

Secure Smart Embedded Devices, Platforms and Applications

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Editors

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Foreword by Fred Piper

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ISBN 978-1-4614-7914-7 ISBN 978-1-4614-7915-4 (eBook)

DOI 10.1007/978-1-4614-7915-4

Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013939824

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*I would like to dedicate this book to the
memory of my father, Georgios
Markantonakis. Thank you dad!*

Konstantinos Markantonakis

*I would like to dedicate this book to my
family and friends, and to people who
succeed despite disadvantage*

Keith Mayes

Foreword

This is the second book to be co-edited by Keith Mayes and Konstantinos Markantonakis. The first, *Smartcards, Tokens, Security and Applications* was published in 2008 and this volume is a natural ‘companion’ of that earlier publication and greatly expands on the range of content. Both are the result of experiences gained in managing the Smart Card Centre (SCC) at Royal Holloway, University of London.

The SCC, which was founded 10 years ago by Vodafone and Giesecke & Devrient, and has since been supported by numerous other companies, teaches a specialist module to students studying for the M.Sc. in Information Security. That module, which has the same title as their first book, focuses strongly on the relevant technical, practical and security issues.

Just as with the earlier book, the editors have produced an informative volume that is easy to read and its wide range of topics, which includes RFID, NFC, Mobile communications and wireless sensor nodes, (to list only a few), will appeal to a much wider audience than the Masters students at whom it is primarily aimed. This wider audience is likely to extend to researchers and experts from industry and governments. The two editors are both active researchers and their enthusiasm for research adds extra interest to a fascinating area.

It is clear that technology has advanced enormously over the years, although the fundamentals of Information Security may not have changed very much. Whether we are dealing with pencil and paper or advanced super computers, the motivation for fraud or security attacks and many of the reasons why vulnerabilities exist still have very human origins. Perhaps the biggest change is that people have transformed from being occasional users of technology to being dependent upon it and its underlying security properties. We also have generations that have grown up with the computer, mobile phone and Internet connectivity as essentials for life and they consume services and share personal data with carefree enthusiasm, whereas older heads might worry about how the technology works, who controls the system and data etc. In response to this it is certainly possible to focus on the security of something “big” like the Internet, but is very important to remember that much of what we rely on to keep us and our data and activities secure, is a collection of increasingly complex smaller devices. For example, the mobile phone is really a concept and what we actually buy and use is an electronic assembly with

processors, memories, security modules, displays, batteries, speakers etc. We could almost describe a car in the same way as it only functions correctly because a large number of embedded electronic modules, processors, sensors and communications links work as they should. Therefore if we are to fully understand the threats to modern systems and services, and then to help protect against them, we should keep abreast of developments in embedded systems. A textbook on secure smart embedded devices, platforms and applications would therefore seem a welcome addition to the bookshelf.

Fred Piper
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Preface

As we progress into the twenty-first century it seems that the pace of technological advance shows no sign of slowing. We are in fact becoming increasingly dependent on technology in our normal day-to-day lives, which means that we are critically reliant on the security of systems and services that are built upon this technology. In exploring this issue within a textbook, one could consider the high-level design aspects or concentrate more on the nuts and bolts of security systems. This book focuses mainly on the latter approach, as the editors and authors felt there was no introductory overview that covered a sufficient breadth of available technology and related issues. Generally speaking, a complex system is made up of smaller components such as devices, processors, security modules, memories etc. and knowing which of these can be trusted (and to what extent) to resist attacks and misuse, is critical to the security of the complete system. For example, a very sophisticated and expensive car might be reliant on a tiny embedded device (chip) in the engine management system, for it to start and for protection against theft. It is hoped that this book will help to clarify the role of embedded devices, their capabilities, and how best to exploit them in secure system designs.

Structure of the Book

The book consists of 24 chapters organised in four sections. Part I introduces some typical embedded devices and hardware, before some more generic information on security issues is provided in Part II. The Part III (which is the largest section) considers a wide range of application aspects and considerations. Part IV is provided for readers who are interested in application development for embedded devices. The chapters are written as self-contained texts, from a range of expert authors and can be read individually or in the book order. The chapters are briefly introduced below.

