An OVSF R-T-CCCA Assignment for WCDMA Systems to Reduce Code Blocking

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الخلاصة

ان مخطط "تخصيص شفرة محكمة من الجذر الى الشفرة" المقترح لنظام "تقسيم شفرة متعدد الوصول ذو الطيف الواسع" اقترح باستخدام شجرة شفرة "عامل الانتشار المتغير المتعامد". في خوارزمية "تخصيص شفرة محكمة" السابق، الشفرات لعامل الانتشار المتغير المتعامد قسمت الى مجاميع حسب سعة النظام والمكالمة القادمة تعالج بالمجموعة الاكثر ازدحاما. في مخطط تخصيص شفرة محكمة من الجذر الى الشفرة المقترح، الشفرات ايضا تقسم الى مجاميع بنفس الطريقة الموجودة في مخطط تقسيم شفرة محكمة ، فقط ان مخطط تقسيم شفرة محكمة من الجذر الى الشفرة تفحص السعة من الجذر الى الشفرة الفارغة المطلوبة، بحيث ان سعة النظام المتوفر بعد عملية التخصيص للشفرة هو اقل مجزأة من مخطط تخصيص شفرة محكمة ومع اكثر تقليلا في حجب الشفرة مقارنة مع مخطط تقسيم شفرة محكمة. وهذا يؤدي الى زيادة في قابليات معالجة المكالمة لنظام تقسيم شفرة متعدد الوصول ذو الطيف الواسع.

Abstract

The proposed "Root-To-Code Compact Code Assignment" (R-T-CCCA) scheme for "Wideband Code Division Multiple Access" (WCDMA) system is proposed by using the "Orthogonal Variable Spreading Factor" (OVSF) code tree. In the previous "Compact Code Assignment" (CCA) algorithm [1], the codes of the OVSF are divided to groups according to the system capacity and the incoming call is treated by most congested group. In the proposed R-T-CCCA scheme, the codes are also divided into groups in the same way that in the CCA scheme, except that the proposed R-T-CCCA scheme check the capacity from the root to the desired vacant code, such that the capacity of the system that available after the assignment of the code is least fragmented than that in the CCA scheme with more reduction in code blocking comparable with the CCA scheme. This leads to increase the call treating capability of the WCDMA system.

1- Introduction

The "First Generation" 1G of mobiles based on analog transmission and only supports voice services. It has many disadvantages like poor quality of voice, poor battery life, big size phone, limited capacity and no security [2-5]. The "Second Generation" 2G appeared in the end of 1980s this technology supports the voice services with a very low bit rate. The 2G uses the digital transmission technology also supports a medium packet services. For the high speed rate transmission the 2.5G is deployed [2-3, 5-6]. The "Third Generation" 3G of mobiles supports a very high bit rates that enables a new services "multimedia services" MS like voice, images, videos and video gaming also supports a wideband services and the most basic technique in 3G is the WCDMA systems. The requirements of the 3G systems are supports a very high data rates, support both switched and packet services, efficient radio spectrum usage… [2, 4 and 6]. The WCDMA is a "Direct-Sequence" DS-CDMA, which provide a wide bandwidth that makes the information bits of users to spread over it, by multiplying the data of users “Symbols” with a random bits “Chips” comes from CDMA spreading codes for supporting very high data rates [7]. The CDMA gives each user a special code (unique) with the same frequency and the same time access. This unique code helps to avoid the interferences between users “Calls” [8]. In WCDMA there are two types of spreading codes namely channelization and scrambling code. The first one uses the OVSF codes. The channels in the forward link use these codes for the transmission which come from the orthogonal function. The second one is used in the uplink transmission. [9]

Section 2 reviews the background of OVSF-CDMA. Section 3 describes code blocking. Section 4 describes code assignment schemes. Section 5 describes the proposed Root-To-Code Compact Code Assignment Scheme. Section 6 describes simulation results & discussions’ showing the performance improvement using R-T-CCCA scheme. The conclusions are given in section 7.

2- OVSF Code Tree

The code tree of the OVSF consists of a number of layers L, each layer has its own “Spreading Factor” SF and the data rates R. Since the SF is starting from the root of the tree is equal to $[1, 2, 4, 8 \ldots 2^{L-1}]$ and the data rate $R = [2R^{L-1}, 2R^{L-2}, 2R^{L-3} \ldots R]$. Each layer has its own codes that it has been given to the users in the downlink transmission represented by $C_{L,n}$, where L is the number of layer, n is the position of the code and the number of codes in each layer equals to the SF of that layer. The maximum code tree capacity is represented by cap 2^{L-1}. The Figure 1 shows the tree of the OVSF. The codes in the code tree of the OVSF must be orthogonally to avoid the interferences between the users during the communication, so to keep the orthogonality between users, one must block the corresponding codes of the used code to avoid these interferences between users [1].

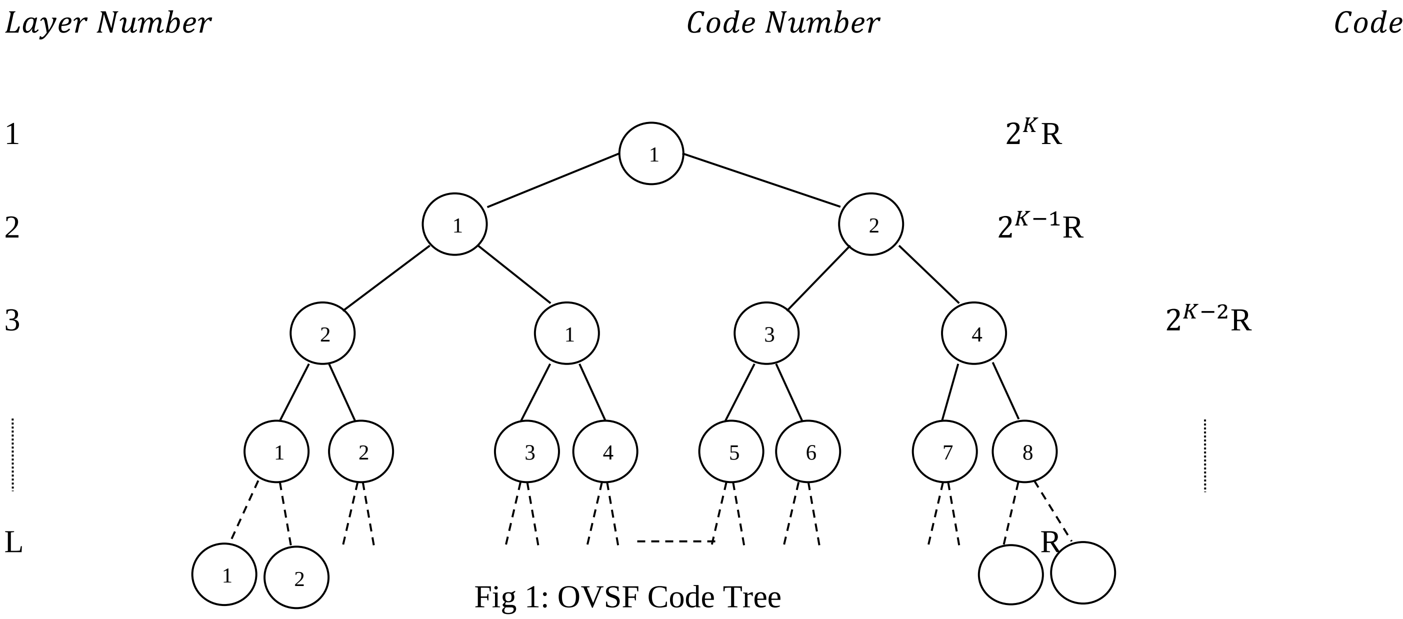


Fig 1: OVSF Code Tree

from layer 1 to 5 are divided into 8 groups by the Equation 1 [1].

