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Analysis of carrier load balancing methods for multi carrier systems

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ABSTRACT

An innovative concept of International Mobile Telecommunications – Advanced (IMT-Advanced) which is specified by the International Telecommunications Union – Radio Communication Sector (ITU-R), aims to perform a peak data rate of up to 1 Gbps for low mobility and 100 Mbps for high mobility. A study item on Long Term Evolution (LTE)-Advanced has been commenced to meet the above need by the 3rd Generation Partnership Project (3GPP), that supports the transmission over a much wider bandwidth than the LTE systems. The techniques for efficient resource allocation for LTE-Advanced systems with aggregation of multiple Component Carriers (CC) are deeply analyzed in this paper. Bandwidth based resource allocation using carrier load balancing methods like Round-robin, Mobile Hashing and Walsh code methods, have been used and their performance analysis is done in terms of the throughput and coverage. It proposes a cross component carrier packet scheduling algorithm for an effective resource allocation among the users with aggregation of component carrier in comparison with the independent packet scheduling per CC. To study the multi carrier system, Long Term Evolution (LTE)-Advanced users and LTE Rel'8 users are selected. The various carrier load balancing methods are compared based on independent and cross CC packet scheduling and then coverage performance, cell throughput and user throughput are analyzed with the help of Full buffer and finite buffer transmission system.

Introduction

Nowadays the emerging field of Wireless communication occupies a vital role in our day to day life. For the last few decades, the wireless communication service areas are expanding continuously with an exponentially increasing rate. Third generation partnership project Long Term Evolution (LTE) targets to do the following: (i) Developing the future demands for mobile broadband services using higher data rates. (ii) Achieving data rates up to 100 Mbps for wide-area coverage and up to 1 Gbps for local area coverage. (iii) The bandwidth may go up to 100 MHz with carrier aggregation of individual Component Carriers (CCs). Mean time, the IEEE 802.16 group is too evolving the Worldwide Interoperability for Microwave Access (WiMAX) system towards IEEE 802.16m. to fulfill the challenges of major enhancements to LTE-Advanced. The performance of two carrier load balancing with different packet scheduling by using two types of buffer transmission over multiple carrier systems is studied in [1]. Various methods for load balancing across CC and estimate the performance of carrier load balancing methods are clearly analyzed in [5] & [6]. Scheduling techniques to enhance the throughput performance of the systems have been perfectly depicted in [16].

System Model

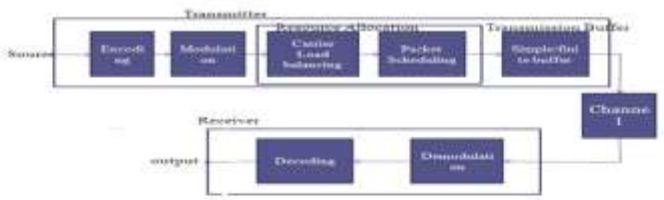

Fig 1. Multi Carrier LTE-A System Model

Fig 1 depicts the model of proposed Multi Carrier LTE-A system. The system model consists of the three main blocks of Transmitter, Channel and Receiver. The Transmitter block performs encoding, modulation, Resource allocation and Transmission Buffer. Demodulation and Decoding are processed by the receiver block.

Each stream will represent a broad service class (for example voice over IP or Audio) or a specific application-layer stream. The Convolution coding scheme is also used in the proposed system.

Radio Resource Management

Radio resource management (RRM) is defined as the system level control of co-channel interference and other radio transmission characteristics in wireless communication systems. The main aim is to use the limited radio spectrum resources and radio network infrastructure in a efficient way.

Carrier Load Balancing Methods

There are three methods for Layer-3 CC load balancing, given for the LTE-Rel'8 users. They are

Round Robin (RR) Balancing:

The RR balancing is referred to as the Combined Carrier Channel Assignment, or Least Load. The main objective is to allocate the newly arrived user to the carrier which has the least number of users and it tries to distribute the load to all carriers evenly. But, there might be small load deviations on various CCs, since the number of Rel'8 users per cell does not divide equally on the number of CCs all the time, or owing to the random departure of users.

MH mobile hashing (MH)

The MH balancing method, otherwise called as the Independent Carrier Channel Assignment or Random Carrier,

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depends on the terminal's hashing algorithm output. The output hash values have been uniformly distributed among a finite set, that maps directly on the CC indices.

Walsh code method (WC)

The Walsh–Hadamard code generates the original message with high probability, at a small fraction of the received word and it is considered as a locally decodable code. It gives rise to applications in computational complexity theory and specifically in the design of probabilistically checkable proofs. In addition, the original message can be recovered as long as less than 1/2 of the bits in the received word have been corrupted and list decoding is utilized to do it. The number of active WC channels in each carrier has been verified in WC balancing and new user is assigned with a carrier which has the fewest active WC channels.

Packet scheduling

Scheduling is defined as the process of picking a particular user among several users which aims to access the common resources of a channel. The user whose data is to be transmitted next is chosen by means of scheduling algorithm.

