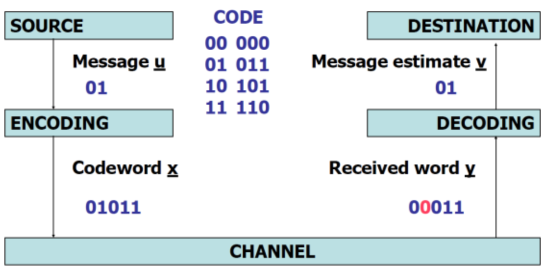
Channel Coding in the Benelux



Jos Weber
Delft University of Technology
The Netherlands

40th WIC Symposium
on Information Theory in the Benelux

KU LEUVEN

9th joint WIC / IEEE SP Symposium
on Information Theory and Signal Processing in the Benelux

28-29 MAY 2019, KU Leuven, Technologiecampus Gent, Belgium

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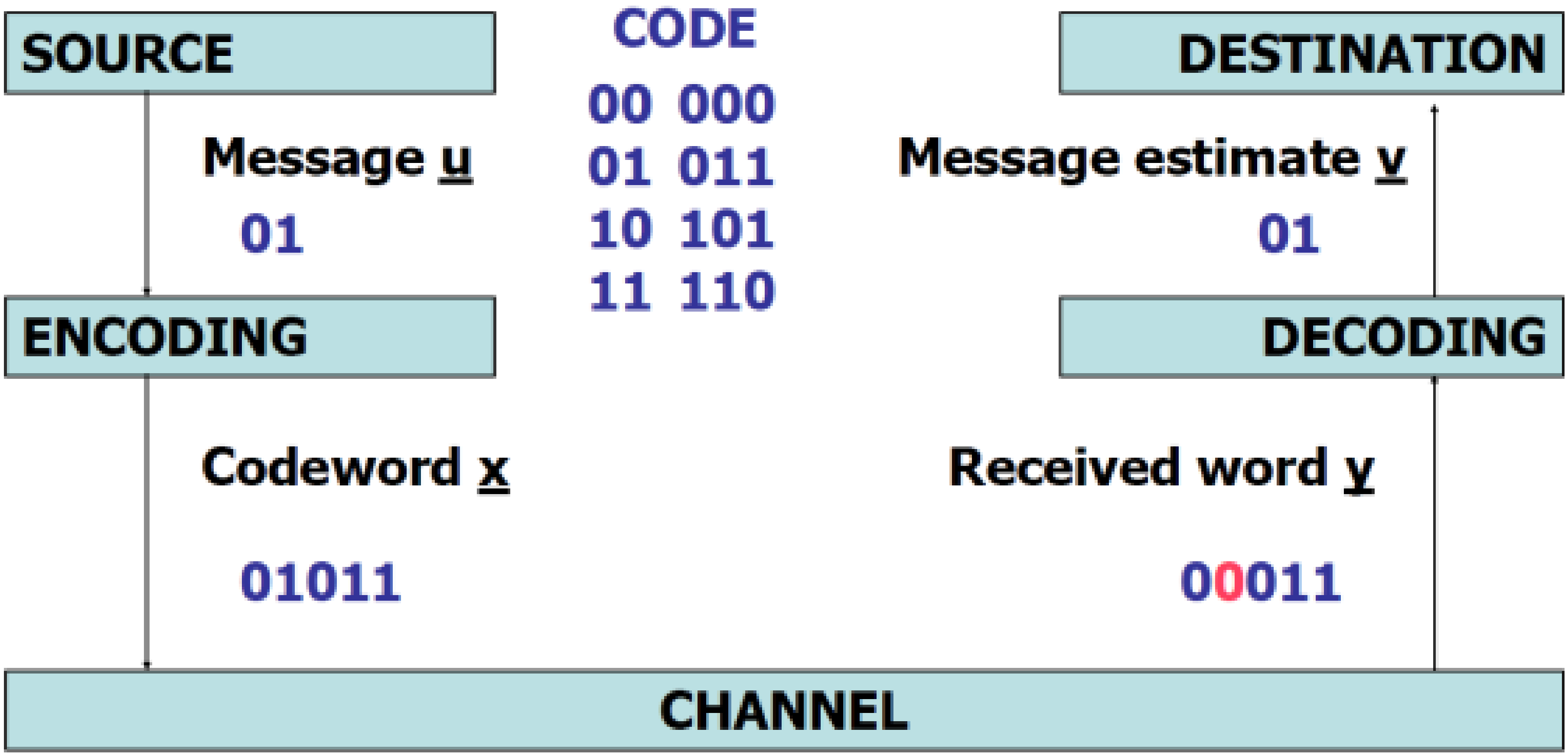
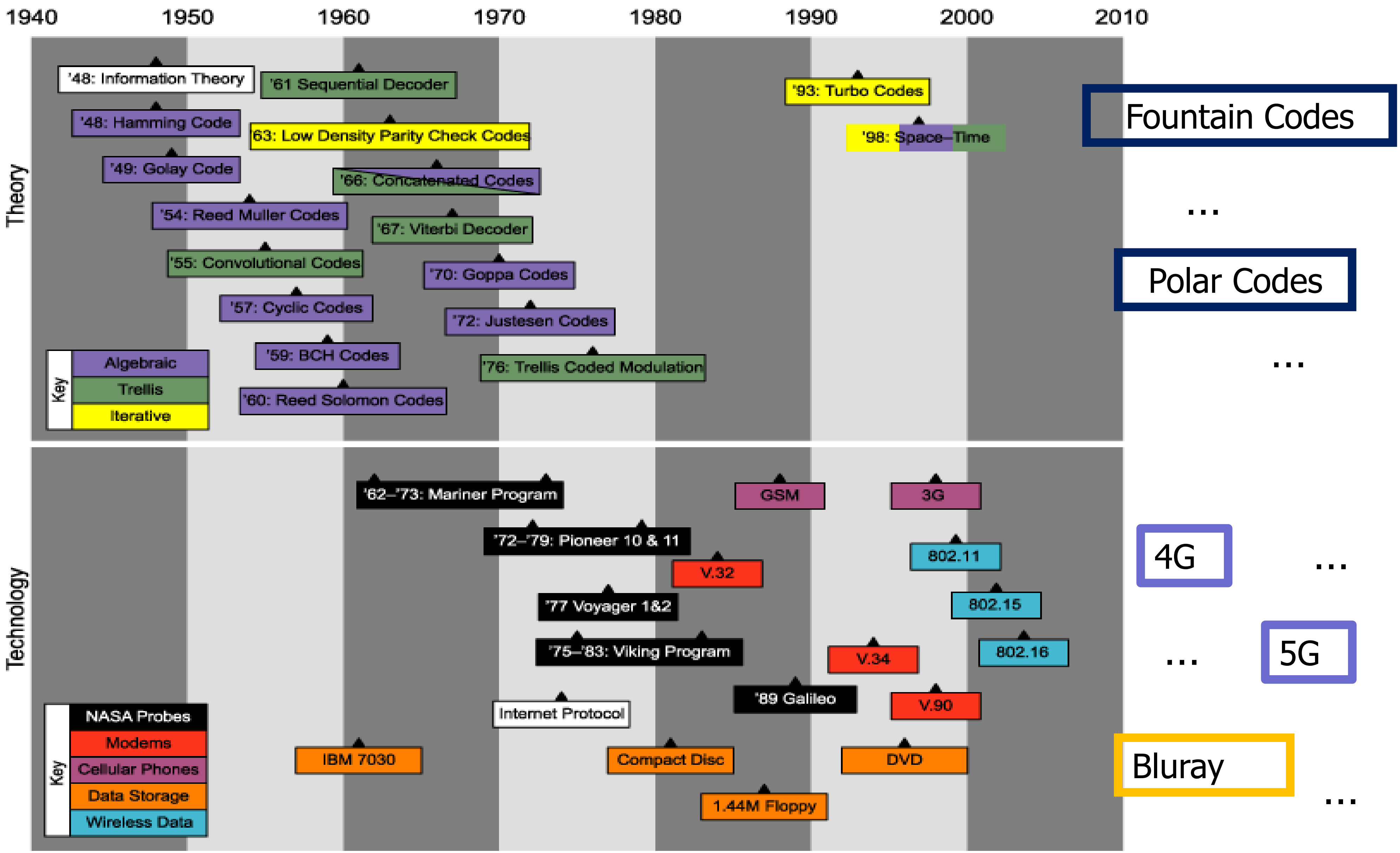
Outline

