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Fast Channel Load Algorithm for Downlink of Multi-Rate MC-DS-CDMA and Smart Grid Communication

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Abstract

The article proposes an optimum code assignment (OCA) scheme which meets the demand of quality of service (QoS) of a call with an improved capacity utilization of the Downlink of Multi-Rate MC-DS-CDMA when used for Smart Grids. The OCA scheme assigns incoming call request to a vacant code which leads to minimum future code blocking while maintaining the QoS of ongoing calls and the new call. The incoming call requests in this article are differentiated on the basis of their type: quantized or non-quantized. To ensure efficient radio resource allocation, a quantized call is assigned to a code with channel load (Cl) of time domain tree less than threshold channel load ($Cl_{Threshold}$) after an incoming call is accepted. The numbers of time domain tree with $Cl<Cl_{Threshold}$ are differentiated on the basis of code blocking probability, the time domain tree which provides minimum future blocking is selected. A nonquantized call request is handled using multiple rakes by first broken into quantized rate fractions and these fractions are assigned to time domain trees for which $Cl<Cl_{Threshold}$ and future code blocking is minimum. Cellular technology with LTE-based Multi-Rate MC-DS-CDMA standards have been a preference for distributed controls and real-time communications in the smart grid due to LTE widely used and forward-looking technology features. Implementation of LTE mobile network for mobile subscribers will lead to wastage in rural areas, the unused radio resources can be used for Smart Grid communication. In this paper, the proposed OCA scheme assigns resources to both type of traffic. Simulation and results show that the proposed scheme provides better E_b/N_0 (energy per bit to noise power spectral density ratio) while maintaining low code blocking probability than other schemes in literature.

Keywords: Code assignment, channel load, VSF-OFCDM, OVSF, MC-DS-CDMA, quantized, non-quantized, SM, SG.

INTRODUCTION

When electrical power grids joined with communication technologies the concept of Smart Grids is evolved [1]. The well-developed wireless communication techniques focused researcher's attention on implementing the wireless communication as the communication medium for power grids and development of smart grids. 3GPP (3rd Generation Partnership Project) proposed the Long Term Evolution (LTE) as the technique to develop a smart grid. LTE is widely accepted technique which provides connectivity to a mobile users at better speed and less latency. The SG communication network take on a ranked architecture which broadly has three levels or three kinds of networks. The home area networks (HANs), neighbourhood area networks (NANs) and wide area networks (WANs). The NANs are basically the backbone communication network which manages the distribution of electricity from distribution units to end users [2].

The Third- Generation Partnership Project (3GPP) has proposed an enhanced third-generation (3G) mobile communication, namely, 3.5G [3]. 3.5G adopts the high-speed downlink packet access (HSDPA) standard to provide a high data rate of 14 Mb/s. For accessing the fast service of cloud, the fourth (4G) cellular communications [4] [5] are announced for the shared packet service. To anticipate the demand the increase of future traffic, the fourth generation (4G) mobile communication systems have data rates of up to 100 Mb/s for high mobility and up to 1 Gb/s for low-mobility nomadic wireless access. Several communication technologies have been proposed i.e. Variable Spreading Factor- Orthogonal Frequency and Code Division Multiplexing (VSF-OFCDM) [6], 3GPPs' [3] Long Term Evolution (LTE) and LTE-Advanced [7], orthogonal frequency division multiplexing (OFDM) etc. [8], and OFCDM can operate at a broadband channel with approximately 100 MHz and supports the data rate ranging from 100 Mb/s to 5 Gb/s**.** OFCDM decreases multipath interference which is a serious issue and therefore leads to higher spectrum utilization than direct-sequence code division multiple access (DS-CDMA) [9]. The proposed variable spreading factor OFCDM (VSF-OFCDM) in [10] combines OFCDM with a variable spreading factor and used for downlink transmission scheme. VSF-OFCDM takes the advantage of OVSF and OFCDM communication technology and adopts a 2-D spreading in the time and frequency domains to control the channel load, delay spread, intercell interference, and increase the spectrum utilization.

WORK IN LITERATURE

OVSF and VSF

Previously, several schemes are proposed in the literature to reduce code blocking in OVSF [11] based networks. These schemes are broadly classified as single code assignment schemes [12-23] and multi-code assignment schemes [24-29]. Some of the schemes of single code assignment are: crowded first assignment (CFA) [12], leftmost code assignment (LCA) [12], fixed set partitioning (FSP) [13] and recursive fewer codes blocked (RFCB) scheme [14]. These schemes used one-dimensional spreading but all these suffer from interference as they don't consider the effect of channel load (C*l*). The multi-code assignment schemes [23-28] uses multiple codes to handle a single call which reduces code blocking at the cost of wastage of radio resources and increased complexity. To address aforementioned problems Universal mobile telecommunications system (UMTS) uses the VSF-OFCDM interface to allocate OVSF codes in two dimensions. An adaptive load balancing (ALM) is proposed in [30] this scheme suffers from higher code blocking problem as it uses *Cl* as a parameter to accept the call and assigns calls to a time domain tree for *Cl*<*Cl_{Threshold}*. The assignment most of the times lead to higher code blocking. The trade-off between the multicode interference and the frequency diversity gain has previously been investigated and analysed in [31]. The scheme in [32] uses a two-stage combining and code allocation scheme to decrease the multicode interference; but the method is inefficient as with the increase in number of user's, the number of orthogonal codes significantly reduces. An interference avoidance (IA+CF) scheme is proposed in [33] which provide significant improvement of code blocking probability at better QoS. Adaptive reward based selection of UMTS and LTE considering the effect of interference and mobility environments are proposed in [34] which are further used for an assignment using multicodes in order to maximize the bandwidth waste [35]. A multicode scheme for OVSF codes is proposed in [36] which provides zero waiting time for real-time calls. The QoS requirements together with higher utilization are the demands of the Multi-Rate MC-DS-CDMA networks. The essential requirement to attain the potential advantages of SG is the productive implementation of a communication infrastructure which is secure, energy aware, reliable and cost effective too [37] . The smart meters (SMs) are connected to the power outlet at homes and industrial units and they usually transmit at low power level using wireless communication medium to the gateways (GWs), gateways are sometime base stations of cellular network or the SMs are connected to BSs in two hop manner using Wireless LANs (WLANs). The data traffic is different from traditional cellular network and enterprise data traffic [38]. The data volume is also significantly low too [39-41]. The OCA scheme in this article address both the demands and also shows significant benefit. The rest of the research article is organized as follows. OVSF and VSF-OFCDM fundamentals are explained in section 3. The proposed assignment scheme is given in section 4. Results and simulations are given in section 5. Finally, the research work is concluded in section 6.

