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BER/Sum Rate Analysis of Composition Non-orthogonal LDM and Orthogonal eMBMS for CDTV Broadcasting

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Abstract- **In this research, performance analysis for the composition of non-orthogonal and orthogonal cellular digital television broadcasting is investigated. A downlink multi-carrier layered division multiplexing (LDM) superimposed with an evolved multimedia broadcast multicast service (eMBMS). We define two broadcast service providers (BSP), which offer different radio access technologies (RAT). The BER and Sum Rate efficiency is selected as our criteria. The proposed downlink composition framework can work without a subscriber identity module (SIM card) uplink and internet protocol (IP). Mathematical analysis, based on the exact closed-form expressions, is consistent with the theory of the proposed composition LDM/eMBMS. Evaluation and performance are done based on the Monte Carlo iterative methodology. The results show that the BER and Sum Rate performance of a composition framework outperforms compared with LDM/eMBMS individually system.**

Index Terms- Composition, CDTV, LDM, eMBMS, BER, Sum Rate, Orthogonal, Non-orthogonal.

I. INTRODUCTION

After 4G cellular technology, trends in broadcasting are toward merging broadband and broadcast in cellular digital television (CDTV) for 5G and next-generation [1]. High bit rate demands for the CDTV are increasing, which causes the number of broadcast service providers (BSP) to grow up. This theme increases the quality of standard-definition television (SDTV) to high definition television (HDTV) for broadcast coverage supplementary [1]-[2]. There are infrastructure radio gaps between different of BSPs for CDTVs coverage, diverse radio access technologies (RAT), and BSPs according to physical layer

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technology [2]-[3]. The issue will offer a set of challenges and opportunities for future CDTV recipients and BSP physical layers [4].

The history of the physical layer cellular broadband generations is changing approximately once every decade, while the television broadcast technology has been changed over time [5]. Nowadays, BSPs are looking to select an alternative to next-generation CDTV platform technology, using existing composition infrastructure physical layers. Besides, there is a demand to supply and deploy transmission live video streaming multi-services point to multipoint (PTM) among broadcast owners for the next CDTV broadcasting [6]. Moreover, restrictions have been imposed by the international telecommunication union (ITU) and local radio frequency regulations organizations to reduce broadcast bandwidth and increase broadband cellular bandwidth, respectively [7]. Incompatibility and contradiction in digital terrestrial television broadcasting (DTTB) infrastructure have been a historical challenge versus CDTV technology for the BSP and mobile recipients [8]. For instance, there was incompatibility in the 3G era of wideband code division multiple access (WCDMA) against digital video broadcasting hand-held (DVB-H) in broadband and broadcast respectively [9]. To address these challenges, broadcast holders and network extenders suggested a juxtaposition approach. It is emerged as a possible solution to have composition technology using a multilayer delivery system recommended by researchers in the last few years. The convergence of broadcast and broadband services are being researched and developed as a kind of integration method worldwide for decades [10]-[11].

In recent years, great advancements and traditional studies have been achieved in terms of integration technologies such as using the long-term evolution broadcast (LTE-B) and power division non-orthogonal multiple access (PD-NOMA) simultaneously. The LTE-B introduced evolved multimedia broadcast multicast services (eMBMS) as an orthogonal service provider and PD-NOMA introduced LDM as a non-orthogonal service provider [12]-[13].

The eMBMS that was embedded in the LTE standard, transmits multimedia content to point to multipoint (PTM) end-user receivers in the local area [14]. The 3GPP and enhancements for Television (EnTV) have suggested a further evolved MBMS (FeMBMS), known as 5G broadcast [15]. Formerly, up to 60% of sub-frames and 40% of sub-frames to broadcast and unicast modes have been allocated in the Rel-13 [16] of the eMBMS, respectively. The new version of FeMBMS features is flexible in sum rate, and as a result, it can allocate up to 100% sub-frames to broadcast mode in Rel-14 [17]. Authors in [18] proposed a framework to overcome the limited performance of the conventional eMBMS due to the lack of dynamic link adaptation capability. Moreover, the LDM is a sub-section of PD-NOMA, which is a form of physical-layer non-orthogonal that uses the available spectrum RBs by assigning a different power value to each user. The infrastructure of LDM technology is based on two layers namely, the upper layer (UL) and the lower layer (LL) [19]. The LDM multi-carrier standards can provide maximum ruggedness against multipath interference downlink Rayleigh fading channel. This is important in the case of reception with simple single input single output (SISO) antennas [20].

As regards, there are multiplexing various services (in-door, handheld, mobile and stationary) with different requirements and data rate throughputs (SDTV, HDTV, 4k, 8k, surround audio) using the same spectrum resource LDM can achieve high spectrum performance [21]. It is possible to transmit high data rates fixed service on LDM-LL and low data rates mobile service on LDM-UL as non-orthogonality [22].

Fig.1. illustrates a simplified proposed framework single-cell next-generation base station (gNB). In this figure, a SISO downlink transmission is broadcasting. The BSP1 and BSP2 are superimposed and broadcast orthogonal eMBMS signal and non-orthogonal LDM signal in a single-tier cell, respectively. LDM-LL is a broadcast fix service high data rate and LDM-UL is a broadcast mobile service simultaneously. BSP1 and BSP2 are working in two radio frequencies orthogonal/non-orthogonal. D_{UL}, $D_{LL,}$ and D_{eMBMS} denote the distance from LDM far user (FU) and near user (NU), and eMBMS user from the gNB, respectively.

II. RELATED WORKS

Shi et al. [4] have defined Cell-TV, which is a paradigm of cellular television broadcasting over mobile networks. The Cell-TV is a BSP that covers a single hexagonal cell by the low-power low tower (LPLT) base station SISO antennas [23]. Zhang et al. [24] presented broadband-broadcast convergence with high spectral efficiency. Razzac et al. have planned in [25] a composition mobile TV service in standalone and cooperative digital video broadcasting-next generation (DVB-NGH) and the LTE model. Tusha et al. [26] suggested a composition power domain utilizing an orthogonal/non-orthogonal framework for downlink transmission with two UEs. Shokair et al. [27] provided a composition broadcast/broadband network as a potential solution to mitigate the increasing demand for mobile TV. Al-Abbas et al. [28] expressed that according to the channel condition, the technology of the composition framework outperforms the separate model due to the flexibility of adapting the transmission approach. Guo et al. [29] focused on a composition unicast-multicast video streaming framework. Fam et al. [30] have presented that both unicast and broadcast systems are optimally used in a composition model. Chen et al. [31] proposed the incorporation of PTM into cellular networks using a non-orthogonal transmission scheme based on the LDM principle. Christodoulou et al. [32], based on the orthogonal frequency division multiple access (OFDMA) scheme for downlink data traffic, expressed both broadcast and eMBMS. Guan et al.[33]

