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Complexity analysis of Reed-Solomon decoding methods combined with erasure information in DVB-H

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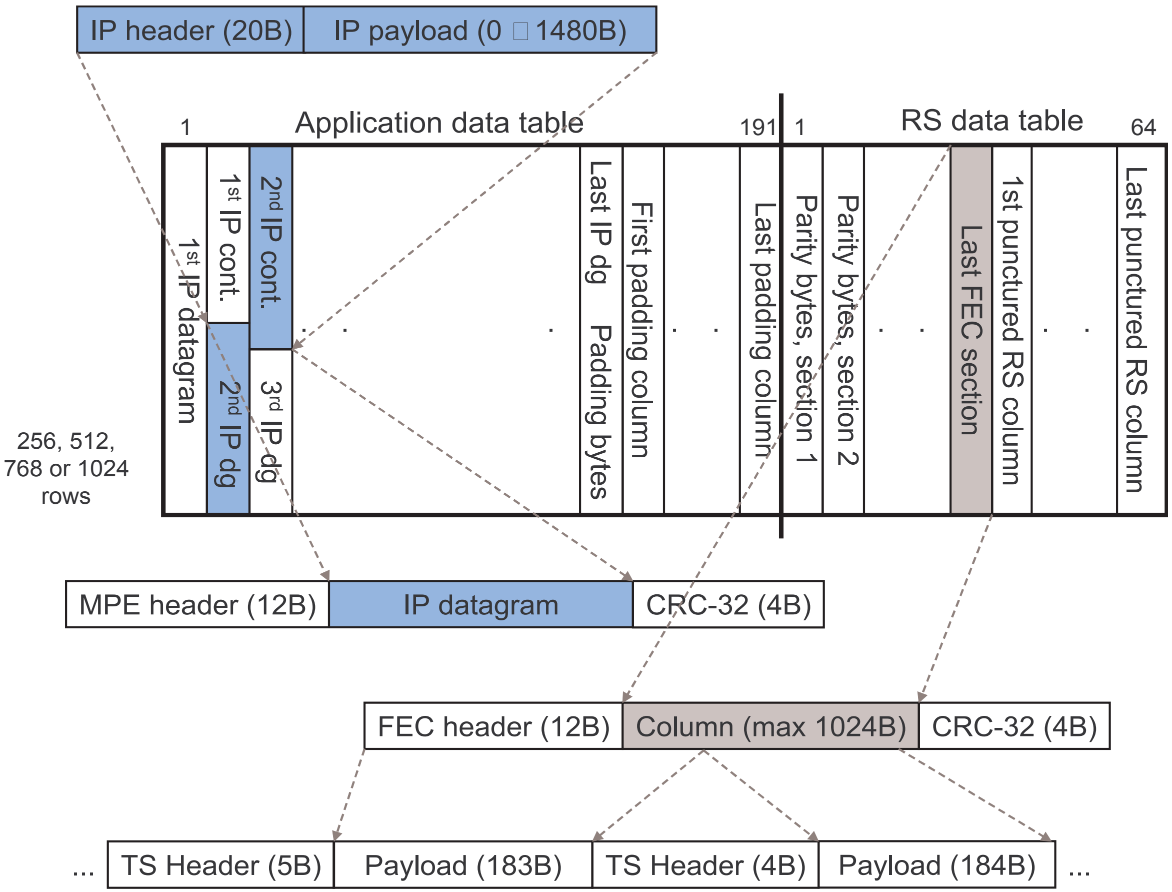
Basic Setting

- DVB-H: A broadcasting standard for handheld devices
- Based on and compatible with DVB-T (Digital Video Broadcasting – Terrestrial)
- Enhancements: MPE-FEC (Multi-Protocol Encapsulation – Forward Error Correction) at link layer, power saving between bursts of data transmission
- IP datagrams are inserted into a MPE-FEC frame column-wise for the row-wise calculation of redundancy bytes with RS(255,191) code (cf. next page)

Our task was to analyse the complexity of the link-layer RS decoding with erasures both in frequency and time domains. The work was motivated by recent articles concerning MPE-FEC error rates in different erasure decoding schemes.

Basic Setting

- MPE-FEC frame: IP datagrams are arranged columnwise while RS parity bits are calculated row by row
- Transport stream packets carry parts of IP datagrams as their payload. In our setting, TS packets are encoded with physical layer RS(204,188)



Erasure Information

- Erasures are errors, whose location in codevector is known but whose magnitude is unknown (might be zero, i.e. no error at all)
- For any Error Correcting Code the use of erasure information greatly enhances decoding:

