SOURCE-CHANNEL DECODING MEETS THE NETWORK

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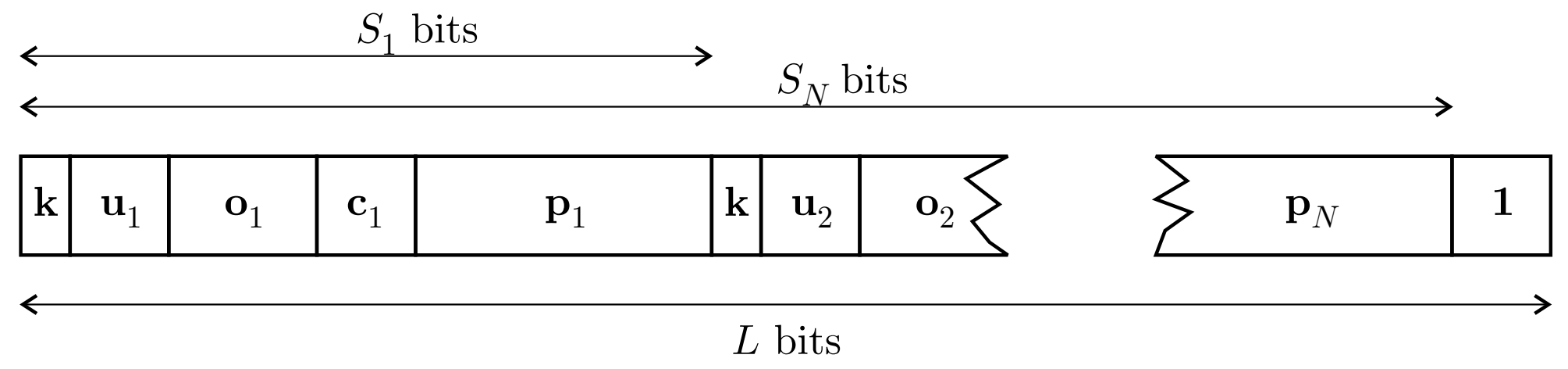
Abstract: Many joint source-channel decoders (JSCD) have been proposed these last years to improve the recovery of multimedia data transmitted over error-prone channels. JSCD employ the residual redundancy left by source coders in compressed bitstream in conjunction with soft information provided by channel decoders. One of the hypotheses made by JSCD is the availability of soft information at upper protocol layers (APL layer), even if there were no clear mechanism able to drive bit reliability information from the PHY layer to the upper layers.
The aim of this poster is to address two problems which have to be solved to allow an efficient transmission of soft information between protocol layers. The first one is concerned with robust segmentation of aggregated packets and is illustrated by the segmentation of aggregated MAC packets in WiMAX PHY frames. The second one deals with the reliable header recovery to allow packets to be efficiently forwarded to upper layers. Simulation results are in that case for a WiFi transmission scheme.

Robust burst segmentation

1 Introduction

Consider a burst $\mathbf{b}$ of L bits formed by

- N *data* packets
- an additionnal *padding* packet (to fill the burst)



A WiMAX burst at PHY layer containing several MAC packets

Each packet, except padding packet, contains header $\mathbf{h}_n$ and payload $\mathbf{p}_n$.
The header of n-th packet consists of

- a *constant* field $\mathbf{k}$, synchronization marker, known data,
- a *length* field $\mathbf{u}_n$, size in bits λ_n of the packet, including the header,
- *other* fields $\mathbf{o}_n$, not useful to perform burst segmentation,
- a *CRC* or *check-sum* $\mathbf{c}_n$, covering header only.

Payload of n-th packet denoted by $\mathbf{p}_n$.

2 Estimators

Burst $\mathbf{b}$ sent over noisy channel and $\mathbf{y}_1^L$ obtained at channel output.
MAP estimator

$$\left(\widehat{N},\widehat{\lambda}_1,\ldots,\widehat{\lambda}_{\widehat{N}}\right)=\arg\max_{N,\lambda_1,\ldots,\lambda_N} p\left(N,\lambda_1,\ldots,\lambda_N \mid \mathbf{y}_1^L\right). \quad (1)$$

Difficulties

- N is only known to satisfy $N_{\min}\leqslant N\leqslant N_{\max}$, with $N_{\min}=\lfloor L/\ell_{\max}\rfloor$ and $N_{\max}=\lceil L/\ell_{\min}\rceil$,
- number of padding bits is unknown at receiver side.

