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RESOURCE SCHEDULING IN FREQUENCY SELECTIVE ENVIRONMENT FOR CARRIER AGGREGATION SYSTEMS

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ABSTRACT

Carrier Aggregation (CA) is one of the core proposals of LTE-A for bandwidth expansion from current limit of 20MHz obtainable in LTE systems to 100MHz for LTE-Advanced in order to meet ever increasing demand for high speed mobile broadband services. Resource scheduling for UEs within frequency selective environment is a complex scenario capable of impeding not only the higher data rate expected but also the throughput and fairness for LTE-A systems. In this paper we proposed a technique to effectively schedule the UEs within frequency selective environment. Our proposed resource allocation paradigm is built on PF algorithm with resource aggregation control mechanism. The control mechanism is meant to improve system throughput and fairness. The improvement is ensued by considering the UEs' environment experience and aggregation capability metrics before scheduling. Our approach titled 'improved proportional fair algorithm for resource scheduling (IPF-RS) is different from existing works that assume non frequency selective environment for scheduling. Simulation results show that the fairness and throughput can be improved.

Keywords: *Carrier Aggregation (CA), Proportional Fair, Resource Scheduling, Improve Proportional Fair, Frequency Selective Environment.*

1. INTRODUCTION

The demand for more spectrums is increasing, especially larger continuous block for higher peak bit-rate applications. Carrier aggregation (CA) is one of the most distinct features of 4G systems including Long Term Evolution- Advanced (LTE-A), which is being standardized in 3GPP as part of release 10[1].Modifications are made to physical, MAC and Radio Link layers of Rel 8 (LTE) to yield LTE-A specifications. Carrier aggregation (also called spectrum aggregation) technology allows multiples (up to 5) contiguous or non-contiguous blocks of spectrum to be treated as if they were one large continuous block [2]. Aggregated component carriers do not need to be continuous in frequency domain. Three cases can be identified as shown in figure 1.The three different forms of carrier aggregation are;

- Intra-band aggregation with frequency-contiguous component carriers
- Intra-band aggregation with non-contiguous component carriers
- Inter-band aggregation with non-contiguous component carriers

User equipment (UEs) with LTE-A capability can be scheduled either on one or more component carrier(s) (CC) depending on the user demand. Investigations in [3-5] have shown that blind scheduling either in downlink or uplink is not the best for UEs and even maximum utilization of networks resources could be impacted. It is in line with this that researchers have proposed different techniques to allocate radio resources to maximize network resource utilization and improve fairness and throughput especially in a multi-user scenario. Different scenarios have been considered. In [6] and references therein considered power consumption by UEs whereas in [7] signal strength is the key factor accounted for. Similar works used interference, pathlosss and load as the index for scheduling.

Comparatively, we are considering frequency selective environment for scheduling in this paper. Considering the backward compatibility towards the older system, the CA systems should be designed to support UEs with different CC capability under the control of the same base station (Evolve NodeB or eNB) such that UEs with LTE-A capability could be scheduled on all or some of CC whereas the legacy UEs may work only on one CC at a time. The main resource to be scheduled is the

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resource block (RB).

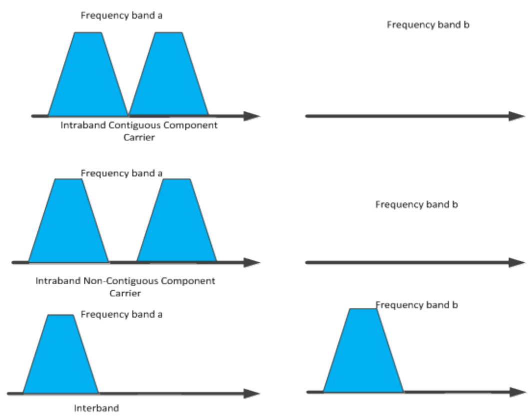

Figure 1: Different Types Of Carrier Aggregation

Resource block is a unit of transmission consisting of 12 subcarriers in the frequency domain and 1 time slot (0.5ms) in the time domain.
It becomes key issue for resource management in multi-CC system to ensure how best to assign the RBs to each UE according to its carrier aggregation capability as well as how to schedule multiple users on each CC [8] and ensure good service for every UE especially in frequency selective environment.

