

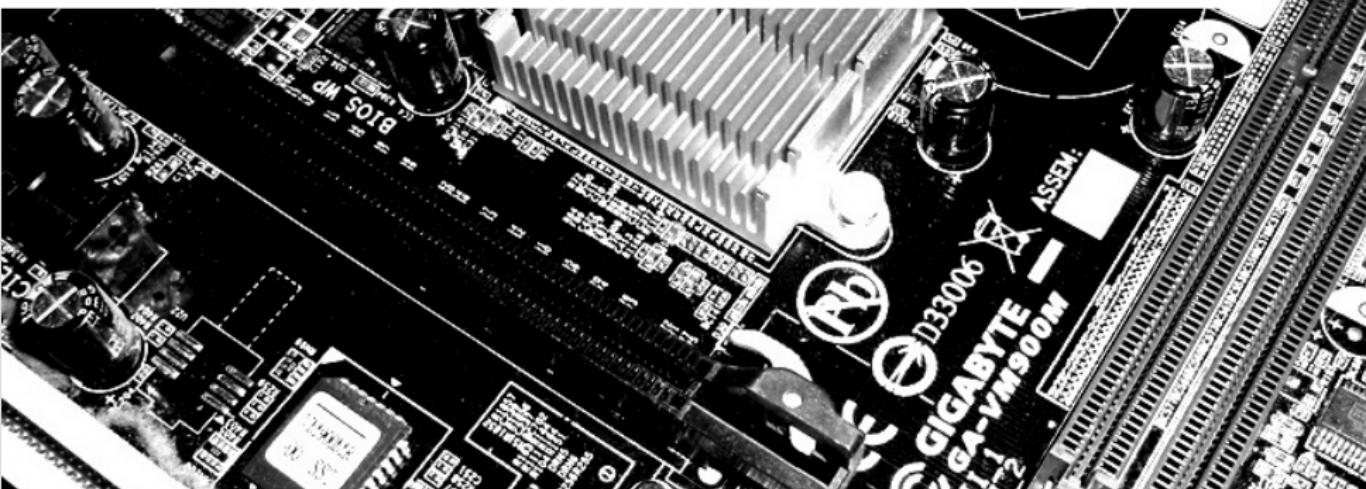
High-Speed Implementation of bcrypt Password Search using Special-Purpose Hardware

10. December 2014

Horst Görtz Institute for IT-Security

Ruhr University Bochum

Friedrich Wiemer and Ralf Zimmermann



Outline

1 Motivation

2 bcrypt

3 Design of Implementation

4 Results

Motivation

Password Hashing Function?

Can't we just store passwords in plain?

¹ blog.ebay.com/ebay-inc-ask-ebay-users-change-passwords

² blogs.adobe.com/conversations/2013/10/important-customer-security-announcement.html

Motivation

Password Hashing Function?

Can't we just store passwords in plain?¹²



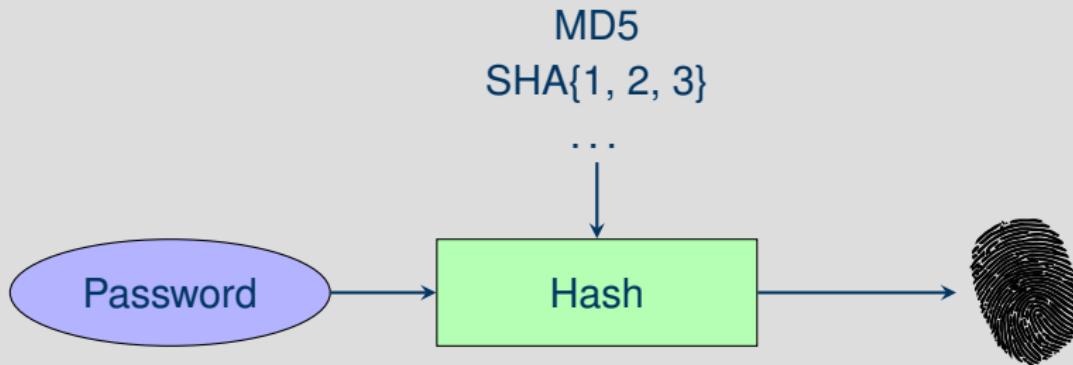
Adobe

¹ blog.ebay.com/ebay-inc-ask-ebay-users-change-passwords

² blogs.adobe.com/conversations/2013/10/important-customer-security-announcement.html

