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TECHNICAL REVIEW OF RRM FOR CARRIER AGGREGATION IN LTE-ADVANCED

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ABSTRACT

With the purpose of satisfying what is required for future IMT Advanced mobile systems, 3GPP presented carrier aggregation (CA) in its latest LTE-Advanced criterions. Although carrier aggregation permits accumulation of carrier components (CCs) disseminated inside and transversely in different bands (intra/inter-band) along with CCs grouping possessing different bandwidths, the expectation is that the carrier aggregation provides a commanding improvement to the user throughput in LTE-Advanced (LTE-A). CA will permit the achievement of the target peak data rates in excess of 1 Gbps in the downlink and 500 Mbps in the uplink and the users has the right to use up to 100 MHz total of bandwidth. Nonetheless, the carrier aggregation (CA) introduced is mentioned in LTE Rel. 10, has essential changes from the baseline LTE Rel. 8 even though individual CC in LTE-A stays backwardly attuned with LTE Rel.8. This article offers carrier aggregation methods' review and the supported scenarios; subsequently necessities on radio resource management (RRM) functionality supporting CA. On-going research on the diverse algorithms supporting CA in LTE-Advanced are charted.

Keywords: *Carrier Aggregation (CA), Component Carrier (CC), Radio Resource Management (RRM)*

1. INTRODUCTION

With the intention of meeting the growing call for high-speed and varied wireless broadband services, the IMT-Advanced (IMT-A) requirements have recognize minimal support for 1 Gbps and 500 Mbps peak rates for downlink (DL) and uplink (UL), individually [1]. In fulfilling these perplexing requirements, one key feature supports the extensive bandwidths up to 100 MHz [2]. To help fulfill what transmission bandwidth's requires, it is expected that all IMT-Advanced candidate technologies back carrier aggregation as introduced by 3GPP in the latest LTE-Advanced standards, inside either adjoining or non-adjoining spectrum bands [3].

Nevertheless, LTE-A carrier aggregation has protracted the idea in introducing noncontiguous spectrums aggregation in diverse spectrum bands [4]. Two or more different bandwidths component carriers (CCs) in different bands can be accumulated (up to 100 MHz with five CCs of 20 MHz) in supporting broader transmission bandwidth between the eNB and the user equipment (UE) [5]. LTE-Advanced backs similar CC bandwidths' range (1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz) that are sustained in LTE Rel. 8. Whereas LTE-A supports bandwidth extension with the aggregation of CCs, subject to spectrum obtain ability and the UE's competence [6], CC backward compatibility is required in LTE-Advanced from the outset. With individual CC in LTE-A's compatibility with LTE Rel. 8, carrier aggregation permits operators migration from LTE to LTE-Advanced while remain as provider for services to any LTE users. This could be done as the eNB and Radio Frequency (RF) specifications linked to LTE Rel. 8 are unaffected in LTE-A [7]. Nevertheless, CA being introduced to LTE-Advanced need different functionalities and modifications to the link layer and radio resource management (RRM) [8].

In this paper, we emphasis on RRM framework supporting how CA functions and present an analysis of present literature on CA related RRM schemes in LTE-A. Moreover, we explain the most

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existing researches of resource allocation algorithms for CA LTE-A system and identify their strengths and limitations.

The organization of the paper is as follows. Section 2 provides a summary of CA in LTE-Advanced. In Section 3 discusses the multi-carrier RRM framework. Section 4 gives an outline of carrier scheduling schemes. Section 5 presents a synopsis on present research on resource distribution for CA-RRM schemes and to conclude Section 6, the directions for future research is presented based on open challenges together with conclusions.

2. CARRIER AGGREGATION (CA)

CA is one of the major capable technologies that have over the time emerged in the LTE-Advanced network used in the realizing high data rates of 1 Gbps as well as 500 Mbps downlink and uplink respectively, users are able to access the highest bandwidth of up to 100 MHz spectrum. The 3GPP LTE system supported component carriers with bandwidth 1.4, 3, 5, 10, 15, and 20MHz.Using LTE-Advanced along with a CA technique brings about a multi component carriers, this could be on the same or in a dissimilar frequency bands which could be aggregated to achieve the attainable target bandwidth and data rates for the user [9].

2.1 CA Classification

In LTE-Advanced system, CA procedure can be categorized into two most important types as indicated in Figure 1 below: (i) Contiguous CA which combined the adjacent multiple accessible component carriers to each other for offer enormous bandwidths. The bandwidth is realizable using a single Fast Fourier Transform (FFT) and a single radio frequency (RF) unit. (ii)Non-contiguous CA: this is a state whereby the multiple obtainable component carriers are detached within the similar frequency band "intraband" otherwise the different frequency band "interband". This entails multiple radio chains, FFTs and needs take notice that diverse CCs will have different path loss and Doppler shifts when designing the RRM algorithm [9][10].