Suboptimal two-steps estimator

$$\widehat{N}_{\mathrm{MAP}}=\arg\max_n P\left(S_n=L|\mathbf{y}_1^L\right), \quad (2)$$

and

$$\widehat{\lambda}_n=\arg\max_\ell P\left(S_n=\ell|\mathbf{y}_1^L\right)-\arg\max_\ell P\left(S_{n-1}=\ell|\mathbf{y}_1^L\right). \quad (3)$$

Both (2) and (3) require evaluation of $P\left(S_n=\ell|\mathbf{y}_1^L\right)$, done with variants of the BCJR algorithm.

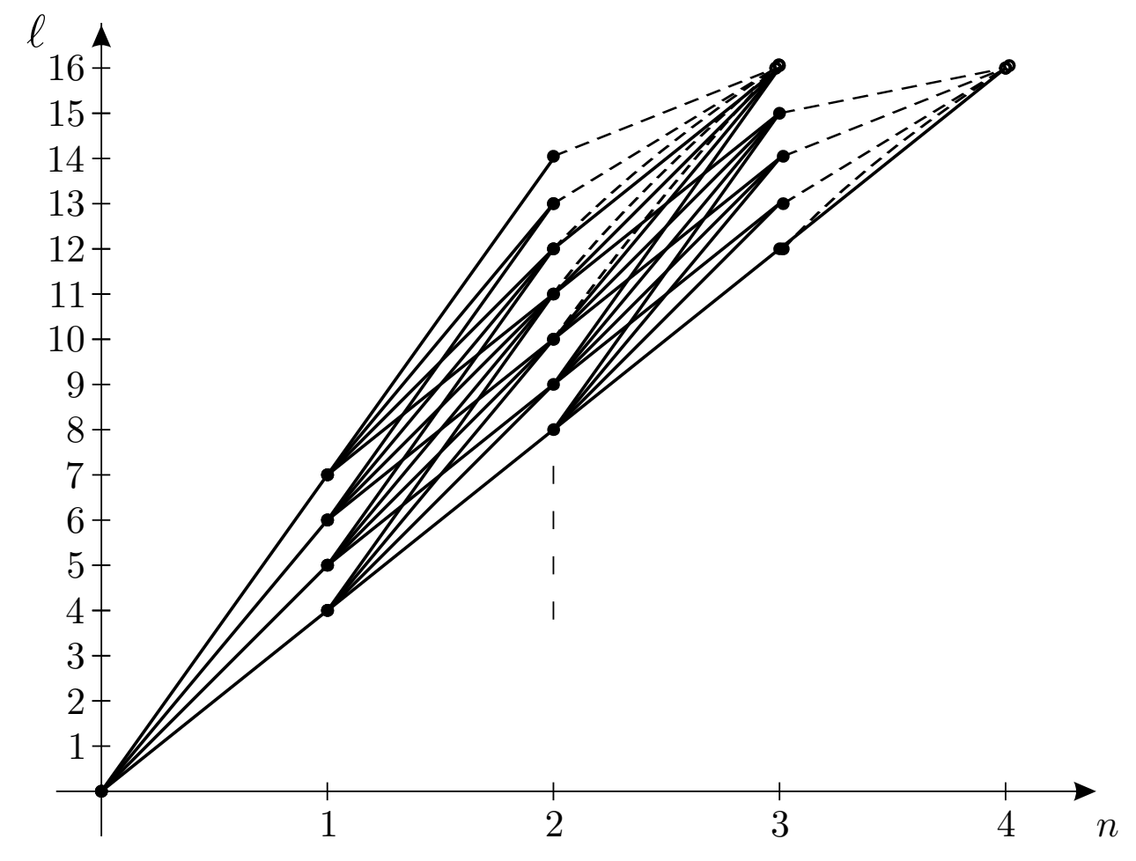
References

[1] R. Bauer and J. Hagenauer. Symbol-by-symbol MAP decoding of variable length codes. In *Proc. 3rd ITG Conference Source and Channel Coding*, pages 111–116, München, 2000.

[2] ANSI/IEEE. 802.11, part 11 : Wireless LAN medium access control (MAC) and physical layer (PHY) specifications. Technical report, 1999.

3 Estimation algorithm

Succession of values taken by S_n, $n=0,\ldots,N_{\max}$ described by trellis [1].



