On an Agent-aided Noisy Feedback Scheme - III

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June 24, 2024

Abstract

In a previous set of notes, the authors proposed a parallel layer next to an asymptoting two-phase noisy feedback scheme, say, of Sahai-Simcek (2004) for the DMC or Chawla (2006) for the AWGNC. This layer is a non-streaming layer, used as a 'scratch-pad' to improve the streaming quality of the main layer. In this continuing note, we provide the encoder and decoder functions of the main forward channel.

In [1, 2], the authors discuss two phase schemes for the achievability part of the AWGNC and DMC noisy feedback reliability function, respectively. In the present note, we propose that in parallel to the anytime-corrected [3] streaming data, we have a side channel which is governed by an AI or other intelligent agent that performs retrospective backtracking (RB) and correction of the data gathered from the main channel (see Figure 1). Specifically, this side channel agent requests, at any given time, the transmitter to re-provide a certain transmission in case of uncorrectable error, continuing to make such requests until a correct transmission is received.

Thus, this side channel will have a geometric random variable governing the expected number of cycles before the first success (correct transmission). Call this expected value β. If β is significantly less than d, the anytime delay of the main channel, then the agent can probabilistic-ally inject its packets into the main stream (with replacement of the corresponding main stream packets) and potentially generate a better streaming performance overall.

The encoder of the forward channel normally would be a map from the product of the message space and the feedback space to the channel input space. However, in the presence of the agent, the encoder of the forward channel is a map from the product of the message space, the feedback space as well as the agent's output space to the channel input space. Let M be the message space, F be the feedback message space and let A represent the agent's output space. The channel input space is represented as X. Thus the forward channel encoder is given as:

$$\mathscr{E} : M \times F \times A \to X. \tag{1}$$

The forward channel decoder on the other hand is given as would normally be given. Thus,

$$\mathscr{D} : Y \to M \tag{2}$$

is the map representing the forward channel decoder, mapping the channel output space to the message space.

Example 1. Assume that A can only take three values: 0, 1 or 2. When A is 0, the encoder output should be as though the agent were absent, when A is 1, the encoder output should be the previous encoder output, repeated and when A is 2, the encoder output should be the previous two encoder outputs, repeated. In this way the agent has the capability to request a repeat transmission with some depth, in this case, 2.

In the normal analysis, to develop a coding theorem, as a first step we generate a random code according to the channel input distribution p(x). In the absence of feedback or an agent, the encoder map would determine how the messages (with their uniform distribution) are mapped to the channel inputs and therefore the form of p(x). In the presence of an agent (and feedback), p(x) might be modified. In particular, it might be constrained to fall within a certain set of distributions. Thus the capacity achieving p(x) would need to be chosen from among these. Whether the choices for p(x) are narrowed or expanded can be determined combinatorially and this would be a factor in determining if the set of distributions is expanded or narrowed which in turn would have an impact on the space from which the optimal distribution (capacity-achieving) is chosen [4].

In future parts, we will complete the above argument to determine the impact on capacity and ultimately build to a study of the reliability function achievable by this scheme.

References

[1] Aman Chawla. Reliability of a gaussian channel in the presence of gaussian feedback. *S.M. Thesis*, 2006.

[2] Anant Sahai and Tunç Şimşek. On the variable-delay reliability function of discrete memoryless channels with access to noisy feedback. In *Information Theory Workshop, 2004. IEEE*, pages 336–341. IEEE, 2004.

[3] Anant Sahai and Sanjoy Mitter. The necessity and sufficiency of anytime capacity for stabilization of a linear system over a noisy communication link - Part I: Scalar systems. *IEEE Transactions on Information Theory*, 52(8):3369–3395, 2006.

[4] Thomas M. Cover and Joy A. Thomas. *Elements of Information Theory*. 2005.

[5] Charles H Bennett, Igor Devetak, Aram W Harrow, Peter W Shor, and Andreas Winter. The quantum reverse shannon theorem and resource tradeoffs

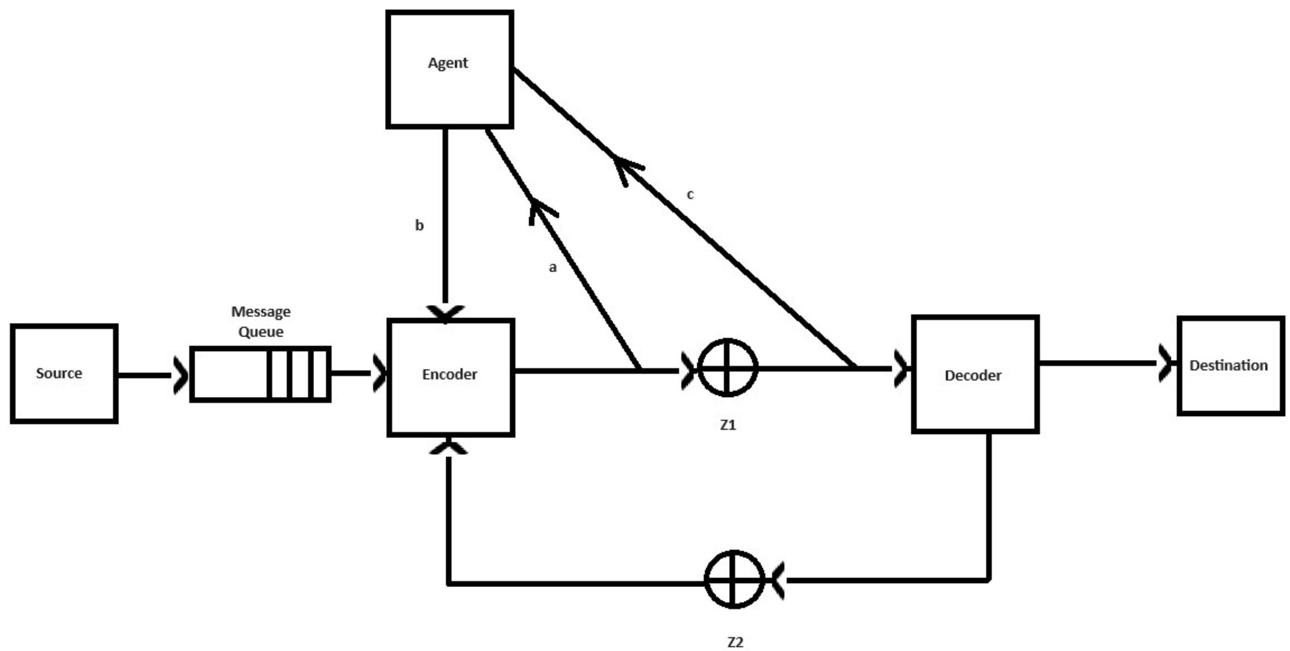

Figure 1: Agent-aided noisy feedback. The agent is a simulated encoder [3, 5]. It determines when the encoder can act differently so as to improve performance, and correspondingly instructs the encoder. Suppose channel a can extract a fraction r of the packets from the forward channel and use these to simulate the forward link say by interpolation or regression or machine learning. In a similar way it knows the output of the forward link. Using these two and regression it monitors the communication situation. When the "d" of the anytime code is very large it means many many transmissions are being interleaved. In such a case the agent can instruct the encoder to repeat and complete more cycles than it is currently performing, using $\beta < d$ repetitions per cycle on average.

for simulating quantum channels. *IEEE Transactions on Information Theory*, 60(5):2926–2959, 2014.