Asymmetrically informed data-hiding optimization of achievable rate for Laplacian host

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ABSTRACT

In data-hiding the issue of the achievable rate maximization is closely related to the problem of host interference cancellation. The optimal host interference cancellation relies on the knowledge of the host realization and the channel statistics (the additive white Gaussian noise (AWGN) variance) available at the encoder a priori to the transmission. The latter assumption can be rarely met in practical situations. Contrarily to the Costa set-up where the encoder is optimized for the particular state of the independent and identically distributed (i.i.d.) Gaussian attacking channel, we address the problem of asymmetrically informed data-hiding optimal encoder design assuming that the host interference probability density function (pdf) is an i.i.d. Laplacian and the channel variance lies on some known interval. The presented experimental results advocate the advantages of the developed embedding strategy.

Keywords: asymmetrical side information, Gel'fand-Pisnker, Costa, parallel source splitting, average rate loss

1. INTRODUCTION

Digital data-hiding appeared as an emerging tool for copyright protection, fingerprinting, authentication and tamper proofing. Design of practical data-hiding methods is a complex task targeting to resolve the trade-off among robustness, visibility and achievable rate of reliable communications.[1]

The optimality of this trade-off solution can be potentially used for the benchmarking of such techniques. However, instead of this complex criterion, usually other measures are exploited for this purpose: the maximum achievable rate of reliable communications undergoing the AWGN channel and the probability of error under some additive attacks assuming the minimum Euclidean distance decoding rule.[1]

A method efficiency with respect to the former performance measure is closely related to the problem of host interference cancellation. The optimal solution to this problem is based on the random binning communications principle for channels with random parameter introduced by Gel'fand and Pinsker.[2]

Costa[3] considered the Gel'fand-Pinsker problem in the i.i.d. Gaussian formulation. He has shown that the maximum achievable rate for such a channel coincides with the capacity of the AWGN channel assuming that the channel variance is known a priori to the transmission at the encoder.

In many practical applications it is not possible to know the attacking variance at the encoder. Furthermore, in robust data-hiding it is supposed that the attacker can know the data-hider strategy but the data-hider has no knowledge about the attacking strategy (at least at the encoder). That is way the encoder structure is usually optimized for certain communication conditions. Performance analysis of these techniques[4] reveals that a deviation from the expected communications conditions causes a rate loss in the performance.[5]

This loss can be justified since most of the existing practical embedding techniques can be considered as approximations to the Costa coding for particular communications conditions. More general problem formulation of the achievable rate maximization in the scenario that includes an aggressive adversary can be found in.[6] The results obtained there might be used for the benchmarking of various practical robust data-hiding methods.

A benchmarking strategy[7] consists in the evaluation of the achievable rate for the AWGN channel assuming that its variance varies within a predefined interval. In particular, in terms of the watermark-to-noise ratio (WNR) range we assume it to be $[-5, 10]$dB in this paper. The rate evaluation is performed assuming a fixed encoder structure.

Motivated by the mismatch in the stochastic image modeling of the host data and by the unavailability of the attacking variance at the encoder, we formulate the main goal of this paper as follows: the performance optimization of an asymmetric data-hiding set-up[5] in terms of achievable rates for a realistic host data model and for an AWGN channel with a variance that lies on some interval. In particular, we select an i.i.d. stationary Laplacian pdf to model the host statistics. The optimality here is measured in a twofold manner: in terms of the average loss of the achievable rate from the AWGN channel capacity and when the minimum rate of reliable communications is specified for the given WNR interval. This paper is organized as follows: A short overview of the Costa communications protocol is presented in Section 2 and the aspects of stochastic image modeling are discussed in Section 3. The asymmetric data-hiding set-up as communications with side information is described in Section 4. The average achievable rates when the pdf of the attacking channel variance is or it is not available are presented in Section 5 and Section 6, respectively.