  Let the number of erasures in a received vector be ρ and the number of undetected errors v. Assume that the bounded distance of the code is d. Now unique decoding is possible if

$$d > 2v + \rho$$

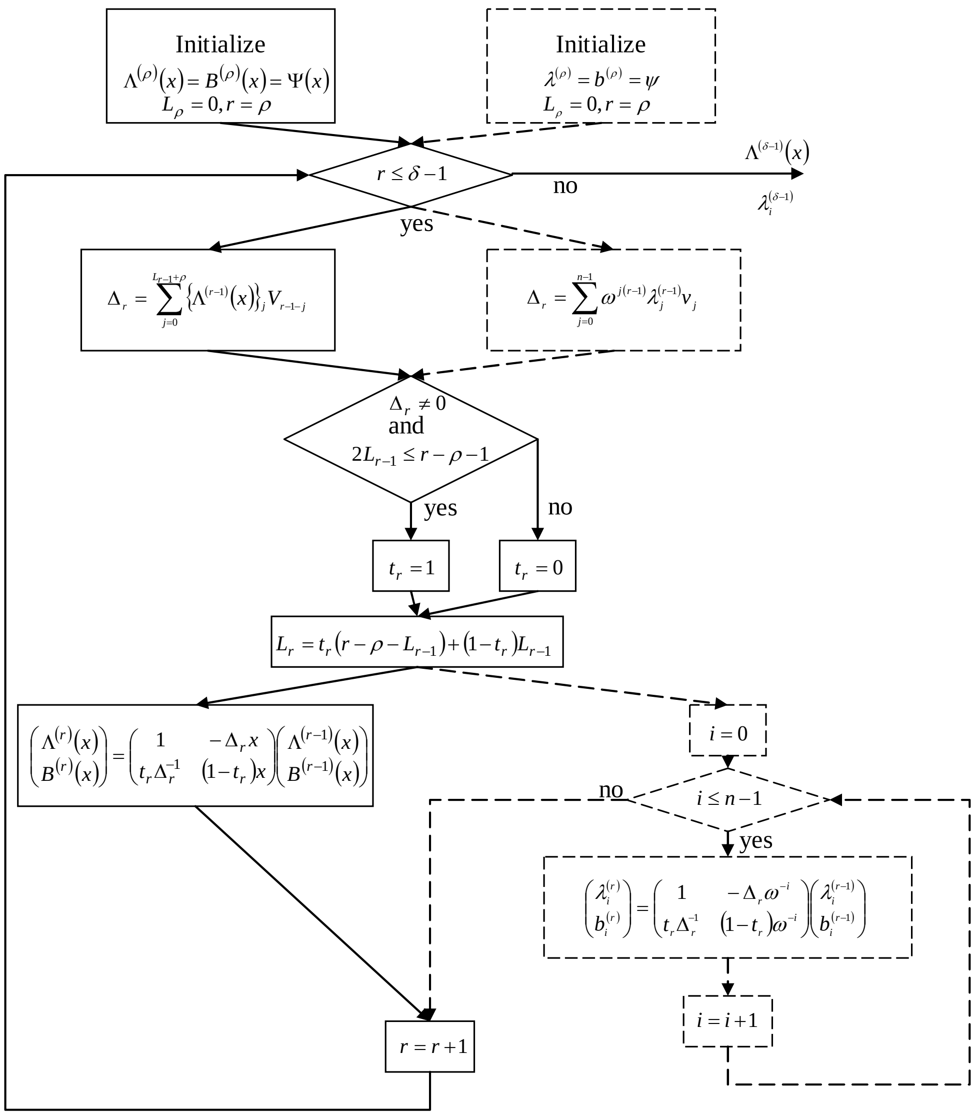
- How does the use of erasure information affect the complexity of the decoding algorithm?

Reed-Solomon Codes and Decoding in Two Domains

- Reed-Solomon codes are optimal cyclic codes (w.r.t. Singleton bound). Code vectors are polynomials generated by a specific generator polynomial
- In DVB-H, we use Reed-Solomon codes with 2^8 symbols. Hence each symbol can be represented by a byte
- Using this representation, Reed-Solomon codes are efficient against bursts of errors
- Berlekamp-Massey algorithm is an efficient decoding scheme for RS-codes.

Due to Berlekamp-Massey, Fourier transform is the natural first step in the decoding algorithm. This leads to decoding in frequency domain. Another alternative is to perform the Fourier-transform inside Berlekamp-Massey (decoding in time domain), but this adds to the complexity of the algorithm.

