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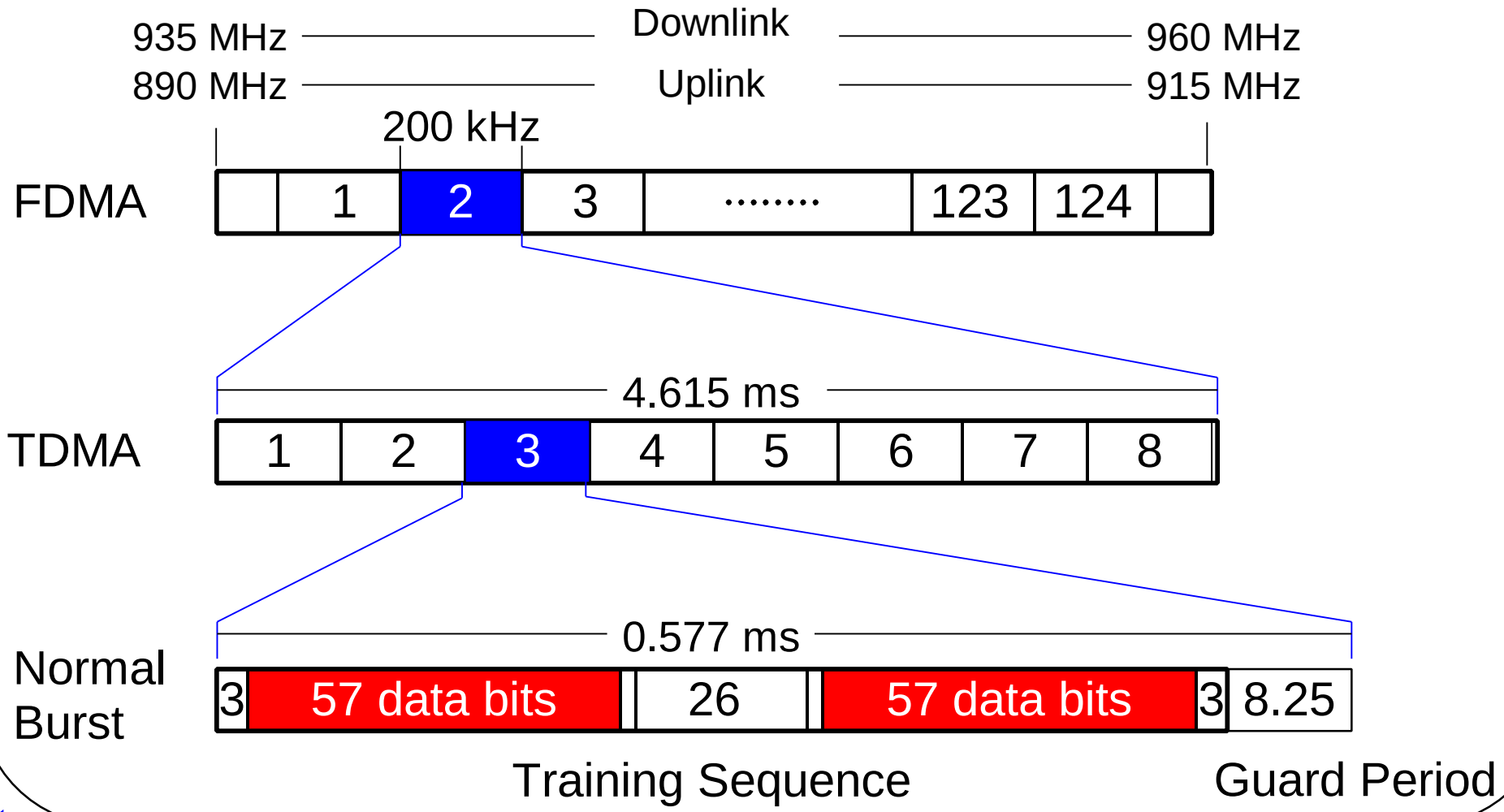
Introduction