Notations We use capital letters X to denote scalar random variables, bold capital letters $\mathbf{X}$ to denote N-length vector random variables, corresponding small letters x and $\mathbf{x}$ to denote the realizations of respectively scalar and vector random variables. m represents the message and $\mathcal{M}$ the set of messages. $\mathbf{X} \sim f_{\mathbf{X}}(\mathbf{x})$ denotes the host signal distributed according to $f_{\mathbf{X}}(\mathbf{x})$, $\mathbf{Z} \sim f_{\mathbf{Z}}(\mathbf{z})$ represents the noise, $\mathbf{W} \sim f_{\mathbf{W}}(\mathbf{w})$ the watermark and $\mathbf{V} \sim f_{\mathbf{V}}(\mathbf{v})$ the received signal. The WNR is defined as $\mathrm{WNR} = 10\log_{10}\frac{\sigma_W^2}{\sigma_Z^2}$, where σ_W^2 and σ_Z^2 stand for the variance of the watermark and the noise, respectively. The watermark-to-image ratio (WIR) is defined as $\mathrm{WIR} = 10\log_{10}\frac{\sigma_W^2}{\sigma_X^2}$, where σ_X^2 denotes the variance of the host. $f_{\mathbf{\Sigma}_X^2}(\sigma_X^2)$ denotes the distribution of the host variances $\mathbf{\Sigma}_X^2$ and the distortion-compensation parameter is denoted as α. The mathematical expectation of a random variable $X \sim p_X(x)$ is designated by $E_X[X]$ or simply by $E[X]$.

2. HOST INTERFERENCE CANCELLATION DATA-HIDING CODES

Costa[3] considered the Gel'fand-Pinsker[2] problem for the Gaussian host, the AWGN and the mean square error distance. In the Costa set-up (Fig. 1) we have $X \sim \mathcal{N}(0, \sigma_X^2)$, $Z \sim \mathcal{N}(0, \sigma_Z^2)$ and the embedding distortion constraint $E[W^2] < \sigma_W^2$. The auxiliary random variable was chosen in the form $U = W + \alpha X$ with optimization parameter α that leads to the following rate of reliable communications:

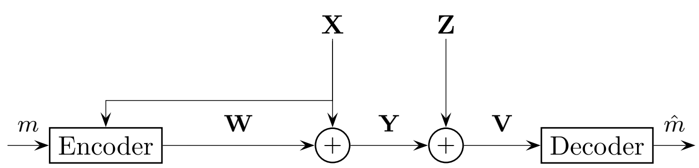

Figure 1. Costa communications set-up.

$$R^{\mathrm{G}}(\alpha, \sigma_X^2) = \frac{1}{2}\log_2 \frac{\sigma_W^2(\sigma_W^2 + \sigma_X^2 + \sigma_Z^2)}{\sigma_W^2\sigma_X^2(1-\alpha)^2 + \sigma_Z^2(\sigma_W^2 + \alpha^2\sigma_X^2)}, \tag{1}$$

where the superscript G stands to indicate a Gaussian host. It was shown that the optimal parameter is $\alpha_{opt} = \frac{\sigma_W^2}{\sigma_W^2 + \sigma_Z^2}$. It requires the knowledge of the noise variance at the encoder. In this case the rate does not depend on the host variance and:

$$R^{\mathrm{G}}(\alpha_{opt}) = C^{\mathrm{AWGN}} = \frac{1}{2}\log_2\left(1 + \frac{\sigma_W^2}{\sigma_Z^2}\right), \tag{2}$$

where C^{AWGN} is the capacity of the AWGN channel without host interference.

Cohen and Lapidoth[8] have shown that it is possible to achieve optimum performance for the Costa set-up[3] and any host pdf for the AWGN channel in case the variance of the AWGN is known. However, the performance of the Costa set-up for non-Gaussian interference under channel statistics ambiguity remains an open issue.

3. THE STOCHASTIC HOST MODELING

The issue of proper stochastic modeling of real images has been extensively studied in image processing community. In particular, it was shown that in some transform domains (like wavelet or discrete cosine transform), image data statistics can be accurately approximated using an i.i.d. Laplacian pdf. Many practical image coders and denoisers are designed based on the Laplacian model.[9, 10] However, even a more significant gain can be achieved when the coefficients are modeled on the local level,[11] and the corresponding local image coefficients classification based on their statistical properties is known as a parallel source splitting.[12]

From the chain rule for probability, one obtains:

$$f_{X,\Sigma_X^2}(x,\sigma_X^2) = f_{\Sigma_X^2}(\sigma_X^2) f_{X|\Sigma_X^2}(x|\sigma_X^2). \tag{3}$$

The global data statistics correspond to the marginal distribution:

$$f_X(x) = \int_0^\infty f_{\Sigma_X^2}(\sigma_X^2) f_{X|\Sigma_X^2}(x|\sigma_X^2) d\sigma_X^2. \tag{4}$$

In the particular case of the Laplacian pdf, the global host pdf $f_X(x)$ is obtained as a weighted mixture of zero-mean conditional Gaussian pdfs given an exponentially distributed local variance[12] $f_{\Sigma_X^2}(\sigma^2) = \beta e^{-\beta|\sigma^2|}$, where β is the scale parameter of the exponential distribution and:

$$f_X(x) = \int_0^\infty \frac{1}{\sqrt{2\pi\sigma_X^2}} e^{-\frac{x^2}{2\sigma^2}} \beta e^{-\beta|\sigma^2|} d\sigma^2 = \sqrt{\frac{\beta}{2}} e^{-\sqrt{2\beta}|x|}, \tag{5}$$

where the mean of the exponential distribution corresponds to the variance of the host: $1/\beta = \sigma_X^2$. The parallel Laplacian source decomposition into $K+1$ Gaussian channels is schematically explained in Fig. 2.

