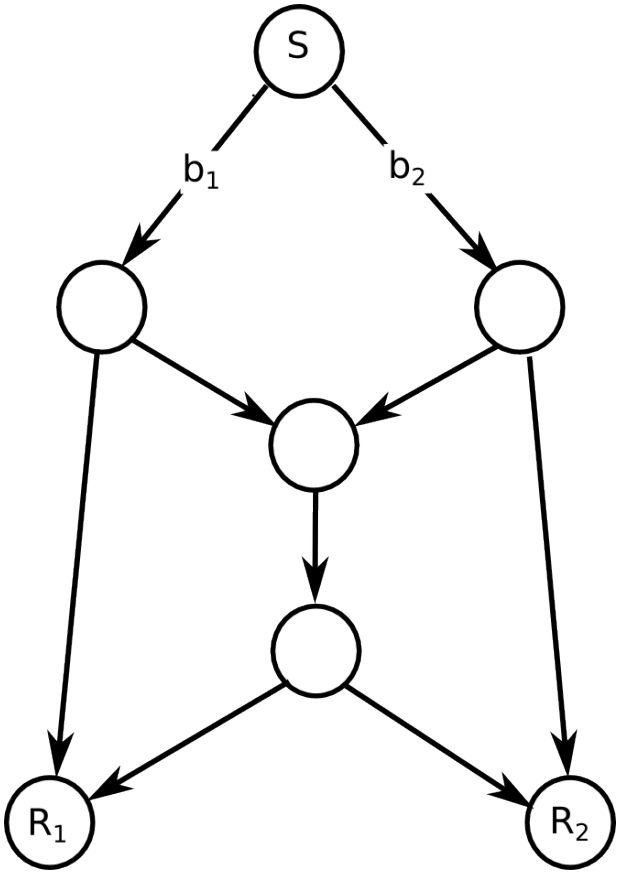
Fulcrum Network Codes

Morten V. Pedersen (mvp@es.aau.dk)
Aalborg University, Denmark

Network Coding

- Information is not a commodity



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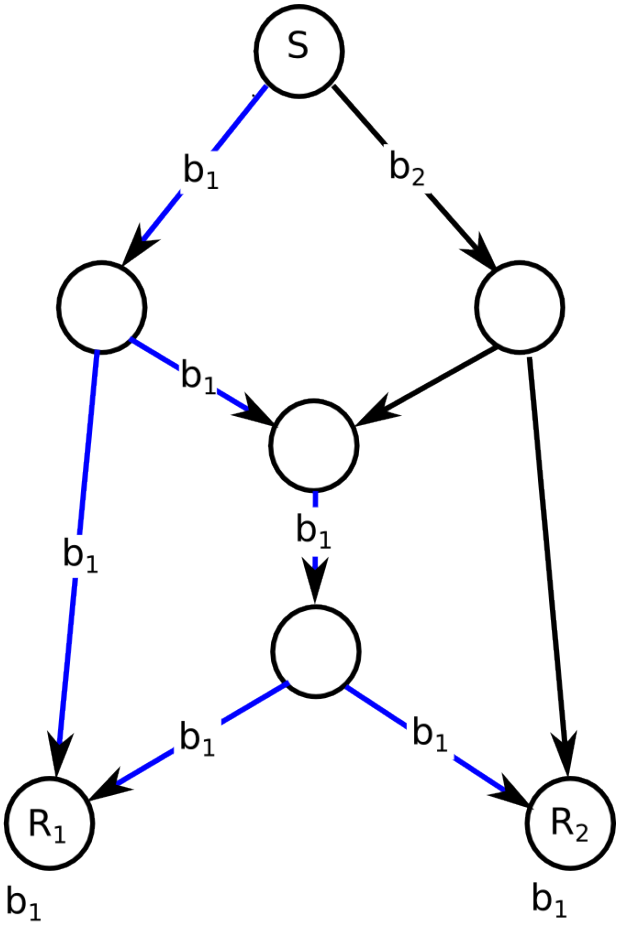

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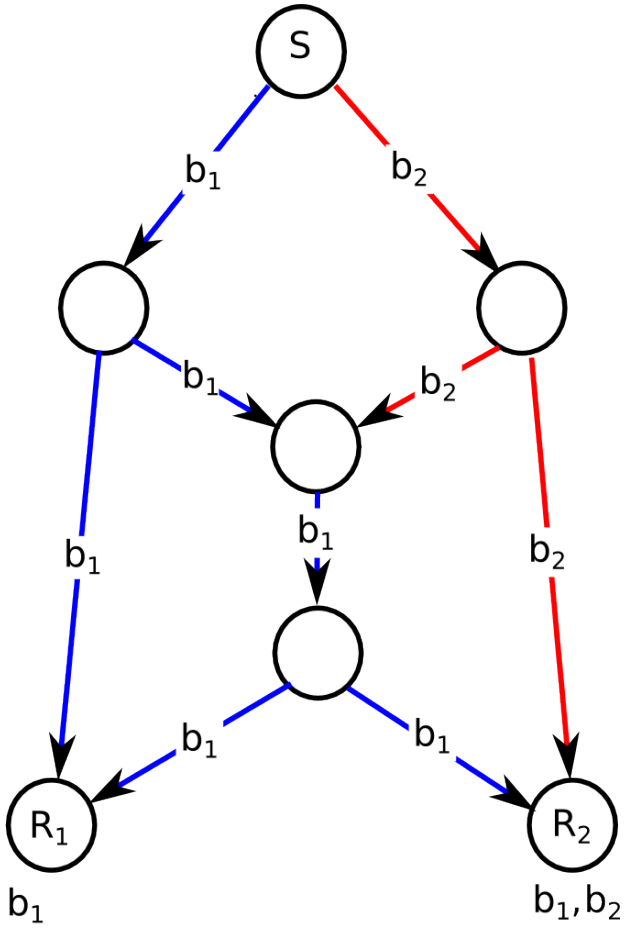