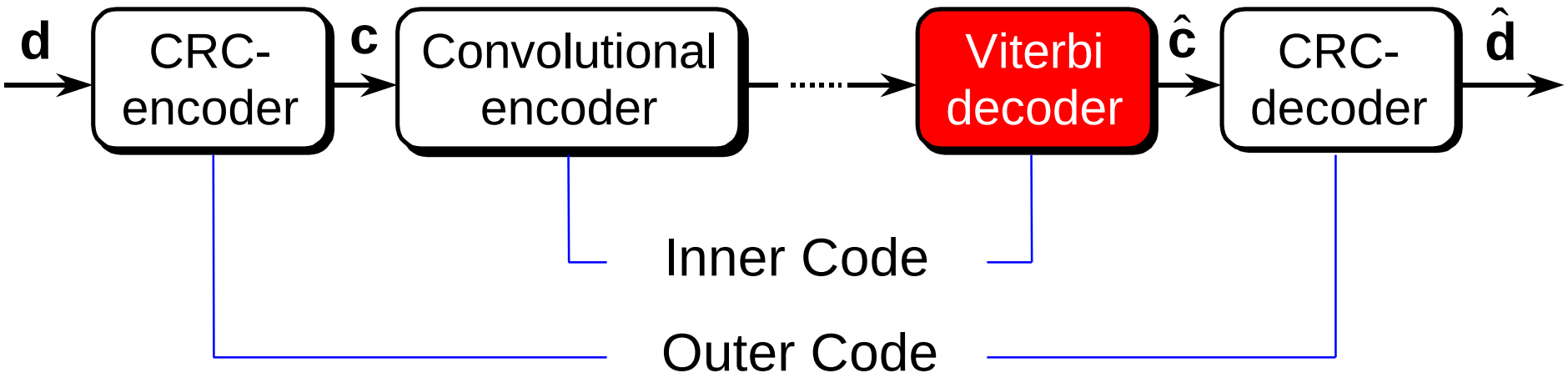
- Growing role of mobile communications in modern life
- Two European standards established
  - GSM
  - DCS 1800
- Still a lot of possibilities to improve the performance
- Improvement results in
  - Better quality of service
  - Reduction of power consumption

