ESTIMATING PAPER IN VARIABLE GAIN RELAYING ON IMPERFECT CSI

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ABSTRACT

Amplify and Forward (AF) relaying, which refers to simple amplification and forwarding of the information sent from a source to destination terminal. For the conventional three node Amplify and Forward (AF) relaying setup, investigate the effect of imperfect channel state information (CSI) at the relaying on the overall performance. In particular, consider variable gain AF relaying and derive expression for the outage and the error probability and expression for the complimentary cumulative distribution function (CCDF) of the peak-to-average power ratio (PAPR) at the relay is calculated. The proposed method was drawn from a performance analysis for outage CSI at the relay. Finally the project work was simulated using the MATLAB software.

KEYWORDS: *Imperfect channel state estimation, outage and error probability, peak-to-average power ratio (PAPR).*

I. INTRODUCTION

Wireless relaying technology is included in the standards of future wireless networks, such as the Long Term Evolution-Advanced (LTE-A) system [1], due to a number of advantages that it promises in terms of system coverage and performance. Amplify and forward (AF) relaying [4], which refers to simple amplification and forwarding of the information sent from a source terminal to a destination terminal, is considered to be the simplest implementation of wireless relaying in practice, since no other form of processing at the relay is required. Among the several variations of AF relaying, the most common one is so-called variable-gain relaying (VGR), where the gain employed at the relay compensates the fading of the source-relay link, aiming at maintaining a constant relay transmits power. In order to do so, the relay has to monitor the source-relay channel, such that the amplification gain can be adjusted according to the obtained channel state information (CSI). In this respect, the majority of the works in the literature assume perfect CSI acquisition [2]. Of particular interest is the work, where it was shown that the gain policy that compensates for the source-relay channel leads to optimal performance of AF VGR, provided, however, that the CSI available at the relay is perfect.

The above assumption of perfect CSI at both the relay and destination. We ground our argument on the fact that the channel estimation is typically realized by using pilot symbols transmitted periodically by the source, where the pilot insertion period depends on the channel coherence time of the end-to-end channel. The source-relay channel estimate at the relay is needed only to set its gain G. In order to conserve energy and to reduce complexity, the relay may estimate the source-relay channel infrequently, i.e., the channel estimation rate at the relay may be insufficient to capture some rapid source-relay channel fluctuations. Thus, although the relay may actually estimate the channel perfectly, these estimates may be outdated by the time they are used to amplify the incoming signal samples, because the actual source-relay channel [3] may change rapidly between two successive channel estimates.

In addition, it is also possible that the relay acquires imperfect CSI in cases where the CSI of the source-relay link is fed back to the relay from another terminal which could be, for instance, a central unit with global CSI knowledge. In such case, the relay may obtain limited feedback CSI, which suffers from quantization noise2. Consequently, in the above scenarios the relay's gain G is set to a value that does not perfectly compensate the source-relay channel. This imperfect CSI at the relay does not necessarily affect the quality of channel estimation at the destination, as highly accurate (perfect) channel estimates are necessary for ideal coherent demodulation, as well as some higher layer functions, such as scheduling. Thus, the destination may update its CSI estimation more frequently than the relay.

The level of CSI imperfection at the relay is quantified through the power correlation coefficient between the actual and the estimated channel values, ρ. The performance metrics considered in this work are the end-to-end outage probability (OP), the average bit error probability (ABEP), and the complimentary cumulative distribution function (CCDF) of the Peak-to-average-power ratio (PAPR) at the output of the relay. It is noted that, as far as we are aware, this is the first time that the latter metric is used for the analysis of AF relaying schemes with imperfect CSI at the relay.

Motivation behind using this metric is that, contrary to VGR schemes [5] with perfect CSI, the relay transmit power in VGR experiences fluctuations when the CSI used for calculation of the relay gain is imperfect. The CCDF of the PAPR can be thus used to obtain the probability with which the power amplifier at the relay operates in its non-linear region, therefore distorting the output signal.

