

Bandwidth Distribution Algorithm of Applications in LTE-Femtocell Network



Anita Jadhav, Y. Srinivasa Rao

Abstract: *The wireless communication has become the essential of today's Internet of Things (IoT) and mobile applications which is increasing exponentially in near future. These applications demand high data rate to speed up the communication among IoT or internet applications. The data rate requirement of individual application is different. To fulfill these demands of every application Long Term Evolution (LTE) integrated with femtocell technology is identified as suitable wireless technology. The running applications on a user equipment changes dynamically. Hence in dense deployment of femtocell and IoT devices, the bandwidth distribution to many active applications becomes more complicated. For multiple running applications per device with available bandwidth constraint, optimal bandwidth allocation to applications has become the most challenging issue. We include the bandwidth allocation to applications during handover of user equipment in LTE-femtocell network. The handover procedure needs efficient cell selection criteria for target cell selection.*

Hence in our research we focus on bandwidth distribution among applications by proposing "Efficient Bandwidth Distribution" (EBD) mechanism and efficient cell selection by "Dynamic Cell Selection" (DCS) mechanisms to mitigate above mentioned issues.

Keywords: *LTE, femtocell, EBD, DCS, Throughput, QoS, 3GPP.*

I. INTRODUCTION

The capacity of wireless networks must grow continuously in order to satisfy the demand of traffic from users and applications. To support these requirements of wireless network, Long-Term Evolution (LTE) and LTE-Advanced (LTE-A) have been standardized by 3GPP [1]. LTE is targeting data rate of 100Mbps/s and 50Mbps/s in the downlink and uplink respectively. The improvements in data rate are due to enhanced channel-dependent scheduling and rate adaptation. The data rate also improved in frequency domain by spatial multiplexing with MIMO, and larger channel bandwidths of up to 20MHz [6]. The standardization of new physical air interfaces is targeting downlink peak data rates of 1Gbit/s at low mobility and 100Mbps/s at high mobility.

Combining the principles of Network Functions Virtualization (NFV) with Software Defined Network (SDN) benefits for programmability and flexibility to the fore [7]. The offloading of software defined radio processing to general processing is achieved through NFV to meet the flexibility of programming [5]. Special emphasis to the 4G cellular Long-Term Evolution network is given through the concept of Self-Organizing Network (SON). It is observed that huge amount of data is generated in the 4G networks and expected more in future due to densification. The future 4G or 5G network management is expected to provide a new set of challenges due to the need to manage very dynamic networks, need to support 1000x traffic, and 10 fold users, improve energy efficiency, need to improve the experience of the users by enabling Gbps speeds and reduced latency, need to handle heterogeneous spectrum access privileges through the LTE. In our paper we will only focus on the applications to 4G network management to meet high data rate, bandwidth optimization, handover management especially during handover and to reduce delay, bit error rate in the LTE network integrated with femtocell. In our work in order to gain higher data rate we optimize the femtocell-femtocell handover procedure in a macrocell area. To optimize the handover using bandwidth and power parameter, we proposed Dynamic Cell Selection (DCS) mechanism. Our DCS helps in load balancing among the neighboring cells by evaluating the measurement reports and selecting the suitable cell which has sufficient resources. The bandwidth measurement in DCS is computed by bandwidth requirement of users and their applications. To calculate the users and applications bandwidth requirement we proposed Efficient Bandwidth Distribution (EBD) mechanism. Our innovative models, the DCS and EBD mechanisms are simulated in NS-3. We studied and evaluated the performance of our models in terms of throughput, bandwidth, user satisfaction rate for LTE integrated with femtocell Networks. We extended our work by another approach that is MIMO antenna technique to achieve higher data rate and larger channel bandwidths of up to 20MHz. The MIMO technique is used in real time implementation for end-to-end communication using Software Define Radio. The AD9361 provides flexible sampling rate which is very wide ranging from 547 Ksps to 61.44 Msps [18]. The end-to-end communication is shown for image transmission over-the-air using MIMO 2x2 and 1x1 antenna configuration with 64 QAM Modulation schemes and 10 MHz bandwidth of LTE. Due to the limited hardware devices, we show the cell search mechanism and end-to-end communication between two user equipment.

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The cell search and cell detection algorithms are executed for the real time transmission and reception of application for active user.

Related work: The subcarrier allocation for guaranteed users is determined for performance analysis as a function of call arrival rates and the blocking probability was represented by analytical model [1].

To achieve the performance objectives, Hybrid Automatic Repeat Request (HARQ) technique and different multiple input multiple output (MIMO) transmission methods are explain in [2],[15]. A distributed game-theoretic resource allocation technique was proposed by [3]. The opportunistic resource block allocation among the cells was mentioned by [4] to increase the average user throughput. Another approach called software defined radios (SDR) offload the edge devices and the base stations (BSs) by performing the signal processing operations on general computing platforms instead of hardware platforms by using multiple antennas at transmitter and receiver improve communication performance and efficiency. This functionality is achieved through Network Function Virtualization (NFV) to enable the deployment of sophisticated central algorithms [5]. The data rate also improved in frequency domain by spatial multiplexing with MIMO, and larger channel bandwidths of up to 20MHz [6]. Combining the principles of Network Functions Virtualization (NFV) with Software Defined Network (SDN) benefits for programmability and flexibility to the fore. 3GPP Release 12 includes optimization and enhancements of small cells in the dense deployment area. 7]. Different wireless communication techniques such as LTE, NB-IoT, EC-GSM, Lora, Sigfox are compared using parameters coverage, Spectrum, Bandwidth, Data rate, Battery life in [8]. The software defined radio technology for LTE transmit diversity is explained using USRP N210 and study the BER performance [9]. In [10] authors have used the RTL-SDR device to receive the signal and perform the decoding of it. The RTL-SDR device is working only as receiver, it cannot transmit the data. According to [11] Transmit diversity (TD) [14] are used in the LTE-A system to boost user performance in low signal-to-noise-ratio conditions, Space frequency coding suffers from PAPR and space time coding has reduced flexibility for the time domain encoding, both of these approaches have same performance at low speed. For resource allocation in macrocell-femtocell network a Genetic Algorithm is proposed by [12]. Femtocell is a low power, low cost, self-configurable wireless access point used to increase the coverage and capacity of the cellular network at the cell edge and indoor environment [17].

Organization: This paper is organized as follows: The notation and network utility function are defined in section II. The working of Efficient Bandwidth Distribution mechanism is presented in section III. Section IV is elaborating on the dynamic cell selection problem in LTE-femtocell network. We have shown various conditions that can be handled by EBD and DCS mechanism through illustration of numerical examples in section V. The simulation of EBD, DCS mechanism in NS3 and partial real time implementation using SDR with their numerical results are provided in section VI. At the end, we have concluded our research work with Section VII.

II. PROBLEM FORMULATION

In this section we explained all the mathematical models that we proposed for LTE-femtocell network scenario including our “Efficient Bandwidth Distribution” and “Dynamic Cell Selection” mechanism.

