Performance Evaluation of Fading Channels In Non-Regenerative Communication Protocol

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Abstract: ***There is a high demand for higher data rates and improved link reliability in wireless communication networks with the growth of multimedia services. Even though Mulltiple-Input-Multiple-Output (MIMO) systems can achieve these demands, they face some limitations when they are deployed in single antenna systems such as mobile handsets. In this context cooperative communication has attracted considerable attention where relays cooperate to achieve MIMO gains. This work evaluates the Bit Error Rate (BER) performance of Multi-hop non-regenerative communication protocol for cooperative communication system deploying Quadrature Phase Shift Keying (QPSK) modulation over different fading channels for 3 hop and 2 hop cases. The simulated results show that the increase in number of relays in non-regenerative communication protocol have same effect when different fading channels are used and that the performance of the system improves due to the extended network coverage even though there is an increase in BER. Also analysed the performance of system in Compress-and-Forward (CF) relaying protocol for cooperative communication system. Simulation is done using MATLAB which is an ideal tool for simulating digital communication system.***

Keywords: BER, cooperative communication, fading, non-regenerative relaying, relaying protocols**.**

1. Introduction

In wireless communication networks, there is an increasing demand for high data rate starting from first generation of wireless cellular networks [1]. One of the solution for this problem is to increase the base stations, which results in high deployment costs. For extending network coverage of future systems, fundamental enhancements are necessary. In order to meet the demand for high data rate and coverage extension, cooperative communication can be used which deploys Multi-hop wireless networking. Multi-hop wireless networks use relays between source and destination. Deployment of relays reduces the transmit power requirements compared to installing Base Station (BS). This permits the amplifier in relay to be economically designed. Furthermore, mast required for relay is not as high as that for BS, thus reducing operation expenses such as maintenance and tower leasing costs.

Single antenna mobiles in a multiuser environment can be used to generate a virtual multiple-antenna transmitter by exploiting the concept of cooperative communication [2]. In cooperative relaying, source node sends a broadcast message to relay node and destination. The relay then forwards additional information about the source message to destination, which combines the received data.

Communication system is characterized by transmitter, receiver and a channel between them. In wireless communication, signal attenuate while propagating from transmitter to receiver as medium introduces impairments to the signal. Rapid fluctuation in amplitude and phase of signal due to multipath propagation of signal is called fading [3].

Different fading models used to estimate the fading over a channel include Nakagami fading, Rayleigh fading, Rician fading, Flat fading and AWGN. In communications theory, Rayleigh, rician and nakagami distributions are used to model scattered signals that reaches the receiver by multipath. Signal will display different fading characteristics depending on density of scatters. Dense scatters are modeled using Rayleigh and Nakagami distributions.

2. Cooperative communication

One of the most promising techniques in wireless communication network is cooperative communication. To assist direct transmission such as "source to destination" transmission mode, one or more Relay Node (RN) is used in this technique. By exploiting broadcasting nature of wireless communications, RN receive signals sent by the source and forward them to destination. In order to achieve diversity gain, destination combines and decodes the signals from independent channels. Most of the existing research work on cooperative communication is focused on Non-regenerative / Amplify-and-Forward (AF), Regenerative / Decode-and-Forward (DF) and Compress-and-Forward (CF) relaying protocols.

In wireless communication networks, deployment of relaying has attracted considerable attention due to its improved spectral efficiency, coverage extension and energy saving. In general, relay transmission schemes can be basically classified into regenerative or non-regenerative systems. Regenerative systems use more complex relays that decode the signal received through first hop and retransmit it, after appropriate encoding, into the second hop.

Idea behind cooperative relaying is to exploit broadcast nature of wireless medium and its ability to achieve diversity through independent channels. Broadcast nature is considered to be a drawback as it leads to mutual interference in wireless network. Cooperative relaying system has source node, relay node and destination node. Source node transmits the signal directly to destination node and also transmits through relay. Destination node combines the signal received from relays and original signal from source. Thus, achieves diversity. In cooperative communication system, each wireless user is assumed to transmit data as well as act as cooperative agent for another user.

3. Cooperative relaying protocols

There are two phases for the transmission of data from source to destination. In first phase, source transmits data both to relay and destination. In the second phase, relay processes the receive data and retransmits it to destination.

3.1 Non-Regenerative Communication Protocol

In non-regenerative relaying, signal from source is first transmitted to destination and relay node in phase 1, whereas relay amplifies the received signal and retransmits it to destination during second phase [4]. Relay receives the information signal with channel gain and noise. At the receiver, it decodes the combined signal using Maximum Ratio Combiner (MRC).