In this project, the effects of outdated channel estimation on the outage performance of amplify-and-forward (AF) relay selection [3.6], where only one out of the set of available relays is activated. In particular, we derive closed-form expressions for the outage probability of two variations of AF relay selection, namely best relay selection and partial relay selection, when the selection is based upon outdated channel estimates .Numerical results manifest that the outage performance of both schemes under consideration is highly dependent on the level of imperfection of the channel estimates. It is further shown that it may be preferable, in terms of outage probability, not to include links in the relay selection process that experience high maximum Doppler shifts.

II. ADDITIVE WHITE GAUSSIAN NOISE

In wireless communications, channel state information (CSI) refers to known channel properties of a communication link. This information describes how a signal propagates from the transmitter to the receiver and represents the combined effect of, for example, scattering, fading, and power decay with distance. The CSI makes it possible to adapt transmissions to current channel conditions, which is crucial for achieving reliable communication with high data rates in multi antenna systems.

CSI needs to be estimated at the receiver and usually quantized and fed back to the transmitter (although reverse-link estimation is possible in TDD systems). Therefore, the transmitter and receiver can have different CSI. The CSI at the transmitter and the CSI at the receiver are sometimes referred to as CSIT and CSIR, respectively.

2.1. Different Kinds of CSI

There are basically two levels of CSI, namely instantaneous CSI and statistical CSI.

1. Instantaneous CSI (or short-term CSI) means that the current channel conditions are known, which can be viewed as knowing the impulse response of a digital filter. This gives an opportunity to adapt the transmitted signal to the impulse response and thereby optimize the received signal for spatial multiplexing or to achieve low bit error rates.

2. Statistical CSI (or long-term CSI) means that a statistical characterization of the channel is known. This description can include, for example, the type of fading distribution, the average channel gain, the line-of-sight component, and the spatial correlation. As with instantaneous CSI, this information can be used for transmission optimization.

The CSI acquisition is practically limited by how fast the channel conditions are changing. In fast fading systems where channel conditions vary rapidly under the transmission of a single information symbol, only statistical CSI is reasonable.

On the other hand, in slow fading systems instantaneous CSI can be estimated with reasonable accuracy and used for transmission adaptation for some time before being outdated. In practical systems, the available CSI often lies in between these two levels; instantaneous CSI with some estimation/quantization error is combined with statistical information.

2.2. Variable Gain Relaying

The variable-gain or voltage-controlled relay is an electronic amplifier that varies its gain depending on a control voltage (often abbreviated CV).A crude example is a typical inverting op-amp configuration with a light-dependent resistor (LDR) [8] in the feedback loop. The gain of the amplifier then depends on the light falling on the LDR, which can be provided by an LED (an opto coupler). The gain of the amplifier is then controllable by the current through the LED. This is similar to the circuits used in optical audio compressors.
A voltage-gain amplifier can be realized by first creating a voltage-controlled relay (VGR), which is used to set the amplifier gain. The VCR is one of the numerous interesting circuit elements that can be produced by using a JFET (junction field-effect transistor) with simple biasing. VCRs manufactured in this way can be obtained as discrete devices, e.g. VCR2N.

2.3. Gaussian Estimation Error

Gaussian Estimation theory is a branch of statistics and signal processing that deals with estimating the values of parameters based on measured/empirical data that has a random component. The parameters describe an underlying physical setting in such a way that their value affects the distribution of the measured data. An estimator attempts to approximate the unknown parameters using the measurements. For example, it is desired to estimate the proportion of a population of voters who will vote for a particular candidate. That proportion is the parameter sought; the estimate is based on a small random sample of voters.
In Gaussian estimation theory, two approaches are generally considered.
(1)The probabilistic approach (described in this particle) assumes that the measured data is random with probability distribution dependent on the parameters of interest.
(2)The set-membership approach assumes that the measured data vector belongs to a set which depends on the parameter vector.