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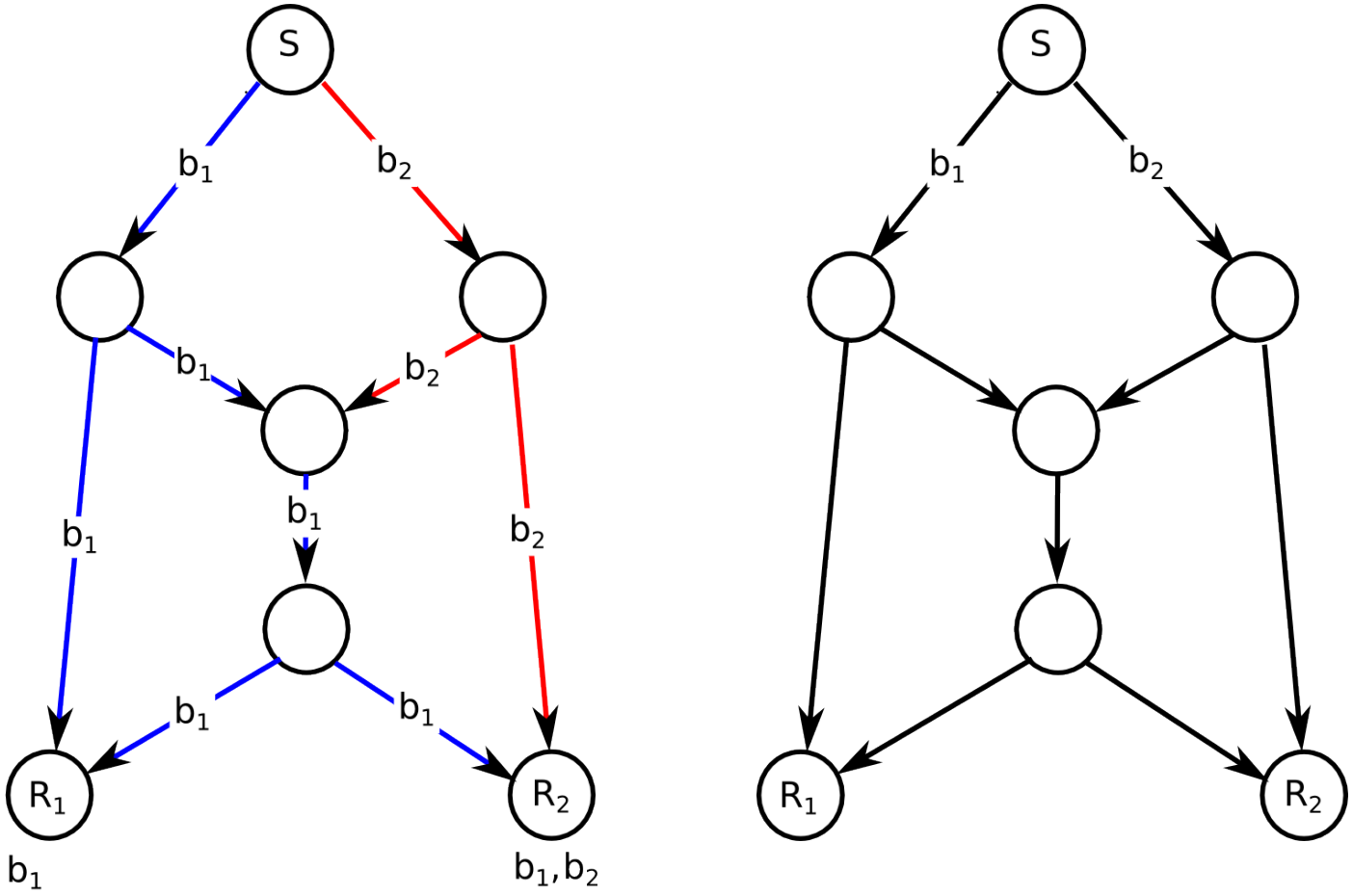

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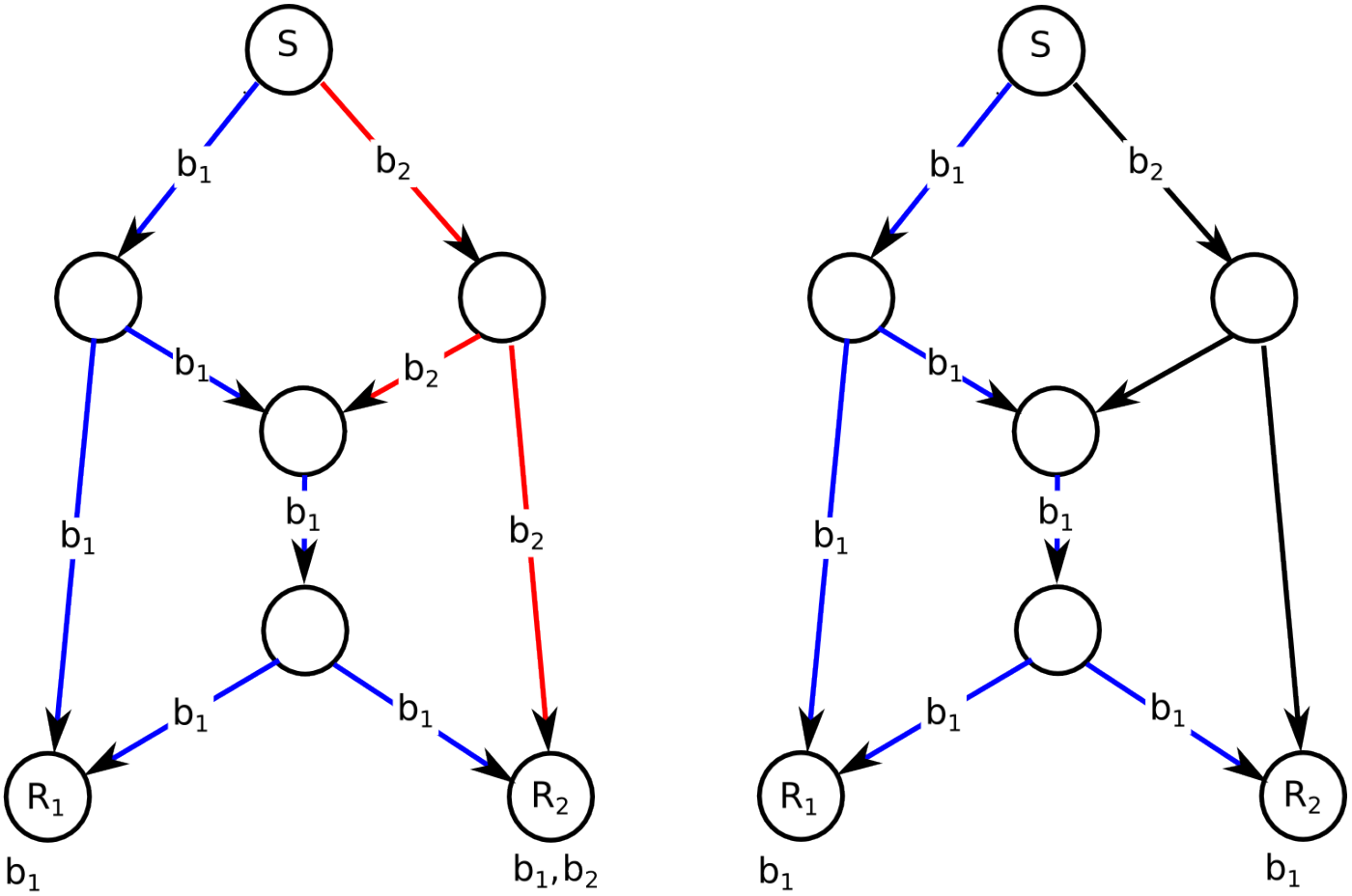

