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Smart Grids and Mobile Traffic Communication for Improved Spectral Efficiency of LTE systems

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Abstract

The paper proposes ahandoff LTE-UMTS (HLU) scheme for a base station (BS) having both universal mobile telecommunications system (UMTS) and long term evolution (LTE) interface for a 4G network handling mobile traffic (M-T) and smart grid traffic (SG-T). The LTE interface is used for high-speed data calls and assigns resource blocks (RBs). The 3GPP UMTSinterface in this paperuses the VSF-OFCDM which allocates OVSF codes which are orthogonal in nature and handles both types of calls data and voice. The codes are spread in both frequency domain and time domain. The HLU scheme assignsRBsor number of codes depending upon the current location and direction of motion of a new call user. The assigned resources are increasedor decreased when the distance of the user increases or decreases from the BS respectively.The handoff calls considered are from one adaptive modulation ad coding (AMC) location to another, which leads to variation in radio resources calls are using. The load on the channel is also considered before assignment in HLU schemefor the UMTS interface i.e number of calls handled by a sub tree which leads to less interference. The traffic arrival is of two types: Mobile Traffic (M-T) and smart grid traffic (SG-T). The SG-T improves the spectral efficiency of the network by using resources during non-busy hours. The simulations and results are shown to for spectral utilization, call blocking probability and code blocking probability. The proposedUMTS scheme is also compared with existing schemes in literature.

Keywords— radio resource management; load balancing; frequency spreading; time spreading; multi-code; single code.

INTRODUCTION

The *LTE* network also provides voice support using *UMTS*. The voice calls are considered as real time calls which cannot tolerate any type of delays. The 3GPP standards proposes Circuit Switched Fall Back (*CSFB*) when voice services are rendered by the mobile station (MS), which means fallback to the heritage radio spectrum. This can result in one of the possible conditions *i.e* a) switching to a UMTS or GSM network, b) switching to a non-*LTE* network, c) opening two connections simultaneously for voice and data respectively. The CSFB to 2G/3G networks is the most common solution for voice call request occurring in *LTE* network for data calls. When a voice call arrives or originated in a deployed network, the eNodeB containing both *LTE* interface and *UMTS/GSM* interface will redirect calls to *LTE* or UMTS/GSM interface. This interface in this paper is *UMTS*.Due to this, the CSFB architecture needs coordination between the evolved packet core (EPC) (*LTE*-interface) and the 2G/3G core (*UMTS*-interface) network. The need to reduce the number of interfaces of the main networks and also utilization of the air interface of the existing *UMTS* for the voice calls to speed up the CSFB deployment. Due to this reason, voice over *LTE* network adopted it[1-3]. There are disadvantages associated with due to the increased coverage of the *LTE* and increased multimedia activities the users need to fallback to legacy *UMTS* frequently,which urges for deployment of a framework that reduces or minimize it. 3GPP standards useGSMA IR.92 IMS profile for voice and SMS services [4] and GSMA IR.94 IMS profile for conversational video [5] to provide better quality IMS-based telephony services using *LTE* radio access. All the industry stakeholders like service providerand user equipment manufacturers, 3GPP functionalities and optimal sets decider must participate to provide compatibility to *LTE* voice or video calls. The implementation of CSFB and VoLTE are essential to provide guaranteed better voice experience in *LTE* network [6-7].

In order to enhance, the *UMTS* interface quality of service (QoS), the orthogonal variable spreading factor (OVSF) codes using OFCDM spreads into two dimensions time and frequency [8-9]. This reduces the interference by using subcarriers which are orthogonal and introduces code blocking problem. This requires an efficient algorithm to manage or assign OVSF codes to incoming variable rate call requests which arrive randomly in the network. The allocations schemes in the literature can be classified into three However, the VSF-OFCDM managed by an OVSF code tree needs an efficient algorithm to allocate codes to different arrival connections. The code allocation algorithms of the VSF-OFCDM scheme can be classified into four categories: single code one-dimensional [10–14], multi-code one-dimensional[15–19], single code two- dimensional [20,21], and multi code two-dimensional [22].

The one dimensional proposed single code schemes in[10–14], most of them suffers wastage of spectrum. The one dimensional multi code schemes proposed in [15-19] are mainly used to reduce spectrum wastage. The papers in [16, 18-19] suffer from higher complexity with no focus on the residual spectrum when multi codes are used for assignment. The [16] does not consider interference also before assignment. In [18], the assignment scheme increases the computation time and overhead for determining the suitable code for an assignment.

