In the name of God

# A New Error Correction Code

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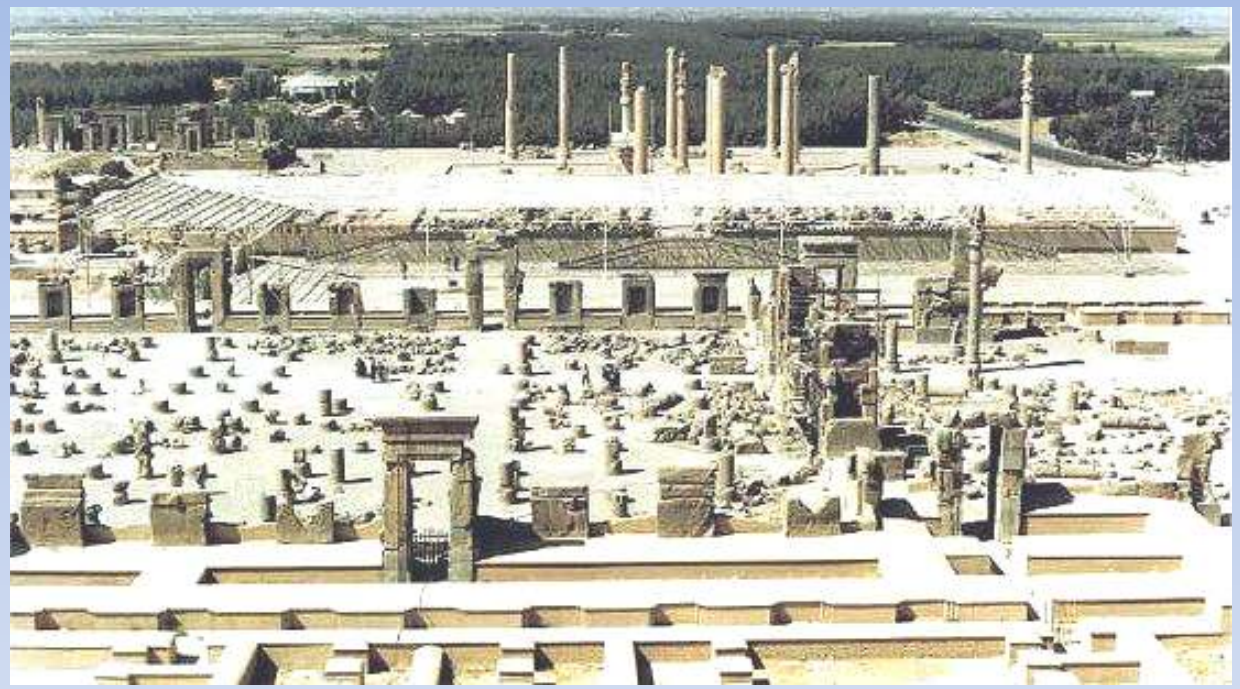
# Introduction

- Communication
- Data corruption
- Reasons
- Error Detection
  - EDCs
- Error Correction
  - ECCs
- Persec
  - PERsian SECurity

# History

- Achaemenian Dynasty

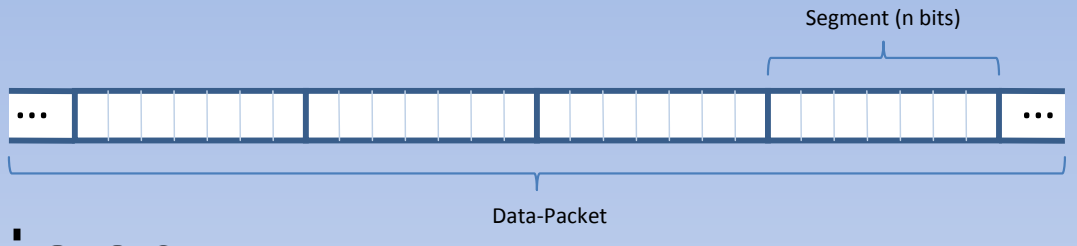


Stone print of an achaemenian soldier

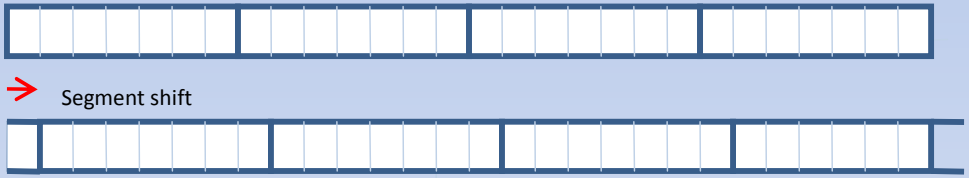
- Immortal army("Sepah Javidan")

