MAX PLANCK INSTITUTE
FOR SECURITY AND PRIVACY

“My life in crypto”

Peter Schwabe

September 17, 2024

High-school until 2000

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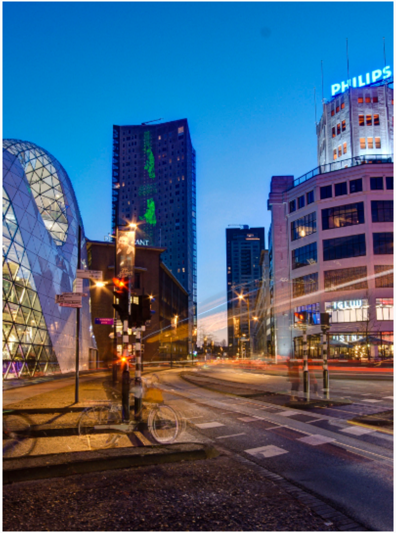
- Quit after 16 months

Lesson 1: Make good decisions.

- Don’t take a certain path just because it’s easy
- Think about what you want
- Figure out what your options are
- Take time for your decision

Ph.D. for real: Eindhoven

- Work on optimizing crypto software
- Very productive environment:
  - Great supervisors
  - Lots of colleagues in crypto
  - Collaborations with other groups
- Payed by EU project CACE



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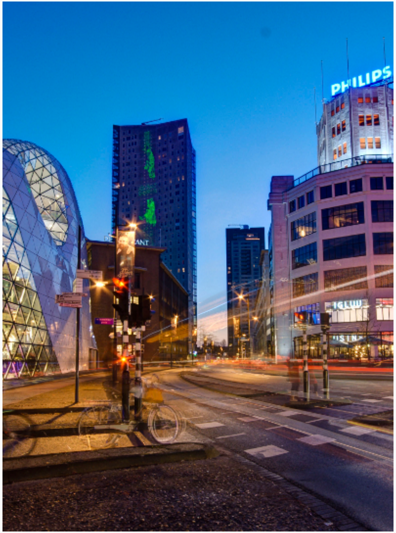

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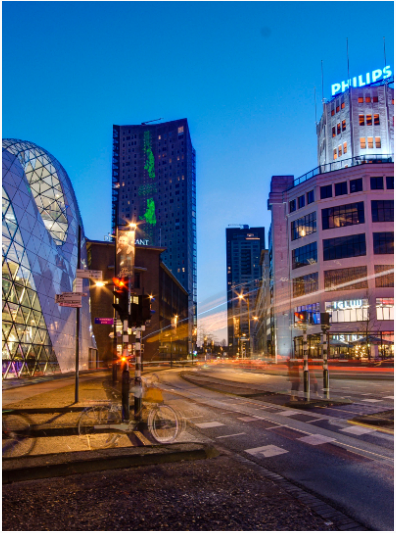
  `https://cryptojedi.org/gallery/Defense-Peter/index.shtml`



Finding topics, part 1: as a student

Lesson 2: talk to people!

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- Present your work, discuss
- Most fun collaborations came out of “hallway sessions”

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  - You want to learn about a particular topic
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- Interesting “switching point” during Ph.D.:
  - At first, you need *some* topic
  - At some point, you need to *choose* from *many* topics

Finding a Postdoc position

- Ask.

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- Finding a Postdoc position is easy
- Postdocs are “cheap”
- Good Postdocs are simply great!

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- (Most) things function very well, just differently
- Could ignore e-mails from my employer

Lesson 3: Move outside your comfort zone!

- Academic research is highly international
- Experience life in a (very) different country
  - What does it mean to not speak the language?
  - What does it mean to be in a different culture?
  - What does it mean to have your friends/family in a different timezone?

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- Important life lesson, helps you understand others
- For me: amazing experience!
- Worth much more than writing another two or three papers

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- Head of Digital Security Group from 2019
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- Teaching (preparation) takes a lot of time!
- Well-prepared exams take less time to grade

Leading a group

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  - Understand and support individual needs and wishes
  - Respect different cultures, priorities, working hours, etc.
  - Clearly communicate what is important to you

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- Best thing: See other people succeed and grow
- Worst thing: Having to “kick people in the butt”

Lesson 4: Everything takes time!