SYSTEM MODEL

The system model in this section describes the notations used, identification of codes and formulae used to find *Cl* of a time domain code.

The OVSF code tree is generated from a complete binary tree with L layers, where$1 \leq l \leq L$. The binary tree is generated as in [9] shown in Fig. 1. A channelization code is denoted by C_{l,n_l}, where l denotes the layer number and n_l denotes its position in layer $l, 1 \leq n_l \leq 2^{L-l}$ the spreading factor (*SF*) of a code is 2^{L-l}. The maximum spreading factor of the code tree is $SF_{max} = 2^{L-1}$. The code positions are sequential from left to right. The rate supported by a code is determined by its *SF*, codes with smaller spreading factor support higher data rate requests and vice versa. The rate of a code is quantized and of the form $2^{l-1}R$. Due to the orthogonal nature of channelization codes an OVSF codes, may be in one the states namely *busy*, *vacant* or *blocked*. The blocked state is due to the orthogonal characteristic *i.e* a busy code blocks all its parent's and children in all layers from an assignment. Therefore, a code can be assigned to a call, if and only if all its parent and children codes are vacant. This leads to fragmentation of available total capacity and leads to code blocking.

This article concentrates on the *Cl* and code blocking probability of Multi-Rate MC-DS-CDMA. A layer l channelization code C_{l,n_l} spreads both in time and frequency domains. The nomenclature for different terms and notations used in the article are given in Table 1.

Table 1: Nomenclature

Symbol	***Description***
l, l_t, l_f	Reference layer, time domain layer and frequency domain layer.
C_{l,n_l}	Code in layer *l* and n_l denotes position in layer *l*.
$C_{2^{l_t-1},n_{l_t}}$	Time domain code in layer l_t and n_{l_t} denotes its position in layer l_t.
$C_{2^{l_f-1},n_{l_f}}$	Frequency domain code in layer l_f and n_{l_f} denotes its position in layer l_f.
N_l	Number of ongoing calls of layer *l*.
Cl, *Cl_{Threshold}*	Channel load and threshold value of channel load.
m	Total number of rakes.
P_{B_i}	Probability of i^{th} class.
P_B	Total code blocking probability.

The time domain spreading code is denoted as $C_{2^{l_t-1},n_{l_t}}$ and frequency domain spreading code is denoted as $C_{2^{l_f-1},n_{l_f}}$. The 2-D spreading in time and frequency domain retains the orthogonal characteristics of channelization code. The relation between spreading factor of channelization code, time domain code and frequency spreading code is

$$2^{L-l} = 2^{k_t-1} \times 2^{k_f-1} \tag{1}$$

The characteristic of L, l, k_t and k_f should satisfy

$$L - l = (k_t + k_f - 2) \tag{2}$$

Where k_t and k_f denotes level index for time and frequency domains.

The characteristic of $n_l, n_{l_t}$and n_{l_f} should satisfy

$$n_l = n_{l_f} + (n_{l_t} - 1) \times 2^{k_f-1} \tag{3}$$

Where $n_l, n_{l_t}$and n_{l_f} denotes code index for OVSF code tree, time domain and frequency domain.

For a new call request of rate *kR*, an optimum code is searched and assigned. An optimum code is defined as the code which leads the minimum code blocking, minimum reassignment and recombination in future with channel load of the time domain code within the threshold and this scheme as an optimum code allocation (OCA). The total channel load of a code is due to the number of busy codes at each layer in sub tree under it *i.e* from lowest layer (l=1) to ($l = L - l_t$), where $l_t = log_2(SF_{l_t} + 1)$, also SF_{l_t} is spreading factor of time domain code at level ($L - l_t$) above layer 1.

The *Cl* of a time domain sub tree at layer $l_t$with N_l busy codes of l^{th} layer is

$$\frac{N_l \times 2^{l_t}}{2^{L-l+1}} \tag{4}$$

The *Cl* for a 8 layer tree is calculated for a different number of busy calls of different layers and is given in Table 2 with variable time domain code. This is available at the base station (BS) which reduces the computation time of calculating *Cl*.

The calls generated by mobile network and SG network are not differentiated on the basis of network, the assignment scheme assigns radio resources on the basis of call request data volume. The SG network is also assumed to request a call of rate γR.

Table 2 Calculation ***of Cl for a 8 layer code tree with variable number of ongoing busy calls***

Time domain SF_{k_t}	Ongoing call layer number (l)	Number of ongoing calls of layer l (n_l)	Cl_i	Cl_fafter accepting call of layer		
				1	2	3
32	1	1	$1/2^2$	$1/2$	$3/2^2$	AT
		2	$1/2$	$3/2^2$	AT	AT
		3	$3/2^2$	AT	$3/2$	AT
	2	1	$1/2$	$3/2^2$	AT	AT
		2	AT	AT	AT	AT
16	1	1	$1/2^3$	$1/2^2$	$3/2^3$	$5/2^3$
		2	$1/2^2$	$3/2^3$	$1/2$	$3/2^2$
		3	$3/2^3$	$1/2^2$	$5/2^3$	$7/2^3$
		4	$1/2$	$5/2^3$	$3/2^2$	AT
	2	1	$1/2^2$	$3/2^3$	$1/2$	$3/2^2$
		2	$1/2$	$5/2^3$	$3/2^2$	AT
		3	$3/2^2$	$7/2^3$	AT	AT
	3	1	$1/2$	AT	AT	AT
8	1	1	$1/2^4$	$1/2^3$	$3/2^3$	$5/2^4$
		2	$1/2^3$	$3/2^4$	$1/2^2$	$3/2^3$
		3	$3/2^4$	$1/2^2$	$5/2^4$	$7/2^4$
		4	$1/2^2$	$5/2^4$	$3/2^3$	$1/2$
		5	$5/2^4$	$3/2^3$	$7/2^4$	$9/2^4$
		6	$3/2^3$	$7/2^4$	$1/2$	$5/2^3$
		7	$7/2^4$	$1/2$	$9/2^4$	$11/2^4$
		8	$1/2$	$9/2^4$	$5/2^3$	$3/2^2$
		9	$9/2^4$	$5/2^3$	$11/2^4$	$13/2^4$
		10	$5/2^3$	$11/2^4$	$3/2^2$	AT
		11	$11/2^4$	$3/2^4$	AT	AT
	2	1	$1/2^3$	$3/2^4$	$1/2^2$	$3/2^3$
		2	$1/2^2$	$5/2^4$	$3/2^3$	$1/2$
		3	$1/2^3$	$7/2^4$	$1/2$	$5/2^3$
		4	$1/2$	$9/2^4$	$5/2^3$	$3/2^2$
		5	$5/2^3$	$11/2^4$	$3/2^2$	$7/2^3$
		6	$3/2^2$	$13/2^4$	$7/2^3$	AT
	3	1	$1/2^2$	$5/2^4$	$3/2^3$	$1/2$
		2	$1/2$	$9/2^4$	$5/2^3$	$3/2^2$
		3	$3/2^2$	$13/2^4$	$7/2^3$	AT
	4	1	$1/2$	$9/2^4$	$5/2^3$	$3/2^2$
		2	AT	AT	AT	AT