# Persec Algorithm (at a glance)

- Base-Number selection denoted by ***n***
- Segmentation




- Different Iterations




- Guard bits
- Construction of Error-Resolution-Table

# Terminology…

- Data-Packet

  Stream of data bits with specified length
- Segment

  Pre-determined number of consequent bits splitting the Data-Packet
- Base (n>2)

  Number of bits in a segment

# …Terminology

- Guard-Bits

  n-1 ones(zeros) appended at the beginning and the end of a Data-Packet

- Iteration

  Segmentation + frequency counting + parity computing

- Hot-Bit

  A bit capable of corruption in each iteration

- Retransmission-Bit

  Diagnosed Hot-Bit in all of the iterations

# Persec Coding Algorithm(in detail)...

Example:

Date-Packet:
11101100001010110000110110011111101011100011010110011001110001010
Base = $n$ = 3

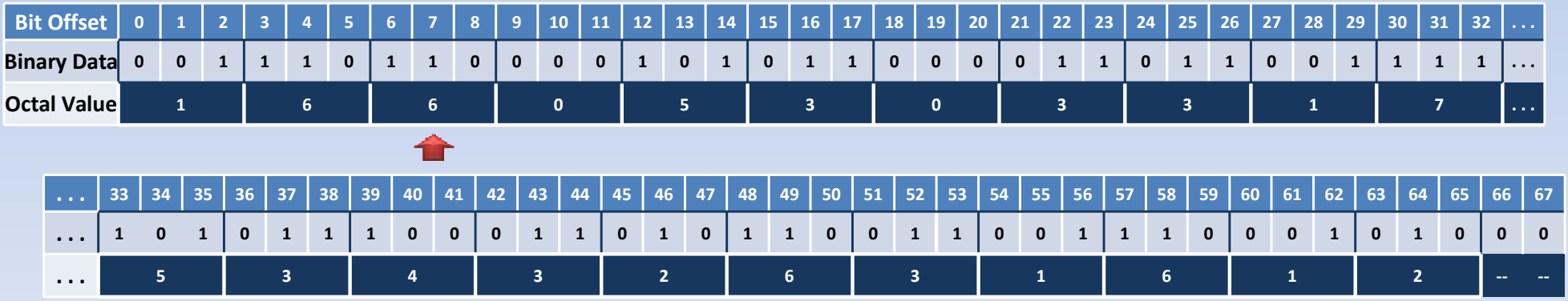
1. Base-Number selection denoted by ***n***
   - Running time of Coding/Decoding
   - Size of header
   - Accuracy of correction

# …Persec Coding Algorithm…

## 2. Guard-Bits

**00** 11101100001010110000110110011111101011100011010110011001110001010 **00**

## 3. Segmentation



# …Persec Coding Algorithm…

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | . . . |
| Octal Value | -- | 3 | | | 5 | | | 4 | | | 1 | | | 2 | | | 6 | | | 0 | | | 6 | | | 6 | | | 3 | | | 7 | | | . . . |

| . . . | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| . . . | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| . . . | 2 | | | 7 | | | 0 | | | 6 | | | 5 | | | 4 | | | 6 | | | 3 | | | 4 | | | 2 | | | 4 | | | -- |

## 4. Frequency & Parity Table

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 2 | 0 | 2 | 0 | 3 | 1 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 1 | 1 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 1 | 1 | 4 | 0 | 3 | 1 |
| 5 | 2 | 0 | 2 | 0 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

# …Persec Coding Algorithm…

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | . . . |
| Octal Value | -- | 3 | | | 5 | | | 4 | | | 1 | | | 2 | | | 6 | | | 0 | | | 6 | | | 6 | | | 3 | | | 7 | | | . . . |

| . . . | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| . . . | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| . . . | 2 | | | 7 | | | 0 | | | 6 | | | 5 | | | 4 | | | 6 | | | 3 | | | 4 | | | 2 | | | 4 | | | -- |