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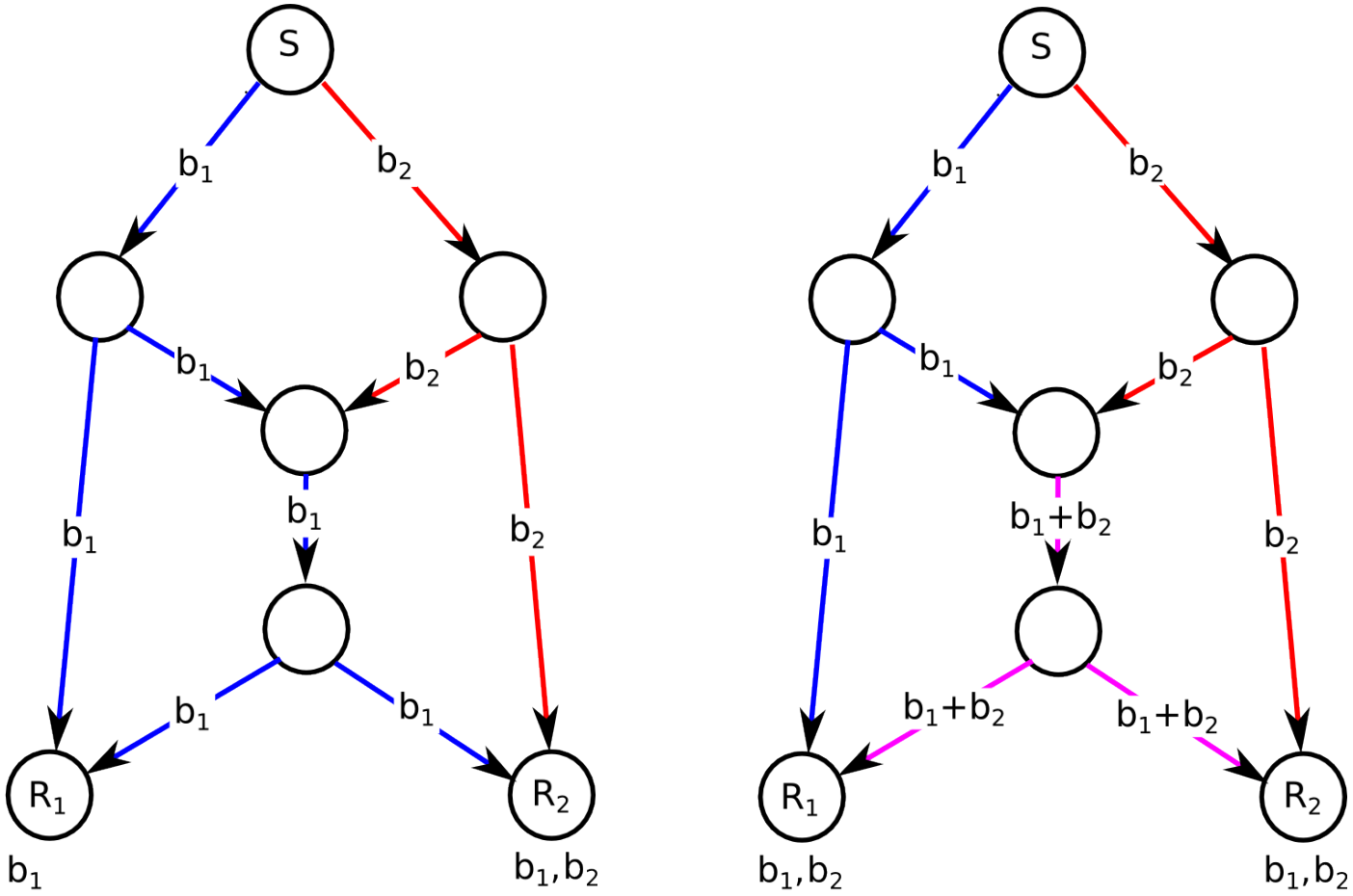
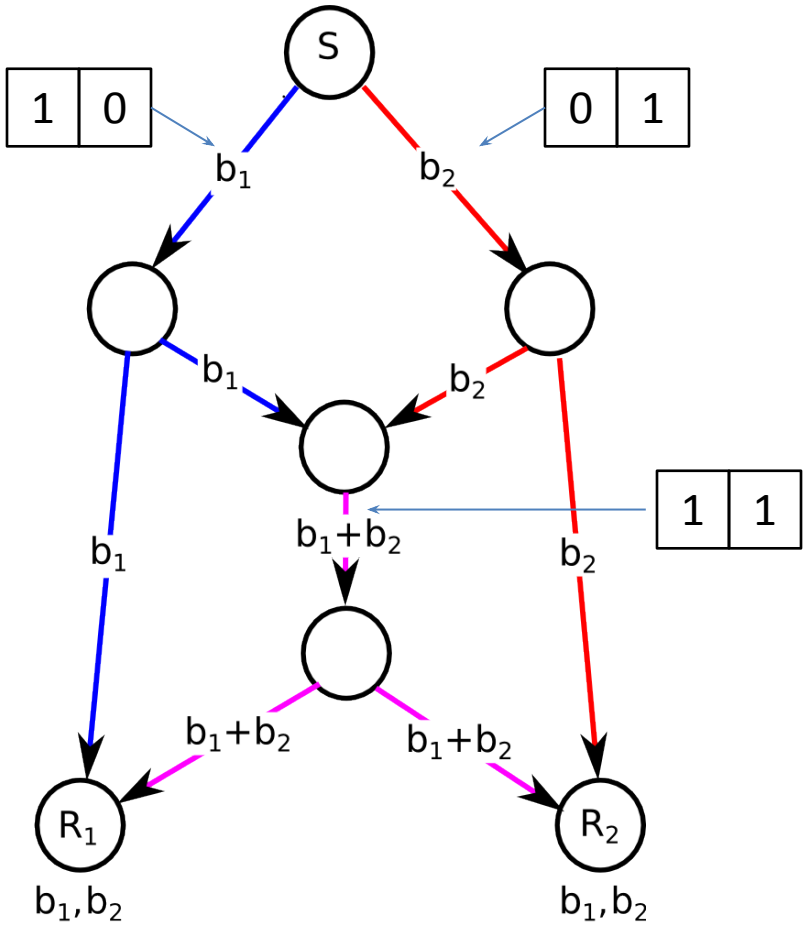