AT: Above threshold

SINGLE CODE ASSIGNMENT APPROACH

In this section, two assignment schemes are proposed which depends upon the type of call request arriving in the system. The basic idea of the schemes is to reduce code blocking which reduces system utilization. The higher utilization of orthogonal frequency domain codes under a time domain tree (code) increases channel load (*Cl*) or multi-code interference increases which affects QoS requirements of ongoing calls.

To allocate the radio resources to the incoming calls of variable rates for higher utilization and to meet QoS requirements, the call requests are classified into two types: quantized and non-quantized call requests. The rate requested by the calls are of type $\gamma^Q R$ $\{\gamma^Q = 2^j, j \in I: integer\}$ for quantized and $\gamma^{NQ} R$ $\{\gamma^{NQ} \in [1-15] - 2^j, j \in [1-3]\}$ for non-quantized. The algorithm starts searching busy sub trees, when no optimum code is available vacant sub trees are searched. For a vacant sub tree lowest possible time spreading code is selected and is recombined with other time spreading codes to accommodate higher number of calls when $Cl > Cl_{Threshold}$ with higher frequency domain *SF*.

Call Request: Quantized

For a quantized call request of rate $\gamma^Q R$, $\gamma^Q R\{\gamma^Q = 2^{l-1}\}$ a vacant code of layer $l^{\gamma^Q} \Big| l^{\gamma^Q} = (log_2\gamma^Q + 1\Big) = I: integer$ is assigned which leads to the total capacity utilization of code.

The algorithm to locate an optimum code for quantized call works as follow.

1. Find, if $UC + \gamma^Q R \leq 2^{L-1}R$ $i.e$ sum of the used capacity (*UC*) with the rate of an incoming call ($\gamma^Q R$) is lesser than the maximum capacity of the code tree, then call can be assigned to any vacant code.
2. Let m_{γ^Q} denotes the number of vacant codes in layer l^{γ^Q}. Find, if $m_{\gamma^Q} \geq 1$.
3. Yes, calculate channel load (*Cl*) of associated time domain codes of these vacant codes as

$$Cl_{\gamma^Q,v} = \frac{N_1 \times 2^{l_t}}{2^{L-1+1}} + \frac{N_2 \times 2^{l_t}}{2^{L-2+1}} + \frac{N_3 \times 2^{l_t}}{2^{L-3+1}} + \cdots + \frac{N_{L-l_t} \times 2^{l_t}}{2^{L-(L-l_t)+1}}, 1 \leq v \leq m_{\gamma^Q} \tag{5}$$

$$\text{or } Cl_{\gamma^Q,v} = \sum_{i=1}^{L-l_t} \frac{N_i \times 2^{l_t}}{2^{L-i+1}} \tag{6}$$

   $Cl_{\gamma^Q,v}$ here is computed by considering the inclusion of new call.
4. When $m_{\gamma^Q} = 1$ && $Cl_{\gamma^Q,m_{\gamma^Q}} < Cl_{Threshold}$, where $Cl_{Threshold}$ denotes the threshold channel load. The call will be assigned to available single vacant code.
5. For $m_{\gamma^Q} > 1$ && $Cl_{\gamma^Q,m_{\gamma^Q}} < Cl_{Threshold}$

The OCA scheme consists of three levels.

1.1.1 Level 1: When $\exists v: Cl_{\gamma^Q,v} < Cl_{Threshold}$, select code(s) with $max \sum_{i=1}^{L-l_t} N_i$, This uses maximum busy time domain tree and will lead to minimum blocking. For a unique code assign call to it, otherwise, go to level 2.

1.1.2 Level 2: For all $v: Cl_{\gamma^Q,v} < Cl_{Threshold}$, find code with $\max(n_{l^{\gamma^Q}}), \forall n_{l^{\gamma^Q}} > 0$ and assign the call to a unique code. The algorithm search for a time domain code with the maximum number of calls of the same rate. This leads to the reduction in code blocking of future calls, as the unused capacity of already blocked codes will be utilized. For a unique code assign call to it, otherwise go to level 3.

1.1.3 Level 3: For all $v: Cl_{\gamma^Q,v} < Cl_{Threshold}$, find code with $\max\limits_{[1,(L-l_t)],i \neq l^{\gamma^Q}} (N_i)$. This also reduces code blocking by using the unused capacity of the higher layer and lower layer codes.

The algorithm is explained with the help of status of code tree in Fig. 1, when a call of rate *R* arrives the *Cl* of all the sub trees is calculated again using the Table 2 available at BS, the new channel load will be 0.625, 0.5, 0.3125 and 0.5625 for sub tree 1,2,3 and 4 respectively. If *Cl* is the only parameter used to decide the optimum code for the assignment, then sub tree 3 is selected. However, this leads to future blocking of the higher rate. The proposed scheme selects sub tree 2 for assignment and code $C_{1,12}$. This leads to full capacity utilization of codes $C_{2,6}$ and $C_{3,3}$ in higher layers with *Cl*=0.5. In a similar way, when a call of rate 2*R* arrives code $C_{2,7}$ will be selected for assignment, which leads to minimum future code blocking with *Cl*=0.625.

Call Request: Non-Quantized

When the incoming call rate is non-quantized and $\gamma^{NQ}R, (l^{\gamma^{NQ}} = (log_2\gamma^{NQ} + 1)) \neq I$calls. If a call is assigned to a quantized code of rate $(2^{\lceil l^{\gamma^{NQ}} \rceil - 1})R$, it will lead to wastage of $(2^{\lceil l^{\gamma^{NQ}} \rceil - 1} - \gamma^{NQ})R$ amount of capacity or increased internal fragmentation. This further reduces system utilization. For improvement in code capacity utilization, non-quantized calls are treated differently in this article. The system parameters are all same except that a non-quantized call is broken down into rate fractions before assignment. To handle a new call multiple codes (rakes) are used. Let the system is equipped with *m* rakes. The algorithm to locate an optimum code for non-quantized call works as follow.