## 4. Frequency & Parity Table

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 2 | 0 | 2 | 0 | 3 | 1 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 1 | 1 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 1 | 1 | 4 | 0 | 3 | 1 |
| 5 | 2 | 0 | 2 | 0 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

# …Persec Coding Algorithm…

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | … |
| Octal Value | -- | 3 | | | 5 | | | 4 | | | 1 | | | 2 | | | 6 | | | 0 | | | 6 | | | 6 | | | 3 | | | 7 | | | … |

| … | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| … | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| … | 2 | | | 7 | | | 0 | | | 6 | | | 5 | | | 4 | | | 6 | | | 3 | | | 4 | | | 2 | | | 4 | | | -- |

4. Frequency & Parity Table
5. Repeat next Iteration from step 3 (Segmentation)

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 2 | 0 | 2 | 0 | 3 | 1 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 1 | 1 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 1 | 1 | 4 | 0 | 3 | 1 |
| 5 | 2 | 0 | 2 | 0 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

# …Persec Coding Algorithm…

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | . . . |
| Octal Value | 1 | | | 6 | | | 6 | | | 0 | | | 5 | | | 3 | | | 0 | | | 3 | | | 3 | | | 1 | | | 7 | | | . . . |

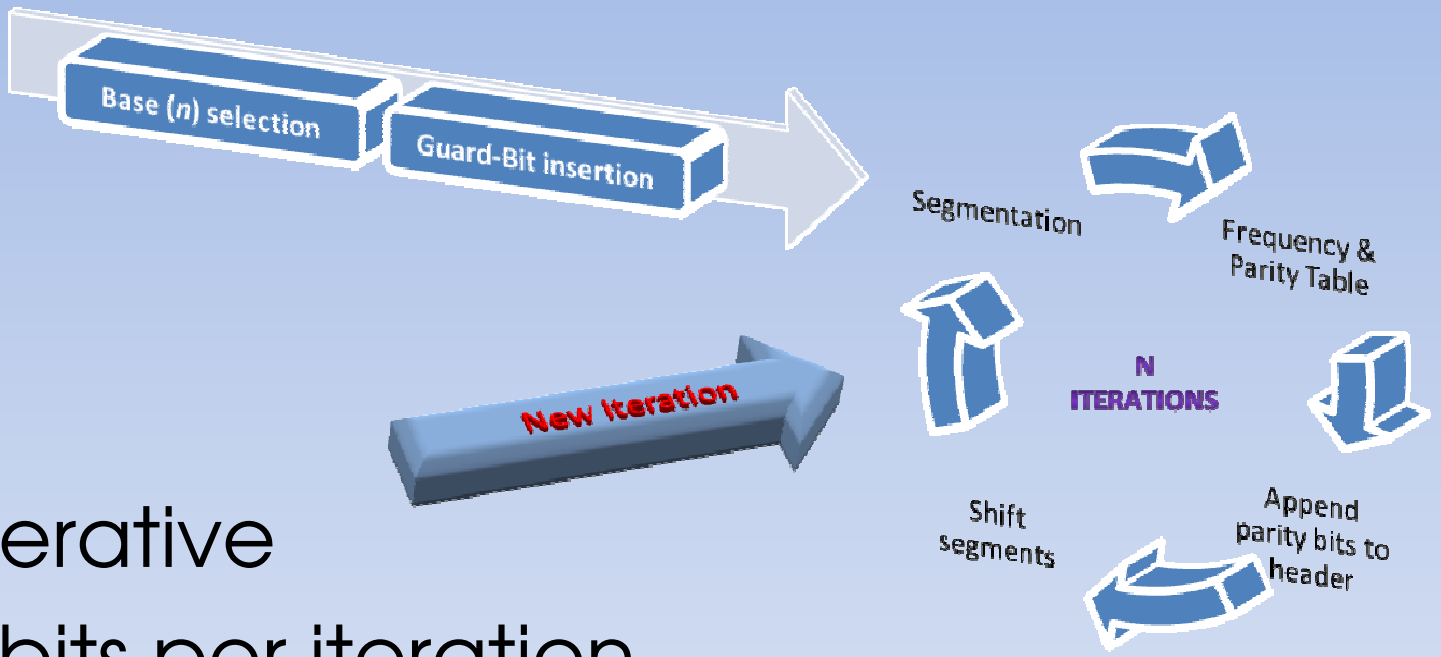
| . . . | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| . . . | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| . . . | 5 | | | 3 | | | 4 | | | 3 | | | 2 | | | 6 | | | 3 | | | 1 | | | 6 | | | 1 | | | 2 | | | -- | -- |