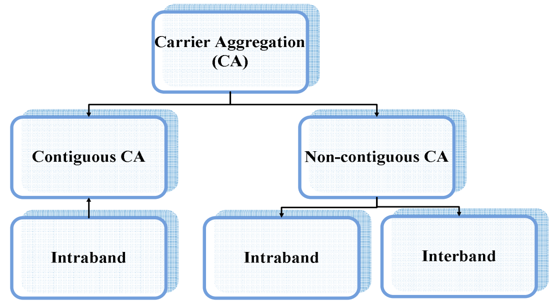

Figure 1: CA Classifications

The support for both contiguous and non-contiguous CA of CCs with diverse bandwidths provides important tractability when utilizing spectrum efficiently, and previous frequencies gradually reframed utilized by additional radio access systems. From the stand point of resource allocation and management, the implementation of contiguous CA is easier. Commonly, the deployment of carrier aggregation systems better user data rates instead of spectral effectiveness, even though operation over multiple carriers provide a certain level of enhanced interference control [11].

The highest sustained bandwidth for LTE Advanced of 100 MHz is achievable using CA of 5 CCs of 20 MHz as illustrated in Figure 2(a). Therefore, a LTE-Advanced user supporting such a lofty bandwidth could possibly be supplied concurrently over all the 5 CCs. Each bandwidth belonging to CC trail on the LTE Rel-8 support bandwidth formation and this consist of 1.4, 3, 5, 10, 15, and 20 MHz's. The cumulative CCs could possibly be contiguous as illustrated in the Figure 2(a), or may be non-contiguous (intra/inter) band, as seen in Figure 2(b, c) [12].

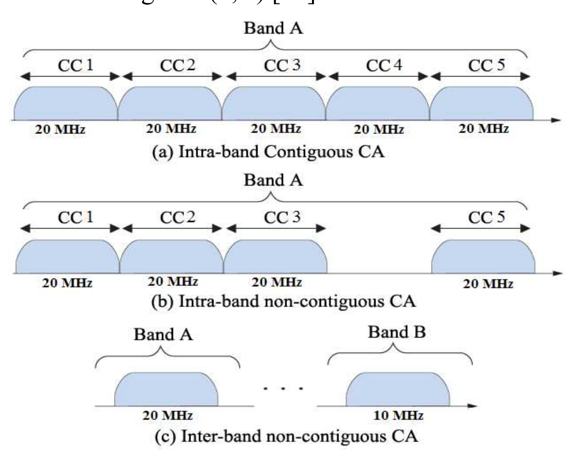

Figure 2: Types of Carrier Aggregation

In carrier aggregation cases, the configuration of diverse LTE-Advanced UEs inside a single eNB with different CCs depends on the UE's ability and

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disposition situations [13]. When an LTE-Advanced UE initially launches or relaunches radio resource control (RRC) connection, only one CC is constructed, mentioned as primary CC (PCC). Based on traffic load and quality of service (QoS) requests, the configuration of UE with one or more supplementary CCs, is referred to as secondary CCs (SCCs) [14][15]. Diverse users may not essentially utilize similar CC as their PCC and a CC at an eNB may be the PCC for one UE and serves as a SCC for another UE.

The movement of UE inside the geographical area is served by an eNB and the alteration of PCC corresponds to CC with the best signal quality. PCC alteration can also be accomplished by eNB based on other deliberations for instance load balancing [16]. As it is dependent on elements such as the buffered data amount, required QoS, and carrier loading, the usage of DL SCCs could be abled and disabled with dynamism. As the signaling number is lessened for the disabled SCCs, UEs battery power consumption could be decreased with the dynamic activation/deactivation SCCs. The designed SCCs are on defaulted de-activation, so the explicit activation is needed before being scheduled. However, a user's PCC activation is always expected and is therefore not subject to any de-activation procedures [17].

3. MULTI-CARRIER RRM FRAMEWORK STRUCTURE

The composition of a multi-carrier structure is demonstrated in Figure 3. The base station foremost execute the control of admission intended for the establishment of a new radio carrier so also are the QoS parameters configured and then it utilizes Layer-3 carrier load to allocate the users on different CCs. There are possibly different techniques in balancing the load across CCs, and this impacts the network performance. The Layer-2 Packet Scheduling (PS) is executed immediately after the users are allocated onto an exact CC(s). In this perspective, the PS principally means the act of taking the task of allotting time frequency resources for every assigned user on the different CCs. Although the independent Layer-1 transmission is employed, it also contained link adaption (LA) and a hybrid automatic repeat request (HARQ) per CC to optimize transmission on dissimilar CCs conferring to qualified radio situations [10]. The settings of diverse transmit powers for specific CCs could provide different levels of coverage [14]. Particularly, in inter-band CA cases, the radio channel characteristics, for example, propagation, path loss, building penetration loss, and Doppler shift, differ significantly at different frequency bands, choosing different transmission parameters comprising modulation scheme, code rate, and transmit power per CC is anticipated to be beneficial in improving user QoS further [18].