In [20] a time slicing scheme is proposed which does spreading in two dimensions in frequency and time code. In [21,22], a single code and multi codes assignment scheme are proposed for two dimensional spreading of OVSF codes which considers the effect of load balancing and the current location of user.

The *LTE* resources can also be used for handling SG-T. A random access for distribution automation (RADA) scheme is given in [23] which provides support to distribution automation (DA) services with minimum effect on M-T. Another resource assignment scheme named as Lotka-Volterra (*LV*) is defined in [24], which first of all do modelling of all classes of traffic, considering themas a species and then look for possible*LTE* resources. The scheme also provides fairness among different classes. The scheme in [25] investigated the use of *LTE* resources in regions of advance meter for transfer of meter readings automatically. The scheme is used for transmission from smart meters to base stations and from aggregators to the *BS*.

MOTIVATION OF THE WORK

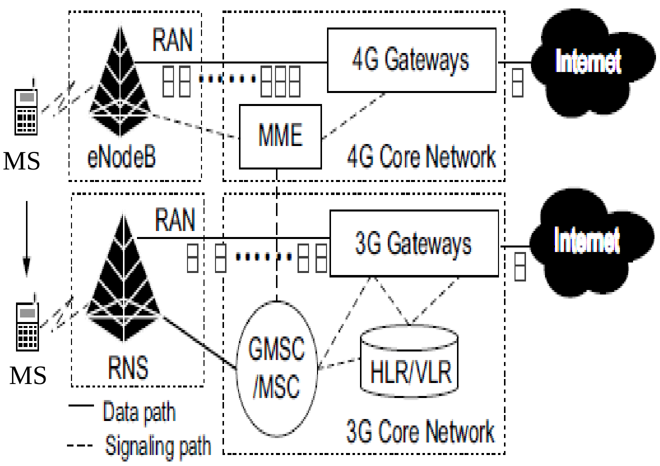

Figure. 1: Architecture of 4G-3G networks.

The *BS* nowadays supports multimedia calls of variable rate and with mobility. Most of the schemes in literature proposed for *LTE* systems focus on spectrum utilization, the spectrum is used for only mobile traffic (M-T). The proposed scheme in this paper uses spectrum available at *BS* for mobile as well as smart grids traffic (SG-T). The *UMTS* interface is used mostly for mobile voice traffic and SG-Ts while *LTE* interface is used for fast moving mobile data traffic and high data SG-Ts. The scheme in [26] uses various modulation techniques to provide codes and *RBs*to a requested call depending upon the current location of the call. The proposed *Handoff LTE-UMTS*(*HLU*) scheme in this paper reduces or increases the assigned resources to a call when the distance of a user decreases or increases from the *BS*. The SG-T communication is usually stationary. The scheme also reserves a portion of code tree for possible handoff, which is likely due to the high mobility of the users.

The remaining organization of the paper is as follows. Section III defines the network architecture and parameters. Next, in section IV, loads of *UMTS*and *LTE*are described.Section V discusses the proposed *HLU*scheme. The results and simulations are given in section VI. The paper conclusion is given in section VII.

Network Architecture and Parameters

The eNodeB of 4G has two interfaces *UMTS* and *LTE*. The eNodeB allows access to different users with different traffic requirements and with different mobility. 4G *LTE* network structure and its 3G network are explained in this section. The *LTE* network with its 3G interface is illustrated in Figure 1. The data (packet) service is offered by *LTE* network. It consists of a core network radio access network (*RAN*) and mobile stations (MSs).Its *RAN* uses eNodeB*i.eLTE* base station (BS) which allows access to MSs. The network core is IP-based and uses mobile management entity (MME) in order to locate MSs movement*e.g* location update and paging information. The 4G gateways are used to route packets between the 4G RAN and the Internet.

In contrast, 3G network provides support to both data and voice calls or in other words packet switched and circuit switched calls. Its *RAN* uses radio network system (RNS) to allow access to radio resources. Its network consists of *a*) Gateway mobile switching centre (GMSC/VLR) which stores/updates user location. *b*) 3G gateway which provides data (packet) service and provides route between the RAN and the internet.