Part I: [Chapter 1](#) provides an overview of smart cards and (RFID), their security capabilities and attack resistance, and their widespread use within a range of security sensitive applications. [Chapter 2](#) then introduces Digital Signal Processor

devices which are widely used in modern devices, such as mobile phones. [Chapter 3](#) relates the historical development of microprocessor and microcontroller chips and goes on to cover the specialist design of secure embedded microcontrollers. [Chapter 4](#) introduces a specific type of secure controller, the Trusted Platform Module (TPM) and its mobile equivalent, that are intended to ensure (amongst other things) the safe boot up of a computing platform, so it is a reliable platform on which to load applications. [Chapter 5](#) considers the Very Large Scale Integration (VLSI) approach to the design of electronic hardware and the potential for security attacks and associated countermeasures.

Part II: [Chapter 6](#) provides a general recap on information security best practices. Although we are focussing on embedded devices we must not forget that without a secure theoretical design the implementation security will be fundamentally flawed. [Chapter 7](#) illustrates how a theoretically sound security design can be undermined by a poor implementation that lacks attack resistance. The chosen attack target is the smart card; however the principles are applicable to most embedded security devices. [Chapter 8](#) considers the Graphics Processing Unit (GPU), a processing platform that is often overlooked for its security capabilities. It can be used as a cryptographic processor; however it is also a target for malware and general misuse. [Chapter 9](#) focuses on the FPGA, which has been exploited both to protect and to attack security systems. The discussion also extends to the protection of valuable Intellectual Property loaded into FPGAs used in commercial systems.

Part III: [Chapter 10](#) considers a range of options for providing mobile communications security controllers. It begins with the conventional Subscriber Identity Module (SIM) and the associated personalisation, management and usage processes, but goes on to consider other possibilities, including software SIMs and TPMs. The action taken by a mobile device depends not just on the security controller, but the validity of the data that it receives, which increasingly can include a representation of physical location. [Chapter 11](#) discusses practical approaches to location estimation, highlighting the possible security vulnerabilities. Car Satellite Navigation systems are just one obvious example of this; however as discussed in [Chap. 12](#) motor vehicles are packed with processing technology that has important safety and security aspects. By contrast, payment card systems tend not to have such emphasis on safety, but they are required to safeguard significant financial transactions. The potential to undermine the payment terminals is discussed in [Chap. 13](#) with reference to published attacks. Another technology where the misuse may have both safety and security implications is the (WSN) which is described in [Chap. 14](#). For example, if a sensor value is modified, replaced or blocked the resulting effect could be serious and/or costly if the system was used for say telemedicine or metering. In fact a number of sensing and terminal solutions are proposed around mobile devices and this seems to be expanding with the arrival of (NFC) Technology. [Chapter 15](#) considers NFC and its security in detail, and how the phone (or laptop, PDA, tablet) may emulate an RFID, or act as an RFID reader, or communicate with other NFC phones over a close proximity link. Although NFC includes a Security Element (SE) some

aspects of the functionality are reliant on the phone platform security, which has vulnerabilities similar to conventional PCs. To clarify this problem, [Chap. 16](#) provides a recap on BIOS and Rootkit infections on computing platforms. Specialist computing/server equipment can get around this problem to some extent by the use of security hardened peripheral devices for sensitive processing. These are commonly known as Hardware Security Modules (HSM), and are discussed in [Chap. 17](#). Such devices are normally required to be formally security evaluated and the Common Criteria approach to this is outlined in [Chap. 18](#). In [Chap. 19](#) there is a description of Physically Uncloneable Functions (PUFs) that have generated significant academic interest and then in [Chap. 20](#) there is an overview of SCADA systems security that has generated significant industry concerns.

Part IV: [Chapter 21](#) provides an overview of the PIC family of microcontrollers that are intended for general-purpose non tamper-resistant implementations; however they are often used as clone platforms, as well as for research experiments. More secure implementations are commonly implemented on Java Card platforms and the programming aspects are introduced in [Chap. 22](#). Java has also been a preferred approach for mobile phone platforms and this approach plus important APIs are described in [Chap. 23](#). Finally, for readers interested in experimenting with Wireless Sensor Nodes, some practical guidance on available platforms is presented in [Chap. 24](#).

