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# SER performance of cooperative systems with the *N*th best path selection in generalized-*K* channels

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**Abstract**

We investigate performance of the both variable and fixed-gain amplify-and-forward cooperative communication systems over composite fading and shadowing channels modeled by independent but not necessarily identically distributed generalized-*K* distribution. We consider two different *N*th best path selection schemes: the *N*th best relay and link selection. In the *N*th best relay selection (RS) scheme, signals received from the *N*th best relay and the direct path are combined with maximal-ratio combining and decoded at the destination. In the *N*th best link selection (LS) scheme, the direct path is included to the selection set and only the signal received from the selected path is decoded at the destination. New symbol error rate (SER) expressions are derived analytically by using the moment generating function (MGF) approach with Padé approximation and the cumulative distribution function approach. The MGF and SER expressions are in closed-form for the *N*th best RS and LS systems, respectively. The derived SER expressions are almost exact at any signal-to-noise ratio. We also present the asymptotic diversity order of the system. The analytical results are verified by Monte-Carlo simulations. Since the generalized-*K* channel model is a quite general channel model, the existing symbol error probability results given in the literature for cooperative systems with path selection over conventional Rayleigh or Nakagami-*m* fading channels can be obtained as special cases of our results.


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## 1. Introduction

Radio signals propagate in wireless channels under various impairments such as multipath fading, shadowing and noise. Typically, the fading is modeled by using Rayleigh, Rician or Nakagami-*m* distributions and the shadowing is modeled by using lognormal distribution [1]. In many practical cases, the fading and shadowing effects should be considered simultaneously to obtain more realistic channel models. For such channels, lognormal-based composite channel models can be used [2]. However, these models do not lead to closed-form expressions for the probability density function of the signal-to-noise ratio (SNR) at the receiver and therefore performance analysis over these channels becomes cumbersome. A relatively new composite channel model is the generalized-*K* channel which allows the mathematical tractability of the system performance analyses [3]. Various channel models such as Nakagami/lognormal are accurately approximated by this channel and also Nakagami-*m* and *K*-distribution are special forms of it. In the literature, performance analysis over generalized-*K* channels was given, e.g., in [4,5].

The receive diversity is an important technique that efficiently combats the destructive effects of the wireless communication channels and increases the system error performance and capacity by using multiple antennas at the receiver side [1]. Two of the most important conventional receive diversity methods are selection combining (SC) where the signal with the highest SNR is selected and maximal-ratio combining (MRC) where the received signals are weighted optimally using the channel state information (CSI) and combined coherently. Although the MRC technique yields the best possible error performance, it is more complex than the SC method due to the full CSI requirement. However, the SC method is the least complicated one since it only requires SNR measurements. This allows to design low-complexity and cheap receivers with reduced power consumption. Obviously, these are important advantages especially for the design of wireless/mobile communication systems and devices. In the literature, error performance analyses of the diversity combining systems are presented over the generalized-*K* channels [6–8]. Although antenna diversity technique provides significant improvements in error performance, mounting multiple antennas on limited-size communication devices might be problem in practice. Cooperative communication efficiently solves this problem since it can create a virtual antenna array by means of several single-antenna terminals [9,10]. In this technique, signals are transmitted from source to destination directly and/or with the aid of relays, hence it provides spatial diversity, coverage extension and capacity enhancement, which are important particularly in regions with severe fading and shadowing in cellular communication. As well known, amplify-and-forward (AF) and decode-and-forward are the most popular signal forwarding methods used at the relays [9,10]. In the AF method, the relay simply amplifies the received signal according to CSI of the source–relay link. The amplification gain can be fixed or variable. Then, the amplified signal is forwarded to the destination. The AF method leads to low-complexity relays as well as low power consumption.

In order to avoid interference in cooperative communications, signals are usually transmitted on orthogonal channels by the source and relays, which leads to spectrally inefficient communication especially when more than one relays are used. In this case, the "full" spatial diversity can be realized in distributed fashion [11]. Fortunately, the path selection approach provides the same asymptotic diversity order, hence good error performance without decreasing the spectral efficiency since it requires at most only two orthogonal channels [12]. The relay selection (RS) [12,14,13,15] and distributed SC [16–22] are two important techniques in this sense. In the RS, the best relay is selected to forward the signal and distributed MRC is applied by using this selected path and the direct path. The transmission takes exactly two time slots in

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