Rate-Compatibility and Incremental Redundancy HARQ for 802.16j LDPC codes

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Source:

Wataru Matsumoto, *Toshiyuki Kuze, Rui Sakai, Koon Hoo Teo* Voice: +81-467-41-2074
Mitsubishi Electric Corp. Fax: +81-467-41-2136
5-1-1 Ofuna Kamakura, Kanagawa 2478501, JAPAN Email: Matsumoto.Wataru@aj.MitsubishiElectric.co.jp

Jun Xu Voice: +86-755-26773000-6574
ZTE Corporation Fax: +86-755-26773000-6615
3/F, Bldg,711,Pengli Induxtrial Park, Email: xu.jun2@zte.com.cn
Liantang, Shenzhen, 518004, R.P.China

I-Kang Fu Voice: 886-3-5712121
National Chiao Tung University (NCTU) Fax:: 886-3-5710116
/Industrial Technology Research Institute (ITRI) Email: IKFu@itri.org.tw
ED922, 1001 Ta Hsueh Rd.,
Hsinchu City, Taiwan 300, ROC

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Purpose:

Propose a Rate-Compatible and IR HARQ for 802.16j to improve reliability and throughput performance on relay links.

Rate-Compatibility and Incremental Redundancy HARQ for 802.16j LDPC codes

Authors:

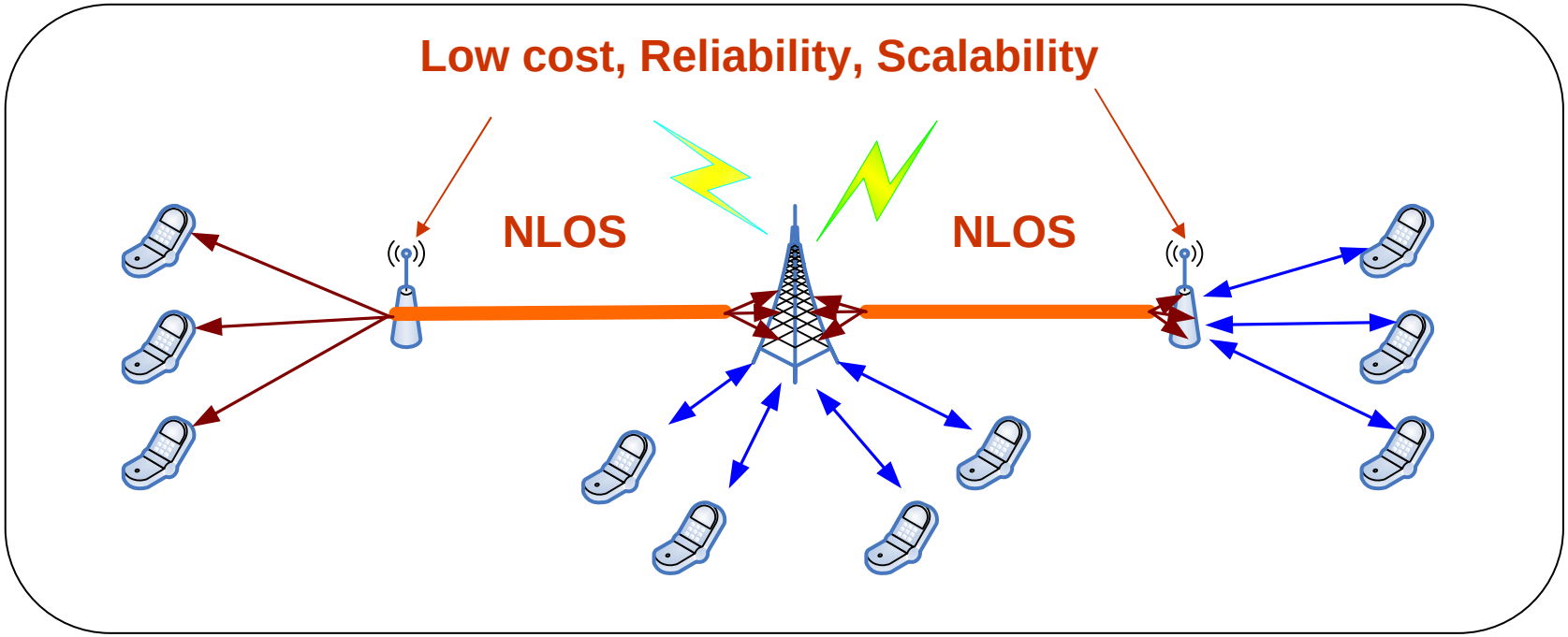
Wataru Matsumoto, Toshiyuki Kuze, Rui Sakai, Koon Hoo Teo
Mitsubishi Electric Corporation

Jun Xu
ZTE Corporation

I-Kang Fu
Industrial Technology Research Institute (ITRI)

Concept of Enhanced Hybrid ARQ (Rate Compatible LDPC)

- The concept of “Enhanced Hybrid ARQ” is to provide Low cost, Reliability and Scalability.



Motivation –Requested issues

- LDPC codes can provide lower cost hardware than CTC.
- High reliability on low data-rate region. → Expansion of coverage area.
- Coexistence of the proposed RC-LDPC codes and the current 802.16e LDPC codes.
  → Minimize of additional circuits for RC-LDPC codes.
- Shorter latency compared to CTC HARQ.
- Extend the code-length to 14400 bits from the current 2304 bits to improve the HARQ efficiency.