- Brief intro to channel coding
- Some Benelux contributors and highlights
- My current research topics:
    - Erasure coding for distributed storage
    - Detection and decoding techniques for channels suffering from gain and/or offset mismatch

Channel Coding Example





http://www.acorn.net.au/telecoms/coding/coding.html

Information Theory in the Benelux:
An overview of WIC symposia
1980 - 2003

CHAPTER 4

Channel Coding

J.H. Weber (TU Delft)
L.M.G.M. Tolhuizen (Philips Research Eindhoven)
K.A. Schouhamer Immink (University of Essen/Turing Machines)

Introduction

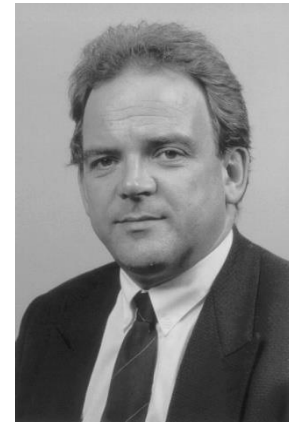
Channel coding plays a fundamental role in digital communication and in digital storage systems. The position of channel coding in such a system is depicted in Figure 4.1 overleaf. The *channel encoder* adds redundancy to the (possibly source encoded and encrypted) messages generated by the information source, in order to

Eindhoven

Jack van Lint

Andries Brouwer

Piet Schalkwijk



Han Vinck

Henk Hollmann

Henk van Tilborg

Ruud Pellikaan

Tjalling Tjalkens

Frans Willems

On the Diamond Code Construction

C.P.M.J. Baggen and L.M.G.M. Tolhuizen

Philips Research Laboratories, Prof. Holstlaan 4, 5656 AA Eindhoven, The Netherlands

Abstract — **We introduce a new error correcting code, which we call *Diamond code*. Diamond codes combine the error correcting capabilities of product codes and the reduced memory requirements from CIRC, the code applied in the CD system.**

I. Diamond Code Construction

The Diamond Code C calls for two codes, C_1 and C_2, of equal length n and defined over the same alphabet. C consists of the bi-infinite strips of height n, with each column in C_1 and each diagonal in C_2.

A convenient way of constructing Diamond codes is by using linear weakly cyclic codes for C_1 and C_2.

Definition: A linear code B is called *weakly cyclic* if

$$(b_0, b_1, \ldots, b_{n-2}, 0) \in B \Leftrightarrow (0, b_0, b_1, \ldots, b_{n-2}) \in B.$$