1. Initialize the number of rakes required to handle the new call as *r*=0.
2. Break incoming call $\gamma^{NQ}R$ into two fractions: $f_1 = 2^{(\lceil l^{\gamma^{NQ}} \rceil - 1) - 1}andf_2 = (\gamma^{NQ} - 2^{(\lceil l^{\gamma^{NQ}} \rceil - 1) - 1})$.
3. If $f_2 == I$,
   Search vacant codes for rate f_1R and f_2R using an approach similar to quantized calls such that there $Cl < Cl_{Threshold}$ and assign the calls to them and update $r = r + 2$.
   Else
   r=2.
   While($l^f == I$), where $l^f = (log_2 f_2 + 1)$
   Break f_2R into two fractions:$f_{21} = 2^{(\lceil l^f \rceil - 1) - 1}andf_{22} = (f_2 - 2^{(\lceil l^f \rceil - 1) - 1})$.

```
        $f_2 = f_{22}$, r=r+2;
        End.
    End.
4.  Find whether if $r \leq m$?
    Yes, handle call using r rakes.
5.  Else if
    Combine fractions such that $c_f = \sum_{i=1}^{n_f} f_i$ with condition $l^{c_f} = (log_2 c_f + 1)$ and $(2^{\lceil l^{c_f} \rceil - 1} - \gamma)R$ is minimum and use $(r - n_f + 1)$ rakes to handle new call.
6.  Else
    Block call.
7.  End.
```

The algorithm is demonstrated with the help of status of code tree in Fig. 1, when a non- quantized call of rate 9*R* arrives, the call is first broken into two fractions 8 and 1, the vacant codes for these fractions are searched and the *Cl* of all the sub trees which have the capacity to handle these fractions is calculated again using the table available at base station (BS), the new channel load for *R* rate will be 0.625, 0.5, 0.3125 and 0.5625 for sub tree 1, 2, 3 and 4 respectively. For 8*R* rate *Cl* will be 0.75 and 1 respectively for sub tree 3 and 4. A vacant sub tree is available for assignment; however, the proposed scheme in this article tries to utilize the unused capacity of the used sub tree. The time domain tree 1, 2 and 3 can be used to handle these calls by reassigning ongoing calls and changing time domain code position in the tree. The time domain tree 1 and 2 are merged together with time domain shifted up by one layer as shown in Fig. 2 and call at code $C_{3,5}$ is shifted to $C_{3,4}$. Codes $C_{1,12}$ and $C_{4,4}$ are used to handle the rate fractions *R* and 8*R* respectively.

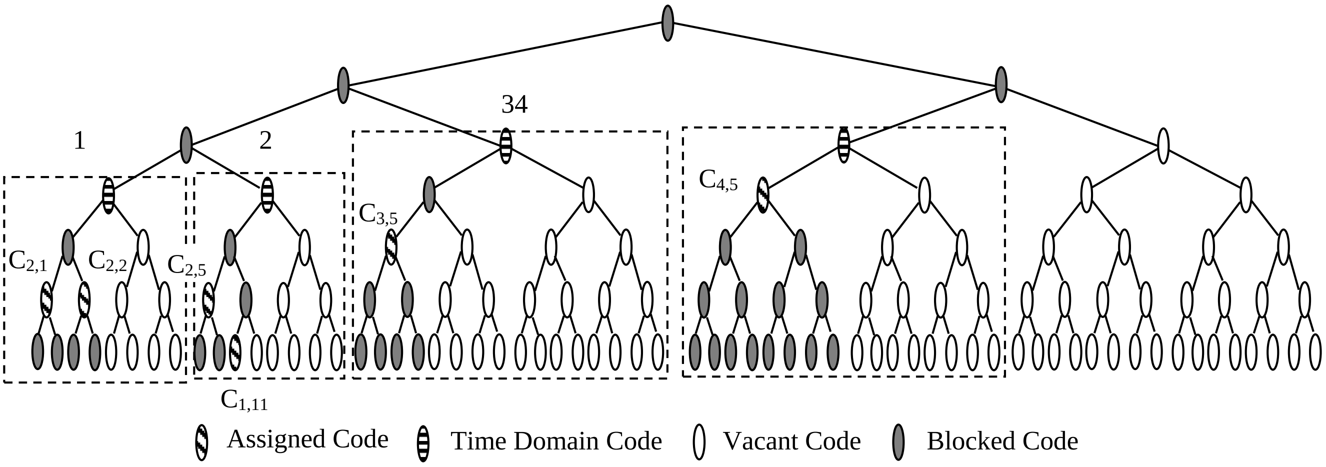

Fig. 1 Illustration of Quantized and Non-Quantized Single code Approach.

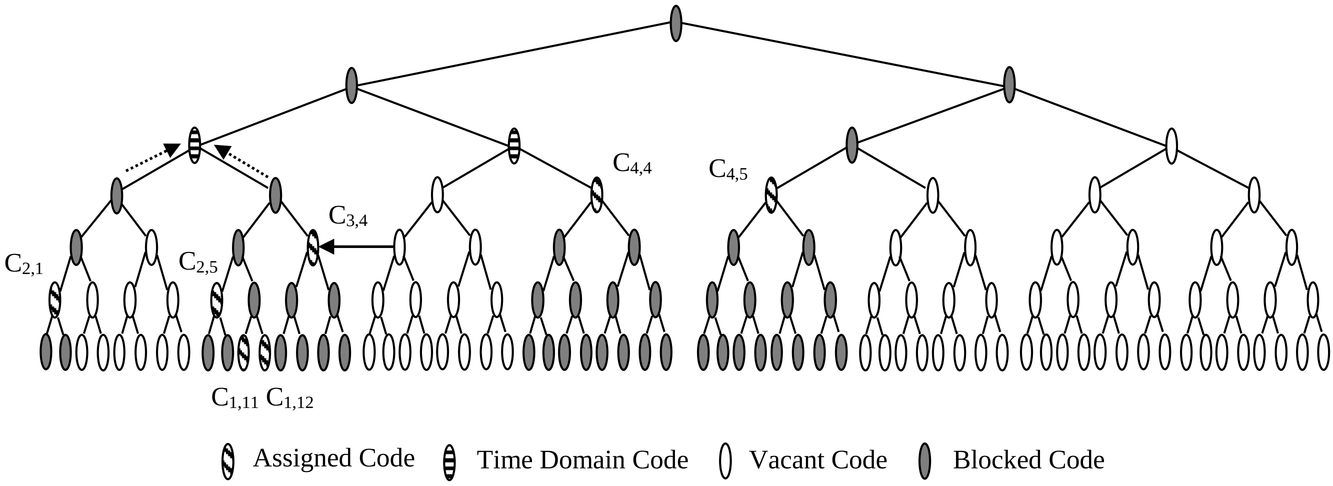

Fig.2 Illustration of Non-Quantized Single code Approach after reassignment.