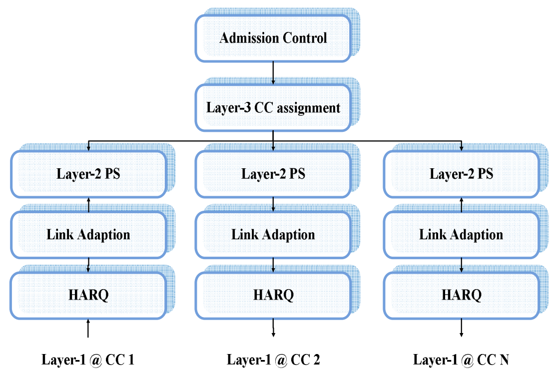

Figure 3: RRM Structure of a LTE-Advanced System with Carrier Aggregation

Within a multi-carrier LTE-Advanced system, LTE-A and LTE users may perhaps exist mutually at the same time. The LTE-A users could possibly be allocated on all CCs, while the LTE users support transmission only exists on one CC. For the radio channel aware multi-user scheduling diversity to be fully exploited and be developed in the trucking effectiveness, one must suppose that the LTE-A users are constantly allocated on all CCs. Therefore, base station requires being selected an appropriate CC for every of the LTE users. Figure 4 illustrates how LTE-A and LTE users are treated diversely in a multi-carrier LTE-Advanced system [19].

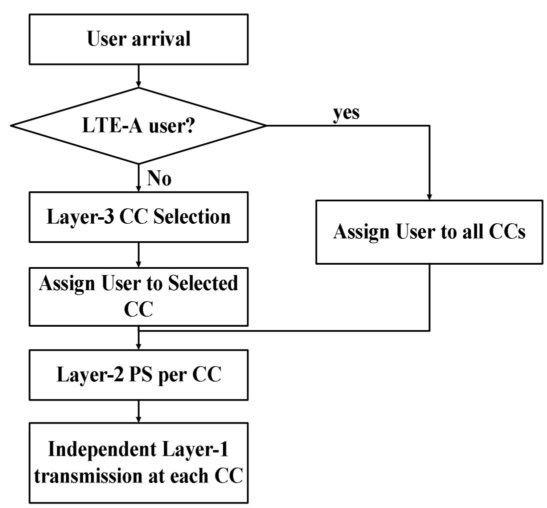

Figure 4: How LTE-A and LTE Users are Treated Diversely

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Having a multiple users on each CC, a frequency domain channel sensitive PS could utilize the frequency as well as the user domain diversity in order to achieve the system performance in contrast to a channel blind Round Robin (RR) scheduler.

In LTE-Advanced system, the RRM framework for a multicarrier is represented in the Figure 5; it fundamentally consists of two cogent parts namely: the CC assignment functionality which it's basic role as to that allocate CC(s) to every user, and PS which is endowed with the responsibility of choosing the resource distribution for all users in every CC. The PS receives the Channel Quality Indicator (CQI) from the response link in order to evaluate and assess the feasible throughput and allocate resources consequently. The RRM decisions are used locally at the base station, it is also forwarded via the downlink control channel to the users so that it could inform them about the allocation. It is of merit remember that the state of the load and the user past throughput on each CC are accessible through the base station. Hence, the CQI is only necessary in the uplink feedback channel. Substituting the user past throughput on each CC is essential for a smooth cross-CC PS as it is illustrated in figure below [19].

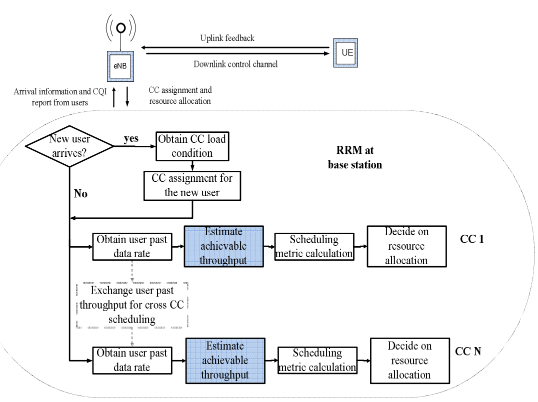

Figure 5: RRM Framework of A multi-carrier LTE-Advanced System

3.1 CC Selection Techniques

Layer-3 CC selection is the new RRM functionality initiated in LTE-Advanced which used the user QoS requirements, terminal capability, aggregated traffic level, and traffic load per CCs for component carrier scheduling. For optimal performance [10], it is advantageous to have roughly equivalent load on the different CCs and bare minimum number of CCs is allocated to UE so as to reduce signal processing complication and power over-utilization. Below are list of different CC selection algorithms:

- CC selection technique to attend to load balancing:
    1. Random selection (RS): These are CCs meant for every UE selected randomly within the obtainable CC set by eNB.
    2. Circular selection (CS): This makes a circular selection of CCs. It offers better throughput and coverage performance compared to the RS.
    3. Least load (LL): This does apportion user's packets to the CC with a smallest possible traffic load. It is better than RS and CS in terms of cell throughput and coverage performance.
    4. Modified Least Load (M-LL): utilizes the projected future average transmission rate. While the benefits are highly dependent on the estimated accuracy of the average user rates, this approach could lead to higher complexity.
- Making a CC choice for load balancing with full consideration for diverse channel characteristics:
    1. Inter-band carrier switch: UE to start with will apportion to CCs which has the high quality in some particular band. Thereafter, the load is verified in both bands for balancing of load. Therefore, if the load of an allocated band is higher compared to the other band, the users with high CQI will be moved to another band. This allows for high throughput however it could result in the boosting complexity and delay.
    2. RSRP based CC selection: This allots the better CCs to the UE whose average data rate is relatively small. It is extra ordinarily proficient for RT traffic
    3. G-factor based selection: For LTE UE, this allocates the best quality CC to cell edge UEs and the slightest load CC to other UEs. For LTE-A UEs, it could apportion all CCs. This improves the coverage performance.

