Downlink Packet Scheduling in LTE Advacned System With Carrier Aggregation

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Abstract--In LTE systems, the downlink scheduler is an important component for structured radio resource utilization, hence, in respectof LTE simulation, the availability of better down-link scheduler models is very significant. LTE is challenging due to undependable and resource-oriented radio interface. In this paper, we evaluated an important problem of downlink resource allocation in LTE-Advanced systems by using carrier aggregation (CA) technology. We assume to provide an equal power allotment among sub-carriers. It is possible to schedule a user on continuous or non-continuous component carriers. When Carrier aggregation is applied, a well mannered Carrier Scheduling (CS) method is necessary to the LTE-Advanced system. Here we proposed two algorithms Joint Scheduling (JS) and Independent Scheduling (INS). JS is optimum in performance but largely increases the signal processing complexity, whereas INS is the simplest resource scheduling but performance is ineffective because it doesn't support CA technology and the system fairness is inadequate. So, for improving the system fairness without having much difficulty to the system we proposed an improved Proportional Fair (PF) scheduling algorithm, which balances the throughput of LTE users and LTE-A users. Performance comparison, analysis and simulation result demonstrate that our scheme shows better throughput and improvement in system fairness.

Keywords--LTE-Advanced system, Carrier Aggregation, Proportional Fair, resource oriented radio interface.

I. INTRODUCTION

Long Term Evolution (LTE) is one of the most positive standards for the fourth generation (4G) wireless networks. One of the main components that affect the performance of the LTE system is the downlink packet scheduler. In recent scenario several downlink packet scheduling algorithm are proposed to concentrate on different aspects of Quality of Service (Qos) which are proposed in future by academic researchers. In order to achieve 1Gbps data rate in the fourth generation (4G) mobile systems CA is launched by 3rd Generation Partnership Project (3GPP) which support a wide range of bandwidth up to 100MHz in the new LTE-Advanced standards.The component carrier can have a bandwidth of 1.4, 2, 5, 10, 15 or 20 MHz and a maximum of five component carriers can be aggregated, so the maximum aggregated bandwidth is 100 MHz. LTE-A supports both LTE-A users and LTE users together for achieving backward compatibility the transmission block from different Component Carriers (CC) are combined at MAC layer. The available carriers are efficiently important to achieve high utilization and load balancing for a improved network. Continuous and non-continuous component carriers are scheduled using CA technology. The system can support more adaptable and well organized data transmissions in both uplink and downlink with carriers aggregating at MAC layer.

The LTE user can only access one Component Carrier (CC) and on the other hand LTE-A can access all component carriers. Basically some CCs are not suitable for the users, so eNB (enhanced NodeB) firstly choose the type of user before it assign CC to a user. It has the capability of distributing the user equipments on many CC. The user equipments (UEs) can transmit or receive multiple CC based on their configuration. Once the eNB selects a particular CC (s) for any user the system performs resource scheduling algorithm. If we use JS algorithm eNB will calculate the throughput of users in all CC's. It shows optimum performance but when number of CCs and users are more the difficult is too high then system is very difficult to design. When we use INS algorithm eNB calculates the user throughput to one component carrier, so complexity reduces as compared to JS algorithm. Also it suffers from low fairness as it can access only one component carrier, so our main problem is to design our scheduling algorithm. For improving the system fairness without adding the high complexity to the system we proposed the improved PF algorithm based on INS algorithm.In this, we discussed about weigh factor for enlighten the throughput of LTE users. By theoretical analysis weigh factor can be calculated by total number of component carriers (CCs) and percentage of LTE users. Through the performance analysis, comparison and calculations the improved PF algorithm shows better fairness as compared to original PF algorithm.

