Resource Allocation Scheme on Aggregation of Unlicensed Spectrum in LTE networks

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Abstract
With the rapid development of technology and the popularity of mobile devices, the demand of transmission data rate has been increasing.The 3GPP proposed the use of 5GHz unlicensed band to extend LTE in order to meet the needs of a large number of users.While the traditional packet scheduling algorithms are not flexible for the aggregation of the unlicensed spectrum, this paper proposes an AHP distribution algorithm for allocating resource to users.Not only the channel quality of each resource block for users, but also whether the users are GBR users and proportion of LTE and LTE-U users are considered.The results of the simulation will show that the proposed method can flexibly allocate spectrum resourcesand maintains the satisfaction of GBR users.
Keywords: Unlicensed Spectrum, Resource Allocation, Analytic Hierarchy Process

I. INTRODUCTION

The 3GPP (3rd Generation Partnership Project) organization proposed the Long Term Evolution (LTE) as an evolution of the 3G system [1]-[2]. The LTE downlink uses OFDMA wireless access technology, and the uplink part takes into account the power efficiency of the mobile phone and uses SC-FDMA wireless access technology. In terms of transmission rate, LTE uplink transmission rate can reach 75Mbps, the downlink transmission rate can reach 300Mbps.

With the rapid development of communication networks and the popularization of mobile devices, the original LTE network will not be able to meet the increasing demand rate. In the face of the increasing demand rate, some innovative technologies are emerging, one of which is to extend LTE to unlicensed spectrum, also known as LTE-U [3] that increases the bandwidth by aggregating LTE resource blocks and unlicensed spectrum resource blocks. Therefore, this paper will study how the system allocates resources after aggregating licensed spectrum and unlicensed spectrum. Traditional PF, MLWDF... etc. packet scheduling algorithms [4] only consider throughput and fairness individually, and do not consider the allocation after adding unlicensed spectrum. Therefore, how to allocate resources to users more efficiently and flexibly is the focus of this paper which proposes AHP allocation algorithm to allocate spectrum resources.

II. RELATEDWORKS

With the rapid development of communication networks and the popularity of mobile devices, the 3GPP proposes to expand the spectrum of carrier aggregation technology to unlicensed spectrum, which aggregate licensed spectrum and unlicensed spectrum, namely LTE-U [3].

The LTE-U increases the bandwidth by aggregating unlicensed spectrum, which will interfere with other technologies that use unlicensed spectrum, such as WiFi. Due to the different communication specifications for unlicensed spectrum in various countries, LTE-U and other technologies that use unlicensed spectrum will coexist in two ways [3,5]. The first, such as the United States and China's specifications, is for unlicensed spectrum. It does not stipulate that Listen Before Talk (LBT) is required before using unlicensed spectrum. Instead, there is another coexistence mechanism for LTE-U and other technologies that use unlicensed spectrum, such as the Carrier-Sensing Adaptive Transmission (CSAT) mechanism [6]. The second type, such as European and Japanese regulations, stipulates that Listen Before Talk (LBT) is required before using unlicensed spectrum. Before using a channel, we must first listen to whether the channel is occupied. If not occupied, we can use this channel. After that, this channel will be released. To want to continue to use the channel, we perform LBT again to coexist with other technologies that use unlicensed spectrum.Ali et al [7] formulated an optimization problem for joint user association and power allocation for licensed and unlicensed spectrum with objective to maximize sum rate ofLTE-U/WiFi heterogeneous network. In [8], boththroughput and fairness for the LTE-U system are maximized by a multi-objective optimization problem and a log-sum exp approximation method is developed toconvert the multi-objective optimization into a single objectiveoptimization problem.Dai et al [9] proposed a fair coexistence criterion and design the duty cycle allocation thatoptimizes the Carrier Sensing Adoptive Transmission (CSAT) mechanism for LTE-U/WiFi.

III. PROBLEMFORMULATION

In order to solve the problem of resource allocation after LTE aggregates unlicensed spectrum, the AHP allocation algorithm is proposed. As this algorithm allocates resources, we consider whether the user is a Guaranteed bit rate (GBR) user or not, the proportion of the number of LTE toLTE-U users, and the CQI value of each UE’s RB.