Suppose both C_1 and C_2 are weakly cyclic codes, with n and q

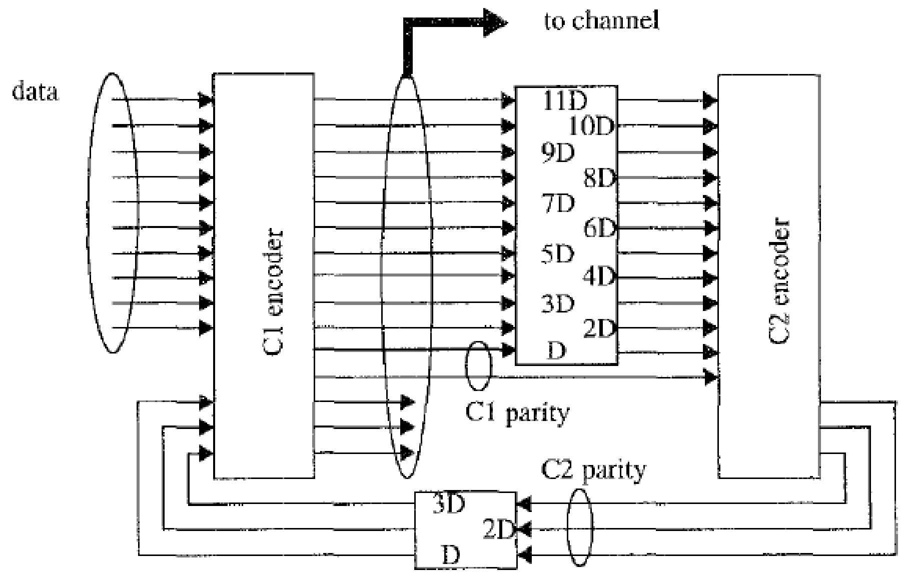
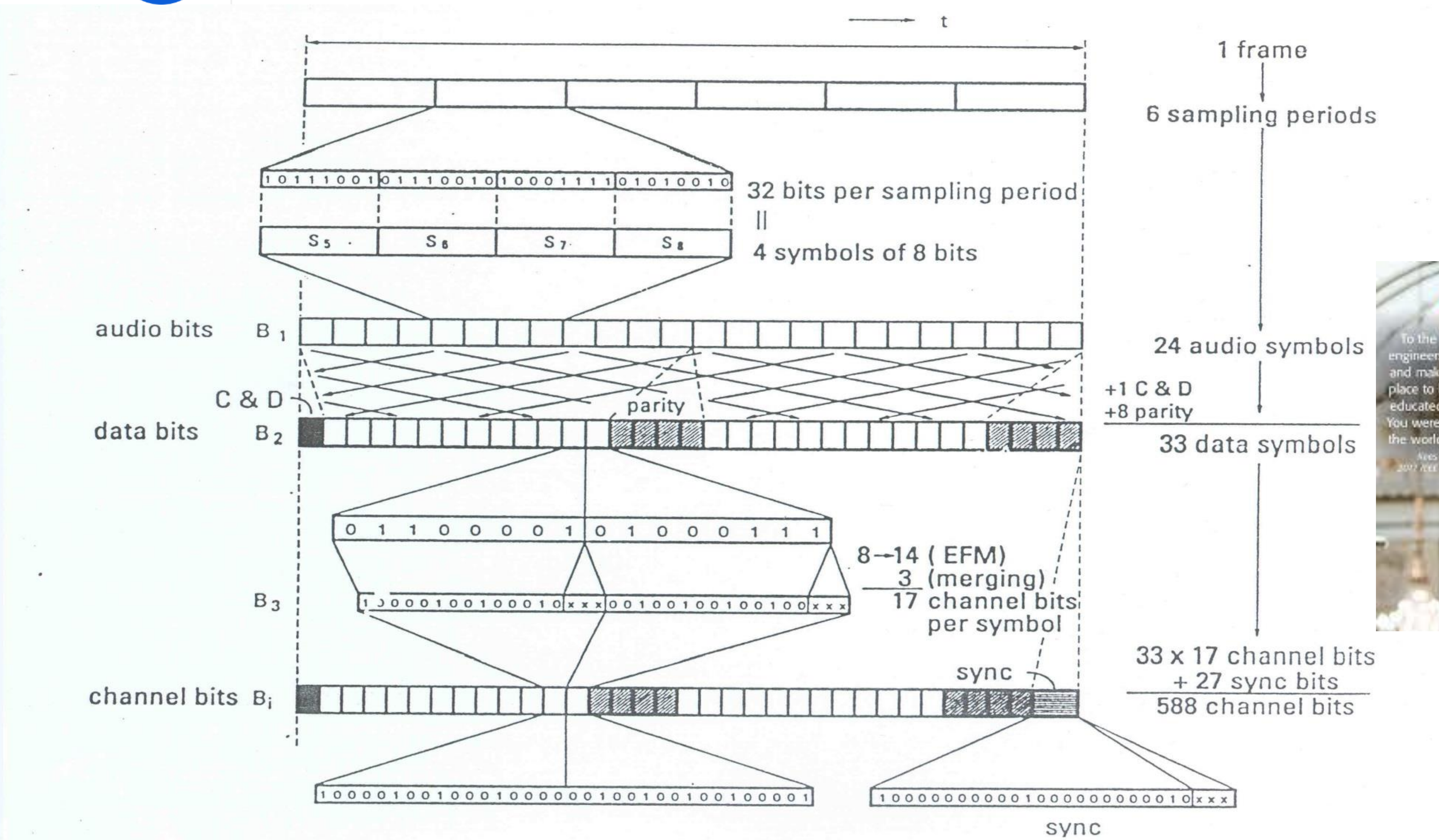


Figure 2: Systematic Diamond encoder

CD



Kees Schouhamer Immink

Phi(l)lip(pe)s

Université catholique de Louvain

Bounds and Constructions for Binary Asymmetric Error-Correcting Codes

PHILLIPPE DELSARTE AND PHILLIPPE PIRET

Abstract—By use of known bounds on constant-weight binary c
new upper bounds are obtained on the cardinality of binary codes cor
ing asymmetric errors. Some constructions are exhibited that come
to these bounds. For single-error-correcting codes some constructions
derived from the Steiner system $S(5,6,12)$, and for double-error-corre
codes some constructions are derived from the Nordstrom–Robinson

Manuscript received November 29, 1979; revised April 7, 1980.

The authors are with the Philips Research Laboratory, 2 Avenue van Becelaere, Box 8, B-1170, Brussels, Belgium.

The Hamming space viewed as an association scheme

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Abstract Block codes of length n over a q-ary alphabet are living in
, q), which has the combinatorial structure of
he Hamming schemes enjoy some remarkable
-*polynomial* and Q-*polynomial*; (ii) they can
chemes, with respect to a

Proc. WIC Symposium 2002, pp. 329-380!!!

IEEE

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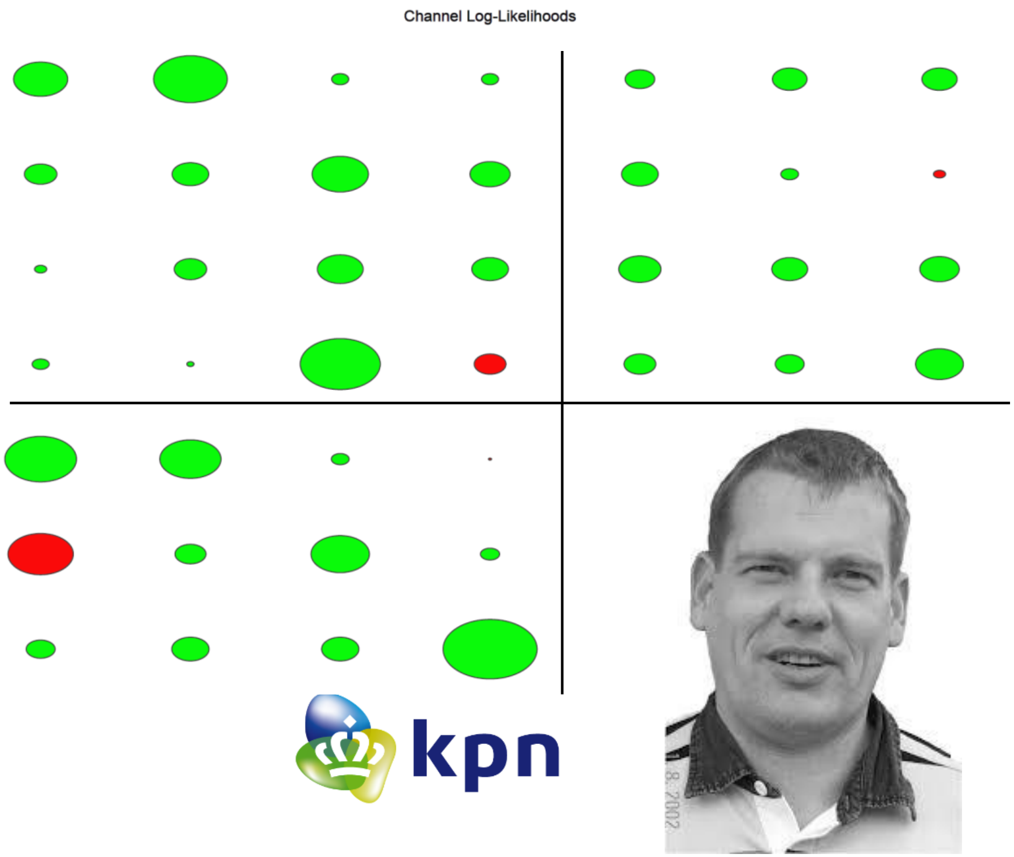
Andries Hekstra