A. Notation and Terminology for LTE-femtocell network

Let the set of active users in an isolated LTE cell be denoted by $N = \{1, \dots, N\}$ and Base Stations $BS = \{BS_0, BS_1, \dots, BS_M\}$. Where N is total number of users and M is the total number of base stations. Here, BS_0 denotes the macro-cell Base Station and BS_i , $i \neq 0$, denotes the i^{th} femto-cell Base Station. We consider the optimal resource allocation to the users in terms of OFDM sub-channels denoted by $S_b = \{S_1, S_2, \dots, S_b\}$. All users can be associated to the macro-cell BS, whereas a subset of specific users is allowed access to a given femto-cell base station F_{BS_i} , $i \neq 0$. Considered that $F_{BS_i} \cap F_{BS_j} = \emptyset$ for $i, j \in \{1, \dots, M\}$ and $i \neq j$. This constraint is referred to as the “closed access” assumption. The outdoor users are considered as open access users and satisfy the constraint as (1).

$$\bigcup_{i=1}^M F_{BS_i} \neq N \quad (1)$$

Where X_{BS_i} denote the users associated with base station BS_i and Y_{BS_i} is the subchannel allocation to which each user in association A_{BS_i} is connected. The pair (X_{BS_i}, Y_{BS_i}) denote the association (A_{BS_i}) between n^{th} user and its allocated subchannel S_j . The vector X_{BS_i} is represented by notation (2) below. While the vector $Y_{BS_i} \in (S_b)$ indicates the sub-channel to which each user in A_{BS_i} is associated shown by mathematical notation (3).

Where

$$X_{BS_i}(n) = \begin{cases} 1, & \text{if } n \in A_{BS_i} \\ 0, & \text{if } n \notin A_{BS_i} \end{cases} \quad (2)$$

$$Y_{BS_i}(S_j) = \begin{cases} n, & \text{if } S_j \text{ in } BS_i \text{ is used by user } n \\ 0, & \text{if } S_j \text{ in } BS_i \text{ is not used by any user} \end{cases} \quad (3)$$

Let us consider a function for the sub-channel index to which each user is connected (4).

$$I(n) = \begin{cases} S_j, & \text{if } \exists BS_i \in BS \text{ such that } Y_{BS_i}(S_j) = n \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

B. Throughput Measurement

One of the objectives of our work is to maximize the total throughput in the microcell-femtocell network using dynamic cell selection and efficient bandwidth distribution mechanisms. The throughput is calculated using the well-known Shannon’s formula given as (5).

$$T = \sum_{i=0}^M \sum_{j=1}^N b_{ij} \log_2(1 + SINR_{ij}) \quad (5)$$

Where M is number of base stations and N is number of users in the network.

The parameter b_{ij} is the bandwidth of j^{th} user associated with i^{th} base station. $SINR_{ij}$ is the signal-to-interference-plus-noise ratio (SINR) for downlink transmission to j^{th} user associated with i^{th} base station. The SINR for user j is calculated using the subcarrier allocation.

We considered the total orthogonal subcarriers S_{BS} available at the base station, each with bandwidth W Hz. The SINR of a user j on subcarrier s is evaluated as (6) and (7).

$$SINR_{j,s} = \frac{(P_{BS,s} G_{j,BS,s})}{(N_0 \Delta f + I)} \quad (6)$$

where

$$I = \sum_{BS'} (P_{BS',s} \cdot G_{j,BS',s}) \quad (7)$$

The parameter $P_{BS,s}$ represents the transmit power of serving base station BS and $G_{j,BS,s}$ represents the channel gain between user j and base station BS on subcarrier s . Similarly the parameter $P_{BS',s}$ represents the transmit power of neighboring base station BS' and $G_{j,BS',s}$ represents the channel gain between user j and neighboring base station BS' on subcarrier s . The N_0 is white noise power spectral density and Δf represent subcarrier spacing. The channel gain G is represented by the path loss (PL) model based on the urban path-loss and given as (8).

$$G = 10^{(-\frac{PL}{10})} \quad (8)$$

Where PL is path loss between outdoor microcell users and a microcell base station PL_m in dB is calculated by equation (8.1).

$$PL_m = 15.3 + 37.6 * \log_{10}(d) + S \quad (8.1)$$

Where d is the distance between the transmitter and receiver. The variable S represents the outdoor shadowing and characterized as Gaussian distribution with standard deviation and zero mean. similarly, the path loss between an indoor femtocell users and femtocell base station PL_f is computed in dB using equation (8.2). Where $0.7d$ shows the penetration loss of walls inside a house and d is the distance in a house.

$$PL_f = 38.46 + 20 * \log_{10}(d) + 0.7(d) \quad (8.2)$$

III. EFFICIENT BANDWIDTH DISTRIBUTION (EBD) MECHANISM

This is our bench mark model, we proposed the mechanism for allocating the bandwidth to different applications of a user named efficient bandwidth distribution (EBD) mechanism. While distributing the bandwidth to active applications of a user we consider the dynamic priority of the applications according to user requirement. We classified all the applications broadly into 9 priority classes [18] as shown in Table I.

In EBD mechanism we proposed the bandwidth allocation from one active application to other active application depending on their required bandwidth and the priority. The priority of any application may change at any time by the user, it demands dynamic bandwidth allocation to all running applications. Our EBD mechanism allows to fetch extra

bandwidth from lower priority application to the higher priority application and vice a versa explained in procedure Case-I of EBD mechanism. On the other hand, if high priority application has shortage of bandwidth then EBD allows to fetch the allocated bandwidth from lower priority application to the higher priority application detailed in Case-II of EBD.

Table- I: QoS Classes of Applications

Preference	Applications	Examples	Data Rate
1	NGBR_IMS	IMS signaling	1mbps
2	GBR_CONV_VOICE	Conversational voice	4-13 kbits/s
3	GBR_GAMING	Real-time gaming	> 500 kbit/s
4	GBR_CONV_VIDEO	live streaming (video conferencing)	400 kbit/s
5	GBR_NON_CONV_VIDEO	buffered streaming	20-384 kbit/s
6	NGBR_VIDEO_OPERATOR	www	150 kbits/s
7	VOICE_VIDEO	Video one-way	5-128 kbit/s
8	NGBR_VIDEO_TCP_REMAINING	FTP	< 384 kbit/s
9	NGBR_VIDEO_TCP_DEFAULT	Email	>4 kbit/s

In EBD mechanism we proposed the bandwidth allocation from one active application to other active application depending on their required bandwidth and the priority. The priority of any application may change at any time by the user, it demands dynamic bandwidth allocation to all running applications. Our EBD mechanism allows to fetch extra bandwidth from lower priority application to the higher priority application and vice a versa explained in procedure Case-I of EBD mechanism. On the other hand, if high priority application has shortage of bandwidth then EBD allows to fetch the allocated bandwidth from lower priority application to the higher priority application detailed in Case-II of EBD.

The objective of our proposed EBD is to optimize the bandwidth among running applications which is represented by the utility function given in (9) with bandwidth constraint given by (10).

Where U_j is the bandwidth utilization function of user j and B_{BSi} is the maximum bandwidth assigned to the base station $BSi \in BS$ to which user j is associated.