$$8\ x\ 2^{m} \quad \ldots\ldots\ldots 1$$

where m is from $[0-4]$. The number of codes in each layer for 8 groups are given in table 1. The division is performed to make the code assignment most compact.

Table 1: Illustration of Number of Codes in Each Group, Where the Number of Groups is 8 [1]:

Layer	No. of codes In each group	Maximum Capacity used
1	16	$16R$
2	8	$16R$
3	4	$16R$
4	2	$16R$
5	1	$16R$

When a new call arrives with the code requirement from any of the layers from 1 to 5, the most compact group is chosen for assignment of the code in CCA scheme and most compact group with more capacity from the root to the desired vacant code is chosen for the assignment of the code. For example, for a code $C_{5,n}$, the code group contains codes given in Equation 2 [1].

$C_{4,2n-1}$, $C_{4,n}$ in layer 4
$C_{3,4n-3}$, $C_{3,4n}$ in layer 3
$C_{2,8n-7}$, $C_{2,8n}$ in layer 2 ………………………………………….. 2.
$C_{1,16n-15}$, $C_{1,16n}$ in layer 1

The algorithm for assignment scheme considering 8 groups each with 5 layers is given below:

3- Code Blocking

It is a phenomenon caused by a user call or a session blocked even if the system's capacity is enough for supporting the requirement of the call rate or a session and this is caused mostly by the code tree's fragmentation [10, 11].

4- Code Assignment Schemes

Assignment schemes of the code are used in the performance optimization of the WCDMA system. In "Random Assignment" (RA) [12], the user takes code randomly for assignment. In "Leftmost Code Assignment" (LCA) [12], the searching starts from the leftmost. In "Compact Code Assignment" (CCA) [1], the tree is divided into groups and the assignment of the code depend on the most congested group, the group with more capacity. The results in [1], approved that the CCA scheme gives the best results comparable to these previous methods.

5- Proposed Root-To-Code Compact Code Assignment (R-T-CCCA) Scheme

The researcher consider an OVSF-CDMA code tree having eight layers, where layers L=8, from 1 to 8 layers. Layer 8 for the root and layer 1 for the leaves. The SF from layer 1 to layer 8 is $2^7, 2^6, 2^5, \ldots, 2^0$ corresponding to $[128, 64, 32, \ldots, 1]$ with data rates R $2^0, 2^1, 2^2, \ldots, 2^7$ corresponding to $[R, 2R, 4R, \ldots, 128R]$. The code in each layer is representing by $C_{L,n}$, where n is the position of the code in layer L and n varies from 1 to SF. System capacity of the whole tree is 2^7, which is $128R$. There are in total eight arrival classes of users corresponding to its eight SFs in OVSF-CDMA system. In Compact Code Assignment (CCA) and Root-To-Code Compact Code Assignment (R-T-CCCA) schemes, the OVSF code trees

CCCA schemes are explained with the example shown in figure 2. The number of groups in total is 8, so that each group has 16 leaves. Five layers have been considered in the OVSF-CDMA system consisting of 2 trees of capacity $16R$ each. Assume the status of the code tree before the arrival of new call is shown in figure 2. If a new call required code in layer 2, there are many numbers of codes vacant alternatives. The codes $C_{2,2}$, $C_{2,3}$, $C_{2,4}$, $C_{2,5}$, $C_{2,6}$, $C_{2,7}$ and $C_{2,8}$ belong to the same group with the group capacity $2R$. Similarly the codes $C_{2,10}$, $C_{2,11}$, $C_{2,12}$, $C_{2,13}$, and $C_{2,14}$ are in the same group with group capacity $6R$. The figure (2.b) shows that the maximum capacity 6R belongs to the second group, so the researcher chooses the second group for the assignment of new call. In CCA scheme any of the vacant codes in layer 2 are chosen for the assignment randomly. In the proposed R-T-CCCA scheme, the searching algorithm checks the capacity from the root to all vacant codes in the layer 2. The capacity from the root to vacant code $C_{2,10}$ is 3, and the capacities from the root to all other vacant codes in layer 2 are 2. So, in this case the researcher chooses the vacant $C_{2,10}$ for the assignment of the new call.

For the incoming user, request code from layer 1 to 5:

1- Calculate the capacity of each group from 1 to 8 groups.

2- Check the capacity and choose the most compact group, the group with more capacity. The capacity of the group is defined as sum of capacities of all the busy descendants of parent of the code $C_{L,n}$ in layer 5. If two or more groups have the same capacity, any of the two are chosen for the assignment.

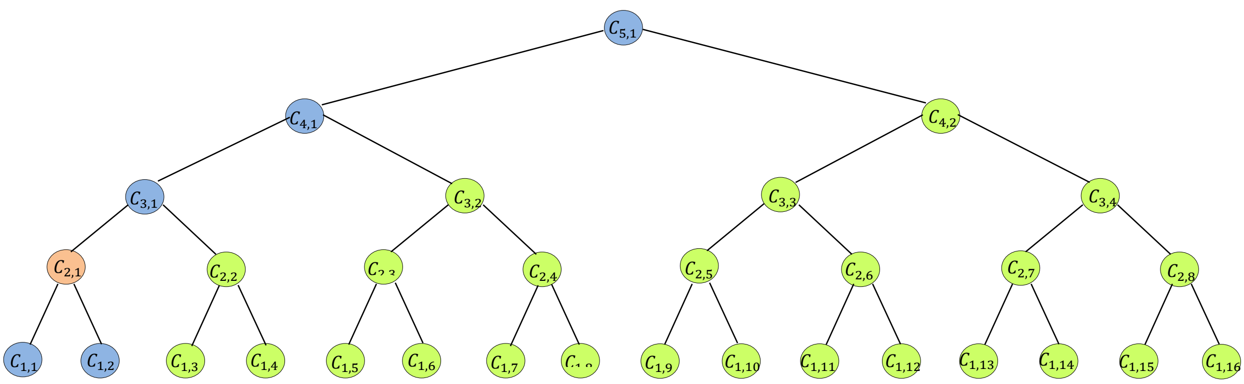
3- Check the capacity from the root to desired vacant codes in layer L.