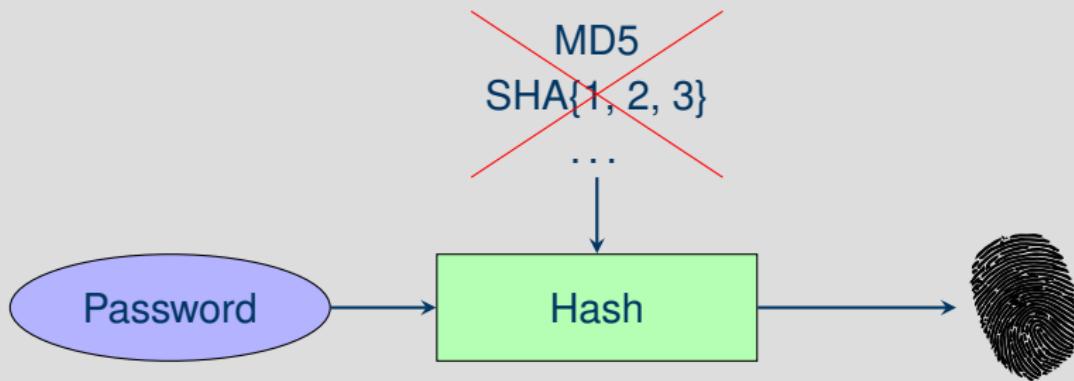
Motivation

Secure Storage?



Motivation

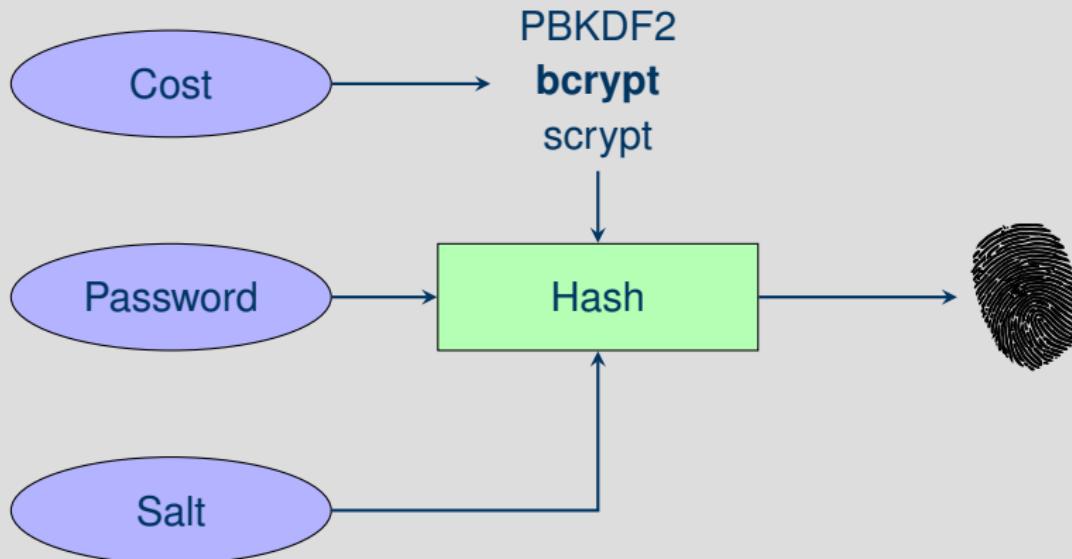
Secure Storage?



don't use standard hash functions

Motivation

Secure Storage!



Why do we care?

- password cracking has an inherent parallel structure
- FPGAs enable to exploit this parallelism
- bcrypt claims to resist hardware optimizations
- currently available implementations³ suffer from interface bottlenecks and instable operations

³K. Malvoni et al. Are Your Passwords Safe: Energy-Efficient Bcrypt Cracking with Low-Cost Parallel Hardware *8th USENIX Workshop on Offensive Technologies (WOOT 14)*, 2014

What is bcrypt?