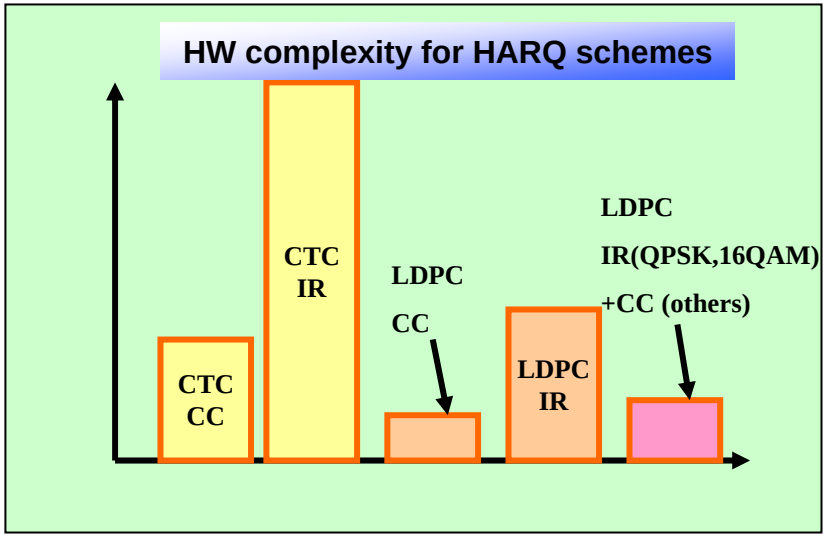


Fig1. Low Cost

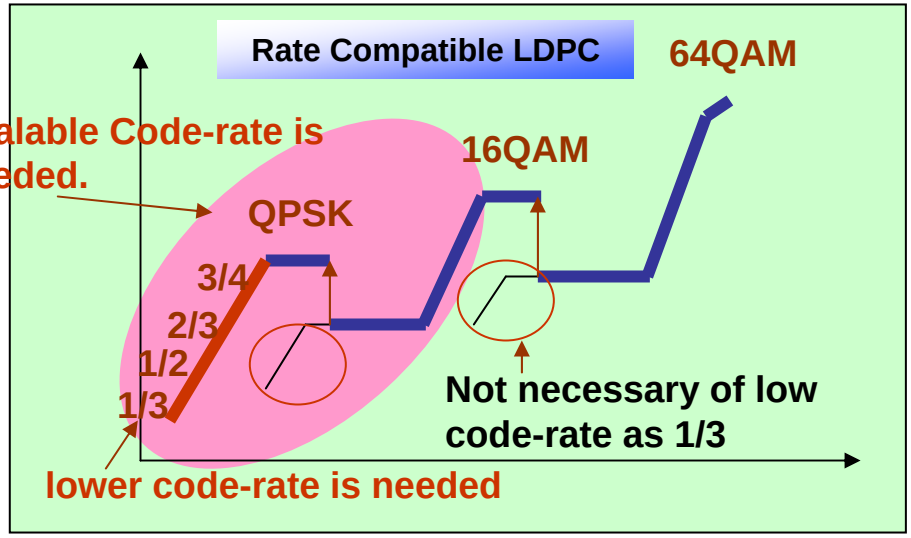


Fig2. Reliability and Scalability

Rate Compatible LDPC

Hybrid ARQ IR with Rate Compatible LDPC

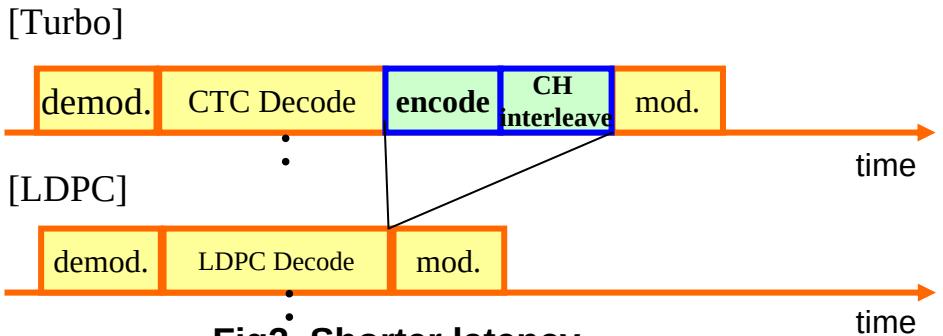


Fig3. Shorter latency

Apply to 802.16e LDPC codes

Rate=1/2 code(802.16e)

−1	94	73	−1	−1	−1	−1	−1	55	83	−1	−1	7	0	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	27	−1	−1	−1	22	79	9	−1	−1	−1	12	−1	0	0	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	−1	24	22	81	−1	33	−1	−1	−1	0	−1	−1	0	0	−1	−1	−1	−1	−1	−1	−1	−1
61	−1	47	−1	−1	−1	−1	−1	65	25	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1	−1	−1
−1	−1	39	−1	−1	−1	84	−1	−1	41	72	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1	−1
−1	−1	−1	−1	46	40	−1	82	−1	−1	−1	0	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1	−1
−1	−1	95	53	−1	−1	−1	−1	−1	14	18	−1	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1
−1	11	73	−1	−1	−1	2	−1	−1	47	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1
12	−1	−1	−1	83	24	−1	43	−1	−1	−1	51	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1	−1
−1	−1	−1	−1	−1	94	−1	59	−1	−1	70	72	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1
−1	−1	7	65	−1	−1	−1	−1	39	49	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	0
43	−1	−1	−1	−1	66	−1	41	−1	−1	−1	26	7	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0