- Most(?) academics are notoriously over-committed.
- Job description: 40% teaching, 40% research, 20% service
- More realistic: 50% teaching, 50% research, 50% service
- You cannot be excellent at everything

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- Job description: 40% teaching, 40% research, 20% service
- More realistic: 50% teaching, 50% research, 50% service
- **You cannot be excellent at everything**
- Learn to prioritize
- Learn to say **no**

Getting funding

Two approaches

1. Figure out what people will pay you for and do that
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"Money makes money"

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"Der Teufel scheißt immer auf den größten Haufen"

Finding topics, part 2: as faculty

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Great collaborations and how/where they started

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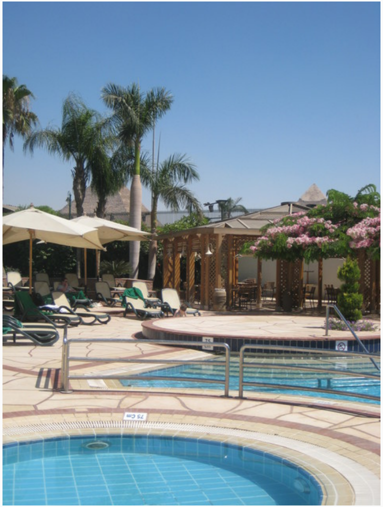

Great collaborations and how/where they started

4630 Bochum

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However:

- Don't be a yes-person
- Say what you want
- Don't let others exploit you

Cryptography – the very basics

Alice

- Alice encrypts a message M using a key K obtains ciphertext C
- Sends C to Bob

Bob

- Bob decrypts C using K and obtains M

Let me introduce Eve

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  - More later . . .

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- In short: Everything forbidden
- Impersonate Alice or Bob, forge messages, obtain keys (most powerful attack!)

The NSA (Eve)

National Security Agency

- US American secret service
- Largest employer for mathematicians in the world
  - Estimated $40000 - 75000$ employees
  - “Black budget” of US$$52.6$ billion / year
  - Power-bill for Utah data center (estimated): US$$40$ million / year

Pictures from the Wikimedia Commons

How secure is cryptography?

Kerckhoffs' principle

An encryption algorithm takes as input a message and a key. The security of the system must rely only on the secrecy of the key, not on the secrecy of the algorithm.

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- If the best known algorithm takes 2^n "operations" to find the key, we say that a system is assumed to have *n* bits of security
- Generic attack against *n*-bit key: try all possibilities. Cost: 2^n
- If a system is believed to have *n* bits of security, an attacker can break it
  - if he can carry out 2^n operations, or
  - if he knows a better attack

How many bits of security has X?

keylength.com

- Various institutions give recommendations based on best known attacks
- NIST (every year)
- ECRYPT (until 2012)
- BSI, ANSSI

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Some examples of popular schemes (NIST, 2012)

- **AES-128:** 128 bits
- **RSA-1024:** 80 bits
- **RSA-2048:** 112 bits
- **256-bit elliptic curve:** 128 bits

Can Eve break AES-128?

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  - Sun is radiating $\approx 2^{58}$ watts onto the earth
  - Geothermal energy: $\approx 2^{46}$ watts
  - Gravitation of moon and sun: $\approx 2^{43}$ watts

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- Second question first:
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- First question:
  - Best mass-market chips: $\approx 2^{68}$ bit ops / watt / year
  - Perfect power usage: 2^{126} bit ops / year
  - AES key guess takes 2^{13} bit ops
  - Break key with probability 1: > 30000 years

So, why do we need research in crypto?

Assumptions, assumptions, assumptions. . .

Side channels

Image by Natasha Martin/Timaru Herald

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  - timing **(even remotely!)**
- Side-channel attacks: Use this data to break cryptographic protection
- Side-channel attacks target specific implementations

It gets much worse than that. . .

MELTDOWN

Hertzbleed

CACHE OUT

[A small demo]

Polynomial-Time Algorithms for Prime Factorization and Discrete Logarithms on a Quantum Computer*

Peter W. Shor†

Abstract

A digital computer is generally believed to be an efficient universal computing device; that is, it is believed able to simulate any physical computing device with an increase in computation time by at most a polynomial factor. This may not be true when quantum mechanics is taken into consideration. This paper considers factoring integers and finding discrete logarithms, two problems which are generally thought to be hard on a classical computer and which have been used as the basis of several proposed cryptosystems. Efficient randomized algorithms are given for these two problems on a hypothetical quantum computer. These algorithms take a number of steps polynomial in the input size, e.g., the number of digits of the integer to be factored.

[Back to our demo]

Ongoing research in my group

Post-Quantum Cryptography

- Signatures and KEMs in NIST-PQC
- Beyond NIST-PQC, e.g., NIKE
- Protocol migration (KEMTLS, PQ-Wireguard)
- Embedded implementations (e.g., pqm4)

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- **High-assurance** crypto
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OpenTitan collaboration

- Open Source HW root of trust
- See `https://opentitan.org`
- (High-assurance) PQC on OpenTitan
- Side-channel security for OpenTitan

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Microarchitectural security

- Protection against SW side channels
- HW SCA and countermeasures
- Spectre countermeasures
- Integration with Formosa Crypto