As the rise of CCs a user has to accept (i.e. surge of bandwidth needed for process) leads to higher signal processing complexity and power consumption, the configuration of minimum amount CCs is needed in high traffic loads [20].

In LTE-Advanced system with the existing LTE-A and legacy LTE UEs, fairness can be a problem in CC development. Subsequently, the LTE-A UEs will be planned on more CCs than the LTE users,

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the LTE UEs attain lower throughput than the LTE-A UEs [21].

As CCs are dynamic alteration depended on the condition of the radio, the RRC's frequency arrangement is amplified, which leads to the increase in RRC signaling even though the SINRs are improved [22]. A UE in power restricted condition may experience outage caused by lack of power in transmitting the necessary feedbacks consistent to all configured CCs [23]. Therefore, it is imperative to lessen the signaling overhead with SCCs being deactivated dynamically. Although the signaling overhead is also inclined by the situation, the CCs carrier aggregation with different coverage surges the RRC signaling overhead.

3.2 Packet Scheduling

Packet scheduling is one most important RRM functionalities aspect which is accountable for the gathering of users as well as transmission of their packets in a manner that the accessible radio resource is resourcefully used and that the users' QoS requirements are met. The PS functions for LTE-Advanced with CA are similar to the PS scheme utilized in LTE Rel-8, with the exception of LTE-Advanced PS are permitted to schedule users across numerous configured and activated CCs for UEs [14].

Scheduling procedure is such one that is involved with the portions allocation of accessible spectrum distributed among users by way of adhering to some specific policies [15]. The policy signify the choice process used in selecting which users should be assigned radio resources (PRBs) in the specified TTI and which users should be deferred to the subsequent TTI [24] to make available the necessary QoS, fairness, spectral efficiency and service priorities. The Figure 6 [25] indicates the model of processing scheduling method; the entire procedure can be grouped in a sequence of their frequent operation, universally in every TTI:

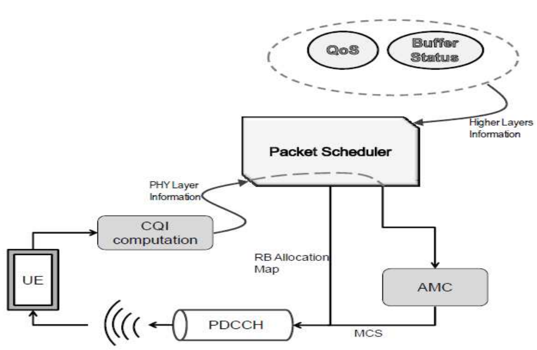

Figure 6: Simplified Model of Packet Scheduler

1. Each UE translates the reference signal, compute the CQI, and convey it back to the eNB.
2. The eNB utilizes the CQI information for the allocation decisions and fills up a RB.
3. The AMC module makes selection of the paramount MCS that ought to be employed for the transmission of data by scheduled users.
4. The information concerning users, the allocated RBs, and the certain selected MCS are conveyed to the UEs on the PDCCH.
5. Each UE reads the PDCCH payload and, in case it has been scheduled, accesses to the accurate PDSCH payload.

The principle of a scheduler is to schedule users requesting diverse services and in accordance to the pre-described packet scheduling algorithms in enhancing the QoS terms to users and the system-level performance [26]. These said different users request diverse QoS requirements such as throughput. The scheduler takes consideration of these requirements and thus re-schedules users respectively. Packets from users queue are therefore sent out accordingly depending on the scheduler decision. Packet Scheduling is therefore a process of managing network bandwidth which can observe the significance of data packets in addition to depending on the priority of the packet to provide it upper or lesser priority.

In [25][27], a dynamic packet scheduler is described as the essential entity which take up scheduling decisions enthusiastically to guarantee high spectral efficiency even as it provides essential QoS.

Packet schedulers' design requirements in LTE-Advanced system with CA, should address:

1. The necessity in handling the packet scheduling in numerous CCs environments.
2. The necessity in supporting the necessary QoS for numerous traffic types.
3. The requirement of a high system throughput.
4. Upholding fairness amongst users (LTE-Advanced and LTE UEs), as recognized in [28].

3.3 Packet Scheduling Strategies in Downlink Systems

The approach behind scheduling of any wireless network can be roughly categorized into four different classes as revealed in Figure 7.

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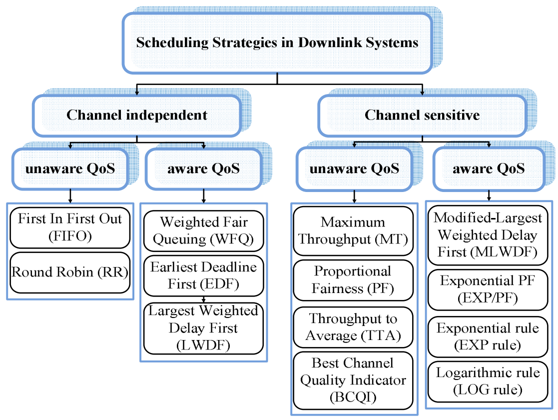

Figure 6: General Classification of Scheduling

Channel independent scheduling is basically founded on the supposition that channel is time invariant as it is also error-free [20].

