# Performance Analysis of LTE Multicast Systems in the Presence of the Colored Noise Jamming

S. Malisuwan, J. Sivaraks, N. Madan, and N. Suriyakrai

***Abstract*—The ever going evolution of advanced wireless technologies makes it financially impossible for military operations to completely manufacture their own equipment. Therefore, Commercial-Off-The-Shelf (COTS) and Modified-Off-The-Shelf (MOTS) are considering in military mission with low-cost modifications. In this paper, we focus on the LTE multicast systems for military communication systems under tactical environments with jamming condition. We examine the influence of the colored noise jamming on the performance of the LTE multicast systems in term of the average throughput. The simulation results demonstrate the degradation of the average throughput for different dynamic ranges of the colored noise jamming versus average SNR.**

***Index Terms*—Performance, LTE, multicast, jamming, throughput.**

## I. Introduction

Multicarrier systems such as OFDMA are employed for high-rate data transmission [1]-[3]. OFDM is used for wireless local area networks (LAN) such as HIPERLAN/2, 4G, High BIT Rate Digital Subscriber (HDSLs), digital video broadcasting (DVB) and asymmetric digital subscriber loops (ADSLs) [4].

Presently most mobile systems work on UHF band which ranges from 300 MHz to 3 GHz spectrum. For UHF band, the main obstacle is buildings which results in attenuation and radio waves cannot propagate through the building. Therefore, base stations are located in an open space and have wide bean antennas in order to reach a large area but this makes it vulnerable to interference from jamming.

Jamming is when a signal to deter communication is transmitted to receiving antenna at the same frequency or sub band, which is usually how the communication transmitter transmits. To deter or prevent communication between two friendly lines the jammer sends a signal in form of tones [5], [6] or noise [7]-[10] to the receiver at the same frequency band or sub-band that the transmitter uses.

However, transmission can never be jammed but rather jammer hinders communication reception at the other end. Hindering communication or jamming is successful if it denies the usability of the communication transmission. Further, usability is denied when the error rate of the transmission cannot be compensated by error correction hence, resulting in hindering of communication in friendly lines. "Usually a successful jamming attack requires that the jammer power is roughly equal to signal power at the receiver" [11].

Usually all digital communication systems require a synchronization signal to be transmitted between communication devices. Therefore, jamming can be focused on the synchronization signal, hence effectively cutting the entire communication transmission between the devices. As a result, synchronization systems are at risk of jamming. If synchronization is lost, the jammer can end the transmission and restart jamming after it is resynchronized.

In this paper, we evaluate LTE multicast performance under jamming. Basically, researchers consider that jammer acts as an additive Gaussian noise source with zero mean, and assuming that the total power of jamming signal is uniformly distributed over entire bandwidth of OFDM multicast spectrum. But, in this paper, we propose the jamming signal model as the additive colored Gaussian noise which is more practical in the tactical communication systems. The performance of the LTE multicast systems will be described as the average throughput of one user with different dynamic ranges.

The organization of the paper is as follows. Section II briefly outlines the LTE multicast systems. Jamming signal model is described in Section III. Performance of LTE multicast in term of the average throughput is furnished in Section IV. The simulation and results are in Section V. Conclusion are drawn in Section VI.

## II. LTE Multicast Systems

LTE multicast is when a base station (BS) broadcasts to a multiple group of users, namely the multicast group. For the signal reception to be good and for each user, a method is adopted where adapting data transmission rate to the worst channel among all users in the multicast group. However, data transmission speed decreases if the number of multicast users increases. "In a system with fixed number of channels (e.g., subcarrier in OFDM systems) and fixed user population, the bandwidth resource allocated to a group is proportional to the number of users in the group" [12].

Fig. 1 illustrates multicast group with $k$ users are allocated $k$ fixed subcarriers in a wireless OFDM system. The BS transmits data to the users on subcarrier $n$ at a transmission rate $r_n^g$ for the $g$-th multicast group [13].

Consider a wireless OFDM multicast system with $J$ subcarriers and $K$ users requiring the same desirable program from the BS. The users are equally divided into $G$ multicast groups. Assuming that $K$ is divisible by $G$ and $J$ is an integer multiple of $K$, each multicast group is associated with $k = K/G$ users and $jk$ subcarriers, where $j = J/K$. For

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simplification, we assume $J = K$ in the rest of the paper, as shown in Fig. 1. Our results, however, easily extends to the case with $j > 1$. We further assume that equal power is transmitted on all subcarriers.