The UMTS interface adopts VSF-OFCDM in order allocate OVSF codes of a code tree spread in two dimensions: time and frequency. The OVSF code tree used is of layer L. The rate of a code in layer is$2^{l-1}R$, where$1 \le l \le L$. The OVSF channelization code in layer l is denoted by C_{l,n_l} where n_l denotes its position in layer l, also $1 \le n_l \le 2^{l-1}$. A layer l OVSF code $C_{sf_l,m}$ spreads in both frequency and time domains. The frequency domain code for which is $C^{F}_{sf_{l_f},m_f}$, where sf_{l_f} denotes its frequency domain spreading, also $sf_{l_f} = 2^{l_f} - 1$ and m_f is position of the frequency domain code in layer l_f, where $1 \leq m_f \leq sf_{l_f}$. The time domain code for which is $C^T_{sf_{l_t, m_t}}$, wheresf_{l_t} denotes its time domain spreading, $m_t$is the time domain code position in layer l_t.

Also, the OVSF code tree spreading factor,frequency domain and time domain spreading factor are related to each other by

$$sf_{l,m} = sf_{l_f} \times sf_{l_t} \quad (1)$$

$$l = l_f + l_t - 1 \quad (2)$$

$$m = m_f + (m_t - 1) \times 2^{l_f - 1} \quad (3)$$

For the *LTE* interface, *LTE-PHY* structure as shown in Figure 2 has 10-time domain subframes, each of which has two slots. The subframe can carry 14 OFDM symbols and the frequency domain subchannel has 12 subcarriers.

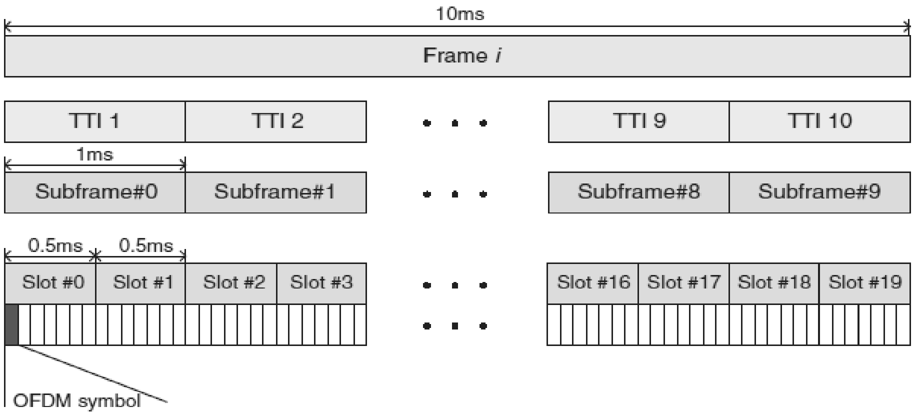

Figure. 2: Frame structure of LTE [21]

The transmission unit for an MS is defined by resource block (*RB*) within a subframe(for time)and a subchannel (for frequency)for *LTE* interface. The *LTE* interface uses spatial multiplexing with four antennas and the eNodeB for every channel pilot symbol is used as the individual reference signal symbol.

For multiuser access in OFDMA, a subframe*RB*s can be allocated to different MSs. For a single user access in OFDM, the *RM*s of the subframe can be allocated to one MS, they cannot be allocated to different MSs. For *LTE* using OFDMA, an MS will be allocated at least one *RB* and in the same subframe duration different MSs can use number of *RB*s allocated to them by eNodeB.

Table 1: AMC schemes and antennas used.

Modulation Scheme Used due to location	Antennas Used at Transmitter and receiver		n_{AMC}
QPSK 1/2	Single		1
16QAM 1/2	Single		2
16QAM 3/4	Single		3
64QAM	Single		6
64QAM	2x2 MIMO		12
64QAM	4x4 MIMO		24

For the *LTE* interface, *LTE-PHY* structure as shown in Figure 2 has 10-time domain subframes, each of which has two slots. The subframe can carry 14 OFDM symbols and the frequency domain subchannel has 12 subcarriers. The number of subchannels depends upon the channel bandwidth (BW)[21]. The transmission unit for an MS is defined by resource block (*RB*) within a subframe(for time)and a subchannel (for frequency)for *LTE* interface. The *LTE* interface uses spatial multiplexing with four antennas and the eNodeB for every channel pilot symbol is used as the individual reference signal symbol.

For multiuser access in OFDMA, a subframe*RB*s can be allocated to different MSs. For single user access in OFDM, the *RM*s of the subframe can be allocated to one MS, they cannot be allocated to different MSs. For *LTE* using OFDMA, an MS will be allocated at least one *RB* and in the same subframe duration different MSs can use number of *RB*s allocated to them by eNodeB.