Channel sensitive scheduling, with the aid of CQI intelligence which is intermittently forwarded by UEs to eNB, the channel quality experienced by each UE is estimated by the scheduler. For this category of scheduling the scheduler may perhaps endeavour to take full advantage of the QoS requirements of every UE (QoS aware scheduling) otherwise it may possibly try to offer fairness with UEs (QoS unware scheduling). Channel sensitive scheduling is made based on the CQI reports from the UE only in LTE [20].

Table 1 demonstrates the similarity of a core packet scheduling algorithms employed in wireless networks which incorporate LTE.

Table 1: Comparison of Different Resource Scheduling Approaches

Strategies	Algorithms	Advantages	Limitations
Channel independent/ unaware QoS	FIFO	• Simple technique.	• Inefficient and unfair technique. • It does not account channel quality variations.
	RR	• Simple technique. • Good fairness.	• Inefficient in terms of throughput. • It does not account channel quality variations.
Channel independent/ aware QoS	WFQ	• It is able to avoid the starvation of low priority applications.	• It does not account channel quality variations.
	EDF	• Avoids deadline expiration.	• It does not account channel quality variations.
	LWDF	• Provides QoS in terms of delay.	• It does not account channel quality variations.
Channel sensitive/ unaware QoS	MT	• Maximize the overall throughput	• Unfair resource sharing.
	PF	• Good trade-off between system throughput and data rate fairness among UE.	• Low spectral efficiency.
	TTA	• Strong level of fairness.	• Low spectral efficiency.
	BCQI	• High system throughput. • Maximize cell capacity.	• Low level of fairness.
Channel sensitive/ aware QoS	M-LWDF	• Good system throughput. • Acceptable level of fairness.	• Inefficient in overloaded condition.
	EXP/PF	• Limited delay of real time services. • Maximize system throughput. • Acceptable level of fairness.	• Complex.
	EXP rule	• Good system performance.	• Complex.
	LOG rule	• Good system performance.	• Complex.

4. CARRIER SCHEDULING SCHEMES IN LTE-ADVANCED

The carrier scheduling CS system in the LTE-A network with CA is categorized in a diverse range of system suppositions. Generally, the supposition involves two facets: (i) is the aggregation scenario and (ii) is the traffic model. According to the CA deployment scenarios as indicated in [21], three aggregation scenarios are considered: (i) intraband

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contiguous CA, (ii) intra-band non-contiguous CA and (iii) interband non-contiguous CA. In the aggregation scenario number (iii), the CCs involved in the diverse frequency bands may possibly cover some notable radio propagation qualities which are distinct from the first two scenarios which ought to be cautiously measured once analyzing the CS system in these scenarios.

In respect to traffic modeling, two kinds of traffic models are suggested in [17] for the purpose of evaluating the performance of LTE-Advanced system. The foremost type is with time-variant user populace. Here a newest user appears randomly at the scheme with a limited-length file for transmission and departs the system whenever the transmission of the whole file is exhausted. Once it departs, the user never comes back anymore. The next category is with static user population. Here each of the users holds a traffic flow with either continuous or elastic traffic input.

While the system is broaden/expanded from a single carrier to numerous carriers, joint user scheduling scheme (JUS) and separated random user scheduling scheme (SRUS) are two straight forward techniques that will respectively control the multiple carriers. When joint user scheduling algorithm is employed [22], the eNB would compute the throughput of users in each CC. This is the optimum scheduling algorithm. Nevertheless, once the amount of users and CCs are huge, the complication of the system is extremely high for performance. If the randomly separated user scheduling algorithm [17] is implemented, the eNB estimates the user throughput in single CC, so as to reduce the complexity and make it smaller than JUS algorithm.

4.1 Resource Scheduler For CA Framework Structure

Each of the UE is allocated a discrete buffer by eNB to accumulate the data coming in from the basic network side. The UEs' buffers are handled by the resource scheduler (RS) at the eNB. There available M RSs in the system and the functionality of the RS is represented in Figure 8.

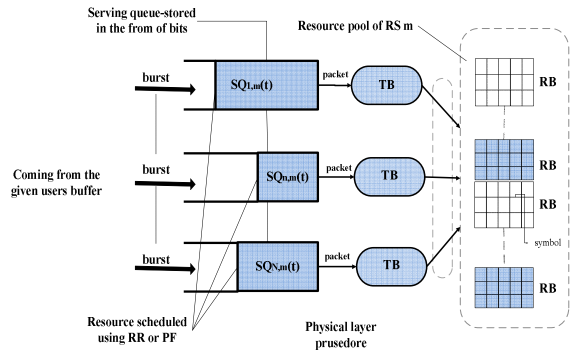

Figure 8: Framework of the Resource Scheduler with CA

There is a serving queue for each UE in each RS and the serving queue of RS m for UE n at model t is indicated by SQn,m (t). Every bit of the serving queues for UE n in diverse RSs is planned to its buffer Qn. The RS is occupied with resource pool m; the RS belonging to the CCs are managed by RS m. The amount of CCs controlled by one RS can be one or numerous but it is not more than the totality of CCs in the scheme. Likewise, one CC resource can simply be allotted to one of the RSs.