4- Pick the vacant code with more capacity from the root to that vacant code for the assignment [1].

The proposed R-T-CCCA scheme leads to the minimum the external fragmentation of the remaining capacity and reduces in code blocking more than the CCA scheme, and gives best result performance.

The higher data rates in both schemes (e.g. data rates of the layer 6, 7 and 8 in all 8 groups) are treated like Leftmost Code Assignment (LCA) algorithm which the assignment of the code begins from the left most of the tree [12]. The flow chart of the proposed R-T-CCCA scheme is shown in figure 3. The CCA and proposed R-T-

G 1



ig (2.a): OVSF Group1 Code Tree

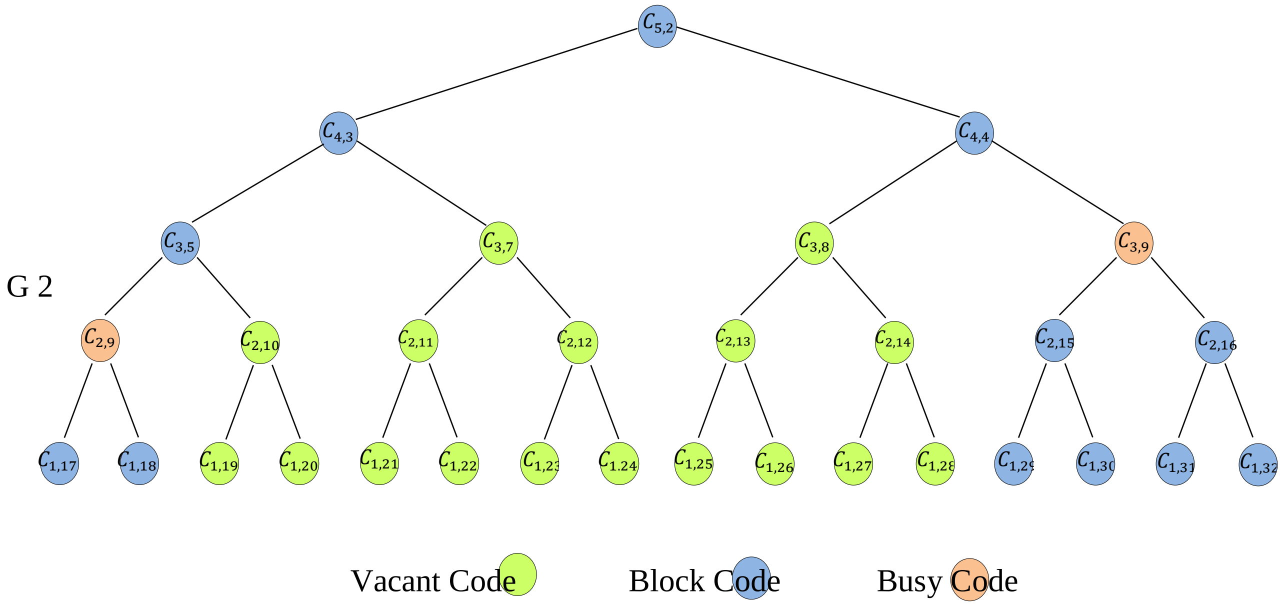


Fig (2.b): OVSF Group2 Code Tree

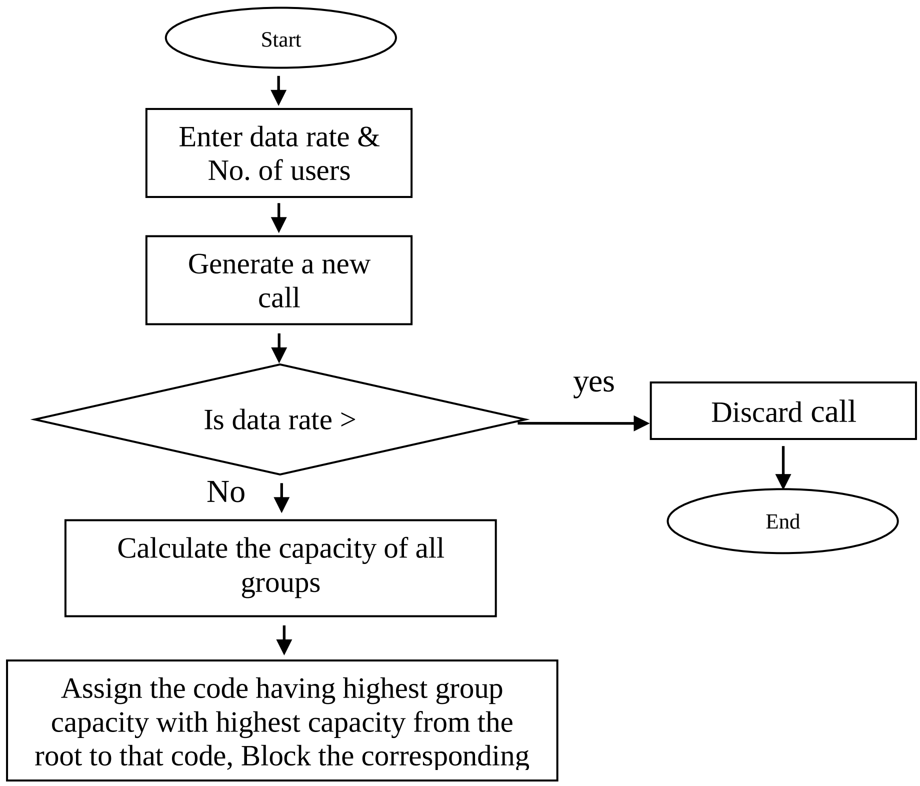


Fig 3: Flow Chart of the Proposed Root-To-Code Compact Code Assignment (R-T-CCCA) Scheme

Event driven simulation has been considered for getting results. The researcher considered a data rates

6- Results & Discussions

For the results, we got (12) Figures. Three figures show the blocks, vacant and blocking probability of the $1R$ data rate users in Y axis with respect 128 users in X axis to complete the code tree. Three figures are for the $2R$ data rate users with number of users 64 to complete the code tree. Three figures are for the data rate $4R$ with 32 number of users. These (9) figures are to show the performance of the proposed R-T-CCCA scheme in the assignment and the best results that the proposed searching algorithm gives comparable to the CCA scheme because the researcher took in each three figures one arrival data rates which are $1R, 2R, and\ 4R$. The researcher got three figures with three different data rates $1R, 2R$ and $4R$ with 60 users in X axis and number of calls blocked, vacant codes and blocking probability in Y axis. Table 2 shows the data rates (taken randomly) for all different arrival classes of users and the figures for each kind of data rates.