Calculation of utilization of LTE interface and UMTS interface

UMTS Interface: The *UMTS* interface in this paper consists of *L* layers. The total capacity of the code tree is $2^{L-1}R$. If the numbers of codes assigned to layer 1, 2, 3 …*L* are n_1, n_2, n_3…n_L, then utilized capacity (*UC*) of the code tree

$UMTS_{UC} = n_1 \cdot R + n_2 \cdot 2R + n_2 \cdot 4R \dots n_{L-1} \cdot 2^{L-1}R$ (4)

$UMTS_{UC} = \sum_{l=1}^{L} n_l \cdot 2^{l-1}R$ (5)

A new call of rate $2^{i-1}R$ will be handled by UMTS interface when

$UMTS_{UC} + 2^{i-1}R \leq UMTS_{Th}$ (6)

here $UMTS_{Th} = 2^{L-1}R$, effect of channel load is not considered.

$UMTS_{UC} + 2^{i-1}R \leq UMTS_{Th}$ (7)

here $UMTS_{Th} = 0.7 \times 2^{L-1}R$, channel load threshold is set to 70%.

LTE Interface: The *LTE* interface assigns *RB*s. If the interface has total number of *RB*s equals toNRB_{total} and $NRB_{Utilized}$ are the number of assigned *RB*s. A new call of rate $2^{i-1}R$ requires $RB_{Required}^{mp}$will be handled by *LTE* interface without any threshold, when

$NRB_{total} - NRB_{Utilized} \geq RB_{Required}^{mp}$ (8)

The number of *RB*s or *UMTS* codes required by the call of rate $2^{i-1}R$ depends upon its position in the cell. The number of *RBs* for a call is calculated

$RB_{required}^{AMC} = \left\lceil \frac{2^{l-1}}{n_{AMC}} \right\rceil$ (9)

Also, the time required for completion of calls

$T_{required}^{AMC} = \frac{t_1}{\left\lceil \frac{2^{l-1}}{n_{AMC}} \right\rceil \times n_{AMC}}$(10)

here$l$=1,2,3,4,5 ,$t_{1=} \frac{d}{144Kbps}s$ is time required for data d and n_{AMC} is bits/symbol value is given in Table 1. $\lceil\ \rceil$: $ceiling\ function.$

PROPOSED HANDOFF LTE-UMTS SCHEME

The rapid increase in traffic and their velocities leads to several handover problems. The proposed *Handoff LTE-UMTS* (*HLU*) for *LTE* and *UMTS* assignment scheme provides access to high data rate calls together with voice calls in high mobility wireless communications forward link. Wireless communication resources are allocated dynamically to stationary and fast moving vehicles which lead to problem of scattered resources. The 4G-3G network consists of both *LTE* architecture and legacy 3G networks. For improved spectral efficiency of *LTE* and *UMTS* interface, SGs traffic can be handled with mobile traffic. The SGs traffic is static and data transfer mostly, which reduces complexity of handling two types of traffics. The SG data calls are used for transferring meter information of subscriber(s) in a particular area. The SG alarm messages are considered as voice calls, these are also static in terms of location. The handoff process considered in the paper is handoff from location of one adaptive modulation and coding (AMC) [26]to another for e.g*QPSK* to 16*QAM* and vice versa. The *HLU* scheme also reserves a portion of capacity in *UMTS* for *LTE* on-going calls for a possible handoff to 3G and checks the *RB* availability in *LTE* interface for a possible handoff from 3G-4G. This is due to the possible movement of a call away from BS. The *HLU* assignment scheme is divided into three levels as it differentiates incoming call on the basis of these parameters

Level 1: Incoming call type data or voice.

Level 2: Current location of the MS.

Level 3: Speed and direction of motion of the MS.

Level 1: Incoming call type data or voice

For an incoming call of rate$2^{i-1}R$, check the incoming call type: voice or data. For a voice call *UMTS* interface is used and if sum of utilized capacity of *UMTS* interface with incoming call rate is less than *UMTS* threshold capacity call is handled using *UMTS* interface otherwise block the call. For data call, go to level 2.

Algorithm:

- Check the incoming call type: voice or data.
- *If* (voice)

  Find whether$UMTS_{UC} + 2^{i-1}R \leq UMTS_{Th}$.

  If (yes)

  The call will be handled by *UMTS* interface using *UMTS* assignment scheme defined in section V.

  Else

  Block the call.

  End
- *Else* (data)

  Go to level 2.
- *End*

Level 2: Current location of the MS

The number of *RB*s or *UMTS* code required by the data call of rate $2^{i-1}R$ depends upon its position in the cell.

Check whether $NRB_{total} = NRB_{Utilized}$

- *If* (yes)

  Find whether$UMTS_{UC} + 2^{i-1}R \leq UMTS_{Th}$.