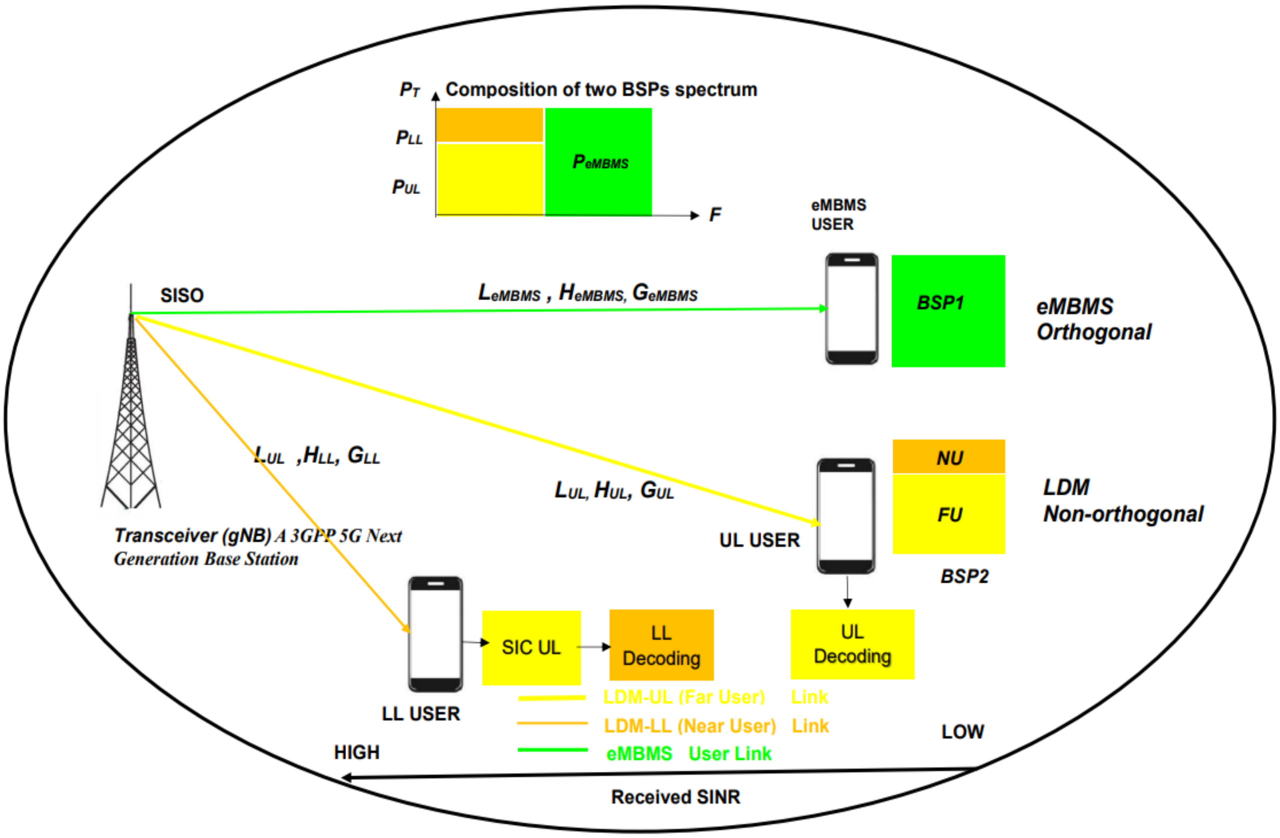


Fig. 1. The simplified multi-service CDTV Proposed framework.

proposed an algorithm for the relation between joint BER and sum rate considering the channel decay and error check style. In this paper, to compensate for the mentioned drawbacks and opportunities, we investigate a cellular composition broadcast and broadband non-orthogonal/orthogonal LDM/eMBMS framework, respectively. The composition framework is proposed as an intermediate method.

It is utilized to overcome the physical structure gap between both mobile and broadcast generations. Of course, based on the discussions earlier, this issue studies cellular from a technological viewpoint. Table I summarizes symbol definitions in association with composition LDM /eMBMS technologies.

A. Contributions

- An orthogonal/non-orthogonal CDTV layout is introduced from the service technology viewpoint, using an intermediate system for two broadcast service operators, which the BSPs offer a middle scheme as a joint technology of non-orthogonal LDM and orthogonal eMBMS broadcasting.
- The BSPs will complete the coverage area between two CDTV generations on the border of edge services.

Table I. Symbol definitions.

Parameter	Definition
P_T	Total transmit power of the base station
P_{LDM}	Total power of LDM technology
P_{UL}	Total power of Upper layer
P_{LL}	Total power of Lower layer
P_{eMBMS}	Total power of eMBMS technology
PS	Per Subcarrier
g	Injection power factor
B	Total bandwidth
RB	Resource Block
M	Total number of resource blocks
ψ	Total number of LDM resource blocks
Ω	Total number of eMBMS resource blocks
γ	signal to noise ratio(SNR)
K_m	Total number of sub-carriers
m	Resource block index
n	Time-domain sample index
k	Frequency domain frequency index
K_{LDM}	Total number of LDM sub-carriers
K_{eMBMS}	Total number of eMBMS sub-carriers
N	FFT points
α_m	Binary coefficients for *m*th RB indicates whether LDM is allocated
β_m	Binary coefficients for *m*th RB indicates whether eMBMS is allocated
T_U	Multi-carrier symbol useful part duration
T_{CP}	The Cyclic Prefix duration
$h(\tau)$	Channel impulse response
$w(t)$	Additive white Gaussian noise
gNB	The next-generation base station
C_{PTM}	The capacity of point to multi-point

- The proposed system will have the potential to work without a SIM card and internet protocol (IP) for uplink in terms of broadcasting conditions.
- The proposed system can select services as composition and as well as individually.

B. Organization

The rest of this paper is organized as follows. In Section III, the system model of LDM/eMBMS and composition framework will be introduced. In Section IV, a mathematical formulation will be analyzed. In Section V, simulation results, BER performance, and sum rate for multi-services, are done. In Section VI, the future directions are expressed and the article concludes.

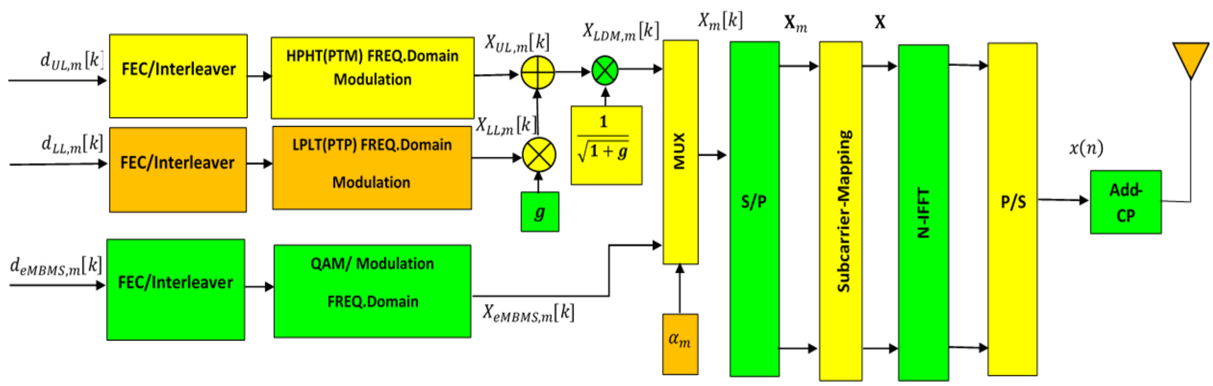
III. SYSTEM MODEL

Our system model considers the power domain downlink composition of orthogonal/non-orthogonal LDM/eMBMS transceiver cellular system, respectively. The gNB has an M resource block including K sub-carriers and U users. There are two groups of users, LDM/eMBMS users. Furthermore, we have two groups of resource blocks, the LDM resource block ψ, and the eMBMS resource block Ω. Each group includes several sub-carriers. The UE and BS are equipped with SISO antennas.

