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LDPC Codes, Application to Next Generation Communication Systems

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Evolution of Error Coding Technology

- 1st Generation Wireless – FM no coding, 10-11 dB C/N threshold
- 2nd Generation Wireless - Convolutional codes with Viterbi decoding 5-7 dB C/N threshold, depending on code rate, and constraint length, 10^{-4} or better BER
- DVB-S – Concatentated Convolutional codes with Reed-Solomon codes, 5-7 dB C/N threshold, depending on code rate, 10^{-9} or better BER
- 3rd Generation Wireless – Turbo Codes, 0-1 dB E_b/N_o threshold at very low code rate (1/4, or 1/3), depending on block length 10^{-2} Packet Error Rate
- DVB-S2 – Low Density Parity Check Codes (LDPC), thresholds at 1 dB, 10^{-7} MPEG Packet Error Rate

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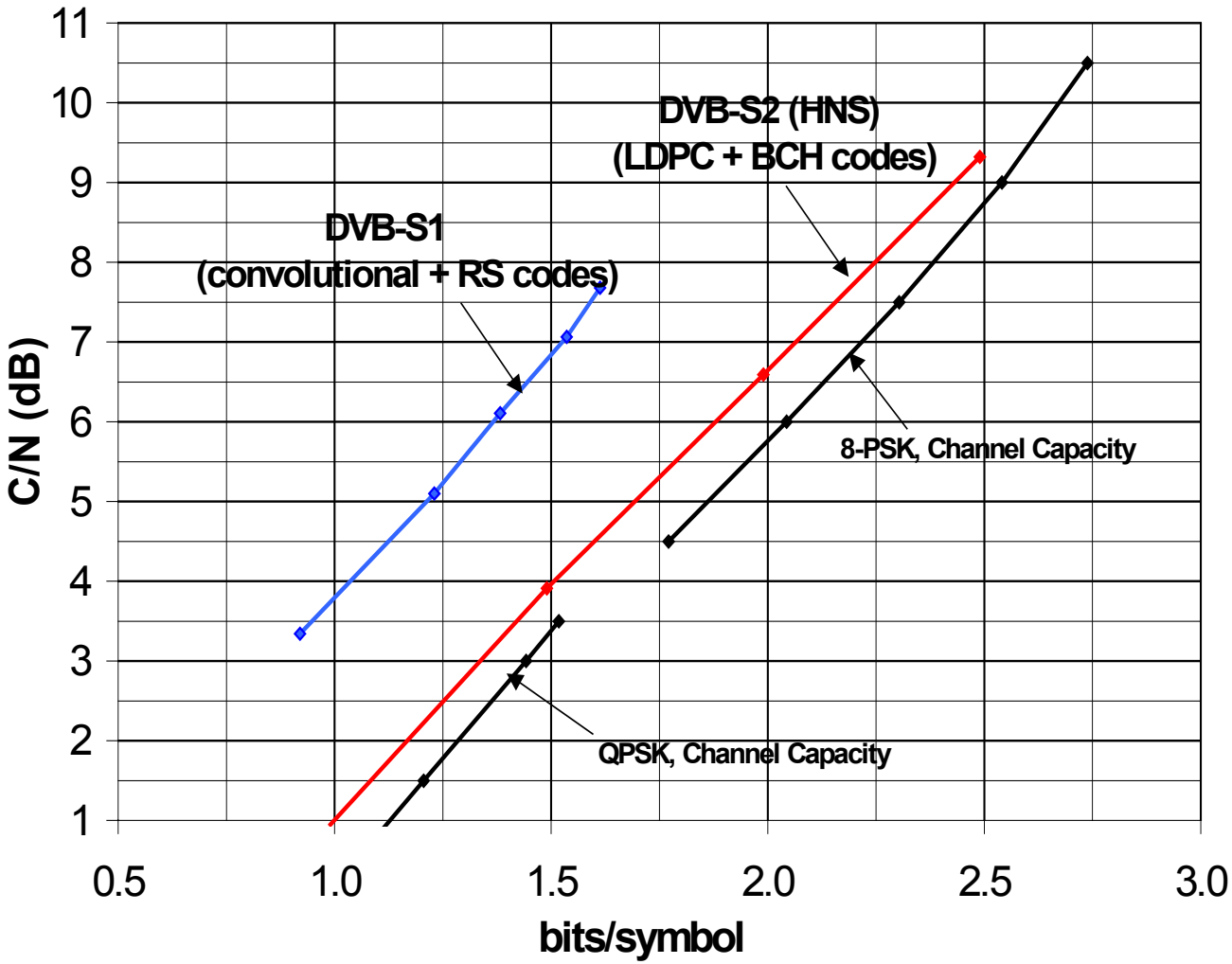
Highlights of LDPC Codes