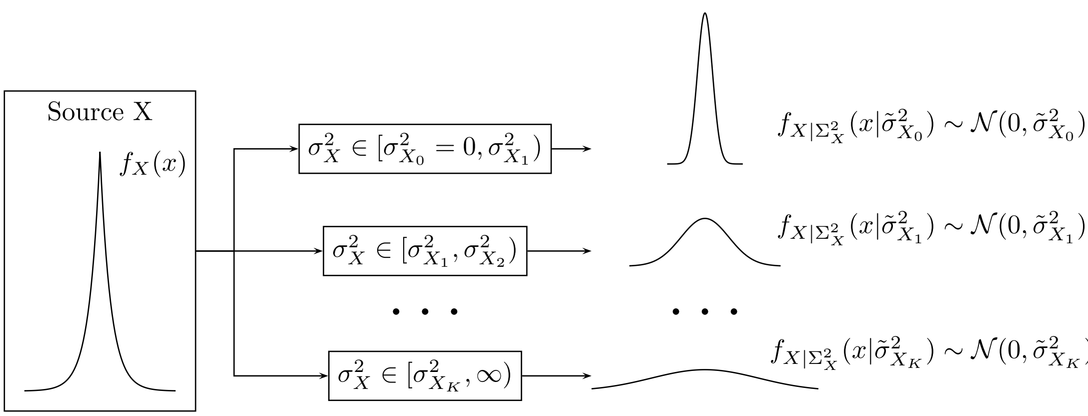

Figure 2. Parallel Laplacian source decomposition into $K+1$ Gaussian channels.

4. ASYMMETRIC DATA-HIDING SET-UP

The communications set-up inspired by an infinite Gaussian representation of the Laplacian source that is analyzed in this paper is presented in Fig. 3. The channel is an additive white Gaussian discrete memoryless channel (DMC) with transition probability $f_{\mathbf{V}|\mathbf{Y}}(\mathbf{v}|\mathbf{y}) = \prod_{i=1}^N f_{V|Y}(v_i|y_i)$, and $f_{V|Y}(v_i|y_i) \sim \mathcal{N}(0, \sigma_Z^2)$. The task of the decoder is to decide based on the channel output and, potentially, on the partial side information $\mathbf{\Sigma}_X^2$ that is correlated with the host $\mathbf{X}$ which message was sent. Σ_X^2 represents the random variable of the local host variances. A key is presented in the scheme since embedding and decoding is performed based on the key. Nevertheless, the key-management is outside of the scope of this paper and we will not consider it in our analysis.

The availability of the host statistics at the decoder by closing the switch S in Fig. 3 makes possible to treat the Laplacian host as an infinite mixture of Gaussians (MG) pdfs according to (4) and to apply a different

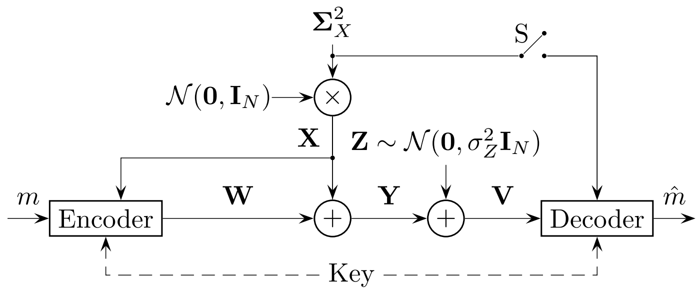

Figure 3. Asymmetric side information data-hiding set-up.

strategy at the encoder. By analogy with communications over fading channels, it was shown that the achievable rate in this set-up is given by the following expectation[5]:

$$R^{\mathrm{MG}}(\alpha) = E_{\Sigma_X^2}[R^{\mathrm{G}}(\alpha, \sigma_X^2)] = \int_0^{\infty} R^{\mathrm{G}}(\alpha, \sigma_X^2) f_{\Sigma_X^2}(\sigma_X^2) d\sigma_X^2. \tag{6}$$

This result is coherent with the one obtained by Cohen and Lapidoth,[8] since the rate of reliable communications coincides with the capacity of the AWGN channel for $\alpha = \alpha_{\mathrm{opt}}$ (2).