Suppose that the source is transmitting its information m to relay and destination with transmission power Ps to destination and relays. Received signal at relay and destination is given by

$$y_{sd} = \sqrt{P_s} h_{sd} m + n_{sd} \quad (1)$$

$$y_{sr} = \sqrt{P_s} h_{sr} m + n_{sr} \quad (2)$$

where h_{sd} and h_{sr} is the fading amplitude of the channel between source and the relay and destination, respectively. In equation, n_{sd} and n_{sr} are the additive noise. In AF relaying scheme amplification factor is given by

$$amp = \sqrt{P_k} / (P_s |h_{sr}|^2 + P_s + N_0) \quad (3)$$

P_k is the transmit power of any relay. Then, all the relays will forward the scaled versions of the received signal to D in the matched phases. So at the destination terminal, the received signals from the relay R can be written as

$$y_{rd} = amp\ h_{rd} y_{sr} + n_{rd} \quad (4)$$

$$= amp\ h_{rd} (\sqrt{P_s} h_{sr} m + n_{sr}) + n_{rd} \quad (5)$$

where h_{rd} is the fading amplitude of the channel between the relay and destination. In the case of Multi-relay cooperation based amplify and forward relaying, each relay applies an MRC detector on the signals that it receives from the source and all previous relays. There will be N + 1 phases for a system with N relay nodes.

3.2 Regenerative communication protocol

Instead of amplifying the signal received from source, another possibility for the relay is to decode the received signal from source and then retransmit to destination. DF scheme can be used to avoid error propagation if the channel between relay and destination is reliable. But, if the decoded signal at the relay is incorrect then forwarding incorrect signal to destination is meaningless. Here, performance of system is limited by worst link from source-relay and source-destination.

4. Fading in wireless communication

Due to multipath propagation of waves, rapid fluctuations in amplitude and phase occurs. This random fluctuations in received signal is called fading. In small scale fading, signal amplitude has a short term fluctuation due to local multipath propagation.

4.1 Flat fading

A received signal is said to undergo flat fading if the mobile radio channel has a constant gain and a linear phase response over a bandwidth larger than the bandwidth of the transmitted signal [5]. When the transmit signal experience flat fading, the received signal consist of pulses at irresponsible delays. That is the received signal consists of multipath with delays much smaller than symbol duration.

4.2 AWGN Channel model

The simplest wireless channel is the AWGN channel where the transmitted signal is added with noise and is given by

$$y = x + n \quad (6)$$

where, x is the signal transmitted and n is the additive white gaussian noise with mean zero and power spectral density $N_0/2$. Here, transmitted signal is added with noise. For deep space communication between earth stations and satellites, AWGN channel is an accurate model. To predict path loss in typical wireless environment, different path loss models have been developed.

4.3 Rayleigh fading

Rayleigh fading is used to model statistics of signals that reaches the receiver by multipath [6]. In this model, signal transmitted through a communication channel will fade according to Rayleigh distribution. If the mobile antenna receives the transmitted signal through number of multiple paths, Rayleigh fading is used. Rayleigh fading model is used as a model that is reasonable for ionospheric and tropospheric signal propagation. It is also used to model the effect of heavily built-up urban environments on radio signal. There is no direct path or Line Of Sight (LOS) component for Rayleigh fading. In Rayleigh fading, the amplitude gain is characterized by a Rayleigh distribution. Its probability density function is given by

$$f(r) = \frac{r}{\sigma^2} \exp\left[\frac{-r^2}{2\sigma^2}\right], \quad r \geq 0 \quad (7)$$

4.4 Rician fading

Rician fading occurs when there exists a line of sight signal, which is much stronger than the others. Amplitude gain in rician fading is characterized by Rician distribution. When there is no line of sight signal, specialised model for stochastic fading is the Rayleigh fading. It is sometimes referred as a special case of the more generalised concept of Rician fading. The probability density function of rician distribution can be written as

$$f(r) = \frac{r}{\sigma^2}\exp\left[\frac{-r^2+B^2}{2\sigma^2}\right] I_0\left(\frac{rB}{\sigma^2}\right), r \geq 0 \qquad (8)$$

Where $I_0(\ )$ is the zeroth-order modified Bessel function of the first kind, B is the strength of the direct component.

4.5 Nakagami fading

Probability distribution which is related to the gamma distribution is the Nakagami distribution or the Nakagami-m distribution [7]. Two parameters of nakagami distribution are shape parameter, m and controlling spread, Ω.

