
Contents

Preface	ix
Introduction	xi
Chapter 1. State of the Art on Network Troubleshooting	1
1.1. Network troubleshooting	1
1.1.1. State of the art	2
1.1.2. Traditional troubleshooting architecture	9
1.2. Background on encryption protocols	10
1.2.1. QUIC	11
1.2.2. Other protocols	16
1.3. Drawbacks of troubleshooting with encrypted traffic	18
1.3.1. Network performance monitoring	18
1.3.2. Intrusion detection system	20
1.4. Conclusion	22
Chapter 2. Novel Global Troubleshooting Framework for Encrypted Traffic	25
2.1. Novel network troubleshooting architecture for encrypted traffic	25
2.2. Proof of concept of novel troubleshooting architecture in SDN	28
2.3. Data collection	32
2.3.1. Data classification	32
2.3.2. Monitoring tools	34

2.3.3. Parameter measurement	37
2.4. Troubleshooting dataset	40
2.4.1. Datasets for root cause analysis	40
2.4.2. Dataset for traffic classification	42
2.5. Conclusion	43

Chapter 3. Traffic Classification: Novel QUIC Traffic Classifier Based on Convolutional Neural Network 45

3.1. Introduction	45
3.2. Background	48
3.2.1. Convolutional network	48
3.2.2. Characteristics of QUIC-based applications	49
3.3. Traffic classification approaches	50
3.3.1. Port-based approaches	50
3.3.2. Payload-based approaches	51
3.3.3. Statistic-based approaches	51
3.3.4. DL-based approaches	52
3.4. Novel traffic classification method for QUIC traffic	53
3.4.1. Traffic collection	55
3.4.2. Flow-based features	55
3.4.3. Preprocessing	56
3.4.4. Novel traffic classification method	56
3.5. Experimental results	59
3.5.1. Dataset specification	59
3.5.2. Performance metrics	60
3.5.3. Performance analysis	61
3.6. Conclusion	65

Chapter 4. Anomaly Detection 67

4.1. Introduction	67
4.2. Anomaly detection approaches	68
4.2.1. Knowledge-based mechanisms	68
4.2.2. Rule inductions	69
4.2.3. Information theory	70
4.2.4. ML-based mechanisms	70
4.3. Anomaly detection approach using machine learning	71
4.3.1. ML-based anomaly detection method	72
4.3.2. Data collection and processing	74

4.4. Experimental results	75
4.4.1. Experimental setup	75
4.4.2. Performance analysis	76
4.5. Conclusion	79
Chapter 5. Temporary Remediation: SDN-based Application-aware Segment Routing for Large-scale Networks	81
5.1. Introduction	81
5.2. Application-aware routing mechanisms	84
5.2.1. Application-aware routing	84
5.2.2. Application-aware MPLS	86
5.2.3. Application-aware SR	86
5.3. Adaptive segment routing mechanism for encrypted traffic	87
5.3.1. Overview of the SDN-based adaptive segment routing framework	87
5.3.2. Network monitoring	89
5.3.3. Anomaly detection	90
5.3.4. Application-aware remediation	91
5.4. Experimental results	95
5.4.1. Experiment setup	95
5.4.2. Benchmark	97
5.4.3. Performance analysis	97
5.5. Conclusion	104
Chapter 6. Root Cause Analysis and Definitive Remediation	107
6.1. Root cause analysis: machine learning based root cause analysis for SDN network	107
6.1.1. Introduction	107
6.1.2. Root cause analysis mechanisms	109
6.1.3. ML-based RCA mechanism	111
6.1.4. Experimental results	114
6.1.5. Conclusion	119
6.2. Definitive remediation: adaptive QUIC BBR algorithm using reinforcement learning for dynamic networks	121
6.2.1. Introduction	121
6.2.2. Congestion control mechanisms	123
6.2.3. Adaptive BBR algorithm	126

6.2.4. Experimental results	128
6.2.5. Conclusion	133
Conclusions and Prospects	135
References	141
Index	159