Here: New decoding scheme using List-Output Algorithms

GSM - Specifications

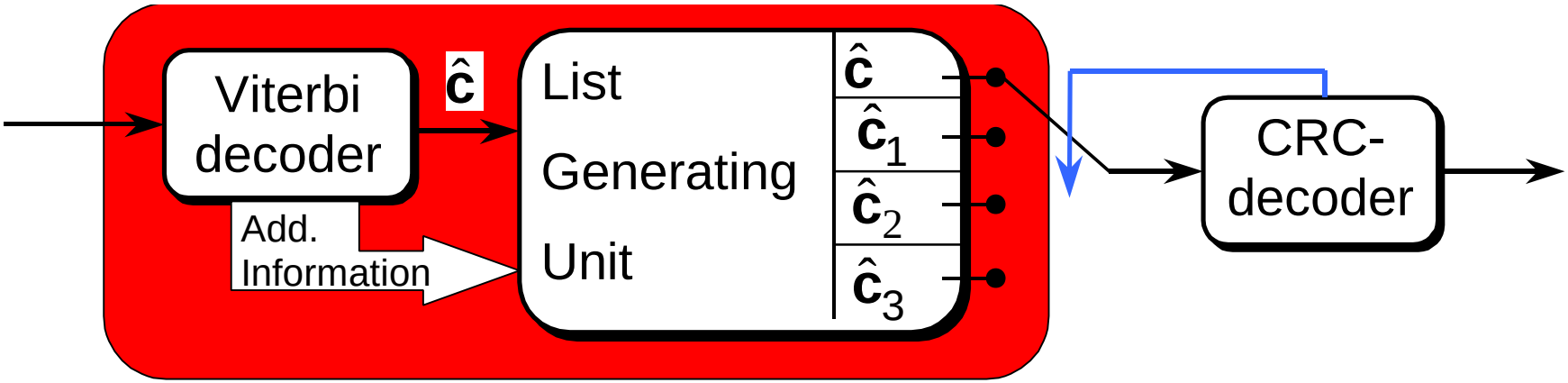


Concatenated Coding in GSM-Systems



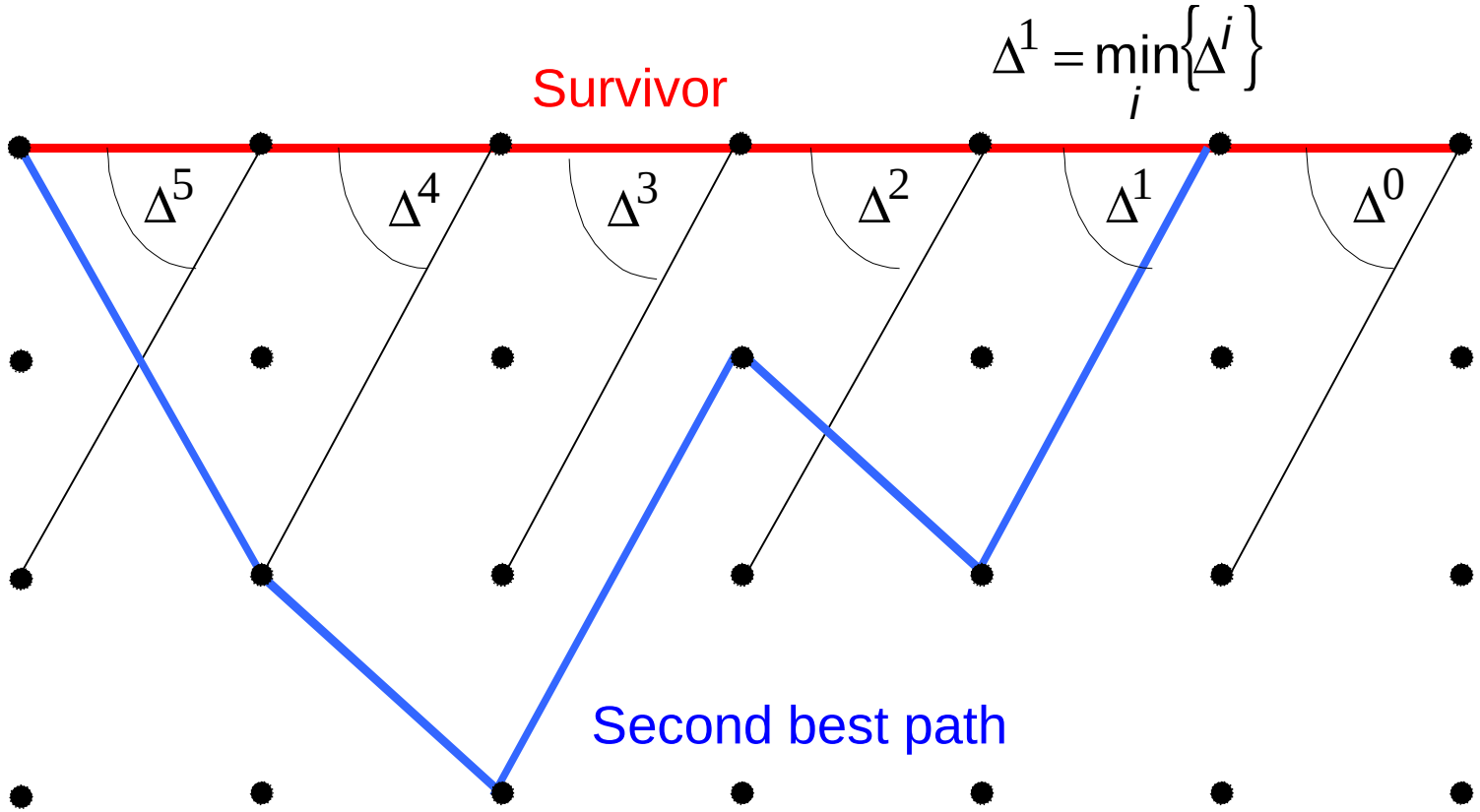
- Outer CRC-code for error-detection
- Inner convolutional code for error-correction
- Viterbi algorithm determines most probable sequence $\hat{\mathbf{c}}$
- CRC-decoder checks sequence for correctness

Applying List-Output Decoding



- List generating unit serially supplies a list of *L* most probable sequences
- CRC-decoder checks one sequence after another for correctness till:
  - Correct sequence is found or
  - End of list is reached

Serial List-Output Viterbi Algorithm (SLVA)



Soft-Output Viterbi Algorithm (SOVA)

- Extension of classical Viterbi algorithm
- SOVA delivers soft-output values for each decoded bit
- Small amplitude indicates a large uncertainty of the decision
- SOVA requires additional device for list-generation
- “1-state-method” and “2^k-method” are well known
- Supplementary interleaver for spreading burst errors introduces additional transmission delay