The LTE-Advanced achieves high user bandwidth by aggregating multiple LTE carrier units, but no matter how the carrier units are aggregated, the throughput that can be improved is still limited because the spectrum resources

$$\overline{r_i}(t) = \beta \cdot \overline{r_i}(t-1) + (1-\beta) \cdot r_i(t) \quad 0 \le \beta \le 1 \text{.........} (2)$$

that operators can use are still the original carrier units, In the future, 5G may carry out carrier aggregation on unlicensed spectrum. Its main purpose is to increase the available spectrum resources and effectively improve system throughput. The aggregated unlicensed spectrum will lock on the 5GHz band with a large bandwidth up to 500MHz, and more unlicensed frequencies in the 5GHz band will be open in the future, so this paper will discuss when the licensed spectrum and unlicensed spectrum are aggregated , how should the system allocate resource blocks to users.

3.1 System Architecture

When the user enters the system through admission control, the base station will assign the carrier unit of the licensed band to the user through the carrier unit allocation algorithm. At this time, the assigned carrier unit will be regarded as PCC

$$m(i,j) = \begin{cases} \frac{r_i(t)}{\overline{r_i}(t-1)} i \in NRT \\ -\log \delta_i \cdot \frac{D_{HOL_i}}{\tau_i} \cdot \frac{r_i(t)}{\overline{r_i}(t-1)} i \in RT \end{cases} \text{...............} (3)$$

(Primary component carrier), the resource blocks in the carrier unit are allocated to users according to the packet scheduling algorithm, so that the data to be transmitted is loaded on the resource blocks in the carrier unit for transmission. Since expanding LTE-Advanced to unlicensed spectrum, this paper treats unlicensed band carrier units as SCC (Secondary component carriers) for use. When PCC resource blocks are allocated, LTE-U users will compete the resource block in the unlicensed carrier band unit.

After the user enters the system through admission control, it is judged whether the user's location is within the service range of the unlicensed spectrum in order to decide whether to aggregate the unlicensed spectrum for use, otherwise the user can only use licensed spectrum. Afterwards, according to the packet scheduling algorithm, we allocate the resource blocks in each carrier unit to users. In this paper, the Proportional Fair (PF)algorithm [10], Modified Largest Weighted Delay First (MLWDF) algorithm [11] and AHP allocation algorithm are used for the packet scheduling algorithm.

The Proportional Fair (PF) algorithm considers both throughput and fairness. Manyalgorithms base on PF. PF gives priority of resource usage to UE with better channelquality. Thus, a less considerate algorithm could let UE with better channel qualityoccupy valuable resource and pretend UE with poor channel quality to have enoughresource, even starve to death. The feature of PF algorithm is that it can lower the weightof the UE which has higher resource usage rate for a longtime at any time.PF is able toallow disadvantage UE to be allocated with proper resources fairly. To take into accountof channel quality and throughput boost, the algorithm is demonstrated by the followingequation.

$$m(i,j) = \frac{r_i(t)}{\overline{r_i}(t-1)} i \in NRT, RT \text{....................................} (1)$$

In Equation (1):

1. $r_i(t)$ denotes the transmission rate of the data flow in time point t. Channel quality and throughput are both considered. The bigger the value of $r_i(t)$, the higher the priority of the data flow. For fairness of resource allocation, $\overline{r_i}(t-1)$ is used for modification.
2. $\overline{r_i}(t-1)$ is regarded as the average transmission rate from the i^{th} data flow to $t-1$. The larger the value of $\overline{r_i}(t)$, the lower the priority. If average rate increases, the weight decreases. Equation (2) figure out $\overline{r_i}(t)$. β value is designed as a parameter to make minor modification in order to control the ratio of average rate to attainable rate.

The Modified Largest Weighted Delay First (MLWDF) has a largest weighted delaycontrol mechanism. It possesses the advantage which PF does and considers servicequality. It guarantees real-time data transmission rate. To take into account head-of-line packet latency and packet loss rate, the algorithm is demonstrated with the equation asfollows.