Maximized

$$\sum_{j=1}^N U_j \leq B_{BSi} \quad (9)$$

subject to the constraint

$$U_{i=1}^m j = \sum B a_{ji} * x_{ji} \leq B_j \quad (10)$$

Where $x_{ji} \in [0,1]$, if application got the enough bandwidth x_{ji} is 1 else it is 0. The variable m is number of applications running on j^{th} user at particular instance. We calculated the maximum bandwidth of a base station (B_{BSi}) from system bandwidth B in terms of number of subcarriers Sb and $|M|$ is as the number of base stations in network formulated as (11) and (12).

$$B_{BSi} = B/|M| \quad (11)$$

Where

$$B = S_b.W \quad (12)$$

We considered X_{BSi} as the number of active users at the base station BSi and let B_j is the total available bandwidth for the j^{th} user. $B a_{ji}$ is the bandwidth for i^{th} application of the j^{th} user and x_{ji} is the weighting factor for the same application. The B_j represents bandwidth constraint for user j , which changes over time according to the active applications on it. The rate requirement (R_j) of user j , is calculated using the number of subcarriers, which can be estimated using the signal-to-interference-plus-noise ratio (SINR) as formulated below (13):

$$R_j = W.(\sum_{k=1}^{S_j} \log_2(1 + a.SINR_k)) \quad (13)$$

where S_j is number of subcarriers required for user j to achieve rate R_j . W denotes the bandwidth for each subcarrier. The parameter a is a constant for target bit error rate (BER) expressed by (14).

$$a = -1.5/\ln(5.BER) \text{ and } BER = 10^{-6} \quad (14)$$

We assumed the SINR of each subcarrier is same, $SINR_1=SINR_2=SINR_{S_j}=SINR$. The number of subcarriers ($S_j \subset Sb$) required by j^{th} user can be calculated by following equations (15).

$$S_j = (R_j.\log_{10} 2)/(W.\log_{10}(1 + a.SINR_{S_j})) \quad (15)$$

From these expressions (11 to 15) we can calculate the bandwidth (B_j) requirement of any user j as formulated in (16) with the constraint (17) on base station bandwidth B_{BSi} . X_{BSi} is the number of users associated to base station BSi . B_{BSi} is the bandwidth of a base station and W is the bandwidth of each subcarrier (15Khz) and S_j is number of subcarriers required by the user j .

$$B_j = S_j.W \quad (16)$$

subject to

$$\sum_{j=1}^{X_{BSi}} B_j \leq B_{BSi} \quad (17)$$

Let the bandwidth allocated to the user is Bu , at a base station. It is computed as base station bandwidth (B_{BSi}) divided by number of users $|X_{BSi}|$ associated to the base station in (18).

$$Bu = B_{BSi}/|X_{BSi}| \quad (18)$$

Let $B a_{ji}$ be the bandwidth allocated to different applications, calculated by their rate requirement at user. The rate requirement of an application ($R a_{ji}$) is calculated in (19).

$$R a_{ji} = W.(\sum_{k=1}^{P_{ji}} \log_2(1 + a.SINR_{jk})) \quad (19)$$

Where $R a_{ji}$ is the rate requirement for i^{th} application of user j . There is the requirement of P_{ji} subcarriers ($P_{ji} \subset S_j$) for gaining rate $R a_{ji}$ with subcarrier bandwidth of W . $SINR_{ji}$ is the signal-to-noise-plus-interference ratio of the connection between user and base station with respective to application i . The rate requirement of various application is specific hence their subcarrier allocation is varying. We have different values of subcarrier requirement P_{ji} according to number of running applications (i) computed as below (20).

$$P_{ji} = (R a_{ji}.\log_{10} 2)/(W.\log_{10}(1 + a.SINR_{ji})) \quad (20)$$

If we consider the values of subcarriers for individual applications, we estimated the resultant vector for all running applications (i) as below (21).

$$P_{ji} = [P_{j1}, P_{j2}, \dots, P_{ji}] \quad (21)$$

Where

$$P_{j1} = \frac{R a_{j1}.\log_{10} 2}{W.\log_{10}(1 + a.SINR_{j1})}$$

$$P_{j2} = \frac{R a_{j2}.\log_{10} 2}{W.\log_{10}(1 + a.SINR_{j2})}$$

$$\vdots$$

$$P_{ji} = \frac{R a_{ji}.\log_{10} 2}{W.\log_{10}(1 + a.SINR_{ji})}$$

We calculated the bandwidth requirement of any application (Br_{ji}) using following formula (22).

$$Br_{ji} = P_{ji}.W \quad (22)$$

Estimating the bandwidth requirement of active applications on a user by (22), we allocated average bandwidth of applications to each active application at a user by (23).

$$B a_{ji} = \sum_{k=1}^l Br_{jk}/|l| \quad (23)$$

The sequence of l applications is dynamically varying according to the priority given to active applications by the user.

While execution of running applications if high priority applications required more bandwidth than the allocated bandwidth by (23), then we apply the efficient bandwidth distribution (EBD) mechanism to all running applications on a user. The EBD mechanism allows high priority applications to fetch the extra bandwidth from one or more applications to fulfill its rate requirement.

Procedure EBD

1. Initialize the l active applications on user j .
 2. Consider the sequence of applications according to user priority.
 3. Compute required bandwidth of active applications ($Rj[l] = Brj[l]$) using "(22)".
 4. Allocate the bandwidth to applications ($Crj[l] = Bajl$) using "(23)".
 5. Calculate the difference between required ($Rj[l]$) and allocated bandwidth of applications $Exj[l] \leftarrow [Crj[l] - Rj[l]]$ // $Exj[l]$ is extra bandwidth
 6. Calculate Sum of above extra bandwidth
- $$Sum = \sum_{k=1}^l Exj[k]$$
7. If $Sum \leftarrow 0$
 8. then solution is optimal bandwidth distribution
 9. Exit // goto step 17
 10. elseif $Sum \geq 0$
 11. then call Case-I //near optimal solution
 12. Exit //Goto step 17
 13. elseif $Sum < 0$
 14. then call Case-II //lowest priority applications may not get enough bandwidth
 15. Exit //Goto step 17
 - 16.endif
 - 17.If user changed priority of any application repeat step 2
 - 18.If number of active applications changed repeat step1
 - 19.end EBD

The working of EBD is considered in two cases based on the extra bandwidth to any application and no application has extra bandwidth. Case I is executed if the sum of extra bandwidth of applications is not null, while case II is executed if the sum of extra bandwidth is null. In case I if the high priority application has less bandwidth than the required standard bandwidth then from one or more low priority application's extra bandwidth is fetched and allocated to high priority applications and vice versa. In case II if the high priority application has shortage of bandwidth and there is no extra bandwidth for any application then bandwidth from the lower priority applications to the higher priority application is allocated. Our proposed Efficient Bandwidth Distribution mechanism is explained in detailed by procedure EBD, which calls cases I and II conditionally. In condition Case-I, we effectively handle the situation so that there is no blocking of applications, while in case-II we focus on minimizing blocking rate of low priority applications.

User may change the priority of any application during communication, so low priority application change to high priority and meets the bandwidth requirement according to our EBD mechanism. Thus, dynamically all applications have got a chance of issuing the enough bandwidth for completing their task. In case if user keep the priority same for longer period then the last few applications may be blocked during that particular time. This blocking of applications is overcome by our EBD as soon as user changes the priority and make low priority application as high priority, blocking rate of applications is significantly reduced.