Arie Koppelaar



ISIT 2000, Sorrento, Italy, June 25-30,2000

Simultaneous zero-tailing of parallel concatenated codes

Marten van Dijk, Sebastian Egner, Ravi Motwani, Arie Koppelaar

Bounds for Binary Codes of Length Less Than 25

M. R. BEST, A. E. BROUWER, F. JESSIE MACWILLIAMS, ANDREW M. ODLYZKO, MEMBER, IEEE, AND NEIL J. A. SLOANE, FELLOW, IEEE

Abstract—Improved bounds for $A(n,d)$, the maximum number of codewords in a (linear or nonlinear) binary code of word length n and minimum distance d, and for $A(n,d,w)$, the maximum number of binary vectors of length n, distance d, and constant weight w in the range $n \leq 24$ and $d \leq 10$ are presented. Some of the new values are $A(9,4) = 20$ (which was previously believed to follow from the results of Wax), $A(13,6) = 32$ (which proves that the Nadler code is optimal), $A(17,8) = 36$ or 37, and $A(21,8) = 512$. The upper bounds on $A(n,d)$ are found with the help of linear programming, making use of the values of $A(n,d,w)$.

I. INTRODUCTION

THE MAIN purpose of this paper is to present tables[1] of two of the most basic functions in coding theory, namely:

$A(n,d)$ = maximum number of codewords in any (linear or nonlinear) binary code of length n and minimum distance d between codewords (see Table I), and

$A(n,d,w)$ = maximum number of codewords in any binary code of length n, constant weight w and minimum distance d (see Table II),

in the range $n \leq 24$, $d \leq 10$. We also give a table of the

TABLE I
VALUES OF $A(n,d)$

n	d=4	d=6	d=8	d=10
6	4	2	1	1
7	8	2	1	1
8	[a]16	2	2	1
9	[d]20[b]	4	2	1
10	[d]38 - 40	6	2	2
11	[d]72 - 80	12	2	2
12	[d]144 - 160	24	4	2
13	256	32[e]	4	2
14	512	64	8	2
15	1024	128	16	4
16	[a]2048	[f]256	32	4
17	[d]2560 - 3276	256 - 340	36 - 37[h]	6
18	[d]5120 - 6552	512 - 680	64 - 74	10
19	[d]9728 - 13104	1024 - 1288	128 - 144	20
20	[d]19456 - 26208	[g]2048 - 2372	256 - 279	40
21	[d]36864 - 43690	[g]2560 - 4096	512	40 - 55
22	[d]73728 - 87380	4096 - 6942	1024	[j]48 - 90
23	[d]147456 - 173784	8192 - 13774	2048	64 - 150
24	[d]294912 - 344636	[g]16384 - 24106	[i]4096	[k]128 - 280

[a] Hamming code [24]

IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, VOL. 15, NO. 1, JANUARY 2016

Optimizing the Code Rate of Energy-Constrained Wireless Communications With HARQ

Fernando Rosas, *Member, IEEE*, Richard Demo Souza, *Senior Member, IEEE*, Marcelo E. Pellenz, Christian Oberli, *Member, IEEE*, Glauber Brante, *Member, IEEE*, Marian Verhelst, *Senior Member, IEEE*, and Sofie Pollin, *Senior Member, IEEE*

Sofie Pollin

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Parallel turbo coding interleavers: avoiding collisions in accesses to storage elements

A. Giulietti, L. van der Perre and M. Strum

imec

Liesbet
Van der Perre

UCL
Université catholique de Louvain

Jerome Louveaux

TURBO-CODED DECODE-AND-FORWARD STRATEGY RESILIENT TO RELAY ERRORS

Harold H. Sneessens, Jérôme Louveaux, Luc Vandendorpe.

Communications and Remote Sensing Laboratory, Université catholique de Louvain, Louvain-la-Neuve, Belgium.

IEEE

TU Delft

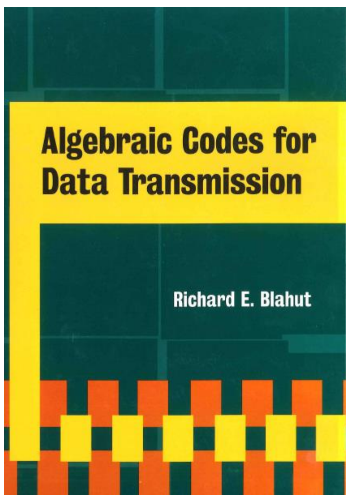
Kees Roos

330 IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. IT-29, NO. 3, MAY 1983

A New Lower Bound for the Minimum Distance of a Cyclic Code

CORNELIS ROOS

DEDICATED TO JESSIE MACWILLIAMS ON THE OCCASION OF HER RETIREMENT FROM BELL LABORATORIES



Again, the roles of ℓ_1 and ℓ_2 can be interchange
nents of V by B.

Corollary 6.4.4 (Roos Bound). *Let n be*
$GCD(n, b) = 1$. The only vector in $GF(q)^n$
components V_j equal zero for $j = \ell_1 + \ell_2 b$

JW

New Upper Bounds on the Size of Codes Correcting Asymmetric Errors

J. H. WEBER, C. DE VROEDT, AND D. E. BOEKEE

A SCHEME FOR COMBINED MODULATION AND ERROR CORRECTION

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Delft University of Technology
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The Netherlands

Physical-layer Network Coding on the Random-access Channel

Jasper Goseling*§, Michael Gastpar†‡§ and Jos H. Weber§

Concatenated Permutation Block Codes for Correcting Single Transposition Errors

Reolyn Heymann*, Jos H. Weber†, Theo G. Swart* and Hendrik C. Ferreira*
* University of Johannesburg, Dept. E&E Eng. Science, South Africa

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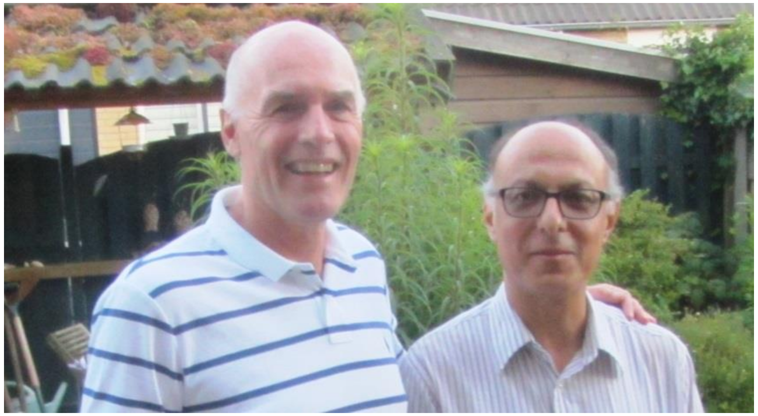
Current Research Topic:

Erasure Coding for Distributed Storage

(joint work with Khaled Abdel-Ghaffar)



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Context

Distributed Storage: data stored at multiple nodes (servers).