5. AVERAGE ACHIEVABLE RATE OPTIMAL COSTA CODING: ENCODING STRATEGIES

In order to achieve the optimal performance, the codebook in the Costa communication protocol should be designed assuming $\alpha = \alpha_{opt}$. Since this selection can only be made for the case when the AWGN channel variance is known at the encoder before transmission, it can be hardly satisfied in practice. According to the motivation presented in the Introduction, the main goal of this Section is to propose a Costa-based communications protocol that will perform optimally in terms of the average achievable rate on the interval of attacking channel variances that correspond to the WNR $\in [\mathrm{WNR}_{\min}, \mathrm{WNR}_{\max}]$. Contrary to the original Costa set-up, in this paper we analyze the proposed asymmetrically informed data-hiding set-up when the local variances of the parallel splitting of the Laplacian host are available at the decoder according to (4). The optimization is performed with respect to the α parameter under the assumption that the attacking variances are distributed according to some $f_{\Sigma_Z^2}(\sigma_Z^2)$ of interest.

This problem can be formulated as the minimization of the rate loss $R_L(\alpha)$ on the given WNR interval:

$$R_L(\hat{\alpha}) = \min_{\alpha} R_L(\alpha) = \min_{\alpha} \int_{\mathrm{WNR}_{\min}}^{\mathrm{WNR}_{\max}} \left(C^{\mathrm{AWGN}} - R(\alpha, \sigma_Z^2)\right) f_{\Sigma_Z^2}(\sigma_Z^2) d\sigma_Z^2, \tag{7}$$

where $f_{\Sigma_Z^2}(\sigma_Z^2)$ is defined on the interval WNR $\in$ [$\mathrm{WNR}_{\min}$, $\mathrm{WNR}_{\max}$]. $R(\alpha, \sigma_Z^2)$ in (7) means $R^{\mathrm{G}}(\alpha, \sigma_Z^2)$ for a Gaussian host as in (1) or $R^{\mathrm{MG}}(\alpha, \sigma_Z^2)$ if the switch S is closed and the host follows a Laplacian pdf as it is shown in (6).

Unfortunately, no close analytical solution to this problem was found and the parameter α optimal in terms of average achievable rate was determined using numerical optimization. The optimization was performed for the interval defined by $\mathrm{WNR}_{\min} = -5$dB and $\mathrm{WNR}_{\max} = 10$dB for two WIRs, $\mathrm{WIR}_1 = -6$dB and $\mathrm{WIR}_2 = -16$dB (here it was assumed that the variance of the watermark σ_W^2=10 in order to satisfy the embedding distortions constrained according to the Stirmark benchmark[13]).

In this paper, we consider three different noise variance pdfs. In the first case, we consider that the noise variance follows a uniform distribution (Fig. 4(a), assuming that there is no reliable knowledge about the attacker channel behaviour):

$$f_{\Sigma_Z^2}(\sigma_Z^2) = \begin{cases} \frac{1}{\sigma_{Z\max}^2 - \sigma_{Z\min}^2}, & \sigma_{Z\min}^2 < \sigma_Z^2 < \sigma_{Z\max}^2; \\ 0, & \text{otherwise.} \end{cases} \tag{8}$$

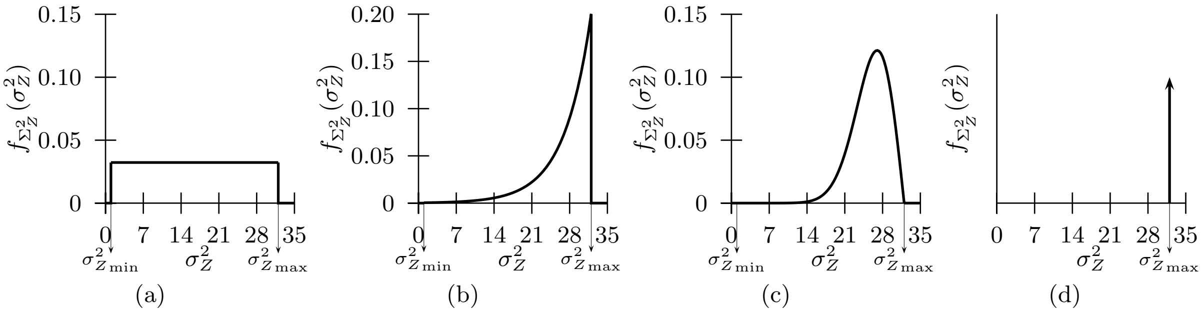

Figure 4. Noise variance pdf shapes: (a) uniform, (b) truncated exponential, (c) truncated Rayleigh and (d) worst case.