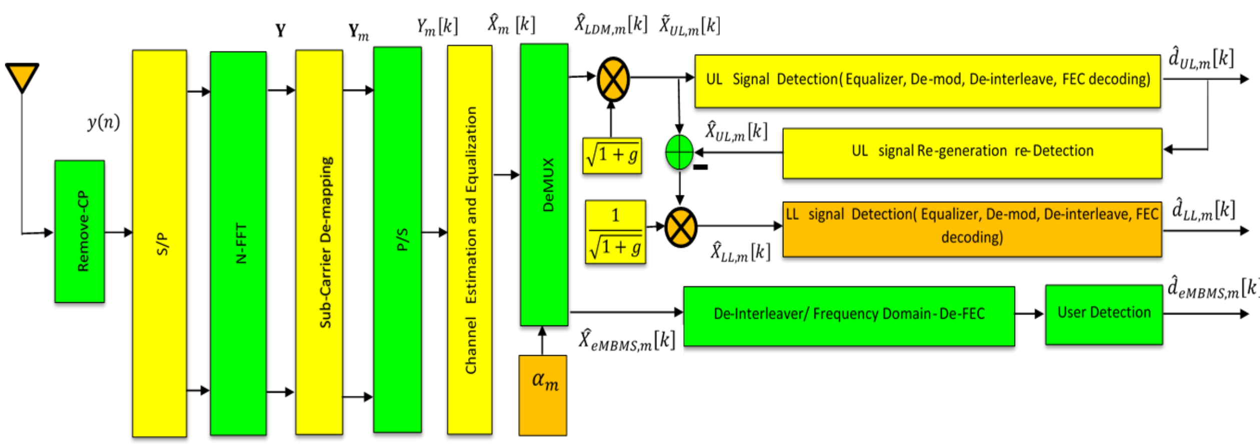
F. 2, shows ig a downlink gNB base station. The LDM non-orthogonal and the eMBMS orthogonal signal are superimposed on the same frequency and time slots physical layer.

In the transmitter part of the system model, as shown in Fig. 2a, the data is generated in two-source, eMBMS, and LDM. The LDM-UL and LL data pass into bit-interleaved coding modulation (BICM) processing blocks in the power domain. As shown in equation (1), the result is multiplied by the g injection power level factor, and then two layers are superposed together in the power domain. The factor g is a parameter related to power adjustment at the transmitter. By utilizing g, the LDM-UL and LL powers are normalized to one. This means that the total power of each bilayer will be equal to one. The other factor which is related to the channel is the average channel variances coefficients power (ACCP) factor which is related to path loss.

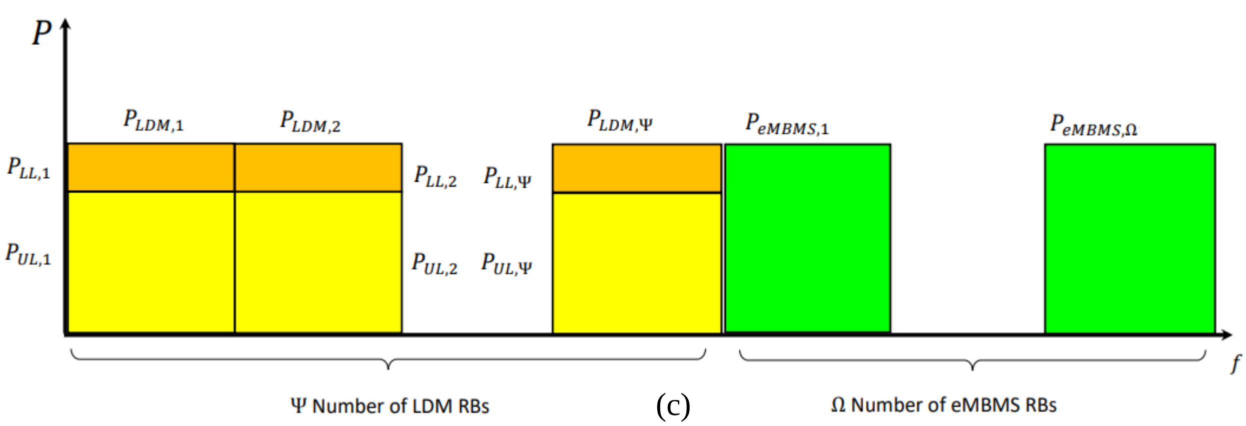
Thereby, the eMBMS signal after passing the BICM will be multiplexed with the LDM part and generates a total transmitting signal [19]-[21]. The composition LDM/eMBMS ultimate signal is converted from serial to parallel. After that, the composition LDM/eMBMS signal is modulated. Then modulated signal passes into the Inverse Fast Fourier Transform (IFFT) [22]. The guard interval is provided by the cyclic prefix (CP). If the CP duration is chosen greater than the delay spread of the channel, then the received OFDM signal does not suffer from inter-symbol interference (ISI). In eMBMS (LTE Broadcast), the normal CP duration is 7% of the core OFDM symbol. Then the signal is converted from digital to analog and it is up-converted into a radio frequency (RF) SISO antenna. The signal passes through the multi-path Rayleigh fading wireless channel. The Rayleigh fading channel is suitable for



(a)



(b)



(c)

Fig. 2 Illustration of Non-orthogonal/Orthogonal LDM/eMBMS transceiver system (a) TX (b) RX (c) RBs Spectrum.

describing wireless channels in densely high power high tower (HPHT) broadcasting populated urban centers [23].

In the reception part, as shown in Fig. 2b, the radio frequency is down-converted and CP is removed from the received signal. The FFT converts the signal from the time domain to the frequency domain and the signal is demodulated. The superimposed signal passes through the channel estimation and equalization block [34]-[36].

The channel estimation and equalization are utilized to select the desired signal along with interference and reduce amplitude, frequency, and phase distortion. Besides, the composing power signal LDM de-normalized and de-multiplexed, and separated into two layers will be decoded by the SIC [37] block, which is employed at the receiver of user equipment (UE). In SIC, the signal of the first user is decoded by treating the signals of other users as interference and then subtracted from the received signals if successfully decoded. The separated eMBMS signal part is detected by a normal receiver. Besides, as shown in Fig. 2c, the composition proposed power-based RBs spectrum is considered in the frequency domain.

IV. MATHEMATICAL ANALYSIS

A. System Basic Formulation

There are M resource blocks (RBs). Each RBs has K sub-carriers and at the m^{th} RB, there are K_m sub-carriers. The number of LDM and eMBMS RBs is ψ and Ω, respectively. If all of the RBs are occupied with LDM and eMBMS data, then the total number of RBs can be written in terms of ψ and Ω as $M = \psi+\Omega$. So the k^{th} sub-carrier mapping of the LDM or eMBMS symbol to the mth RB will be as bellow

$$X_{\mathbf{m}}[k] = \alpha_m X_{\mathbf{LDM},\mathbf{m}}[k] + \beta_m X_{\mathbf{eMBMS},\mathbf{m}}[k] \qquad m = 1, 2, ..., M \text{ or } k = 1, 2...., K_m \tag{1}$$

Where α_m and β_m are allocating symbol coefficients to m^{th} RB for LDM and eMBMS technology, respectively. To select the m^{th} RB from LDM symbols, we assign the variable binary factor as $\alpha_m = 1$ and $\beta_m = 0$. So, to select the m^{th} RB from eMBMS symbols, $\beta_m = 1$ while $\alpha_m = 0$. Hence, $X_{LDM,m}[k]$ indicates the carried symbols in the kth sub-carrier of mth RB in the case of LDM is equal to the summation of UL symbol $X_{UL,m}[k]$ and LL symbol $X_{LL,m}[k]$.