MLWDF processes Real Time (RT) data and Non-Real-Time (NRT) data separately. NRT data is processed usingPF's method. Yet, with regard to RT data, packet latency and loss rate must be taken into consideration. Therefore, in Equation (3), denotes acceptable loss rate. $D_{Hi}$is the latency of data flow . is the upper limit of the latency of data flow . Compared to the equation of NRT data, RT data transmission contains an additionalparameterofweight, $-\log \delta_i \cdot \frac{D_{HOL_i}}{\tau_i}$ for increasing the algorithm's stability.

AHP allocation algorithm

For allocating resource blocks, the AHP allocation algorithm not only considers the user's channel quality indicators for each resource block, but also the proportion of the number of LTE and LTE-U users and whether they are GBR users or not. The following will introduce the two methods used in the AHP allocation algorithm, namely the simple weighting method (Simple Additive Weighting, SAW)and the hierarchical analysis method in multi-attribute decision making (Analytic Hierarchy Process, AHP) [12]-[13].

Simple Additive Weighting (SAW)

Multi-attribute Decision Making (Multi-attribute Decision Making) is often used to help decision makers choose an ideal solution from a limited number of options. There are usually multiple variables that affect the decision. The variables in the plan are evaluated and all the plans are sorted in order to select an ideal plan.

There are many methods for multi-attribute decision-making, but they can be divided into three categories based on the type of data provided by the decision maker. According to the classification of multi-attribute decision-making methods proposed by Hwang and Yoon [12], the third type of multi-attribute decision-making methods that can obtain the basic information feature type of user's preference for attributes includes simple weighting method (SAW) and hierarchical weighting method (HAW), ideal solution (TOPSIS), selection method (ELECTRE)... etc. Different methods have different principles of decision-making. Simple weighting methods and hierarchical weighting methods are used to select options with the greatest effectiveness, ideal solutions have the greatest relationship with the ideal solution, and the selection method best meets the consistency measurement. However, no matter what method is used, it has little effect on the final result. The goal of this section is to discuss how to allocate resource blocks, so Simple Additive Weighting (SAW) is adopted.

The simple weighting method selection scheme is based on the weight value of each evaluation standard, multiplied by the normalized value of the evaluation standard, and then the total score obtained is compared. The solution with the highest total score is selected and the formula of the simple weighting method is as follows:

$$K = \arg\max \left(\frac{\sum_{j=1}^{m} W_j * r_{ij}}{\sum_{j=1}^{m} W_j}\right) \quad i=1\ldots n,\ j=1\ldots m \ \ldots\ldots\ldots(4)$$

In Equation (4), K is the selected plan, n is the number of alternative plans, m is the number of evaluation criteria, W_j is the weight of the evaluation criteria, and $\sum_{j=1}^{m} W_j = 1$.The parameter r_{ij} is the normalized value of evaluation criterion j in option I and the normalization process is based on the attributes of each evaluation criterion. If the evaluation criterion is a benefit attribute, the normalization method is shown in Equation (5). Otherwise if the criterion is the cost attribute, the normalization method is as in Equation (6)

$$r_{ij} = \frac{x_{ij}}{x_j^{max}} \quad i=1\ldots n, j=1\ldots m \ldots\ldots\ldots\ldots(5)$$

$$r_{ij} = \frac{X_j^{min}}{X_{ij}} \quad i=1\ldots n, j=1\ldots m \ \ldots\ldots\ldots(6)$$

Where X_{ij} is the original evaluation value of the evaluation criterion j in the alternative scheme i, X_j^{max} and X_j^{min} respectively represent the maximum value and the minimum value in the evaluation criterion j. After the evaluation standard is normalized, $r_{i,j}$ will lie between 0 and 1. Usually the basic assumption of the simple weighting method is that each evaluation standard needs to be completely independent, which means that the contribution of each evaluation standard is independent of other evaluation standards. This paper uses a simple weighting method for allocating resource blocks. The evaluation criteria for allocating resource blocks include whether they are GBR users, the channel quality index CQI corresponding to each resource block and the proportion of the number of LTE and LTE-U users. The formula as follows:

$$K = \arg\max(RB_i) \quad i=1、2、3、4\ldots..$$

$$RB_i = \frac{GBR_i * W_{GBR} + CQI_i * W_{CQI} + \text{LTE ratio}_i * W_{lte-ratio}}{W_{GBR} + W_{CQI} + W_{lte-ratio}} \ldots\ldots\ldots..(7)$$