$1R, 2R, and\ 4R$, with number of users $128, 64, and$ 32 to complete the OVSF code tree. $1R, 2R$ and $4R$ corresponding to 3 different data rates, with number of users 60. The total number of code groups considered in this work is 16 to make the maximum capacity $128R$ (equal to capacity of the WCDMA system). The results of the simulation show the number of code blocks, number of vacant codes and the blocking probability of the proposed R-T-CCCA scheme. The results are done with iteration (100000) and it took time (8 Hours and 20 Minutes). The new call blocking (P_B) is defined in equitation 3 [1]:

$$P_B(\%) = No. of\ calls\ blocked\ / \ Total\ No. of\ calls \ \ldots\ldots\ldots\ldots\ldots \ 3$$

The number of calls blocked, vacant codes and the blocking probability of the proposed R-T-CCCA scheme compared with those that in the CCA scheme.

Table 2: Illustration of different kinds of the arrival data rates, figures for each kind of data rates.

Data rate	Data rate equal to No. of users	Block Figure	Vacant Figure	Blocking probability(%) Figure
$1R$	128	4	5	6
$2R$	64	7	8	9
$4R$	32	10	11	12
$1R, 2R, 4R$	1 2 2 1 4 4 2 1 2 4 2 2 1 1 4 2 2 1 4 1 2 2 1 2 2 2 1 1 4 4 2 4 1 4 2 2 1 4 1 2 1 4 2 4 2 2 1 2 1 2 4 1 1 2 1 4 1 2 1 2	13	14	15

Figure 4, shows the block calls of the proposed R-T-CCCA scheme in and the CCA scheme in Y axis, for the data rate $1R$ with respect to the number of users in X axis. The researcher notice below in figure 4 that the proposed R-T-CCCA algorithm first assignment of the code, when both schemes have the same vacant codes and the code tree empty. The second reason when both schemes code tree have the same vacant codes, blocked codes and both schemes assign the same codes. The third reason when the CCA scheme assigns the code randomly and blocked codes are less than the proposed R-T-CCCA scheme this leads to give the same code blocking in both code trees, but in all states, the proposed R-T-CCCA scheme gives best results performance comparable with the CCA scheme. When the number of users 17 and more than 17 the proposed R-T-CCCA searching algorithm reduce in code blocking comparable with the CCA.

gives best result performance comparable to CCA scheme in the reduction of code blocking and it leads to minimize the external fragmentation of the code tree. As the researcher notice that in the first assignment of the code both schemes give the same number of blocked calls because the tree is empty, so both schemes give the same number of blocked calls, after the first assignment to the number of users 16 the proposed R-T-CCCA scheme gives best results in the reduction of code blocking as the researcher notice in figure 4 below, when the number of users equal to 16 both schemes give the same code blocking results, this type of problems occurs for three reasons, the first one is the same of the

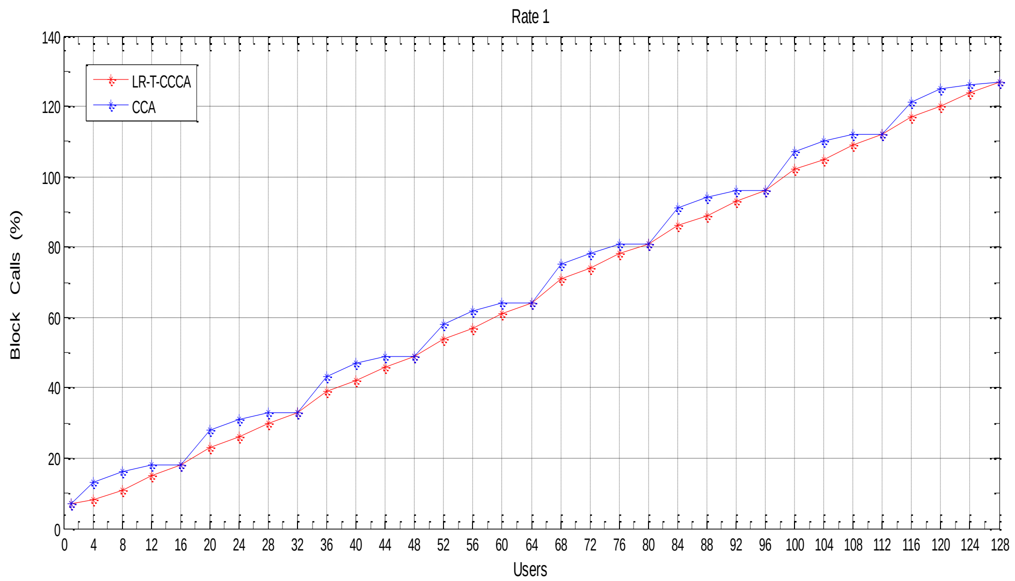


Fig 4: Block Calls VS Users of Data Rate 1*R*

tree are vacant and it has 8 layers which make all codes 255. The researcher notice from the figure 5 that the proposed algorithm gives best result performance comparable to the CCA scheme and when the number of users equal to 16 both schemes give the same number of vacant codes.

Figure 5, shows the vacant codes of the proposed R-T-CCCA scheme and the CCA scheme in *Y* axis for the data rate 1*R* with respect to the number of users in *X* axis. The researcher notice from the figure 5 that the line starts from the point 255, the higher point to the lower point because the code tree in both schemes is empty before the first assignment, so all codes in the code

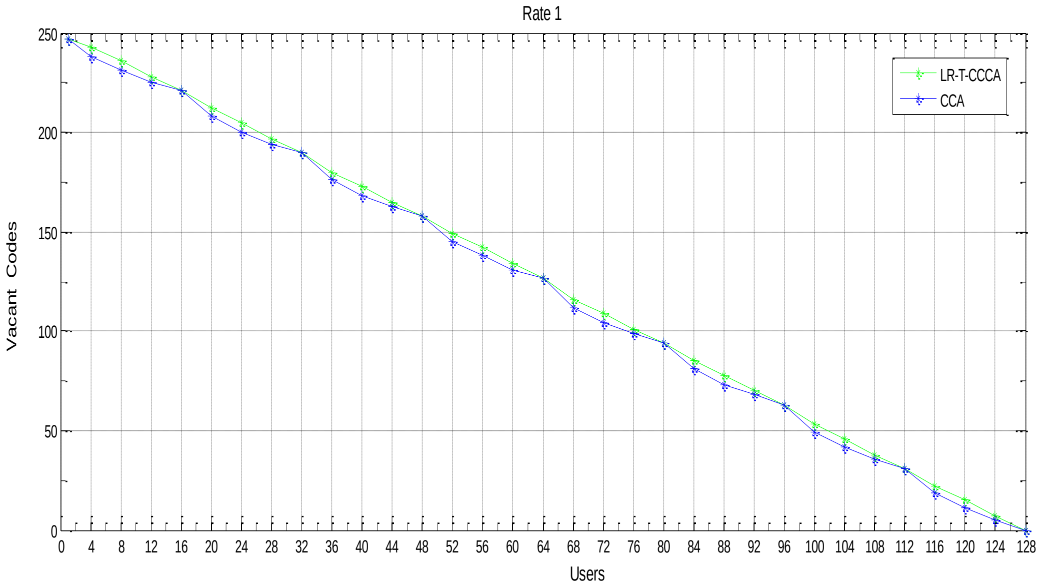


Fig 5: Vacant Codes VS Users of Data Rate 1R

blocking probability when the tree is almost empty because the tree are empty, there are many codes vacant in the tree and the CCA scheme assigned the codes randomly in the most compact group, in which this type of assignment blocked more codes and the proposed scheme is assigned the codes with respect to the capacity from the root to all vacant codes in the desired layer.

