

Contents

Abstract	iii
Contents	xv
1 Introduction	1
1.1 Introduction and Architecture	1
1.2 SDN Controllers	5
1.2.1 Opensource Controllers	6
1.2.2 Proprietary Controllers	10
1.2.3 Application-oriented Controllers	11
1.3 Applicability and challenges of SDN	13
1.4 Objectives and motivation	15
1.5 Precedents	16
1.6 Thesis Structure	18
2 State of the Art	19
2.1 Introduction	19
2.2 SDN Controller Studies	21
2.3 Improving QoS or QoE	22
2.4 SDN Applications	29
2.5 Routing in SDN	31
2.6 AI Routing	32
2.7 Conclusion	35
3 Design and Implementation of a Custom SDN Controller	37

3.1	SDN Background	37
3.1.1	Routing fundamentals	38
3.1.2	OpenFlow Communication and Messages	39
3.1.3	Virtualization in SDN	54
3.2	Architecture	56
3.3	Use Cases	58
3.4	Component and Class Diagrams	64
3.5	Sequence Diagrams and Implementations Fragments	71
3.6	Topology Discovery Process	85
3.7	User Interfaces	86
3.8	Performance Evaluation	93
3.8.1	Linear Topology	93
3.8.2	Tree Topology	98
3.8.3	Torus Topology	103
3.9	Conclusion	108
4	Routing Proposal	111
4.1	Introduction	111
4.2	Dynamic OSPF Adaptation	112
4.2.1	Routing Proposal	112
4.2.2	Metric Analysis	116
4.2.3	Messages	119
4.2.4	Algorithm and Process	120
4.2.5	Methodology and Results	124
4.2.6	Comparison with other OSPF variations	132
4.2.7	Conclusion	134
4.3	Intelligent SDN Routing Protocol	136
4.3.1	Aim and scope	137
4.3.2	Data Structures	138
4.3.3	States and algorithm	140
4.3.4	Messages	146
4.4	Conclusion	152
5	Artificial Intelligent Module	155
5.1	Introduction and architecture	155
5.2	Video Transmission Study	156
5.2.1	Development and Analysis of QoS Results in Video Transmission	157
5.2.2	Development and Analysis of QoE Results in Video Transmission	161
5.2.3	Data Preprocessing	165
5.3	QoS Degradation Estimator	167
5.3.1	Database Pre-processing	168

5.3.2	QoE Estimation Model	169
5.3.3	Classification Model of the Type of Traffic	178
5.3.4	Network Architecture of the Type of Traffic Classification Model	182
5.3.5	Classification and Modelling of Network and Video for QoE Regulation	189
5.4	Robust Multimedia Traffic Management System	196
5.4.1	Network Architecture	196
5.4.2	Simple Management Algorithm	197
5.4.3	Robust Management System Implementation	200
5.4.4	Test Bench	202
5.4.5	Conclusion	207
5.5	A Proposed Machine Learning System to Solve Multimedia Transmission Problems	208
5.5.1	Architecture	209
5.5.2	Network Considerations	210
5.5.3	Reinforcement Learning Algorithm	211
5.5.4	Results	225
5.5.5	Conclusion and Future Work	237
5.5.6	Reward Update System	239
5.6	Routing Alternative Evaluation	240
5.6.1	Scenario 1	243
5.6.2	Scenario 2	246
5.6.3	QoE Results	249
5.7	Conclusion	251
6	Applications	253
6.1	Introduction	253
6.2	SDN Applied to Smart Irrigation	253
6.2.1	Urban Scenarios	254
6.2.2	Employed Sensors	255
6.2.3	Architecture	256
6.2.4	Messages	260
6.2.5	Algorithm	265
6.2.6	Requirements for the implantation of the proposal	266
6.2.7	Conclusions	268
6.3	SDN for Video Surveillance	269
6.3.1	Architecture	270
6.3.2	Algorithm	272
6.3.3	Messages	273
6.3.4	Methodology and Results	276
6.4	SDN for Emergency Management in Smart Cities	282

6.4.1	Architecture and Algorithm	282
6.4.2	Messages	284
6.4.3	Energy Consumption Model	288
6.4.4	Methodology and Results	292
6.4.5	Conclusion	298
6.5	Conclusion	300
7	Conclusions	305
7.1	Introduction	305
7.2	Conclusion	305
7.3	Problems Faced and Personal Contributions	308
7.4	Future Research	309
7.5	Publications derived from the PhD Thesis	310
	References	313