The $P_{UL,m}[k]$ and $P_{LL,m}[k]$ notations are called LDM powers. In this paper, we assume LDM transmit powers don't change from sub-carrier to sub-carrier and RB to RB, but we will drop sub-carrier and RB indices. Therefore, the superposed transmit LDM symbol can be written as follows,

$$X_{\mathbf{LDM,m}}[k] = \sqrt{P_{UL}}\, X_{\mathbf{UL,m}}[k] + \sqrt{P_{LL}}\, X_{\mathbf{LL,m}}[k] \tag{2}$$

So, in an LDM resource block, there can be two users and for eMBMS, RB only one user can be allocated per sub-carriers. LL sub-carriers power is changed with an injection level factor (g) and the summation power is normalized to P_{LDM} . So, the LL and UL transmit powers will be as bellows

$$P_{LL} = \frac{g}{1+g} P_{LDM} \quad and \quad P_{UL} = \frac{1}{1+g} P_{LDM} \tag{3}$$

In this article, we assume that equal power was allocated to the RBs, so the power of the LDM part can be calculated as $P_{LDM} = P_T \frac{\Psi}{M}$. In this case P_{LL} and P_{UL} was calculated. Let T denotes the multicarrier symbol duration and T_{CP} denotes the cyclic prefix duration. The total multi-carrier block duration is $T^{'} = T_U + T_{CP}$. The frequency spacing is $\Delta\mathrm{f} = 1/\mathrm{T}$. The *k*th sub-carrier is defined as $f_k = f_0 + k\Delta f,\ k = 0, \ldots, K - 1$, where f_0 is the first sub-carrier frequency in the pass-band and as a result, the bandwidth will be $B = K\Delta f$. Let $\{X[k]\}_{k=0}^{K-1}$ denotes the information symbol to be transmitted on the *k*th sub-carrier. Let $\{x(n)\}_{n=-K_{CP}}^{K}$, be the cyclic prefixed multicarrier frame sequence. The obtained baseband OFDM modulation in eMBMS can be formulated as

$$x(n) = \frac{1}{\sqrt{K}} \sum_{k=0}^{K-1} X[k] \exp\left(j2\pi \frac{k\langle n\rangle_k}{K} \right) \quad for \quad n = -K_{cp}, \ldots..K-1 \tag{4}$$

Where $K_{CP} = T_{CP}K/T$ and $\langle n\rangle_k$ denotes n mod K. The time-domain transmitted signal in baseband mode is given as follows

$$x(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{K-1} X[k]\ \mathrm{e}^{(j2\pi k\Delta ft)}, \qquad t \in \left[0, T^{'}\right] \tag{5}$$

The baseband received signal y(t) can be written as

$$\mathrm{y(t)} = \int_{-\infty}^{\infty} x(t-\tau)h(\tau)d\tau + w(t) \tag{6}$$

Where $w(t)$ is the complex Additive White Gaussian Noise with zero mean and variance N_0. The $h(\tau)$ is the baseband equivalent of multi-path Rayleigh channel impulse response as bellows

$$h(\tau) = \frac{1}{\sqrt{N}} \sum_{l=0}^{L-1} \alpha_l \mathrm{c}(\tau - \tau_l)\ \mathrm{e}^{(j2\pi f_0 \tau)}, \tag{7}$$

Where $c(\tau)$ is the aggregate impulse response of the transmit and receive filters. The α_l denotes the complex path gains of the multipath fading channel and there are L paths. The discrete baseband channel frequency response H_k can be calculated by using Fourier transform as follows

$$H\left[k\right] = C\left[k\right]\sum_{l=0}^{L-1}\alpha_l \ \mathrm{e}^{-\left(j2\pi f_k \tau_l\right)}, \tag{8}$$

The received signal is sampled at $t = nT_s$ for $t \in \left[0, T^{'}\right]$. Hence, sampled received signal after removing CP samples [33] using (8) is as bellow

$$Y(\mathrm{n}) = \frac{1}{\sqrt{K}}\sum_{k=0}^{K-1} X[\mathrm{k}]H\left[k\right] \ \exp\left(j2\pi kn/K\right) + w(n) \tag{9}$$

After passing through the FFT block, the received signal can be as follows

$$Y\left[\mathrm{k}\right] = \frac{1}{\sqrt{K}}\sum_{n=0}^{K-1} y(n) \ \exp\left(j2\pi kn/K\right) + w(n) \tag{10}$$

$$Y\left[\mathrm{k}\right] = X[\mathrm{k}]H\left[k\right] + W\left[k\right] \tag{11}$$

$$W\left[k\right] = \frac{1}{\sqrt{K}}\sum_{n} w(\mathrm{n}) \ \exp\left(j2\pi kn/K\right) \tag{12}$$

The signal $Y_m\left[k\right]$ is the subcarrier de-mapping recipients from its own RB/RBs which can be introduced as follows

$$Y_m\left[\mathrm{k}\right] = X[\mathrm{k}]H\left[k\right] + W_m\left[k\right] \qquad \forall m \in \{1, 2, ..., M\} \tag{13}$$

In this paper, we assume perfect channel state information (CSI), the channel is frequency selective and time-varying for broadband mobile multi-path broadcasting. The linear estimation for an arbitrary signal from another interference signal is used. The channel estimation can be done using the frequency domain approach. It mainly decreases the computational complexity in the time domain. As shown in Fig. 1 (b), after channel estimation and equalization block, the estimated transmit signal [38] at m^{th} RB can be found as follows

$$\hat{X}_m\left[\mathrm{k}\right] = \frac{Y_m\left[k\right]}{H_m[\mathrm{k}]} \tag{14}$$

If this RB is arranged for an eMBMS user ($\alpha_m = 0$), detection of the user data $\hat{d}_{eMBMS,m}$ is done with this estimated signal. However, if the LDM signal RB is received, $\hat{d}_{UL,m}$, denotes the UL user data detection will do after the signal is de-normalized. Also, the $\hat{d}_{LL,m}$, the LL user data detection, will be done by SIC procedure and is followed by the LL receiver.

B. BER Performance Analysis

In this section, an average BER performance expression for the UL and LL users of the LDM system, using Kara and Kaya's and Jain's derivations [38]-[39], is determined through a mathematical analysis function. Hence, the average error probability of the UL will be as follows

$$\overline{P}_{UL}(e)=\frac{1}{4}\left[\left(1-\sqrt{\frac{\overline{\gamma}_A}{2+\overline{\gamma}_A}}\right)+\left(1-\sqrt{\frac{\overline{\gamma}_B}{2+\overline{\gamma}_B}}\right)\right] \tag{15}$$

Where $\overline{\gamma}_A=\frac{\sqrt{2P_{UL}}+\sqrt{2P_{UL}}E\{|H_{UL}|^2\}}{N_0}$, $\overline{\gamma}_B=\frac{\sqrt{2P_{UL}}-\sqrt{2P_{UL}}E\{|H_{UL}|^2\}}{N_0}$ Here, E{.} is an expectation operator.

The $\overline{\gamma}_A$ and $\overline{\gamma}_B$ notations are the average signal-to-noise ratios (SNRs) for the different signal constellation points for superposed BPSK modulated UL symbols and QPSK modulated LL symbols. The error probability of the LL is as follows

$$\overline{P}_{LL}(e)=\frac{1}{2}\left(1-\sqrt{\frac{\overline{\gamma}_C}{2+\overline{\gamma}_C}}\right)+\frac{1}{8}\left[\left(\sqrt{\frac{\overline{\gamma}_D}{2+\overline{\gamma}_D}}\right)-\sqrt{\frac{\overline{\gamma}_E}{2+\overline{\gamma}_E}}-\sqrt{\frac{\overline{\gamma}_F}{2+\overline{\gamma}_F}}+\sqrt{\frac{\overline{\gamma}_G}{2+\overline{\gamma}_G}}\right] \tag{16}$$

Where the definitions of $\overline{\gamma}_c=\frac{P_{LL}E\{|H_{LL}|^2\}}{N_0}$, $\overline{\gamma}_D=\frac{(\sqrt{2P_{UL}}+\sqrt{2P_{LL}})^2E\{|H_{LL}|^2\}}{N_0}$, $\overline{\gamma}_E=\frac{(\sqrt{2P_{UL}}-\sqrt{2P_{LL}})^2E\{|H_{LL}|^2\}}{N_0}$,

$\overline{\gamma}_F=\frac{(2\sqrt{2P_{UL}}+\sqrt{P_{LL}})^2E\{|H_{LL}|^2\}}{N_0}$ and $\overline{\gamma}_G=\frac{(2\sqrt{P_{UL}}-\sqrt{P_{LL}})^2E\{|H_{LL}|^2\}}{N_0}$ are notations of the average SNRs. The error probability is obtained from [40] and localized in eMBMS part can be written as follows

$$\overline{P}_{eMBMS}(e)=\frac{1}{2}\left(1-\sqrt{\frac{\overline{\gamma}}{2+\overline{\gamma}}}\right) \tag{17}$$