Introduced in 1999 by Provos and Mazières.⁴ Implemented in OpenBSD 2.1, Ruby on Rails, and PHP as standard password hash.

bcrypt

- cost-parameterized
- based on modified Blowfish

⁴ www.usenix.org/events/usenix99/full_papers/provos/provos.pdf

What is bcrypt?

Introduced in 1999 by Provos and Mazières.⁴ Implemented in OpenBSD 2.1, Ruby on Rails, and PHP as standard password hash.

bcrypt

- cost-parameterized
- based on modified Blowfish

Blowfish

- symmetric blockcipher
- Feistel network

⁴ www.usenix.org/events/usenix99/full_papers/provos/provos.pdf

Structure

- setup state, using the *password* and *salt* as key with modified Blowfish key schedule
- encrypt magic value
- output ciphertext as hash

Structure

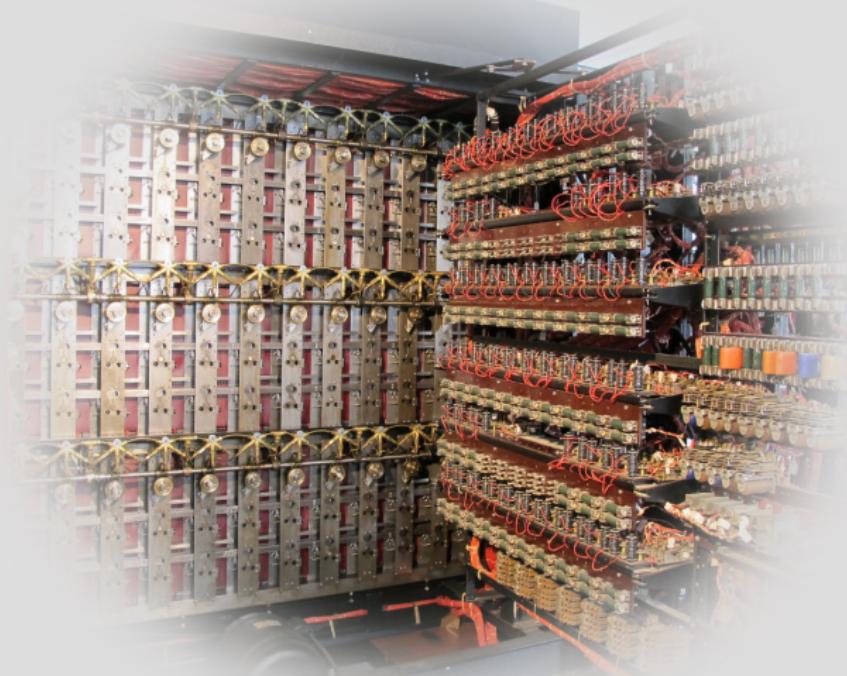
- setup state, using the *password* and *salt* as key with modified Blowfish key schedule
- encrypt magic value
- output ciphertext as hash

Work

- needs $(2^{\text{cost}+1} + 1) \cdot 521$ Blowfish encryptions (roughly $2^{\text{cost}+10}$)
- needs $3 \cdot 64$ Blowfish encryptions