H_{CH}

Extend for Rate=1/3 code

−1	94	73	−1	−1	−1	−1	−1	55	83	−1	−1	7	0	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	27	−1	−1	−1	22	79	9	−1	−1	−1	12	−1	0	0	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	−1	24	22	81	−1	33	−1	−1	−1	0	−1	−1	0	0	−1	−1	−1	−1	−1	−1	−1	−1
61	−1	47	−1	−1	−1	−1	−1	65	25	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1	−1	−1
−1	−1	39	−1	−1	−1	84	−1	−1	41	72	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1	−1
−1	−1	−1	−1	4	Z	0	−1	82	−1	−1	−1	79	0	−1	−1	−1	−1	D	−1	−1	−1	−1	−1
−1	−1	95	53	−	1	−1	−1	−1	14	18	−1	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1	−1
−1	11	73	−1	−1	−1	2	−1	−1	47	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1	−1	−1	−1
12	−1	−1	−1	83	24	−1	43	−1	−1	−1	51	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1	−1
−1	−1	−1	−1	−1	94	−1	59	−1	−1	70	72	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	0	−1
−1	−1	7	65	−1	−1	−1	−1	39	49	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	0
43	−1	−1	−1	−1	66	−1	41	−1	−1	−1	26	7	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0
−1	−1	−1	−1	−1	17	−1	9	−1	−1	−1	20	0	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	36	−1	−1	−1	−1	−1	−1	7	−1	−1	−1	0	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	5	−1	−1	−1	−1	−1	−1	5	−1	−1	−1	−1	0	−1	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	−1	−1	−1	23	−1	11	−1	−1	−1	23	−1	−1	−1	0	−1	−1	−1	−1	−1	−1	−1	−1
−1	−1	−1	−1	−1	5	−1	32	−1	−1	−1	38	−1	−1	−1	−1	0	−1	−1	−1	−1	−1	−1	−1
−1	−1	7	−1	−1	−1	−1	−1	−1	19	−1	−1	−1	−1	−1	−1	−1	I	−1	−1	−1	−1	−1	−1
−1	−1	−1	−1	−1	A	1	−1	23	−1	−1	−1	48	−1	−1	−1	−1	−1	0	−1	−1	−1	−1	−1
−1	−1	−1	−1	−1	29	−1	37	−1	−1	−1	7	−1	−1	−1	−1	−1	−1	−1	0	−1	−1	−1	−1
−1	−1	6	−1	−1	−1	−1	−1	−1	3	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	−1	−1	−1
−1	−1	1	−1	−1	−1	−1	−1	−1	2	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	−1	−1
−1	−1	−1	−1	−1	37	−1	26	−1	−1	−1	8	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0	−1
−1	−1	3	−1	−1	−1	−1	−1	−1	6	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	0

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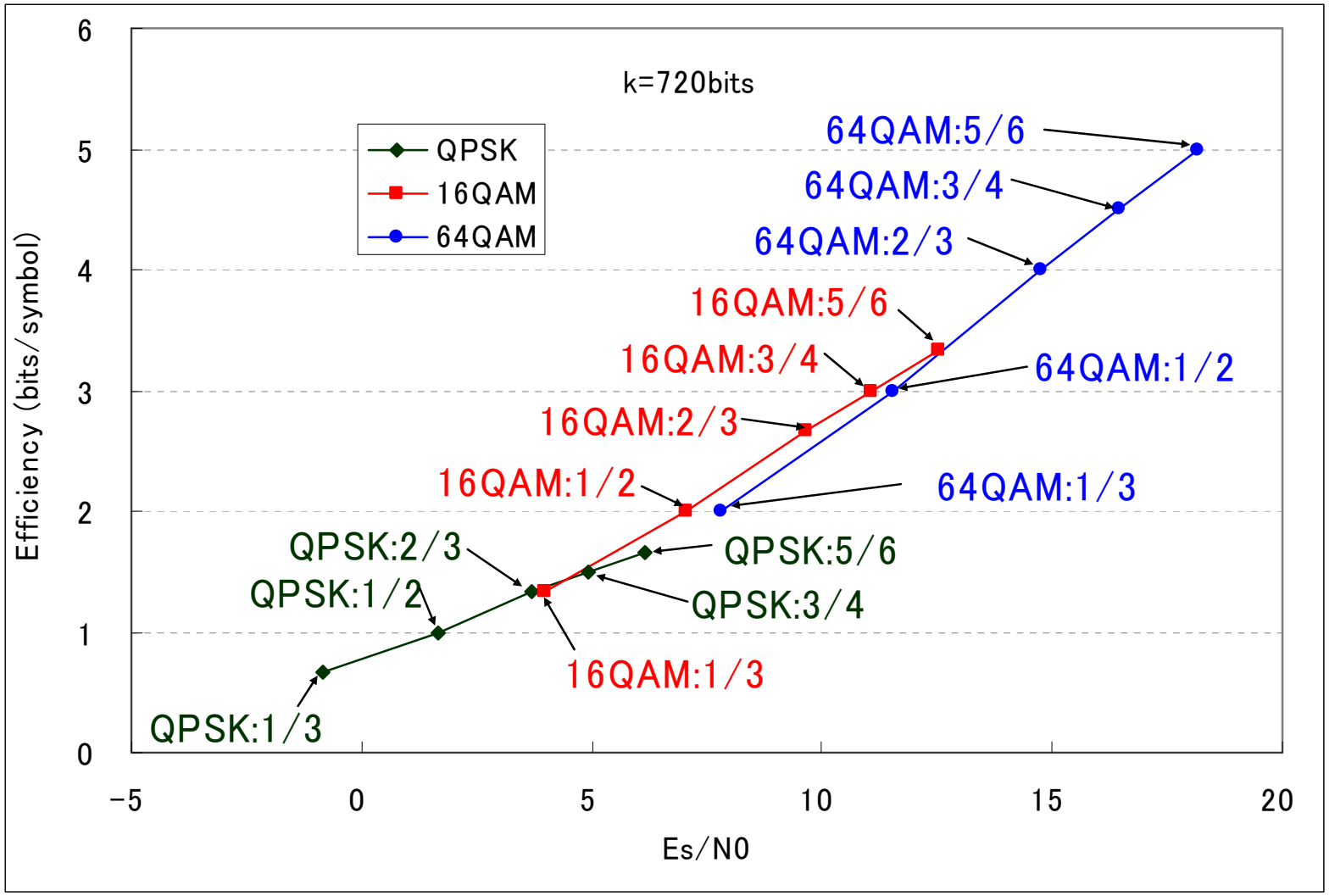
Efficiency Performance of LDPC codes on MCS