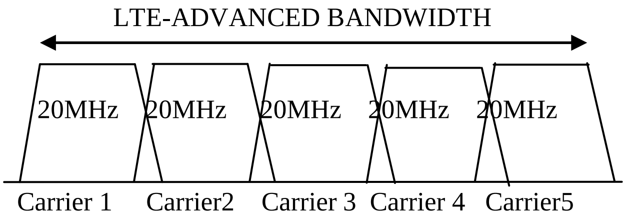

Fig1: Continuous aggregation of five CCs with equal bandwidth

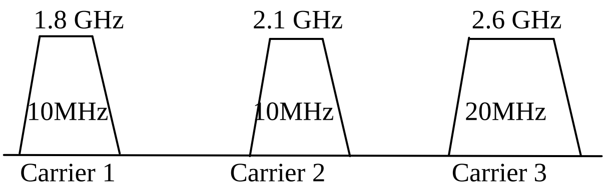

Fig2: Non-Continuous aggregation of five CCs with equal bandwidth

II. CARRIER AGGREGATION FUNDAMENTALS:

1. *CARRIER AGGREGATION-FDD*:In LTE, direct method to increase capacity is adding more bandwidth. The bandwidth is increased in LTE-A, it is opted from the aggregation of R8/R9 carriers. Carrier aggregation is used for both TDD and FDD. The aggregated carriers areconsidered as CCs. CC having bandwidth of 1.4,2,5,10,15 or 20 MHz and upto five component carriers can be aggregated. Therefore the maximum bandwidth is 100MHz. Number. The individual component carriers may be of different bandwidths.

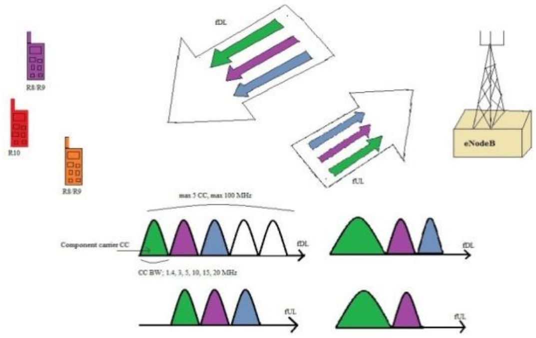

Fig3:Carrier aggregation-fdd

2. *CARRIER AGGREGATION-INTRA AND INTER BAND ALTERNATIVES:*By using contiguous CCs within the same operating frequency band we can easily arrange aggregation, which is known as intra-band contiguous. It is not always be possible, due to frequency allocation scenarios. For non-contiguous allocation it may be intra-band, the component carriers belong to the same operating frequency band, but they are separated by a frequency gap or it could be inter-band, in which CCs belong to different operating frequency bands.

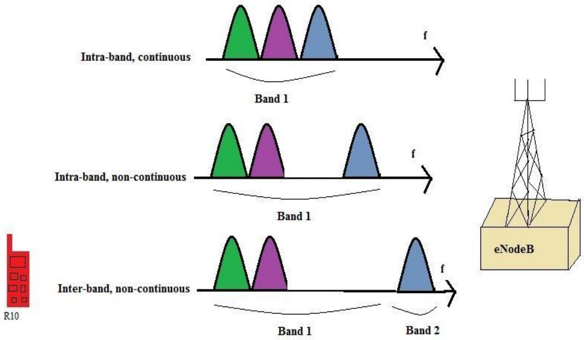

Fig4:Carrier Aggregation-intra and inter band alternatives

3. *CARRIER AGGREGATION-SERVING CELLS:* Whenwe use carrier aggregation there are a number of serving cells,out of which one is allocated for each component carrier. The coverage of the serving cells may vary due to component carrier frequencies but also from power planning which is useful for heterogeneous network planning. The primary serving cell handles the RRC connections which is served by the primary component carrier (DL and UL-PCC) while remaining component carriers is referred as secondary component carrier (DL and UL-SCC), serving the secondary serving cells.

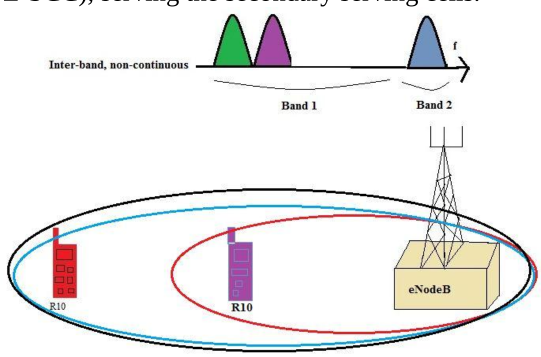

Fig5:carrier aggregation-serving cells

Different component carriers are used to provide different coverage in different cell size. In case of inter-band carrier aggregation the component carriers will face different path loss, which increases with increase in frequency. The carrier aggregation on all three component carriers can only be used for the black UE, the white UE is out ofthe coverage area of the red component carrier as shown in figure.

III. SYSTEM MODEL

Generally, two types of users are there, LTE-A users and LTE users. Data aggregation can be achieved by using MAC layer where the transmission blocks are constructed such a way that they are transparent to higher layers (RLC and PDCP). This block diagram shows the downlink protocol stack with carrier aggregation of multi components of LTE-A system.