Where $\overline{\gamma}=\frac{2P_{eMBMS}G_{eMBMS}[n]}{N_0}$ is the average SNR of the eMBMS QPSK modulated symbols. We introduce criterion as the channel response normalized by noise and define it as $G_{m,n}=|h_{m,n}|^2/\delta^2$ .Where $h_{m,n}$ is the channel coefficient and $\delta_k^{\ 2}$ is the variance noise power on *k*th sub-carrier in RBs [41]. To assess the effect of the number of RBs on the LDM or eMBMS part, we define the overall average BER error probability of the proposed composition system will be as follows

$$\overline{P}(e)=\frac{\psi(\mathrm{k}_{LL}+\mathrm{k}_{UL})\overline{P}_{LDM}(e)+\Omega\,\mathrm{k}_{eMBMS}\,\overline{P}_{eMBMS}(e)}{\psi(\mathrm{k}_{LL}+\mathrm{k}_{UL})+\Omega\,\mathrm{k}_{eMBMS}} \tag{18}$$

Where $k_{LL} = \log_2 M_{LL}$ and $k_{UL} = \log_2 M_{UL}$ denote the number of bits per LL and UL symbols, respectively. Here M_{LL} and M_{UL} denote the modulation order of the LL and UL symbols, respectively. So, $\overline{P}_{LDM}(e)$ denotes the average BER of the LDM part and can be written as bellow

$$\overline{P}_{LDM}(e) = \frac{1}{(\mathrm{k}_{LL} + \mathrm{k}_{UL})}(\overline{P}_{LL}\,\mathrm{k}_{LL} + \overline{P}_{UL}\,\mathrm{k}_{UL}) \tag{19}$$

C. The Sum Rate Capacity Performance Analysis

A PTM channel distribution BSP is composed of one transmit point and $J > 1$ received points. In such a network, collaboration among the received points may improve the power gain and thus the capacity gain. Denote h_j as the channel coefficient of receive point j with unit variance, and all the $h_j\left(j = 1, 2, 3, \ldots J\right)$ follow the same distribution [41]. The sum rate capacity for PTM becomes

$$C_{PTM} = B\log_2\left(1 + \sum_{j=1}^{J}\frac{P\left|h_j\right|^2}{N_0}\right) \qquad \text{for} \quad j = 1, 2, 3, \ldots J \tag{20}$$

For multiple BSPs transmitting simultaneously, a multiple access rate region is characterized by all the upper bound on the rates based on Shannon's rate law. Since there are LDM and eMBMS and the composition framework, the total sum rate is the summation of each layer rate as bellow

$$R_T = R_{LDM} + R_{eMBMS} \tag{21}$$

Where R_{LDM} and R_{eMBMS} denotes the sum rate of LDM and eMBMS parts, respectively [42]. The sum rate of the eMBMS part can be written, based on Shannon's rate formula, as bellow

$$R_{eMBMS} = \frac{B}{N}\sum_{n=1}^{K_{eMBMS}}\log_2\left(1 + \gamma_{eMBMS}\right) \qquad \forall\ n \in \left\{1, 2, 3, \ldots K_{eMBMS}\right\} \tag{22}$$

Where $\gamma_{eMBMS} = \frac{p_{eMBMS}G_{eMBMS}\left[n\right]}{N_0{}^{ps}}$ is the signal-to-noise ratio per subcarrier received by the eMBMS. It also, $p_{eMBMS} = P_T\frac{\Omega}{MK_{eMBMS}}$, $\forall\ n \in \left\{1, 2, 3, \ldots K_{eMBMS}\right\}$ denotes the transmit power per eMBMS sub-carrier, $K_{eMBMS} = \Omega.K_m$ denotes the total number of eMBMS subcarriers, and $N_0{}^{ps} = N_0\frac{1}{N}$ denotes the noise power per subcarrier. Accordingly, the Shannon rate law for the eMBMS part can be defined as follows

$$R_{eMBMS}\left[n\right] = \frac{B}{N}\sum_{n=1}^{K_{eMBMS}}\log_2\left(1 + \frac{p_{eMBMS}G_{eMBMS}\left[n\right]}{N_0{}^{ps}}\right) \tag{23}$$

The sum rate of the LDM part can be written as

$$R_{LDM}[n] = \frac{B}{N}\sum_{n=1}^{K_{LDM}}\left[\log_2\left(1+\gamma_{LL}\right)+\log_2\left(1+\gamma_{UL}\right)\right] \tag{24}$$

We denote as following $G_{LL}[n] = E\left\{\left|H_{LL}[n]\right|^2\right\}$, $G_{UL}[n] = E\left\{\left|H_{UL}[n]\right|^2\right\}$ and $G_{eMBMS}[n] = E\left\{\left|H_{eMBMS}[n]\right|^2\right\}$. In this case, the total rate of non-orthogonal parts introduce as below

$$R_{LDM}[n] = \frac{B}{N}\left[\sum_{n=1}^{K_{LDM}}\log_2\left(1+\frac{p_{LL}G_{LL}[n]}{N_0{}^{ps}}\right)+\sum_{n=1}^{K_{LDM}}\log\left(1+\frac{p_{UL}G_{UL}[n]}{p_{LL}G_{LL}[n]+N_0{}^{ps}}\right)\right] \tag{25}$$

Where $\gamma_{LL} = \frac{p_{LL}G_{LL}[n]}{N_0{}^{ps}}$ is the signal to noise ratio per subcarrier of LL part of LDM received power $p_{LL}E\left\{|H_{LL}|^2\right\}$ or power density spectrum multiply input signal and received noise, $N_0{}^{ps}$,

$$\gamma_{UL}[n] = \frac{p_{UL}G_{UL}[n]}{p_{LL}G_{LL}[n]+N_0{}^{ps}} \tag{26}$$

Where the (26) is the SINR per subcarrier of UL layer. The $SINR_{UL}$ is the signal to interference noise ratio per subcarrier of UL layer of LDM received power and LL interference plus received noise. Moreover, $p_{LL} = P_{LL}\frac{1}{K_{LDM}}$ and $p_{UL} = P_{UL}\frac{1}{K_{LDM}}$, $\forall\ n \in \{1,2,3,\ldots K_{LDM}\}$ denote the transmit powers per subcarrier of LL and UL respectively and $K_{LDM} = \Omega.K_m$ denotes the total number of LDM subcarriers. Moreover, the second part $p_{UL}G_{UL}[n]$ is receiving power and $N_0{}^{ps}$ is a receiving noise power from the UL, hence, the $p_{LL}G_{LL}[n]$ term is introduced as interferer noise to the UL from the LL for decoding in the SIC receiver.

V. SIMULATION RESULTS

Simulation parameters are shown in Table II. In our scenario, we assign half of the sub-carriers to eMBMS and the others to LDM with equal power allocation for all subcarriers. In our scenario, we assign half of the sub-carriers to eMBMS and the others to LDM with equal power allocation for all subcarriers.

Table II. Simulation Parameters.