2.4. Semi Blind FGR

The performance of the semi-blind amplify-and-forward (AF) relay channel [7], where the intermediate relay node is selected depending on the instantaneous and partial channel knowledge, is investigated. Using closed-form expressions for the cumulative distribution function of the end-to-end signal-to-noise ratio (SNR), outage probability, SNR moments and average bit error rate are derived.
The performance analysis is concerning fixed gain relays apply to blind relays with arbitrary fixed gain. The statistical CSI about the first hop and have a particular knowledge of the average fading power $\Omega 1$ which changes slowly (relative to $\alpha 1$) and as such does not imply continuous monitoring system of the channel (as it is the case in CSI-assisted relay).The relay gain in the semi-blind scenario is chosen such as

$$G2= E [Є2/Є1\ \alpha 1+N01].$$

2.5. APS FGR

The average power scaling is defined as the rate of energy flow averaged over one full period (recall that f =1/T).

$$Pavg= E/ T= EF.$$

It is easy to calculate the power or energy of optical pulses if theright parameters are known. Presented here are the relationships among some basic quantities often needed when working with laser pulses and power or energy meters.
In the average power scaling FGR the relay gain are given as

$$G2= ER/ [ESE (\alpha 2)+N0]$$

The relay transmits power leading E (PR) = ER, i.e., the relay’s average transmit power equals ER.

2.6. Amplify and Forward

The Nakagami distribution [9] or the Nakagami-m distribution is a probability distribution related to the gamma distribution. It has two parameters: a shape parameter m and a second parameter controlling spread, Ω.
The parameters m and Ω are

m= E2 [X2]/Var[X2],
Ω = E[X2].

An alternative way of fitting the distribution is to re-parametrize Ω and m as σ = Ω/m and m. Then, by taking the derivative of log likelihood with respect to each of the new parameters, the following equations are obtained and these can be solved using the Newton-Raphson method:

г (m) = x2m/σm,
σ = x2/m

It is reported by authors that modeling data with Nakagami distribution and estimating parameters by above mention method results in better performance for low data regime compared to moments based methods.
It describes the amplitude of received signal after maximum ratio diversity combining. After k-branch maximum ratio combining (MRC) with Rayleigh-fading signals, the resulting signal is Nakagami with m = k. MRC combining of m-Nakagami fading signals in k branches gives a Nakagami signal with shape factor mk..
The sum of multiple independent and identically distributed. Rayleigh-fading signals have Nakagami distributed signal amplitude. This is particularly relevant to model interference from multiple sources in a cellular system.
The average time delay is assumed to differ significantly between clusters. If the delay times also significantly exceed the bit time of a digital link, the different clusters produce serious intersymbol interference, so the multipath self interference then approximates the case of co-channel interference by multiple incoherent Rayleigh-fading signals. The Rician and the Nakagami model behave approximately equivalently near their mean value. This observation has been used in many recent papers to advocate the Nakagami model as an approximation for situations where a Rician model would be more appropriate. While this may be accurate for the main body of the probability density, it becomes highly inaccurate for the tails.
As bit errors or outages mainly occur during deep fades, these performance measures are mainly determined by the tail of the probability density function (for probability to receive a low power). The amplifying and forward (AF) relaying, the amplify-and-forward relay protocol is a protocol defined for wireless cooperative communications. An example of a wireless communication network in which cooperation improves the performance of the system is the relay network.
Figure 1 shows the AF relay functions with signal notations. The AF relay function is an amplification of the received signal,

FAF (ySR) = βySR

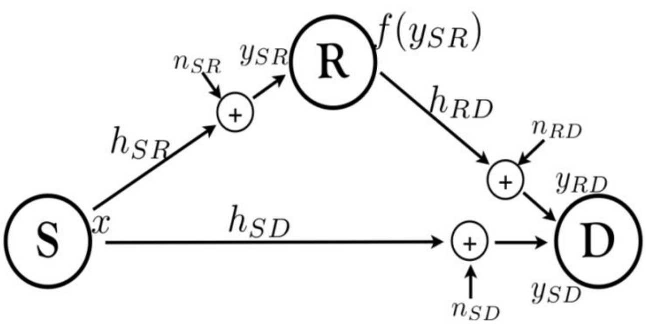

Figure 1. Relay network with signal notations.

With β the relay transmit average power constraint coefficient. The coefficient β ensures that the average transmits power at the relay is constant and equal to PR, therefore β is derived in a similar way to the one obtained by Laneman:

E [|f (ySR) |2] ≤ PR

$$E[|\beta ySR|2] \leq PR.$$

The probability of error may be considered as being the probability of making a wrong decision and which would have a different value for each type of error. Secondly, it arises in the context of statistical modeling (for example regression) where the model's predicted value may be in error regarding the observed outcome and where the term probability of error may refer to the probabilities of various amounts of error occurring.