Procedure Case-I

1. For $a \leftarrow 1$ to l do // each application
2. If $Crj[a] < Rj[a]$ // $Rj[a]$ required bandwidth and $Crj[a]$ current bandwidth
3. For $r \leftarrow l$ to 1 by -1 do // each low to high priority application
4. If $(Exj[r] > 0 \text{ and } (r \neq a))$
5. $Crj[a] \leftarrow Crj[a] + Exj[r]$ //Add extra bandwidth of r^{th} application to a^{th} application
6. $Exj[a] \leftarrow Exj[a] + Exj[r]$ //update extra bandwidth of a^{th} application
7. $Crj[r] \leftarrow Crj[r] - Exj[r]$ //update current bandwidth of r^{th} application
8. $Exj[r] \leftarrow Exj[r] - Exj[r]$ //update extra bandwidth of r^{th} application
9. If $Rj[a] \leq Crj[a]$
10. Exit //stop for a^{th} application goto step 13
11. Else $r \leftarrow r - 1$
12. repeat step 3
13. Else $a \leftarrow a + 1$
14. Repeat step 1
15. End Case-I

Procedure Case-II

1. For $a \leftarrow 1$ to l do // each application
2. If $Crj[a] < Rj[a]$ // $Rj[a]$ required bandwidth and $Crj[a]$ current bandwidth
3. For $r \leftarrow l$ to a by -1 do // each low priority application
4. If $Exj[r] \leq 0$ //Add extra bandwidth of last application r^{th} to a^{th} application
5. If $Crj[r] > (-Exj[a])$
6. $Crj[a] \leftarrow Crj[a] - Exj[a]$ //Add extra bandwidth of application r^{th} to a^{th} application
7. $Crj[r] \leftarrow Crj[r] + Exj[a]$ // update current bandwidth of r^{th} application
8. $Exj[a] \leftarrow Exj[a] - Exj[a]$ // update extra bandwidth of a^{th} application
9. $Exj[r] \leftarrow Crj[r] - Rj[r]$ // update extra bandwidth of r^{th} application
10. Else $r \leftarrow r - 1$ endif //step5
11. If $Crj[a] \geq Rj[a]$
12. Exit // for loop of a , goto step 19
13. Else $r \leftarrow r - 1$
14. endif // of step 4
15. Else $r \leftarrow r - 1$
16. Endif //of step 4
17. repeat step 3
18. Else $a \leftarrow a + 1$
19. Repeat step 1
20. End Case-II

IV. DYNAMIC CELL SELECTION (DCS) MECHANISM

In the LTE integrated with femtocell network we considered mobility to user. During the ongoing communication if a user moves from his current location to other location along a random path and observed the reduction in signal strength, it switches to other cell in its vicinity for resources, this process is called as handover. At the edge of base station user may receive signal from one or more neighboring base stations. Since the user equipment (UE) could not get the sufficient signal strength from the current base station the communication may be interrupted and unsuccessful.

In such situation the UE need to select other base station from the neighboring base stations and perform handover to it. To select appropriate target base station, we used concept of dynamic depth first search method. We assumed that the user is moving randomly in particular direction instead of back and forth. For such situation the depth first search mechanism is very much suitable to identify the target cell. The advantage of depth first search over breadth first search is that the number of base stations is reduced for computation, which reduces the space and time complexity of cell selection method. Using the RSRQ measurement, channel state information of all neighboring cells is available at the UE. From this initial information user detects the suitable neighboring cells. The dynamic cell selection (DCS) mechanism puts the constraint on the required bandwidth and power parameters of cell. These parameter constraints contribute in the load balancing among base stations. Our dynamic cell selection mechanism is explained in detailed with procedure DCS.

Procedure DCS

```
//For a user assumed, source cell as u, target cell as v, neighbor
cells are store in a queue w.
1. At each time interval t UE perform measurement for the
   RSRQ of neighboring cells
2. The detected neighbor cells are stored in a queue w in
   nonincreasing order of RSRQ
3. For each cell v in queue w do
4. //Bu and Bv is maximum bandwidth of base station u and v
   respectively
5. //BW(.) is bandwidth function for base station
6. Calculate available bandwidth of BW(u) ≤ BBSi(u) and BW(v)
   ≤ BBSi(v) //by "(25)"
7. If BW(v) > BW(u) then
8. Do RSRP measurement of u and v
9. // P(.) is a power function for base station Ptu total power
   of u, Ptv total power of v
10. Calculate P(u) ≤ Ptu and P(v) ≤ Ptv // using power
    function "(27)"
11. If P(v) > P(u)
12. Select v as target cell and perform handover from u to v
13. Exit // goto step 16
14. Else continue with source cell u
15. Else repeat step 3 for next neighbor v from w
16. repeat step 1
```

The bandwidth utilization is calculated using the sum of bandwidths of all users on a particular base station. Suppose maximum bandwidth of a base station is B_{BSi} according to "(11)" and the total bandwidth utilization of i^{th} base station is Bi . The number of users associated with i^{th} base station are X_{BSi} , then the bandwidth utilization Bi is formulated as (24).

$$Bi = \sum_{j=1}^{X_{BSi}} B_j \quad (24)$$

Hence the available bandwidth of a base station is calculated using (25).

$$B(i) = B_{BSi} - Bi \quad (25)$$

Power function of base station is used to calculate the available power at base station at any instance with the constraint of total power (P_{BSi}) of that base station. The consumed power is the sum of the powers of all users of that base station. The parameter X_{BSi} is number of users associated to the base station, P_{BSi} is the maximum power assigned to the

base station by operator. P_i represents utilized power of base station computed as (26), P_j represents the power utilized by user j .

$$P_i = \sum_{j=1}^{X_{BSi}} P_j \leq P_{BSi} \quad (26)$$

The unutilized power of i^{th} base station is $P(i)$ formulated as (27).

$$P(i) = P_{BSi} - P_i \quad (27)$$

V. ILLUSTRATION OF EBD AND DCS MECHANISM

In this section we focus on the numerical representation of our method through examples. We considered specific conditions to show that our mechanism works efficiently for these conditions by the solution of examples.

A. Illustration of EBD

We assume that for the given instance of applications on a user, the bandwidth distribution to applications is done using formula (23), which is considered as current bandwidth of applications. The extra bandwidth or less bandwidth is computed as difference between current bandwidth and required bandwidth of respective applications. To make the optimal bandwidth distribution of applications we apply EBD mechanism. To observed the behavior of EBD procedure at various conditions and their expected output, we created the specific situation and illustrated through numerical examples given below.

Example 1 is illustrated to represent the situation of bandwidth distribution from high priority to low priority application by case-I condition. The Example 2 shows that if there is more femtocells and more users in LTE than the capacity, the bandwidth distribution to user and to applications is insufficient. Hence the condition case-II satisfies and feasible solution of bandwidth distribution is computed by EBD mechanism.

Example 1. The five different active applications with their user priority, bandwidth requirement and application number are given below. Find the optimal bandwidth distribution of this instance using EBD mechanism on a user?

Priority	1	2	3	4	5
Application No. (a)	1	3	2	4	5
Required BW (R)	2	6	3	5	4

Solution 1.

Step 1: After considering the given values of required bandwidth of applications, further steps of EBD mechanism are used to calculated the current distribution (Cr) of bandwidth to each application by formula (23). The difference between required bandwidth and the current bandwidth is shown as extra bandwidth.

Current BW (Cr)	4	4	4	4	4
Extra BW (Cr-R)	2	-2	1	-1	0

Step 2: Knowing the extra bandwidth value, depending on the condition step 7 onwards of EBD algorithm, this instance satisfies case-I. Hence to solve the example we follow the case-I procedure iteratively as shown below. We observed that after iteration 4 extra bandwidth array for all applications is 0, it represents optimal bandwidth distribution to applications. In this example total bandwidth of user = 20 and bandwidth distributed to applications by EBD=20. It satisfies bandwidth utility function (10).