Its probability density function (pdf) is

$$f(x; m, \Omega) = \frac{2m^m}{\Gamma(m)\Omega^m} x^{2m-1}\exp\left(-\frac{m}{\Omega}x^2\right) \qquad (9)$$

The parameters m and Ω are

$$m = \frac{E^2[x^2]}{Var[X^2]} \qquad (10)$$

and

$$\Omega = E[X^2] \qquad (11)$$

Rayleigh and Rician can be considered the special cases of Nakagami distribution. In the special case m=1, Nakagami tends to Rayleigh distribution. For m>1, Nakagami reduces to Rician distribution.

5. Results and discussions

To assess the performance of a system transmitting a signal from source to destination, key parameter used is BER. There are different parameters for determining performance of system. For the time being, BER is taken as a parameter to assess the performance of a system.

Table 1: System parameters

Parameters	*Specification*
Number of bits	10e6
Total transmitted power	1
SNR vector	0 to 40dB
Modulation scheme	QPSK
Number of relays	2, 3
Combining technique	MRC
Channels	Rayleigh, rician, nakagami, flat fading and AWGN channel

Figure 1 gives the BER vs Signal-to-Noise-Ratio (SNR) graph of multihop relays deploying QPSK modulation over Rayleigh fading channel for AF relaying scheme. For evaluating the BER performance of Multi-hop relays, considered two and three relays. From the graph, it is noticeable that BER for three relay system is higher than two relay system. Even though the deployment of three hop increases the BER compared to two relay, it increases the performance due to increased network coverage.

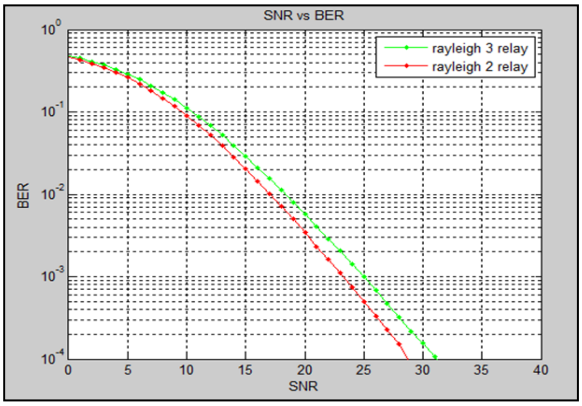

Figure 1: Simulated BER vs SNR graph for Rayleigh fading

Figure 2 shows the BER vs SNR graph of Rician fading which gives almost the same results as that described for Rayleigh distribution.

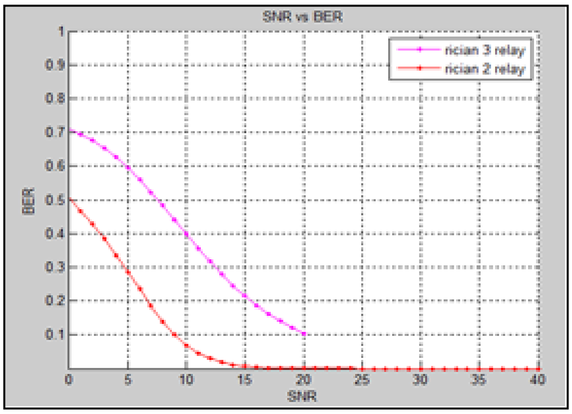

Figure 2: Simulated BER vs SNR graph for Rician fading

Figure 3 and Figure 4 illustrates that both AWGN and flat fading is expected to have approximately same BER performance. But for flat fading BER converges to zero at low values of SNR.