One or more nodes may fail -> erasures!

Repairing data from failed node(s) by accessing other nodes.

Employ coding!

-> Storage overhead (redundancy)

-> Transmission overhead (**locality**):

nodes to be accessed in the repair process

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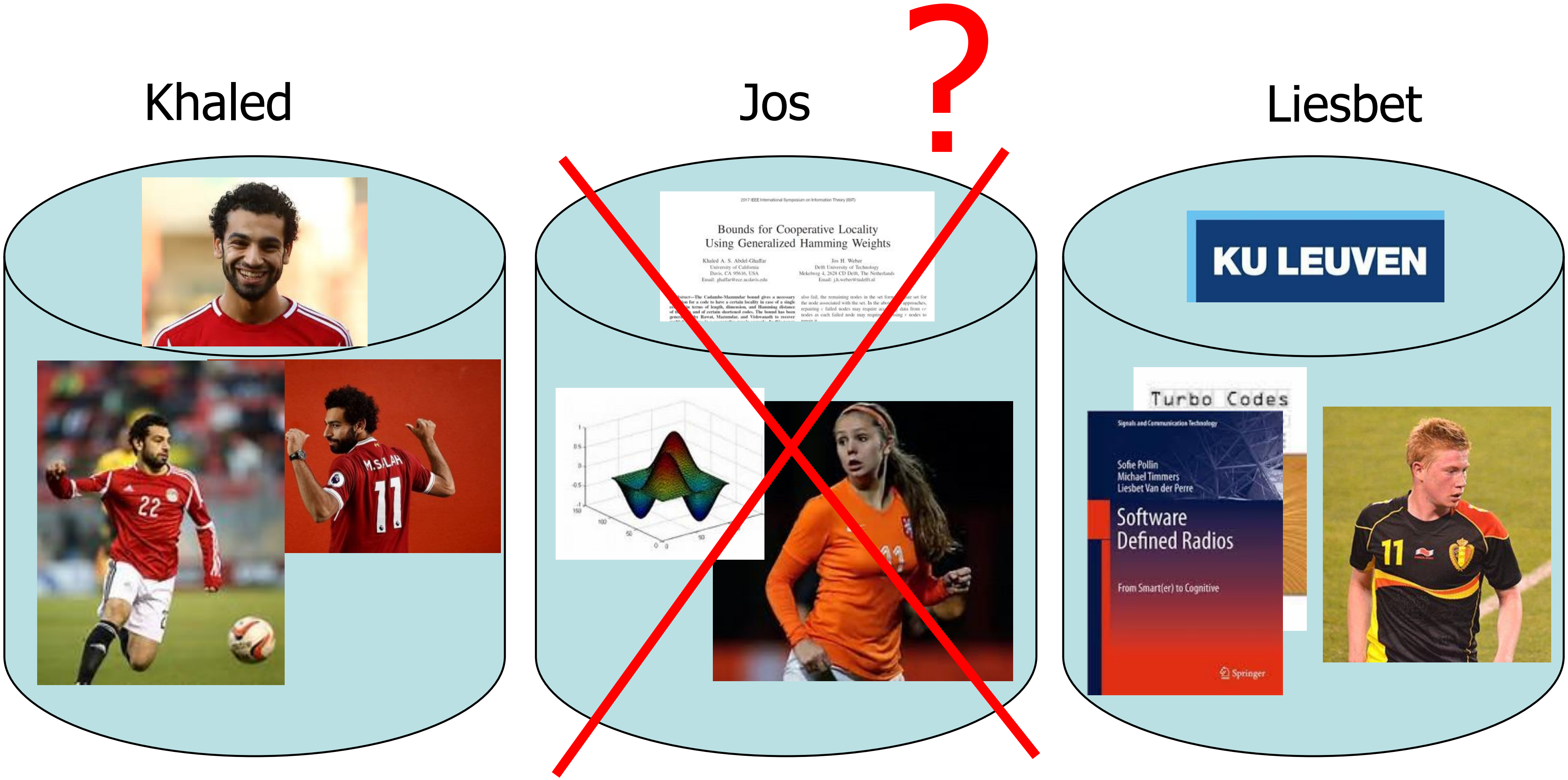
Storage

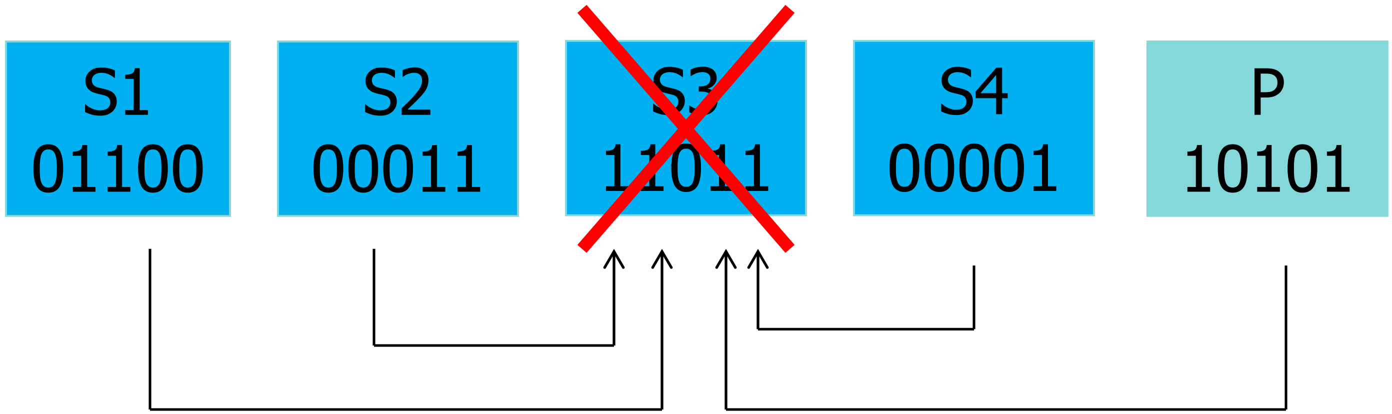


Khaled
Jos
?
Liesbet
Bounds for Cooperative Locality
Using Generalized Hamming Weights
Khaled A. S. Abdel-Ghaffar
Jos H. Weber
KU LEUVEN
Turbo Codes
Signals and Communication Technology
Sofie Pollin
Michael Timmers
Liesbet Van der Perre
Software
Defined Radios
From Smart(er) to Cognitive
Springer
M.SALAH