The two remaining attacking scenarios correspond to an attacking behaviour that is usually the case in robust data-hiding. Thus, the second case of interest corresponds to an exponentially varying noise variance pdf on the selected WNR interval (Fig. 4(b)):

$$f_{\Sigma^2_Z}(\sigma^2_Z) = \begin{cases} \left(e^{\beta\sigma^2_{Z\max}} - e^{\beta\sigma^2_{Z\min}}\right)^{-1} \beta e^{\beta\sigma^2_Z}, & \sigma^2_{Z\min} < \sigma^2_Z < \sigma^2_{Z\max}; \\ 0, & \text{otherwise}, \end{cases} \tag{9}$$

where β is the parameter of the exponential distribution. Finally, we analyze the case when the attacking variance follows a truncated Rayleigh pdf (Fig. 4(c)):

$$f_{\Sigma^2_Z}(\sigma^2_Z) = \begin{cases} \left(1 - e^{\frac{-(\sigma^2_{Z\max} - \sigma^2_{Z\min})^2}{2\rho^2}}\right)^{-1} (\sigma^2_{Z\max} - \sigma^2_Z)\rho^{-2} e^{-\frac{\sigma^2_{Z\max} - \sigma^2_Z}{2\rho^2}}, & \sigma^2_{Z\min} < \sigma^2_Z < \sigma^2_{Z\max}; \\ 0, & \text{otherwise}, \end{cases} \tag{10}$$

where ρ is the parameter of the Rayleigh distribution.

The achievable rate maximization introduced by Moulin and O'Sullivan[6] can also be considered in the scope of this formulation assuming that the noise variance pdf is a delta function on the maximum possible noise variance as in Fig. 4(d).

Uniform variance pdf case The obtained optimization parameters $\hat{\alpha}$ for a uniformly varying noise variance and a Laplacian host are presented in Table 1 and in Fig. 5 for two WIRs. α_{WC} is the optimum Costa parameter for the maximum variance of the noise, i.e., the worst case. The results of optimization are given versus those obtained under the assumption that the data-hider is targeting to optimize the performance for the worst channel conditions, meaning for the maximum variance of the noise in the interval. The proposed strategy achieves better performance in the middle and high-WNR, while a small loss in performance is observed in the low-WNR regime with respect to the worst case encoding strategy. We can observe that using the worst case strategy, the average rate loss in performance is at least 1.83 times larger. In order to compare it with the original Costa set-up without host statistics available at the decoder (Fig. 1), we analyze the optimum in average encoding strategy for a Gaussian host and AWGN channel. The obtained optimization parameters for a uniformly varying noise variance are presented in Table 2 and in Fig. 5, where R_L^{G} denotes the rate loss for a Gaussian host.

WIR	$\hat{\alpha}$	$R_L^{\text{MG}}(\hat{\alpha})$	$R_L^{\text{MG}}(\alpha_{\text{WC}})$	$R_L^{\text{MG}}(\alpha_{\text{WC}})/R_L^{\text{MG}}(\hat{\alpha})$
-16dB	0.4252	0.08696	0.1587	1.83
-6dB	0.4501	0.05747	0.1132	1.97

Table 1. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for uniformly varying noise variance and a Laplacian host when the host statistics are available at the decoder.

WIR	$\hat{\alpha}$	$R_L^{\mathrm{G}}(\hat{\alpha})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})/R_L^{\mathrm{G}}(\hat{\alpha})$
-16dB	0.4204	0.0938	0.1689	1.802
-6dB	0.4462	0.0698	0.1355	1.94

Table 2. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for uniformly varying noise variance and a Gaussian host.