Implementation

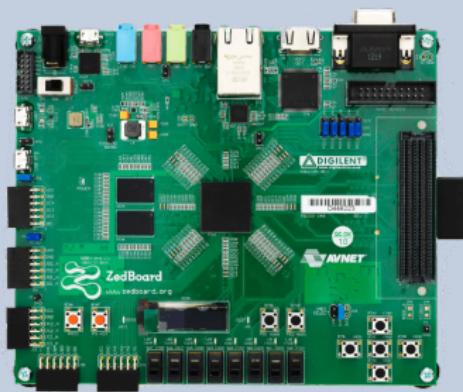
Cracker



Target Platforms

Low cost, low power FPGA

Zedboard



Target Platforms

Low cost, low power FPGA

Zedboard



High Performance FPGA

Virtex-7

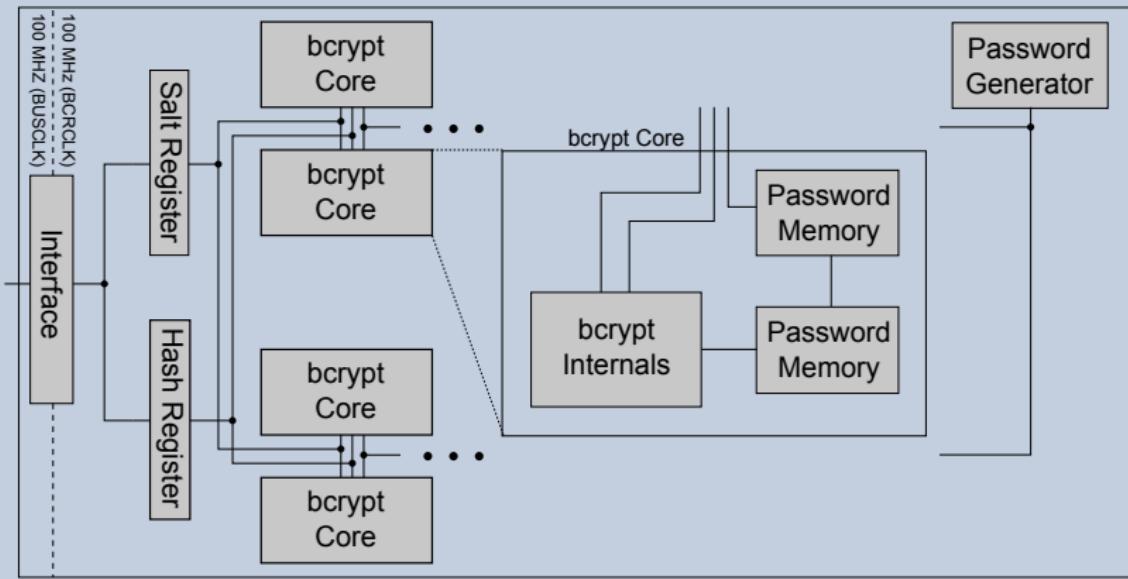


Optimization Goal?

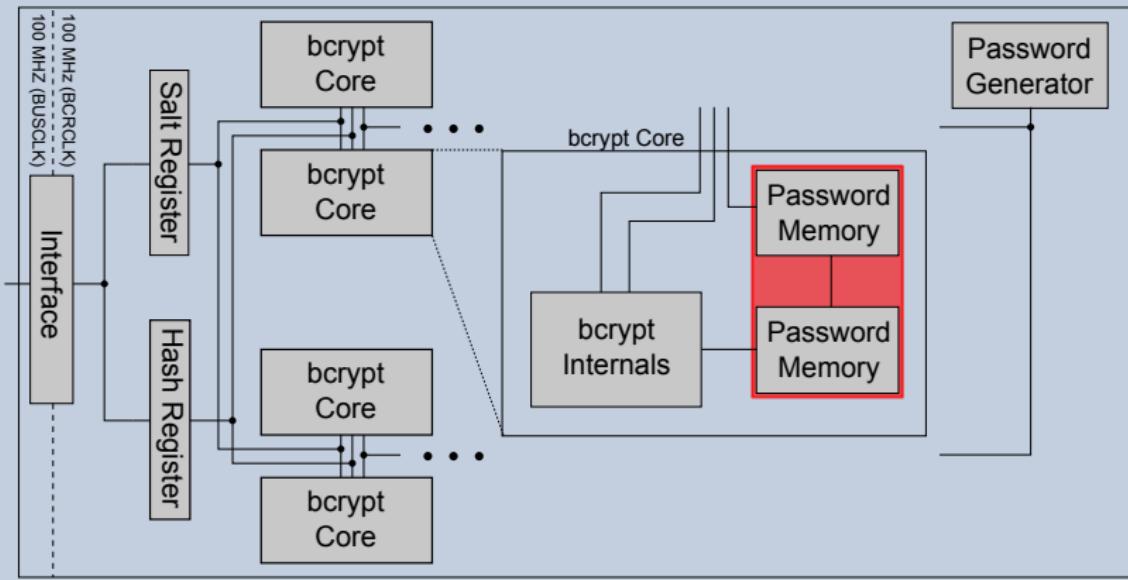
Low Area Footprint (bcrypt)

