Simulation of packet dropouts over wireless channels considering Rayleigh fading effects

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***Executive Summary*— This document describes how we implement a Rayleigh fading model for use in a multi-robot communication simulation. The main objective of this work is to characterize communication losses in multi-agent settings that require high levels of collaboration.**

I. INTRODUCTION

Rayleigh fading models should ideally consider the effects of time-correlation, thus accurately simulating burst errors. In the communications literature, there are three popular methods of generating correlated Rayleigh random variates, filtering of white Gaussian noise (WGN) [1], Monte-Carlo superposition of sinusoids method [2] [3], and the inverse discrete Fourier transform (IDFT) method [4] [5]. The three methods are thoroughly compared and quantitative statistical results are presented in [5]. The IDFT technique is well known to be a high-quality and efficient fading generator. Therefore, we implement the *IDFT method* with a moving horizon to mitigate the computation requirements.

We consider a band-limited Rayleigh fading process, whose power spectral density (PSD) is zero past the maximum Doppler frequency. The propagation path is assumed to consist of isotropic scattering and the receiver is assumed to have a vertical monopole antenna. We use UDP as the protocol to transmit packets; it utilizes checksums for data integrity. The signal is said to be *lost* if the received power falls below the receiver sensitivity threshold [6].

The proposed model depends on the required time horizon of the fading sequence h, symbol (or packet) frequency f_s, maximum Doppler frequency f_m, and the required number of points within the Doppler spectrum, N. The maximum Doppler shift, f_m is defined as v/λ, where v is the relative velocity between transmitter and receiver, and λ is the wavelength of radio waves, assumed to lie within the 2.4GHz bandwidth. The Rayleigh variates are generated once every h seconds.

II. OUR METHODOLOGY TO GENERATE RAYLEIGH VARIATES

The dataset consisting of the Rayleigh variates is computed through the following steps, (see Figure 1)

1) Initialise the parameters: h, f_s, f_m and N
2) Generate two sets of i.i.d. zero-mean, unit-variance Gaussian variables of length N: $A[k]$ and $B[k]$, in-phase and quadrature components, respectively.

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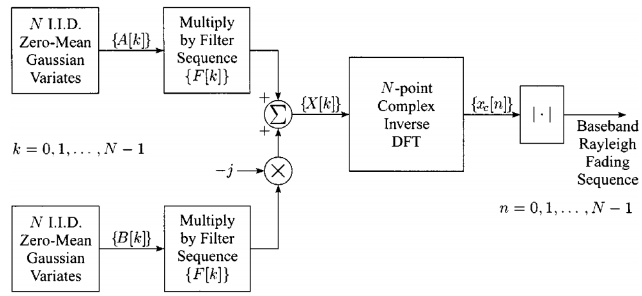


Fig. 1: Block diagram to generate Rayleigh fading variables using IDFT [5]

3) Weight the sequences with a set of real-valued filter coefficients $F[k]$, as defined in [5].
4) Add the in-phase and quadrature components to form the complex Gaussian sequence.
5) Perform an inverse FFT on this sequence to yield a time-series data.
6) Compute the absolute value of the complex sequence to form the Rayleigh fading variates
7) Repeat steps 2-6 for $t = h, 2h, 3h \ldots$, where, h is the length of the time-horizon.

Note that the horizon length h, over which we require the Rayleigh variates, should be greater than or equal to N/f_s. Also h should not be too large, that performing the IDFT operation becomes computationally intractable.

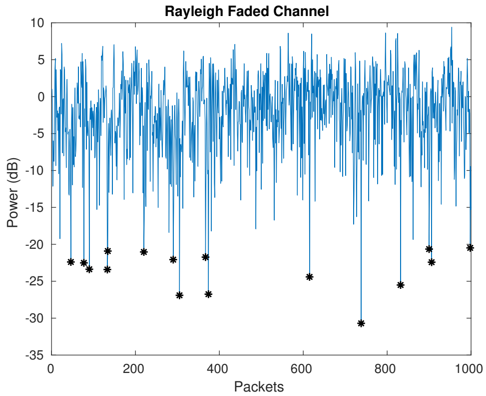
III. PRELIMINARY RESULTS

The signal communication for stationary as well as moving receivers was simulated in MATLAB. The Rayleigh variates were generated using inverse Fast Fourier Transform (IFFT) to optimize the computational effort. Figure 2 illustrates the Rayleigh fading effects and subsequent packet loss. Figure 2b corroborates the fact that the generated variates are indeed Rayleigh-distributed.

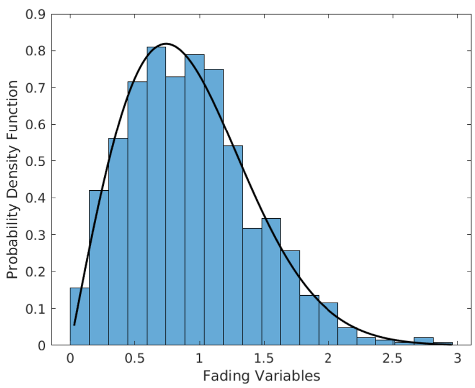
The total signal attenuation P_L, expressed in dB, is given by $P_L = P_{PL} + P_S + P_F$. Where, P_{PL}, P_S and P_F are the power loss due to path loss, shadowing and fading, respectively. The path loss and shadowing are modelled as,

$$\begin{aligned} P_{PL} &= P_{L_0} + 10\gamma \log_{10}\left(\frac{d}{d_0}\right) \\ P_S &= 10 \log_{10}\left(\mathcal{N}(0, \sigma)\right) \end{aligned} \tag{1}$$

where γ is the path loss exponent, P_{L_0} is the loss in signal power at a reference distance d_0, and $\mathcal{N}(0, \sigma)$ refers to a zero-mean Gaussian process. The total power loss and consequent packet loss based on (1) have also been studied for a stationary transmitter and a receiver moving at various velocities (see Figure 3).



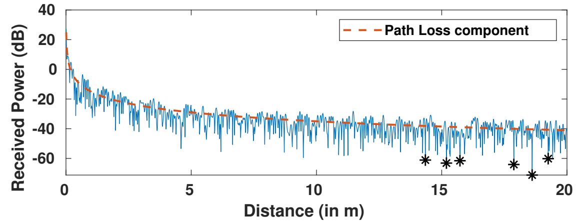
(a) Noise in received signal



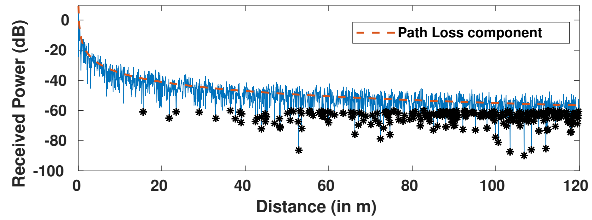
(b) Probability distribution of the generated variates

Fig. 2: Simulation results: Fading effects observed by a receiver moving at 3 m/s, with transmitter being stationary. * represents packets that have got dropped.

In Figure 3, we observe that even though the mean signal power (dashed line) is above the sensitivity threshold value, packets get dropped because of the fading effects. Therefore, it is highly imperative to pay more attention in modelling and incorporating the fading phenomenon.



(a) $v = 1\ m/s$



(b) $v = 6\ m/s$

Fig. 3: Simulation results: Signal attenuation observed by a moving receiver. The receiver sensitivity threshold is $-60\ dB$. * represents packets that have got dropped.

References

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