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

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

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

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The concept of “Enhanced Hybrid ARQ” is to provide \textit{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

![Fig1. Low Cost](image1)

![Fig2. Reliability and Scalability](image2)

![Fig3. coexistence of current LDPC](image3)

2006/11/13
Apply to 802.16e LDPC codes

Rate=1/2 code

Extend for Rate=1/3 code
## Rate-Compatible LDPC codes

**IR with Mother Rate=1/3 parity check matrix**

<table>
<thead>
<tr>
<th>Rate &gt; 1/2</th>
<th>Information bits</th>
<th>Puncturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate = 1/2</td>
<td>Information bits</td>
<td>Parity bits</td>
</tr>
<tr>
<td>Rate &lt; 1/2</td>
<td>Information bits</td>
<td>Parity bits</td>
</tr>
</tbody>
</table>

- 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.
## Comparison with Turbo

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

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>LDPC</th>
<th>TC</th>
<th>Complexity of LDPC / Complexity of TC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LBP Min-Sum + Offset</td>
<td>Max Log Map + extrinsic scaling</td>
<td></td>
</tr>
<tr>
<td>Number of Iterations</td>
<td>20</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Total cost (R=1/3)</td>
<td>38.5K x 20 = 770K</td>
<td>171K x 8 = 1368K</td>
<td>56%</td>
</tr>
<tr>
<td>Total cost (R=1/2)</td>
<td>28.8K x 20 = 576K</td>
<td>171K x 8 = 1368K</td>
<td>42%</td>
</tr>
<tr>
<td>Total cost (R=3/4)</td>
<td>20.6K x 20 = 412K</td>
<td>171K x 8 = 1368K</td>
<td>30%</td>
</tr>
</tbody>
</table>

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

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

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

![Graph showing the performance of RC LDPC codes for different rates.]
Performance of RC LDPC

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

Chase Combining / OPTIMAL

-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0

CNR (dB)

information length (bit)

-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0

rate 1/3
rate 1/2
IR(1/3⇒1/4)
CC(1/2⇒1/4)
Throughput Performance of LDPC Chase Combining and IR HARQ

Required SNR for BLER=$10^{-2}$

- code-rate: $4/5$ (1st)
- $3/4$ (1st)
- $2/3$ (1st)
- $1/2$ (1st)
- $1/3$ (1st)
RC-LDPC and 802.16e LDPC

LDPC provides low cost higher efficiency parallel decoding.

802.16e LDPC with CC for higher throughput.

RC-LDPC with IR for channel with hostile conditions.
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.

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

Our Typical Model

Aggregation of traffic

Low Cost RS
Conclusions

- LDPC support high throughput with less hardware complexity and lower cost compared to Turbo codes

- 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