The probability of the detector making an incorrect decision is called probability of error. Using the Euclidean distance d, the Probability of error can be calculated as (for white noise)

$$Pbe = 1/2 \text{ erfc } (d2/4N0)$$

Probability of Symbol error

$$Pse = lPbe$$

Where l is the number of adjacent signal points with respect to any one signal Point.

The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power).

$$PAPR = |x|peak2/xrms2 = C2$$

2.6.1. Peak-To-Average Power Ratio

A peak-to-average power ratio meter (Par meter) is a device used to measure the ratio of the peak power level to the time-averaged power level in an electrical circuit. This quantity is known as the peak-to-average ratio (P/A r or PAR). Such meters are used as a quick means to identify degraded telephone channels. Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independent (and hence uncorrelated). In applications, Gaussian noise is most commonly used as additive white noise to yield additive white Gaussian noise.

Noise by definition is just unwanted sound. However, there is one special type of noise that has broad application in the hearing sciences. This is gaussian noise. We will discuss some reasons for its popularity in class. Gaussian noise is noise that has a random and normal distribution of instantaneous amplitudes over time.

Figure 2 below shows a sample of gaussian noise with the normal (bell) curve drawn to the right to represent the distribution of instantaneous amplitudes.

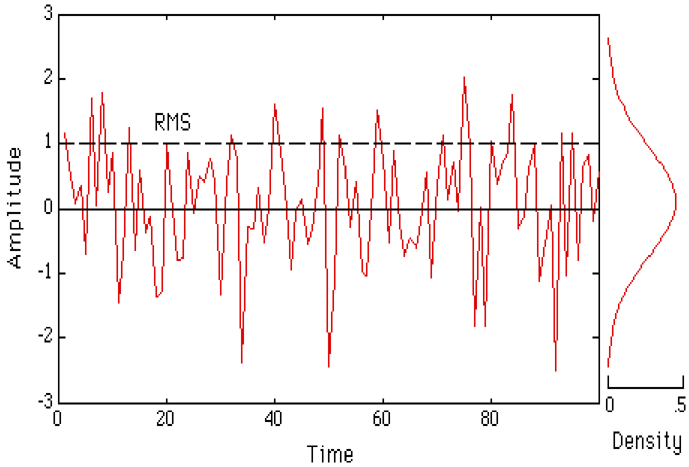

Figure 2. Gaussian noise sample with normal bell

Relays that receive and retransmit the signals between base stations and mobiles can be used to increase throughput extend coverage of cellular networks. Infrastructure relays do not need wired connection to network thereby offering savings in operators' backhaul costs. Mobile relays can be used to build local area networks between mobile users under the umbrella of the wide area cellular networks.

Amplify-and-forward (AF) relays retransmit the signal without decoding while decode–and-forward (DF) relays decode the received signal, encode the signal again, and transmit. Furthermore, relays can

operate in half-duplex mode, i.e. they do not transmit and receive simultaneously in the same band, or in full-duplex mode. The latter operation requires a spatial separation between transmit and receive antennas to reduce loop-back interference from the transmit antennas to the receive antennas.
From signal processing point of view AF relays offer interesting challenges, especially when the AF relay operates in full-duplex mode: Adaptive algorithms are required for loop-back interference cancellation [10]. Furthermore, the effect of interference must be incorporated into analytical performance studies. Spectral shaping of the transmitted signal requires advanced techniques for digital filter design. The research benchmarks AF relays with DF relays taking into account the aforementioned issues. We cooperate with High-frequency and microwave engineering group to gain understanding of the actual propagation environment and loop-back interference with full-duplex relays.

2.7. Result

Finally, a comparison between VGR with outdated CSI and FGR, in terms of the CCDF of the PAPR, is shown in figure3. Similarly to the comparison in terms of the ABEP, we notice that there exists a correlation coefficient threshold, ρ0, such that for ρ < ρ0 the CCDF of the PAPR is higher for VGR than for FGR.