Network Coding

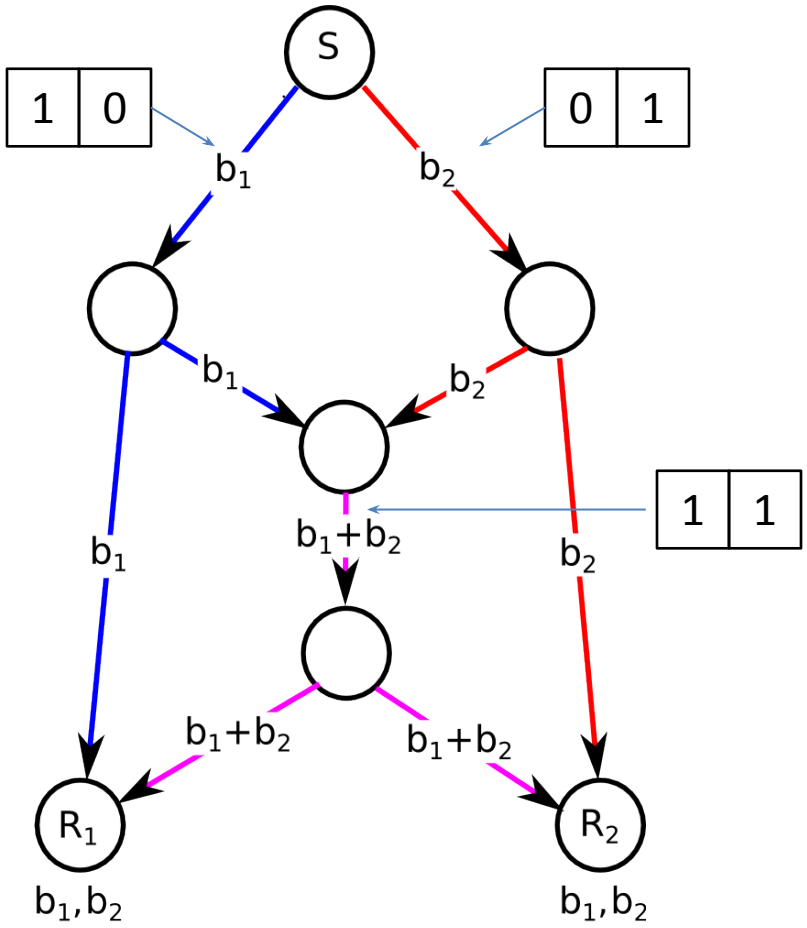
- We need to describe the coding we are doing (encoding vector)
- One coefficient per packet
- Each coefficient is q bits for a finite field of 2^q



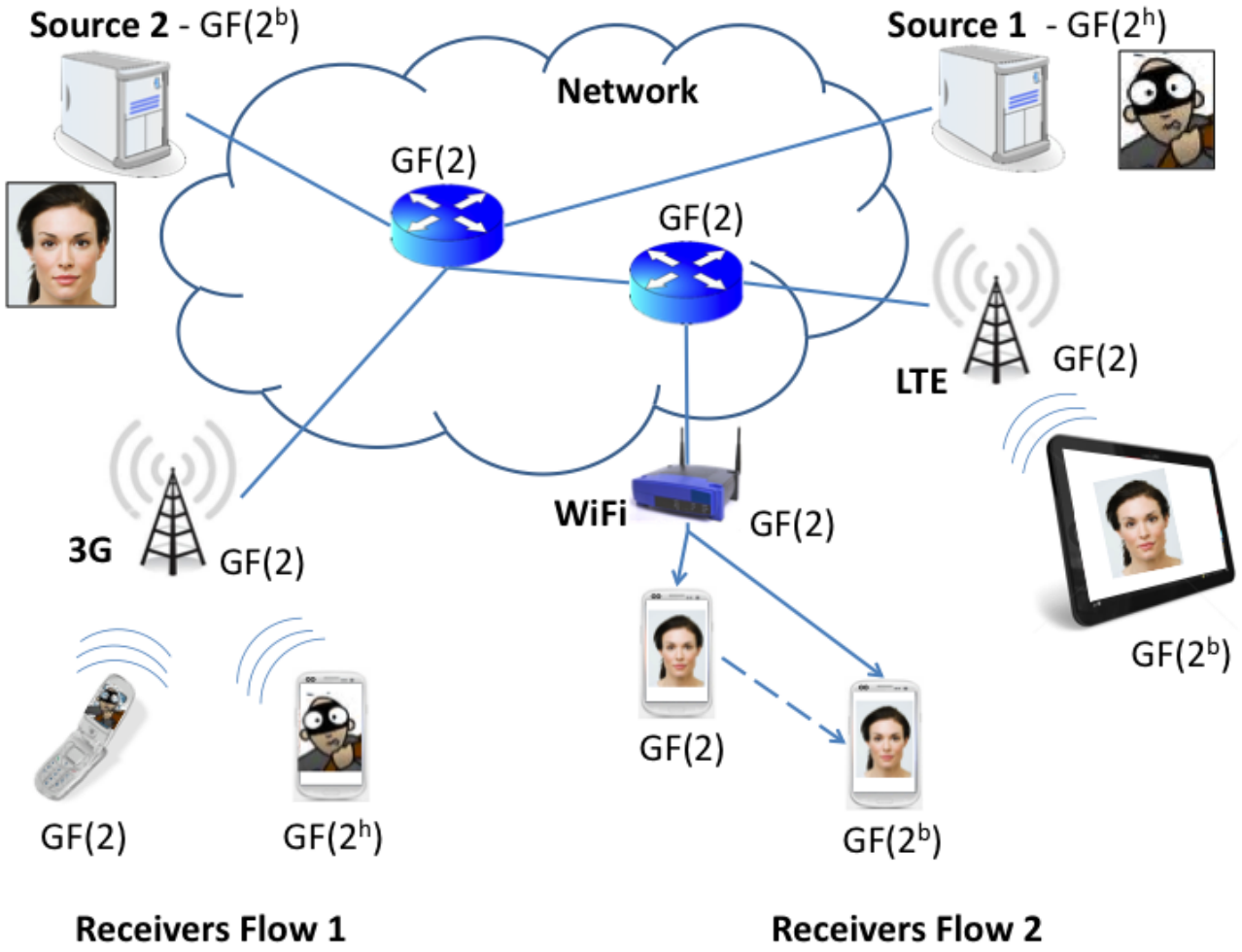
Network Coding

- We need to describe the coding we are doing (encoding vector)
- One coefficient per packet
- Each coefficient is log2(q) bits for a finite field of 2^q