Parameter	Value
Channel RF System Bandwidth	5 MHz
Antenna system	SISO
Transmitted power: $P_{T\max}$	46dBm
Number of total Resource blocks: M	16
FFT size: N	8192
OFDM symbol duration	224μs
Guard Interval	0.25 KHz
Center frequency f_0	2.1 GHz
The total number of users U for equal LDM/eMBMS	24
Modulation for LL, UL, and eMBMS	QPSK,BPSK,QAM
Sub carriers separation Δf	0.97 KHz
Channel model	Rayleigh fading channel
Injection Level (g) factor	$0 < g < 1$
A total number of sub-carriers per RBs: K_m	512
Thermal noise density / Noise figure	−174 [dBm/Hz] / 10 [dB]
Number of existing BSPs per cell/layers	2/3

The BS is located in a single cell with a single SISO antenna structure. We suppose that the channel gains of users are modeled as large and small scale fading. Two BSPs seek to provide service to their subscribed users. Users are uniformly distributed in a hexagonal cellular area with a unit length. We consider to BER and sum rate results of the LDM/eMBMS composition framework over a multipath Rayleigh fading channel. The BER and sum rate closed-form simulation and theoretical expressions are matched completely. Moreover, iterative Monte Carlo simulation results are used to evaluate the performance of the proposed non-orthogonal/orthogonal LDM/eMBMS system. To illustrate the performance gains, this section provides simulation results for various LDM/eMBMS composition setups. Primary performance metrics will be coming in the following two sub-sections. In sub-section A,

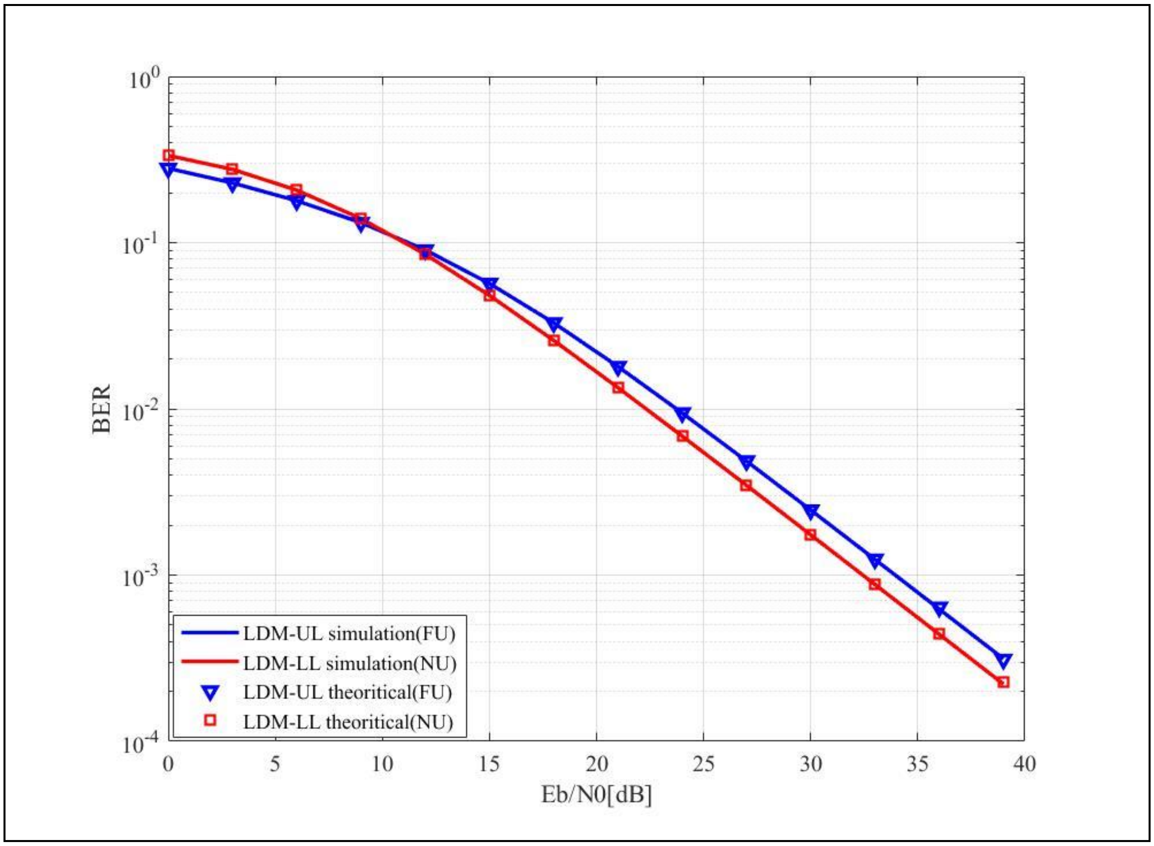


Fig. 3. BER performance of LDM with QPSK for LL (near user)and BPSK for UL (far user).

BER performance results for multi-services, in sub-section B, sum rate performance results for multi-services are used.

A. BER performance results for Multi-services

Simulation results, as shown in Fig. 3, investigate the BER performance of the LDM layers versus E_b/N_0 (dB) under different numbers of receive antennas at the BS. In our scenario, we assume the number of RBs for LDM and eMBMS are equal to $\Omega = \Psi = 8$ blocks. Fig. 3 shows that both theoretical and simulation UL and LL results match completely. Furthermore, LDM technology can support two users in each sub-carrier. Hence, there is facilitate meeting sum rate for two service mobile and fix requirements. Since we use QPSK modulation for LL (near user) and BPSK for UL (far user), the bits per symbol for both layers are $k_{LL} = 2$ and $k_{UL} = 1$, respectively.

As UL users are far from BS compared to LL, we assume that the average frequency domain channel coefficient for UL to be 3 dB lower than LL. To compensate for this, we adjust fixed normalized transmit powers for UL and LL as $P_{LL} = 0.4$ and $P_{UL} = 0.6$. For E_b/N_0 =10 dB up to 40 dB, the LDM-LL

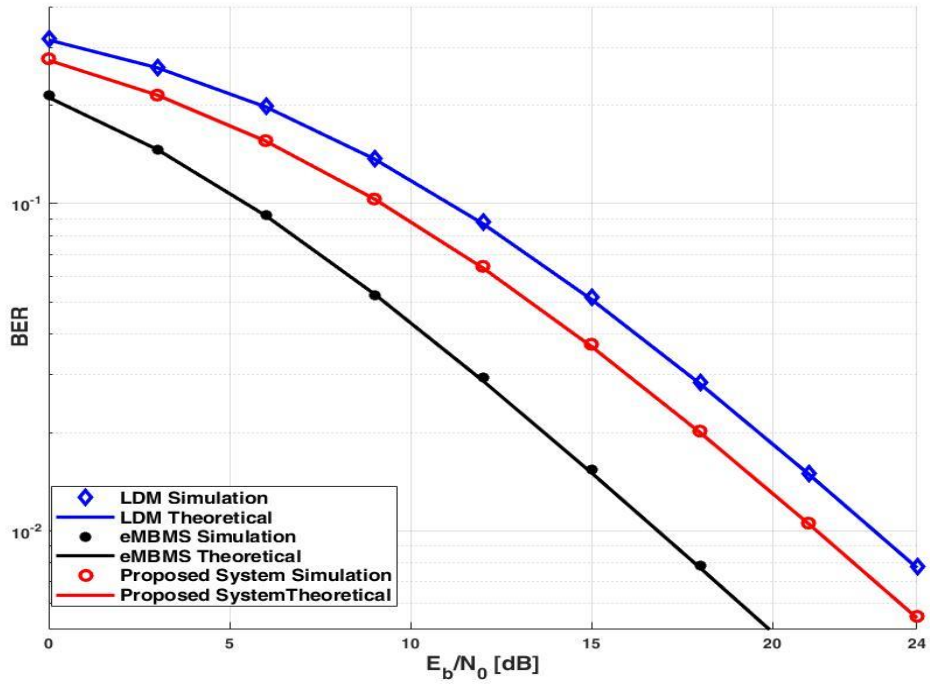


Fig. 4. Comparison of BER performance of LDM/eMBMS individually versus the proposed composition framework.

outperforms BER performance than the LDM-UL. In other words, if E_b/N_0>10dB, it shows the near user outperformed the performance of the far user.

Simulation results, as shown in Fig. 4, we compare the BER performance of LDM and eMBMS with the composition proposed framework against the E_b/N_0 (dB). When the E_b/N_0 (dB) increases, the eMBMS BER performance compared with the LDM and the proposed system framework is improved significantly.

According to the expressions in (15-18), both theoretical and simulation LDM and eMBMS and the proposed results match completely. As expected, the composition proposed framework simulation results are shown that the overall performance average has been located between LDM and eMBMS technologies individually. The results show that the proposed system has the properties of both systems separately.