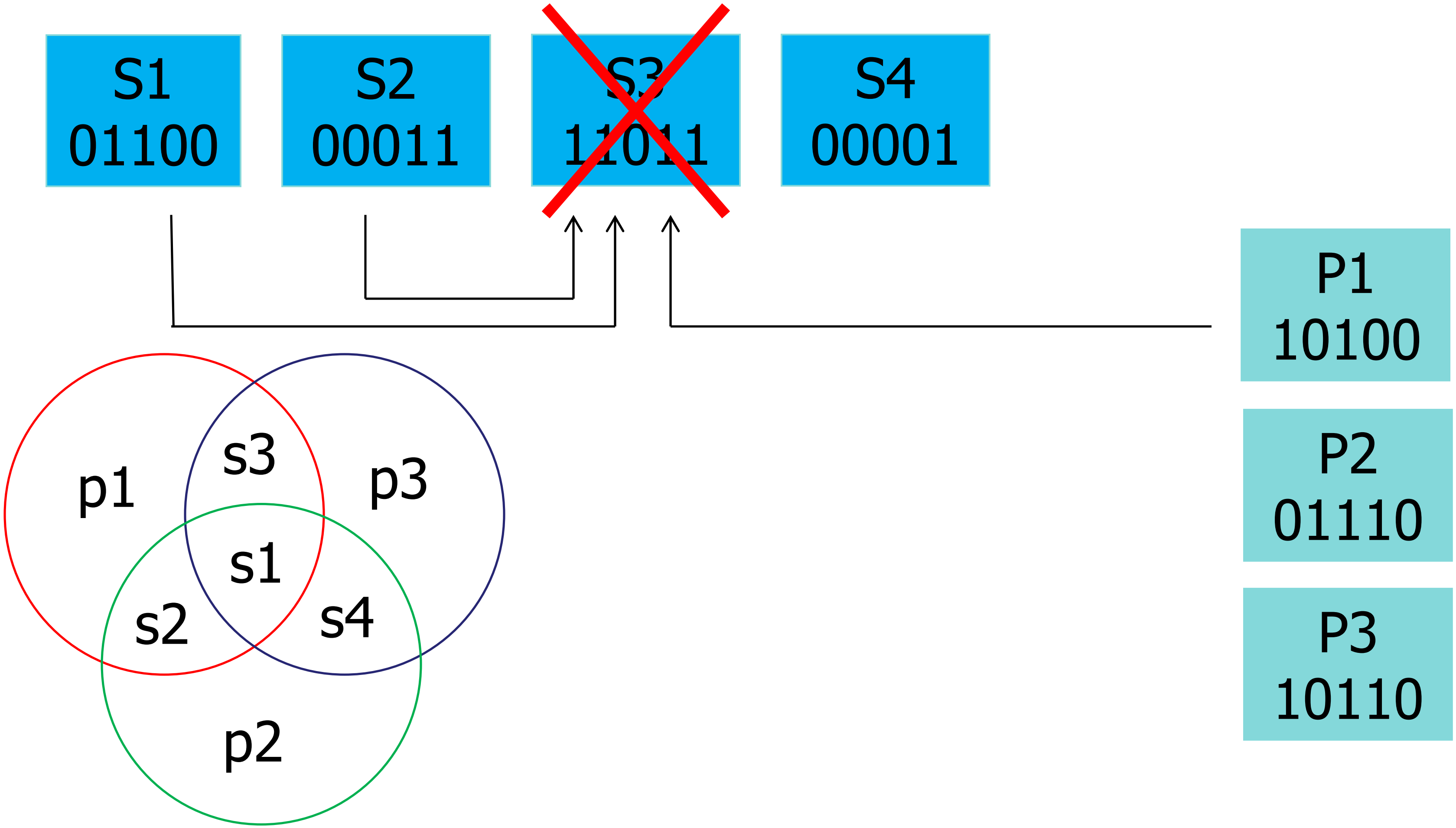
Duplication

S1 01100	S2 00011	~~S3 11011~~	S4 00001
P1 01100	P2 00011	P3 11011	P4 00001

Single Parity Server



Hamming Code Based System



Summary: Trade-Off!

	Redundancy	Locality
Duplication	4	1
Single Parity	1	4
Hamming	3	3

N.B. Hamming code can also deal with 2 erasures!

Our contribution: bounds on *cooperative locality*

Current Research Topic:

Detection and decoding techniques for channels suffering from gain and/or offset mismatch

Joint work with

Renfei Bu

Kees Immink

Theo Swart

TURING MACHINES INC

UNIVERSITY OF JOHANNESBURG

Cai Kui

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

Simon Blackburn

ROYAL HOLLOWAY UNIVERSITY OF LONDON

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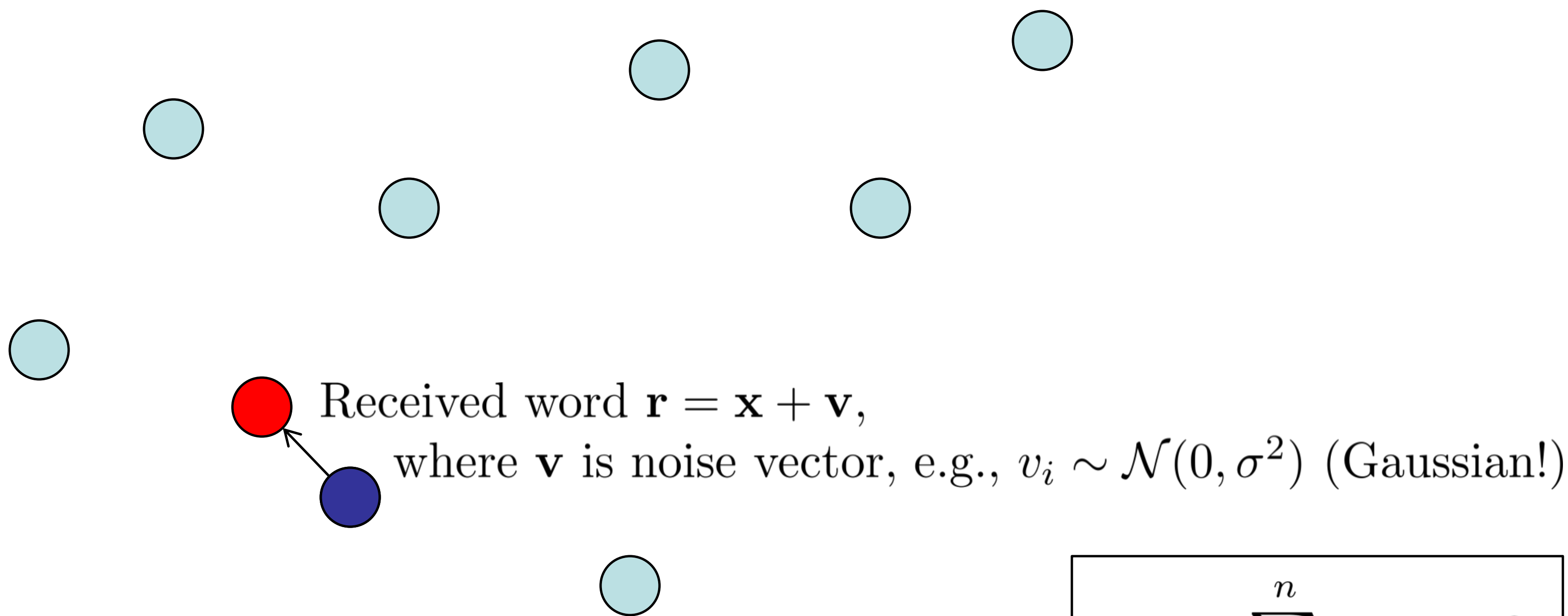
Codewords in Euclidean Space