Trellis representing all MAC frame combinations within a MAC burst, $\ell_{\min}=4$, $\ell_{\max}=7$, and $L=16$

Evaluation of $P(S_n=\ell,\mathbf{y}_1^L)$ done as

$$P(S_n=\ell,\mathbf{y}_1^L)=\alpha_n(\ell)\,\beta_n(\ell) \quad (4)$$

where $\alpha_n(\ell)=P(S_n=\ell,\mathbf{y}_1^\ell)$, and $\beta_n(\ell)=P(\mathbf{y}_{\ell+1}^L|S_n=\ell)$.

3.1 Evaluation of α_n and β_n

Now for $n=1,\ldots,N_{\max}$, BCJR forward and backward recursions

$$\alpha_n(\ell)=\sum_{\ell'}\alpha_{n-1}(\ell')\gamma_n(\ell',\ell),\text{and}\beta_n(\ell)=\sum_{\ell'}\beta_{n+1}(\ell')\gamma_{n+1}(\ell',\ell),$$

with $\gamma_n\left(\ell',\ell\right)=P(S_n=\ell,\mathbf{y}_{\ell'+1}^{\ell}|S_{n-1}=\ell')$.

3.2 Evaluation of γ_n

Involves many sources of redundancy.

- If n-th packet contains only padding bits, these bits are perfectly determined (assume, *e.g.*, that they are all equal to 1).
- If n-th packet is a data packet, first bits equal to $\mathbf{k}$, length field $\mathbf{u}_n$ should be $\ell-\ell'$, value of the CRC $\mathbf{c}_n$ influenced by $\mathbf{k}$ and $\mathbf{u}_n$.

Taking this into account, one may show that when $\ell\neq L$, one gets

$$\gamma_n\left(\ell',\ell\right)=\gamma_n^{\mathrm{d}}\left(\ell',\ell\right)$$

and when $\ell=L$, one gets

$$\gamma_n\left(\ell',L\right)=\gamma_n^{\mathrm{d}}\left(\ell',L\right)+\gamma_n^{\mathrm{p}}\left(\ell',L\right),$$

with

$$\begin{aligned}\gamma_n^{\mathrm{d}}\left(\ell',\ell\right) &= p\left(S_n=\ell|S_{n-1}=\ell'\right)P\left(\mathbf{y}_{\mathrm{k}}|\mathbf{k}\right)P\left(\mathbf{y}_{\mathrm{u}}|\mathbf{u}\left(\ell-\ell'\right)\right)\\ &\sum_{\mathbf{p}}P\left(\mathbf{y}_{\mathrm{p}}|\mathbf{p}\right)2^{-\ell(\mathbf{p})}\sum_{\mathbf{o}}\left(P\left(\mathbf{y}_{\mathrm{o}}|\mathbf{o}\right)\right.\\ &\left.P\left(\mathbf{y}_{\mathrm{c}}|\mathbf{c}=\mathbf{f}\left(\mathbf{k},\mathbf{u}\left(\ell-\ell'\right),\mathbf{o}\right)\right)P\left(\mathbf{o}\right)\right)\end{aligned}$$