Priority	1	2	3	4	5
Application No. (a)	1	3	2	4	5
Required BW (R)	2	6	3	5	4
Iteration1	Enough bandwidth to 1 st application				
Current BW (Cr)	4	4	4	4	4
Extra BW (Cr-R)	2	-2	1	-1	0
Iteration2 -1	Case-I satisfies for 2 nd application				
Current BW (Cr)	4	4 → 5	4 → 3	4	4
Extra BW (Cr-R)	2	-2 → -1	1 → 0	-1	0
Iteration2- 2	Case-I satisfies for 2 nd application				
Current BW (Cr)	4 → 2	5 → 7	3	4	4
Extra BW (Cr-R)	2 → 0	-1 → 1	0	-1	0
Iteration3	Enough bandwidth to 3 rd application				
Iteration4	Case-I satisfies for 4 th application				
Current BW (Cr)	2	7 → 6	3	4 → 5	4
Extra BW (Cr-R)	0	1 → 0	0	-1 → 0	0

Example 2. The five different active applications with their user priority, bandwidth requirement and application number are given below. Find the optimal bandwidth distribution of this instance using EBD mechanism on a user?

Priority	1	2	3	4	5
Application No. (a)	4	3	2	1	5
Required BW (R)	5	4	4	5	4

Here we consider the situation where case-II satisfies.

Solution 2.

Step 1: Similar to examples1 compute current and extra bandwidth of given applications.

Current BW (Cr)	4	4	4	4	4
Extra BW (Cr-R)	-1	0	1	-1	0

Step 2: Here sum of extra bandwidth is less than zero so it satisfies the case-II condition of EBD and follow steps of case-II iteratively for given applications.

Priority	1	2	3	4	5
Application No. (a)	4	3	2	1	5
Required BW (R)	5	4	4	5	4
Iteration 1	Case-II satisfies for 1 st application				
Current BW (Cr)	4 → 5	4	4	4	4 → 3
Extra BW (Cr-R)	-1 → 0	0	0	-1	0 → -1
Iteration 2	Enough bandwidth for 2 nd application				
Iteration 3	Enough bandwidth for 3 rd application				
Iteration 4	Case-II satisfies for 4 th application				
Current BW (Cr)	5	4	4	4 → 5	3 → 2
Extra BW (Cr-R)	0	0	0	-1 → 0	-1 → -2
Iteration 5	Application 5 cannot get enough bandwidth so it is block				

In this example Total bandwidth of user = 20, bandwidth distributed to applications by EBD = 18. It satisfies bandwidth utility function (10) and we got the feasible solution, because last application is blocked.

B. Illustration of DCS

For the illustration of our bandwidth utility function (9) and (10) we considered more than one user with multiple applications running on them and solve the instance given in example 3.

Example 3. Consider an instance of 3 users i.e. $(|X_{BSi}|) = 3$ and one base station, with bandwidth $(B_{BSi})=90$ mbps, number of applications $l=3$, required bandwidth of applications at particular user are $(Br1l) = \{10,12,10\}$, $(Br2l) = \{10, 12, 8\}$, $(Br3l) = \{6, 10, 12\}$ find the optimal solution of bandwidth distribution on all users with given active applications using efficient bandwidth distribution algorithm?

Solution 3: Initially the bandwidth allocated to the active applications is done through procedure of EBD as:

Total bandwidth of base station $(B_{BSi}) = 90$, number of users $(|X_{BSi}|) = 3$.

Hence bandwidth to each user calculated by (18) is

$(B_u) = 90/3 = 30$ mbps.

Hence the total bandwidth of each user is 30 mbps.

i.e. $B_1 = B_2 = B_3 = 30$

Initial distribution of bandwidth by (23) to all active applications is done as:

$(B_{ajl}) = B_u/l = 30/3 = 10$, for all l applications of each user.

Hence $B_{a1l} = \{10, 10, 10\}$, $B_{a2l} = \{10, 10, 10\}$,

$B_{a3l} = \{10, 10, 10\}$,

The vector x is the solution vector for each user, and it is represented as 0 (bandwidth not allocated) or 1 (bandwidth allocated). When the Efficient Bandwidth Distribution algorithm is traced on this instance following values are obtained:

The solution vector for user 1 is $x_{1l} = \{1, 1, 0\}$

The solution vector for user 2 is $x_2 = \{1, 1, 1\}$

The solution vector for user 3 is $x_3 = \{1, 1, 1\}$

Using model (9)-(10) solution vector x for all users is used to calculate Total Bandwidth (T) of a system as:

$$T = (10 \times 1 + 12 \times 1 + 8 \times 0) + (10 \times 1 + 12 \times 1 + 8 \times 1) + 8 \times 1 + 10 \times 1 + 12 \times 1$$

Total Bandwidth = 82 ≤ 90 //True

Hence the optimal distribution of a system for this instance is 82 mbps.

With these problems we have illustrated our bench mark model (9) and (10) of EBD mechanism. Hence EBD satisfies the given constraints and distributes the available bandwidth efficiently to multiple active applications using dynamic programming method.

VI. IMPLEMENTATION AND RESULTS

Our practical implementation includes simulation of our proposed EBD and DCS mechanism using NS3 software. We have shown through our experiment that Software Define Radio (SDR) platform is suitable to implement these kinds of mechanisms for performance analysis in real time, which we explained in following subsections.

A. Simulation of EBD and DCS in NS3

Because For practical consideration we use NS3 simulation software to implement our DCS and EBD mechanism. The DCS method is applied for the efficient handover procedure between femtocell to femtocell. The main focus of our proposed mechanism is to utilized the maximum available bandwidth among all active applications with user Quality of Service (QoS) and high system throughput. We consider a microcell including 4 femtocells with more than one user (≤5). Each user has multiple active applications. We show that user-3 is moving with constant velocity and perform handover from femtocell-1 to femtocell-2 with ongoing communication. The mobile user-3 used the DCS mechanism for efficient cell selection. The DCS evaluates the required bandwidth of all running applications on the user by the EBD mechanism. If the required bandwidth of a user calculated by bandwidth of all active applications on it and the available bandwidth of the target cell satisfies the criteria of enough bandwidth, handover takes place. Thus user-3 satisfies the criteria and perform the successful handover to the selected target femtocell-2. All other nonmoving users optimized the bandwidth of their applications by EBD mechanism. The simulation parameters are given in Table II.

Table- II: Simulation Parameters

Parameters	Value
Total available bandwidth	200mbps
eNB power transmission	46 dBm
HeNB power transmission	22 dBm
Adaptive modulation and coding	best-effort
Number of mobile users	10
Number of femtocells	4
Epoch Duration	38 sec
Maximum data rate	100 Gbps
Maximum transmission units	1500

The multiple active applications on all users are shown in

Table III. Table III shows the initial attachments of users to femtocell (Cell ID) and all running applications on each user (IMSI), the applications are represented according to their preference number given in the priority queue. Table III shows that row 1 has Cell ID 1, IMSI 1, 2, 3, 4 and running applications as {2,3}, {1,4}, {1,2,5}, {1,3} this means IMSI 1, 2, 3, 4 are attached to Cell ID 1. The IMSI 1 has application 2 and 3 as active application on it. Similarly, IMSI 2 has application 1 and 4 running on it and so on for all Cell IDs.

Table III shows that row 1 has Cell ID 1, IMSI 1, 2, 3, 4 and running applications as {2,3}, {1,4}, {1,2,5}, {1,3} this means IMSI 1, 2, 3, 4 are attached to Cell ID 1. The IMSI 1 has application 2 and 3 as active application on it. Similarly, IMSI 2 has application 1 and 4 running on it and so on for all Cell IDs.