In Equation (7), RB_i is the total score of resource block i, GBR_i is whether the i-th user is a GBR user. A GBR user is given a value of 0.7, otherwise a value of 0.5 is given. The CQI_i is the user's normalized value of the channel quality index of resource block i, LTE Ratio is the number ratio between LTE users and LTE-Uusers ($\frac{LTE\ \ number}{LTE_{number} + LTE-U_{number}}$), W_{GBR} is the weight of GBR, W_{CQI} is the weight of the channel quality index.We have

$$W_{GBR} + W_{CQI} + W_{lte\ ratio} = 1\ldots\ldots\ldots. (8)$$

and the weights W_{GBR}、W_{CQI}、$W_{lte\ ratio}$ are calculated based on the method of AHP hierarchical analysis, which will be explained in detail below.

The main purpose of the Analytic Hierarchy Process (AHP) is to assist decision makers in solving the problems they face, to express the concept of decision makers' decision-making through visual hierarchical relationships, and to evaluate the relative importance of various evaluation criteria. Finally, the weight value of each evaluation standard is calculated.

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty [14]. It is mainly used in uncertain situations and decision-making problems with multiple evaluation criteria. The method is divided into 4 steps, which are 1. Establishing a hierarchical structure, 2. Establishing a paired comparison matrix, 3. Calculating weights, and 4.Consistency verification, which will be introduced as follows.

Step 1. Build a hierarchy

Figure 1 is an analysis diagram of the hierarchical structure established for allocating resource blocks. The first layer is the problem to be solved, the second layer is the evaluation criteria that affect the decision of the first layer, and the third layer is the options that can be selected.

Step 2. Build a pairwise comparison matrix

Table 1 is the evaluation scale. This step is to compare the evaluation criteria, and establish the relative importance between the evaluation criteria through the evaluation scale.

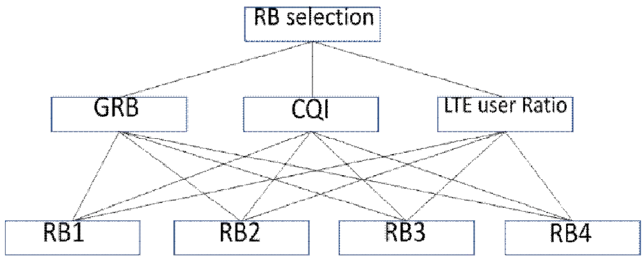

Figure. **1** Hierarchical structure

Table 1: Evaluation scale

scale	definition	description
1	**Equal Importance**	**The contribution of the two comparison schemes is of equal importance**
3	**Moderate Importance**	**Experience and judgment are slightly inclined to prefer a certain plan**
5	**Essential Importance**	**Experience and judgment have a strong tendency to prefer a certain plan**
7	**Very Important**	**Actually shows a very strong preference for a certain plan**
9	**Extreme Important**	**There is enough evidence to definitely like a certain plan**
2,4,6, 8	**intermediate values**	

Table 2: Pairwise comparison matrix

	CQI	LTE user ratio	GBR
CQI	1	1	5
LTE user ratio		1	3
GBR	1/5	1/3	1

Table 2 is the pairwise comparison matrix established after the evaluation criteria are compared. The comparison criteria are based on experience and judgment. In determining the evaluation scale, we allocate resource blocks to focus on CQI and the proportion of LTE people. The relative importance scale of GBR is 5, and the relative importance scale of the number of LTE people is 3 compared to GBR, and the relative importance scale of CQI to the number of people is 1. When the lower triangle of the matrix is established, the upper triangle of the matrix is the inverse of the lower triangle.