Figure 6, shows the blocking probability of the proposed R-T-CCCA scheme and the CCA scheme in Y axis for the data rate 1R with respect to the number of users in X axis. The researcher notice from the figure 6 that the proposed R-T-CCCA algorithm gives best results in the reduction of code blocking comparable to the CCA scheme and he show the big differences between both schemes in the

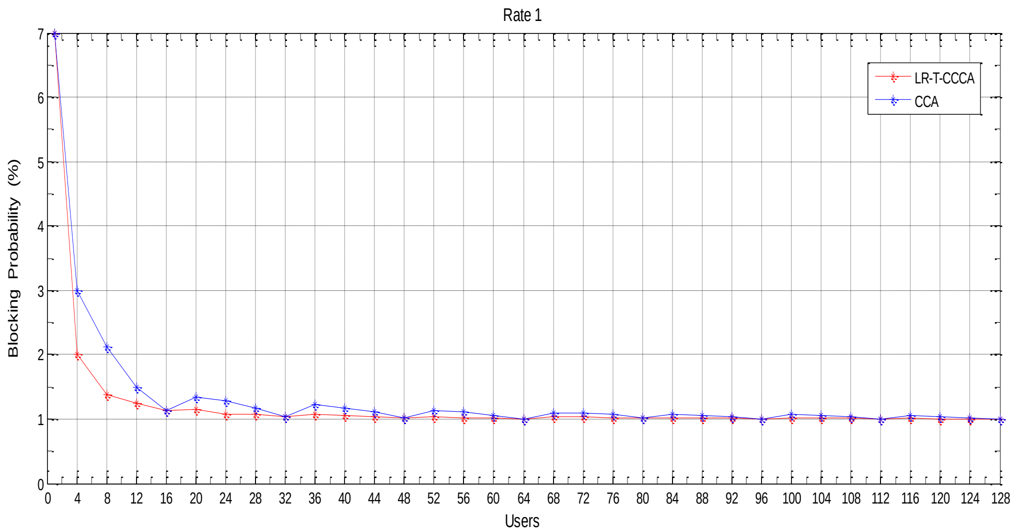


Fig 6: Blocking Probability (%) VS Users of Data Rate 1R

in Y axis for the data rate 2R with respect to the number of users which is 64 in X axis.

Figure 7, shows the block calls of the proposed R-T-CCCA and the CCA schemes group, picks one vacant code from 16 codes. So, the probability of calls blocked is big if there are 16 codes, but when the new call required code with data rate $2R$, the CCA code tree searched and picked one vacant code randomly from 8 vacant codes, the probability of calls blocked is less comparable with data rate $1R$.

From the figure 7, the researcher notice that the differences between both schemes in code blocking is less than that when the incoming user took the data rate $1R$ (see figure 4), because there are 16 vacant codes in each group with data rate $1R$ and 8 vacant codes with data rate $2R$, so when the new user arrived required code with rate $1R$, the searching algorithm of the CCA code tree takes code randomly in the most compact

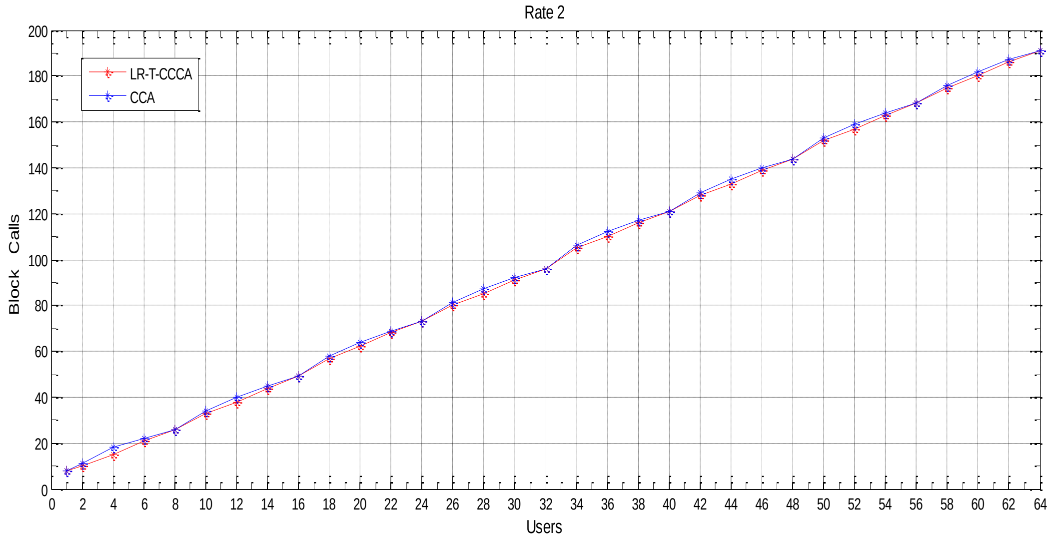


Fig 7: Block Calls VS Users of Data Rate $2R$

vacant codes in both schemes are equal as the researcher explain that in page 7 after the user 9 the proposed scheme returns to give more vacant codes which means best results performance comparable to the CCA scheme, until the number of users 16, the number of vacant codes returns to be equal in both schemes, and in the number of users 18 the proposed R-T-CCCA scheme returns to give more vacant codes.

Figure 8, shows the vacant codes of the proposed R-T-CCCA scheme and the CCA scheme in Y axis for the data rate $2R$ with respect to the number of users in X axis. The researcher notice from the figure 8 that the result performance of the proposed scheme is best and it is exactly opposite of the previous figure 7, and he notice below in figure 8 that the proposed scheme gives more vacant codes than the CCA from the first user to the last user and in some points like in the number of users 7 and 8, the