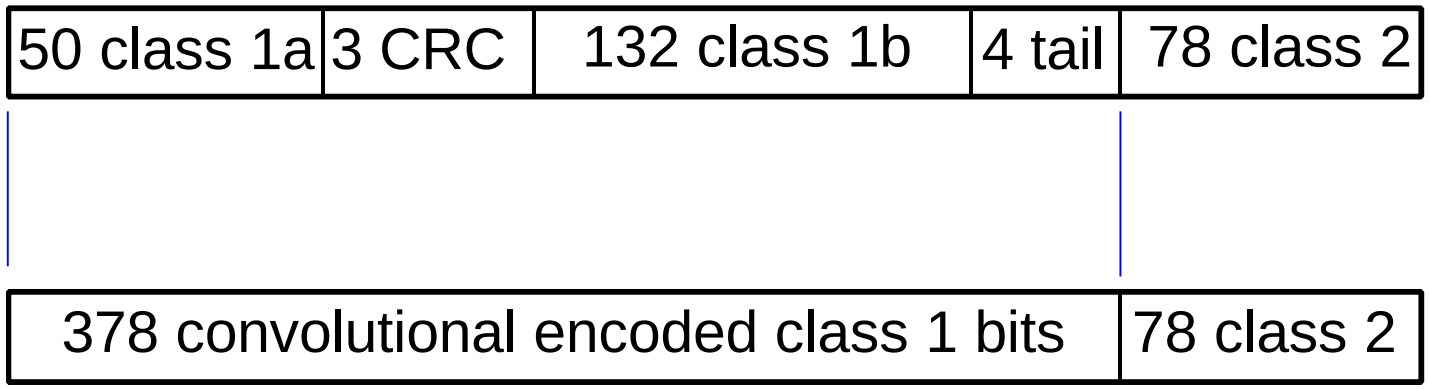
New List Generating Algorithm (LGA)

- New algorithm considers single errors as well as burst errors
- $L/2$ smallest reliability values within a data frame are determined
- $L/2$ single errors are obtained by separately flipping each bit associated with the smallest reliability values
- Burst error of length m is obtained by flipping the m smallest reliability values together
- ➡ Algorithm provides $L/2$ single errors and $L/2$-1 burst errors without additional transmission delay

Simulation Parameters

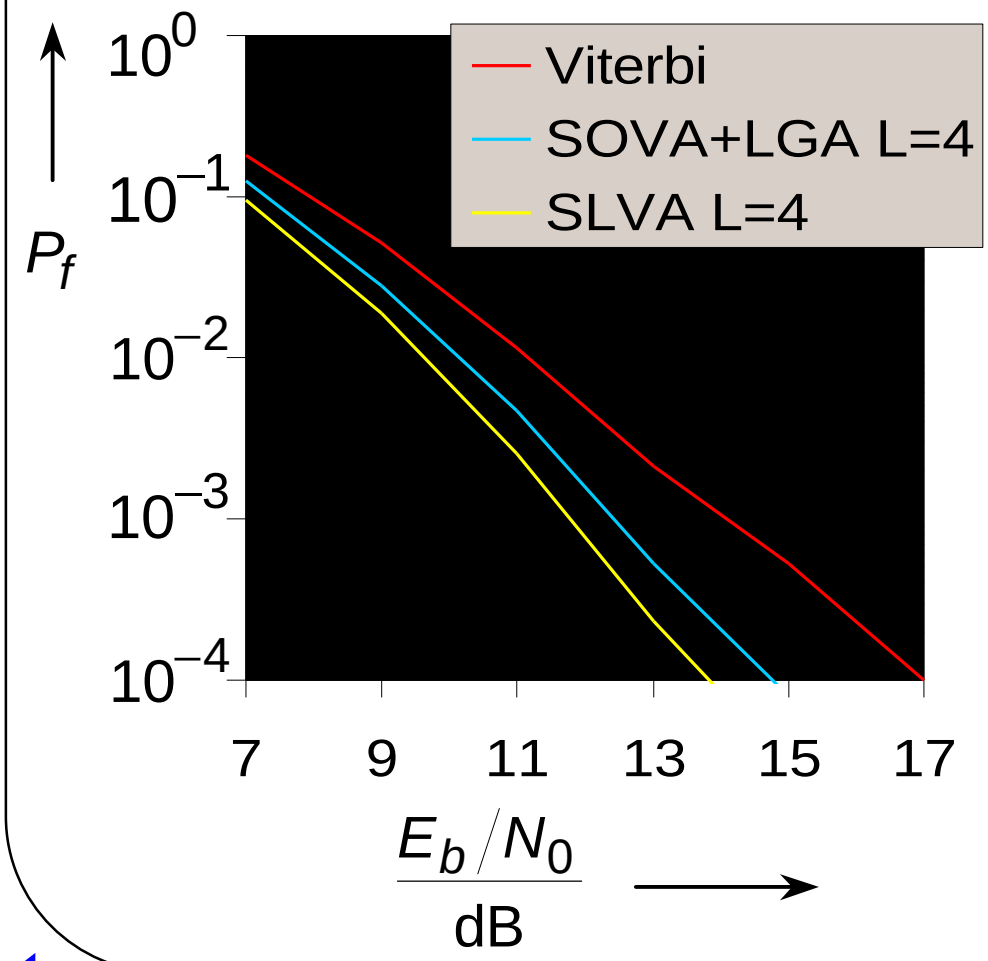
- Implementation of full TDMA-structure
- GMSK-Modulation with 4 samples/symbol
- Hilly terrain profile as channel model
- Maximum Doppler frequency of 83 Hz
- Channel estimation with training sequence
- Measurement of
  - Frame Error Rate P_f
  - Residual Frame Error Rate $P_{f,R}$