Fig. 5, shows simulation results for the overall system with different numbers of eMBMS RBs allocation. For both technologies, the number of occupied RBs is the same and the total number of RBs equals M=Ω+Ψ=16.

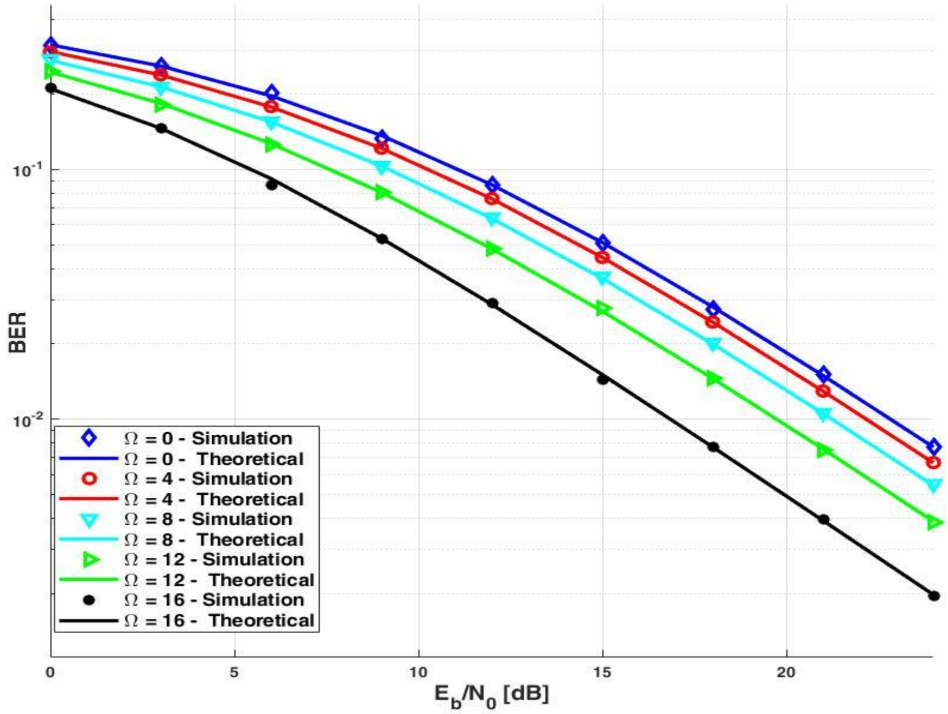


Fig. 5. BER performance of the proposed composition framework over multipath Rayleigh channel while the number of eMBMS RBs (Ω=0,4,8,12,16) changes with different E_b/N_0.

But, the number of eMBMS RBs, Ω , are sequentially taken {0,4,8,12,16} and so the number of MC-LDM RBs, Ψ, is taken {16,12,8,4,0}. It can be easily seen that, while an increasing number of eMBMS RBs, Ω, outperform the BER performance of the overall system. In other words, decreasing the number of LDM RBs, Ψ, leads to outperforming the proposed composition BER performance. Moreover, Fig. 5 shows that closed-form simulation and theoretical expressions are exactly matched.

In Fig. 6, we investigate the impact of the proposed composition BER performance against the number of eMBMS resource block RBs (Ω). Fig. 6 shows that with an increasing number of the eMBMS RBs, the overall BER is outperformed. There is a trade-off between the overall BER and the total sum rate of the system. Also, in Fig. 6, it is assumed Eb/N0 is fixed to 24dB.

B. Sum Rate Performance results for Multi-services

In this work, we have investigated sum rate simulation and the results are shown in Figs. 7, 8, and 9. The sum rate of a SISO mobile broadcast LDM/eMBMS individually and the proposed framework has been illustrated.

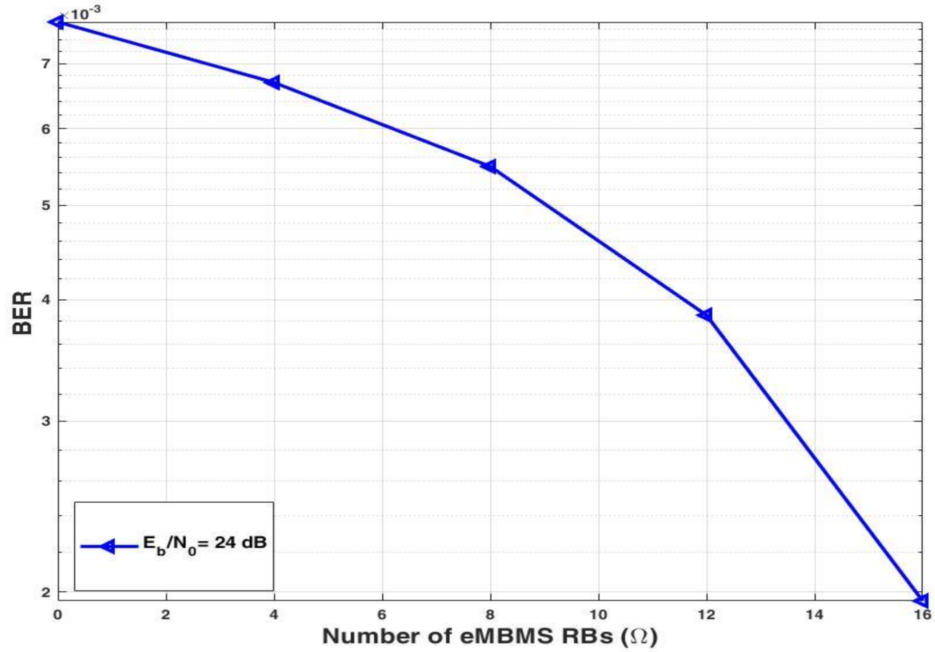


Fig. 6. BER performance of the proposed composition framework versus the number of eMBMS RBs Ω with E_b/N_0=24dB.

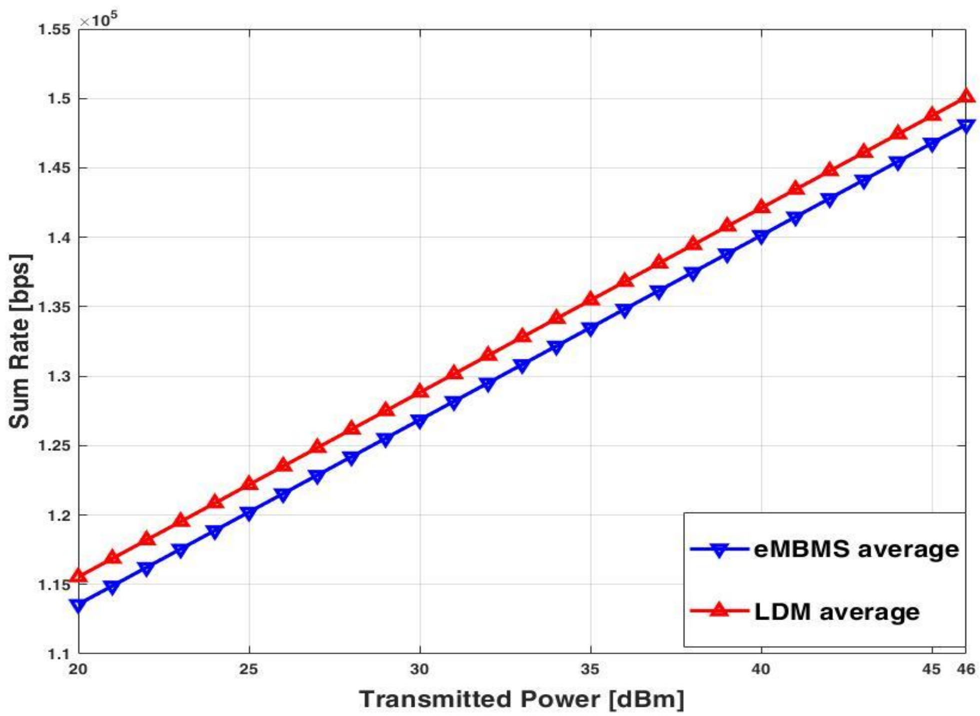


Fig. 7. The average sum rate comparison for the eMBMS and LDM exactly matched the closed-form expression.