2. PROBLEM OF FREQUENCY SELECTIVE ENVIRONMENT FOR CA SYSTEMS

Frequency selective environment is the type of environment that has different behaviors for selected frequencies; it attenuates certain frequencies and enhances others. In CA systems more than one frequency is usually incorporated to eNBs but the UEs operational frequency band may differ depending on their primary design. Examples are legacy UEs that operate only on one frequency aside LTE-A UEs that capable of operating in multi-frequency bands. Typically the Release 10 UEs might be at higher advantage over legacy UEs, without any mechanism to ensure proper scheduling that offer fairness and consider UEs' throughput the system would be biased to in favor of non-legacy UEs. The situation will even be worst if the legacy UEs fall within frequency band that is highly impacted in a frequency selective environment.

Yellow link indicates f_a carrier link while green indicates f_b carrier link.

While f_a coverage could rarely reach UEs antenna the f_b is capable of reaching beyond.

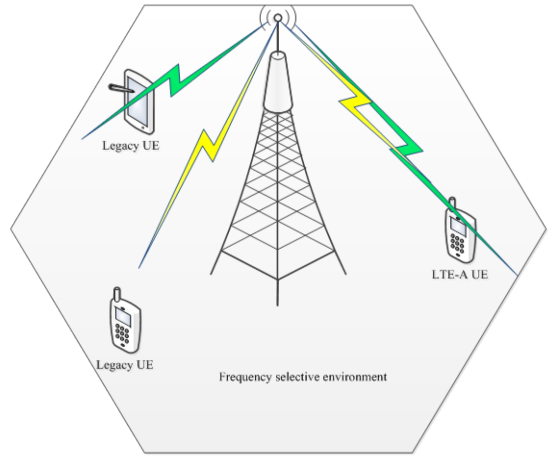

Figure 2: Schematic Presentation Of Frequency Selective Environment With Links Indicating Different Carrier Coverage.

3. SCHEDULING UES WITHIN FREQUENCY SELECTIVE ENVIRONMENT

Without much argument scheduling of LTE-A required more than what is obtainable in LTE scheduling, thus, in multi-user network deployment (LTE-A/LTE) there is need for determining each user's QoS parameters, radio bearer configuration, channel state information (CSI), service requirement and terminal capability prior to scheduling. Legacy UEs naturally only support one CC, and shall therefore only be allocated on a single CC. For optimal system performance, it is desirable to have approximately equal load on different CCs, so own-cell load information (including load per CC) is needed as input as well to facilitate optimal CC load balancing and configuration [9] For LTE-A UEs capable of accruing RBs from multiple CCs, QoS parameters such as the QoS class identifier (QCI), guaranteed bit rate (GBR), and aggregated maximum bit rate (AMBR) for non-GBR bearers provide useful information for determining the number of required CCs for the user. The exact CC scheduling algorithm is still at discretion of eNB manufacturers[10].

Autonomous Component Carrier Selection (ACCS) mechanism is a self-organizing and fully distributed interference management concept on a component carrier (CC) level that avoids interference in Heterogeneous Network (HetNet). ACCS techniques schedule each user (either LTE-A or LTE) after admission into network on a primary CC (PCell) and add more CC for LTE-A as the needs arises depending on the mutual traffic and

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interference coupling with surrounding eNBs. The basic procedure for ACCS is explained in [11]. To enhance fairness and to reap the benefit of CA with multi-user diversity based on 3gpp standards, proper scheduling can be implemented. The crucial point influencing the overall system performance is allocation of appropriate amount of RBs to individual UEs depending on their current needs and environmental experience. If resources are not distributed in the right way, some UEs can experience resource starvation situations resulting in system unfairness and UEs' QoE decreases. Though, the normal Proportional Fair (PF) algorithm is capable of addressing the challenges of fairness and throughput if the environment under study is purely flat (i.e. UEs experience the same environmental factors), but in exceptional case like frequency selective environment the UEs environmental experience need to be put into cognizance before scheduling. In order to increase system fairness and improve UEs' QoE, we suggest a mechanism that pre-determines the UEs environmental experience before scheduling while maintaining the original PF algorithm. The obtained results show that the fairness can be improved however, the system throughput also exhibit better performance for below 133Mbps throughput.