Table- III: Initial Attachment of users with Femtocells and Running Applications

CELL ID	IMSI	Preference ID of running applications on IMSI in sequence
1	1, 2, 3, 4	{2, 3}, {1, 4}, {1, 2, 5}, {1, 3}
2	5, 6	{1, 2}, {3, 5}
3	7, 8	{1, 5}, {3, 5}
4	9, 10	{1, 2}, {3, 5}

Table IV represents the running applications on user equipment during simulation. We have given preference ID to all applications, for our simulation we used first 5 applications running on different users as shown in Table III. The type of these 5 applications are given in table IV, such as application having preference ID-1 is NGBR_IMS, preference ID-2 is GBR_CONV_VIDEO and so on.

Table- IV: Running Applications use in Simulation

Preference ID of Application	Application type
1	NGBR_IMS
2	GBR_CONV_VIDEO
3	GBR_GAMING (multi-player, video)
4	GBR_NON_CONV_VIDEO
5	NGBR_VOICE_VIDEO_GAMING (video)

Table IV represents the running applications on user equipment during simulation. We have given preference ID to all applications, for our simulation we used first 5 applications running on different users as shown in Table III. The type of these 5 applications are given in Table IV, such as application having preference ID-1 is NGBR_IMS, preference ID-2 is GBR_CONV_VIDEO and so on.

The initial scenario before handover of LTE-femtocell network is shown in Fig. 1.

While the scenario after successful handover of the user is shown in Fig. 2. These are the screens captured during the simulation in Net-Anim.

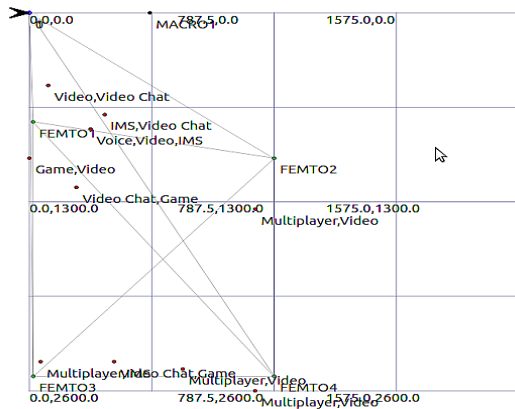


Fig. 1. Scenario Before handover

The performance evaluation of the proposed algorithms DCS and EBD are done from the trace files generated using NS3 simulator. The following performance measurements are used in order to verify and compare proposed algorithms with 3GPP method. 1. Bandwidth usage, 2. System throughput, and 3. Users' satisfaction rate.

1. Bandwidth usage B_u of the proposed system is given by the following formula (28). It is defined as the ratio of bandwidth used by all users to the total available bandwidth.

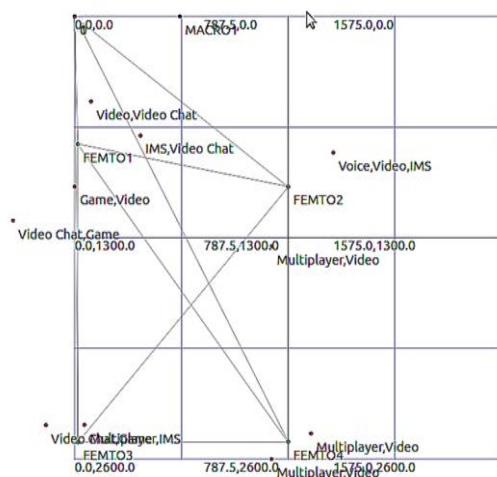


Fig. 2. Scenario After handover

$$B_u = \sum_{i=1}^{X_{BSi}} B_i / B \quad (28)$$

The variable B_i is the bandwidth of individual user. There are X_{BSi} users in the system and B is the total available bandwidth of the system. The bandwidth allocation is done by EBD mechanism to maximize the objective function as given in (9). It gives better bandwidth usage than the 3GPP method. This is because the unutilized bandwidth is distributed to the needy applications using the EBD mechanism during communication. The bandwidths allocated to all users by 3GPP and the proposed algorithm EBD is shown in the Table V. The bandwidth achieved by EBD and 3GPP method is compare and shown in the Fig. 3. The average difference of bandwidth between 3GPP and EBD mechanism is 2.83292

mbps. Hence the average bandwidth allocated by the EBD is more, which increases the data rate of the users as compare to 3GPP.

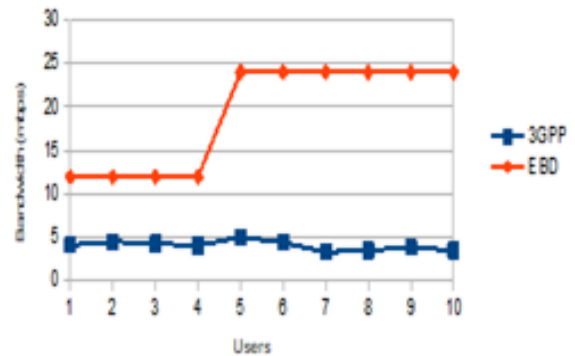


Fig. 3. bandwidth comparison of 3GPP and EBD

2. System throughput is calculated using the (5) as mentioned above. The achieved throughput by EBD and 3GPP is shown in following Fig. 4. Table VI shows the throughput comparison between 3GPP and EBD for our scenarios. It is observed that the average throughput value of the EBD algorithm is more than the 3GPP by the amount of 1.3009949. Hence EBD algorithm achieves higher system throughput than the 3GPP method. It results in increase in the data rate using EBD as compare to 3GPP.

Table- V: Bandwidth Allocated to users by EBD and 3GPP

User	Minimum Required BW (mbps)	BW allocated by 3GPP to users	BW allocated by EBDA to users
1	6.2	4.1340	12
2	2.2	4.5457	12
3	6.03	4.3227	12
4	11	4.0905	12
5	7.2	5.0816	24
6	18	4.4280	24
7	14	3.3358	24
8	18	3.5508	24
9	7.2	3.87201	24
10	18	3.5368	24

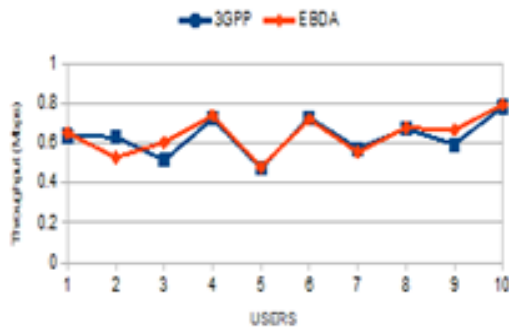


Fig. 4. Throughput comparison of 3GPP and EBD

3. User's Satisfaction rate R is given by the following formula (29), it is calculated as the ratio of sum of allocated bandwidth to demanded bandwidth of applications for user j .

$$R = \sum_{u=1}^N B_u / \sum_{j=1}^N B_j \quad (29)$$

Where R is the user's satisfaction rate, there are total N users in the system. B_u is the allocated bandwidth of user i and B_j is the bandwidth demand of user j . The graph of user satisfaction rate is shown in Fig. 5. for EBD and 3GPP comparison. The user satisfaction rate of EBD is calculated as 1.6531.

B. Real Time Experimental Set-Up using SDR

The Software Define Radio (SDR) platform can be used to analyze the performance of LTE-femtocell network. Hence, we used SDR to improve the LTE-femtocell network performance by Multiple Input Multiple Output (MIMO) antenna technique. MIMO is used to increase the data rate of the system so that data transmission become fast. We have done the real time experiment for the cell search and efficient cell selection using single femtocell (SDR) due to hardware limitations. The experimental set-up of SDR and the host machine is shown in Fig. 6.