For simplification component carriers are divided as two types. LTE-A user can only access LTE-A components whereas LTE component carriers can be used by all users. Whenever a new user arrives in a system then that system decides to serve a particular user and opt to allocate the user with different CC by CC selection. The LTE-A can access more number of component carriers when compared to LTE users. In resource scheduling each CCs has M PRBs (Physical resource blocks) which are distributed to the users where PRB is a small unit of resource scheduling. PRBs are defined as one slot in time domain (0.5ms) and 12 consecutive sub carriers (180 KHz) in frequency domain.Each user have at least one radio bearer called default radio bearer. In addition to default bearers the users have some extra bearers configured.The PDCP (Packet Data Convergence Protocol) contains functionalities like ROHC (Robust header Compression), security. The RLC (Radio Link Control) contains segmentation and ARQ (Automatic Repeat Request). MAC controls the multiplexing of data for all logical channels to user and a HARQ (Hybrid Automatic Repeat Request).

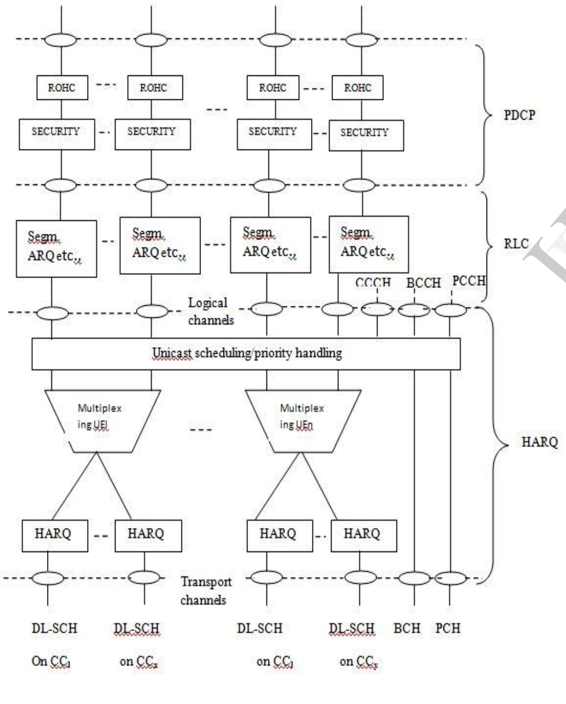

Fig6:Downlink protocol stack with CA of multi components of LTE-A system.

The interface between MAC layer and RLC layer is called as Logic Channels. The transmission blocks sent on different CCs are sent by using coding schemes. There is independent link adaptation which is optimum formatching the transmission of different CCs.

In this paper, we discuss the PF algorithm in LTE-A system which can be classified in two ways: Joint scheduling system (JS) and Independent scheduling (INS).

III.A. Joint Scheduling PF Algorithm (JS-PF):

The JS algorithm provides optimum performance where we discuss the throughput from all component carriers. In PF scheduler, the PRB is allotted to a user that have maximum PF metric among all component carriers. With $R_{k,i,m}(t)$ is estimated throughput of user k at 't' time slot, i^{th} component carrier CC at m^{th} PRB group, $R_{k,total}(t)$ is the i^{th} user throughput among all aggregated CC.$R_{k,i}(t)$ is the average throughput of i^{th} component carrier of the user. Here, we calculate the estimated throughput for user k, average throughput for user i^{th} component carrier which is calculated using the algorithm. The average window length value T is 1000. In JS each user receives the signal continuously from all CCs in a sequential pattern. It increases the power consumption and the complexity of signal processing.

Algorithm:

Start
Clear the CC assignments for all UE's
PRB is allocated to UE which has maximum PF metric
For UE(K), k=1,2,3…..k from HOL(1,2…k)d0
For i=1,2…N
For k=1,2,…K
For resource block
R=1,2,….M d0
Metric=backlog*channel rate of resource block I for $UE_{j;}$
$S(k)=\max(P_{k,i,m})$;
$K_{i,m}=\arg s(k)$;
$R_{k,total}(t)=R_{k,i}(0)+R_{k,i}(t)$;
$P_{k,i,m}=R_{k,i,m}/\overline{R}_{k,total(t)}$;
i=i+1, j=j+1;
break;
for t=1,2…..1000
updated new average throughput=get $\overline{R}_{k,i}(t)$ from PRB group
$\overline{R}_{k,i}(t+1)=(1-1/T)\overline{R}_{k,i}(t)+(1/\Gamma)\,R_{k,i}(t)$;
End if
End
End
End

III.B.INS-PF (Improved INS-PF):

When the system uses INS, UE's behavior is similar to that of single carrier systems. The user don't uses the characteristics of other CCs and the PF metric is given as

$$P_{k,i,m}= R_{k,i,m}(t)/\underline{R}_{k,i}(t)$$

The performance of INS is unsuitable which results from the aspect that in multiuser wireless communication system, for achieving higher spectral efficiency, we allot resource to the appropriate user in the system which has to send the data.The user set is just a subset in each CC, because of which the spectral efficiency of INS is lower than JS. The INS lead to a case where CCs stand idle because serving data have been completely finished.