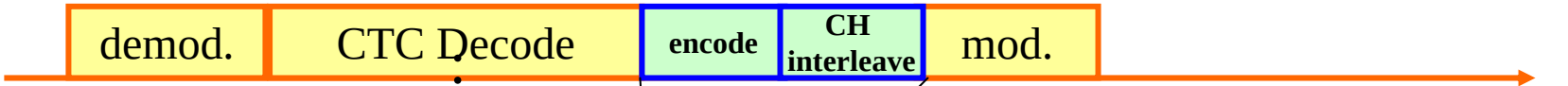
Latency benefit of LDPC codes

- **In the case of LDPC codes for Relay station**

LDPC decoder output LLRs for the whole codeword.

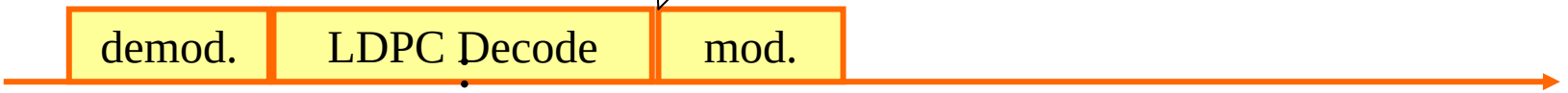
But CTC decoder only output those for the information bits, so CTC have to re-encode to do channel interleaving before modulation.

[Turbo]



time

[LDPC]



time

Relay station with LDPC can relay the signal with lower latency.

Conclusions

- LDPC support high throughput with lower hardware complexity and cost compared to Turbo codes
- Shorter latency compared to CTC
  - No re-encoding and channel interleaving are required.
- RC-LDPC is an enhanced version of the 802.16e LDPC
  - 802.16e LDPC will be used as a baseline
  - RC-LDPC is rate compatible
  - Backward compatible to 802.16e LDPC
  - 802.16e LDPC with CC HARQ provides support for higher throughput link
- RC-LDPC provide improved robustness for channel in hostile conditions with
  - Low code rate such as 1/3 code rate
  - Incremental Redundancy for HARQ

Comparison with Turbo

Table. Operations count comparison of sub-optimal decoders LDPC and CTC decoders.

	LDPC	CTC	Complexity of LDPC / Complexity of CTC
Algorithm	LBP Min-Sum+Offset	Max Log Map +extrinsic scaling	
Number of Iterations	20	8	
Total cost (R=1/2)	28.8K x 20 = 576K	171K x 8 x 2 = 2736K	21%
Total cost (R=3/4)	20.6K x 20 = 412K	171K x 8 x2 = 2736K	15%

Reference: R1-060874, " **Complexity Comparison of LDPC Codes and Turbo Codes** "

3GPP TSG RAN WG1#44bis, Athens, Greece 27-31 Mar. 2006.