Step 3.Calculate weight

After the pair comparison matrix is established, the eigenvectors and eigenvalues of the pair comparison matrices are then calculated where the the maximum eigenvalueλ_{max} corresponding to eigenvector is the weight. There are four approximate methods commonly used to calculate eigenvectors, namely, Average of Normalized Columns, Normalization of the Row Average, and Normalization of the Inverse column Sum, and the method of Normalization of the Geometric Mean of the rows. This paper uses the column vector geometric mean method and the formula is as follows:

$$w_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n} / \sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n} \quad i,j = 1,2,\ldots,n \ldots\ldots\ldots(9)$$

In Equation (9),w_i is the weight value of the evaluation criterion i, a_{ij} is the value in the comparison matrix, and n is the order of the matrix. The application of this formula in this paper is as follows:

$$\begin{bmatrix} 1 & 1 & 5 \\ 1 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix} \rightarrow \begin{bmatrix} \sqrt[3]{5} / \sqrt[3]{5} + \sqrt[3]{3} + \sqrt[3]{1/15} \\ \sqrt[3]{3} / \sqrt[3]{5} + \sqrt[3]{3} + \sqrt[3]{1/15} \\ \sqrt[3]{1/15} / \sqrt[3]{5} + \sqrt[3]{3} + \sqrt[3]{1/15} \end{bmatrix} \rightarrow \begin{bmatrix} 0.4806 \\ 0.4053 \\ 0.1139 \end{bmatrix}$$

Among them, 0.4806 is the weight of CQI, 0.4053 is the weight of the proportion ofLTE people, and 0.1139 is the weight of GBR in Equation (7).

4.Consistency test

Based on the basic assumptions of AHP, the pairwise comparison matrix is a consistentmatrix. However, due to the subjective judgment of the decision maker, the pairwisecomparison matrix may not meet the consistency. So Saaty proposed to use the Consistency Index (CI) and consistency Consistency Ratio (CR) to check whether thepairwise comparison matrix achieves consistency, the formula is as follows:

$$CI = (\lambda_{max} - n) / (n-1) \ldots\ldots(10)$$

$$CR = CI / RI \ldots\ldots(11)$$

In Eq.11, $\lambda_{max}$is the largest eigenvalue in the paired comparison matrix, and n is the order of the paired comparison matrix. The Consistency Vector (CV) will be used before calculatingλ_{max} as shown below.

$$C = A \cdot W = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix} \ldots\ldots (12)$$

In Equation (12) A is the pairwise comparison matrix, and W is the matrix of the obtained weight values. The formulas for calculating the Consistency Vector (CV) and λ_{max} are as follows:

$$CV_i = \frac{c_i}{w_i} \quad \ldots\ldots\ldots (13)$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} CV_i}{n} \ldots\ldots\ldots (14)$$

If CI=0, the comparison matrix is consistent before and after judgment.But CI>0 represents inconsistent judgment before and after, and0<CI<0.1 is an acceptable error. Random Index (Random Index, RI) is amatrix of positive and negative values generated from the evaluationscale 1 to 9. Different CI values are generated under different orders. Thevalue will increase with the increase of the order of thematrix. Usuallyused RI is used based on the random index table summarized by Saaty. Asshown in Table 3, the ratio of the consistency index to the random indexis the consistency ratio. When CR<0.1, it means that the pairedcomparison matrix has a satisfactory consistency.

Table 3: Random Index

rder	1	2	3	4	5	6	7	8	9	10	11	…
RI	0	0	.58	0.9	.12	.24	.32	1.41	.45	.49	.51	…

Finally, the process applied in this paper is as follows which means that the paired comparison matrix has a satisfactory consistency.

$$\begin{bmatrix} 1 & 1 & 5 \\ 1 & 1 & 3 \\ 1/5 & 1/3 & 1 \end{bmatrix} \begin{bmatrix} 0.4806 \\ 0.4053 \\ 0.1139 \end{bmatrix} \cong \begin{bmatrix} 1.4554 \\ 1.2276 \\ 0.3451 \end{bmatrix}$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} CV_i}{n} = \frac{\frac{1.4554}{0.4806} + \frac{1.2276}{0.4053} + \frac{0.3451}{0.1139}}{3} = 3.029$$

