Say it in 51 bytes

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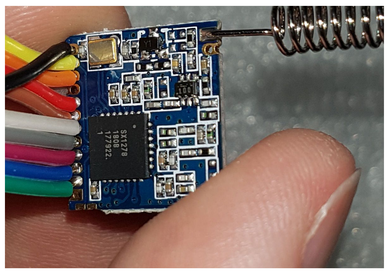
Problem statement

When you want to send your measurement data to some internet database, there are a number of options that require very little energy. A popular one is LoRa (Long Range) radio, which can run for months on a few AA batteries. The disadvantage is that the amount of information that can be sent is very limited. A typical maximum message length is 51 bytes and, normally, only a few messages can be sent per day.



Typical LoRa module with antenna and SPI connections.

Source: Wikimedia CC0

The question then becomes: How can I stuff as much information as possible in 51 bytes? The answers depend heavily on the nature and number of data collected and the envisioned applications.

51 Bytes

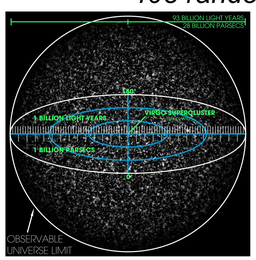
This sentence contains fifty-one ASCII characters!! A “naive” format, like CSV, would go about sending information in this way.

At the same time:

51 bytes = 2^{408} combinations ≈ $6.6*10^{122}$ >> Number of electrons in universe >> $4.6*10^{46}$ = Weijs-vandeGiesen constant ≈ Number of water molecules on Earth.*

```
00100111 11101111 11011110 10100000 11110000 10100101
11100101 10110010 01011111 11011100 11101010 00101011
01010100 11101100 11101110 01101000 10101110 00000011
11001011 11000011 11000101 11100101 00111010 10110110
01000101 00100111 01101001 00011001 10001000 10111001
00110001 10111000 01101110 00100101 01011011 10111010
11100110 11100011 00111101 11100110 11101011 10100110
01111001 00100110 00001010 10011101 01011000 11000111
                  11000101 11011111 11000000
```

408 random bits



Observable universe.

Source: https://commons.wikimedia.org/wiki/File:Observable_Universe_with_Measurements_01.png

*Assuming there is more than one [1].

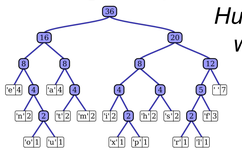
Quantification

If you want to report water levels once per hour over a day, there is no need for processing. You would have two bytes per measurement, which should normally be enough if you report the water level in centimeters, or millimeters, above a reference level as integer. For many measurements, 256 levels would provide sufficient resolution but the range usually has to be scaled properly.

On the other side of the spectrum would be the case in which there are so many data that only a statistical description would fit, such as for a disdrometer. There is a little known but very handy algorithm to calculate cumulatively as many moments as one wants as one collects data in a well-scaled way [2]. Two bytes per moment will transmit a lot of detail!

Optimal coding

Once the observations have been quantified, they have to be encoded in such a way that as much information as possible is captured. Huffman coding provides a straightforward way to to encode as much information in as shirt a message as possible.



Huffman coding assigning shortest words to most frequent events.

Source: Wikimedia, CC0

The most frequently occuring events are given the shortest descriptions.

If no standard reporting intervals are needed, one could simply write a message, using a few bits for boring stuff and more bits for surprising stuff until 51 bytes are filled and then transmit. An adaptive algorithm needs to be designed.

NOTES

[1] See Wheeler conjecture (https://www.nobelprize.org/prizes/physics/1965/feynman/lecture/)

[2] Philippe Pebay (2008): Formulas for Robust, One-Pass Parallel Computation of Covariances and Arbitrary-Order Statistical Moments (https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2008/086212.pdf)

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