- Members of a codebook $\mathcal{C}$
- Transmitted codeword $\mathbf{x} = (x_1, x_2, \ldots, x_n) \in \mathcal{C}$

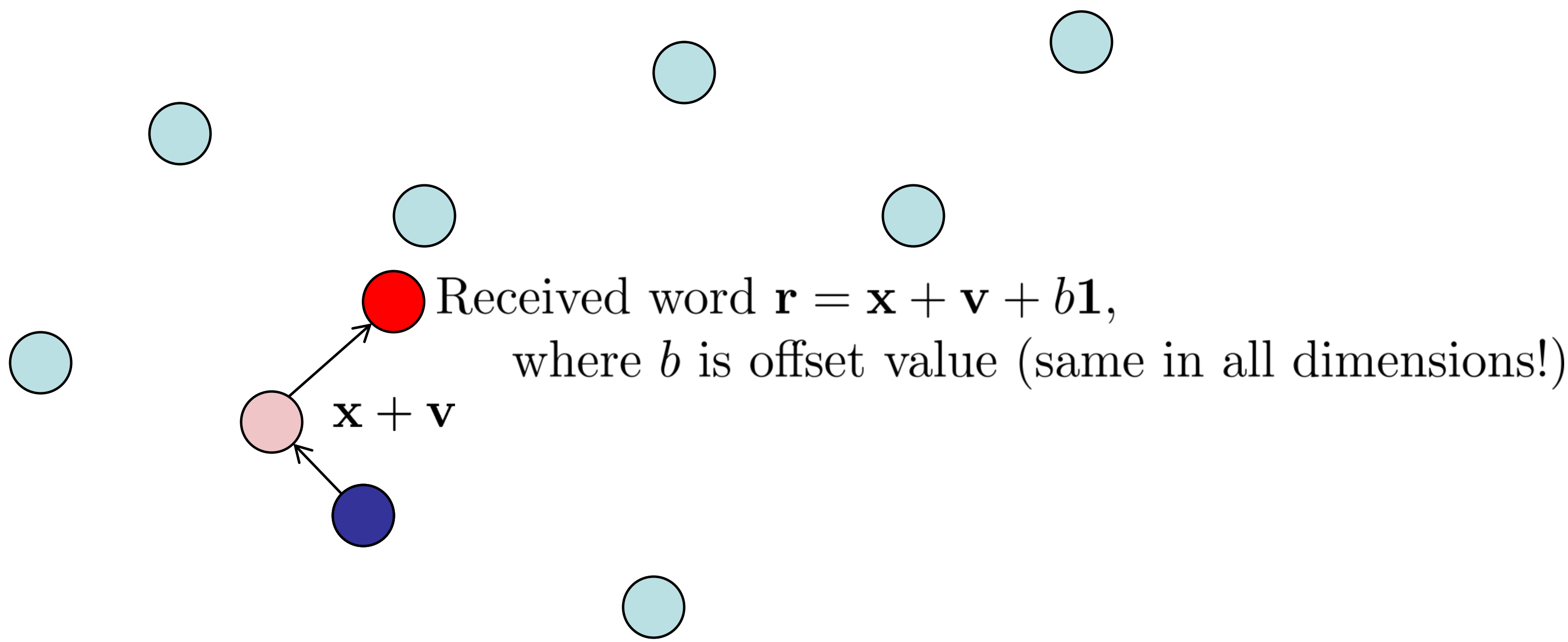


Euclidean distance detector is very suitable in this case: $\boxed{\arg\min_{\hat{\mathbf{x}} \in \mathcal{C}} \sum_{i=1}^{n} (r_i - \hat{x}_i)^2}$

Offset

Members of a codebook $\mathcal{C}$

Transmitted codeword $\mathbf{x} = (x_1, x_2, \ldots, x_n) \in \mathcal{C}$



Euclidean distance detector is **not** very suitable in this case!

Channel Model

$$\mathbf{r} = a(\mathbf{x} + \mathbf{v}) + b\mathbf{1}$$

received vector

codeword

gain (>0)