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | . . . |
| Octal Value | -- | | 3 | | | 5 | | | 4 | | | 1 | | | 2 | | | 6 | | | 0 | | | 6 | | | 6 | | | 3 | | | 7 | | . . . |

| . . . | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| . . . | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| . . . | 2 | | | 7 | | | 0 | | | 6 | | | 5 | | | 4 | | | 6 | | | 3 | | | 4 | | | 2 | | | 4 | | | -- |

# …Persec Coding Algorithm…

6. Construction of header




- Iterative
- $2^n$ bits per iteration
- Header length = $n \times 2^n$

# Persec Error Detection…

- Removes header
- Adds Guard-Bits
- Perform *n* Iterations
- Compares parity-table results with header
- Suppose $7^{th}$ bit has corrupted in our example:

# …Persec Error Detection

Iteration I

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | 1 | | | 6 | | | 6 | | | 4 | | | 5 | | | . . . |

Iteration II

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | -- | 3 | | | 5 | | | 5 | | | 1 | | | . . . |

Iteration III

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | -- | -- | 7 | | | 3 | | | 2 | | | 2 | | | . . . |

Frequency & parity table *before sending* data

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 2 | 0 | 2 | 0 | 3 | 1 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 1 | 1 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 1 | 1 | 4 | 0 | 3 | 1 |
| 5 | 2 | 0 | 2 | 0 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

Frequency & parity table *after receiving* data

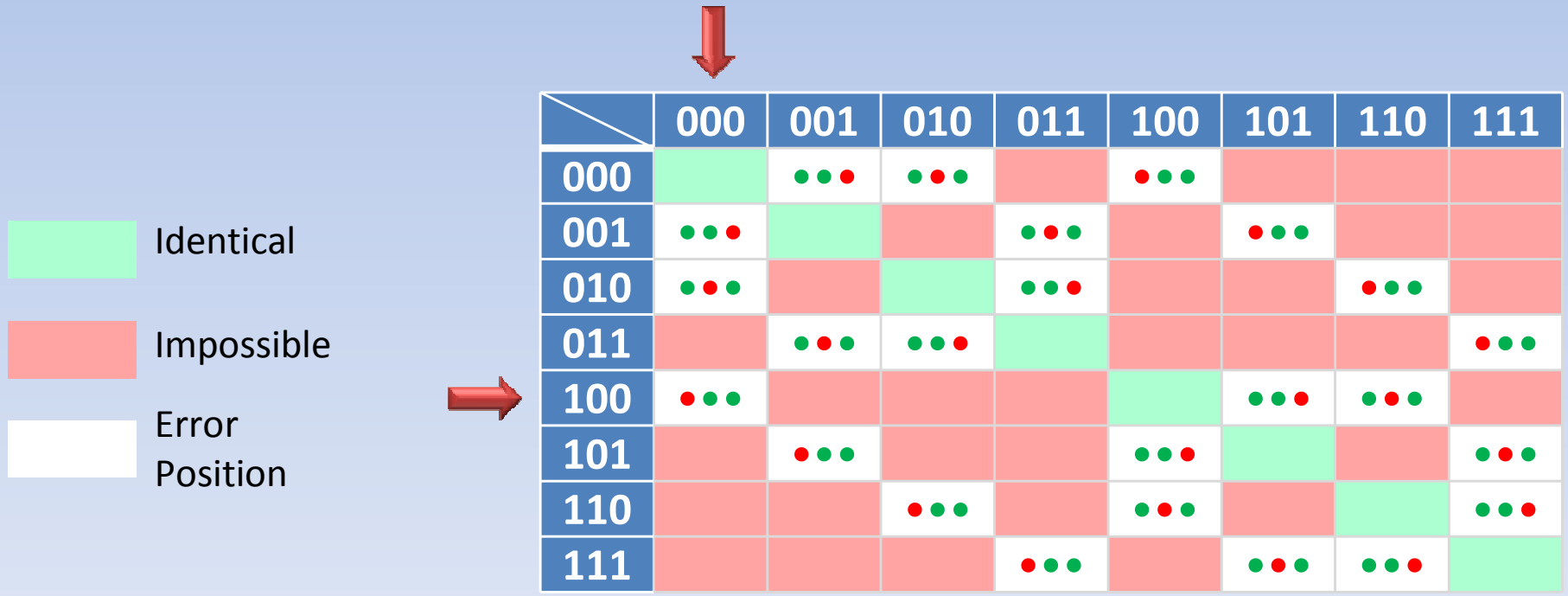
| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 1 | 1 | 2 | 0 | 2 | 0 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 2 | 0 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 2 | 0 | 3 | 1 | 3 | 1 |
| 5 | 2 | 0 | 3 | 1 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