The ISG Smart Card Centre
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Keith Mayes
Konstantinos Markantonakis

ISG Smart Card Centre—Members Message

The (SCC) was established more than 10 years ago at Royal Holloway, University of London. The primary objective was to create a World-Wide Centre of Excellence for training and research in the field of Smart Cards, applications and related technologies. Over the years this has expanded into RFID, NFC, mobile devices and general embedded/implementation system security. Following the success of its first textbook in 2008 (Mayes and Markantonakis (eds), *Smart Cards, Tokens, security and Applications*, Springer) it was felt that this new book was now needed to cover more aspects of Secure Embedded Devices.

The SCC is part of the World renowned Information Security Group (ISG) that is one of the oldest and largest such groups and is one of the UKs Cyber Security Academic Centres of Excellence, with alumni of over 2,000 M.Sc./Ph.D. postgraduates. The SCC in common with ISG principles is very strongly engaged with industry, focussing on responsible research into real world projects of significant impact, and actively engaging industry experts into postgraduate training, research and publication.

As representing the range of supporting industrial members, we are pleased to be associated with the work and publications of the SCC.

Orange Labs (UK)
Transport for London
UK Cards Association
ITSO

Acknowledgments

This book would not have been possible without the help and support of a number of organisations and individuals. Firstly we would like to thank Orange Labs (UK), Transport for London, The UK Cards Association, ITSO and Royal Holloway, University of London for their tremendous support of the ISG Smart Card Centre. We owe an enormous debt of gratitude to all chapter authors and reviewers for their expert contributions and patient co-operation. We would also like to extend our thanks to Fred Piper for writing the foreword. Last, but certainly not least, we must thank Raja Naem Akram for his tremendous efforts in helping to bring this book to print and to Sheila Cobourne for proof reading on an epic scale.

Contents

Part I Embedded Devices

1	An Introduction to Smart Cards and RFIDs	3
	Keith Mayes and Konstantinos Markantonakis	
1.1	Introduction	3
1.2	Application Requirements	5
1.2.1	Mobile Communications	5
1.2.2	Banking Cards	7
1.2.3	Passports	8
1.2.4	Satellite Pay-TV	9
1.2.5	Transport Ticketing	10
1.2.6	Product Tagging	11
1.2.7	Comparing Requirements	12
1.3	Contact and Contactless Smart Cards/RFIDs	13
1.3.1	Cards with Contacts	13
1.3.2	Contactless Smart Cards/RFIDs	14
1.3.3	APDU Communication	15
1.4	The Range of Smart Card Devices	16
1.4.1	Simple ID Tag/Card	16
1.4.2	Memory Tag/Card	17
1.4.3	Secured Memory Tag/Card	17
1.4.4	Secured Microcontroller ID/Tag	18
1.5	The Importance of Providing Attack/Tamper-Resistance	19
1.6	Mobile and NFC	20
1.7	Conventional Smart Card Lifecycle Management Processes.	21
1.8	Conclusion.	23
	References	24
2	Embedded DSP Devices	27
	Serendra Reddy	
2.1	Overview.	28
2.2	Digital Signal Processing.	29

2.2.1	The DSP Processor	30
2.2.2	The Real-Time DSP System	32
2.2.3	The FPGA in DSP	34
2.2.4	The ASIP in DSP	35
2.3	Embedded DSP Systems	36
2.3.1	The Embedded DSP Architecture	37
2.3.2	The Embedded DSP Processor and RISC	40
2.3.3	Embedded DSP and Security	42
2.3.4	Embedded DSP and the Mobile Phone	44
2.4	Discussion	46
	References	46
3	Microprocessors and Microcontrollers Security	49
	Chris Shire	
3.1	Microcontrollers and Microprocessors Security Needs.	49
3.2	Historical Development.	51
3.3	The Microprocessor	52
3.3.1	32 Bit Microprocessor Designs.	53
3.3.2	64 Bit Microprocessor Designs.	54
3.3.3	RISCs and ARM	54
3.4	Security Design of Embedded CPU Architectures.	56
3.4.1	Security of Embedded CPU Memory	61
3.4.2	Security of Embedded CPU Interfaces	64
3.5	Advanced Chip Design	65
3.6	Conclusion.	67
	References	68
4	An Introduction to the Trusted Platform Module and Mobile Trusted Module	71
	Raja Naeem Akram, Konstantinos Markantonakis and Keith Mayes	
4.1	Introduction	71
4.2	The Trusted Platform Module	72
4.2.1	Trusted Platform Framework	72
4.2.2	Basic Architecture	73
4.3	TPM Operations.	76
4.3.1	TPM Endorsement Key.	76
4.3.2	TPM Ownership.	77
4.3.3	Attestation Identity Keys.	78
4.3.4	Measurement and Reporting Operations	79
4.3.5	Migration Model	83
4.4	The Mobile Trusted Module	85
4.4.1	Basic Architecture and Operations	85
4.5	TPM/MTM Technology Contenders	88
4.5.1	ARM TrustZone.	88