Table- VI: Throughput of users by EBD and 3GPP

User	Thrpt-3GPP	Thrpt-EBD
1	0.635274	0.651156
2	0.630184	0.527013
3	0.513192	0.603912
4	0.721435	0.736851
5	0.473719	0.478974
6	0.727808	0.719345
7	0.572496	0.553839
8	0.67103	0.676692
9	0.593121	0.665961
10	0.782927	0.791659

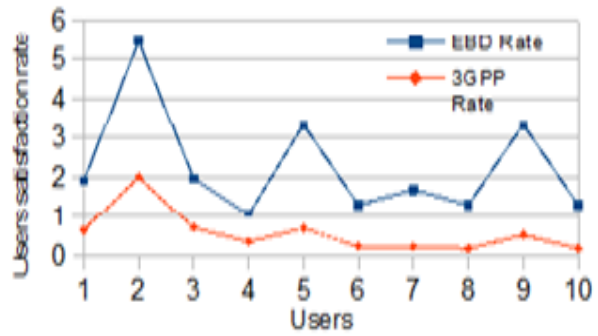


Fig. 5. User satisfaction rate comparison of 3GPP and EBD



Fig. 6. Experimental set-up of SDR

We use MATLAB communication tool box for interfacing SDR device to host machine. For the end-to-end communication using over-the-air transmission we installed the LTE System Toolbox, Communication System Toolbox support package for Xilinx Zynq-Based. We used Single Analog Device AD9361/AD9364 FCOMMS2/3/4 and the Z-Board.

We have considered this set up as the small cell within a room, thus it has limited coverage of the room size. Hence, we considered the single cell and perform the end-to-end communication for two users. For transmission and reception of data, the UE should be active user; hence we consider the image transmission application to make user active. The parameters used in transmission for LTE and SDR are listed in Table VII.

Table- VII: Experimental Set-Up Parameters for LTE-SDR

Parameter	Value
SDR device name	ZC706 and FCOMMS/3/4
IP address	192.168.3.2
Bandwidth	10 MHz, 1.4 MHz
Cell ID	88
Initial frame number	700
Center Frequency	2.45e9 Hz
Number of Transmit Antennas	2, 1
Transmitter gain	-10
No of LTE radio frames	5
Transmission Scheme	TxDiversity
Duplex Mode	FDD
Cyclic Prefix	Normal

BaseBand Sample Rate	15.36 Msps
Carrier frequency	2.1 GHz
Centre frequency	2.45e9 Hz
Channel type	Urban in a room
Number of Base stations	1
Transmission mode	SISO, MIMO
Number of subframe	50
Data modulation	64 QAM
Channel Estimation	Perfect Channel Estimation over-the-air
Cyclic Prefix (CP) length	4.7 μ sec
Number of Tx antennas	1, 2
Transmitter Sampling Rate	15.36 Msps
Power Scale factor	0.8

For the experimental set up, first the basic information of the SDR device is configure as device information. The device information contains device name and the IP address of the device to check the connection with computer system.

We use LTE System Toolbox of Matlab for interfacing with the hardware. The SDR device is connected to the computer using net cable and the loop back using USB connection. We configured the SDR card by selecting the correct Ethernet connection, and for xilinx zynq-based device for Matlab. For the end-to-end communication we set up the and tune the parameters of the transmitter and the receiver appropriately as mentioned below.

Transmitter Setup: We set the SDR transmitter parameters as shown in table VII. This application is configured to transmit and receive LTE MIMO on single Analog device for one-by-one and two-by-two antennas. To prepare the image file for transmission, read the data from image file scaled it and convert to a binary data stream. We scale it to form 5 LTE radio frames by scaling factor of 0.5. The binary data stream coded into multiple transport blocks to transmit in the Physical Downlink Shared Channel (PDSCH). Then the LTE baseband signal is generated using the parameter setting given in table VII. The baseband signal is scale for better power output, then it is casted to int16 which is the native format for the SDR device. The transmit antenna parameter is set 1 for 1x1 antenna scenario SDR-1 and 2 for 2x2 antenna scenario SDR-2 respectively, explained further. This LTE baseband is transmitted continuously using the transmit repeat function on the Zynq-Based Radio platform.

Receiver Setup: The sample rate of the receiver is 15.36MHz, which is a standard sample rate for capturing an LTE bandwidth of 50 resource blocks. The receiver parameters are configured similar to the transmitter. It is assumed that the transmitted PDSCH parameters are known. Using the blind cell search the MIB is decoded to get the actual cell-specific reference ports. Initially it was assumed as four (CellRefP = 4), because receiver do not have any knowledge about it. The number of resource blocks of the received waveform is obtained from the lookup table using the value of sampling rate. Channel configuration and estimation is performed using cell-specific reference signals. To minimize the noise effect a 9-by-9 averaging window is used in channel estimation. The type of pilot symbol averaging is set to 'User Defined', interpolation type is set to 'Cubic' with interpolation window type as 'Centered' and the interpolation window size is set to 3. The LTE frames are captured over-the air and decoded for detailed information. By decoding the Master Information Block (MIB) correctly,

system frame number is identified. Once the frame number has been determined, the PDSCH and DL-SCH are decoded and the equalized PDSCH symbols are shown. There is no data in subframe 5, therefore its captured data is ignored for decoding.

Scenario SDR-1: For 1x1 antenna

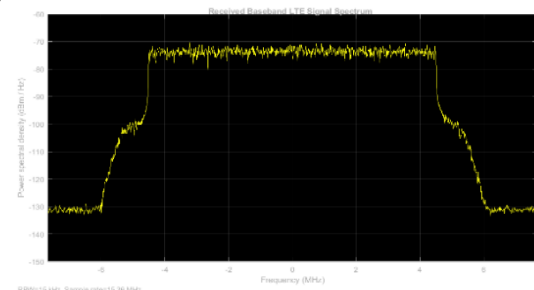
We perform end-to-end communication between 2 UEs in LTE-Femtocell Network using 1 by 1 antenna and 64 QAM modulation scheme. In this scenario UE1 is transmitting an image to UE2 using resources of femtocell (SDR device). The image is transmitted successfully by detecting the Cell ID 88 of the transmission correctly with bit error rate zero. Transmitted image is as shown in Figure 10. The received image is shown in Fig. 11.

Scenario SDR-2: For 2x2 antenna

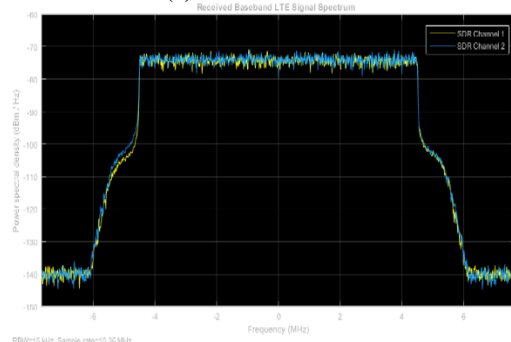
This scenario considered end-to-end communication from UE1 to UE2 in LTE-Femtocell Network using MIMO 2 by 2 antenna and 64 QAM modulation scheme.

We used 2x2 MIMO for image transmission between UE1 and UE2, which are served by a femtocell (SDR device). We observed that the image is transmitted successfully over the air. Hence 2x2 MIMO has completed communication in this scenario gaining high data rate. The result shows that bit error rate is zero, that means it has corrected the frequency and time offset of the received signal correctly. It has detected transmitted Cell ID as 88 which we had set for the cell. Transmitted and received image is as shown in Fig. 10 and Fig. 12 respectively.