- Challenges
  - Overhead from coefficients
  - Agree on finite field
  - Larger fields have high complexity



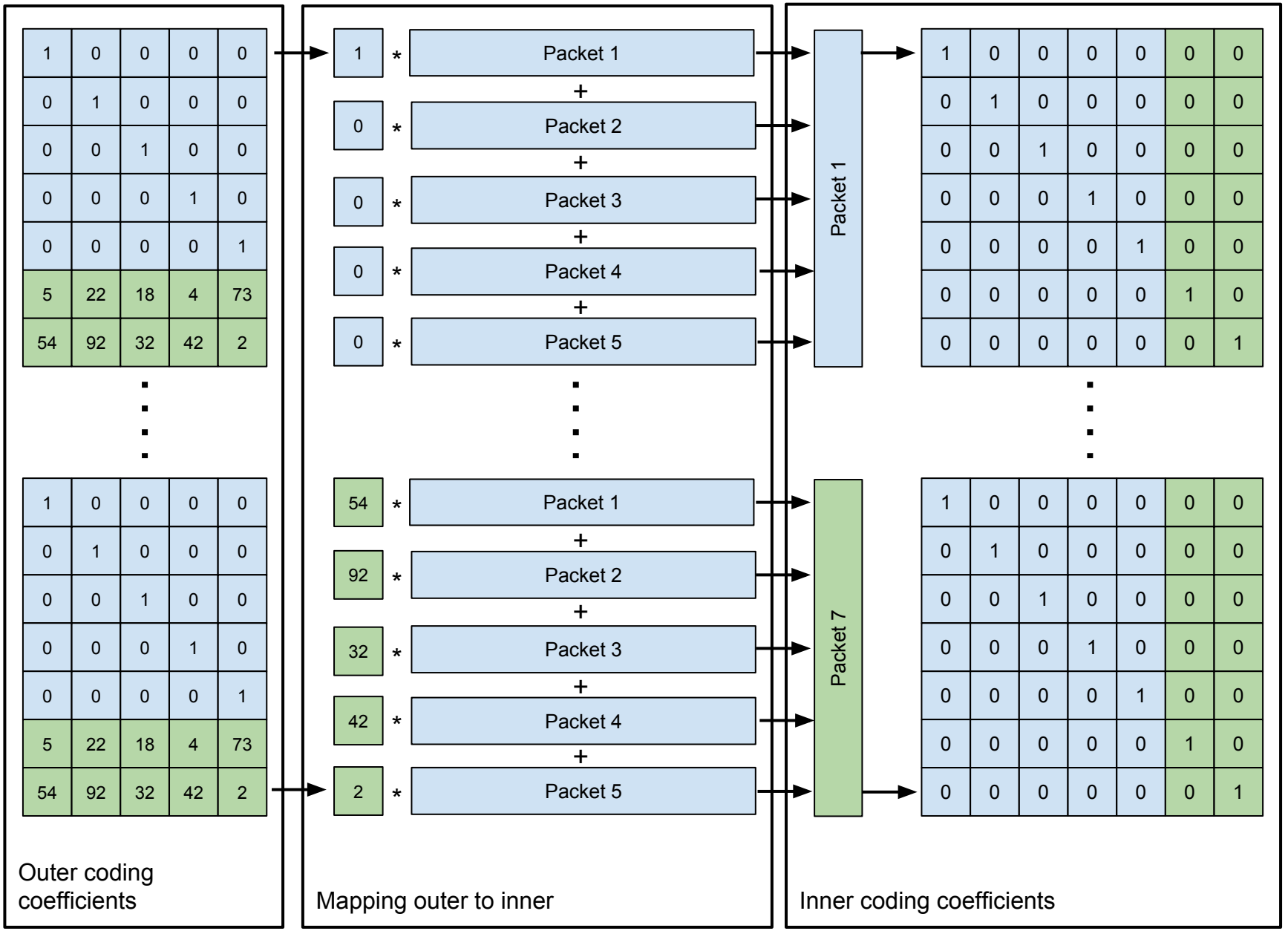
General Ideas



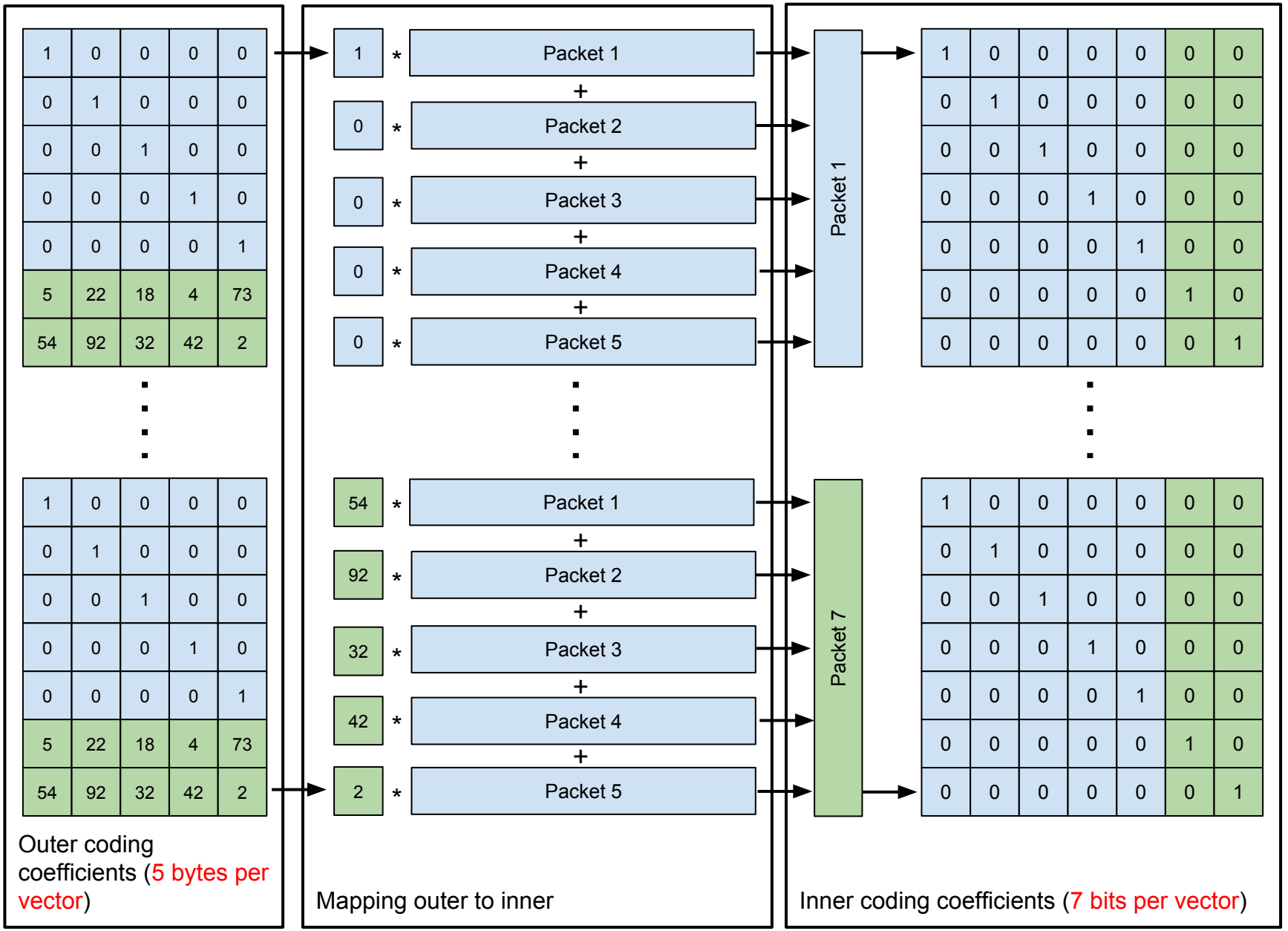
Key: code concatenation with different field sizes