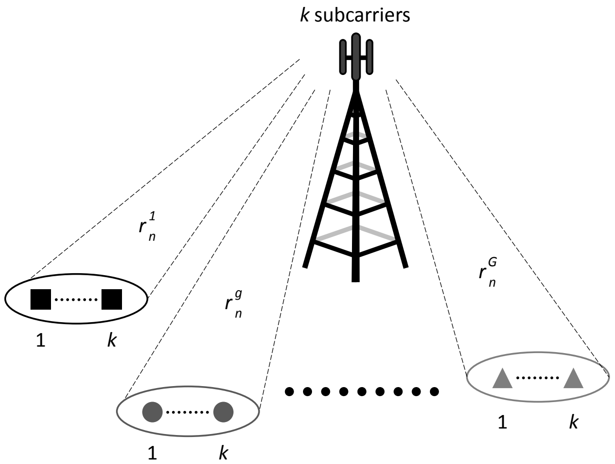


Fig. 1. LTE Multicast system: a base station (BS) broadcasts data to multicast groups.

"All subcarriers of an OFDM signal are radiated with the same power. Therefore its power spectral density is constant or "white" over its whole bandwidth. It is also a common assumption that the distribution of the amplitudes of an OFDM signal is Gaussian" [14].

In this paper, we investigate the influence of an OFDM multicast system under jamming. In modern tactical communication today, it cannot be concluded that the jamming can be necessarily interpreted as AWGN.

## III. Jamming Signal Model

Due to the specification of the OFDM systems, we can expect the channels to be frequency synchronized. Time synchronization, however, is not very likely since OFDM signal and jamming signal are radiated from different base stations and come into the receiver over independent paths.

In this paper, we propose a discrete channel model for data transmission with additive colored Gaussian noise that can be used to model the influence of a jamming OFDM channel for our study.

To describe the concept of the jamming signal model we restate the derivation of the model from the reference [15] in this section.

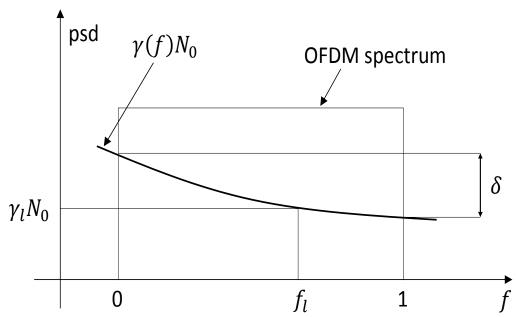


Fig. 2. An OFDM user spectrum and the psd of the colored noise process over the normalized frequency.

In our jamming signal model, we adopt the concept of the colored noise process over the normalized frequency in [15]. Fig. 2 shows the illustration of an OFDM user spectrum and the psd of the jamming signal over the normalized frequency. $\delta$ is the dynamic range, defined as:

$$\delta = \frac{\gamma_{max}}{\gamma_{min}}. \tag{1}$$

It is the power ratio between the highest and lowest value of $\gamma$.

To model the shape of its psd, we define a frequency dependent power weighting factor $\gamma \in \mathbb{R}^+$. So the noise psd at frequency $f_l$ is $\gamma_l N_0$ with $\gamma_l = \gamma(f_l)$. For convenience, we normalize the frequency so that $f = 0$ represents the left edge and $f = 1$ represents the right edge of the OFDM bandwidth. A symbol that is transmitted at frequency $f_l$, is then distorted by AWGN with noise power spectral density $\gamma_l N_0$.

Based on the reference [15], the frequency interleaver maps every complex symbol $x_i$ to a certain frequency $f_i$. So if we assume ideal interleaveing, this frequency can be regarded as random variable, that is uniformly distributed over the interval (0, 1).

This leads to our proposed discrete channel model in Fig. 3. The sequence $\mathbf{x}$ of $K$ complex data symbols is distorted by additive noise $\mathbf{n} = (n_1, \dots, n_K)^T$. This noise vector $\mathbf{n}$ results from the multiplication of white Gaussian noise $\mathbf{w} = (w_1, \dots, w_K)^T$ with variance $\boldsymbol{E}\{w_i^2\} = \sigma^2 = N_0/2$ and the matrix of weighting factors $\mathbf{L} = diag(\sqrt{\gamma_1}, \dots, \sqrt{\gamma_K})$. The factors $\sqrt{\gamma_i}$ can be found via the transformation of the uniformly distributed random variable $f$ through $\gamma_i = \gamma(f_i)$. The input to the receiver is

$$\mathbf{y} = \mathbf{x} + \mathbf{L}\mathbf{w} \tag{2}$$

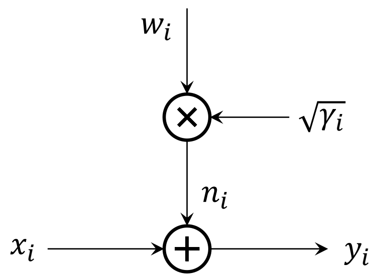


Fig. 3. Proposed channel model for additive colored Gaussian noise.

## IV. Performance of LTE Multicast: Average Throughput

To achieve the objective of this paper, we evaluate the performance of the LTE multicast per one user. We use the procedure in [12], [15] to obtain the user's average throughput as a function of the size of a multicast group.

