Contents

Abstract iii

Resumen v

Resum vii

Contents ix

List of Figures xiii

List of Tables xix

Acronyms xxi

Preface 1

1 State of the art of non-binary low-density parity-check codes 9

1.1 LDPC codes and decoding process. 9

1.2 Nomenclature 11

1.3 Decoding schedules 12

1.4 Decoding architectures 15

1.5 NB-LDPC decoding algorithms and architectures. 18

1.5.1 Trellis Extended Min-Sum Algorithm 23

1.6 Frame Error Rate (FER) Performance 26

1.7 Conclusions of the state of the art 30

2 Simplified Trellis Min-Max Decoder Architecture for NB-LDPC Codes 31

2.1 Introduction 32
2.2 Trellis Extended Min-Sum Algorithm 34
2.3 Simplified Trellis Min-Max Algorithm 36
2.3.1 Algorithm Description 36
2.3.2 Frame Error Rate Performance 39
2.4 Check Node Architecture 39
2.5 Architecture for the Complete Decoder 44
2.5.1 Decoder Schedule 44
2.5.2 Decoder Architecture 45
2.5.3 Decoder Timing 47
2.5.4 Decoder Complexity and Implementation Results 48
2.6 Comparisons With Other NB-LDPC Decoders 49
2.7 Conclusions 51

3 One Minimum Only Trellis Decoder for NB-LDPC Codes 53

3.1 Introduction 54
3.2 Trellis - Extended Min-Sum algorithm 56
3.3 One Minimum Only Trellis Decoder 58
3.3.1 Estimators for the second minimum value 58
3.3.2 Statistical analysis of the different estimators 60
3.3.3 Frame Error Rate Performance 62
3.4 OMO T-EMS and OMO T-MM Hardware Architectures 63
3.4.1 Check Node Architecture 64
3.4.2 Complete decoder architecture 68
3.5 Conclusions 70

4 Reduction of complexity for NB-LDPC decoders with compressed messages 71

4.1 Introduction 72
4.2 Non-binary LDPC message passing 73

4.3 Compressed Non-Binary Message-Passing (CNBMP) 76
4.4 Hardware impact of CNBMP 77
4.5 Conclusions 80

5 A 630 Mbps Non-Binary LDPC Decoder for FPGA 81

5.1 Introduction 82
5.2 Basis on NB-LDPC codes and T-MM decoding algorithm 83
5.3 Proposed Decoder Architecture 85
5.3.1 Check-node architecture 85
5.3.2 Top-level decoder architecture 87
5.4 Conclusions 91

6 High-performance NB-LDPC decoder with reduction of message exchange 93

6.1 Introduction 94
6.2 Trellis Min-Max decoding algorithm 96
6.3 Modified Trellis Min-Max Algorithm 98
6.3.1 Reformulation of Trellis Min-Max Algorithm 99
6.3.2 Reduction of replicated information in check-to-variable exchanged messages 99
6.3.3 Modified Trellis Min-Max algorithm 102
6.4 NB-LDPC Decoder Implementation 107
6.4.1 CN architecture for mT-MM algorithm 109
6.4.2 Top-level decoder architecture 110
6.4.3 Decoder implementation results and comparisons 115
6.5 Conclusions 117

7 Reduced-complexity NB-LDPC decoder for high-order GF based on T-MM algorithm 119

7.1 Introduction 120
7.2 T-MM decoding algorithm with compressed messages 123
7.3 T-MM algorithm with reduced set of messages 125
7.3.1 Reduction of the CN-to-VN messages 126
7.3.2 Performance Analysis 127
7.3.3 Generation of the set $I^*(a')$ 129

7.4 Check Node architecture 132
7.5 Top-level decoder architecture and complexity comparison. 138
7.5.1 Decoder implementation results and comparisons 139
7.6 Conclusions 141

8 Discussion and conclusions 143

8.1 Summary of the main contributions 143
8.2 Analysis of results. 146
8.3 Comparison with other works from literature 153
8.4 Conclusions 156
8.4.1 Objective 1: reduction of area and latency of Check Node (CN) processors 156
8.4.2 Objective 2: reduction of the number of messages exchanged between processors in NB-LDPC decoders 157
8.4.3 Objective 3: implementation of high-performance decoders for Galois fields larger than 32. 158
8.4.4 Final Comments 159
8.5 Future Research Lines 160