  If (yes)

The call will be handled using *UMTS* interface using the assignment scheme defined in section V.

Else

Block the call.

End

- *Else*

Find the current location of MS. Determine the minimum number of *RB*s required at this location $RB_{Required}^{mp}$ using equation (9).

- *If* $(RB_{Required}^{mp} + NRB_{Utilized} \leq NRB_{Total})$

If $(RB_{Required}^{mp} \leq RB_{Threshold})$

Assign $RB_{Required}^{mp}$ to the call.

Else

Go to level 3.

End

- *Else*

Block the call.

- *End*
- *End*

Level 3: Speed and direction of the MS

When the direction of motion of the M-T is taken into consideration. For example, let the requested call of rate 8*R* is at a 16QAM ½ location and is moving towards 16QAM3/4 location. The number of $RB_{Required}^{AMC} = 4$ at 16QAM ½ location, i.e $RB_{Required}^{AMC} \geq RB_{Threshold}$=3and at 16QAM3/4, $RB_{Required}^{AMC} = 3$. For $NRB_{Total} - NRB_{Utilized} \geq 6$, the $RB_{Required}^{AMC}$ are assigned to new call. When it will enter another *AMC* location, the network can reduce the number of assigned *RBs* whenrequired. The different call arrivals, the resourcesrequired or assigned and the effect on call duration is shown in Table 2.

The performance of the algorithm can be improved by assigning more *RBs* to a callthan required. This will also improve spectral efficiency. For example, when a data call requires 3*RBs* and due to availability of resources *BS* assigns 6 *RBs* for the complete duration of call, the duration of call reduces to half. This assignment of resources is dynamic due to the dynamic nature of calls and also due to the mobility of the calls.

Table 2: Call Completion time with different assigned RBs for AMC scheme

Modulation Scheme Used due to location	Antennas Used at Transmitter and receiver	Offered Rate	Assigned RBs	Call Completion time for a data 'd'
Requested call rate - 2R				
QPSK 1/2	Single	144 Kbps	2	$\frac{t_1}{2}$
16QAM 1/2	Single	288 Kbps	1	$\frac{t_1}{2}$
16QAM 3/4	Single	432 Kbps	1	$\frac{t_1}{3}$
64QAM	Single	864 Kbps	1	$\frac{t_1}{6}$
64QAM	2x2 MIMO	1728 Kbps	1	$\frac{t_1}{12}$
64QAM	4x4 MIMO	3.456 Mbps	1	$\frac{t_1}{24}$
Requested call rate - 4R				
QPSK 1/2	Single	144 Kbps	4	$\frac{t_1}{4}$
16QAM 1/2	Single	288 Kbps	2	$\frac{t_1}{4}$
16QAM 3/4	Single	432 Kbps	2	$\frac{t_1}{6}$
64QAM	Single	864 Kbps	2	$\frac{t_1}{6}$
64QAM	2x2 MIMO	1728 Kbps	1	$\frac{t_1}{12}$
64QAM	4x4 MIMO	3.456 Mbps	1	$\frac{t_1}{24}$
Requested call rate - 8R				
QPSK 1/2	Single	144 Kbps	8	$\frac{t_1}{8}$
16QAM 1/2	Single	288 Kbps	4	$\frac{t_1}{8}$
16QAM 3/4	Single	432 Kbps	3	$\frac{t_1}{9}$
64QAM	Single	864 Kbps	2	$\frac{t_1}{12}$
64QAM	2x2 MIMO	1728 Kbps	1	$\frac{t_1}{12}$
64QAM	4x4 MIMO	3.456 Mbps	1	$\frac{t_1}{24}$
Requested call rate - 16R				
QPSK 1/2	Single	144 Kbps	16	$\frac{t_1}{16}$
16QAM 1/2	Single	288 Kbps	8	$\frac{t_1}{16}$
16QAM 3/4	Single	432 Kbps	6	$\frac{t_1}{18}$
64QAM	Single	864 Kbps	3	$\frac{t_1}{18}$
64QAM	2x2 MIMO	1728 Kbps	2	$\frac{t_1}{24}$
64QAM	4x4 MIMO	3.456 Mbps	1	$\frac{t_1}{24}$
$t_1 = \frac{d}{144\,Kbps}$				