4. SYSTEM MODEL

We consider network layout of eNBs with contiguous frequency bands aggregation scenario. In this paper we examine contiguous with a uniform transmit power. The entire channel bandwidth is divided into M CCs in the ratio of a1:a2:a3. Due to variation in channel response for frequency selective channel the UE's experience per frequency band is different and varies with time and user location. Knowing well that LTE-A UEs can be scheduled on one, two or all the available CCs whilst legacy UEs can only be scheduled on one CC at a time.

Each component carrier has Q resource blocks (RBs). The total number of RBs to be aggregated is the stream of all RBs from the entire bandwidth from all component carriers, with our earlier denotation of respective frequency band's bandwidth as a1, a2 and a3. Next, we introduce the format used for the channel gain and the Signal plus Interference to Noise Ratio (SINR) computation.

For an UE k ($k = 1, 2.......K$) the channel gain $H_{k,q}$ denotes the sampled frequency response of the channel between the eNBs the k^{th} UE. Thus, we assume that the channel gain is constant in each time slot t but varies from slot to slot. We also assume that each CC undergoes flat fading. Under these assumptions, the received SINR of the q^{th} ($q \in Q$) RB of the k^{th} UE at t^{th} slot can be expressed by [12];

$$\eta_{k,t} = \frac{p(k,q)\left\| W_{k,q}^{H} \bullet H_{k,q} \right\|_2^2}{\sigma^2 \sum_{v \neq k}^{m} p(k,q) \bullet \left\| W_{k,q}^{H} \bullet H_{k,q} \right\|_2^2} \quad (1)$$

$p(k,q)$ is the average received power of k^{th} UE on the RB q .The achievable data rate is given as;

$$r(q,t) = \int_0^{q_k} q \log_2(1+\eta_{k,t}) p(\eta_{k,t}) d\eta_{k,t} \quad (2)$$

Where $p(\eta_{k,t})$ is the probability density function of $\eta_{k,t}$ .Assuming uniform distribution of the RBs to be aggregated by UEs and every UE has the tendency of being scheduled on any available RB subject to its channel experience. The conventional trends for resource scheduling include round robin -RR, maximum rate -MAX C/I and proportional fair -PF. The later is the most prevalent in resource scheduling because of its dual advantage of fairness and throughput. The relation for PF scheduling is determined by;

$$k^* = \arg\max_k \frac{r_k(q,t)}{T(t)} \quad (3)$$

Where $r_k(q,t)$ is the instantaneous rate of transmission on the RB q for k UE while $T(t)$ is the measure of UE's throughput per TTI. To keep track of the average throughput $T(t)$ of each UE on every RB in a past window of length t_c in time slot t , the $T(t)$ is updated as follows;

$$T(t+1)_{k,q} =$$

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$$\begin{cases} \left(1+\frac{1}{t_c}\right)T(t)_{k,q}+\frac{1}{t_c}r(q,t)\ for\ k=k^*(t) \\ \left(1+\frac{1}{t_c}\right)T(t)_{k,q}\ \text{for}\ k\neq k^*(t) \end{cases} \quad (4)$$

Now, let $\chi_{k,q}$ be the probability that q RBs is allocated to k UE then the PF allocation RBs for the UE would be determined by

$$\chi_{k,q}=\Pr\left\{\theta_{k,q}=\max\left\{\theta_{1,q},\theta_{2,q}......\theta_{T,q}\right\}\right\}$$

$$=\int_0^\infty f_{\theta_{k,q}}(x)dx \quad (5)$$

where $f_{\theta_{k,q}}$ is k^{th} UE pdf with highest value of $\theta_{k,q}$ among the N UEs.

In a CA systems described in section 2 with variation in channel response per frequency band due to frequency selective environment. The probability that k^{th} UE is being scheduled should take into cognizance the channel behavior. Whence, the new scheduling criteria need to be improved as;

$$\chi_{k,q}^{new}=\Pr\left\{\theta_{k,q}=\max\left\{\theta_{1,q},\theta_{2,q}......\theta_{T,q}\right\}\right\}\bullet....$$

$$.......\Pr\left\{g(k)\in n(G)\right\}$$

$$=\Pr\left\{\theta_{k,q}^{new}=\max\left\{\theta_{1,q}^{new},\theta_{2,q}^{new}......\theta_{T,q}^{new}\right\}\right\} \quad (6)$$

Where $n(G)$ is the total number of group of UEs formed according channel experience and the groups are mutually independent. Similarly, $g(k)$ is the smaller grouping of UEs that are experiencing similar channel response and are subset/ element of $n(G)$.