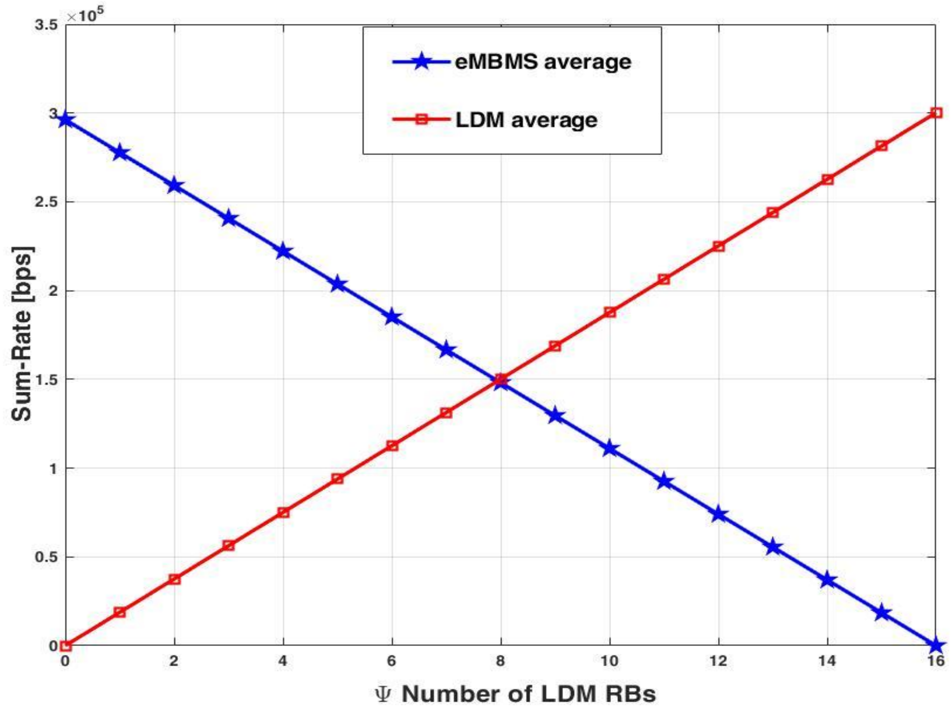


Fig. 8. Comparison of the eMBMS and LDM sum rate of the proposed framework while LDM RBs are changed.

As is shown in Fig. 7, the sum rate of the LDM/eMBMS versus the transmitted power are compared, which indicates that by increasing of transmitted power the LDM sum rate performance is increased. We expected the average LDM sum rate outperforms the average eMBMS sum rate because the LDM channel carries two user symbols channels and the eMBMS carries one user symbol per channel. Fig. 7, shows that a closed-form expression of the achievable sum rate, which holds theoretical and simulation completely matches any number of users. Regarding the transmitted power in the horizontal axis, a comparison has been made with references in [43] - [45].

Fig. 8, shows comparisons of the average sum rate of LDM/eMBMS individually as a function of the Ψ with respect to the number of LDM RBs. Increasing the Ψ the number of LDM RBs, the sum rate will outperform the LDM average system. Decreasing the Ψ, the sum rate value is better than the eMBMS system. We will try to optimize the number of RBs for maximizing the sum rate and minimizing BER.

From another side, Fig. 8, shows the comparison of the sum rate of the eMBMS and LDM as a function of the Ω. The Ω is the number of eMBMS RBs. Hence, by increasing the Ω, the number of eMBMS RBs sum will outperform the eMBMS average system. Decreasing the Ω, the number of eMBMS RBs sum

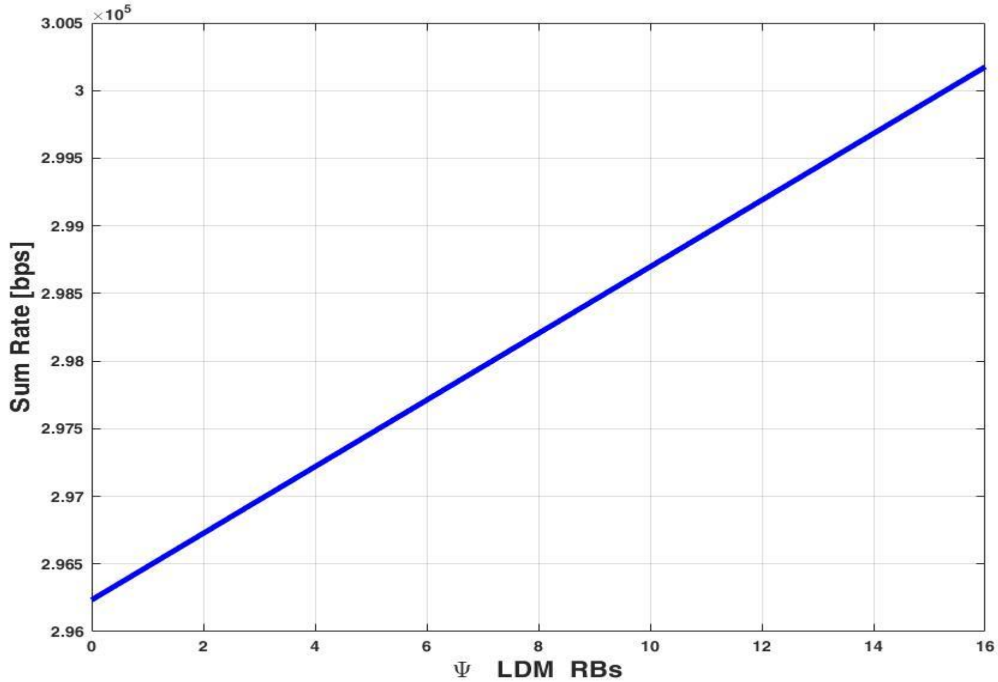


Fig. 9. The total sum rate of the proposed composition framework while a number of LDM RBs Ψ are changed.

rate will be better than the LDM system. We see that the achievable sum rate of closed-form expressions exactly matched with theoretical completely.

Fig. 9, shows the total sum rate performance as a function of the number of LDM RBs Ψ. With increasing Ψ, from 0 to 16 RBs, the sum rate will increase to 0.3 Mbps outperforming the total proposed composition system. Of course, for future directions, we will plot the sum rate of the proposed framework as a function of the number of M-Ψ function, LDM RBs, and try to optimize the number of RBs for maximizing the sum rate and minimizing BER. On contrary, with the decline, the Ω, from 16 to 0, RBs, the sum rate will be reduced to -0.3 Mbps. So, this is the worst case for the total proposed composition system.

VI. CONCLUSION

In this paper, we concentrated on a novelty framework for radio access CDTV service technology. An approach for a composition of orthogonal/non-orthogonal multi-radio layers broadcasting technology multiple services was suggested. We have analyzed the performance of composition LDM/eMBMS versus the individual single-layer BSP. We have investigated the impact of two BSPs in single-cell downlink beamforming over the Rayleigh fading channel multipath system. The system has two binary switch radio access. The binary switch allocation service has been using two options. These options were shown as α_m and β_m. In the proposed idea, the orthogonal eMBMS and non-orthogonal LDM are composed. Both broadband and broadcast are converged. They are utilized for 5G and the next cellular generation broadcasting. The system can work without SIM card uplink and IP for situation crises. An exact closed-form BER and sum rate performances expression are derived. MATLAB simulation results highlight that both theoretical expressions and simulated plots with each other match exactly. Therefore, it is concluded that non-orthogonal/orthogonal average composition LDM/eMBMS framework technology outperformed BER and sum rate performance compared to an individual technology. Therefore, we recommend it for next-generation CDTV broadcast.

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