SIMULATIONS AND RESULTS

The section evaluates the performance of the proposed scheme for the MC DS-CDMA system in the single cell environment. The compared schemes includes the popular 3GPP UMTS random assignment (RM) [10], crowded first assignment (CFA) [12], left code assignment (LCA) [12], recursive fewer code blocked (RFCB) [12] and IA+CF [31]. RA, CFA, LCA, and RFCB carried out assignment without considering the effect *Cl*. The IA+CF scheme used for load considers the effect of *Cl*. The simulation network and traffic parameters are given in Table 3. The basic data rate is R and the total capacity of UMTS OVSF code tree is 256R. The paper uses multiple classes of traffic arrival rate γR, $[1 \leq \gamma \leq 8]$. The arrival traffic quantized rates are [R,2R,4R,8R] and non-quantized rates are [3R,5R,6R,7R] effectiveness of the proposed assignment scheme for the MC-DS-CDMA system.

Table 3 Simulation Parameters and Assumptions

Parameters	***Value/Range***
User Classes	R,2R,3R,4R,5R,6R,7R,8R
Arrival rate (λ) is Poisson Distributed	Mean value varying from 0-4 calls/minute
Call duration (1/μ) is Exponentially Distributed	Mean value of 1 minutes.
Total Capacity of Code tree	256R
Number of users	10000
Results average	10
Arrival rate and service rate for i^{th} class	λ_i and μ_i , $i \in [1,8]$
Average Traffic Load	$\rho = \sum_{i=1}^{8} \lambda_i / \mu_i = \sum_{i=1}^{8} \lambda_i$
$Cl_{Threshold}$	0.75
The same data bits carrying subcarriers are assumed to experience independent flat Rayleigh fading. The background noise is modelled by white Gaussian noise with double-sided power spectrum density of N0/2 and the transmitting Eb/N0 = 12 dB.	

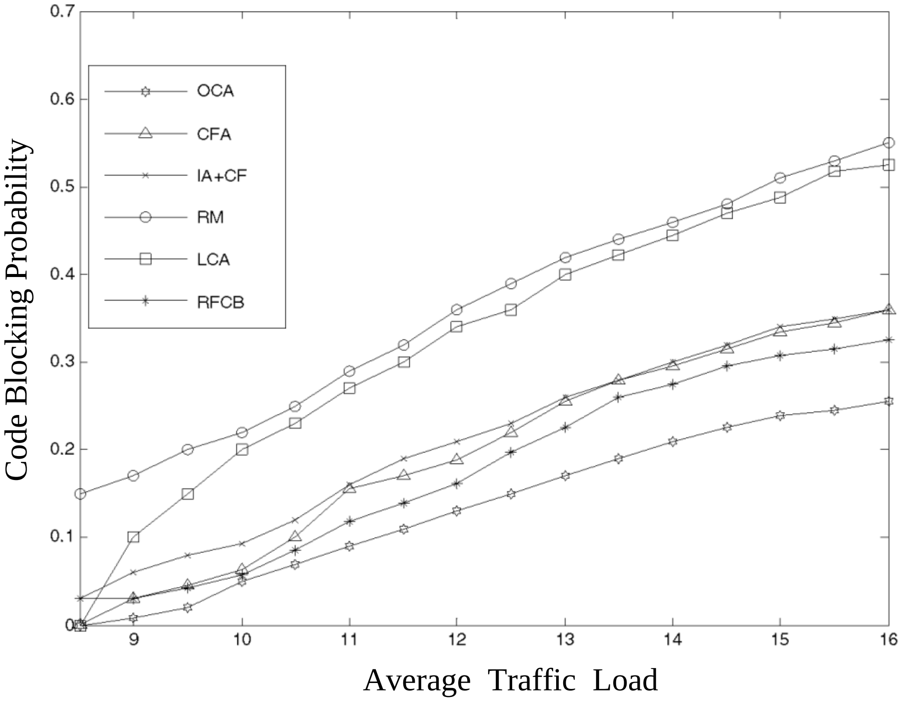

Fig. 3 Comparison of code blocking probability for uniform distribution of Quantized arrival rates [R,2R,4R,8R].

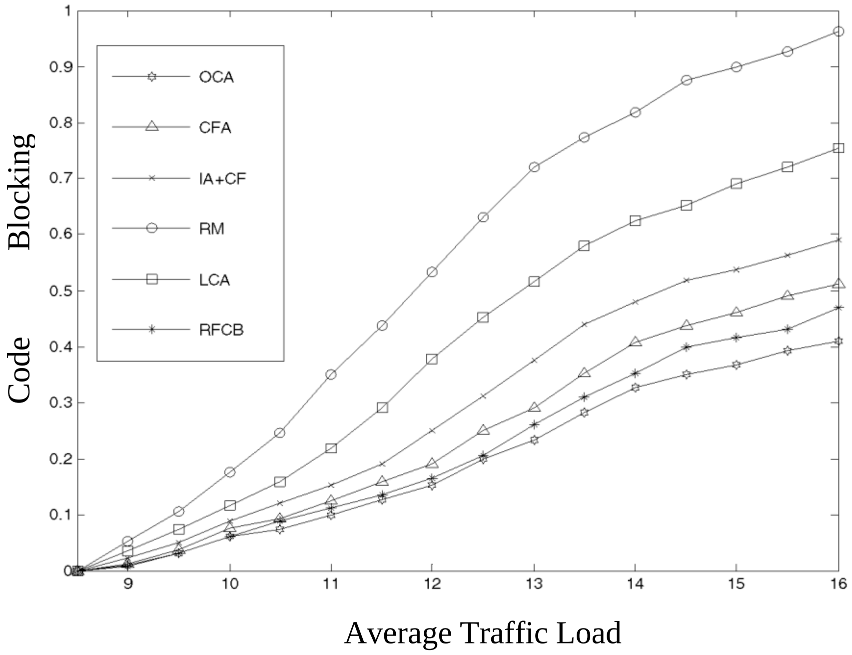

Fig. 4 Comparison of code blocking probability for uniform distribution of Quantized rates and Non-quantized rates both [*R*,2*R*, 3*R*,4*R*,5*R*,6*R*,7*R*, 8*R*]