CI= (3.029- 3) / (3 - 1) =0.0145

CR = CI/RI= 0.0145/0.58 = 0.025

IV. SIMULATION RESULTS AND DISCUSSION

Table 4 shows the system environment and parameters simulated in this paper as follows:

Table 4 Simulation paramters

Downlink wireless access technology	OFDMA
CC Bandwidth	20MHz
Number of RB per CC	100
Number of Licensed CC	1
Number of Unlicensed CC	1
Traffic Type	GBR：Video Non-GBR：FTP
Number of UE	Video：20-70 FTP：30-80
GBR guaranteed bit rate(bps)	Video：2Mbps

Table 5 is the modulation technology used in the simulation of this paper where efficiency refers to the number of bits that can be loaded by an RB. The relationship with the modulation and code rate as shown in Eq. 15, and the relationship between bits per RB per subframe and efficiency is shown in Eq. 16 which means that there are two RBs in one subframe, and one RB is composed of 12 subcarriers multiplied by 6 OFDM symbols.

$$\text{efficiency} = log_2{}^{\text{modulation}} * \frac{\text{code rate}}{1024} \ldots\ldots\ldots (15)$$

$$\text{bits per RB per subframe} = 2 * 12 * 6 * \text{efficiency} \ldots\ldots\ldots (16)$$

Table 5:CQI Table

CQI index	modulation	code rate *1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1154
15	64QAM	948	5.5547

In the simulation of this paper, two different types of traffic are used, namely Video and FTP, where Video is a GBR type and FTP is a non-GBR type. Video parameters are shown in Table 6 and FTP file size is 50Mbytes.

Table 6: Video parameter

Number of packets in a frame	8
FPS	25

Inter-arrival time between each frame	40ms
Inter-arrival time between each packet	Mean 5ms
Packet (slice) size	Mean 1375Bytes
Average data rate	2Mbps
Video length	As simulation time

In the simulation, there are three resource block allocation methods are compared, namely the Proportional Fair algorithm, the Modified Largest Weighted Delay First algorithm, and the AHP allocation algorithm used in this paper.
As the AHP allocation algorithm proposed in this paper, it will not only consider the channel quality of each resource block for users, but also based on whether it is a GBR user and the proportion of LTE and LTE-U users. The simulation results show that the method proposed in this paper has more flexible resource allocation compared with other methods.

➢ Ratio of Satisfactionis defined as follows.

$$\text{Satisfaction} = \frac{\textit{user really gets amount of data}}{\text{user requests amount of data}}$$

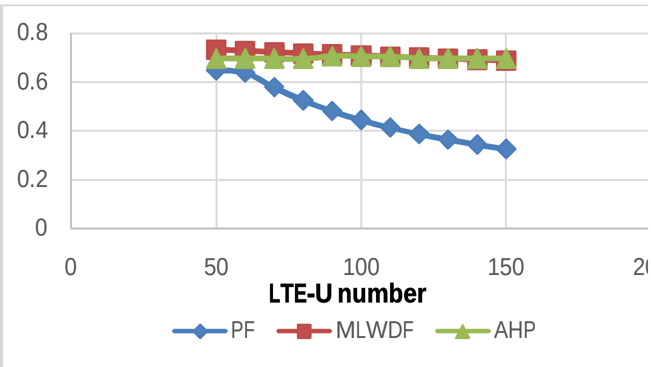

Figure 2 Satisfaction (Video user=40, FTP user=60，LTE user=100)

From Figure 2., it can be seen that the AHP distribution algorithm and the M-LWDF distribution algorithm have similar satisfaction levels, while the satisfaction of the PF distribution algorithm is significantly lower than the other two. That is because the AHP distribution algorithm and the M-LWDF distribution algorithm have similar satisfaction levels. The M-LWDF distribution algorithm considers the quality of service and guarantees the instantaneous flow rate during distribution, while the PF distribution algorithm does not consider this.