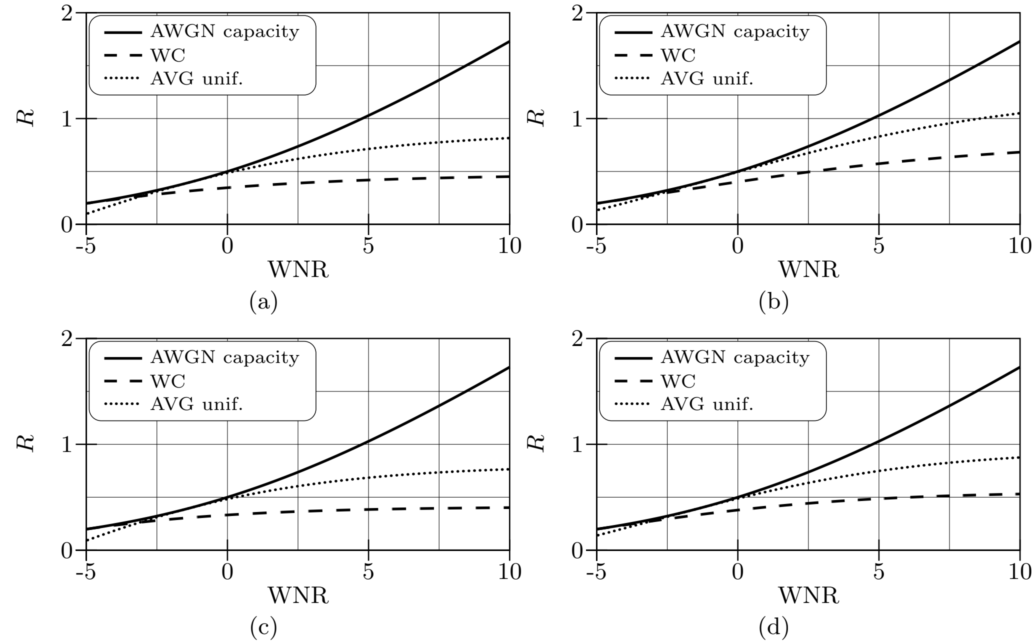

Figure 5. Achievable rate performance comparison of on-average optimal Costa coding assuming uniformly varying variances (AVG unif.) versus worst case encoding strategy (WC). (a,c) WIR $= -16$dB and (b,d) WIR $= -6$dB. (a,b) Laplacian host and (c,d) Gaussian host.

Although there is a minor difference in the average rate loss for the asymmetric set-up with Laplacian host and the Costa set-up under the above conditions, one can clearly observe the significant difference in the achievable rates according to Fig. 5. For example, for WNR $= 10$dB and WIR $= -6$dB, it constitutes 1.05 versus 0.9 bits per sample for the above set-ups, respectively. The achieved gain is about 3dB in terms of WNR.

Exponential variance pdf case The minimum average rate loss in performance assuming an exponentially varying noise variance for the specified WNR interval and Laplacian host is achieved using the $\hat{\alpha}$ values presented in Table 3, as it is shown in Fig. 6. In this paper we use $\beta = 0.2$. In this case, the average performance gain respect to the worst case encoding strategy is at least 1.55 times better. In case the host follows a Gaussian distribution and host statistics are not available at the decoder, the obtained α values are presented in Table 4 as it is shown in Fig. 6.

WIR	$\hat{\alpha}$	$R_L^{\mathrm{MG}}(\hat{\alpha})$	$R_L^{\mathrm{MG}}(\alpha_{\mathrm{WC}})$	$R_L^{\mathrm{MG}}(\alpha_{\mathrm{WC}})/R_L^{\mathrm{MG}}(\hat{\alpha})$
-16dB	0.2753	0.00716	0.0112	1.56
-6dB	0.2778	0.00437	0.00677	1.55

Table 3. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for exponentially varying noise variance and a Laplacian host when the host statistics are available at the decoder.

WIR	$\hat{\alpha}$	$R_L^{\mathrm{G}}(\hat{\alpha})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})/R_L^{\mathrm{G}}(\hat{\alpha})$
-16dB	0.275	0.00813	0.0126	1.55
-6dB	0.2779	0.00437	0.00864	1.52

Table 4. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for exponentially varying noise variance and a Gaussian host.