To assign frequency domain resources to multiple users it needs PS at Layer-2 has to be performed. The proposed system chooses a commonly used scheduler, namely Proportional Fair (PF). PF knows the frequency selective channel conditions for every user, and it offers a Frequency Domain Packet Scheduling (FDPS) gain. The resource is assigned to the user by means of PF Scheduler and increases the following scheduling metric on each CC:

$$K_{i,j} = \text{argmax}_k \{M_{k,i,j}\} \qquad (1)$$

Where

$K_{i,j}$ - selected user on i^{th} CC at j^{th} Physical Resource Block group

$M_{k,i,j}$ - scheduling metric for user k on i^{th} CC at j^{th} PRB group

The LTE-Advanced physical layer structure assumes one PRB is the minimum resource element, consisting of 12 consecutive subcarriers with sub-carrier spacing of 15 kHz, which is for one transmission time interval . The difference between the independent and the cross-CC PS lies in the method of evaluating the scheduling metric for every PRB.

Independent PS per CC

It is similar to the PS in a traditional single carrier system, in which the transmission characteristics on the other CCs are not being taken into account. Dividing the instantaneous throughput by the average throughput, provides the result known as scheduling metric,

$$M_{k,i,j} = \frac{R_{k,i,j}}{\overline{R}_{k,i}}$$

Where

$R_{k,i,j}$ - estimated throughput for user k on i^{th} CC at j^{th} PRB group

$R_{k,i}$ - average delivered throughput for user k on the same CC in the past

Cross-CC PS

It is concluded that the PS can achieve better resource allocation than Independent PS, by taking the statistics from all CCs into consideration. To lessen the complexity for upgrading the existing LTE systems, a PS algorithm is proposed which still operates within all CC. But it takes the past user throughput over all aggregated CCs into consideration which differs from independent scheduling per CC, i.e.

$$M_{k,i,j} = \frac{R_{k,i,j}}{\sum_{i=1}^{N} \overline{R}_{k,i}}$$

where

$R_{k,i,j}$ - estimated throughput for user k on i^{th} CC at j^{th} PRB group.

$R_{k,i}$ - average delivered throughput for user k on the same CC in the past user throughput over all aggregated CCs.

The LTE-Advanced users possess a reduced scheduling metric since their overall throughput is larger than the throughput per CC. But the LTE-Rel'8 users maintain their scheduling metric effectively, since their transmission and reception are restricted to a single CC. Hence, they are more prioritized in comparison with the LTE-Advanced users in resource allocation, and it fulfills the aim of enhancing fairness among users. The only necessity to upgrade from independent PS is to aggregate the past user throughput across all CCs.

All users in the system are presumed to have data to send or receive at any time as per the need in full buffer user traffic model. It can be stated otherwise that there is always a constant rate of data that requires to be transferred, as opposed to burst of data with a probabilistic arrival time distribution. The proposed system lets the spectral efficiency, independent of actual user traffic distribution type. If the residual packet error rate after HARQ re-transmission exceeds 1%, a user is outage.

Performance Measures

The following parameters are taken as performances measures to analyze the system.

Average cell throughput

It is defined as the summation of the user throughput in every cell, averaged across multiple runs (full buffer model), or a one long duration simulation run (finite buffer model).

Average user throughput

It is estimated by the Average throughput over all the simulated LTE-Advanced (or Rel'8) users.

Coverage throughput

This can be obtained by the 5^{th} percentile worst user throughput over all simulated users.

Frequency domain Proposed Fair (Fdps) Gain

The FDPS gain from frequency domain PF over RR scheduling follows a logarithmic function versus the active number of users in an OFDMA system. The relation is based on the available transmission bandwidth, the scheduling frequency resolution, the channel conditions, and the distribution of users within every cell. It represents the FDPS gain in average cell throughput for an LTE system with the simple approximation for the modeling purposes:

$$G_k = \begin{cases} 1, k = 1 \\ 0.11 * \ln(k) + 1.10, 1 < k \le 13 \\ 1.38, k > 13 \end{cases}$$

Where,

k - number of users for the CC.

The above equation is valid for a uniform distribution of users over the cell area. The selection of CC doesn't have any mechanism to guarantee exactly such behavior, since it works independent of location of the user. The proposed system does the approximation per CC by assuming that over a enough number of realizations the users on a specific CC will possess uniform distribution over the cell area.

Full Buffer Transmission with Packet Scheduling Per Cc

1. Analysis for various Balancing method with full buffer transmission

If the carrier balancing method will be used, the average number of users on each CC equals

$$\overline{K} = K_{\alpha} + (K - K_{\alpha})/N$$

The average cell throughput with K_α LTE-Advanced users is

$$\overline{R}_{cell}\left(K_{\alpha}\right) = \frac{CG_{\overline{K}}}{G_{\infty}}$$

Where,

C - equivalent cell throughput, however with full buffer transmission and PF scheduler in every CC.

$$\overline{R}_{cell} = \frac{C}{G_{\infty}} \sum_{K_{\alpha}=0}^{K} P_{K_{\alpha}} G_{\overline{K}}$$

