Synchronizing Heavily Encoded Data in Bad Weather

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Deep space missions choose a data rate to ensure reliable communication under most conditions. Certain critical data can be more heavily encoded, to be decoded under particularly bad atmospheric conditions. This article shows that, in such a system, finding and synchronizing critical data will not be a problem.

I. Introduction

Deep space missions choose a data rate so that data will be received reliably under most conditions. Under certain atmospheric conditions, however, performance is degraded. Further decreases in the data rate make this less likely, at the cost of less information under most conditions.

In order to increase the probability that certain "critical" data are received reliably, such data can be more heavily encoded. Earlier work (Ref. 1) argued for a very simple system: put critical data into separate frames and, after the usual channel encoding, repeat symbols in those frames. (The number of repetitions would depend on the amount of attenuation.) On the ground, during bad weather, the other data might be useless but the critical data could be decoded.

The analysis in Ref. 1 ignores problems of synchronization: can we find the critical data to decode it? The purpose of this article is to show that, if the symbol synchronizer assembly (SSA) is not losing lock, critical data can be found and synchronized.

II. Analysis

We are assuming a system in which critical data bits are repeated (in whole frames) enough times to make up for possible weather attenuation, and we want to know whether the critical frames can be found and synchronized. We are further assuming that the SSA is not losing lock, and that we will be free to design a frame synchronizer to whatever standards are necessary.

Since the repetitions apply to the frame synchronization marker, we can think of this as a problem of whether the (repeated) marker can be found in a very long frame: the critical frame followed by a lot of noncritical frames. Since the repetition code serves exactly to bring the signal-to-noise ratio (SNR) back after the attenuation, the SNR is not a factor in the answer. The amount of critical data is, however, a factor since it determines the number of non-critical frames between critical frames, and their frame synchronization markers.

Of course, with long enough buffers, one can always find and synchronize data which are different from other data. The question is whether it can be done in a reasonable length of time. The calculations described below show that, under reasonable circumstances, a very simple system declaring synchronization after six critical frames will fail to declare synchronization less often than once in 10^6 and will declare synchronization incorrectly less than one time in 10^8.

We are assuming that all data are (7, 1/2) convolutionally encoded. Consider the following parameters, chosen because they are plausible: Suppose that critical data symbols go into the SSA at -4.3 dB (symbol SNR). This means that critical data are attenuated 3 dB from the requirement for the bit-error rate 10^{-5} for concatenated coding. (E_b/N_0 is 2.3 dB; subtracting 3.6 dB for concatenated coding overhead and 3 dB for attenuation gives -4.3 dB.) Also suppose that frames are 10,000 bits long and one in every 50 frames is made up of critical data. Assume that each frame begins with a 32-bit synchronization marker, and every symbol corresponding to a critical frame has been repeated once. This would mean that frames of critical data begin with a 104-symbol ($104 = 2 \cdot 2 \cdot (32\text{-}6)$) pattern. (Six bits are needed to flush the encoder. This leaves 26 bits in the marker. Rate 1/2 convolution coding and the repetition make this into a 104-symbol marker.) Finally, assume that 3-bit quantized symbols leave the SSA and go into a long buffer, from which strings of 104 symbols are compared to the pattern which announces the beginning of critical data. What is the likelihood that a simple algorithm could pick out the critical data within 6 critical data frames?

Several simplifying assumptions have been made: that convolutionally encoded random data look like random data, that the sum of 104 independent random variables is Gaussian, and that overlaps between the marker and itself, whether repeated or not, look random. We also assume a very simple algorithm for finding the critical data: at each place, 3-bit quantized symbols leaving the SSA are compared to the marker. They are assigned "disagreement levels" of 0, 1, 2, 3, or 4, depending on whether and how much they disagree with each marker symbol. A threshold and a required number of threshold crossings are set. The 104 disagreements are summed and compared as a possible beginning, until six frames of critical data ($6 \cdot 50$ frames of total data) have been checked. At this time, the place at which the threshold has been reached most often is declared the critical data marker, assuming that threshold has been crossed at that place at least the fixed number of times.

This calculation gave a probability smaller than 10^{-6} of failure to declare synchronization after six critical frames, and smaller than 10^{-8} of incorrect declaration of synchronization. In a system with more critical data, there are fewer non-critical frames between critical frames, and synchronization is faster; less critical data would make synchronization slightly more difficult.

Of course, if this system were really being used, a comparison could be made to a more efficient set of counter increments (Ref. 2), or to a system more complicated than a simple crossing of threshold, and comparisons could be made for different sizes of buffers. The point of this calculation is that finding and synchronizing critical data will not be a problem. Further questions seem more appropriate to a time when such a scheme is being considered.

III. Conclusions

We have shown that, under reasonable circumstances, synchronization will not be a problem in a system which repeats frames of critical data to make up for possible attenuation from atmospheric conditions.

References

1. Swanson, L., and J. H. Yuen, "A Strategy for Successful Deep Space Information Transmission in Bad Weather," *TDA Progress Report 42-78*, Jet Propulsion Laboratory, Pasadena, California, August 15, 1984, pp. 143-151.

2. Swanson, L., *A Comparison of Frame Synchronization Methods*, JPL Publication 82-100, Jet Propulsion Laboratory, Pasadena, California, December 15, 1982.