

Table of Contents

Foreword	v
Preface	vii
Table of Contents	xi
List of Figures	xv
List of Tables	xvii
List of Abbreviations	xix
I The Preliminaries	1
1 Introduction	3
1.1 Hope for the Best, Prepare for the Worst	3
1.2 Outline	7
1.3 Summary of Research Contributions	9
2 Related Work	11
3 Brief Background in Security and Cryptography	13
3.1 Enforcing the Secrecy of Secrets	13
3.2 Symmetric-Key Cryptography	14
3.2.1 Data Encryption Standard	15
3.2.2 Advanced Encryption Standard	17
3.3 Asymmetric-Key Cryptography	19
3.3.1 Rivest Shamir Adleman	22
3.3.2 Elliptic Curve Cryptography	23
3.4 Recommended Key Lengths	26
3.5 Hash Functions	27

3.6	Message Authentication Codes	29
3.6.1	Block Cipher Based Message Authentication Codes	30
3.6.2	Hash Function Based Message Authentication Codes	30
3.7	Cryptographic Implementations	31
3.7.1	Software Implementations	31
3.7.2	Hardware Implementations	32
3.8	Trusted Computing Technology	35
3.8.1	Trusted Computing Components	35
3.8.2	Trusted Computing Basic Functionalities	37
3.9	Security Schemes in the Automotive Domain	40
3.9.1	Digital Signatures	40
3.9.2	Key Exchange and Hybrid Encryption	41
3.9.3	Public-Key Infrastructure	43
3.9.4	Challenge-Response Protocol	44
3.10	Cryptanalysis	45

II The Threats 47

4	Security-Critical Vehicular Applications 49
4.1	Introduction 49
4.2	Theft Protection 49
4.2.1	Electronic Immobilizer 50
4.2.2	Remote Door Lock 51
4.3	Counterfeit and Intellectual Property Protection 53
4.3.1	Counterfeit Protection 53
4.3.2	Intellectual Property Protection 53
4.4	Software Updates 54
4.5	After-Sale Applications 56
4.5.1	Feature Activation 56
4.5.2	Infotainment 57
4.6	Legal Applications 58
4.6.1	Milage Counter 58
4.6.2	Electronic License Plate 59
4.6.3	Digital Tachograph 60
4.6.4	Event Data Recorder 61
4.6.5	Electronic Log Book 62
4.6.6	Road Pricing 62

4.7	Vehicular Communication	63
4.7.1	In-Vehicle Communication	63
4.7.2	Vehicle-to-Device Communication	64
4.7.3	Vehicle-to-Infrastructure Communication	66
4.7.4	Vehicle-to-Vehicle Communication	68
4.8	Protection of Safety-Critical Applications	71
4.9	Privacy Protection	73
5	Attackers and Attacks in the Automotive Domain	77
5.1	Attackers in the Automotive Domain	77
5.2	Attacks in the Automotive Domain	80
5.2.1	Logical Attacks	82
5.2.2	Physical Attacks	86
5.2.3	Further Attacks	88
6	Security Analysis and Characteristical Constraints in the Automotive Domain	91
6.1	Security Objectives Analysis	91
6.2	Security Requirements Engineering	94
6.3	Characteristical Advantages	97
6.4	Characteristical Constraints	98
6.4.1	Technical Constraints	99
6.4.2	Non-Technical Constraints	100
III	The Protection	105
7	Vehicular Security Technologies	107
7.1	Physical Security	107
7.1.1	Tamper-Evidence	108
7.1.2	Tamper-Resistance	109
7.1.3	Tamper-Detection	110
7.1.4	Tamper-Response	110
7.2	Security Modules	110
7.2.1	Software Module	112
7.2.2	Security Controller	113
7.2.3	Trusted Platform Module	113
7.2.4	Security Box	115

7.3	Vehicular Security Architectures	115
7.3.1	Central Security Architecture	116
7.3.2	Distributed Security Architecture	117
7.3.3	Semi-Central Security Architecture	119
8	Vehicular Security Mechanisms	121
8.1	Why Proper Security Application is Hard	121
8.2	Secure Component Identification	122
8.2.1	Cryptographic Component Identification	123
8.2.2	Physically Unclonable Functions	125
8.3	Secure User Authentication	125
8.4	Secure Data Protection	126