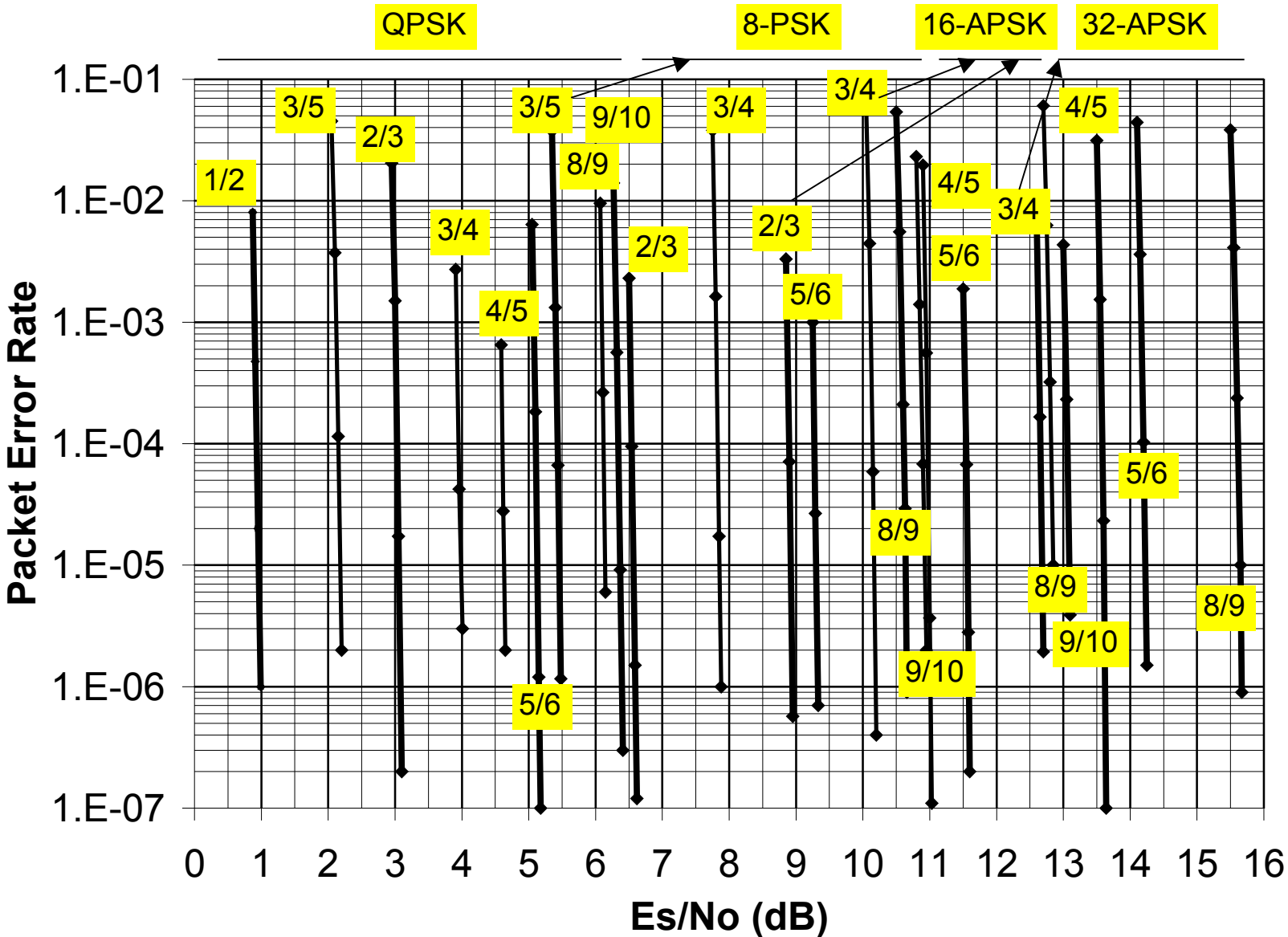
- LDPC codes are discovered by R. Gallager in the mid 60s
  - Random Coding theory states that almost all randomly designed codes are good, as long as they are sufficiently long
  - Fewer ones in the parity check bits makes decoder simple to implement
  - Still too complex to implement in the 60s, or even 80s
- Due to the performance of turbo codes, whose performance is built upon
  - Large random interleaver
  - Iterative decoding
- Neal and McKay "rediscovered" LDPC codes recently employing iterative decoding to achieve turbo-like performance
- To design a good LDPC code, efficient use of modern Random Access Memory (RAM) architecture is the key. Design of the codes that has sufficient structure to allow efficient read/write, but still preserve sufficient "randomness" to retain coding gain are necessary
- LDPC codes are selected as the DVB-S2 standard over 7 other turbo code based candidates because of its more efficient implementation as well as better performance