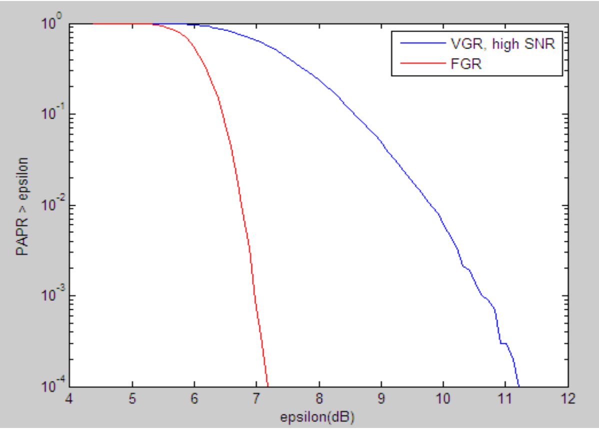

Figure 3. Output of PAPR

The higher (ε) value of interest (equivalently, the larger the linear region of the power amplifier at the relay), the higher ρ0. Therefore, Figure 3 shows sheds some light on the required reliability of the CSI at the relay such that VGR is preferable over FGR. When we increased SNR (signal to noise ratio) by using quantization, the overall performance of variable gain relaying can be improved. Figure 4 and figure 5 shows variable gain relaying communication and increased SNR.

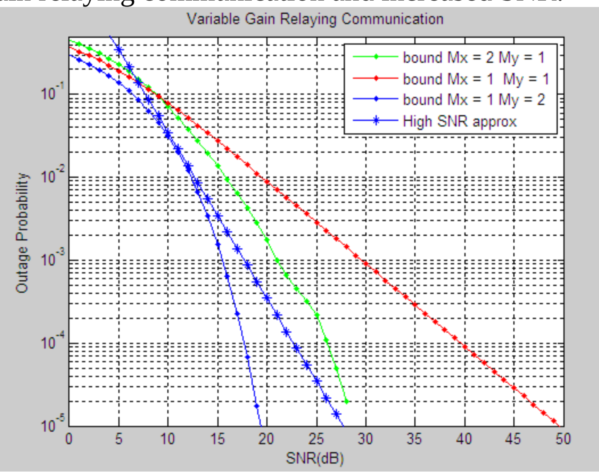

Figure 4. Variable Gain Relaying Communication

When we increased SNR (signal to noise ratio) by using quantization, the overall performance of variable gain relaying can be improved.

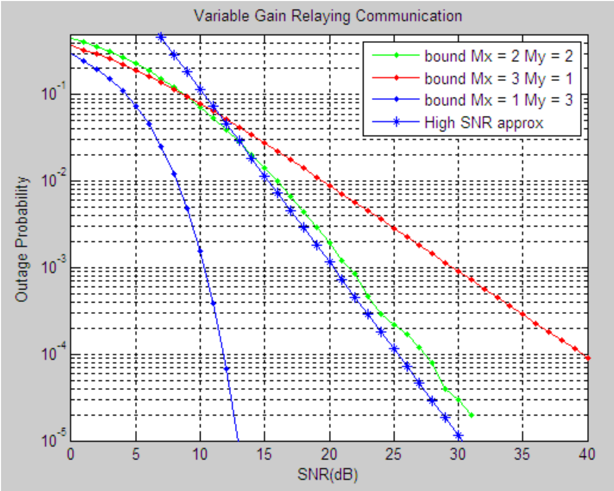

Figure 5. Increased SNR

III. CONCLUSIONS

When the gain used for channel compensation in AF variable gain relaying is based on imperfect CSI, the overall performance is considerably impaired. The performance degradation is the larger the lower the correlation between the actual and the estimated source relay channel, yet such performance degradation does not affect the slope of the outage and error probability curves. This conclusion was drawn from a performance analysis for outdated CSI at the relay. Nevertheless, it was shown that the same analysis can also accommodate the case of Gaussian CSI errors at the relay. It was further observed that, depending on the maximum Doppler frequency, variable gain relaying requires frequent updates of the source-relay channel in order to outperform its less complex counterpart, that is, fixed gain relaying. Our investigation also included an analysis of the peak-to-average power ratio for variable and fixed gain relaying, revealing that the probability of exceeding the amplifier's linear region (and thus causing signal distortion) can be higher for variable gain relaying, if the CSI at the relay is not reliable enough.

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