Key: Outer and inner code independent

Encoder


1 0 0 0 0
0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 0 1
5 22 18 4 73
54 92 32 42 2
1 0 0 0 0
0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 0 1
5 22 18 4 73
54 92 32 42 2
Outer coding coefficients
1 * Packet 1 + 0 * Packet 2 + 0 * Packet 3 + 0 * Packet 4 + 0 * Packet 5
54 * Packet 1 + 92 * Packet 2 + 32 * Packet 3 + 42 * Packet 4 + 2 * Packet 5
Mapping outer to inner
Packet 1
Packet 7
1 0 0 0 0 0 0
0 1 0 0 0 0 0
0 0 1 0 0 0 0
0 0 0 1 0 0 0
0 0 0 0 1 0 0
0 0 0 0 0 1 0
0 0 0 0 0 0 1
1 0 0 0 0 0 0
0 1 0 0 0 0 0
0 0 1 0 0 0 0
0 0 0 1 0 0 0
0 0 0 0 1 0 0
0 0 0 0 0 1 0
0 0 0 0 0 0 1
Inner coding coefficients

Encoder


1 0 0 0 0
0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 0 1
5 22 18 4 73
54 92 32 42 2
1 0 0 0 0
0 1 0 0 0
0 0 1 0 0
0 0 0 1 0
0 0 0 0 1
5 22 18 4 73
54 92 32 42 2
Outer coding coefficients (5 bytes per vector)
1 * Packet 1 + 0 * Packet 2 + 0 * Packet 3 + 0 * Packet 4 + 0 * Packet 5
54 * Packet 1 + 92 * Packet 2 + 32 * Packet 3 + 42 * Packet 4 + 2 * Packet 5
Mapping outer to inner
Packet 1
Packet 7
1 0 0 0 0 0 0
0 1 0 0 0 0 0
0 0 1 0 0 0 0
0 0 0 1 0 0 0
0 0 0 0 1 0 0
0 0 0 0 0 1 0
0 0 0 0 0 0 1
1 0 0 0 0 0 0
0 1 0 0 0 0 0
0 0 1 0 0 0 0
0 0 0 1 0 0 0
0 0 0 0 1 0 0
0 0 0 0 0 1 0
0 0 0 0 0 0 1
Inner coding coefficients (7 bits per vector)

Decoder

Several decoding algorithms possible:

1. Inner decoding we only decode the inner coder - *weak devices that can only do GF(2)*

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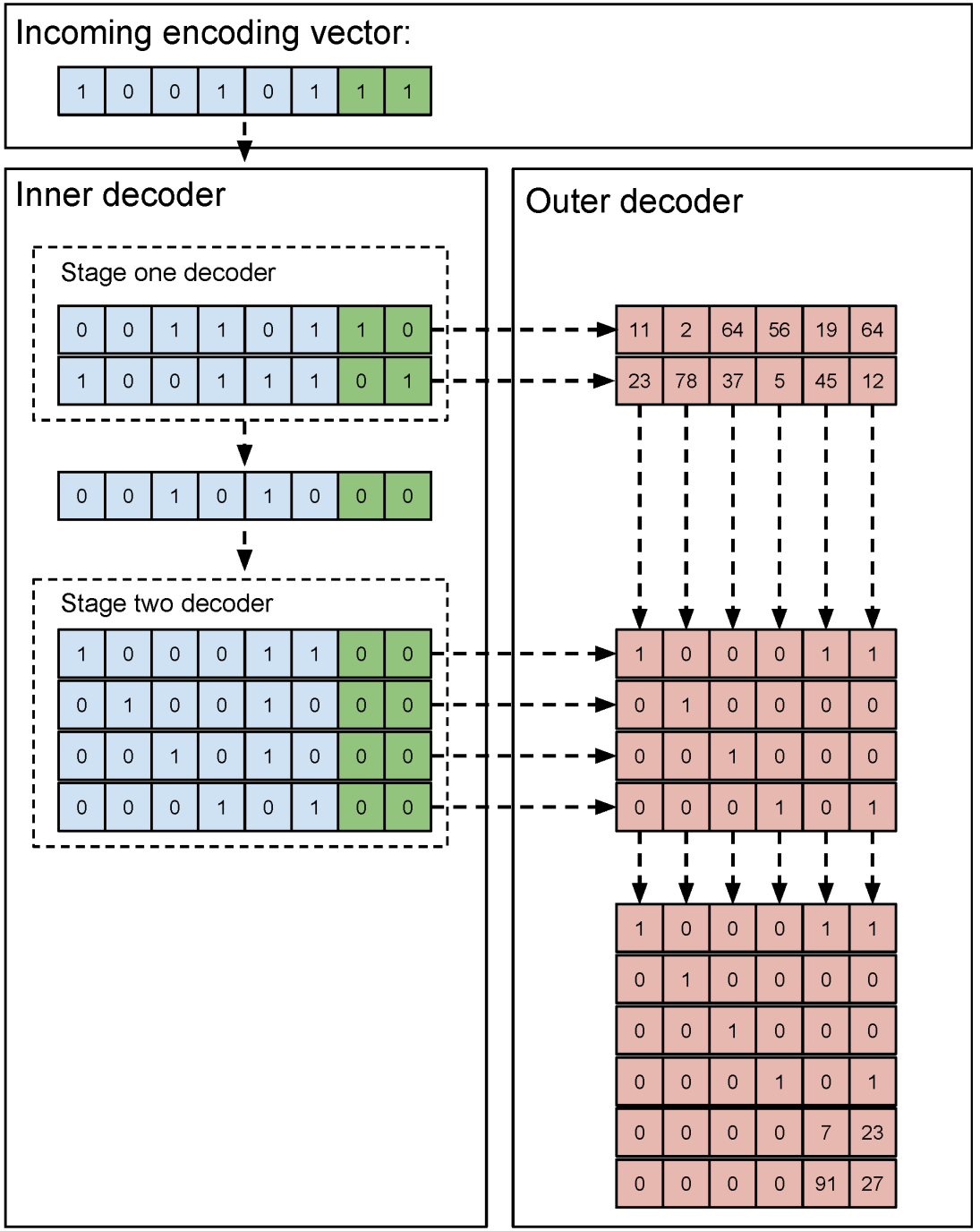
2. Outer decoding we map immediately to the outer code and decode - *powerful devices that can do GF(2^q)*