Full-Rate Speech Channel: Specifications



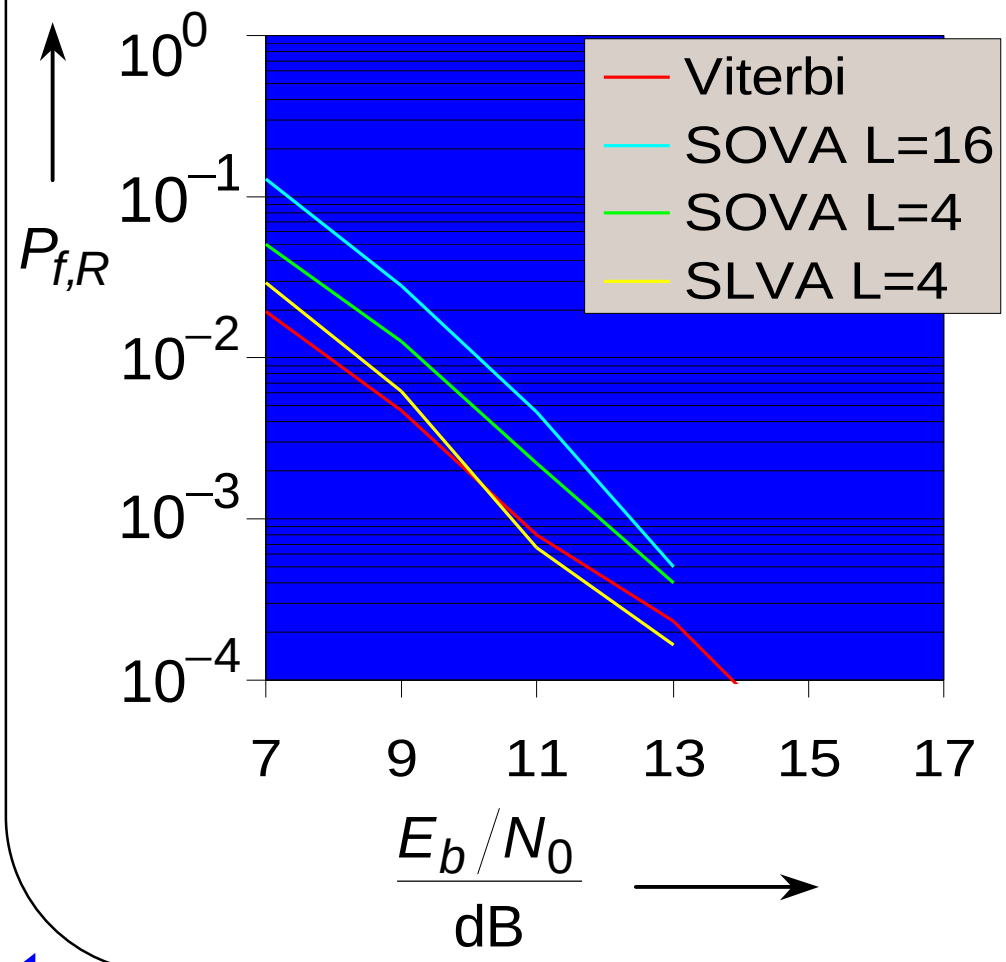
- Speech codec delivers blocks of 260 bits every 20 ms
- Blocks are divided into three parts:
  - 78 uncoded class 2 bits
  - 132 convolutional encoded class 1b bits
  - 50 CRC-encoded **and** convolutional encoded class 1a bits
- List generation only for class 1a bits