4.5.2	M-Shield	88
4.5.3	GlobalPlatform Device	88
4.5.4	Trusted Personal Devices.	89
4.5.5	Secure Element	89
4.5.6	Comparative Analysis of TPM/MTM Technology Contenders.	89
4.5.7	What Lies Ahead?	91
4.6	Conclusion.	91
	References	92
5	Hardware and VLSI Designs	95
	Mario Kirschbaum and Thomas Plos	
5.1	Introduction and Motivation.	96
5.2	VLSI Design Cycle.	97
5.3	Design Space of Hardware Circuits	100
5.4	Secure Hardware Design	102
5.4.1	Power Consumption of CMOS Gates	103
5.4.2	Countermeasures Against Power-Analysis Attacks . . .	104
5.4.3	Verification of Countermeasures by Means of Simulations	107
5.5	Instruction-Set Extensions	108
5.6	A 32-Bit Processor with ISEs and SCA Countermeasures . . .	110
5.7	Testability and Security.	112
5.8	Hardware Trojans	113
5.9	Conclusion and Summary	114
	References	115

Part II Generic Security and Processing Platforms

6	Information Security Best Practices	119
	Keith Mayes and Konstantinos Markantonakis	
6.1	Introduction	119
6.1.1	What is Information Security and Who are the Adversaries?	120
6.2	Security Objectives.	121
6.2.1	Data Assets	122
6.2.2	Critical Functions	122
6.2.3	The Range of Security Protection.	122
6.3	Cryptographic Algorithms	123
6.3.1	Symmetric Algorithms	124
6.3.2	Asymmetric Algorithms	132
6.3.3	Other Algorithms/Modes	134

6.4	Key/Trust Management	135
6.4.1	Asymmetric Key Management	136
6.4.2	Trust and Management	137
6.5	Security Evaluation and Common Criteria	138
6.6	Handling Imperfection.	139
6.7	Case Study the MIFARE Classic	140
6.7.1	Impact.	141
6.8	Concluding Remarks	142
	References	143
7	Smart Card Security	145
	Michael Tunstall	
7.1	Introduction	145
7.2	Cryptographic Algorithms	147
7.2.1	Data Encryption Standard	147
7.2.2	RSA	149
7.3	Smart Card Security Features.	152
7.3.1	Communication	153
7.3.2	Cryptographic Coprocessors.	154
7.3.3	Random Number Generators	154
7.3.4	Anomaly Sensors	155
7.3.5	Chip Features.	155
7.4	Side Channel Analysis	157
7.4.1	Timing Analysis.	157
7.4.2	Power Analysis	158
7.4.3	Electromagnetic Analysis	163
7.4.4	Countermeasures	164
7.5	Fault Analysis	166
7.5.1	Fault Injection Mechanisms	166
7.5.2	Modelling the Effect of a Fault	167
7.5.3	Faults in Cryptographic Algorithms	168
7.5.4	Countermeasures	171
7.6	Embedded Software Design	172
7.6.1	PIN Verification.	172
7.6.2	File Access	174
7.7	In Conclusion.	175
	References	175
8	Graphics Processing Units	179
	Peter Schwabe	
8.1	An Introduction to Modern GPUs.	180
8.1.1	NVIDIA GPUs.	180
8.1.2	AMD GPUs.	183
8.1.3	Programming GPUs in High-Level Languages.	183

