UE to preferentially adjust the better carrier resources in the way of sharing carriers, so the E-ACCS is still higher in the main carrier configuration.

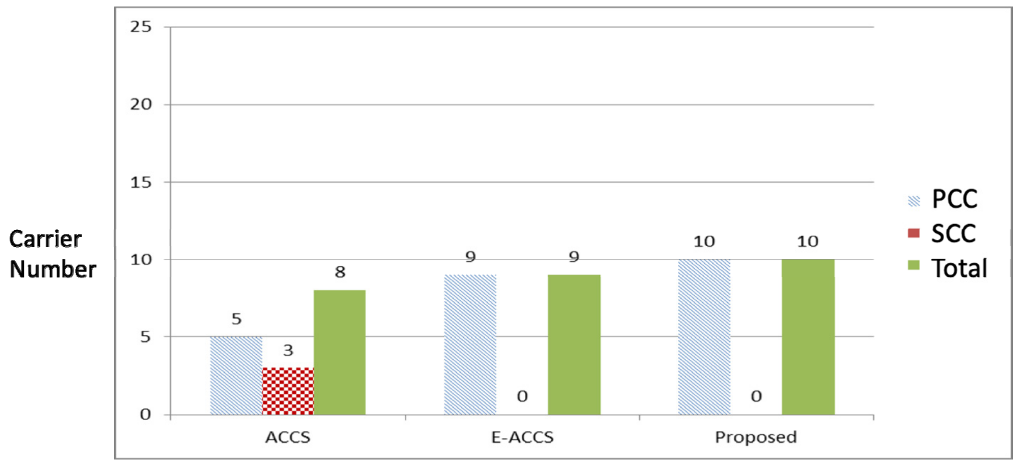


Fig. 14. The carrier usage in centralized model

4.3.3 Comparison of the Random Model

When in the base station in a random deployment environment, the simulation result is shown as Fig. 15. The three methods are more normal in the allocation of the primary carrier or the secondary carrier. However, the proposed method is further re-configured after considering the interference state of the user equipment. In order to improve the user equipment connection and the number of secondary carriers, the effect is more obvious in the random deployment.

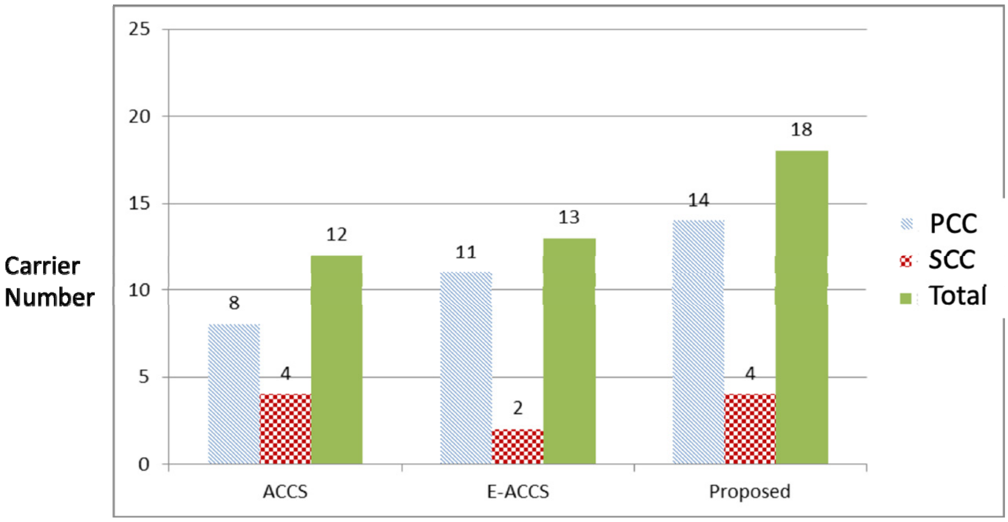


Fig. 15. The carrier usage in random model

4.3.4 Comparison of the Carrier Capacity

Fig. 16 presents the comparison the carrier capacity among the three methods in random construction, the horizontal axis is the system simulation time, and the vertical axis is the current system performance. When the simulation time passes 300 seconds, E-ACCS and the proposed method can configure the primary carrier by releasing the secondary carrier. Finally, the method performs interference scheduling of the user equipment by releasing all the carriers that are to be configured to configure the base station. Therefore, the overall of system performance is improved.

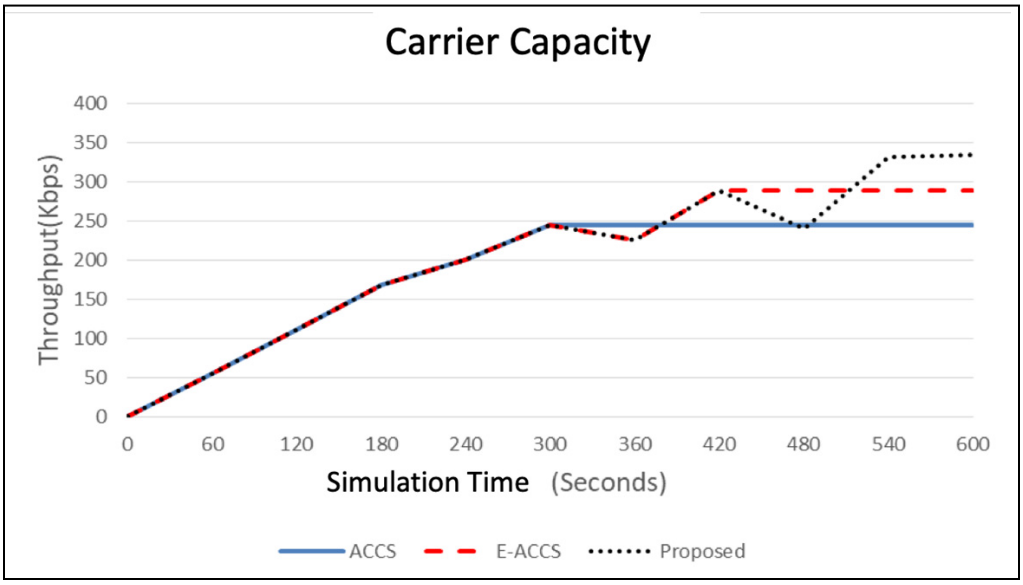


Fig. 16. The carrier capacity comparison

5 Conclusion and Future Works

5.1 Conclusion

This research proposes a carrier redistribution method based on user scheduling. It improves the number of user connections by re-adjusting the carrier that the base station has been configured to. Even if the user equipment cannot be configured with the primary carrier due to strong interference after rescheduling, the carrier reserved by the rescheduling configuration can still be used as the secondary carrier configured for the neighboring base station. Finally, the overall performance is increasing.

The simulation results show that the proposed method has better performance than the standard ACCS and improved E-ACCS in different construction environments. The overall carrier usage has been enhanced, thus demonstrating that the overall performance of this study is better.

5.2 Future Works

In the future, factors that consider user movement will be included. The interference condition will change when the user equipment moves, and the scheduling and carrier configuration of the carrier resources in the user interference situation need to be re-evaluated.

As well as integrating other LTE-A technologies, a more efficient carrier aggregation allocation method is designed.

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