The average user throughput on every CC is defined as the ratio between the corresponding per CC cell throughput and the average number of users. Since the LTE-Advanced users have been scheduled on N CCs, their throughput is tend to be N times that of the LTE-Rel'8 users. Consequently, the average user throughput is obtained as follows.

$$\overline{R}_{user,} = \frac{N^{I}}{K} \frac{\overline{R}_{cell}}{\sum_{K_{\alpha}=0}^{K} P_{K_{\alpha}} \overline{K}}$$

Where I=0 assigned for LTE-Advanced users and I=-1 assigned for Rel'8 users

Simulation Parameters

The simulation parameters that are used for Carrier load balancing and packet scheduling is shown in figure 5.1

The simulation results have been got for allocating the resource by using various carrier load balancing and packet scheduling (independent PS per CC/cross CC PS) with Full buffer and finite buffer model. The full buffer system model performance has been compared with the different types of packet scheduling per CC. The results have been observed for Average user, cell and coverage throughput with full buffer transmission by using independent PS/ Cross CC PS.

The graph shows the average user throughput in Mbps versus Percentage of LTE-A user in %.

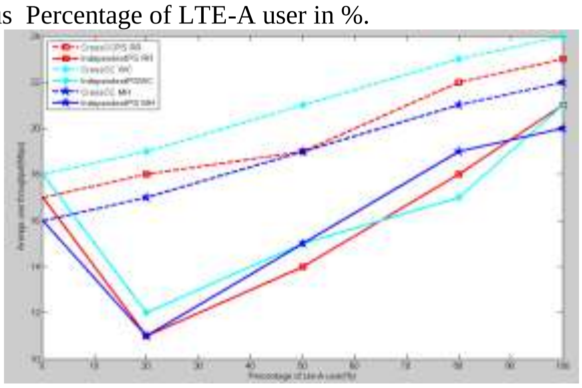

Fig.5.1 Graph showing Percentage of LTE-A user Vs average User throughput (Mbps)

The hashed lines show Independent Packet Scheduling and the straight lines other than dashed show Cross CC Packet Scheduling. The Turkish blue color line represents WC, Red color line is used for RR and the Blue color line is shown for MH. It is concluded from the graph that for WC, for Cross CC PS, if the percentage of LTE-A user increases, the average user throughput too increases rapidly. However for Independent CC PS, performance of WC is not up to the mark as in the cross CC PS. It is well depicted that WC is best among the other two methods in case of Cross CC Packet Scheduling.

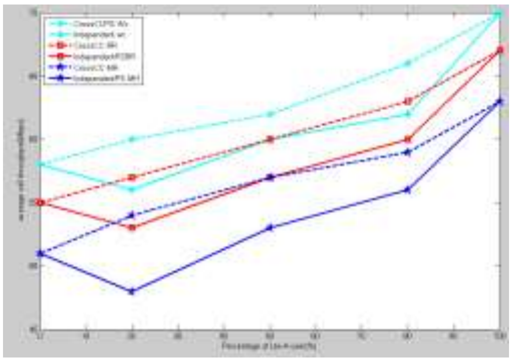

Fig.5.2 Graph indicates Percentage of LTE-A user (%) Vs average Cell throughput (Mbps)

The performance of average cell throughput for full buffer model with independent/cross CC packet scheduling using different load balancing method is shown in figure 5.2. The graph is drawn between the average cell throughput in Mbps and the Percentage of LTE-A user in %.

From seeing the graph, it is noted that if the percentage of LTE-A user increases, then the average cell throughput also increases. RR will come next to WC followed by MH. WC method proves to be best among the other two load balancing methods RR and MH as like as average user throughput performance.

The figure 5.3 illustrates the performance of coverage throughput for full buffer model independent/cross CC packet scheduling by using different load balancing method. The coverage throughput in Mbps versus the Percentage of LTE-A user in % is shown in graph.

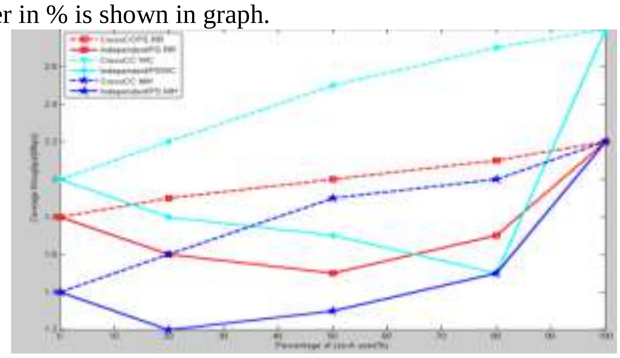

Fig 5.3 Graph illustrates Percentage of LTE-A user (%) Vs Coverage throughput (Mbps)

Conclusion

The three carrier load balancing methods are under consideration by using two different kinds of packet schedulers- independent PS and Cross CC PS. It is concluded from the simulation result is that Cross component carrier packet scheduling is better than the Independent packet scheduling to enhance the performance in terms of cell and coverage throughput. Also the simulation result illustrates that the Walsh code method is the best one for allocating the resource in comparison with other carrier load balancing methods such as Round Robin and Mobile Hashing.

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