In every system, each RS translates data from its serving queue array to develop transmission blocks (TBs) in support of its serving users. The TBs are ultimately packed into the RBs and transmitted to the UEs after the physical layer processing. The resource scheduling strategy controls the processing of the RS, taking for instance the round robin (RR) or proportional fair (PF). However, the CS scheme is responsible for deciding the quantity of RSs in the system, the volume of each RS's resource pool and the serving users of each RS.

4.2 Joint User Scheduling Scheme (JUS)

JUS is one of the straightforward CS system used in managing the numerous CCs. It is responsible for combining the multiple carriers simultaneously making them become one carrier. As demonstrated in Figure 9, JUS places the RBs of the entire CCs in the resource pool of a single RS, that is M = 1. Consequently, this single RS served all the users, JUS simply require one-level scheduling, namely, resource scheduling, which is completely managed by RS. This is the similar as the scheduling process in the traditional single-carrier method.

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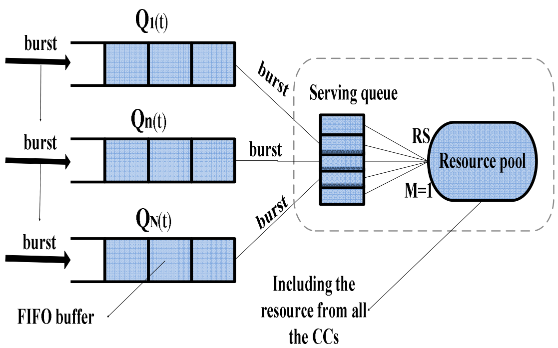

Figure 9: Illustration of The JUS Scheme

JUS necessitates every user to receive signal from the entire CCs concurrently and endlessly, although one user's data is only possible for transmission on several of the CCs. It basically multiplies the signal processing complication and as such, the power consumption at the UEs is also increased.

Nevertheless, the absolutely combined processing apparatus facilitate and aids JUS in maximizing the spectral efficiency in the specified opportunity resource scheduling strategy. Temporarily, it also causes JUS in accomplishing the saturated resource operation. Hence, in respect to performance, JUS is the optimum CS scheme best for the LTE-advanced system with CA.

4.3 Separated random User Scheduling Scheme (SRUS)

Discrete from JUS, SRUS activate each CC autonomously as shown in Figure 10, such that there have to be the equal amount of RS and CC in the system, explicitly, M = L. Therefore, the resource contained in every RS's resource pool comes from just one of the CCs. SRUS confines the UEs to receive from just one of the CCs. The CC in which a user is attached to be randomly chosen in the preliminary access and thus makes it unchangeable any further. Evidently, SRUS requires two stages scheduling. The first stage is the one saddled with taking charge of the user allotment among the CCs, which is sort of a static scheduling, and the second stage is the standard resource scheduling operated and supervised by each RS.

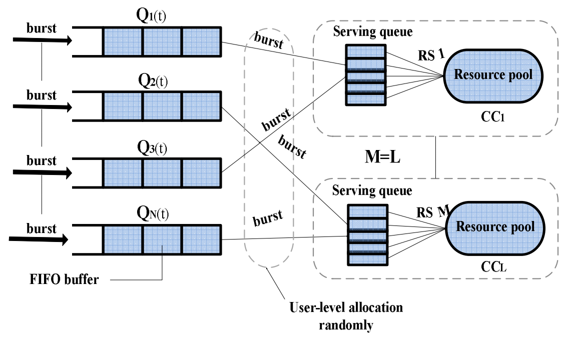

Figure 10: Illustration of The SRUS Scheme

As earlier depicted, while SRUS employed, the UEs' performance is essentially similar to that of the single-carrier systems. Therefore, for the UEs scheme, it is unnecessary to alter anything. As a result, the SRUS is the easiest CS scheme meant for the LTE-Advanced scheme containing a CA. On the other hand, the function ability of a SRUS is still ineffective. At the same time, within the multiple user wireless communication systems, the means of attaining maximum spectral efficiency is to allocate resources to the suitable user which has data to transmit within the system [29]. Though, when employing SRUS, the selected user placed in each RS is solely a subset of the entire uses. Thus, the spectral efficiency of SRUS is inevitably lesser than that of JUS. Alternatively, SRUS will result to various CCs standing inoperative because their users serving data have been absolutely exhausted in the scenario of elastic traffic input, even as other CCs are still functioning hard. In other words, SRUS may build the traffic load transversely to unbalanced CCs. For that reason, the SRUS cannot completely make use of the resource available in the system.

As mentioned earlier in the paper, the decomposition of aggregated spectrum allocation into CC selection and RB assignment phases is possible to lessen the computational complexity. Additionally, the automatic traffic load balancing over CCs is predictable in JUS while SRUS may cause unbalanced loading across CCs [30]. Thus, SRUS cannot fully use the resources. JUS is seen as LTE-Advanced system with CA optimal scheduler at the cost of high complexity [31].