# Persec Error Correction…

- Considering single error:

  7(111) may only change to 6(110), 5(101), 3(011)

  but it can't convert to e.g. 0(000)




| | 000 | 001 | 010 | 011 | 100 | 101 | 110 | 111 |
|---|---|---|---|---|---|---|---|---|
| 000 | | ●●● | ●●● | | ●●● | | | |
| 001 | ●●● | | | ●●● | | ●●● | | |
| 010 | ●●● | | | ●●● | | | ●●● | |
| 011 | | ●●● | ●●● | | | | | ●●● |
| 100 | ●●● | | | | | ●●● | ●●● | |
| 101 | | ●●● | | | ●●● | | | ●●● |
| 110 | | | ●●● | | ●●● | | | ●●● |
| 111 | | | | ●●● | | ●●● | ●●● | |

Remember that it is only for the case of single error

# …Persec Error Correction…

- Error-Resolution-Table
  - *n* rows, one for each iteration
  - Each Iteration is processed independently
  - Last row counts frequency of Hot-Bits in a column
  - Error is corrected or some retransmission-bits are identified

# …Persec Error Correction…

- Case of ***Correction***

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hot-Bits(1st Iteration) | | | | | | | | | | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | … |
| Hot-Bits(2nd Iteration) | | | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | | | … |
| Hot-Bits(3rdIteration) | | | | | | | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | | | | | … |
| Error/Retransmission-bits | | | | | | | | | | Err | | | | | | | | | | | | | | | | | | | | | | | … |

| … | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| … | | | | | | | | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | | | | | | |
| … | | | | | | | | | | | | | | | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | ● | ● | ● | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | ● | ● | ● | | | | ● | ● | ● |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# …Persec Error Detection

Iteration I

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | 1 | | | 6 | | | 6 | | | 4 | | | 5 | | | . . . |

Iteration II

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | -- | 3 | | | 5 | | | 5 | | | 1 | | | . . . |

Iteration III

| Binary Data | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | . . . |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octal Value | -- | -- | 7 | | | 3 | | | 2 | | | 2 | | | . . . |

Frequency & parity table *before sending* data

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 2 | 0 | 2 | 0 | 3 | 1 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 1 | 1 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 1 | 1 | 4 | 0 | 3 | 1 |
| 5 | 2 | 0 | 2 | 0 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

Frequency & parity table *after receiving* data

| Octal Number | Iteration I | | Iteration II | | Iteration III | |
|---|---|---|---|---|---|---|
| | Sum | Parity | Sum | Parity | Sum | Parity |
| 0 | 1 | 1 | 2 | 0 | 2 | 0 |
| 1 | 4 | 0 | 1 | 1 | 3 | 1 |
| 2 | 2 | 0 | 3 | 1 | 2 | 0 |
| 3 | 6 | 0 | 3 | 1 | 2 | 0 |
| 4 | 2 | 0 | 3 | 1 | 3 | 1 |
| 5 | 2 | 0 | 3 | 1 | 5 | 1 |
| 6 | 4 | 0 | 5 | 1 | 2 | 0 |
| 7 | 1 | 1 | 2 | 0 | 3 | 1 |