Decoder

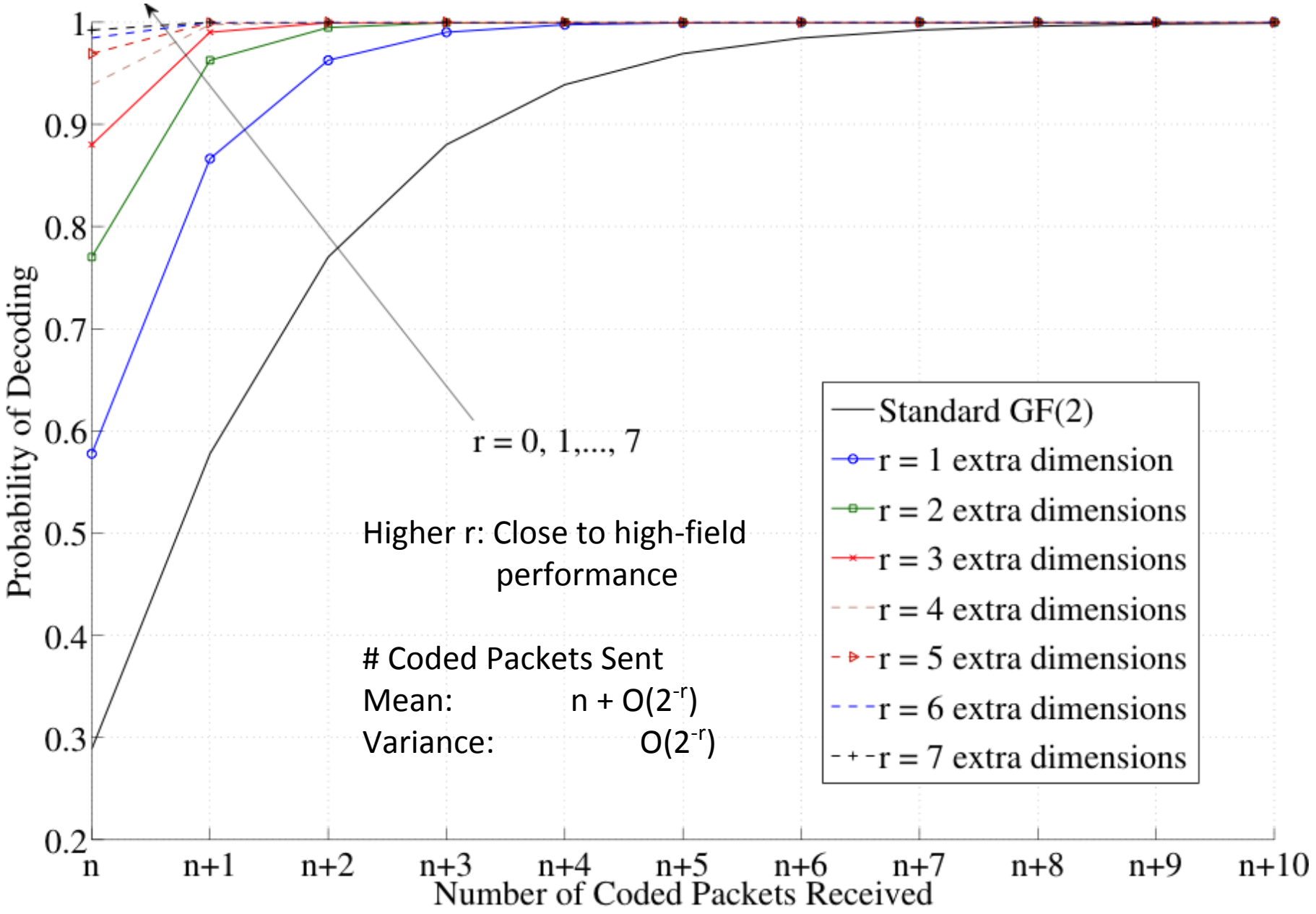
Several decoding algorithms possible:

1. Inner decoding we only decode the inner coder - *weak devices that can only do GF(2)*
2. Outer decoding we map immediately to the outer code and decode - *powerful devices that can do GF(2^q)*
3. Combined decoding - *medium power devices*