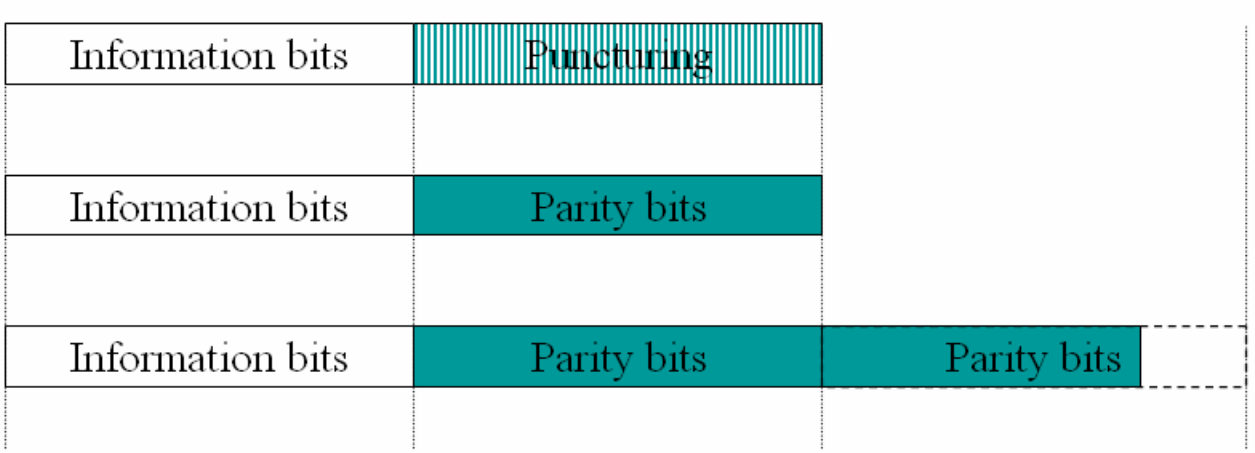
Rate-Compatible LDPC codes

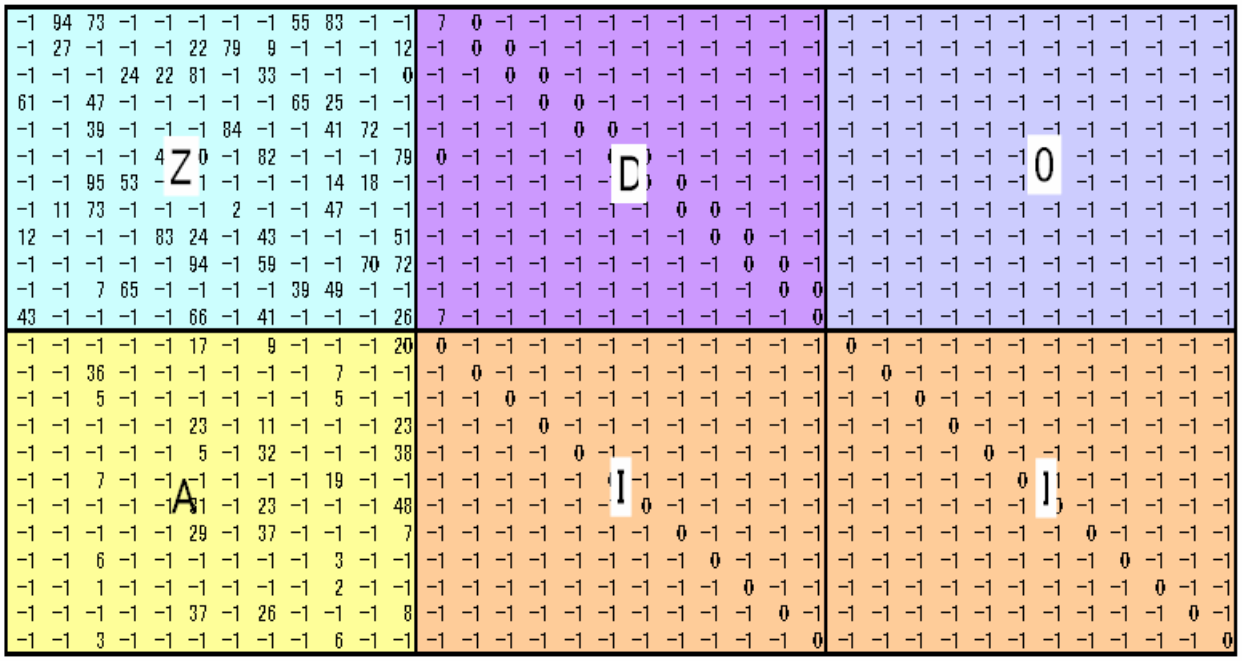
IR with Mother Rate=1/3 parity check matrix