# …Persec Error Correction…

- Case of ***Correction***

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hot-Bits(1st Iteration) | | | | | | | | | | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | … |
| Hot-Bits(2nd Iteration) | | | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | | | … |
| Hot-Bits(3rdIteration) | | | | | | | | | ● | ● | ● | ● | ● | ● | | | | | | | | | | | | | | | | | | | … |
| Error/Retransmission-bits | | | | | | | | | | Err | | | | | | | | | | | | | | | | | | | | | | | … |

| … | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| … | | | | | | | | ● | ● | ● | | | | | | | | | | | | | | | | | | | | | | | | | | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | 000 | 001 | 010 | 011 | 100 | 101 | 110 | 111 |
|---|---|---|---|---|---|---|---|---|
| 000 | | ● ● ● | ● ● ● | | ● ● ● | | | |
| 001 | ● ● ● | | | ● ● ● | | ● ● ● | | |
| 010 | ● ● ● | | | ● ● ● | | | ● ● ● | |
| 011 | | ● ● ● | ● ● ● | | | | | ● ● ● |
| 100 | ● ● ● | | | | | ● ● ● | ● ● ● | |
| 101 | | ● ● ● | | | ● ● ● | | | ● ● ● |
| 110 | | | ● ● ● | | ● ● ● | | | ● ● ● |
| 111 | | | | ● ● ● | | ● ● ● | ● ● ● | |

# …Persec Error Correction

- Case of ***Retransmission***

| Bit Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hot-Bits(1st Iteration) | ● | ● | ● | | | | | | | | | | | | | ● | ● | ● | | | | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | … |
| Hot-Bits(2nd Iteration) | | | | | | | | | | | | | | ● | ● | ● | ● | ● | ● | | | | ● | ● | ● | ● | ● | ● | | | | | … |
| Hot-Bits(3rdIteration) | | | | | | | | | | | | | | | ● | ● | ● | ● | ● | ● | | | | ● | ● | ● | ● | ● | ● | | | | … |
| Error/Retransmission-bits | | | | | | | | | | | | | | | | | RB | | | | | | | | | RB | | | | | | | … |

| … | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| … | | | | | ● | ● | ● | | | | ● | ● | ● | | | | | | | ● | ● | ● | ● | ● | ● | | | | ● | ● | ● | ● | ● | ● | | |
| … | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | |
| … | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | | | | ● | ● | ● | | | | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Actual error has occurred in the 23rd bit of Data-Packet

(25th bit after appending guard bits)

# Analysis of Persec…

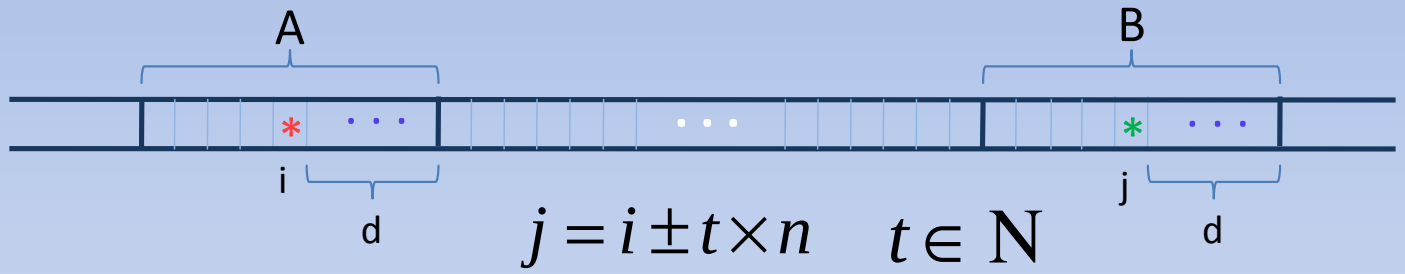
- Persec (L, k)

$$L = k + n \times 2^n$$

  - *L: Size of coded data*
  - *k: Size of Data-Packet*
  - $n \times 2^n$ *: cte. Only dependent on Base (n)*

