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(Ref: [1])

1. **System model**



Figure 1. System model of cooperative communication between Primary and Secondary networks.

Figure 1 presents a system model of direct communication between the transmit source, S, and receive destination, D. We assume that each node has a single antenna and the transmit power *P* and node D suffers the zero-mean additive white Gaussian noise (AWGN) with the variance *N0*.

In Figure 1,  denotes the **Rayleigh** fading channel coefficient and the link distance of S-D. Therefore, the channel gain  is **exponential** distribution random variable (RV) with parameter which is given as, where is the path-loss exponent. The probability density function (PDF) and cumulative distribution function (CDF) of RV *g* are and .

The S broadcasts a signal *xS* to the D, . The received signal at the D is given as:

 (1)

where *nD* is the zero-mean at node D.

The received signal-to-noise ratio (SNR) at the D can be expressed as

 (2)

where is the transmit SNR.

In a two-dimensional plane, the coordinates of the nodes are set to S(0, 0), and D(1, 0). Hence, the distance of the S-D link is 1 (*d=1*) during the simulation intervals. We assume that the path-loss exponent, and the target data rate of the direct network are constants (), and the SNR symbol in the *x*-axis is defined as.

1. **Outage Probability**

The achievable data rate between the S and the D is given from (1) as

 (3)

The outage probability at the D is expressed as

 (4)

1. **BER/ESR**

The average SER of link S-D can be calculated as

 (5)

where *a* and *b* are constants that depend on the modulation type, e.g., *a=b=1* for BPSK modulation;  is the received SNR at the node D; and is the CDF of the RV  and is given as  (6)

Then,  is solved as

 (7)

1. **Average Capacity**

The average capacity of link S-D can be calculated as

 (8)

Where:  is the incomplete gamma function, .

**Probability Book:** Probability, Random Variables and Stobchastic Processes, 4Th Ed - Athanasios Papoulis, S Unnikrishna Pillai (Mcgraw-Hill) (quickly: Chapter 4, 5 and 6)

[1] "<2020 Performance Analysis of Reconfigurable Intelligent Surface-Assisted Wireless Systems and Comparison With Relaying.pdf>."