Full-Rate Speech Channel: Frame Error Rate



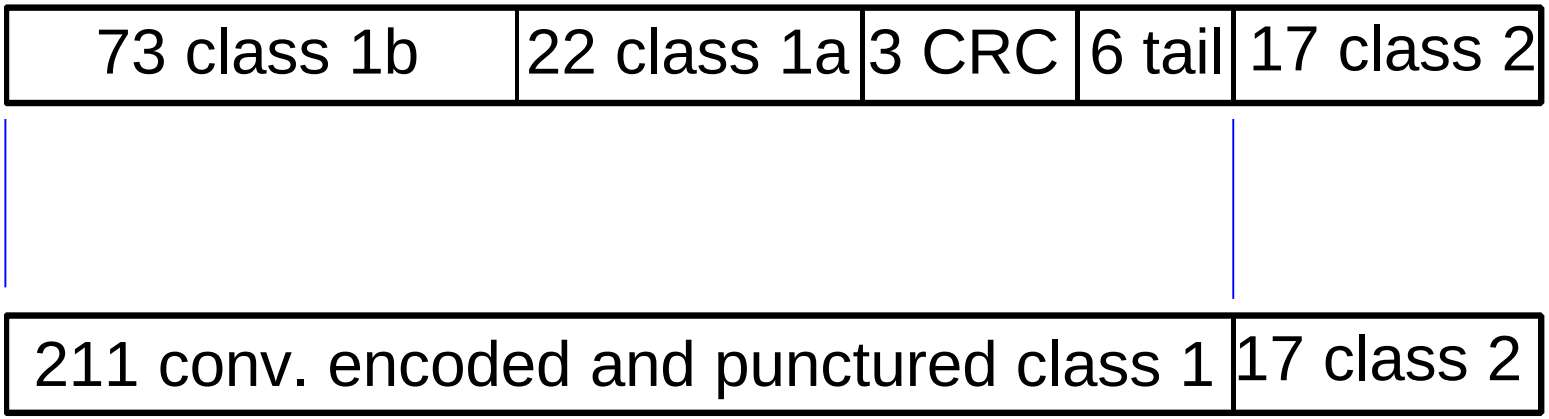
- SLVA gains 3 dB over Viterbi algorithm at $P_f=10^{-4}$
- Gain of 2 dB for SOVA with new List Generating Algorithm
- Similar results for SOVA with $L=4$ and $L=16$
- $L=4$ list elements is an appropriate choice
- Bit error rate of whole frame nearly unchanged