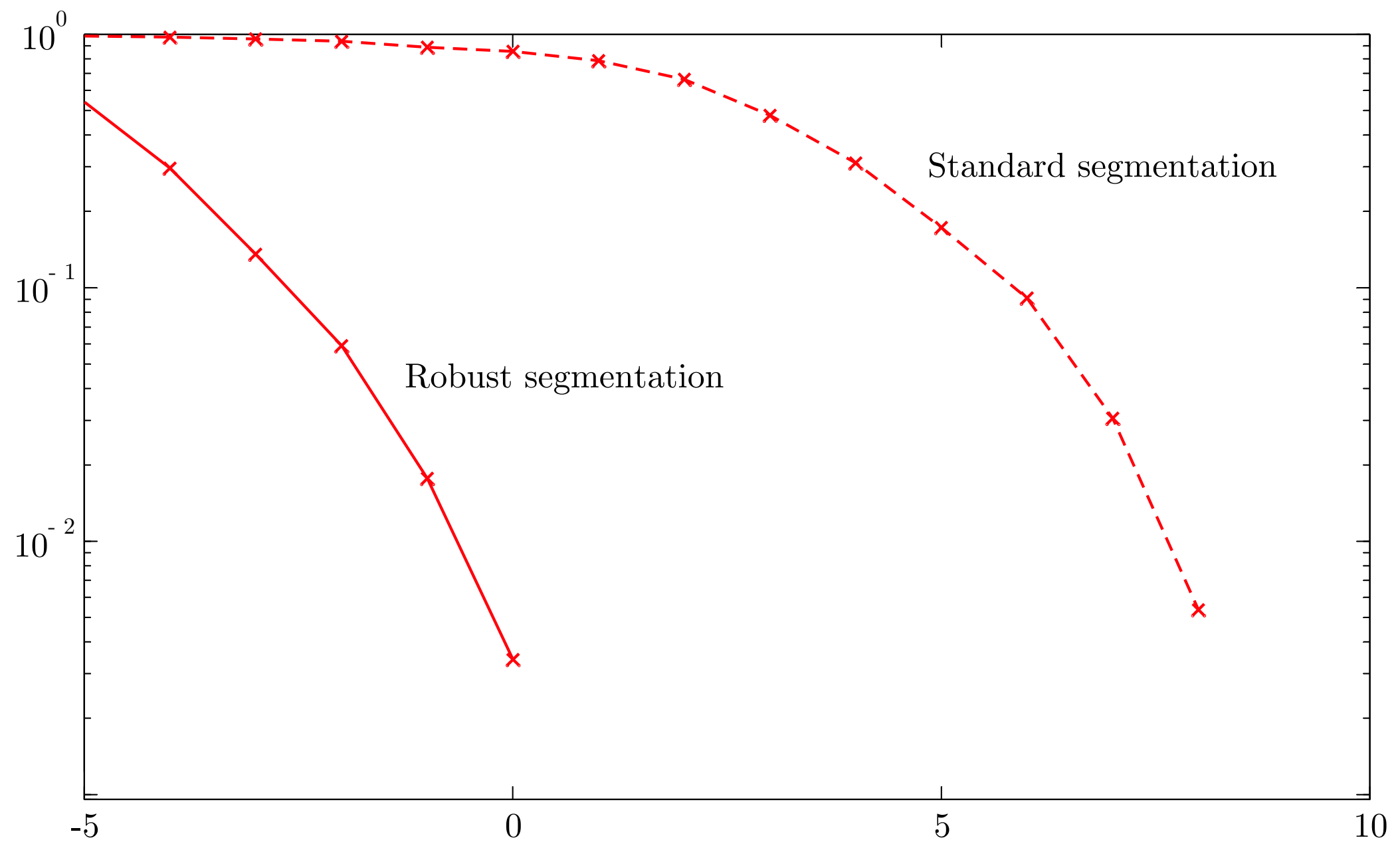
and

$$\gamma_n^{\mathrm{p}}\left(\ell',L\right)=P\left(\mathbf{y}_{\ell'+1}^L|\mathbf{x}=\mathbf{1}\right)\left(1-\pi_{L-\ell'}\right),$$

where $\mathbf{u}\left(\ell-\ell'\right)$ is the binary representation of $\ell-\ell'$ and $\mathbf{f}\left(\cdot\right)$ is a generic CRC encoding function.

4 Simulation results

Simulator: MAC burst generator, AWGN channel, receiver.
Random sized data packets with $\ell_{\min}=50$ bytes and $\ell_{\max}=150$ bytes are aggregated in bursts of $L=500$ bytes.