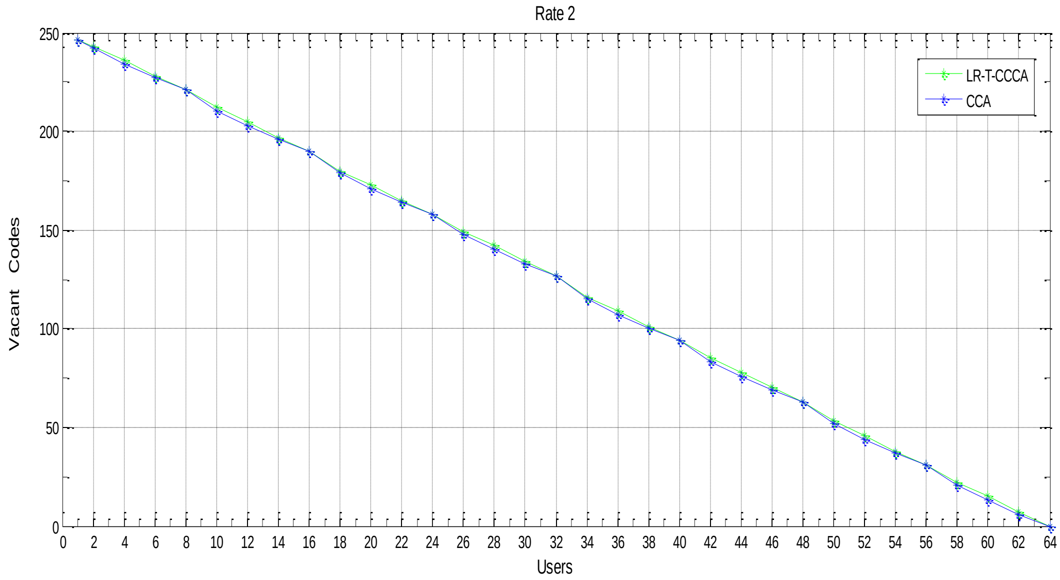


Fig 8: Vacant Calls VS Users of Data Rate $2R$

probability of the proposed scheme is less than the CCA scheme after the first assignment of the code, and he see the big differences in the results of blocking probability when the tree is almost empty.

Figure 9, shows the blocking probability of the proposed R-T-CCCA and the CCA schemes in Y axis for the data rate $2R$ with respect to the number of users 64 in X axis to complete the code tree. As the researcher notice in figure 9, the blocking

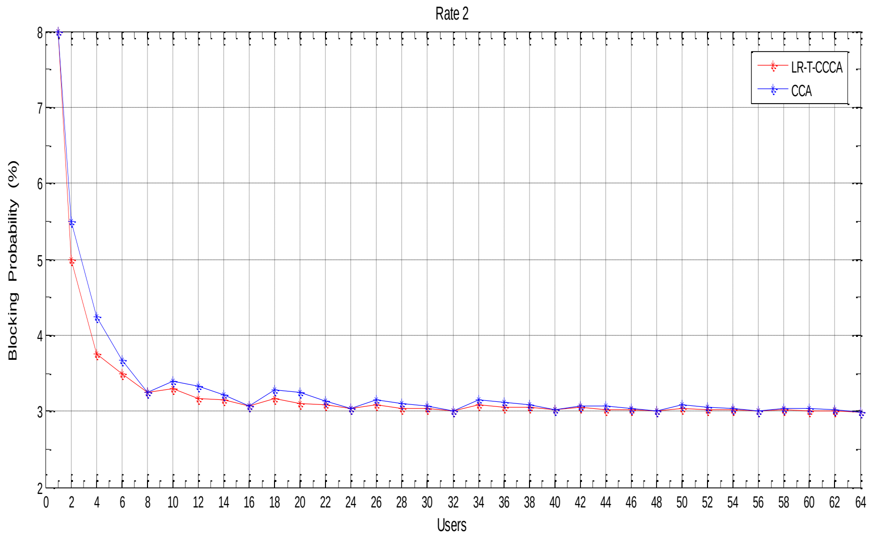


Fig 9: Blocking Probability (%) VS Users of Data Rate $2R$

CCA scheme, the reason behind this is that in the assignment of the code with data rate $4R$, there is only 4 codes in both schemes in each group for the assignment of the code, so the CCA searching algorithm may pick the same vacant code that the proposed algorithm used.

Figure 10, shows the block calls of the proposed R-T-CCCA and CCA schemes in Y axis for data rate $4R$ with respect to the number of users in X axis. From the figure 9, the researcher notice that there is no significant difference in the number of block calls in both schemes; the proposed and the

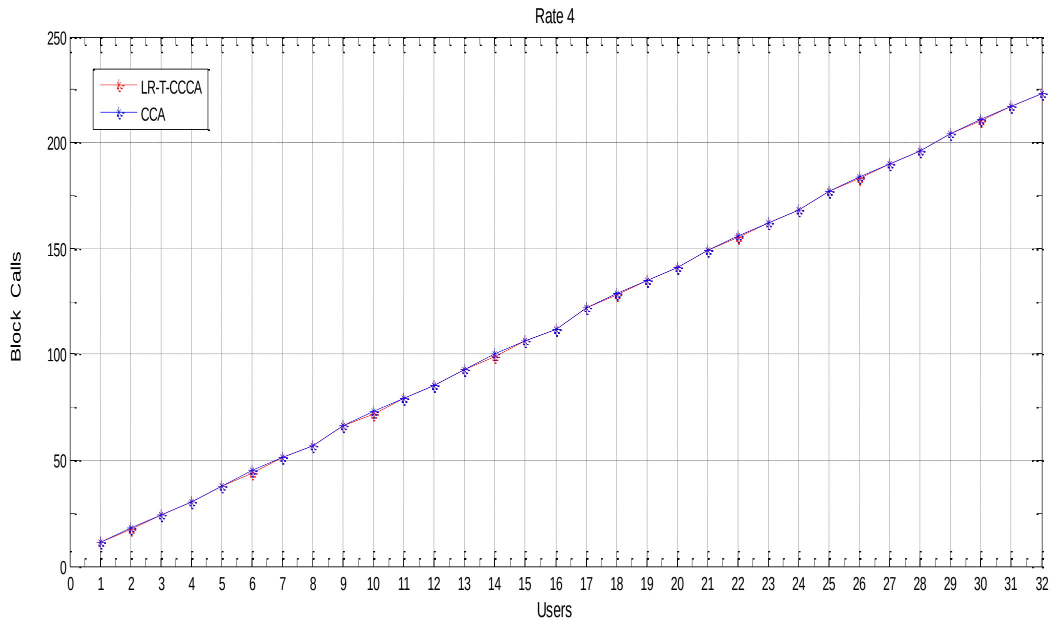


Fig 10: Block Calls (%) VS Users of Data Rate 4R

point because the code tree is empty before the first assignment and there is 255 vacant codes in each code tree. The researcher notice from the figure 11, that the proposed algorithm gives best result performance comparable to the CCA scheme in the providing vacant codes and correspond that it reduce in the code blocking.