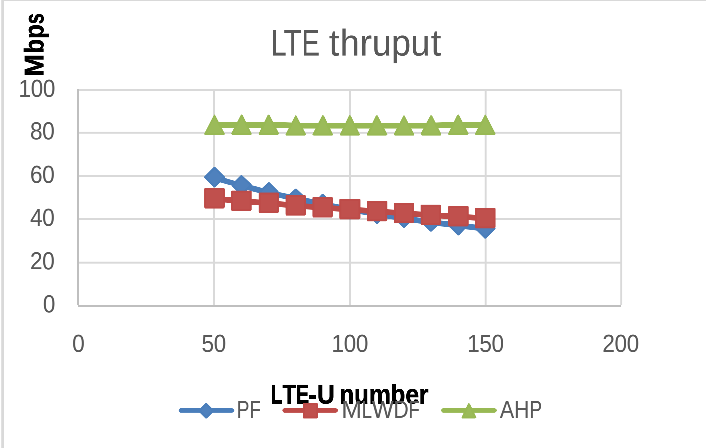

Figure3LTEthroughput (Video user=40, FTP user=60，LTE user=100)

It can be seen from Figure 3 that when the number of LTE-U users, the number of fixed LTE, and GBR users is changed, the LTE user throughput of the AHP allocation algorithm is better than the PF algorithm and the M-LWDF algorithm. When the number of LTE-U users is small, the throughput of the PF allocation algorithm is slightly higher than that of the M-LWDF allocation algorithm. However, as the number of LTE-U users is large, the performance of the PF allocation algorithm can be seen slightly lower than the M-LWDF allocation algorithm.

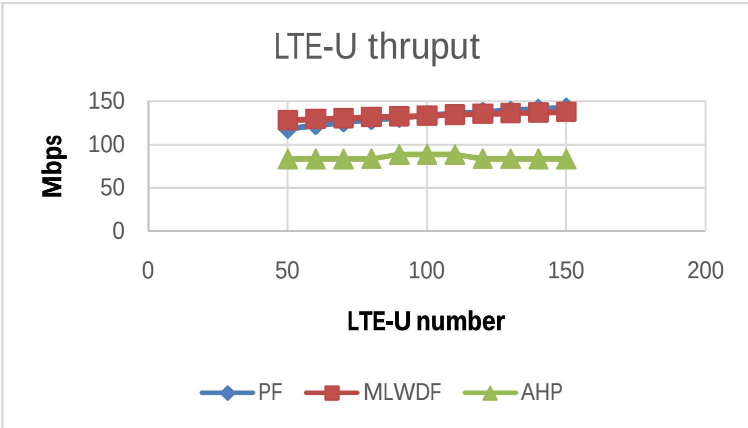

Figure 4 LTE-Uthroughput

It can be seen from Figure 4that the LTE-U user' throughputs of the PF allocation algorithm and the M-LWDF allocation algorithm are higher than that of the AHP allocation algorithm, and when the number of LTE-U users is small, the throughput of PF allocation is slightly lower than that of the M-LWDF allocation algorithm. But when the number of LTE-U users is large, it can be seen that the throughput of the PF allocation algorithm is slightly higher than the M-LWDF allocation algorithm

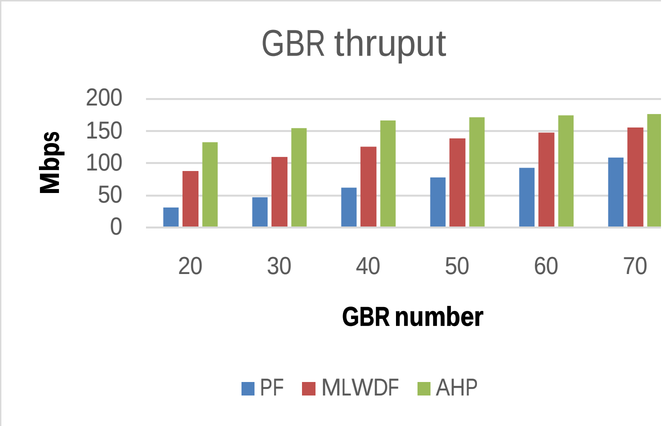

Figure 5GBR thruput (LTE-U=120，LTEuser=100)

It can be seen from Figure 5 that the GBR user throughput of the AHP allocation algorithm is higher than that of the M-LWDF allocation algorithm, and the M-LWDF allocation algorithm is higher than that of the PF allocation algorithm. In the AHP allocation algorithm, when different users have the same channel quality index, GBR users will have higher scores than non-GBR users and they have a higher chance of obtaining resources so that GBR user throughput will be promote.