Berlekamp-Massey algorithm



Decoding Reed-Solomon with Erasures

- Erasure information gives us locations – the remaining task is to decide the right symbols
- Berlekamp-Massey is an involved algorithm. Erasure information decreases the complexity of decoding, since we need less from BM
- Using erasures on correct symbols increases complexity
- It is suggested in DVB-H implementation guidelines that MPE section based erasure information is used, i.e. if the CRC indicates that the section contains errors, the whole IP datagram carried in it is erased
- This leads to unnecessary loss of data, as more efficient schemes may be used

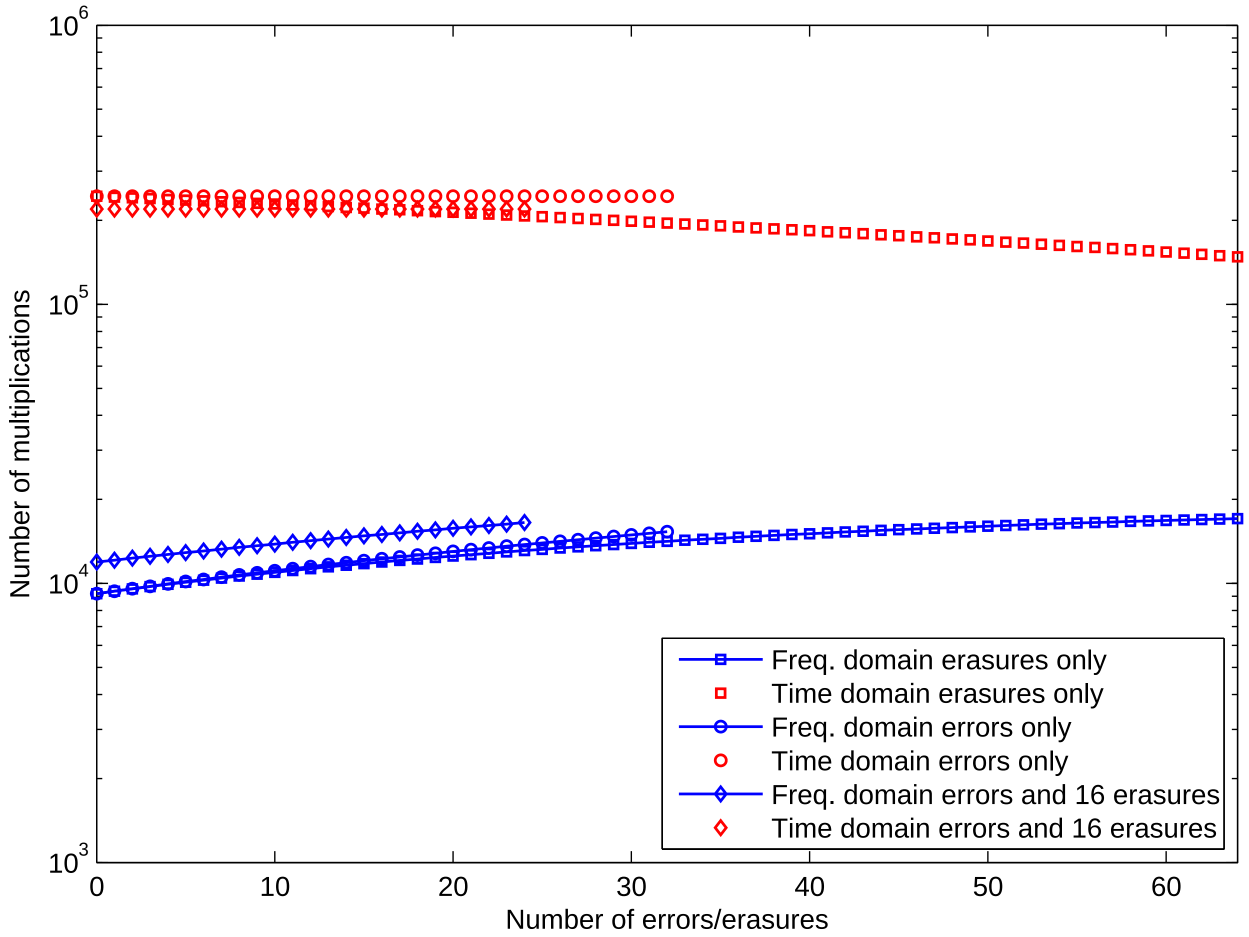
Different Erasure Schemes in DVB-H

- Erasure Information may be gathered

  1) from the CRC of the MPE-FEC sections (standard)

  2) from Transport stream packet headers (TS). This is done via physical layer RS(204,188), since we get the information whether this decoding failed
- When errors are encountered, the respective bytes may be erased or whenever possible, inserted into the MPE-FEC frame
- The most beneficial way in terms of MPE-FEC error rate is to use the so-called PID-erasure decoding (PE). In PE, one inserts all but unreceived payloads of Transport stream packets to the MPE-FEC frame
- From our complexity analysis it follows that this scheme also minimizes the complexity of RS(255,191) frequency domain decoding.

Complexity Curves of RS(255,191)



References

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- Tero Jokela, Jarkko Paavola, Heidi Himmanen and Valery Ipatov: ”Performance Analysis of Different Reed-Solomon Erasure Strategies at the DVB-H Link Layer”, Proc. PIMRC’06 (The 17th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications), Helsinki, Finland, September 2006
- Tero Jokela and Eero Lehtonen, “Reed-Solomon decoding algorithms and their complexities at the DVB-H link layer”, Proc. IEEE International Symposium on Wireless Communication Systems 2007, Trondheim, Norway, October 2007