Rate-compatible Polar Coding and HARQ

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Rate compatible polar codes

- *{C1,C2...CN} be a compound channel with R1>R2>R3...>RN, and block lengths n1<n2...<nN*
- **Then the set is rate compatible if codeword for Ci can be built by removing nj-ni bits from codewords of code Cj ,j>i**
- Can be constructed by puncturing low rate codes.
- *Polar codes for degraded channels is inherently RCP*

HARQ =*ARQ+FEC*

Type –I

1. Send ***MSG+ED+EC***
2. If recoverable with EC do so.
3. Else use ED to detect error and Retransmit

- Use ***Chase combining*** (like MRC) to decode finally
- Effective SNRs for each Tx add.

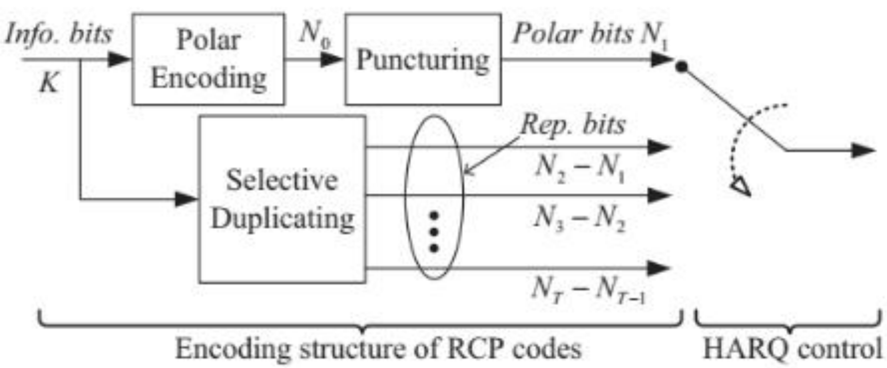
Type –II

1. Send ***MSG+ED***
2. if decodable do so.
3. Else Send ***EC incrementally***
4. Decode using all the previous information.
5. Repeat from 3 if not decodable

- ***Incremental Redundancy***
- *Data sent on step 3 is RV or redundancy vector, can be chosen appropriately*
- Coding Gain obtained

HARQ for polar codes need a RCP and a HARQ scheme

Scheme 1 *(Kai chen)*



- K information (msg) bits to be sent

<u>RCP</u>

- Use N_0 (block length of a low rate polar code)
- Puncture to create $N_1<N_2<N_3\ldots<N_T<N_0$
- T is the maximum number of repeats

<u>RCP Block (K<=M<=N):</u>

M (polar bits)	N-M repetition bits
K information bits	Chosen from the K bits

Scheme 1 *(Kai chen)*

HARQ

- A Type II ARQ (IR)
- First Transmission N1 polar bits are sent
- 2^{nd} onwards till 'T'th transmission N_t-N_{t-1} repetitions bits are sent.(N_t,K,M) RCPs constructed on each iteration.
- i.e, The RVs are repetition bits chosen as follows

Selection of repetition bits

1. Choose the most error prone channel among the K bits,repeat this bit.
2. Step 1 increases the reliability , which is re-calculated.
3. Repeat from step 1.

Scheme 2 *(Kai chen , Incremental freezing)*

- A improvement over the previous scheme.
- Uses ***reliability ordering*** to create puncturing patterns, thus the RCP.
- Applicable to degraded channels only.
- RV is repetition bits, choice of repetition bits is based on reliability ordering.
- Extended to general channels by Mondelli , Hassani, using universal polarization (scheme 2a)
- We have implemented this.

Scheme 3*(Tavildar)*

RCP

- Uses *Subset Polar codes* as RCP

Subset Polar code

- Start with (N,K) polar code mother code
- Create (M,K) subset code by puncturing, N>M, as follows:

1. Fix a BLER
2. puncture 1 bit
3. estimate BLER
4. change rate to get fixed BLER
5. repeat from step 1 till (M,K) reached

Scheme 3 *(Tavildar)*

HARQ

- Uses *Uses Equivalent subset polar code* as RV.

Equivalent subset Polar codes

Let S = {s1, s2, ..., sM} and T ={t1, t2, ..., tM}

be two (N M, K) subset polar codes. We say S is equivalent to T if $si = ti \oplus x \ \forall \ i, 1 \leq i \leq M$ for some integer x, where $1 \leq x \leq N$

cont...

Scheme 3 *(Tavildar)*

<u>Equivalent subset polar codes create redundancy as:</u>

If S, T are equivalent subset polar codes, then channels $W^{(i)}N,S$ and $W^{(i)}N,T$ are equivalent for each $1 \leq i \leq N$.

Where , bit channel equivalence is defined as follows:

Let W1 and W2 be two binary input channels with output alphabets Y1 and Y2 respectively. We define the two channels are equivalent, $W1 \sim W2$, if there exists an invertible function $f : Y1 \to Y2$ such that $W1(y1|x) = W2(f(y1)|x)$.

Simulations suggest this beats previous schemes in terms of reliability under joint decoding.

Use of CRC(DLC layer artefact) as ED

- CRC is supposedly used or ED in all mentioned schemes.
- Rateloss is negligible ***but not if short blocklengths are used.***
- Has other adverse effects like complexity due to cross layer cooperation.
- Mukhtar et al. proposed CRC free HARQ with Turbo product codes using inherent ED capability of TPC.

We are trying to get CRC-free HARQ with polar codes

Proposition 1:

- If we can estimate the expected value of the abs(LLRs) of all the channels from some analytical expression(eg, Z) then ED is **Binary** Hypothesis testing between exactly **2** LLR vectors in each step.Further we can try ML decoding of this received LLR vector using some gaussian approximation of the LLR distribution(which looked like gaussian).

Proposition 2:

Errorchecking using frozen bits as mentioned here:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4142331/