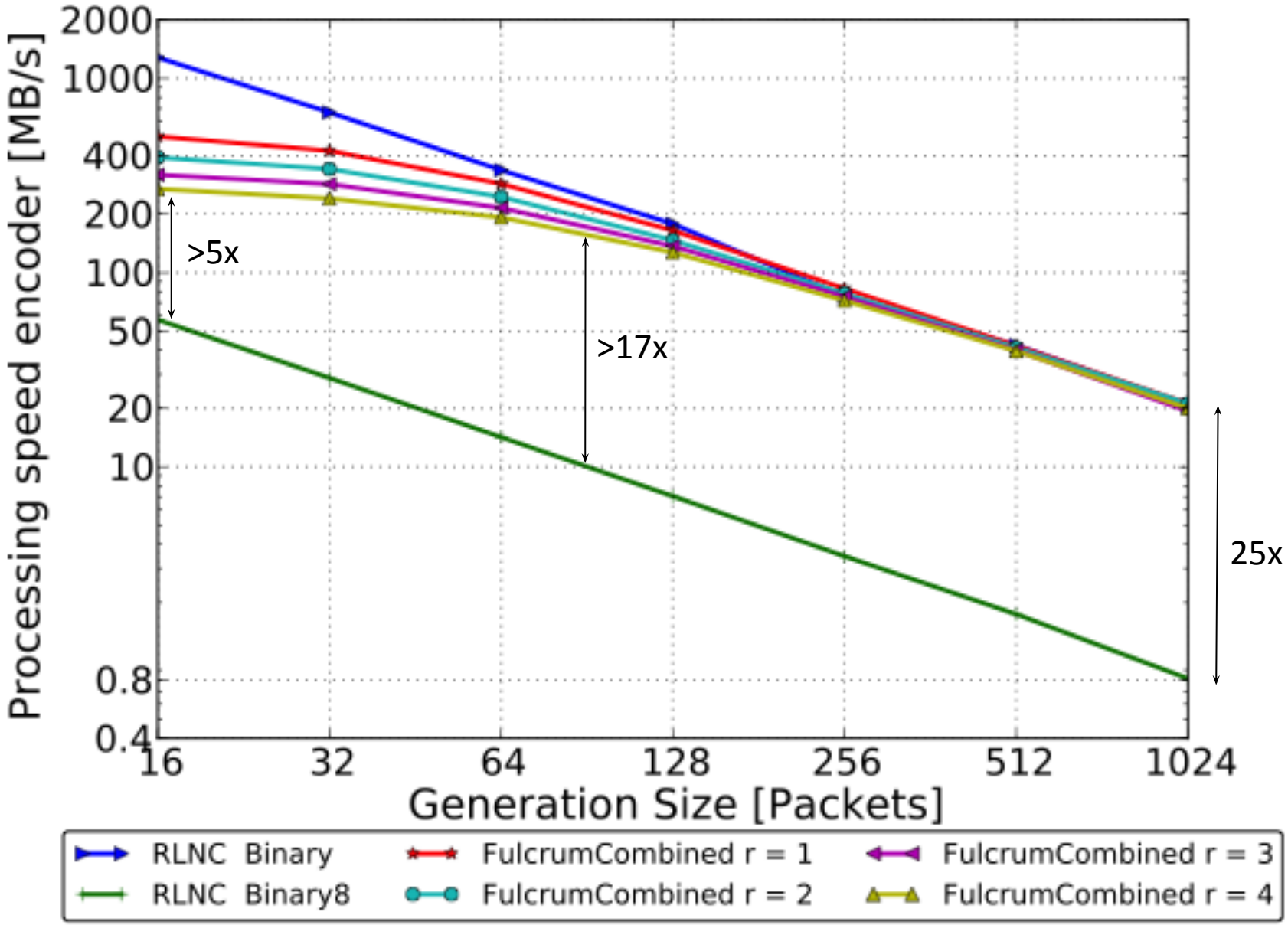
Combined decoding



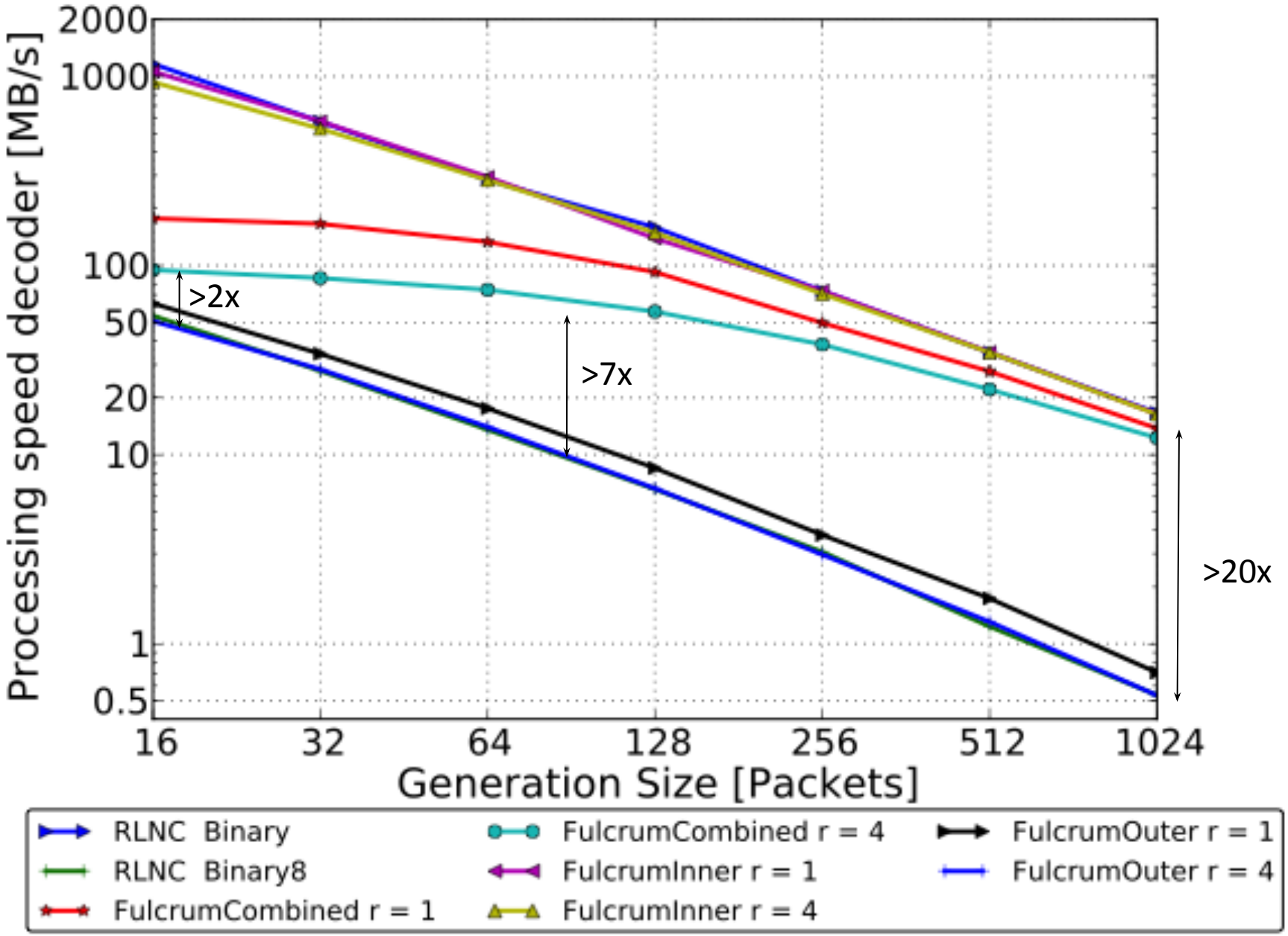
Received Packets before Decoding



Performance Results: Encoder



Performance Results: Decoder



Advantages

- Low overhead:
  - 1 + r/n ~ 1 bit per coefficient per packet → like GF(2)
  - Total transmitted packets: n + $O(2^{-r})$ → like higher fields
- Processing speed (complexity) compared to GF(2^8):
  - Encoder 5x to 25x faster
  - Decoder 2x to >20x faster
- Increases support for heterogeneous receivers
- Network can implement a bare minimum:
  - Just XOR packets!

Thanks for your attention