Eb/No vs Throughput Performance in AWGN



- About 0.6-0.8 dB away from Shannon limit
- About 0.3 dB better than the best turbo code candidates in the DVB-S2
- About 0.7 dB better than turbo code based ASIC solutions we have tested
- About 2.5-3.0 dB power advantage, or up to 30 % through-put improvement over DVB-S
- Further performance improvement not expected for decades to come

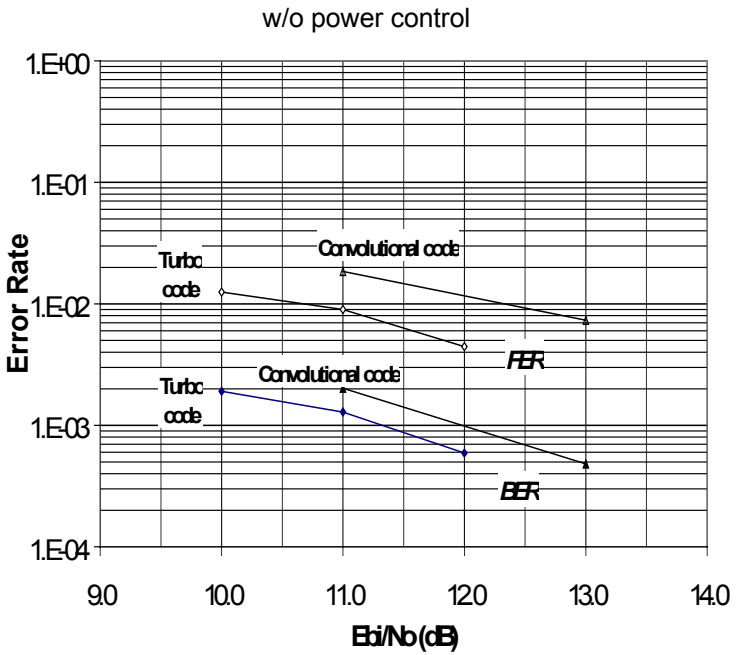
...LDPC Performance in AWGN

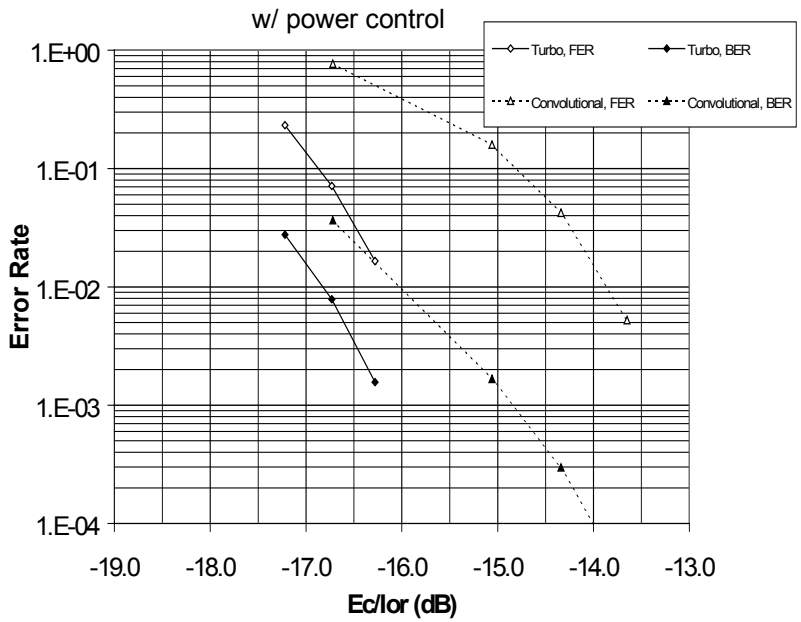


Why LDPC Codes are Strong Candidates for Next Generation Wireless Systems

- Next Generation Wireless Systems typically require higher data throughput in a given bandwidth
  - High rate FEC with higher order modulation (e.g. cdma2000 EVDV, HSDPA) is required
  - Applications require high speed by default permit use of long blocks
- Turbo codes tend to lose performance at high code rates due to excessive puncturing, turbo trellis codes become rather complex to implement for higher order modulation
- DVB-S2 work demonstrated possibility of achieving close to Shannon limit performance over a very wide range of C/N
- Typical performance is about 0.7-1.0 dB closer to Shannon limit than 3G turbo codes we developed earlier
  - 17-20 percent more capacity

Translates AWGN results to Raleigh Fading Channel





- **Our previous work on turbo codes indicated that with power control, the gain of turbo codes over convolutional codes observed in the AWGN channel can be restored in the Rayleigh fading channel**
- **We expect relative gain of LDPC over 3G turbo codes in the AWGN channel can also be preserved when power control is applied**

Future Work

- Considerable additional creativity needed to tailor specific codes to specific system architectures and operating environment
- More work is needed to optimize LDPC codes for shorter blocks
  - Based on our experience with turbo codes, we should not rule out the possibility
  - Only Shannon capacity is the limit