Rate>1/2

Rate=1/2

Rate<1/2



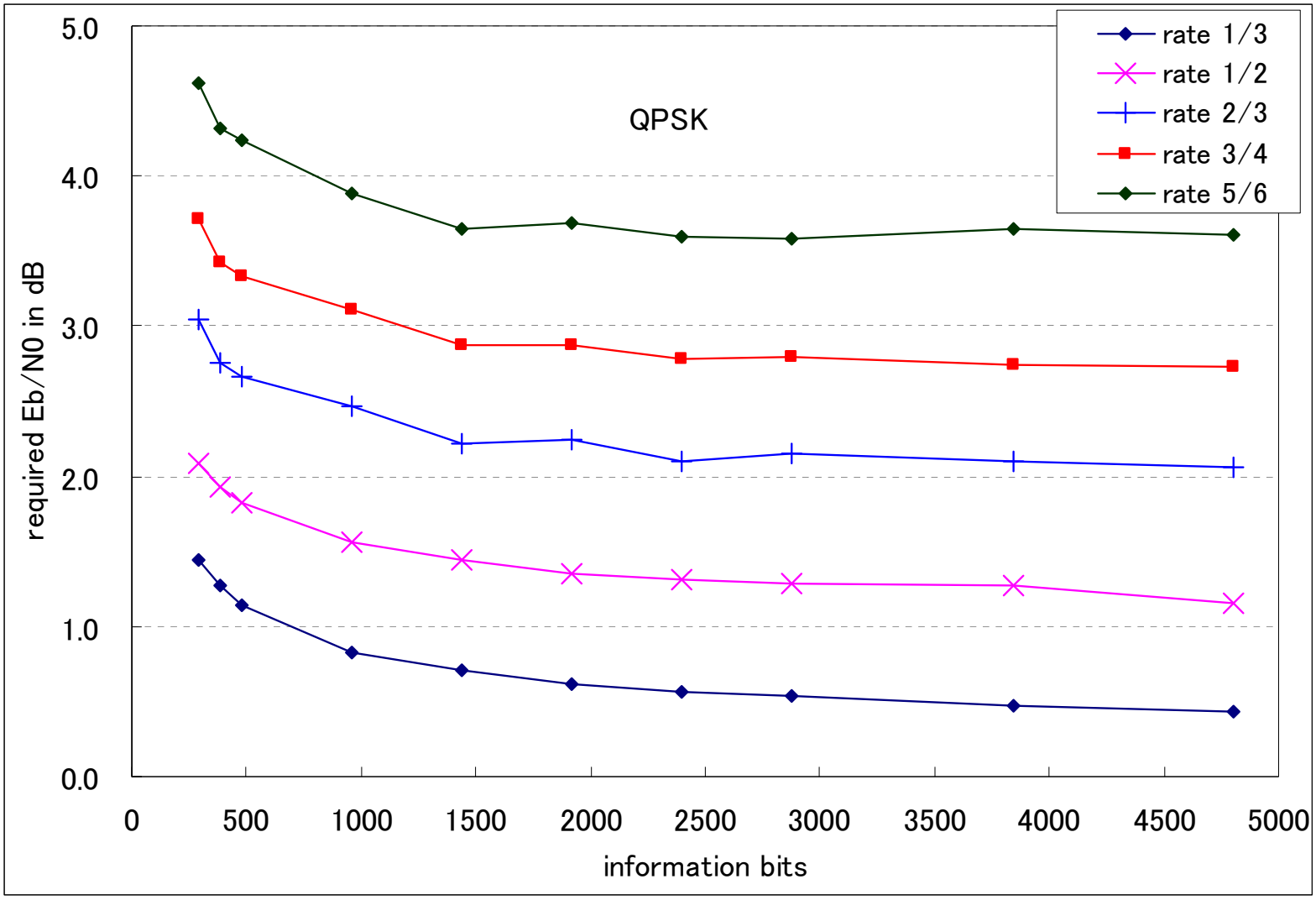


- In addition to puncturing, extended parity matrixes are used to achieve flexible coding rate and rate compatibility