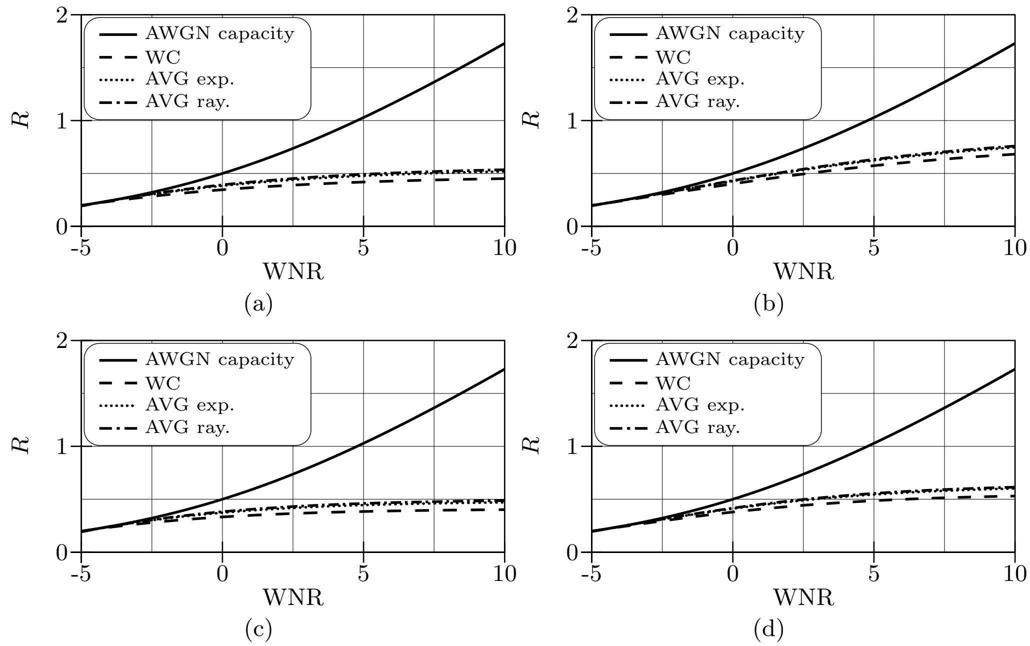

Figure 6. Achievable rate performance comparison of on-average optimal Costa coding assuming exponentially (AVG exp.) and Rayleigh (AVG ray.) varying variances versus worst case encoding strategy (WC). (a,c) WIR = −16dB and (b,d) WIR = −6dB. (a,b) Laplacian host and (c,d) Gaussian host.

Rayleigh variance pdf case When the noise variance varies following a Rayleigh pdf, the optimum $\hat{\alpha}$ values (Table 5) are very similar to those of exponentially varying variance. In this paper we use $\rho = 5$. Consequently, the achievable rates are very close to those obtained in such a case (Fig. 6). Nevertheless, in this case the average performance improvement using this technique instead of the worst case encoding strategy is at least 4 times larger. As in the previous case, for Gaussian host and no side information available at the decoder the obtained α values are presented in Table 6 and in Fig. 6.

WIR	$\hat{\alpha}$	$R_L^{\mathrm{MG}}(\hat{\alpha})$	$R_L^{\mathrm{MG}}(\alpha_{\mathrm{WC}})$	$R_L^{\mathrm{MG}}(\alpha_{\mathrm{WC}})/R_L^{\mathrm{MG}}(\hat{\alpha})$
-16dB	0.2842	0.002017	0.008115	4.023
-6dB	0.2851	0.00096703	0.00431	4.46

Table 5. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for Rayleigh varying variance and a Laplacian host when the host statistics are available at the decoder.

6. COSTA CODING PERFORMANCE UNDER UNCERTAINTY ABOUT THE CHANNEL VARIANCE

It is evident that the optimization performed in the previous Section will not be possible whenever the distribution of the attacking variances is unknown. This condition can be referred to as the condition of universal coding under assumption of prior ambiguity concerning the attack channel statistics. In this case one can consider the

WIR	$\hat{\alpha}$	$R_L^{\mathrm{G}}(\hat{\alpha})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})$	$R_L^{\mathrm{G}}(\alpha_{\mathrm{WC}})/R_L^{\mathrm{G}}(\hat{\alpha})$
-16dB	0.2841	0.002592	0.009429	3.64
-6dB	0.2850	0.001565	0.005719	3.66

Table 6. Average rate loss analysis of on-average-optimal Costa coding versus worst case encoding strategy for Rayleigh varying variance and a Gaussian host.