8.1.4	Programming GPUs in Assembly	185
8.1.5	GPU Performance Bottlenecks	185
8.2	GPUs as Cryptographic Coprocessors	187
8.2.1	AES on GPUs	188
8.2.2	Asymmetric Cryptography on GPUs	190
8.3	GPUs in Cryptanalysis	192
8.4	Malware Detection on GPUs	194
8.5	Malware Targeting GPUs	195
8.6	Accessing GPUs from Web Applications	196
	References	197
9	A Survey of Recent Results in FPGA Security and Intellectual Property Protection	201
	François Durvaux, Stéphanie Kerckhof, Francesco Regazzoni and François-Xavier Standaert	
9.1	FPGAs: An Overview	202
9.1.1	Structure	202
9.1.2	Design Flow	204
9.1.3	Technologies	205
9.2	Security IPs	205
9.2.1	The AES Case	206
9.2.2	Performance Evaluation.	209
9.2.3	Side-Channel Attacks and Countermeasures.	210
9.2.4	Fault Attacks and Countermeasures	212
9.3	IP Security.	213
9.3.1	Bitstream Security	213
9.3.2	Design Security	214
9.4	Conclusions	219
	References	220
 Part III Applications and Platform Embedded Security Requirements		
10	Mobile Communication Security Controllers	227
	Keith Mayes and Konstantinos Markantonakis	
10.1	Introduction	227
10.2	An Overview of the SIM.	229
10.2.1	The SIM in Operation.	230
10.3	Security Analysis	232
10.3.1	Categories of Cellular Usage	232
10.3.2	The Roles in Communication Solutions.	233
10.4	Security Fundamentals	236
10.4.1	Trust Operations.	237

10.4.2	Initialisation, Personalisation and Key Management	238
10.4.3	Authentication/Encryption	238
10.4.4	Management of SIM Data and Application	239
10.4.5	Migration	239
10.4.6	Extended Operations/Value-Added Service Management	240
10.4.7	NFC Management	240
10.5	Generic Attacks on Smart Cards.	241
10.5.1	Logical Attacks	241
10.5.2	Physical Attacks	242
10.5.3	Side Channel Attacks	244
10.5.4	Fault Attacks	246
10.5.5	Summary and Main Points.	246
10.6	SIM Implementation Options	247
10.6.1	Pure Software SIM	247
10.6.2	Hardware Shared Security Software SIM Solution (HS-SSIM)	249
10.6.3	Standalone HW Security SIM Solution	251
10.7	Trusted Platform.	254
10.7.1	Roots of Trust	255
10.7.2	Authenticated Boot and Secure Storage.	256
10.7.3	Ownership	256
10.7.4	Mobile Trusted Platform (MTP).	257
10.8	Summary.	260
10.8.1	Value Added Service Management.	263
10.8.2	Concluding Remarks.	264
	References	265
11	Security of Embedded Location Systems	267
	G. P. Hancke	
11.1	Introduction	267
11.2	Embedded Location Systems	268
11.3	Security and Resilience of Location Information	270
11.3.1	Security and Resilience of Position Estimation Methods	273
11.4	Securing Position Estimation Methods	277
11.5	Global Navigation Satellite Systems	280
11.5.1	GPS Security	280
11.5.2	Future Efforts on Securing GNSS.	283
11.6	Conclusion.	284
	References	284

12 Automotive Embedded Systems Applications and Platform Embedded Security Requirements.	287
Jan Pelzl, Marko Wolf and Thomas Wollinger	
12.1 Introduction: Smart Embedded Platform Automotive	287
12.1.1 Smart Communication Platform	289
12.1.2 Smart After-Market Platform	290
12.1.3 Smart Future Platform.	290
12.2 Security Aspects of Smart Embedded Automotive Platforms.	291
12.2.1 Automotive Attackers	292
12.2.2 Automotive Attack Paths.	292
12.2.3 Automotive Security Threats and Risks.	296
12.2.4 Security of Automotive Safety Mechanisms.	296
12.2.5 Security of Automotive Legal Applications	298
12.2.6 Security of Automotive Business Models	298
12.2.7 Automotive Privacy Aspects	299
12.2.8 Real-World Automotive Security Incidents	299
12.2.9 Examples of Automotive Security Mechanisms	300
12.3 Smart and Secure Open Automotive Platforms Platform	302
12.3.1 OVERSEE Virtualisation.	302
12.3.2 OVERSEE Security Services Architecture.	304
12.3.3 OVERSEE Security Implementation.	306
12.4 Conclusions	308
References	308
13 Analysis of Potential Vulnerabilities in Payment Terminals	311
Konstantinos Rantos and Konstantinos Markantonakis	
13.1 Introduction	311
13.1.1 EMV Standard	314
13.2 Current Terminal Status	316
13.2.1 Types of Terminals.	316
13.2.2 Where does Security Apply?	317
13.3 Types of Attacks	320
13.3.1 Attacking the Supply Chain.	320
13.3.2 Exploiting Inadequate Security Measures	322
13.3.3 Skimming	324
13.3.4 Covert Channels to PINs.	325
13.3.5 PIN/PIN Block Interception and Cracking	326
13.3.6 Manipulating the Terminal-Card Interface	327
13.3.7 Relay Attacks.	330
13.4 Conclusions and Future Considerations	331
References	332