noise vector

offset

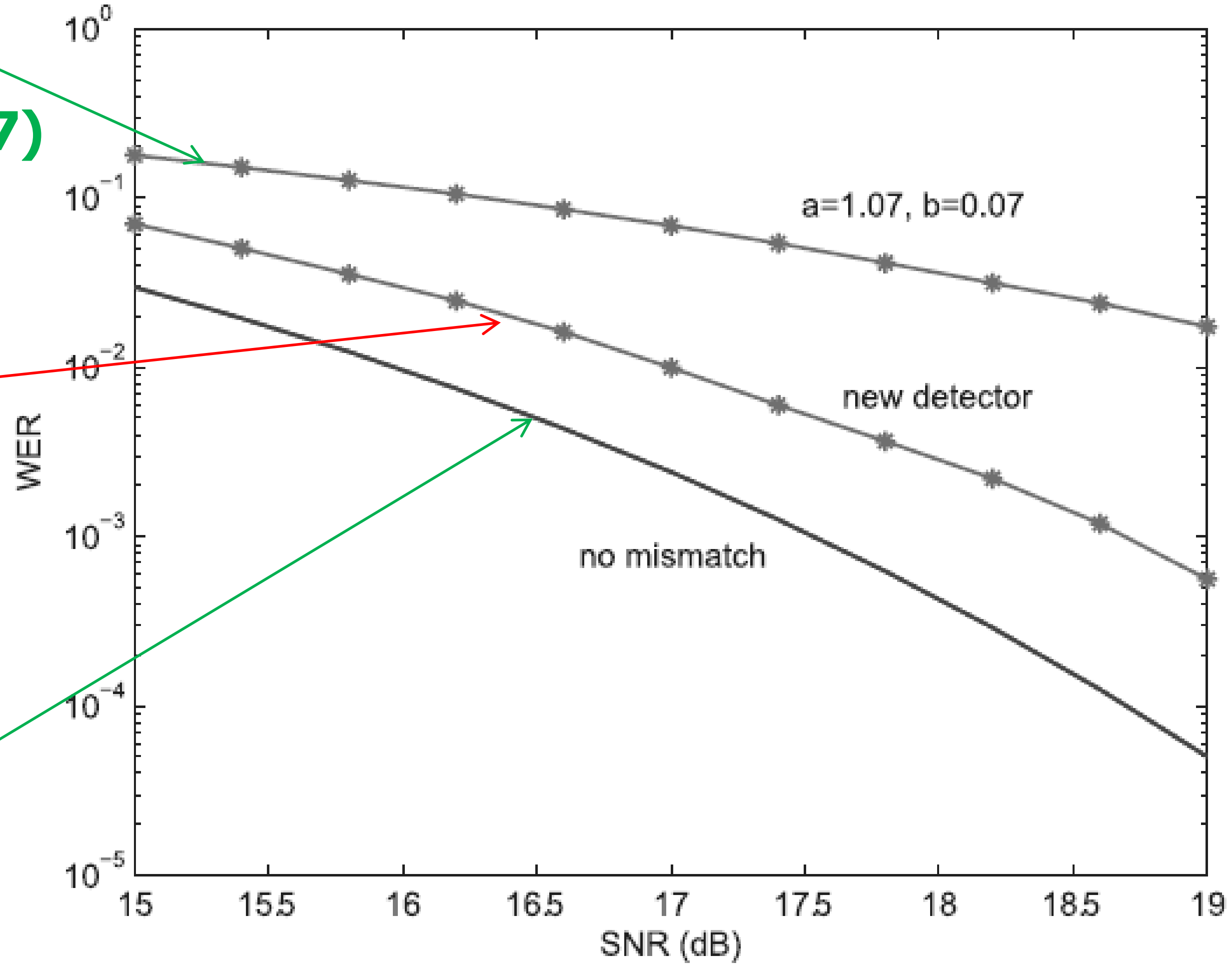
- N.B. noise varies per symbol; gain and offset vary per block
- Motivation: storage systems like flash memories
- Unknown gain and/or offset significantly degrade performance of Euclidean distance based detectors
- Solutions: reference symbols, balancing constraints (expensive!) Promising alternative: Pearson distance based detection!

Performance Example (q=4, n=8)

Euclidean
(a=1.07, b=0.07)

Pearson
(any a and b)

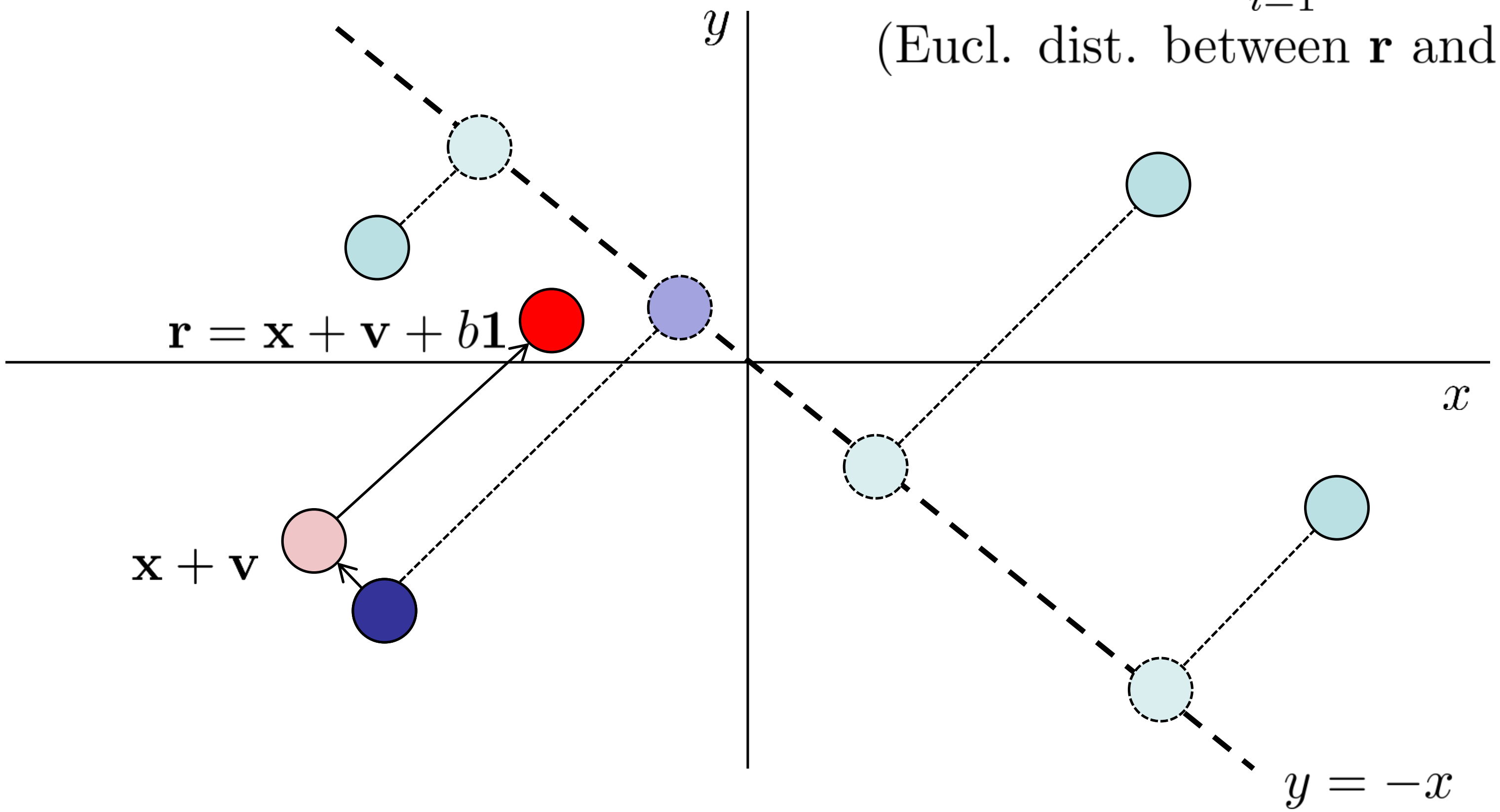
Euclidean
(a=1, b=0, i.e., no mismatch)



Clarification (n=2, a=1)

Pearson-based measure between $\mathbf{r}$ and candidate codeword $\hat{\mathbf{x}}$: $\sum_{i=1}^{n}(r_i - \hat{x}_i + \overline{\hat{\mathbf{x}}})^2$

(Eucl. dist. between $\mathbf{r}$ and $\hat{\mathbf{x}} - \overline{\hat{\mathbf{x}}}\mathbf{1}$)



Channel Coding in the Benelux

Conclusion:

- Great history!
- Still nice areas to be explored!

Greetings from the Dutch coding maffia!

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