Problem formulation:

In original PF algorithm the systems have N CC's and K users then all users are uniformly distributed in entire area then average amount of PRB given to each user is represented as follow:

$$E(n_i)=(NM)/K$$

Where M is total number of PRB at each CC and n_i is average number of PRB.

While in case of LTE-A system, LTE users can't process all CC. Average PRB number given to LTE users is:

$$E(n_{LTE})=(N\beta M)/K$$

And average PRB allocated to LTE-A users is given as:

$$E(n_{LTE\text{-}A})=\frac{NM(1-\beta)}{K(1-\alpha)}+\frac{NM\beta}{K}$$

Where β denotes percentage of LTE CC's and α denotes percentage of LTE users.

Here we see that LTE advanced users obtain more PRB than LTE users because of which original PF algorithm is unsuitable for LTE-A system. So, it needs some change in the original PF algorithm to improve throughput of LTE users.

The average amount PRB of LTE-A user is calculated using following algorithm:

Algorithm:

UE(i) allocated to the resource blocks PRB(j) (j=1,2…k);
Next resource block PRB(k+1) allocated to UE(i);
For i=1,2…P
E(i)=NM/k;
E(n)=NβM/k;
New average number of PRB LTE-A used= get % of LTE-A users
R(i)=(NMβ)/k;
$E(n_{LTE\text{-}A})=NM(1-\beta)/(1-\alpha)k + R(i)$;
End if
End
End

III.C. Improved INS-PF algorithm:

In INS-PF, we focus on the value of weigh factor (μ). For precision value, we first calculate average number of PRB obtained through each user. Two types of carriers are in the system.

In LTE-A CC, average PRB is NM(1-β) and K(1-α) LTE-A user, so we calculate the average number of PRB allocated to LTE-A user K_1.

In LTE CCs, total number of CCs is Nβ and LTE user k_2 access only a single CC. So, average PRB amount obtained through user k_1 and k_2 can be calculated. The calculations of PF metric of LTE users, LTE-A users and average PRB allocated to users are done using the algorithm as follow:

Algorithm:

Calculate average number of PRB obtained by each user first
For resource blocks i=1,2,… Md_0
Choose the UE j with largest metric
Metric=backlog * channel rate of resource block 'i' for UE 'j';
PF metric (LTE)= $\mu R_{k2,i,m}(t)/\overline{R}_{k2,i(t)}$;
PF metric(LTE-A)= $R_{k,i,m}(t)/\overline{R}_{k,i}(t)$;
$E(n_k,LTE\text{-}A)=N M(1-\beta)/k(1-\alpha)$;
For i=1,2,…N
$E(k_1,i)=E(nk_1)-E(nk_{1,i})$;
$E(k2,i)=E(nk_2)-E(nk2_{,i})$;
M1=Nβ(1-α)/(β-α);
If β≤α
M=-[μ1];
Else
μ=μ1;
average PRB number assigned to LTE users < NM/k;
for m=1,2…M
if β>α
$P_{k,i,m}=N\beta[(1-\alpha)/(\beta-\alpha)][R_{k,i,m(t)}/\overline{R}_{k,i(t)}]$
$P_{k,m}=R_{k,i,m(t)}/R_{k,i(t)}$;
Else
$P_{k,i,m}=R_{k,i,m(t)}/\overline{R}_{k,i,(t)}$;
$P_{k,i,m}=P_{k,m}$;
End if
End
End
End

If we design a PF metric of LTE users in LTE CCs, all users acquire a same amount of PRB. So, the system fairness is improved. The improved PF algorithm balances the throughput of LTE users and LTE-A users which is better than other algorithms and we prefer it for LTE-A system.