14	Wireless Sensor Nodes	335
	Serge Chaumette and Damien Sauveron	
14.1	Introduction	335
14.2	Applications.	336
14.3	Constraints.	337
	14.3.1 Costs: Production Versus Performance	337
	14.3.2 Energy	338
	14.3.3 Management: Self and Decentralized	339
14.4	Architecture and Operating System.	339
	14.4.1 Sensing Unit	340
	14.4.2 Processing Unit	341
	14.4.3 Communication Unit.	342
	14.4.4 Major Features of Operating Systems	342
14.5	Security Concerns.	343
	14.5.1 Security of Wireless Sensor Nodes	343
	14.5.2 Security in Networks of Wireless Sensor Nodes.	345
	References	347
15	Near Field Communication	351
	Gerald Madlmayr, Christian Kantner and Thomas Grechenig	
15.1	Introduction	351
15.2	NFC Technology	352
	15.2.1 Physical Layer	352
	15.2.2 Use Cases and Applications.	354
15.3	Hardware Integration	355
	15.3.1 NFC Chip	355
	15.3.2 Secure Element	356
	15.3.3 Host Controller	357
15.4	NFC and Linux	359
15.5	NFC Integration in Android.	359
	15.5.1 NFC Chip	360
	15.5.2 API for the NFC Chip.	361
	15.5.3 API for the Secure Element Access	362
	15.5.4 Security.	362
15.6	NFC Tags	364
	15.6.1 Tag-Types	364
	15.6.2 NFC Data Exchange Format (NDEF)	364
15.7	Conclusion.	366
	References	366
16	The BIOS and Rootkits	369
	Graham Hili, Keith Mayes and Konstantinos Markantonakis	
16.1	The BIOS	369
	16.1.1 The BIOS Subsystem Functionality	370

16.2	Attacks on the BIOS Subsystem	371
16.2.1	Countermeasures to BIOS Attacks	373
16.3	Rootkits	373
16.3.1	Introduction to Rootkits	373
16.4	Rootkit Infections	374
16.4.1	Detection of Rootkits	376
16.4.2	Removal of Rootkits	378
16.5	Conclusion	379
	References	379
17	Hardware Security Modules	383
	Stathis Mavrovouniotis and Mick Ganley	
17.1	Introduction	383
17.2	HSM Usage	384
17.3	HSM Physical Security	388
17.4	HSM Security Evaluation and Approvals	389
17.5	HSM Management	393
17.6	Key Management	395
17.7	Command Manipulation Attacks	399
17.8	Conclusions	403
	References	404
18	Security Evaluation and Common Criteria	407
	Tony Boswell	
18.1	Introduction	407
18.2	Security Evaluation Issues	408
18.2.1	The Security Evaluation Model	412
18.2.2	Structure and Use of the Common Criteria	413
18.2.3	Structure of Common Criteria	415
18.2.4	Assurance Requirements and Assurance Levels	416
18.2.5	CC Interpretation and Supporting Documents	416
18.2.6	Attack Potential Calculations	417
18.3	Evolution of Common Criteria	418
18.3.1	CC Technical Communities	419
18.3.2	New Generation Protection Profiles	420
18.4	Other Security Evaluation Schemes	420
18.4.1	FIPS 140	421
18.4.2	PCI PIN Transaction Security Requirements	422
18.5	Example Protection Profiles	423
18.5.1	Security IC PP	423
18.5.2	Payment Terminal (Point of Interaction) PP set	424
18.5.3	Trusted Platform Module PP	425
	References	426