When assigning two CCs to ten users, it was discovered that more symmetrical user assignments on CCs can cause in higher throughputs. As there are load balancing impacts fairness between users, in situations where CCs are distributed unstably, users' throughput on the more crowded carrier is lessened. Nonetheless, JUS based CA scheduling

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shows better fairness among the users by mechanically balancing the load.

5. ONGOING RESEARCH ON ALGORITHM FOR CA-RRM

In this part, the most of the existing researches on resource allocation algorithms for CA LTE-A system are provided; all studies suppose the downlink of the wireless system since higher application throughputs are requested in the downlink rather than in the uplink [40].

Round Robin and Mobile Hashing carrier load balancing techniques [28] was used in Cross-CC packet scheduling for allocating the CCs to the users which target to maximize the coverage performance and resource allocation fairness among users. RR balancing assigns a new arrived user to the carrier that has the least number of users, whereas the (MH) balancing distributes the users uniformly. Hence, the system will suffer from reduced trunking efficiency.

The proposal of CC coupling idea [32] was to attain the resource utilization. When the CCs are in different working states (busy/idle), the users linked to the busy CCs can be momentarily permitted to transmit on those idle CCs for a limited time through CC coupling. There remaining challenges linked to the development of the efficient coupling methods for numerous CCs of different BWs belonging to different bands.

Anew proposed carrier scheduling [33] which namely Separated Burst Level Scheduling (SBLS) was proposed for achieve higher resource utilization under acceptable complexity level. It is the same as SRUS but difference in user allocation where the user is not served by the fixed RS. The RS of one user can be changed in the burst level but its number still one. However, there remains challenges associated with CC switch delay.

An efficient packet scheduling algorithm based on proportional fair criterion in LTE-Advanced with carrier aggregation [34] was design for supporting real time traffic and non real time traffic simultaneously. All packets are first classified into real time, non real-time packets by classifier and delivered into RT/NRT queues. Based on dispatching policy which namely, dispatching frequency and RB reservation, RT packets in the queue can be delivered into transmission queue for every frame but NRT packets will delivered periodically every n frames or RT packets can be transmitted over all RBs, whereas NRT packets can only transmitted over some RBs. However, this structure needs to be studies more on how to adaptively adjust dispatching frequency and the RB reservation level for RT traffic throughout the scheduling process to attain the best overall system performance.

A Semi-JUS carrier scheduling scheme [35] was proposed to improve the LTE-A performance in terms of average serving time, average user throughput and ensure lower complexity. UEs are limited to transmit and receive from only one CC at any time and the traffic load of each CC could be balanced by switching the connected CC for UE in burst level by using RR or SQ dispatching policies.

A SPF-PF crossing component carrier joint scheduling algorithm [36] which considers interband CA scenario. It uses a similar PF algorithm to select CC for users based on CC's characteristic and the user's location whereas PF algorithm to allocate RBs on each CC for user for maximize the system throughput and fairness and ensure load balancing on each CC.

A novel quality of experience (QoE) based carrier scheduling scheme [37] was deployed in LTE-A network with multiple services to maximize the user QoE which determined by application level QoS and network level QoS, which is the quality metric of media resource and reliable delivery of service data over the network respectively.

The joint CC, RB and power allocation (JCRPA) algorithm [38] was proposed to improve system performance in terms of network utility, average throughput, and fairness. The users are classified into baseband and broadband users based on their CA capabilities and deploy minimizing system utility loss (MSUL) algorithm to allocate CC and RBs dynamically with fixed power allocation. Multilevel water-filling power allocation algorithm is developed to optimize the power allocation for given CC and RB assignment.

An improved PF scheduling algorithm based SRUS [39] was proposed with weigh factor which related to the number of carriers and the percentage of LTE users for improves the LTE user throughput and system fairness.

Cross CC and Cross BS scheduling algorithms were used in energy coordinated scheduling mechanism [40] to minimize the energy consumption in cellular networks by dynamically switching off CCs and eNB according to load variations. The former is suitable for high user traffic and the CCs to be deactivated in each E-BS can be centralized or distributed scheduling,

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whereas the latter is suitable for low user traffic, in which E-BS could be switched off to further reduce power consumption while the surrounding cell ranges are covered by C-BS through increased the transmit power.

A multi carrier scheduling algorithm is based on joint two dimensioned PRB and CC [41] with consider the user's QoS requirements, which enables the best user allocation over any number of CCs for achieve the user throughput.

To improve the performance of cell edge users and LTE users throughput, [42] was proposed an improved PF scheduling suitable to multi-carrier system which called (SJS-PF) by introduced a carrier weight factor. The carrier weight factor is composed of carrier coverage weight factor which improve the cell edge user throughput and the user category weight factor which achieve the LTE user performance.

A distributed inter-cell cooperation scheme for joint Packet Scheduling between two base stations in LTE-A system with CA [43] was proposed which improve the average cell edge user throughput.

A joint carrier aggregation and packet scheduling [44] was suggested dynamic CCs assignment algorithm based on channel conditions and network load for achieve load balancing and backlog based resource blocks scheduling scheme with weighted-CQI based intelligent link adaption to obtain good throughput and delay fairness.

Carrier aggregation with per CC different tilting and cross-CC scheduling algorithm conducted by [45] to maximize cell edge user throughput.