Full-Rate Speech Channel: Residual Error Rate



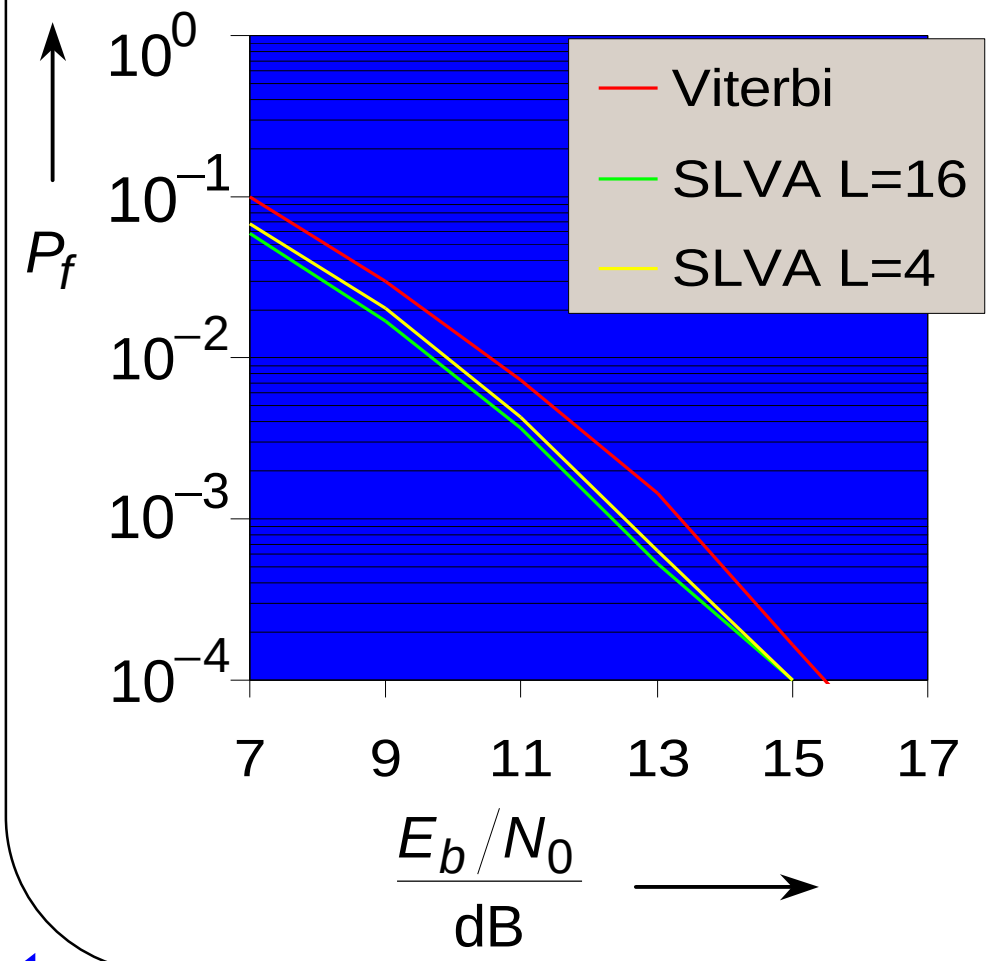
- Residual Frame Error Rate describes undetected errors
- List-Output Decoding always enlarges $P_{f,R}$
- No growth of $P_{f,R}$ for SLVA
- SOVA increases $P_{f,R}$ by a factor between 2 and 7
- Poor error detecting capability of CRC-code responsible for high $P_{f,R}$

Half-Rate Speech Channel: Specifications



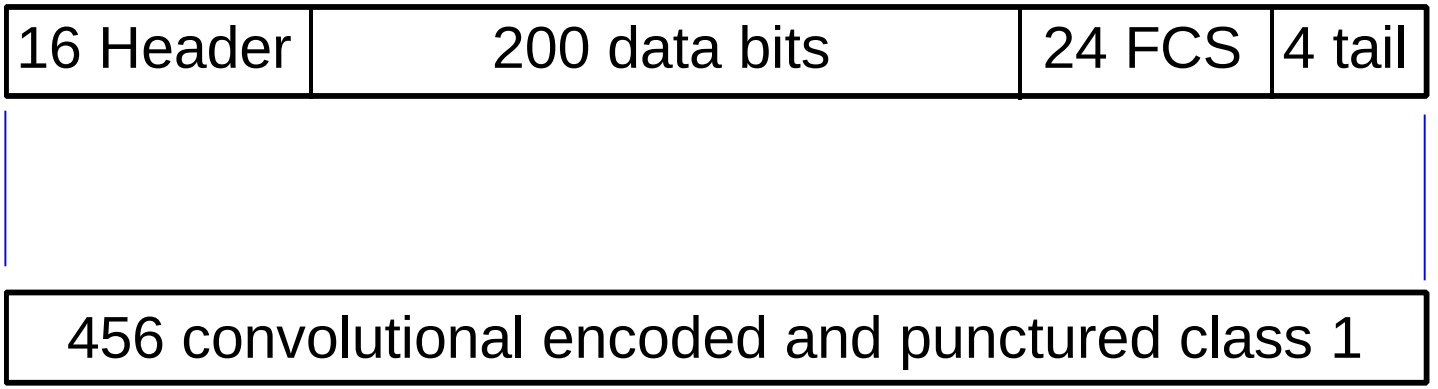
- Speech codec delivers blocks of 112 bits every 20 ms
- Structure of frame similar to that of full-rate speech channel
- Proportion between the three classes of bits different
- List generation only for class 1a bits