Figure 11, shows the vacant codes of the proposed R-T-CCCA scheme and CCA scheme in Y axis for the data rate 4R with respect to the number of users in Y axis. The researcher notice from the figure 11, the similarity in the results between figure 11 and the figure 10 of block calls, only that is the line of the vacant codes in figure 11 starts from the higher point to the lower

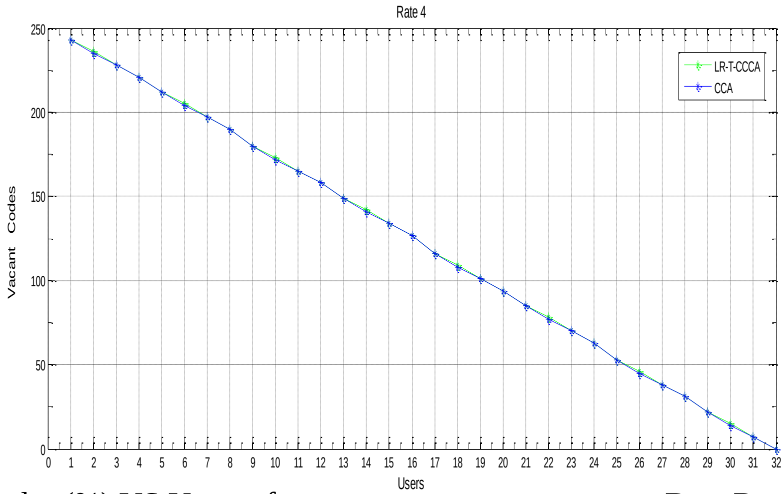


Fig 11: Vacant Codes (%) VS Users of Data Rate 4R

differences in both schemes clearly more than that in the figures of block calls and vacant codes of the data rate $4R$ the same blocking probability in the first assignment that is because the same code blocking with

Figure 12, shows the blocking probability of the proposed R-T-CCCA and the CCA schemes in Y axis for the data rate $4R$ with respect to the number of users in X axis. In the figure 12 of blocking probability, the

the CCA scheme and gives best results, after 6, users the researcher notice from the figure 12 that the lines of blocking probability of both schemes is close to each other with best results of the proposed algorithm in some points with the same results in other points. until the last user, the proposed algorithm gives best results performance in the reduction of code blocking, even with the data rate $4R$.

only one user in both schemes, when the second user arrived, the proposed algorithm gives best results in the probability of blocking compared with the CCA scheme, until the number of users 5, both schemes give the same results and the researcher mentioned that in page 7, of block calls, when the number of users equal to ,6 the proposed algorithm returns to reduce in probability of blocking calls comparable to

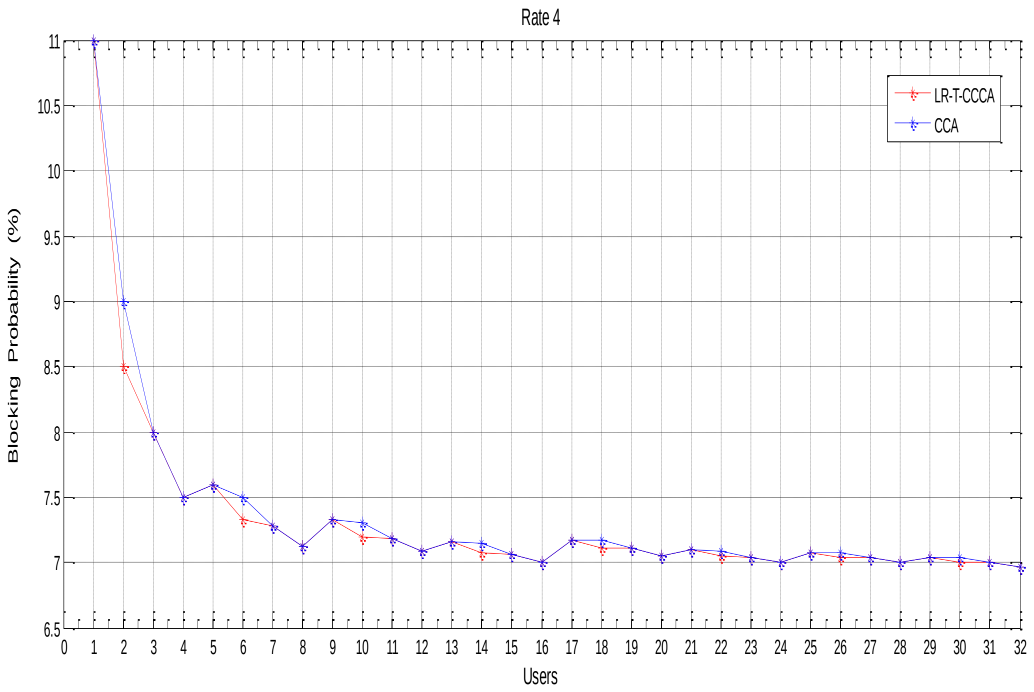


Fig 12: Blocking Probability (%) VS Users of Data Rate 4R

schemes give the same results, when the number of users 25 until the user 48, the proposed algorithm returns to give the best results performance comparable to CCA scheme. From the user 49 until the last user, the propose algorithm gives the best results, so the figure 13 shows us that the proposed R-T-CCCA scheme is best in code blocking reduction and gives best results performance and minimizes the external fragmentation of the code tree even when the researcher used different data rates comparable to the CCA scheme.

Figure 13, shows the block calls of the proposed R-T-CCCA and CCA schemes in X axis by using the rates $1R, 2R$ and $4R$ with respect to the number of users in Y axis. The researcher notices that the figure 13 differs from the previous figures of block calls when he uses different data rates with to keep the best results of the proposed algorithm. In the first assignment, both schemes give the same block calls, from the second user until the user 20, the proposed algorithm gives the best results in the reduction of code blocking When the number of users is equal to 22 to 24, both

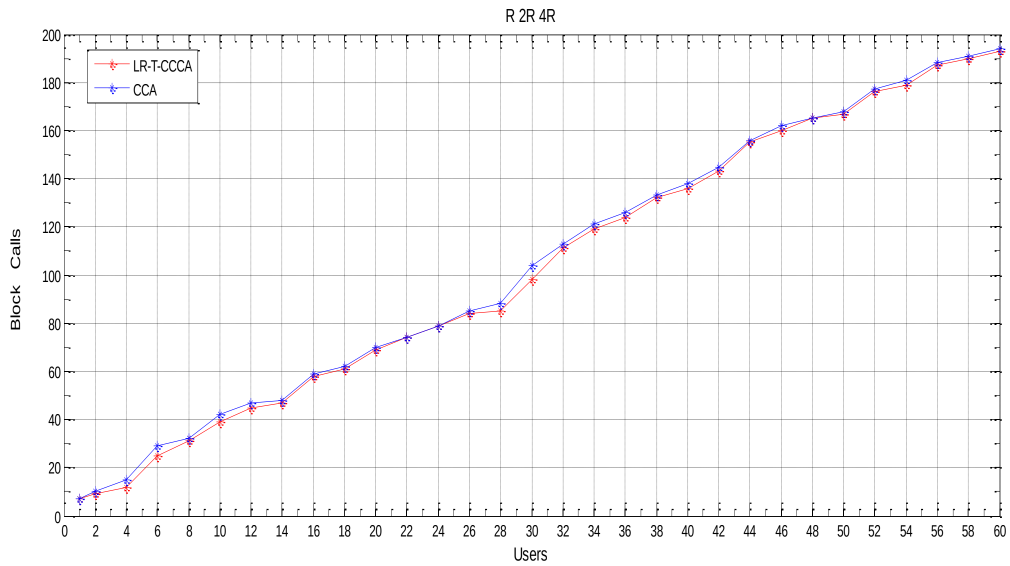


Fig 13: Block Calls VS No. of Users

researcher notice that from the second user until the last assignment the proposed algorithm gives best results in providing vacant codes corresponding that the reduction in code blocking only when the number of users equal to 22 to 24, both schemes give the same number of vacant codes, but in all states the proposed scheme is the best in results.