In the LTE multicast transmission of this research, we transmit the BPSK symbols over the channel model from section III.

At the transmitter, data bits are mapped to complex symbols and, following the OFDM principle, $N_c$ symbols are radiated simultaneously over orthogonal subcarriers within the bandwidth $B = N_c T_s^{-1}$.

Based on [15], the results of the derivation of the psd of the colored noise process are used in this paper. We also adopt the average throughput of one user in [12]. By assuming each user perceives i.i.d. Rayleigh fading channels, the average throughput of one user is given by:

$$C = k \int_{\gamma} B \log_2 \left(1 + \frac{PT_s}{N_0 N_c}\gamma\right) p(\gamma) d\gamma \tag{3}$$

As psd of the colored noise process shown in Fig. 2, we choose the function

$$\gamma(f) = \frac{a}{f + b} \tag{4}$$

with $a, b \in \mathbb{R}^+$ free but constant parameters.

The uniformly distributed random variable $f$ is transformed to the random variable $\gamma$ by Eqn.(4). The probability density function (pdf) $p(\gamma)$ of this transformed random variable is defined by $p(\gamma)d\gamma = -df$, where the minus sign is used because $\gamma(f)$ is monotonically decreasing. Hence,

$$p(\gamma) = \frac{a}{\gamma^2}. \tag{5}$$

## V. Simulation and Results

In this section, we analyze the average throughput from Eqn. (3) under the different dynamic ranges $\delta$ of the colored noise jamming for the multicast group size $k = 100$. We also simulate in the case of increasing the multicast group size ($k$) to observe the performance of the systems.

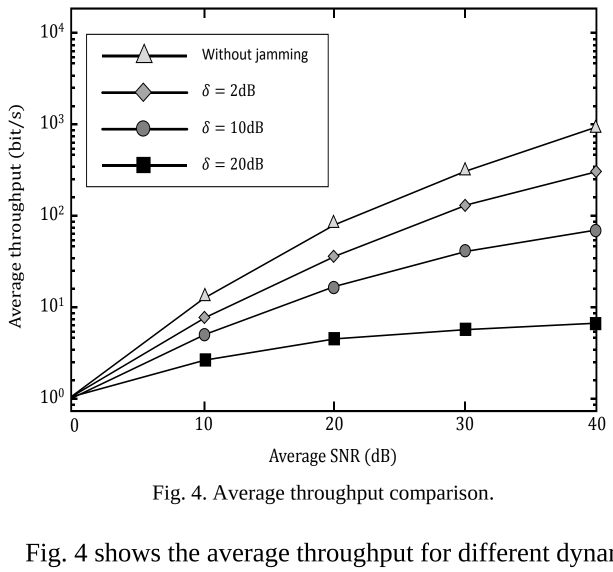


Fig. 4. Average throughput comparison.

Fig. 4 shows the average throughput for different dynamic ranges versus average SNR that is simulated by MATLAB. The simulation results can be explained that, for noise jamming with $\delta = 2$dB, most of all subcarriers are received correctly. For $\delta = 10$dB, there are some subcarriers that are corrupted by very intense jamming signal therefore the average throughput is degraded. For $\delta = 20$dB, most of all subcarriers are corrupted by very intense jamming signal. So, the performance of the systems is unacceptable.

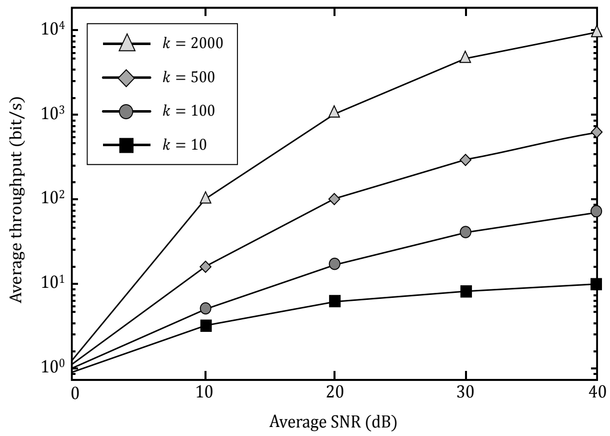


Fig. 5. Throughput comparison for different group size with $\delta = 10$dB.

In Fig. 5, we can observe that when the multicast group size increases, the average throughput also increases even though under the jamming condition. It has been also proved in [12] that despite the decreasing data rate on each subcarrier with the increasing group size, the analysis shows that the expected throughput received by each user increases with the number of users in a group.

## VI. Conclusion

In this paper, we investigate the performance of LTE multicast systems when the bandwidth resource allocated to a multicast group is jammed by the colored noise jamming signal. We observe that when the dynamic range of the colored noise jamming signal increases, the average throughput decrease with a specific multicast group size. However, we also observe that when we increase a multicast group size, the average throughput received by each user increases. Our analysis matches the simulation results in the previous researches.

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