1.	Introduction							
2.	Preliminaries							
	2.1.	The Pa	atterson Algorithm for the Decoding of Goppa Codes	7				
	2.2.	The M	cEliece PKC	8				
	2.3.		iederreiter PKC	8				
3.	Optimization for Resource-constrained Devices 1							
	3.1.	On-Lir	ne public Operation for Code-based Schemes	11				
		3.1.1.	The Storage Problem on Memory Constrained Devices	12				
		3.1.2.	Public Key Infrastructures	12				
		3.1.3.	Description of the On-line Public Operation	13				
		3.1.4.	Transmission Rates	15				
		3.1.5.	Example Implementation	16				
		3.1.6.	Non-interactive Version of the Protocol	17				
		3.1.7.	Simulation of higher Transmission Rates	17				
		3.1.8.	Experimental Results	· 18				
		3.1.9.	Column-wise vs. Row-wise Matrix-Vector Multiplication	18				
		3.1.10.	Code-based Signature Schemes	20				
	3.2.		ece Decryption without the Parity Check Matrix	fatrix 20				
		3.2.1.	Optimized Algorithm for the Syndrome Computation without the					
			Parity Check Matrix	21				
		3.2.2.	Implementation and Performance Results	22				
	3.3.	Efficie	nt Root-Finding during the Decryption	23				
		3.3.1.	Remarks about the \mathbf{F}_{2^m} Operations	23				
		3.3.2.	Variants of Root Finding	24				
			3.3.2.1. Exhaustive Evaluation with and without Division					
			3.3.2.2. Berlekamp Trace Algorithm	25				
			3.3.2.3. Root Finding with linearised Polynomials					
			3.3.2.4. New Hybrid Variants	27				
		3.3.3.	Performance of the Root-finding Variants	28				
	3.4.		arison of the McEliece and Niederreiter PKCs in Terms of Efficiency					
		3.4.1.	•					
		3.4.2.	Private Key Size and Decryption Speed					
			Massaga and Cinhartaut Sizes					

VII



•	Side	ty	33			
	4.1.	Message-aimed Side Channel Attacks against the Decryption Operation .				
		4.1.1.	Timing '	Vulnerabilities in the Root-Finding based on the Degree		
			of the E	rror Locator Polynomial	33	
		4.1.2.	Timing '	Vulnerability of the Key Equation solving EEA and Coun-		
·			termeasi	ires ,	35	
			4.1.2.1.	Identification of the Vulnerability		
			4.1.2.2.	Timing Countermeasure	38	
			4.1.2.3.	Implementation and Verification of the Countermeasure .	38	
		4.1.3.	A related	d Simple Power Analysis Attack against the Key Equation		
			Solving 1	EEA		
			4.1.3.1.	Measurement Setup	40	
			4.1.3.2.	Attacks against the insecure Implementation	41	
			4.1.3.3.	Countermeasure	41	
		4.1.4.	Vulneral	oility in Root-Finding with exhaustive Evaluation and Di-		
vision						
4.2. Side Channel Attacks against the secret Support				ttacks against the secret Support	44	
		4.2.1.	Timing .	Attacks against the EEA	46	
			4.2.1.1.	Properties of the Syndrome Inversion		
			4.2.1.2.	Linear Equations from $w = 4$ Error Vectors	47	
			4.2.1.3.	Cubic Equations from $w = 6$ Error Vectors	50	
			4.2.1.4.	Enlargement of the Timing Differences by the Key Equa-		
				tion Solving EEA	51	
			4.2.1.5.	The Zero Element of the Support from $w = 1$ Error Vec-		
				tors	52	
			4.2.1.6.	Combining the " $w = 1$ ", " $w = 4$ ", and " $w = 6$ " Vulner-		
				abilities to a practical Attack		
			4.2.1.7.	•		
			4.2.1.8.	Effect of Countermeasures against other Attacks		
			4.2.1.9.	Possible Extensions of the Attack		
				The Problem of Countermeasures		
		4.2.2.	Timing	Attacks against Root-Finding Algorithms		
			4.2.2.1.	Vulnerability of eval-div-rf		
			4.2.2.2.	Vulnerability of dcmp-rf	. 64	
	4.3.	Fault	Attacks .		. 66	
		4.3.1.		ttack Vulnerability revealing the Degree of the Error Lo-		
				olynomial	. 66	
		4.3.2.		tack Vulnerability revealing Information about the Num-		
				oots of the Error Locator Polynomial	. 66	
	4.4.		•	of the Vulnerabilities and Countermeasures to the Nieder-		
		reiter	PKC		. 67	

	4.5.	. Relation of the Side Channel Vulnerabilities to those of other Cryptosystems						
		4.5.1.	_	imed Side Channel Attacks against Cryptosystems with				
				hic Properties	67			
				Manger's Attack against RSA-OAEP	68			
				Iomomorphic Properties of RSA and the McEliece Cryp-				
				osystem	70			
				Comparison of Message-aimed Side Channel Attacks against				
				RSA and McEliece	70			
			4.5.1.4. N	Methodology for the Analysis of public Key Cryptosys-				
			t	ems with homomorphic Properties	72			
		4.5.2.	Blinding C	Countermeasures for Code-based Cryptosystems	73			
5.	Emb	edded	Implement	ations of the McEliece PKC	75			
	5.1.	A Flex	ible Platfor	rm independent Implementation of the McEliece PKC .	75			
		5.1.1.	Description	n of the Implementation	75			
		5.1.2.	Performan	ce Results	75			
	5.2.	A Sma	rt Card Im	plementation of the McEliece PKC	79			
		5.2.1.	Description	n of the Implementation	79			
		5.2.2.	Performan	ce Results	81			
6.	Ope	n Prob	ems		83			
	6.1. Potential Cache-Timing Vulnerabilities in Code-Based Decryption Oper-							
					83			
	6.2.		Countermeasures Against the Low-Weight Error Vector Attacks 83					
		Side Channel Security of BTA-rf						
				ure Implementation of dcmp-div-rf	86			
				he Optimal Root-Finding Algorithm for Embedded Im-				
				th Hardware Support	88			
7.	Con	clusion			89			
Δ	Δnn	endix			97			
٦.			Equations i	involving less than four Basis Elements are impossible.	97			
		Jubic	rdagacine i	morang loss man four basis bicinents are impossible.	91			