Figure 14, shows the vacant codes of the proposed scheme and the CCA scheme in Y axis by using the rates $1R, 2R$ and $4R$ with respect to the number of users in X axis. The figure 14 is exactly the opposite of figure 13. The researcher notice from the figure 14, the best results that the proposed algorithm gives in providing more vacant codes ready to use from the new user compared with the CCA scheme and the

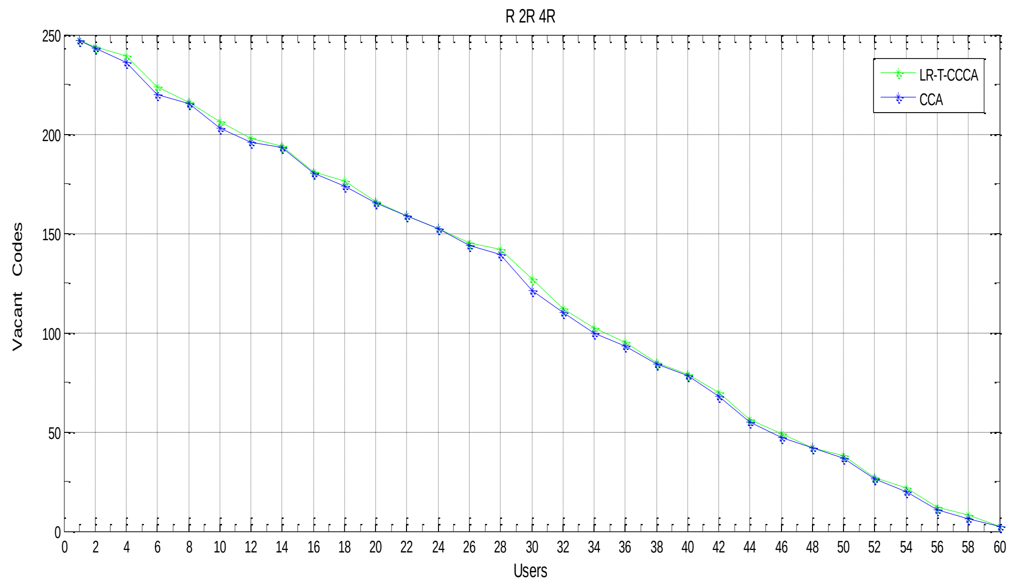


Fig 14: Vacant Codes VS No. of Users

researcher notice from the figure 15 that the blocking probability line ascends in some points and descends in other, the reason behind that is in the arrival data rates,

Figure 15, shows the probability blocking of the proposed and the CCA schemes in Y axis with the rates $1R, 2R$ and $4R$ with respect to the number of users in X axis. The reached to 3.7. The data rate $4R$, in layer 3 required capacity 4, it needs block 4 calls more than lower layer, such as layer 2 and layer 1. This leads to change the probability blocking line in figure below from the bottom to the top with best results of the proposed scheme comparable with the CCA scheme. For the data rate $2R$, it required capacity 2, so the line changed from the up bottom in both schemes with best results of the proposed algorithm. The researcher notice from the figure below that the proposed algorithm gives the best performance in the blocking probability from the beginning to the last user to make the code tree almost complete, just in some points, both schemes with the same blocking probability and the researcher explained the reason in the previous figures.

because each type of data rates used a capacity different from the other layers. So, the lower layer blocks few calls comparable to the higher layers that required more capacity and blocked more vacant codes. So, this leads to make the line ascends in some points and descends in the other points. The table 2 above shows that in the first assignment with data rate $1R$, both schemes give the same blocking probability. The second user and the third user, both used the data rate $2R$, the CCA assigned the codes randomly. The proposed algorithm gives the best results compared with the CCA scheme. The third user with data rate $1R$, here the searching jumped from the second layer to the first layer, from capacity 2 to capacity 1, so the line of the proposed scheme reached the lower point in figure 15 which is 3, and the CCA scheme line

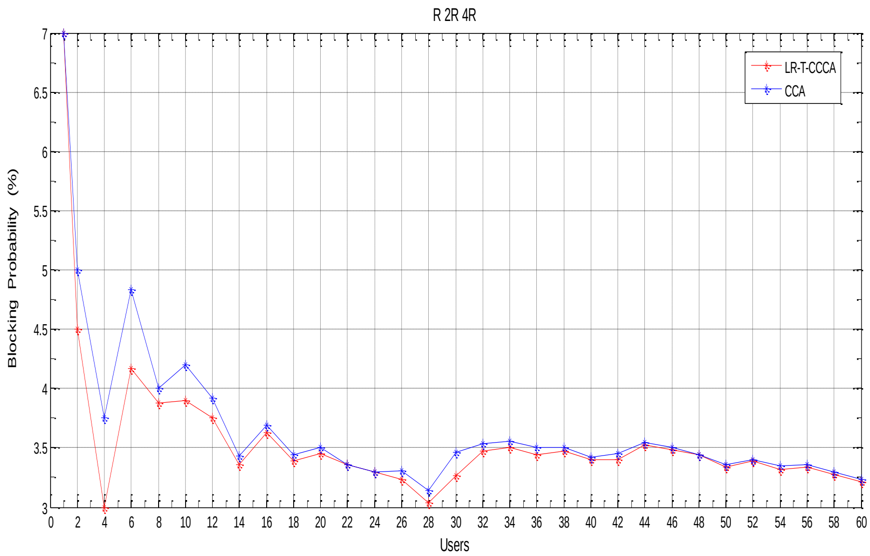


Fig 15: Blocking Probability VS No. of Users

call in such a way that the remaining capacity of the system is least fragmented comparing with the CCA scheme making the assignment of the code most compact than the CCA scheme. This proposed R-T-CCCA scheme gives more reduction in code blocking with providing more vacant codes to the incoming users. This leads to improve

7- Conclusion

A root-to-code compact code assignment scheme is proposed to efficiently use the codes of the OVSF in 3G WCDMA wireless communication systems. The benefit of the proposed R-T-CCCA scheme is that it assigns the code to new incoming

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the WCDMA system performance. The results in chapter 4 show that the proposed scheme gives best results in the performance comparable to the CCA scheme and this leads to increase the capability of call treating in WCDMA system.

The conclusions of the work are shown as follows:-

1- Showing more reduction of the code blocking comparable with the CCA scheme.
2- Providing more vacant codes to the incoming user (call).
3- Minimizing the external fragmentation of the tree that makes the code tree of the OVSF more compact comparable with the CCA code tree.
4- Increasing the call handling capability by reducing the load of the WCDMA system.
5- Increasing the number of the users comparable with the CCA scheme.

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