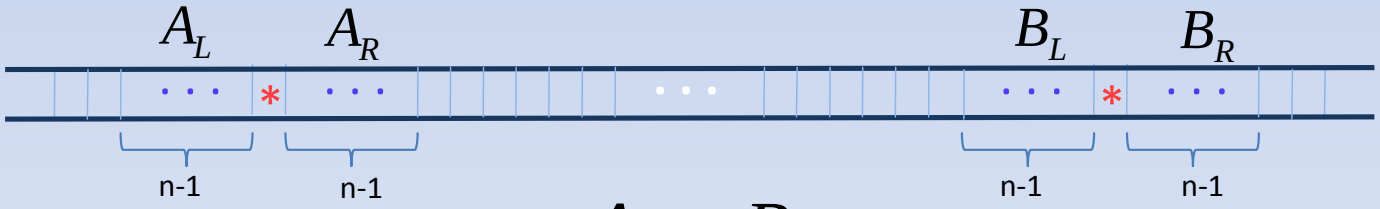
# Analysis of Persec…

- Zero or more than one Hot-Bits
- Restrictions on Hot-Bits



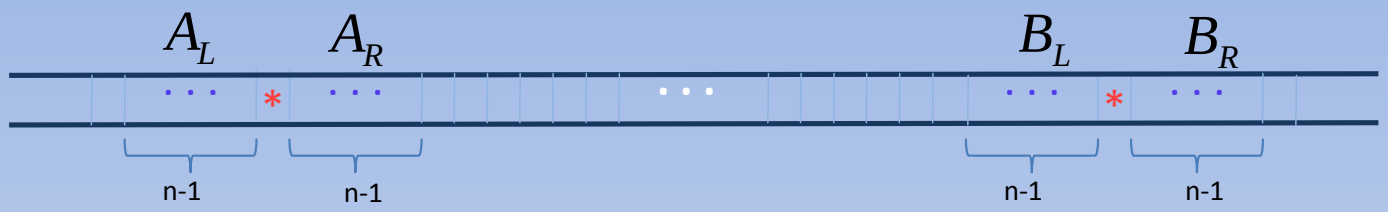

$$j = i \pm t \times n \quad t \in \mathbb{N}$$

- Restrictions on Retransmission-Bits




$$A_L = B_L$$
$$A_R = B_R$$

# Probability of Single Error Correction




$$\Pr(A_L = B_L) = \Pr(A_R = B_R) = \frac{1}{2^{n-1}}$$

$$\Pr(\text{i}^{\text{th}} \text{ bit is not a RB}) = 1 - \frac{1}{(2^{n-1})^2}$$

$$\Pr(\text{No RB}) = \Pr(\text{Error Correction}) = \left(1 - \frac{1}{(2^{n-1})^2}\right)^{\frac{L}{n}-2}$$

# Simulation Results…

| Data-Packet Length (bit) | Redundancy % | C+ (Formula) % | C+ (Simulation) % | Retransmission (Per bit) % | Process Time (ms) |
|---|---|---|---|---|---|
| 1K | 204.8 | 99.25 | 99.31 | 0.20 | 2.7 |
| 2K | 102.4 | 98.50 | 98.39 | 0.10 | 4.2 |
| 4K | 51.2 | 97.01 | 96.93 | 0.05 | 7.2 |
| 8K | 25.6 | 94.09 | 93.65 | 0.03 | 11.5 |
| 16K | 12.8 | 88.52 | 88.37 | 0.01 | 16.9 |
| 32K | 6.4 | 78.35 | 78.31 | 0.01 | 24.1 |
| 64K | 3.2 | 61.37 | 60.89 | 0.00 | 35.0 |

- Results for Base 8

- Data-Stream of 3200K bits.
- Sending in 32K bit Data-Packets.

$$\frac{3200Kbits}{32Kbits}\times(100\%-78.35\%)\times(0.01\%\times 32Kbits)$$

$$=100\times\frac{21.65}{100}\times\frac{0.01}{100}\times 32000bits$$

- Expected number of retransmitted bits per each Data-Packet :