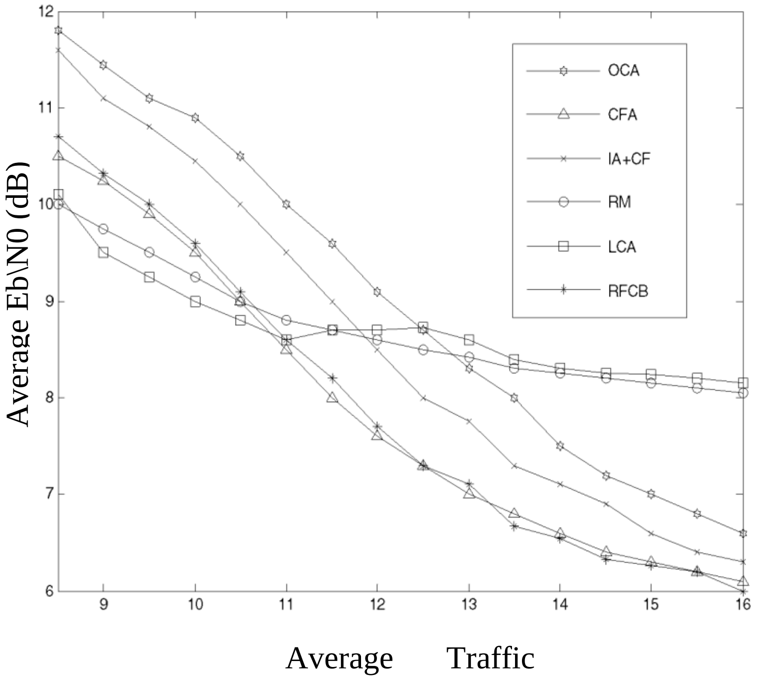

Fig. 5 Comparison of average received Eb\N0 (dB) for uniform distribution of Quantized arrival rates [*R*,2*R*,4*R*,8*R*].

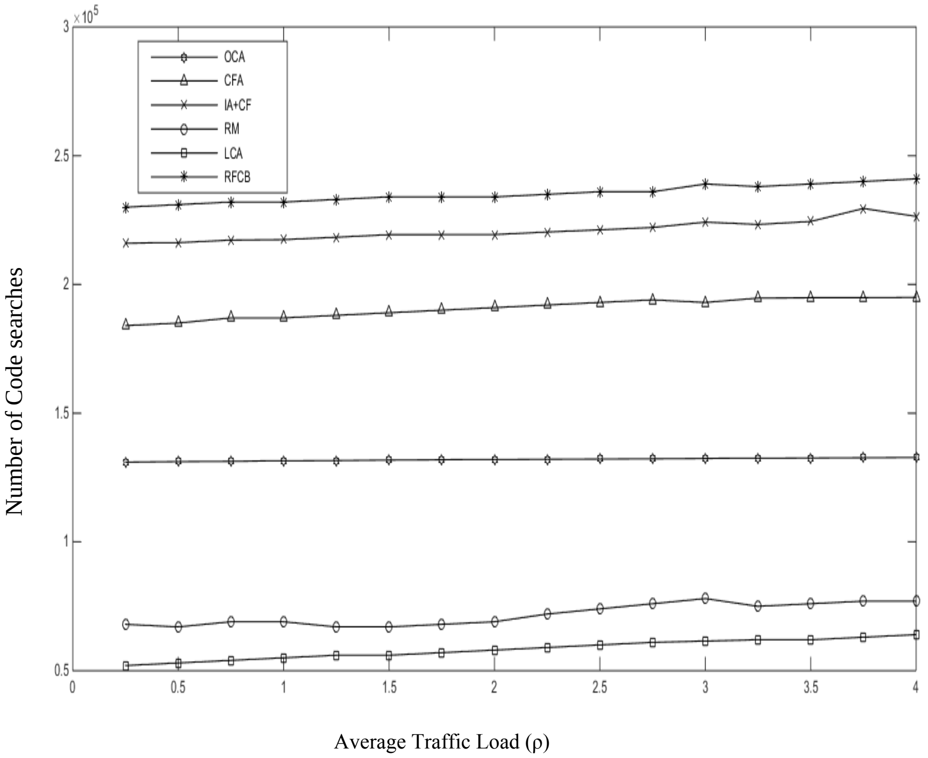

Fig. 6 Comparison of code blocking probability for uniform distribution of arrival rates [R-16R].

The schemes RA, CFA, LCA, RFCB, IA+CF and proposed OCA scheme evaluated for code blocking probability and Eb/N0 in Fig. 3, Fig. 4 and Fig. 5. For simulation, the average arrival rate (λ) is from 8.5 to 16. The average holding time of all the classes of traffic is exponentially distributed, and the mean is normalized to 1. The results indicate that the OCA scheme provides optimum utilization of code tree while maintaining QoS. The code blocking probability of all schemes increases as the arrival rate increases.

The average code blocking for an 8 class system is defined as

$$P_B = \sum_{i=1}^{8} (\lambda_i P_{B_i} / \lambda) \tag{7}$$

where P_{B_i} is the code blocking probability of i^{th} class.

The OCA schemes yield the lowest code blocking probability as it selects a time domain tree which leads to minimum blocking of future calls and leads to higher utilization of code tree. For Fig. 3, arrival traffic rate is only quantized [R,2R,4R,8R] and for Fig. 4 arrival traffic rate are both quantized and non-quantized [R,2R,3R,4R,5R,6R,7R,8R], the non-quantized rate increases blocking for all the schemes. However, the OCA scheme differentiates calls on the basis of their type which reduces internal fragmentation and eventually leads to lesser code blocking. The selection of an optimum code in OCA scheme is done at three levels which minimize the probability of a block call as compared to existing schemes. The pure RFCB and CFA do not consider the effect of *Cl* while IA+CF uses *Cl* and crowded strategy for allocation, which assigns to crowded time domain tree without taking care of blocking it will introduce.