- 802.16e LDPC will be used as the baseline for enhancement of the RC-LDPC

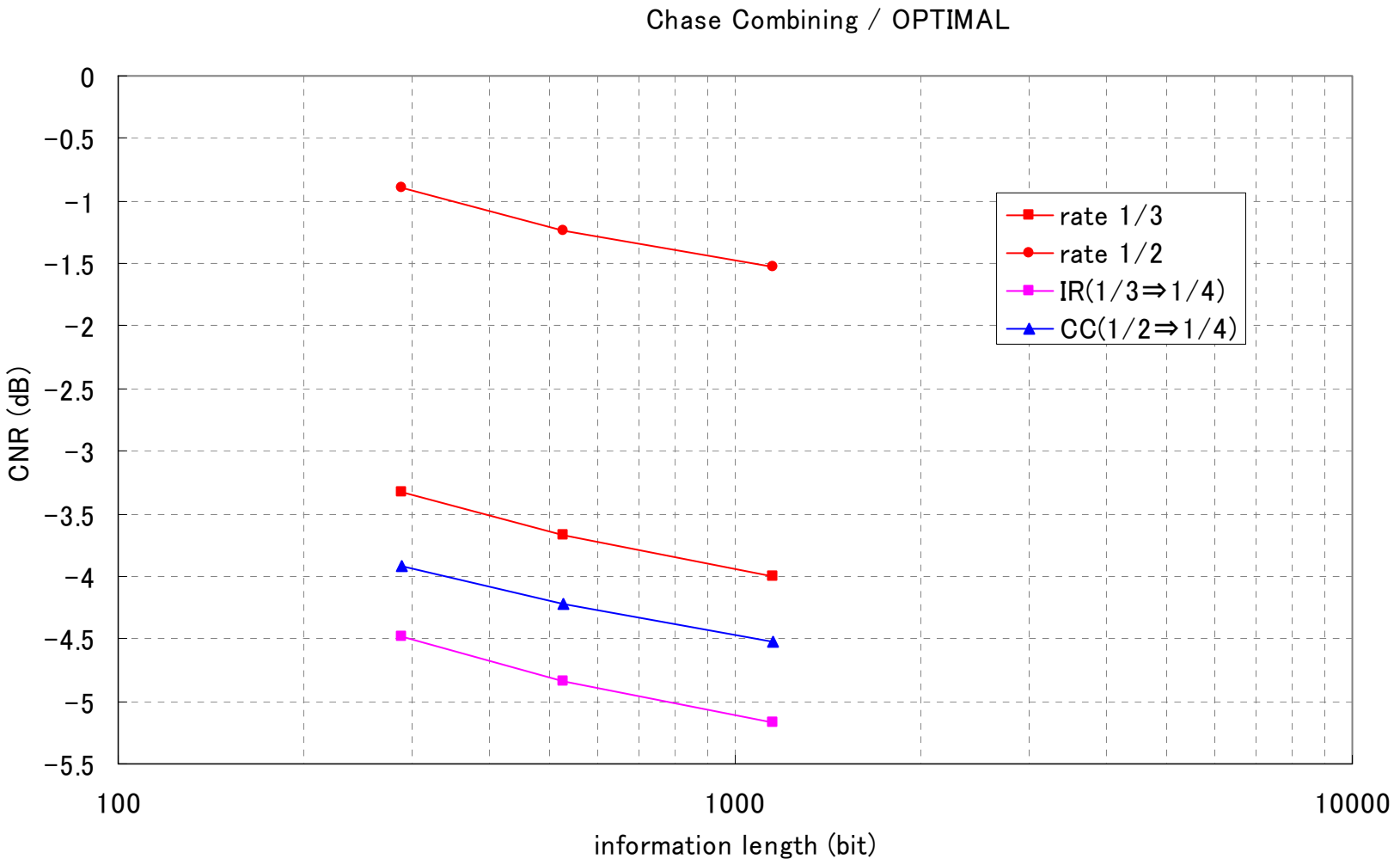
Performance of RC LDPC

Performance for RC LDPC codes based on the 16e LDPC codes

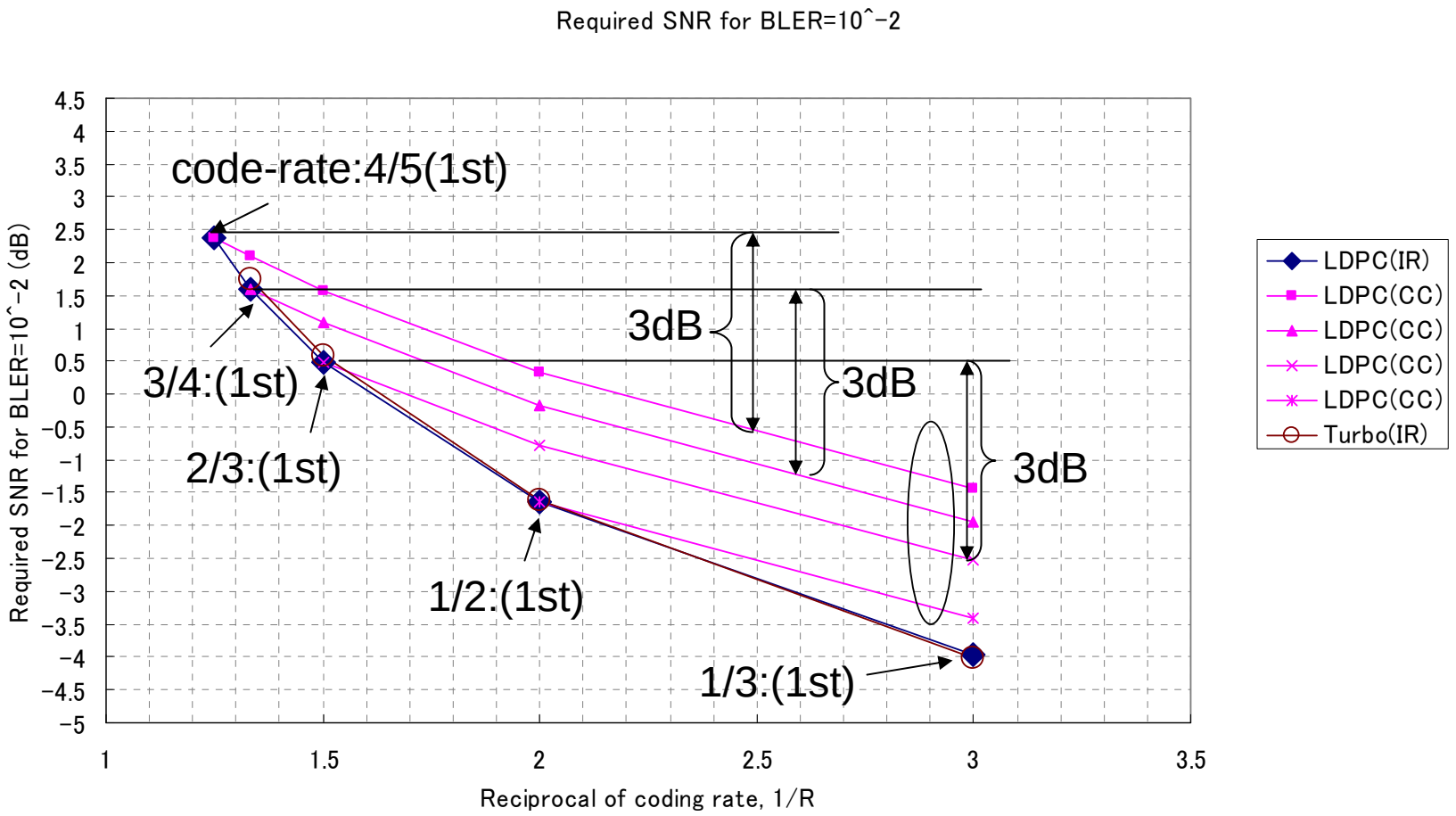


Performance of RC LDPC

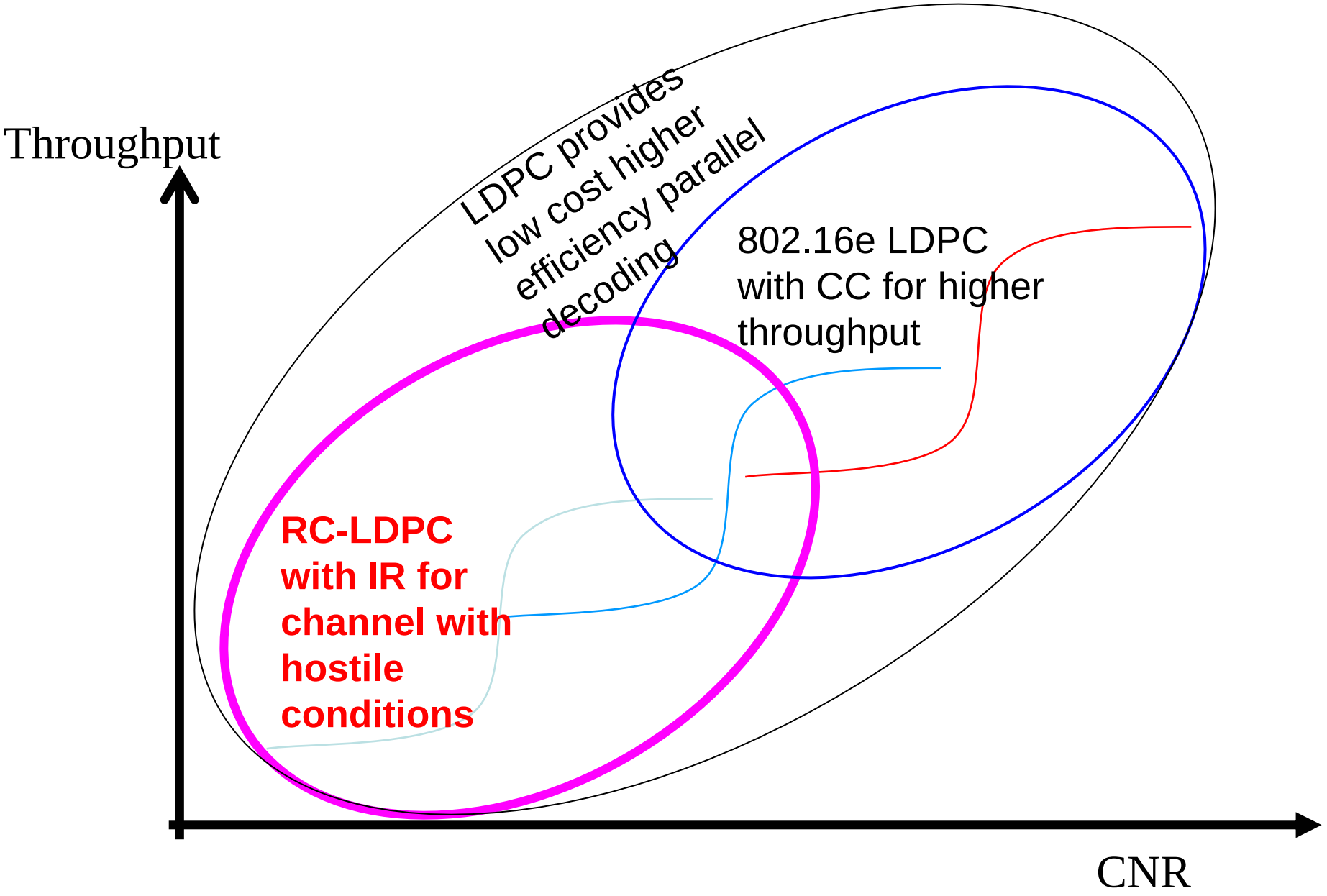
Performance for RC LDPC codes based on the 16e LDPC codes