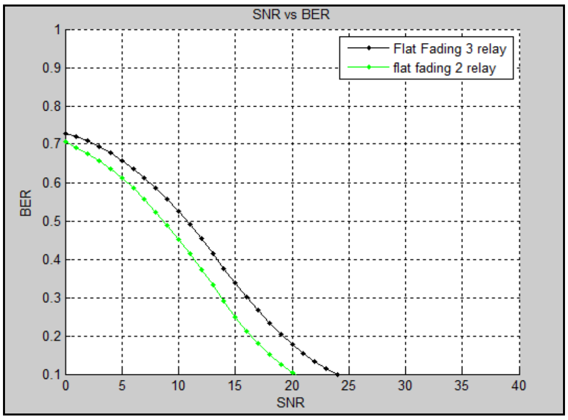

Figure 3: Simulated BER vs SNR graph for flat fading

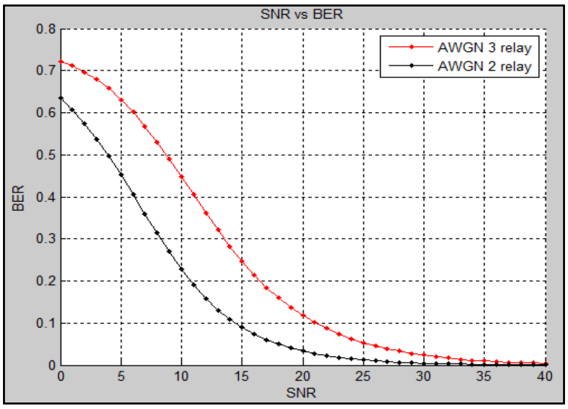

Figure 4: Simulated BER vs SNR graph for AWGN fading

Rayleigh and rician fading channels are the special cases of Nakagami fading channel. BER vs SNR graph of nakagami fading channel is shown in the Figure 5.Here also, obtained the similar results as that of other fading channels. As the number of relay increases, performance improves due to coverage extension even though there is an increase in BER.

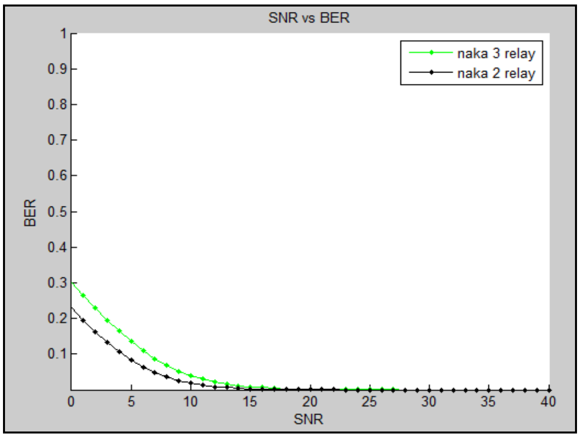

Figure 5: Simulated BER vs SNR graph for Nakagami fading

Rayleigh and Rician can be considered the special cases of Nakagami distribution. In the special case of m=1, Nakagami reduces to Rayleigh distribution. For m>1, Nakagami tends to Rician.

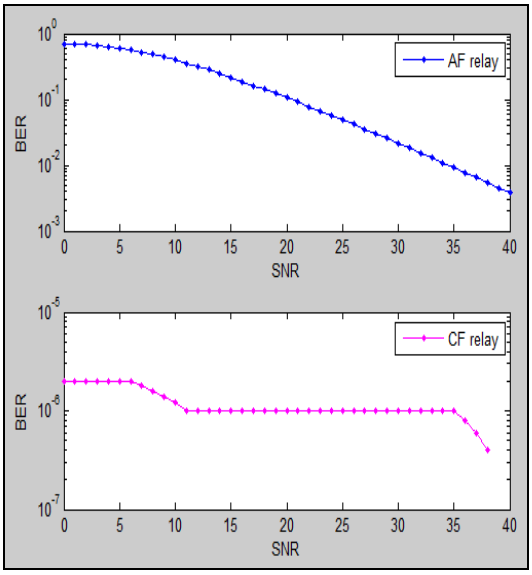

Figure 6: Comparison of AF and CF relay channel

Figure 6 illustrates the comparison of non-regenerative (AF) and CF relay channels. From the graph, it is noticeable that BER for AF is higher than CF. In an AF relaying scheme, the relays simply amplify and forward a received noisy signal to the destination node which results in increased noise level. But, this has an advantage over eavesdropper assisted relay channel as they amplifies the noise along with the signal. Relays in a CF relaying scheme map the received signal and only forward the compressed signal to the destination node. Because of simplicity, AF relaying scheme is widely used.

6. Conclusion

In communications theory, different distributions can be used to model the signals that reaches the receiver by multipath. In this paper, BER performance of Multi-hop non-regenerative communication protocol over different fading channels deploying QPSK modulation for 3 hop and 2 hop cases are evaluated and simulated. Fading channels such as Rayleigh, Rician, Nakagami, AWGN and Flat fading is considered. The simulated results show that as the number of relay increases, performance of the system improves due to extended network coverage even though there is an increase in BER. It is also analyzed and concluded that increasing number of relays in non-regenerative communication protocol have the same effect on BER performance of different fading channels. The performance of system in CF relaying protocol is also examined. Even though the BER for AF is higher than CF, due to simplicity, AF relaying protocol is widely used and it also has an advantage over eavesdropper assisted relay channel as they amplifies the noise along with the signal.

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