Erroneous Packet Location Rate as a function of channel PSNR

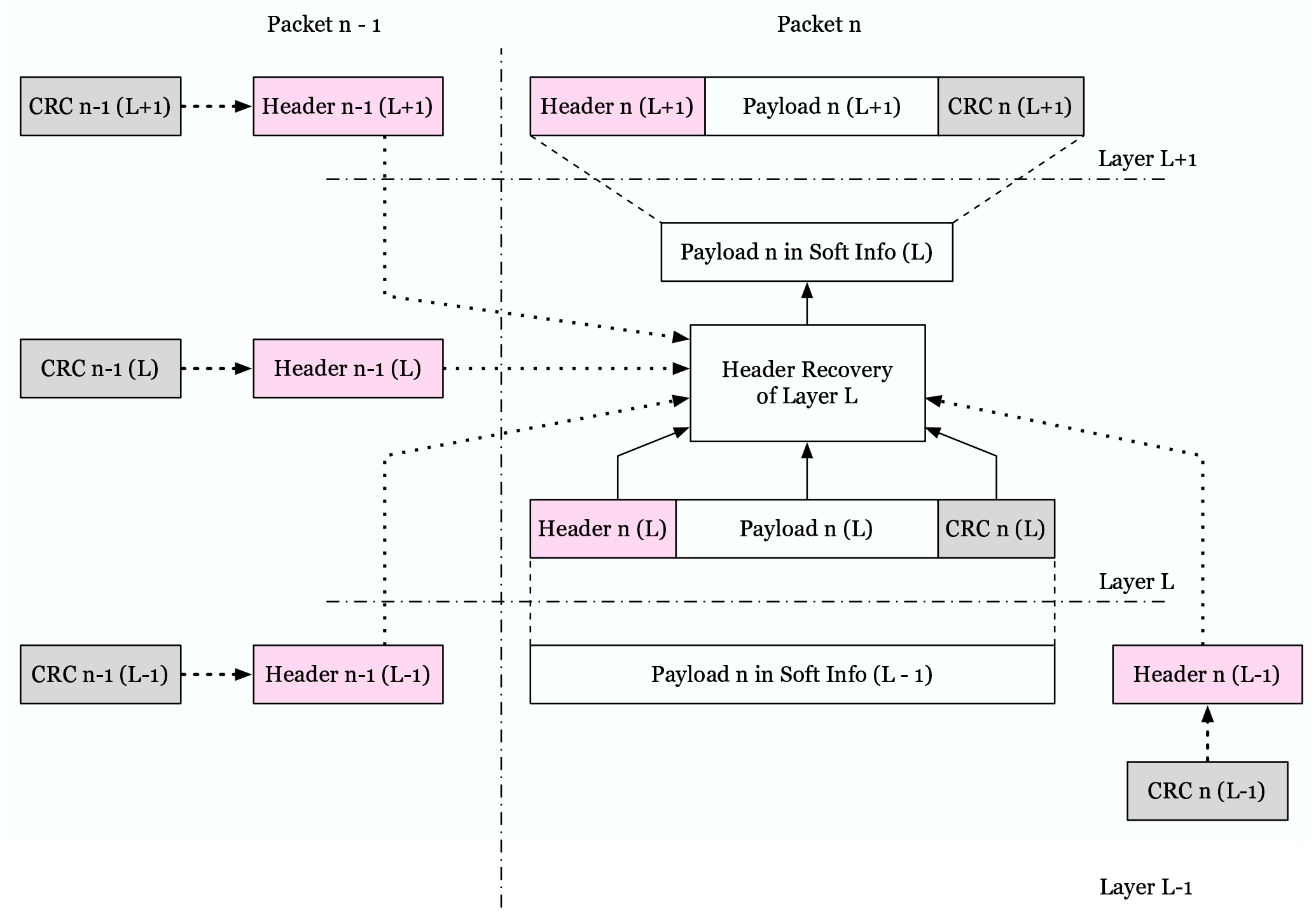
Robust header recovery

1 Introduction

Header impaired by transmission errors do not allow transmission of data to upper protocol layers.

Need for robust header recovery mechanism involving

- intra-layer redundancy
- inter-layer redundancy
- CRC or checksum seen as error-correcting code



2 Estimator

Information protected by the CRC $\mathbf{c}$ may be split in four parts:

1. The constant fields, $\mathbf{k}$, are *known*
2. The *predictable* fields, $\mathbf{p}$, are totally estimated by using the *intra- and inter-layer redundancy* denoted by R
3. The important *unknown* fields, $\mathbf{u}$, are limited to a set of valid combinations Ω_u depending on $\mathbf{k}$, $\mathbf{p}$, and R
4. The *other* fields, $\mathbf{o}$, are not required for processing the packet at this layer

Additionally, we consider that $\mathbf{c}=\mathcal{F}([\mathbf{k},\mathbf{p},\mathbf{u},\mathbf{o}])$.

Vector $[\mathbf{k},\mathbf{p},\mathbf{u},\mathbf{o},\mathbf{c}]$ is transmitted over a channel and received data are denoted by $\mathbf{y}=[\mathbf{y}_k,\mathbf{y}_p,\mathbf{y}_u,\mathbf{y}_o,\mathbf{y}_c]$.