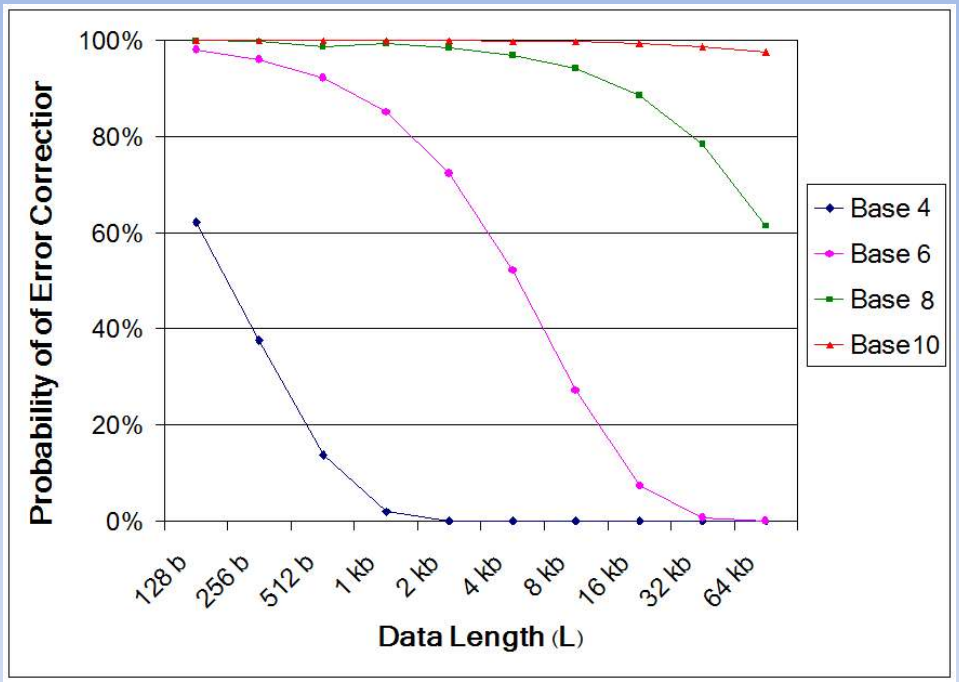
**Retransmission rate * Data-Packet length**

$$=69.28bits$$

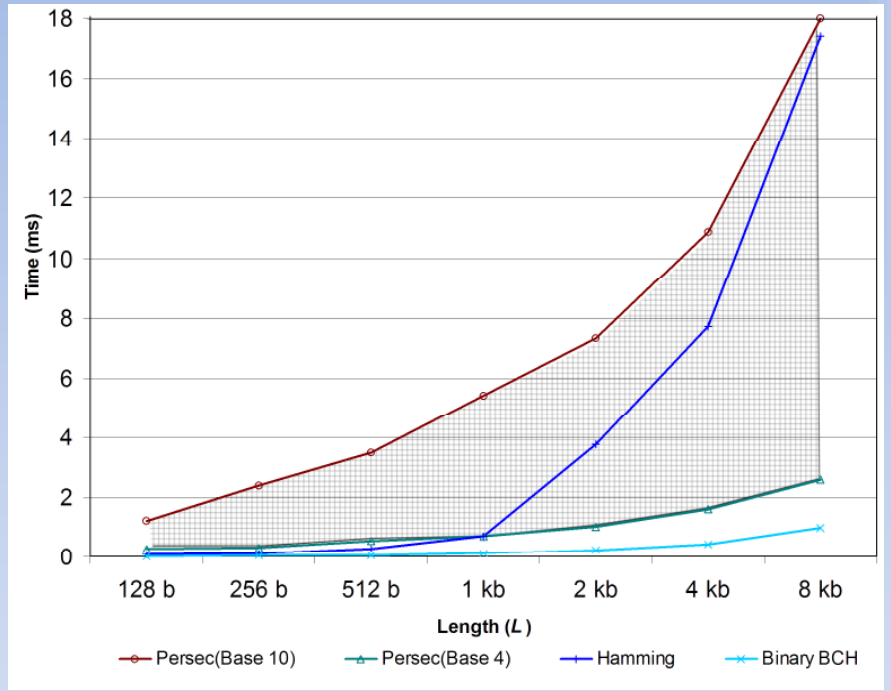
- Expended number of retransmitted bits over all data stream:

$$\approx 69bits$$

# …Simulation Results




❑ Probability of Persec Error Correction




❑ Process Time Comparison

# Conclusion

- Profs:
  - Simple basic (parity numbers)
  - Independent of Data-Packet length
  - Versatile to different conditions and required precision
  - Few number of retransmitted bits
  - Simple hardware implementation
  - Real time detection and fast correction
- Disadvantages:
  - Not sensible for  small data-streams
  - No guarantee for full correction
  - Header needs a protection mechanism individually

# Future Works

- Multi Error Correction
- Mathematical computation of hamming distance
- Best base-value selection algorithm
- 100% correction for burst errors
- Exact formula for Correction probability