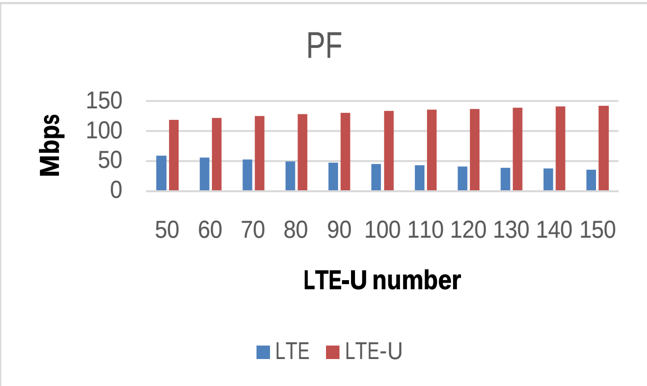

Figure 6:PF throughput

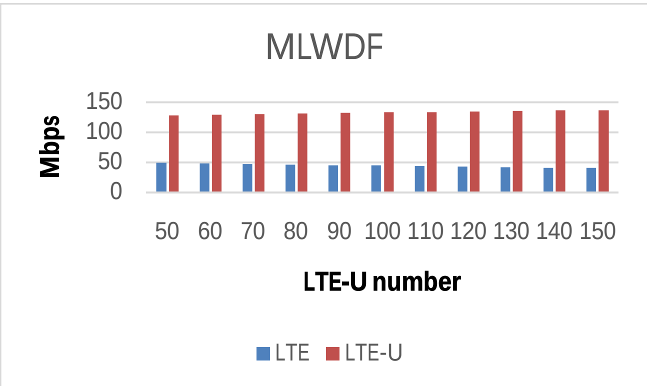

Figure 7: M-LWDF throughput

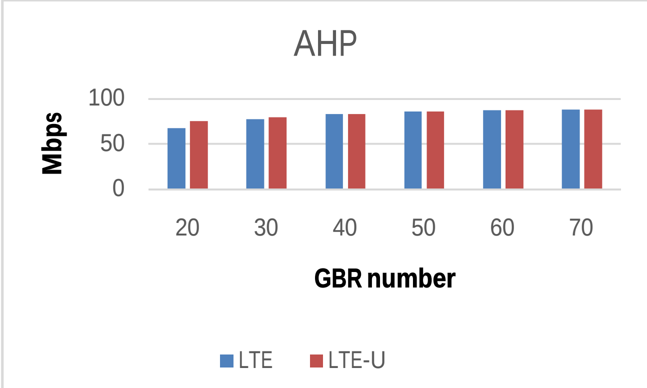

Figure8AHP throughput (LTE-U=120，LTE user=100)

From Figure 6 to Figure 8, it can be clearly seen that after considering the aggregation of unlicensed spectrum resources, the PF and M- LWDF allocation algorithms are not flexible enough for resource allocation. Only the throughput of LTE-U users has increased significantly and there is no increase for LTE users. In the AHP allocation algorithm, because the proportion of LTE and LTE-U people and the channel quality of each resource block for users are considered, LTE users will get more resources and LTE-U users can also get good throughput because they have LTE-U resources available.

V. Conclusion

In the LTE-Advanced network environment, this paper proposed an AHP allocation algorithm by aggregating licensed spectrum and unlicensed spectrum. Not only the channel quality of each resource block for users , but also whether the users are GBR users and proportion of LTE and LTE-U users are considered. In addition to maximizing system throughput, it will also take into account service quality to ensure the performance of real-time traffic by dynamically adjusting amount of resource blocks. Thus, the AHP allocation algorithm can be more flexible enough to allocate resources and maintains the satisfaction of GBR users.

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