Low Area Footprint (bcrypt) High-Speed (Blowfish)

First Attempt

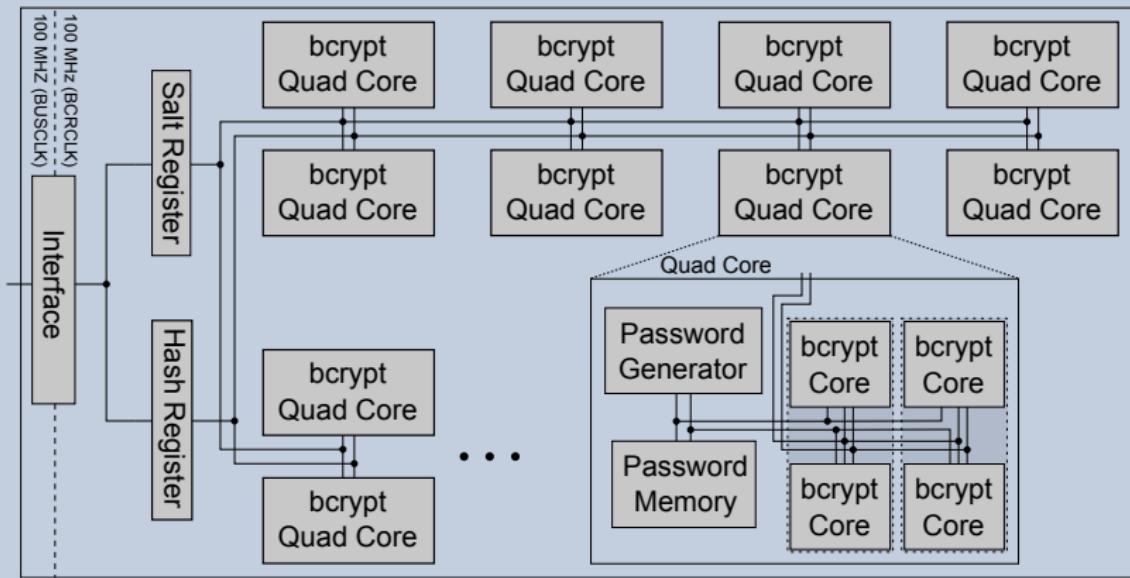


First Attempt



Design

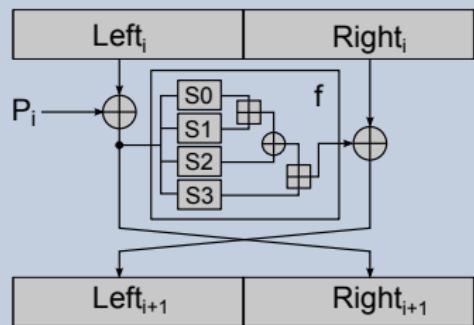
Quad Core



Design

Blowfish Core

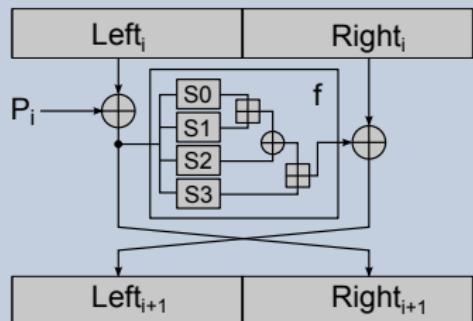
One Round



Design

Blowfish Core

One Round



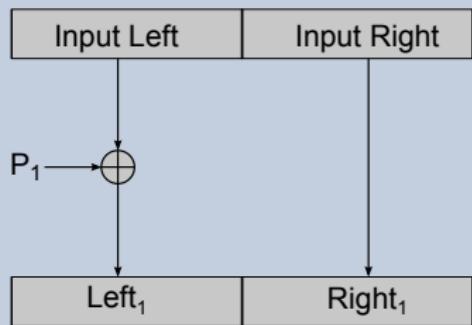
Problematic

- SBox addresses can not be computed in the same clock as the look up is used
- needs 2 clock cycles per round