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PROPOSED UMTSANC SCHEME

The scheme for 4G and beyond communication networks available in literature assigns codes to a new call on the basis of its current location. Due to this reason more calls are blocked which leads to poor utilization of available UMTS resources. The proposed scheme uses the adaptive modulation and coding (AMC) process which is defined in [26] conditions when interference or distance varies between MS and eNodeB. The paper also considers 64-QAM, 16-QAM, QPSK and BPSK adaptive modulation schemes for comparison with existing schemes. The data rate which these schemes offer decreases from 64-QAM to BPSK. These schemes support data rate of 8*R*, 4*R*, 2*R*, and *R* for single code assignment respectively from 64-QAM to BPSK. The 64-QAM location provides a better *SNR* and offers an 8*R* data rate for one channelization code, therefore when a call request of 8*R* at 64-QAM location arrives it can be handled by using one code. The same call of rate8*R* handled using 8 codes of rate *R* at BPSK location. The data rate supported by single channelization code for different*AMC* schemes is given in Table 3.

A. Multi code assignment scheme

For an incoming call of rate $2^{i-1}R$, at the location ofQPSK. The number of codes required are $\frac{2^{i-1}R}{2R} = 2^{i-2}$ *i.e* number of rakes required are 2^{i-2} . The multi code assignment now checks the direction of motion. When the user is moving towards 16-QAM location, the algorithm will search for a vacant code of rate $2^{i-1}R$ with time domain code channel load less than 0.70.

a. If (*a vacant code of rate* $2^{i-1}R$ *available*)

Assign new call to the codes of rate 2^{i-2} using 2^{i-2}rakes.

b. Elseif (*search vacant codes of rate* $2^{i-2}R$ *in the code tree with time domain code channel load less than 0.75*)

Assign call to all codes using 2^{i-2} rakes and count number of vacant code of rate 2^{i-2} denoted by k_1.

c. Elseif (*search vacant codes of rate* $2^{i-3}R$ *in the code tree with time domain code channel load less than 0.75*)

Count number of vacant code of rate 2^{i-3} denoted by k_2.Assign call to $k_1$codes of rate $2^{i-2}R$ and k_2 codes of rate 2^{i-3}using $k_1 + k_2$ rakes.

d. Else

Block the call.

e. End.

When the user enters 16-QAM location merge codes of lower rates and handle call using lesser number of rakes. These rakes can be used for other calls.

For illustration of *ANC* multi code assignment scheme, consider arrival of a call of rate 8*R* at a location of QPSK moving towards 16-QAM. TheQPSK supports 2*R* for a single code assignment, therefore requires 4 codes of rate 2*R* which is under channelization code $C_{5,4}$ as shown in Figure3 (a) and assigned in Figure 3 (b) using 4 rakes with codes $C_{2,25}$ to $C_{2,28}$. When it will enter, the 16-QAM location, the call be handled by codes $C_{3,13}$and$C_{3,14}$ using 2 rakes, the remaining two rakes can be used for future calls. If the same user is moving towards the BPSK location then will require 8 codes of rate *R*, the system has enough rakes to support the call, the call will be handled using those rakes otherwise call will be either blocked or handled at lower QoS. Consider the status of OVSF code tree in Figure3 (b), when the second call of 8*R* arrives with the location of BPSK, it will require 8 codes of rate *R*. It will use 2 codes, 3 codes and 3 codes under time spreading codes ($C_{1,5}$, $C_{1,6}$), codes ($C_{1,12}$, $C_{1,13}$, $C_{1,13}$), codes ($C_{1,12}$, $C_{1,13}$, $C_{1,13}$), codes ($C_{1,25}$, $C_{1,26}$, $C_{1,27}$) using 8 rakes.

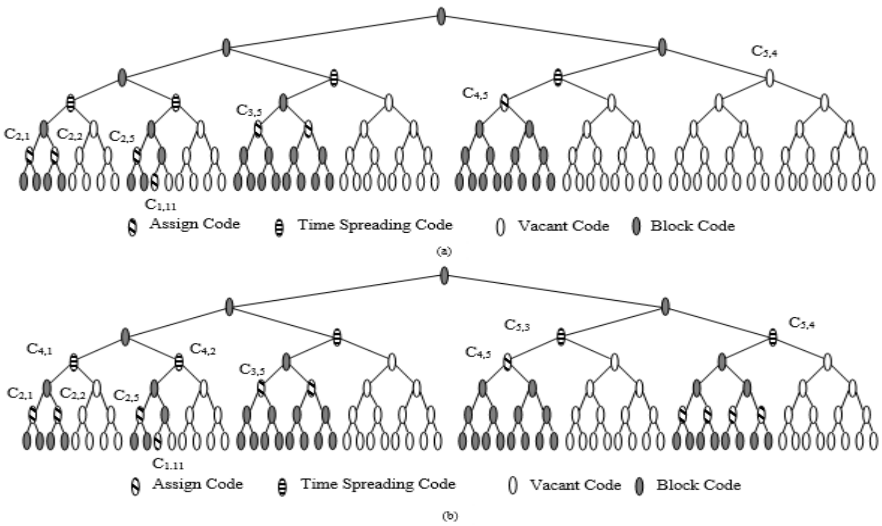

Figure 3: Illustration of ANC multi code assign (a) 8*R* arrives (b) 8*R* arrives again