Half-Rate Speech Channel: Frame Error Rate



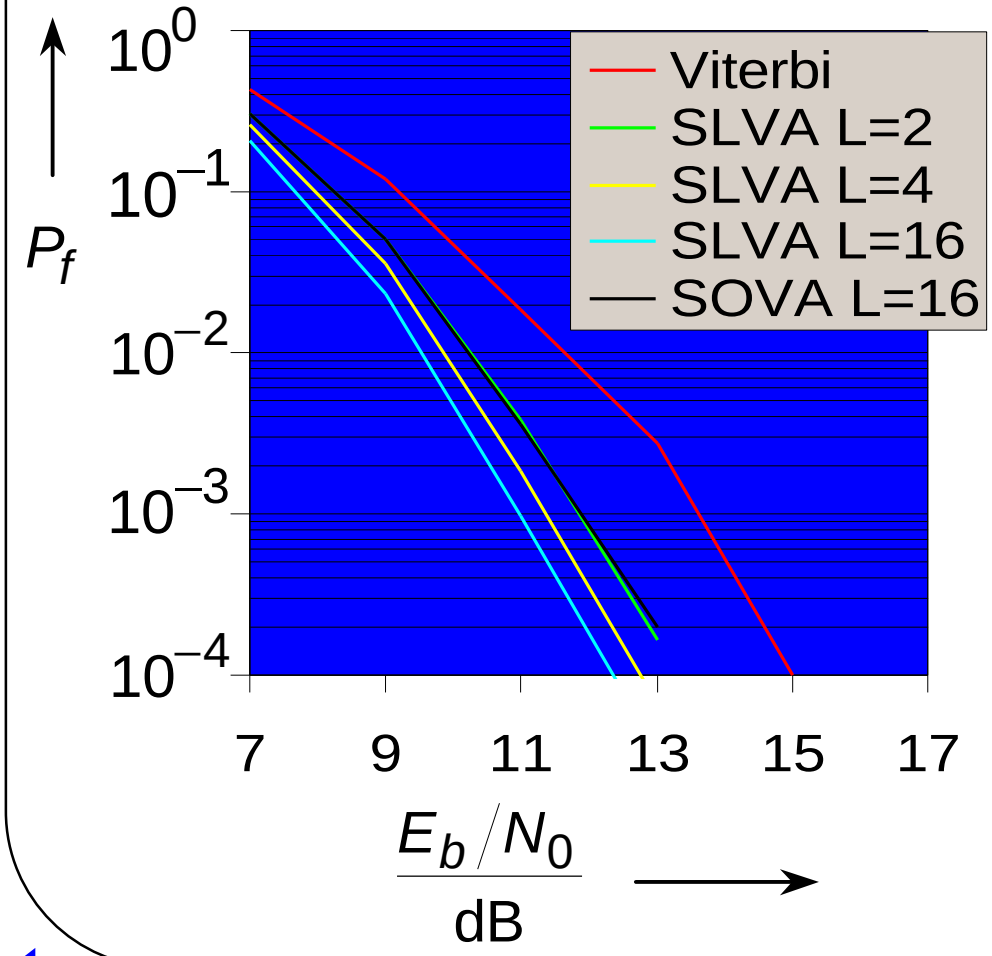
- Gains of 1 dB for List-Output Decoding
- Similar results for L=4 and L=16
- L=4 list elements is an appropriate choice
- Very high residual error rate
- Further investigations concerning effect of FER and residual FER

Full-Rate Data Channel: Specifications



- Transparent and nontransparent modes are specified in GSM
- Nontransparent mode uses Radio Link Protocol (RLP)
- Header and data bits are encoded by frame check sequence (FCS) **and** convolutional code
- Whole frame is affected by list generation

Full-Rate Data Channel: Frame Error Rate



- Gains of nearly 3 dB for SLVA with L=16
  - Halving signal power without performance loss
  - Fewer re-transmissions for data channel with same signal power
- SOVA with L=16 as good as SLVA with L=2
- No increased residual error rate due to powerful CRC-code

Conclusion

- Performance of digital mobile radio systems improved by means of list output decoding
- Gains up to 3 dB are possible
- For speech transmission residual error rate increases
- SLVA yields best results

- No change of existing standards necessary
- No bandwidth expansion nor additional delay required
- Higher computational effort needed