Fig. 5, shows the received Eb/N0 with average traffic load. The following observations are made from it. First, comparing with those schemes whose performance in code blocking probability is close to OCA scheme. RFCB, CFA and IA+CF all schemes have lower received Eb/N0 for total average arrival rate ($8.5 \leq \rho \leq 16$). The LCA and RM schemes provide better received Eb/N0 for $12.5 \leq \rho \leq 16$, this is due to the accommodation of more number of calls in OCA scheme, also due to the number of rakes used by OCA scheme which influences Eb/N0 significantly. For both, LCA and RM schemes code tree vacant capacity are scattered due to the nature of assignment process due to which both suffers from high code blocking. These schemes handle fewer calls in given intervals, therefore provide better received Eb/N0.

Fig. 6 compares the complexity analysis of different schemes in the form of the number of code searches for uniform distribution of call arrival. The computation time required for code searches for OCA scheme is given in Appendix. For analysis RFCB, CFA, LCA, RM and IA+CF number of code searches are derived from the articles in [42] and [31]. The result shows that the number of code searches for OCA scheme is lesser then CFA, RFCB, and IA+CF schemes, as these schemes check the complete code tree for new call arrival. The scheme is ideal for mobile network and SG network traffic originating together. The IA+CF uses CFA with interference avoidance due to this requires a maximum number of code searches. Also, the computation time is higher for IA+CF which is most comparable with OCA, it searches the same codes again in case of ties. The RFCB and CFA also repeat the searches in case of a tie. The OCA scheme most of the time searches only those codes which are in busy sub tree or time domain tree. The LCA and RM computation time or a number of code searches are minimum, with higher code blocking probability.

CONCLUSION

To maximize the utilization of available radio resource for the downlink of Multi-Rate MC-DS-CDMA, the proposed OCA scheme in this paper handles a quantized and non-quantized call differently. The SG traffic is also handled by the OCA scheme, in rural areas leads to improved spectrum utilization. The non-quantized call is first broken into multiple quantized rates. The quantized rate call(s) are allocated to a time domain tree(s) which leads to minimum future blocking and Cl less than the threshold value. The number of quantized rates is lesser than or equal to the number of available rakes. By simulations and analysis, the benefits of OCA schemes are demonstrated which shows that the scheme is adaptive and ability to counter with current and future higher rate demands. In future work, can be done to use unused rakes of ongoing calls.

APPENDIX

For an L layer code tree and the total number of channelization code that can be assigned to new call are 2^{L-1}. Let the computation time for searching one code is denoted by $T(1)$.

If all the codes are blocked or busy in worst case then number of codes searched

$$N_s = 2^{l-1}, 1 \leq l \leq L \quad \text{A.1}$$

The computation time for 2-D spreading

$$T_{2D} = T(N_s.L) \quad \text{A.2}$$

The Cl of all the combinations is given in Table 2, checking Cl of available optimum codes $T(1)$.

For v vacant codes available, the computation time is $= T(v)$.

The OCA quantized scheme consists of three levels.

The computation time for level 1$= T(N_s.L) + T(v)$ A.3

For a tie at level 1 between v_1 codes

The computation time for level 2$= T(N_s.L) + T(v) + T(v_1)$ A.4

For a tie at level 2 between v_2 codes

The computation time for level 3$= T(N_s.L) + T(v) + T(v_1) + T(v_2)$ A.5

For a non-quantized call, the computation time will become

$$m.(T(N_s.L) + T(v) + T(v_1) + T(v_2)) \quad \text{A.6}$$

Where m denotes the number of rakes here.

REFERENCES

[1] Zheng J, Gao D W, Lin 1. Smart Meters in Smart Grid: An Overview[C]// IEEE Green Technologies Conference. IEEE, 2013:57-64.

[2] W. Meng, R. Ma, and H. Chen, “Smart Grid Neighborhood Area Networks: A Survey, “IEEE *Network*, vol. 28, no. 1, pp. 24-32, Jan. 2014.

[3] 3GPP. [Online]. Available: http://www.3gpp.org.

[4] Meik, K. (2010). LTE- Advanced Technology Introduction White paper. Rohde & Schwarz, 3-22.

[5] TR 36.913 Versions 10.0.0 (2011). Requirements for Further Advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced). 3GPP, 4-15.

[6] Maeda, N., Kishiyama, Y., Higuchi, K., et al: ‘Experimental evaluation of throughput performance in broadband packet wireless access based on VSF-OFCDM and VSF-CDMA’. Proc. Int. Conf. on Personal, Indoor and Mobile Radio Communications, 2003,1 , pp. 6-11

[7] Daniel, G.-A., Iain, S., & Bob, S. (2010). LTE and LTE Advanced. Steepest Ascent, pp. 1-16.

[8] Nikookar, N., Prasad, R.: ‘OFDM performance evaluation over measured indoor radio propagation channels’. Proc. Int. Conf. of Universal Personal Communication, pp. 968-972

[9] Adachi, F., Garg, D., Takaoka, S., Takeda, K.: ‘Broadband CDMA techniques’, IEEE Wireless Communications, 2, (2), pp 8-18

[10] Atarashi, H., Abeta, S., Sawahashi, M.: ‘Variable spreading factor orthogonal frequency and code division multiplexing (VSF-OFCDM) for broadband packet wireless access’, IEICE Transactions on Communication, E86-B, (1), pp 291-299

[11] Adachi, F., Sawahashi, M., Okawa, K.: ‘Tree-structured generation of orthogonal spreading codes with different lengths for forward link of DS-CDMA mobile radio’, IEE Electronics Letters, 1997, pp 27-28

[12] Tseng, Y. C., Chao, C. M., Wu, S. L.: ‘Code placement and replacement strategies for wideband CDMA OVSF code tree management’. Proc. Int. Conf. of GLOBECOM, 2001, 1, pp. 562-566

[13] Park, J. S., Lee, D. C.: ‘Enhanced fixed and dynamic code assignment policies for OVSF-CDMA systems’. Proc. Int. Conf. ICWN, Las Vegas, 2003, pp. 620-625.

[14] Rouskas, A. N., Skoutas, D. N.: ‘Management of channelization codes at the forward link of WCDMA’, IEEE Communication Letters, 2005, 9, (8), pp 679-681.

[15] Hwang, R.-H., Chang, B.-H., Tsai, K.-C.: ‘An efficient adaptive grouping for single code assignment in WCDMA mobile networks’, Wireless Personal Communication, 39, (1), 2006, pp 41-61.

[16] Chang, B.-H., Chang, P. -S.: ‘Multicode-based WCDMA for reducing waste rate and reassignments

in mobile cellular communications'. Computer Communications, 2006, 29, (6), pp 1948-1958.