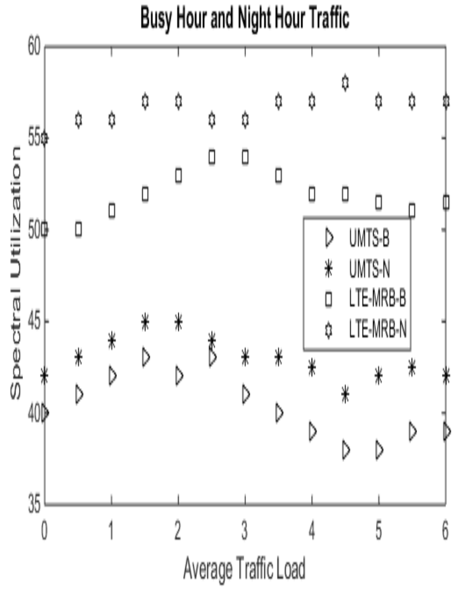

Figure. 4: Spectral utilization of UMTS and LTE interface in Busy and Night Hours.

RESULTS AND SIMULATIONS

a) HLU Scheme

The arrival rate is average from 0 to 6. The arrival of calls during busy hours is mostly M-T (80%) and SG-T (20%). In night hour's arrival of calls is mostly M-T (20%) and SG-T (80%). The average call duration of all traffic rates is exponentially distributed with normalized mean value 1. The arrival distribution of rates [*R*, 2*R*, 4*R*, 8*R*]. The LTE interface capacity used is 345.6 Mb/s and of UMTS interface 256*R* (3.4Mb/s). Figure 4, determines the spectral utilization of *UMTS* and *LTE* interface in busy and night hour traffic. For a network handling only M-T, spectral utilization is around 50% and 33% respectively for *LTE* and *UMTS* interface, especially during night hours. The proposed scheme assigns resources to SG-T too, this increases spectral utilization of both interfaces. Also, during the night hours the maximum resource block (MRB) threshold increases from 3 to 6 for *LTE* interface. This considerably reduces the call blocking probability shown in Figure 5 for both M-T and SG-T data traffic denoted MT-d and SGT-d. The network gives preference to M-T in busy hours and SG-T in night hours. The SGT-d considered is metering information's equivalent to a voice call when from the single meter and a data call when from aggregator.

b) ANC Scheme

The performance of *adaptive number of codes* (ANC) is compared with the crowded first assignment (CFA) and random assignment (RA) scheme proposed in [12] and ALM approach in [21]. For the performance comparison, the parameters used are code blocking probability and quality of service ratio (QoSR). The total capacity of the code tree is assumed to be 256*R*. The performance is compared for the downlink of the network and traffic arrived is of variable rate. The number of rakes used are from 1 to 8.

The arrival rate (average) is from 12 to 39. The average call duration of all traffic rates is exponentially distributed with normalized mean value 1. The arrival distribution is assumed to be uniform *i.e* for rates [*R*, 2*R*, 4*R*, 8*R*], the percentage is equal 25%. Figure 2 (*a*), the code blocking probability of the compared schemes. The code blocking probability of all the calls increases with traffic load. The reason is fragmentation of vacant code in the code tree due to random behavior of arrival and departure of calls. The ANC scheme provides the minimum code blocking probability as it searches the complete code tree in absence of single code of requested rate and utilizes the fragmented capacity in the code tree. Figure 2 (*b*),

the quality of service ratio (QoSR), the QoSR of all schemes decreases with the increase of traffic load due to interference. The *ANC* scheme performs better than compared scheme as it increases or decreases as number of rakes required to handle the call. In other words, decreases or increases codes capacity which is handling the call.

