

Table of contents

Resumen	i
Resum.....	iii
Abstract.....	v
List of acronyms.....	vii
Chapter 1. Introduction	1
1.1. Rationale.....	1
1.2. Framework of this Thesis	3
1.3. Research objectives	4
1.4. Outline of this work	5
1.5. Contributions of this Thesis	7
1.6. References	9
Chapter 2. Evolution from OCS to OPS networks.....	11
2.1. Introduction	11
2.2. Optical network evolution	12
2.3. Optical packet switched networks	18
2.4. All-optical label switching (AOLS): the LASAGNE project.....	20
2.5. Migration scenarios: State of the art.....	26
2.6. Proposed migration scenarios in LASAGNE project	28
2.6.1. Introduction of OPS nodes in an OCS network	28
2.6.1.1 Node per node migration	29

2.6.1.2. Migration based on the definition of OPS node islands:.....	30
2.6.2. Client-Server hybrid optical network.....	32
2.6.3. ORION	33
2.7. LASAGNE node modification: Performance monitoring and recovery issues	36
2.7.1. Routing protocol based on quality requirements	41
2.8. Summary and conclusions	43
2.9. References	46

Chapter 3. Optical performance monitoring in optical networks. State of the art.....51

3.1. Introduction	51
3.2. Optical performance monitoring	52
3.3. Current OPM technologies for transparent circuit switched networks	56
3.3.1. Optical Spectrum Analyzer (OSA).....	57
3.3.2. Polarization nulling	57
3.4. Advanced OPM concepts for dynamically reconfigurable networks	58
3.4.1. RF spectrum analysis	59
3.4.1.1. Pilot tones	59
3.4.1.2. Clock tones	62
3.4.2. Sampling methods.....	63
3.4.3. Monitoring based on interferometric configurations	65
3.4.3.1. Chromatic dispersion monitoring using an optical delay-and-add filter	65
3.4.3.2. OSNR monitoring method based on optical delay interferometer. 66	66
3.4.3.3. Simultaneous monitoring of chromatic and polarization-mode dispersion in OOK and DPSK transmission	67
3.4.4. Polarization-based methods	67
3.4.4.1. Monitoring based on degree-of-polarization (DOP) measurements	67
3.4.4.2. Monitoring using polarization scrambling	69
3.4.4.3. OSNR monitoring technique based on the orthogonal delayed-homodyne method	70
3.4.5. Nonlinear effects.....	71
3.4.5.1. OPM using nonlinear detection	71
3.4.5.2. Monitoring techniques based on Four-Wave Mixing	72
3.4.5.3. Monitoring techniques based on SPM and/or XPM.....	73
3.4.6. Comparison of existing monitoring techniques.....	75
3.5. OPM in optical packet-switched networks	77
3.5.1. All-optical Time-to-Live using error-checking labels in optical label switching networks.....	78
3.5.2. An OSNR monitor for optical packet switched networks	79
3.5.3. Single technique for simultaneous monitoring of OSNR and chromatic dispersion at 40 Gbit/s	80

3.5.4. Basis of monitoring techniques proposed in this Thesis	81
3.5.4.1. Monitoring-field/payload separation circuit.....	82
3.5.4.2. Monitoring field definition.....	84
3.6. Summary and conclusions	85
3.7. References	87

Chapter 4. OSNR monitoring using optical correlators..... 95

4.1. Introduction	95
4.2. OSNR monitoring for OPS networks	96
4.2.1. Description of the OSNR monitor	98
4.3. FBG-based optical correlator.....	102
4.3.1. FBG-based correlator design	103
4.3.2. Fabrication process	112
4.3.3. Characterization of the fabricated correlator	118
4.4. Experimental validation of the OSNR monitoring technique	119
4.5. Applications of the proposed OSNR monitoring technique	124
4.5.1. Monitoring for QoS implementation	124
4.5.2. Monitoring for OSNR-assisted routing.....	126
4.5.3. Path monitoring for restoration functions.....	128
4.6. Summary and conclusions	129
4.7. References	131

Chapter 5. PMD monitoring using XOR gate 135

5.1. Introduction	135
5.2. Principle of operation	136
5.2.1. XOR-based DGD Monitoring	137
5.2.2. Optical packet switch	139
5.3. Simulation results	141
5.4. Experimental validation	146
5.5. Summary and conclusions	150
5.6. References	154

Chapter 6. All-optical TTL decrementing using XOR gates 157

6.1. Introduction	157
6.2. TTL-based monitoring system	158
6.2.1. Basis of the TTL-based monitoring.....	158
6.2.2. Description of the system	160
6.2.3. 1-bit binary subtraction	161
6.2.4. Architecture of the 1-bit binary subtractor	161

6.3. Results and discussion	166
6.4. Conclusions	171
6.5. References	173
Chapter 7. PMD monitoring using RF tones	175
7.1. Introduction	175
7.2. Study of the applicability of the monitoring techniques based on RF spectrum measurement in optical packet-switched networks	177
7.2.1. Synchronization issues	177
7.2.2. Response time	177
7.2.3. Sensitivity analysis	178
7.3. DGD monitoring using an additional shifted optical carrier	180
7.3.1. Description of the DGD monitoring technique	181
7.3.2. Simulation results	184
7.3.3. Modelling of the cascade of two DGD elements	187
7.4. DGD monitoring using an additional orthogonal shifted optical carrier	193
7.4.1. Description of the DGD monitoring technique	193
7.4.2. Simulation results	194
7.4.3. Experimental results	196
7.5. Summary and conclusions	201
7.6 References	203
Chapter 8. Conclusions and future work	207
8.1. Introduction	207
8.2. Summary of the work	207
8.3. Future work	211
8.4. References	214
Appendix A. Matrix transfer approach	217
A.1. Introduction	217
A.2. Transfer matrix of uniform FBG	217
A.3. Transfer matrix of phase-shifted gratings	221
Appendix B. VPI simulation parameters and schematics	223
B.1. Introduction	223
B.2. Simulation schemes	223

B.2.1. PMD monitoring using XOR gate	223
B.2.2. All-optical TTL decrementing using XOR gates	228
Appendix C. List of Ph.D. publications	231