Note; $\Pr\left\{g(k)\in G\right\}=P\left(\bigcap_{i=1}^{M}g(k)_i\leq G\right)$ with independence theorem

$$P\left(\bigcap_{i=1}^{M}g(k)_i\leq n(G)\right)=\prod_{i=1}^{M}p\left(g(k)_i\leq n(G)\right)$$

where $g(k)$ is the sub group of UEs.

Comparatively, from equation (6)

$$\theta_{k,q}^{new}=\theta_{k,q}\bullet\prod_{j=1}^{M}p\left(g(k)_j\leq n(G)\right)$$

$$=\theta_{k,q}\bullet\Gamma \quad (7)$$

Hence, our new scheduling factor can be given as

$$k^*=\arg\max_k\frac{r_k(q,t)}{T(t)}\bullet\Gamma \quad (8)$$

Subject to

$$n(G)=n(g(k)_1\cup n(g(k)_2.......\cup n(g(k)_M$$

.

The Γ is now a new weighting factor that group the UEs according to channel experience and enforce channel quality criteria in radio resource scheduling.

5. SIMULATION RESULTS AND DISCUSSIONS

In this and succeeding sections, the performance of IPF algorithm is evaluated by two objectives, namely the system overall fairness and UEs' throughput. The simulation assumption is based on 3GPP specification criteria. A Network deployment of cells using hexagonal grid sectored into 3 at angle of 120 degree. UEs were uniformly distributed on each sector.

The performance of the IPF is evaluated on the downlink with two contiguous carrier frequencies f_a and f_b with equal bandwidths of Q. According to our simulation results the system fairness tends to improve with IPF algorithm as depicted in figure 3. A remarkable result for improving fairness among UEs is exhibited.

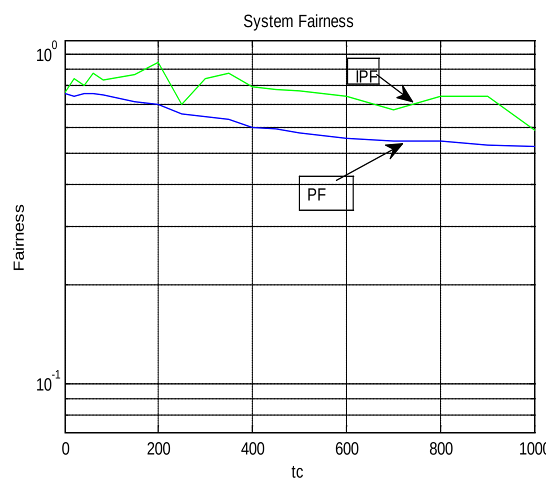

Figure3. System Fairness.

To further examine the performance of our proposed algorithm IPF we conduct computer simulations over hexagonal cellular systems and consider two carrier frequencies for UEs' throughput evaluation. Figure 4 shows the UEs' throughput performance for simulations conducted

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for the original PF and IPF under the same load and power distributions for RBs. We observe that the IPF algorithm Exhibit better performance than PF for throughput less than 133Mbps, however, the IP seems to be better beyond.

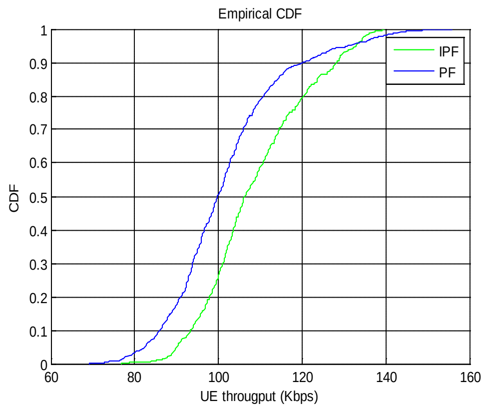

Figure 4 Ues' Throughput Comparison.

6. CONCLUSION

In this paper the improved proportional fair -IPF algorithm for resource scheduling scheme within frequency selective environment has been introduced to solve the issue of UEs suffering bad throughput when accessing network resources within such environment. With assumptions aligned with 3GPP criteria, the simulation results show no deviation from the analysis in theory. Hence, we have proved the possibility of improving not only network UEs' throughput but also fairness among UEs within LTE-Advance network deployment with carrier aggregation.

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