IV. SIMULATION RESULTS AND ANALYSIS:

Here, we showed the performance of proposed PF scheduling algorithm. There are four component carriers to be aggregated, where number of LTE CCs is 2. Here we discussed two cases for α. The percentage of LTE users is 0.25 and 0.5. the average window length T=1000. Other parameters are given in the table below:

For performance analysis, we use CDF (Cumulative distributive function) of all users for LTE-A system because it reflects the system fairness and user throughput. The simulation result of CDF is shown in figure for α=0.25 and 0.5.When α=0.25 then weigh factor is coming approximately 6, if the system adopt INS-PF algorithm the throughput of LTE users and LTE-A users in graph is very far from each other which lead to a poor fairness but if system uses JS-PF algorithm through graph we can see that the throughput of LTE-A users is slightly more than

Parameter	Description
Site layout	3 sectorized hexagonal grid with 7 cells wrap-around
Site-site distance	500m
Aggregation configuration	4CCs, with 10MHz per CC
Number of PRBs per CC	50(12 subcarriers per PRB)
Total BS power	40W
Antenna configuration	1*1
Modulation and coding schemes	QPSK (1/3 to ¾) 16 QAM (1/2 to 4/5) 64 QAM (2/3 to ¾)
CQI frequency domain resolution	1 CQI per 3 PRBs
Transmission BLER target	10%
Number of UEs per sector	8
Traffic model	Full buffer
The percentage of LTE CCs	0.5

Table1**:** System simulation parameters

LTE users. So the system fairness is improved.If we increase the value of α to 0.5 then LTE CC are occupied by LTE users and LTE-A CC are occupied by LTE-A users.

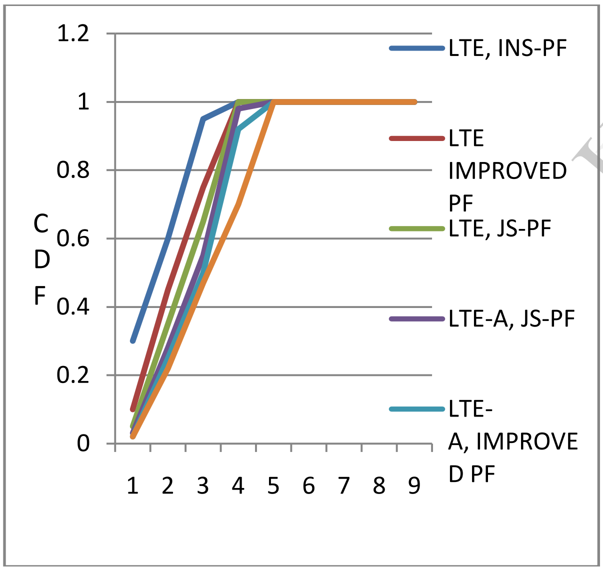

Fig7: Comparison of User Throughput(Mbps) with CDF at α=0.25

User throughput (Mbps)

So, the throughputs of both CC are approximately similar to each other as shown in graphs which are overlapping each other. So, improved PF algorithm is best suitable for improving the fairness because system distributes all PRBs to LTE-A and LTE users in same amount.

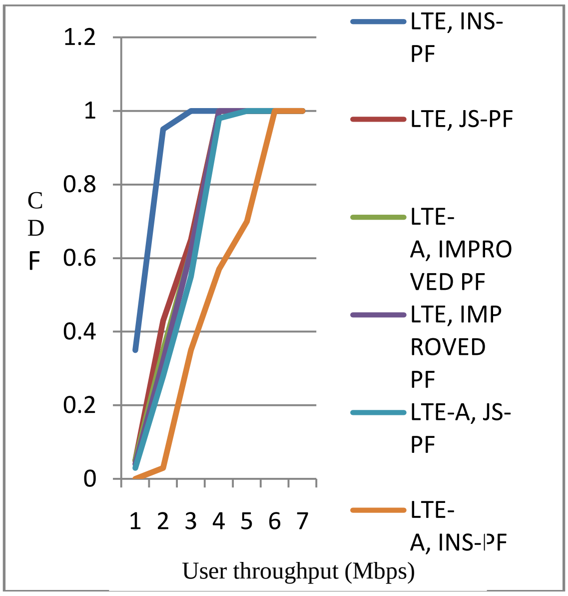

Fig 8: Comparison of User Throughput(Mbps) with CDF at α=0.5

V.CONCLUSION:

In this paper, we considered two types of users in the system. So we proposed a new algorithm for downlink LTE-A system. In which we calculated weigh factor to improve throughput and data rate of LTE users. The simulation shows that the proposed algorithm balances the throughput of LTE and LTE-A users which improves the system fairness and enhance the data rate at α=0.5(percentage of LTE users). This algorithm is based on independent scheduling so the performance of this algorithm is better than JS-PF and INS-PF algorithm.

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