[17] Chang, B.-J., Chen, M.-X., Wang, R.-H., et al.: 'Single code-based dynamic grouping with cycle interleaving algorithm for reducing waste rate in WCDMA cellular networks', IEICE Transactions on Communications, 2006, 89, (12), pp 3306-3317

[18] Tseng, Y.-C., Chao, C.-M.: 'Code placement and replacement strategies for wideband CDMA OVSF code tree management', IEEE Transactions on Mobile Computing, 2002, 1, (4), pp 293-302

[19] Cheng, S.-T., Hsieh, M.-T.: 'Design and analysis of time-based code allocation schemes in W-CDMA systems', IEEE Transactions on Mobile Computing, 2005, 4, (6), pp 604-615

[20] Chao C. –M., Tseng Y.-C., Wang, L.-C.: 'Dynamic bandwidth allocation for multimedia traffic with rate guarantee and fair access in WCDMA systems', IEEE Transactions on Mobile Computing, 2005, 4, (5), pp 420-429

[21] Park, J.-S., Huang, L., Kuo, C. C. J.: 'Computationally efficient dynamic code assignment schemes with call admission control (DCA-CAC) for OVSF-CDMA systems', IEEE Transactions on Vehicular Technology, 2008, 57, (1), pp 286-296

[22] Tsai Y-R, Lin L-C.: 'Quality-based OVSF code assignment and reassignment strategies for WCDMA systems', IEEE Transactions on Vehicular Technology, 2009, 50, (2), pp 1027-1031

[23] Balyan, V., Saini, D.S.: 'A same rate and pattern recognition search of OVSF code tree for WCDMA networks', IET Communications, 2014, 8, (13), pp 2366-2374

[24] Saini, D.S., Sharma, N.:' Reduction in code blocking using scattered vacant codes for orthogonal variable spreading factor-based wideband code division multiple access networks', IET Communications, 2013, 7, (1), pp 40-48

[25] Yang, Y., Yum, T. S. P.: Multicode multirate compact assignment of OVSF codes for QoS differentiated terminals', IEEE Transactions on Vehicular Technology, 2005, 54, (6), pp 2114-2124

[26] Saini, D.S., Upadhyay, M.: Multiple rake combiners and performance improvement in 3G and beyond WCDMA systems', IEEE Transactions on Vehicular Technology 2009, 58, (7), pp 3361-3370

[27] Saini, D.S., Hastir, V., Sood, M.: 'Multi code assignment and reduction in code rate wastage for 3G and beyond WCDMA systems'. Proc. Int. Conf. Of Advance Computing, 2009, pp. 946-951

[28] Chang, W.-Y., Ouyang, W., Wang, C.-Y., et al.: 'Graph model for OVSF code placement'. Proc. Int. Conf. on Future Information Technology, 2010, pp. 1-6

[29] Balyan, V., Saini, D.S.: 'An efficient multi code assignment scheme to reduce call establishment delay for WCDMA networks'. Proc. Int. Conf. on Parallel Distributed and Grid Computing (PDGC), Solan, 2010, pp. 278-283

[30] Chang, B.-H., Wu, C.-H.: 'Adaptive load balancing MDP based approach of two-dimensional spreading for VSF-OFCDM in 4G next-generation cellular communications', IEEE Transactions on Vehicular Technology, 2009, 58, (3), pp 1143-1156

[31] Maeda, N., Kishiyama, Y., Atarashi, H., Sawahashi, M.: 'Variable spreading factor-OFCDM with two dimensional spreading that prioritizes time domain spreading for forward link broadband wireless access', IEICE Transactions on Communication, 2005, E88-B, (2), pp 487-498

[32] Hasegana, K., Shimura, R., Ohno, T., et al.: 'OVSF code allocation and two-stage combining method to reduce inter-code interference in OFCDM system'. Proc. Int. Conf. on Personal, Indoor and Mobile Radio Communications, 2005, 4, pp 2500-2504.

[33] Wang, L. C., Chang, C.W., Huang, H.: 'An interference avoidance code assignment strategy for downlink multi-rate MC-DS-CDMA with TF-domain spreading', IEEE Transactions on Wireless Communications,2007, 6,(7), pp 2508-2517

[34] Chang, B. –J, Liang, Y. -H, Cao, K. X.: 'Reward-based radio interface selection of hybrid 4G UMTS and LTE Communication for fast cloud accesses', Wireless Personal Communication, 2014, 76, pp 675-691

[35] Chang, B. –J, Liang, Y. -H, Cao, K. X.: 'Adaptive radio resource management for maximizing reward and balancing loads in 4G hybrid universal mobile telecommunications system and long term evolution communications', Wireless communications and mobile computing, Wiley, 2015, 15, pp 510-526.

[36] Saini, D.S. , Balyan, V.:'An efficient multicode design for real time QoS support in OVSF based CDAM networks', Wireless Pers. Communication, 2016, 90(1), 1799-1810.

[37] Q.-D. Ho, Y. Gao, and T. Le-Ngoc, "Challenges and research opportunities in wireless communication networks for smart grid," *IEEE Wireless Commun.*, vol. 20, no. 3, pp. 89–95, Jun. 2013.

[38] W. Luan, D. Sharp, and S. LaRoy, "Data traffic analysis of utility smart metering network," in *Proc. IEEE Power Energy Soc. Gen. Meeting*, Vancouver, BC, Canada, Jul. 2013, pp. 1–4.

[39] M. Kuzlu, M. Pipattanasomporn, and S. Rahman, "Communication network requirements for major smart grid applications in HAN, NAN and WAN," *Comput. Netw.*, vol. 67, pp. 74–88, Jul. 2014.

[40] D. F. Ramirez, S. Céspedes, C. Becerra, and C. Lazo, "Performance evaluation of future AMI applications in smart grid neighbourhood area networks," in *Proc. IEEE Colombian Conf. Commun. Comput. (COLCOM),* Popayán, Colombia, May 2015, pp. 1–6.

[41] R. H. Khan and J. Y. Khan, "A comprehensive review of the application characteristics and traffic requirements of a smart grid communications network," *Comput. Netw.*, vol. 57, no. 3, pp. 825–845, Feb. 2013.

[42] Saini, D.S. , Balyan, V.: 'Top Down Code Search to Locate An Optimum Code and Reduction in Code Blocking for CDMA Networks', Wireless Personal Communication, 2014, 75(1):465–482.