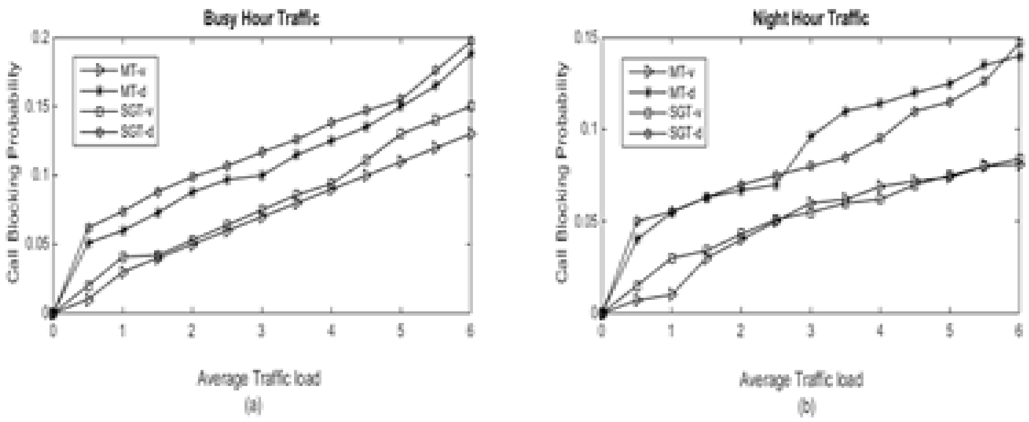

Figure 5: Call Blocking Probability of Mobile Traffic and Smart Grid Traffic *(a)* Busy Hour *(b)*Night Hour.

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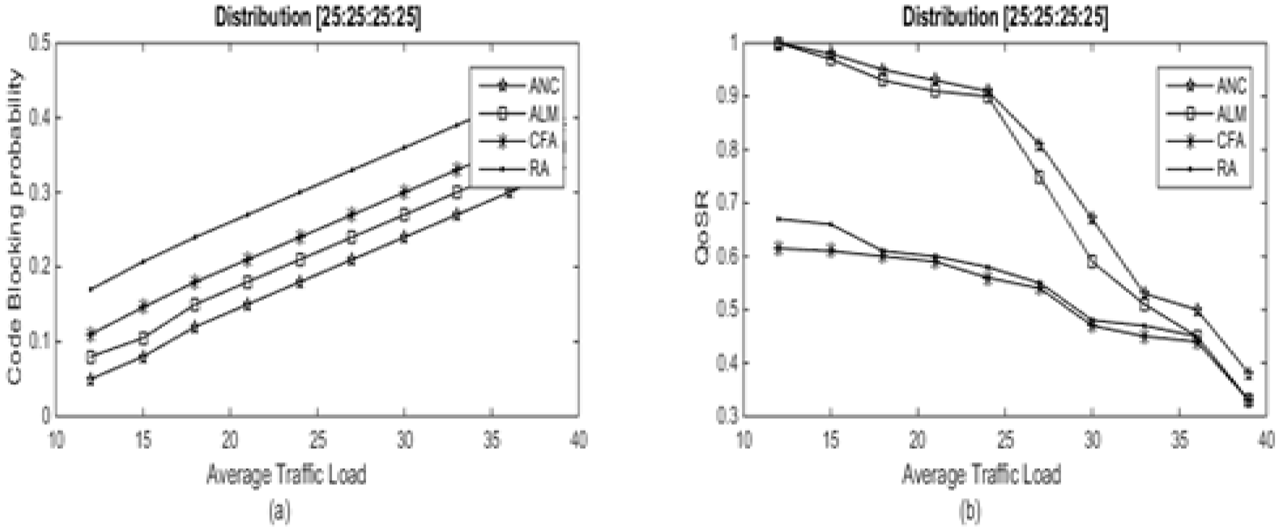

Figure 6: (*a*) Code blocking probability in presence of variable traffic load (*b*) QoSR in presence of variable traffic load.

CONCLUSION

The proposed scheme in this paper assigns capacity available at LTE and UMTS interface to mobile and smart grid traffic, which improves spectral utilization of both interfaces. Further, during night hours when mobile users are inactive smart grid metering information available with aggregators are sent at a faster speed using *LTE* interface by assigning more *RBs*. The scheme also takes into consideration the effect of mobile user motion which leads to dynamics in the resource allocated or handoff of resources. The *UMTS* interfaceuses two dimensional spreading of codes in time and frequency for mobile users with higher mobility. The ANC scheme manages the number of available rakes adaptively without influencing QoS and with reduced code blocking probability as compared to compared schemes. The ANC scheme also considers both location and direction of motion in the cell before assignment. In future, work can be done to find complexity associated with changing number of rakes during the duration of the call.

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