The Power Spectral Density (PSD) of the captured waveform is plotted to show the received LTE transmission as shown in Fig. 7. The constellation diagram is shown in Fig. 8 and channel estimation of frequency response in Fig. 9 for 1x1 and 2x2 antenna. The comparison of image transmission using 1x1 and 2x2 antenna is shown in Table VIII.

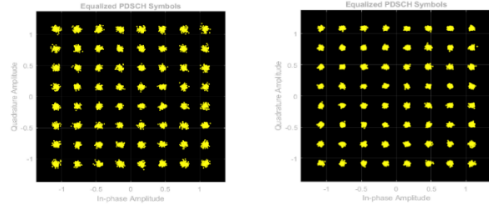


(a). For 1x1 antenna

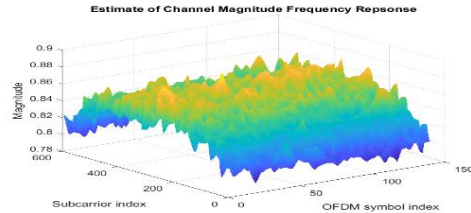


(b). For 2x2 antenna

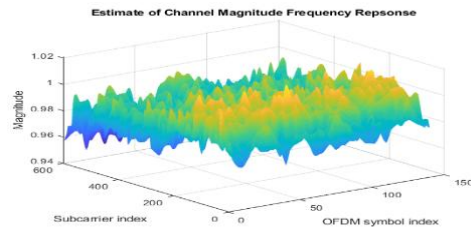
Fig. 7. Spectrum Scope- Power Spectral Density of received LTE baseband signal



(a). 1x1 (b). 2x2
Fig. 8. Constellation diagram: Equalized PDSCH Symbols of 64 QAM



(a). 1x1



(b). 2x2

Fig. 9. Channel estimation of frequency response for 64QAM



Fig. 10. Transmitted image

Received Image: 1x1 Antenna Configuration



Fig. 11. Received image 1x1

Received Image: 2x2 Antenna Configuration



Fig. 12. Received image 2x2

Table- VIII: Comparison of Image Transmission Using 1x1 and 2x2 Antenna

No of Antenna → ↓ Parameters	1 by 1	2by 2
BER	0.00	0.00
Number of bit errors	0	0
EVM Peak (%)	13.535	2.818
EVM RMS (%)	3.204	0.732
Frequency offset (Hz)	1.701430e+00	-7.888362e-01
Timing offset (no. of samples)	24931	150580
No of transmitted bits	1179648	1179648
Occupied bandwidth	99%	Ch-1 99% Ch-2 99%

VII. CONCLUSION

We proposed Efficient Bandwidth Distribution (EBD) mechanism to maximize the bandwidth utilization among applications on a user. We also address the efficient cell selection problem during handover through dynamic cell selection (DCS) mechanism. Through our research work we are able to (1) select the best target cell and perform handover, (2) optimally allocate the bandwidth resources among active applications, and (3) reduce the blocking rate of applications. From the simulation analysis, we observed that our algorithms are able to use 96% of the available bandwidth over 92% of the genetic algorithm (GA) based resource allocation and more than the 3GPP method. We are able to achieved better user satisfaction rate and the system throughput as compare to 3GPP method. The real time experiment has shown the successful image transmission over the air by channel estimation using MIMO antenna system. It has improved the bit error rate and utilized 99% bandwidth of the channel. Therefore, our proposed mechanisms outperform the 3GPP and GA in terms of bandwidth, user satisfaction rate and throughput of LTE integrated with femtocell networks.

REFERENCES

1. Uttara Sawant, Robert Akl, "Subcarrier Allocation in LTE Network Deployment with Mobility", IEEE, 2017.
2. Anthony Busson, Iyad Lahsen-Cherif, Hindawi WiLer, "Impact of Resource Blocks Allocation Strategies on Downlink Interference and SIR Distributions in LTE Networks: A stochastic Geometry pproach", Wireless Communications and Mobile Computing vol. 2018, June 2018.
3. Omid Namvar Gharehshiran, Alireza Attar, Vikram Krishnamurthy, "Collaborative Sub-Channel Allocation in Cognitive LTE Femto-Cells: A Cooperative Game-Theoretic Approach", IEEE transactions on communications. Vol. 61, no1, January 2013.

4. Dae Kyu Shin, Wan Choi, and Takki Yu, "Statistically Controlled Opportunistic Resource Block Sharing for Femto Cell Networks", Journal of Communications and Networks, vol. 15, No. 5 October 2013.
5. Rami Akeela, Behnam Dezfouli, "Software-defined Radios: Architecture, State-of-the-art, and Challenges", Internet of Things Research Lab, Department of Computer Engineering, Santa Clara University, USA, March 2018.
6. K Fazel, S Kaiser, "Multi-Carrier and Spread Spectrum Systems from OFDM and MC-CDMA to LTE and WiMAX", Second Edition, A John Wiley and Sons, Ltd, Publication, 2008.
7. Jessica Moysen, Lorenza Giupponi, "From 4G to 5G: Self-organized Network Management meets Machine Learning", Project 5GNORM, Jan 2018.
8. Min chen, Yiming Miao, Xin Jain, Xiaofei Wang, Iztok Humar, "Cognitive-LPWAN: Towards Intelligent Wireless Services in Hybrid Low Power Wide Area Networks", IEEE transactions on green communication and networking, 2018.
9. Kalle Ruttik, Riku Jantti, "LTE Transmit Diversity Techniques using Software-Defined Radios", School of Electrical Engineering Thesis submitted for examination for the degree of Master of Science in Technology. Espoo 13.02.2017
10. Robert W. Stewart, Kenneth Barlee, Dale Atkinson, Louise Crockett, "Software Defined Radio using MatLab & Simulink and the RTL-SDR", book, ACM Digital Library, 2015.
11. Gilberto Berardinelli, Troels B. Sorensen, Luis Angel Maestro Ruiz de Temino, Prebrn Mogensen, Kari Pajukoski, "Open Loop Transmit Diversity Solutions for LTE-A Uplink", 18th European Signal Processing Conference 2010, Aalborg, Denmark, 2010.
12. Hanaa Marshoud, Hadi Otrouk, Abdallah Jarray, Zbigniew Dziong, "Resource allocation in macrocell-femtocell network using genetic algorithm", ResearchGate, Oct. 2012.
13. S. Caban, Ch. Mehlhuhler, M. Rupp, M. Wriiich, "Evolution of HSDPA and LTE", John Wiley & Sons, 2012.
14. S. M. Alamouti, "A Simple Transmitter Diversity Scheme for Wireless Communications," IEEE J. Select. Areas Communications, vol. 16, pp. 1451 – 1458, Oct, 1998.
15. Mohammad T. Kawser, Nafiz Imtiaz Bin Hamid, Md. Nayeemul Hasan, M. Shah Alam, and M. Musfiqur Rahman, "Downlink SNR to CQI Mapping for Different Multiple Antenna Techniques in LTE," International Journal of Information and Electronics Engineering, Vol. 2, No. 5, September 2012.
16. Idin Motedayen-Aval, "Modeling a 4G LTE system in MATLAB", Mathwork 2012.
17. Anita B. Jadhav, Y. S. Rao, "Double Threshold Handover Algorithm", IEEE explorer 2015.
18. Ana Cristina Barreiras Kochem, Eliane Lucia Bodanese, "A Quality of Service Management Scheme over GPRS", IEEE Southeast Con 2003.
19. "Quality of Service (QoS) and Policy Management in Mobile Data Networks, Validating Service Quality to Ensure Subscriber Quality of Experience (QoE)", white paper Ixia 915-2731-01, 2013.

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