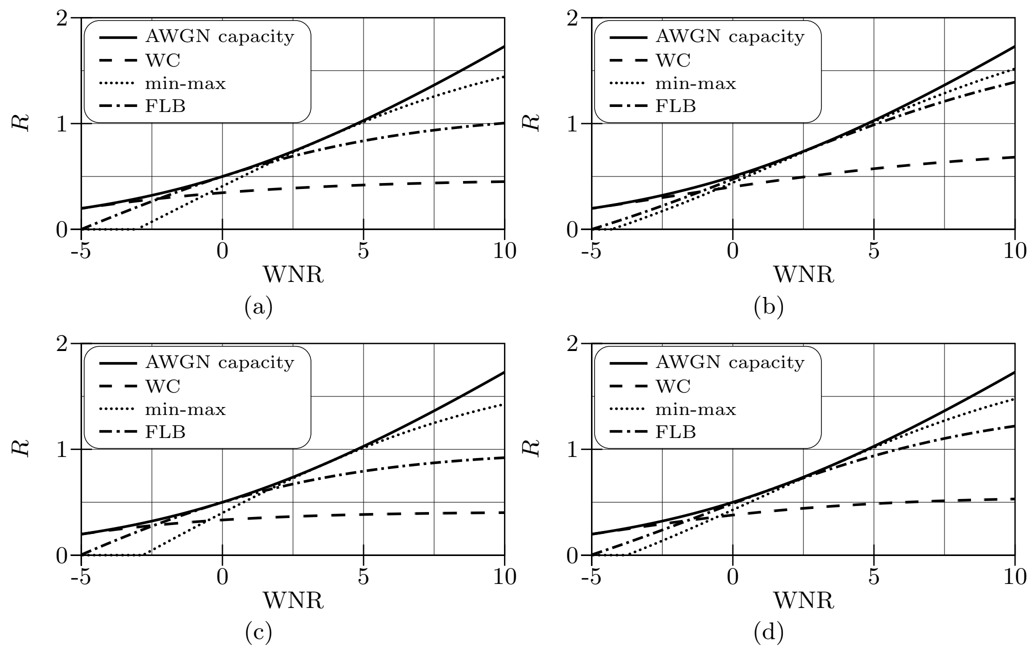

Figure 7. Achievable rates performance comparison when the distributions of the attacking channel is unknown (min-max) and with the fixed lower bound (FLB). (a,c) WIR = -16dB and (b,d) WIR = -6dB. (a,b) Laplacian host and (c,d) Gaussian host.

rate optimization problem from a min-max performance perspective:

$$\min_{\alpha} \max_{\mathrm{WNR} \in [\mathrm{WNR}_{\min}, \mathrm{WNR}_{\max}]} \left(C^{\mathrm{AWGN}} - R^{\mathrm{MG}}(\alpha, \sigma_Z^2) \right). \tag{11}$$

The solution to this problem for the above assumptions indicates that the optimal value for the optimization parameter is $\alpha = 0.6985$ for all WIR and host pdfs, assuming an AWGN attack.

The obtained optimization results presented in Fig. 7 allow to conclude that for some particular low-WNRs only zero-rate communications are possible. Obviously, such a solution is not acceptable for robust data-hiding. In order to overcome the revealed problem, one can apply a modified scenario where it is supposed to guarantee not a minimum of the maximum rate loss but the minimum possible of the maximum rate loss with a predefined minimum achievable rate of reliable communications (i.e., to guarantee a lower rate bound of reliable communications while aiming to use the presented min-max strategy). One can compute the minimum achievable rate of reliable communications supposing that 64 bits should be reliably communicated through an 512×512 pixel image ($R = 2.4 \cdot 10^{-4}$ bits per pixel). For the presented scenario, the optimization parameter values following this strategy are $\hat{\alpha} = 0.5107$ and $\hat{\alpha} = 0.6289$ for WIR = -16dB and WIR = -6dB, respectively. If the host is Gaussian and the host statistics are not available at the decoder, the optimization parameter values are $\hat{\alpha} = 0.49$ and $\hat{\alpha} = 0.58$ for WIR = -16dB and WIR = -6dB, respectively. The achievable rates for such a coding are presented in Fig. 7.

The obtained results shows a larger rate loss in the high-WNR, but the minimum achievable rate is guaranteed in all the WNR range.

7. CONCLUSIONS

In this paper we have analyzed the asymmetrically informed data-hiding communications setup with Laplacian host interference assuming different levels of a priori information about the statistics of the attacking channel. We have proposed rather than optimizing the system performance for a certain WNR to maximize the average achievable rate at the given interval of WNRs assuming that the attacking channel variances are distributed following a uniform, exponential or Rayleigh pdfs.

The solution of the formulated problem gives the value of the optimization parameter α to be used in the codebook design. Furthermore, we have considered the case when the distribution of these variances is unknown and performed the analysis within the min-max framework. The obtained result revealed the problem of zero-rate communications for the low-WNR regime. The disclosed problem solution was obtained assuming that a fixed rate of reliable communication should be guaranteed for the worst communication conditions.

The obtained results demonstrate a smaller average rate loss than using the optimum Costa parameter for the maximum variance within the interval. This difference is specially significant for large noise variance pdfs concentrated in an small area such as the results of the truncated Rayleigh noise variance pdf. The presented strategy has been validated in the original Costa set-up with Gaussian host pdf and in the asymmetric data-hiding set-up considering a Laplacian host pdf.

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