At the receiver, only $\mathbf{u}$ required, MAP estimator

$$\widehat{\mathbf{u}}=\arg\max_{\mathbf{u}} P(\mathbf{u}|\mathbf{k},\mathbf{p},R,\mathbf{y}_u,\mathbf{y}_o,\mathbf{y}_c),$$

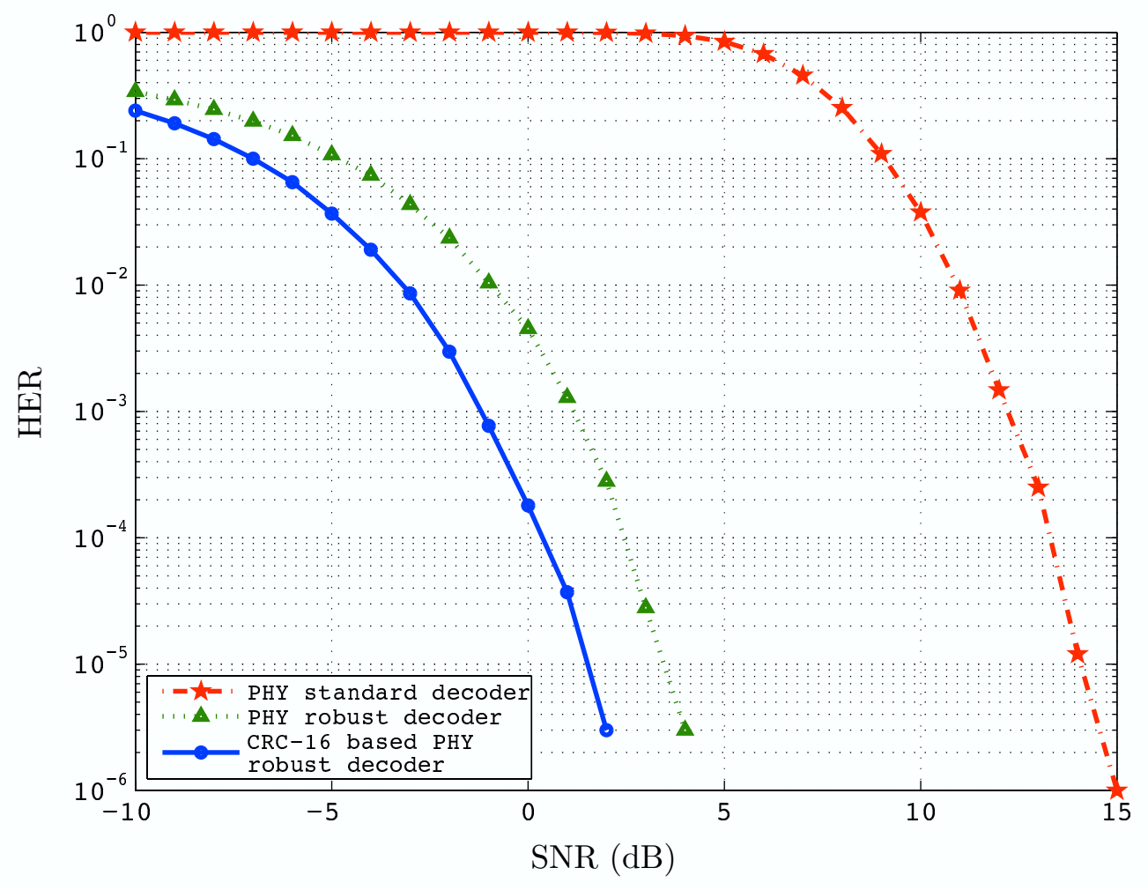
after some derivations

$$\widehat{\mathbf{u}}=\arg\max_{\mathbf{u}\in\Omega_u} P(\mathbf{u})P(\mathbf{y}_u|\mathbf{u})\sum_{\mathbf{o}}P(\mathbf{o},\mathbf{y}_o,\mathbf{y}_c|\mathbf{k},\mathbf{p},\mathbf{u}). \quad (5)$$

3 Simulation results

Method applied to PHY and MAC layers of WiFi [2]. PHY and MAC packets generated and DBPSK modulated. Data then transmitted over AWGN channel.

A – PHY layer: CRC covers header fields only → $\mathbf{o}$ is empty.
↪ High performance for reduced complexity.



B – MAC layer: CRC protects header fields and payload → marginalization on the payload is required.
CRC-32 split into 4 blocks of 1 byte.