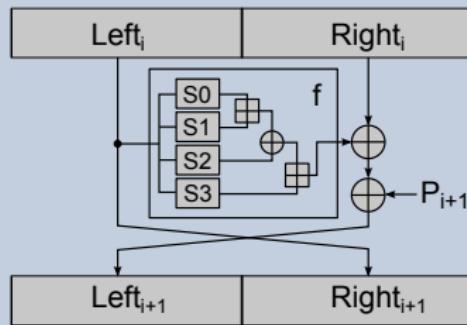
Design

Blowfish Core Retimed

Prefetch



Retimed Round



Advantages

- needs only 1 clock per round

Resulting Resources

Zedboard

- estimations for one zedboard:
40 cores as upper bound, BRAMs as limiting resource
- first design attempt (password in registers):
12 cores fit, LUT utilization way to high
- Quad Core Design:
40 cores fit, while using “big” interface

Virtex-7

- Quad Core Design:
316 cores per FPGA

Resulting Resources

Resource utilization of design and submodules

	LUT	FF	Slice	BRAM
Overall	64.8%	13.06%	93.29%	95.71%
Quad Core	2,777	720	801	13
Single Core	617	132	197	3
Blowfish Core	354	64	71	0
Password Generator	216	205	81	0

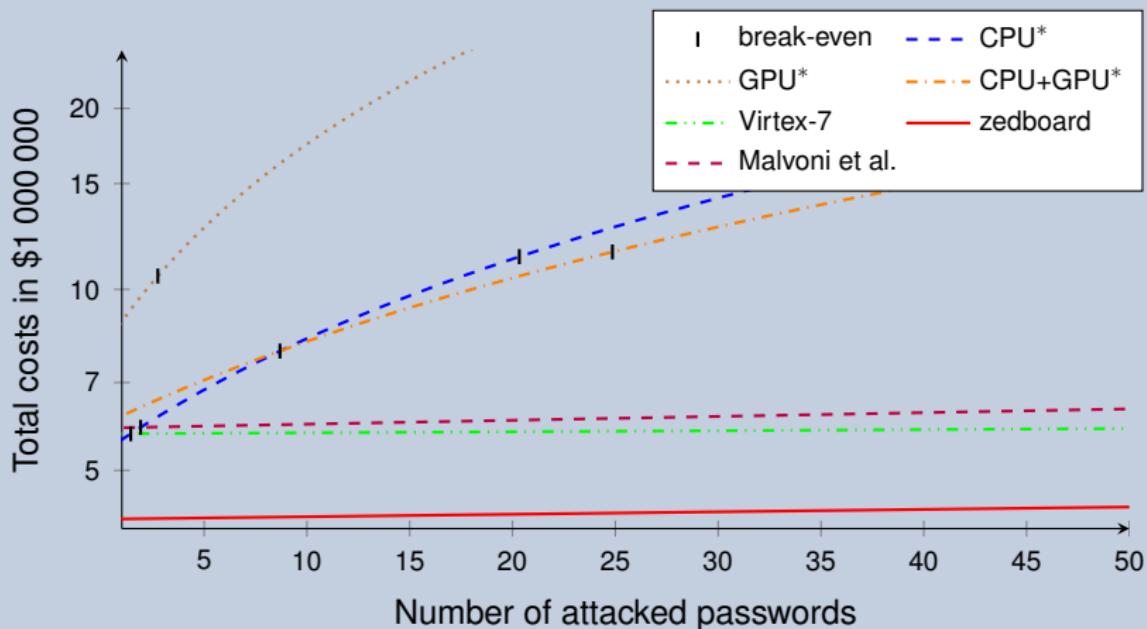
Resulting Hashrates

Compared to

	cost factor 5		cost factor 12	
	Hashes Second	Hashes Watt Second	Hashes Second	Hashes Watt Second
Zedboard	6,511	1,550	51.95	12.37
Malvoni (GSoC)	780			
Malvoni et al.	4,571	682.24	64.83	9.68
Virtex-7	51,437	2,572	410.4	20.52
Xeon E3-1240	6,210	20.7	50	0.17
GTX 750 Ti	1,920	6.4	15	0.05

Brute Force Attack

Cost 5



Questions?

Thank you for your attention!



Images: Wikimedia Commons, flickr