19	Physical Security Primitives	429
	Ahmad-Reza Sadeghi, Steffen Schulz and Christian Wachsmann	
19.1	Introduction	429
19.2	Physically Unclonable Functions	431
19.2.1	PUF Concept and Properties	431
19.2.2	PUF Types	432
19.2.3	Noise Compensation and Privacy Amplification.	435
19.2.4	Characterizing the Unpredictability of PUFs	436
19.3	Attacks Against PUFs and PUF-Based Systems	437
19.3.1	Emulation Attacks	437
19.3.2	Side-Channel Attacks	437
19.3.3	Fault Injection Attacks	438
19.4	Advanced PUF Concepts	438
19.4.1	Controlled PUFs.	439
19.4.2	Emulatable PUFs	439
19.5	Common Applications of PUFs	440
19.5.1	Device Identification and Authentication.	440
19.5.2	Secure Key Storage and Key Generation.	441
19.6	Future Directions	441
19.6.1	Logically Reconfigurable PUFs	441
19.6.2	PUF-Based Remote Attestation	442
19.7	Open Questions and Challenges	443
19.8	Conclusion.	444
	References	445
20	SCADA System Cyber Security.	451
	Igor Nai Fovino	
20.1	Introduction	451
20.2	SCADA Architecture Overview	452
20.2.1	SCADA Protocols Overview	453
20.3	SCADA Vulnerabilities and Attacks	455
20.3.1	Architectural Vulnerabilities	456
20.3.2	Security Policy Vulnerabilities	457
20.3.3	Software Vulnerabilities	459
20.3.4	Communication Protocol Vulnerabilities	459
20.4	SCADA Security Countermeasures	460
20.4.1	Communication Protocol Countermeasures	461
20.4.2	Filtering Coutermeasures	462
20.4.3	Monitoring Coutermeasures	464
20.4.4	General Architectural Best Practices	465
20.5	Conclusion.	469
	References	469

Part IV Practical Examples and Tools

21 An Overview of PIC Microcontrollers and Their Suitability for Cryptographic Algorithms.	475
Mehari G. Msgna and Colin D. Walter	
21.1 Introduction	475
21.2 Microcontroller Structure.	476
21.3 Peripheral Interface Controllers	477
21.3.1 PIC Architecture.	477
21.3.2 Memory	478
21.3.3 Other Components	479
21.3.4 Development Tools.	479
21.3.5 Summary.	480
21.4 AES on a PIC	480
21.4.1 Implementation of AES.	481
21.5 Attack Example	482
21.5.1 Differential Power Analysis.	483
21.5.2 Practical Implementation of DPA.	485
21.6 Conclusion.	493
References	493
22 An Introduction to Java Card Programming.	497
Raja Naeem Akram, Konstantinos Markantonakis and Keith Mayes	
22.1 Introduction	497
22.2 Smart Card Programming	498
22.2.1 Smart Card Architecture	498
22.2.2 Smart Card Hardware	499
22.2.3 Communication Architecture	500
22.2.4 Application Development Lifecycle	502
22.3 Java Card	503
22.3.1 Java Card Classic	503
22.3.2 Java Card Connected	504
22.4 Java Card Programming	506
22.4.1 Java Card Applet Architecture	506
22.5 My First Applet	507
22.5.1 Application Design.	507
22.5.2 Coding	509
22.5.3 Simulating and Testing	511
22.6 Conclusion.	512
References	512

