

# **CONTENTS**

## **APPROVAL PAGE**

## **SELF DECLARATION AGAINST PLAGIARISM**

<b>ABSTRACT</b>	<b>i</b>
<b>ACKNOWLEDGMENTS</b>	<b>ii</b>
<b>PREFACE</b>	<b>iii</b>
<b>CONTENTS</b>	<b>iv</b>
<b>LIST OF FIGURES</b>	<b>viii</b>
<b>LIST OF TABLES</b>	<b>x</b>
<b>I INTRODUCTION</b>	<b>2</b>
1.1 Background . . . . .	2
1.2 Problem Identification . . . . .	4
1.3 Objective and Contributions . . . . .	5
1.4 Scope of Work . . . . .	5
1.5 Hypothesis . . . . .	6
1.6 Research Methodology . . . . .	6
1.7 Research Schedule . . . . .	9
1.8 Writing Systematic . . . . .	9
<b>II BASIC CONCEPTS</b>	<b>10</b>
2.1 High-Speed Railway Concept . . . . .	10
2.2 Passenger Characteristics of The Network Service . . . . .	10
2.2.1 On-Board Passenger . . . . .	10
2.3 The Communication Standard . . . . .	11
2.3.1 Train Communication Network (TCN) . . . . .	11
2.3.2 Communication System . . . . .	12
2.4 Fiber Optic as LTE Backbone Technology . . . . .	14
2.4.1 Characteristics of Fiber Optics in LTE Networks . . . . .	14

2.4.2	Fiber Optic Power Budget . . . . .	15
2.4.3	Fiber Optic Delay . . . . .	16
2.5	LTE Network Calculation . . . . .	17
2.5.1	LTE Coverage Planning . . . . .	17
2.5.1.1	MAPL Calculation . . . . .	17
2.5.1.2	Propagation Loss Measurement . . . . .	21
2.5.1.3	Overlapping Coverage . . . . .	22
2.5.1.4	Site Calculation . . . . .	22
2.5.2	LTE Capacity Planning . . . . .	23
2.5.2.1	Passenger Estimation . . . . .	23
2.5.3	Quality of Service . . . . .	23
2.5.3.1	Throughput . . . . .	23
2.5.3.2	Latency . . . . .	24
2.5.3.3	Jitter . . . . .	25
2.5.3.4	Packet Loss . . . . .	25
2.6	LTE Radio Frequency Parameter . . . . .	25
2.6.1	Reference Signal Received Power (RSRP) . . . . .	26
2.6.2	Reference Signal Received Quality (RSRQ) . . . . .	26
2.6.3	Network Throughput . . . . .	27
2.7	Network Optimization . . . . .	27
2.7.1	Physical Tuning . . . . .	27
2.7.2	Mobility Robustness Optimization . . . . .	28
2.8	Economic Feasibility Analysis . . . . .	29
2.9	Regulation . . . . .	29
<b>III SYSTEM MODEL AND THE PROPOSED DESIGN</b>		<b>30</b>
3.1	Proposed Method . . . . .	30
3.2	System Model . . . . .	32
3.3	FO-RF Backbone Integration . . . . .	32
3.3.1	Topology and Communication Flow Design . . . . .	32
3.4	Research Area Imaging . . . . .	33
3.5	Existing Sites . . . . .	35
3.6	Data Collections . . . . .	37
3.6.1	Drive Test Measurement . . . . .	38
3.6.2	Passenger Survey . . . . .	39
3.7	Theoretical Calculation . . . . .	40
3.7.1	Fiber Optic Power Budget and Delay . . . . .	40
3.7.2	FO-RF Total Delay . . . . .	41

3.7.3	LTE Coverage Planning . . . . .	43
3.7.3.1	MAPL Calculation . . . . .	44
3.7.3.2	Propagation Loss Measurement . . . . .	44
3.7.3.3	Overlapping Coverage Calculation . . . . .	45
3.7.3.4	Site Calculation . . . . .	45
3.7.4	LTE Capacity Planning . . . . .	45
3.7.4.1	Passengers Estimation . . . . .	45
3.8	Quality of Service . . . . .	46
3.9	System Simulation . . . . .	46
3.10	Data Analysis . . . . .	47
3.11	Network Optimization Method . . . . .	48
3.11.1	Physical Tuning . . . . .	48
3.11.2	Mobility Robustness Optimization . . . . .	48
3.12	Economic Feasibility Analysis . . . . .	49
<b>IV PERFORMANCE EVALUATIONS</b>		<b>50</b>
4.1	Calculation . . . . .	50
4.1.1	Fiber Optic Power Budget and Delay Calculation . . . . .	50
4.1.2	FO-RF Delay Calculation . . . . .	52
4.1.3	LTE Capacity Planning Calculation . . . . .	54
4.1.4	LTE Coverage Planning Calculation . . . . .	62
4.1.5	Quality of Service Calculation . . . . .	62
4.2	Drive-test Measurement Results . . . . .	63
4.2.1	RF Measurements . . . . .	64
4.2.2	QoS and QoE Measurements . . . . .	70
4.2.3	4G Real-Time Handover Drive Test . . . . .	72
4.3	Train Passenger Internet Usage Survey . . . . .	74
4.4	Justification for Network Optimization . . . . .	75
4.5	Optimization and Analysis . . . . .	76
4.5.1	Optimization Process Flow . . . . .	76
4.5.2	Optimization Method 1: Physical Tuning . . . . .	77
4.5.3	Optimization Method 2: Mobility Robustness . . . . .	89
4.6	Economy-Business Calculation and Analysis . . . . .	92
4.6.1	Capital and Operational Expenditure . . . . .	93
4.6.2	Revenue Share Scheme . . . . .	95
4.6.3	Revenue Projection . . . . .	96
4.6.4	Cash Flow Projection . . . . .	96
4.6.5	Net Present Value . . . . .	97

4.6.6	Internal Rate of Return . . . . .	98
4.6.7	Payback Period . . . . .	98
4.6.8	Economic-Business Analysis . . . . .	98
4.6.9	Sensitivity Analysis . . . . .	98
<b>V</b>	<b>CONCLUSIONS AND FUTURE WORKS</b>	<b>101</b>
5.1	Conclusions . . . . .	101
5.2	Future Works . . . . .	102
<b>REFERENCES</b>		<b>104</b>
<b>Appendix</b>		<b>107</b>