A novel dynamic aggregation carrier (DAC) scheme for downlink transmission suggested by [46], which enables CCs to aggregate with each other in a dynamic manner. The dynamic nature of this scheme based on round robin wit priority or serving the longest queue methods for allows the total CCs capacity to be fully utilized, whereas the number of aggregated supplementary CCs is decreased so as to lower the computational complexity at user equipment (UE). Furthermore, the DAC scheme offers good performances in terms of delay and throughput while reducing power consumption and the signaling overhead at UEs.

QoS based SRUS in cognitive LTE-A system with CA [47] was study for improve the performance in terms of QoS performance. It classifies the services according to delay sensitive degree and gives priority to them. It assignment CCs to UEs based on load balancing whereas the RBs will allocate according to service priority.

Joint Queue scheduler with priority analyzer was investigated by [48] to overcome queue waiting infinite on high traffic load. Priority analyzer defines the priority among the users on basis of their tariff priority and bandwidth requirement. It improves the overall performance, reduce average error, and reduce latency and fairness.

Genetic algorithm based self-organized downlink resource allocation [49] was suggested; where the joint CC selection and RBs scheduling is considered for resource allocation. It improves the average user throughput and system fairness.

A Novel greedy –based scheme [50] was proposed to assign RBs of each CC and MCSs to UE at each TTI, to maximize the system throughput while maintaining proportional fairness. The scheduler can reassign CCs to each UE at each TTI based on channel quality with only one MCS can be selected for each assigned CC across all its assigned RBs for UE at any TTI.

A new packet scheduling named Enhanced Cross-CC (EPF) was consider by [51] that satisfies the fairness among the different kinds of UEs by designing a weighting factor to PF based on the number of CCs which assigned to UE and the number of available CCs while achieving their throughput.

A resource reserved PF resource allocation algorithm with power allocation was investigated by [52] where the users are classified into center-cell and edge-cell users. During each resource allocation period, a certain number of CCs and RBs were reserved only for the edge-cell users and these resources were transmitted with higher power to enhance the transmission capacity and fairness of cell edge users while the remaining resources will be allocated to the center-cell users by PF with lower power to avoid co-frequency interference.

An efficient joint resource allocation and link adaption algorithm for downlink 5G LTE-A network which namely, efficient RB allocation algorithm (ERAA) was study by [53] where multi user diversity and users CA capabilities are exploited by eNB to allocate CCs, RBs and MCS. It offers better proportional fair throughput and higher fairness index.

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6. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Carrier aggregation is an influential trait that allows ultimate flexibility and effectual use of frequency resources which resulted in user data rates significant improvement even though rate of increase slows down at higher traffic loads. Nevertheless, the introduced CA is directly followed in deciding the number of bands and bands must be used with the intention of satisfying the requirements under different constraints. This executes numerous encounters to the design of RRM mechanisms for CA based systems.

One important feature is the necessity for original CC selection techniques. Strategies to optimize CCs collection for UEs could assist in satisfying the QoS requirements of numerous traffic classes while the high system throughput and the fairness among diverse UEs classification is guaranteed. To date, a majority of CC selection algorithms proposed, inter-carrier load balancing is seen as the metric of choice owing to attainable improvements in spectrum application. CC selection schemes' performance is also subjected to the deployment scenario.

The complexity of the existing algorithms for SRUS and JUS causes high process delay which results in scheduling performance degradation, since longtime and much iteration is required to get the final scheduling decision. That definitely causes a huge amount of packets to be dropped from the transmission system. It results in the throughput not being fairly distributed among the users, since it may focus on servicing specific users (real time users) and bar other users from being served (the non-real time users). This means that no balance will be achieved among users and the system will enter into the endless loop of non-real time dropping packets.

Most of the recent algorithms in LTE-A do not offer sufficient fairness among users since there is an inefficient resources allocation among users. Moreover, most of existing scheduling algorithms are based on one criterion to allocate the network resources among active users.

Various studies decoupled resource allocation issue into CC range and RBs scheduling with the intention of reducing application difficulty. In this case, however, if CCs are selected without considering the channel's quality, good performance from the scheduler should not be anticipated. Hence, considering CCs selection and RB scheduling algorithms is needed as joint CC selection and RB scheduling algorithm perform better when likened with any decoupled CC selection and RB scheduling approaches, joint allocation algorithms' designs with rational levels of complexity must be studied further.

Dependent on the deployment scenario, spectrum availability, and the device capability, the types of carrier aggregation could be decided. For inter-band CA, diverse channel features and transmission performance must be put into consideration in planning CC selection schemes. Furthermore, the joint multiple component carrier resource allocation and transmission parameters adaptive adjustment such as transmission power for different CCs is still seen as an open research topic. In the case of intra-band contiguous CA, the guard bands subcarriers between the CCs can be utilized to transmit and raise the spectral efficacy. The methods using the guard bands can be examined more to improve the spectrum utilization.

This paper provides a literature survey on the latest RRM schemes for CA in LTE-Advanced and charted areas that needs more research. Very-high-data-rates supporting inside both contiguous and non contiguous spectrum bands, through carrier aggregation is predicted to continue to be one of the most significant methods to improve the system performance in the future generation telecommunication systems.

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