23	A Practical Example of Mobile Phone Application	
	Using SATSA (JSR 177) API	515
	Lishoy Francis	
23.1	Introduction	515
23.1.1	A Brief Overview of SATSA Framework	517
23.1.2	A Brief Overview of Java Card Framework.	518
23.2	Practical Example.	518
23.2.1	Developing a MIDP Application (MIDlet)	
	Implementing SATSA APDU Communication API . .	518
23.2.2	Developing a Java Card Applet	525
23.2.3	Results: Testing MIDlet and Java Card Applet.	531
23.3	Conclusion.	532
23.3.1	Source Code of MIDP Application (MIDlet)	533
23.3.2	Source Code of Java Card Applet.	535
23.3.3	Java Card Applet Download-Script.	537
	References	539
24	Wireless Sensors (Languages/Programming/Developments	
	Tools/Examples)	541
	J��r��mie Albert, Lionel Barr��re, Serge Chaumette	
	and Damien Sauveron	
24.1	Introduction	541
24.2	Sun SPOTs (Sun Small Programmable Object Technology). . .	542
24.2.1	Introduction	542
24.2.2	History	543
24.2.3	Hardware Overview	543
24.2.4	Software Overview	544
24.2.5	How to Start with a Sun SPOT	544
24.2.6	Hello World (“Shake and Blink”)	546
24.2.7	Networked Sun SPOTs Applications.	548
24.3	Arduino.	550
24.3.1	Introduction and History	550
24.3.2	Hardware Overview	550
24.3.3	Software Overview	551
24.3.4	How to Start with a Arduino	552
24.3.5	Hello World (“Blinking SOS”)	553
24.3.6	Networked Arduino Application.	555
24.4	TinyOS	556
24.4.1	Introduction	556
24.4.2	Hardware Overview	557
24.4.3	How to Start with TinyOS.	558
24.4.4	Hello World (“Sense and Blink”).	559
24.4.5	Networking with TinyOS.	560
24.5	Sensor Network Deployment: An Example	561

24.5.1	Introduction	561
24.5.2	Hardware Architecture	561
24.5.3	The Time Synchronization Issue.	562
24.5.4	Data Collection, Location and Network Load Issues. .	563
24.5.5	The Problem of Missing Information	563
24.5.6	Conclusion.	564
	References	564
 Errata to: Secure Smart Embedded Devices, Platforms and Applications		 E1
 Errata to: Secure Smart Embedded Devices, Platforms and Applications		 E3
	Index	565

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Colin Walter has spent the last 25 years concentrating on the practical implementation of cryptography, partly in industry and partly in academia. He helped design one of the first RSA chips for Plessey-Crypto in 1989. He published the first fully systolic array for modular exponentiation in 1993 and this is now widely used in SSL accelerator chips. In the late 90s he did some consultancy for Multos to understand and reduce side channel leakage from public key cryptography on smart cards. This led to some important work on the implementation of Montgomery modular multiplication and some improved algorithms for exponentiation. He joined the ISG at Royal Holloway in 2009 after 8 years working on product development as head of cryptography at a well-known certificate authority. For many years he was on the steering committee of the IACR CHES workshops, and was programme chair and local organiser for two of these. He is a senior member of the IEEE.

Marko Wolf Dr.-Ing. Marko Wolf is a senior IT security expert and branch manager of ESCRYPT GmbH in Munich. Marko is primarily active in the area of automotive data security and privacy protection for various industry customers in Europe, Asia, and the US as well as for different national and international government authorities and standardization bodies. Marko studied Electrical Engineering and Computer Engineering at the University of Bochum (Germany) and at Purdue University (USA). After receiving his M.Sc. in 2003, he started his Ph.D. in the area of Trusted Computing and vehicular IT security at the Chair for Embedded Security hold by Prof. Dr. Christof Paar. Wolf completed his Ph.D. in 2008 with the first comprehensive work about vehicular IT security engineering. He is editor/author of the books *Embedded Security in Cars* (Springer, 2006) and *Security Engineering for Vehicular IT Systems* (Vieweg+Teubner, 2009), program chair of the international Embedded Security in Cars (escar) workshop series, and has published over 30 articles in the area of embedded IT security and privacy.

Thomas Wollinger Dr. Wollinger has worked in the area of data security and embedded security since 1997. He implemented and led several projects, for instance, at secunet AG. Dr. Wollinger has published numerous articles at international conferences and in relevant journals in the area of security. Dr. Wollinger frequently gives invited talks and teaches data security courses (e.g. at Motorola Labs Paris, gits AG, and TV Academy Rhineland). He obtained his B.S. from the University of Dieburg and obtained his Master of Science at the Worcester Polytechnic Institute, USA. In June 2003, he obtained his Ph.D. with honors from the University of Bochum. Dr. Wollinger worked as Chief Sales Officer (CSO) at ESCRYPT from 2005 to 2007. Dr. Wollinger established the technical sales and marketing structure of the company. He was involved in all acquisitions regarding ESCRYPT projects. Since 2007, Dr. Wollinger is Managing Director of ESCRYPT GmbH.