Throughput Performance of LDPC Chase Combining and IR HARQ



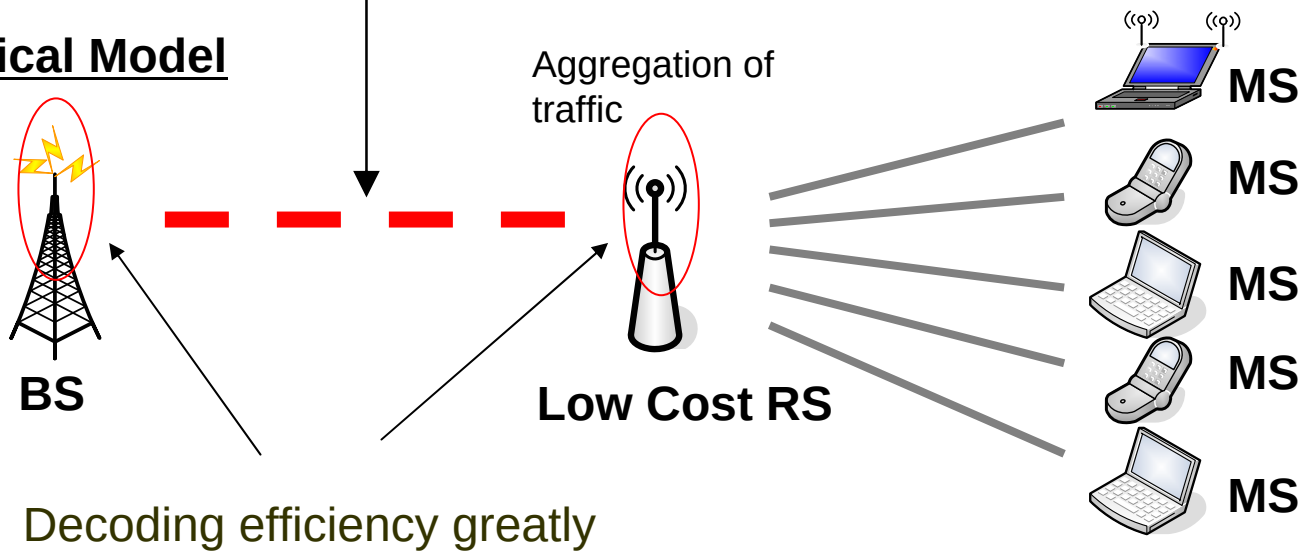
RC-LDPC and 802.16e LDPC



Merits of RC-LDPC and 802.16e LDPC

Improved robustness provided by RC-LDPC low code rate and HARQ IR especially for channels with hostile conditions

Our Typical Model



Decoding efficiency greatly improved by LDPC and making high throughput and low cost RS/BS possible for UL and DL