You vs. the NSA

Why everybody needs high-security crypto

Peter Schwabe

Radboud University Nijmegen, The Netherlands

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Florianópolis, Brazil

Cryptography – the very basics

Alice

Bob

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

- Bob *decrypts* C using K and obtains M

Let me introduce Eve

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  - More later ...

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Eve's goals

- In short: Everything forbidden

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

You (Alice and Bob)

- Average computer user
- Your computing and communication equipment:
  - Laptop (2–3 GHz)
  - Smartphone (1–2 GHz)
- No expert knowledge about cryptography
- Use readily available software

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

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Kerckhoffs' principle

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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 algorithm

How many bits of security has X?

keylength.com

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

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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

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- Problem: Warnings are often ignored

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- Used in RSA Security products until 2013

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- I would not be surprised if NSA had broken SHA-1 even more

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Attacking implementations

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- Another big target: OpenSSL library
- A practical attack against one of these *implementations* breaks a lot!

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- *Side-channel attacks*: Use this data to break cryptographic protection
- Side-channel attacks also target specific *implementations*

Timing attacks

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- Two main sources for timing-attack vulnerabilities
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- For many algorithms it is *hard* to write (efficient) constant-time software
- Most cryptographic software in use today leaks secret data through timing information

Practical timing attacks

Linux hard-disk encryption

- Osvik, Shamir, and Tromer in 2006: timing attack against `dmcrypt`
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AES-CBC in TLS

- AlFardan and Kenneth G. Paterson in 2013:
  Plaintext recovery attack against TLS with AES-CBC

  > *"we expect all implementations – whether open or closed – to be vulnerable to our attacks to some extent."*

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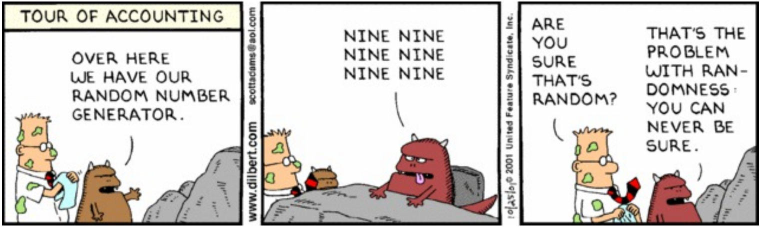
- Many implementations have been fixed by now, see, e.g.
  https://www.imperialviolet.org/2013/02/04/luckythirteen.html

Randomness



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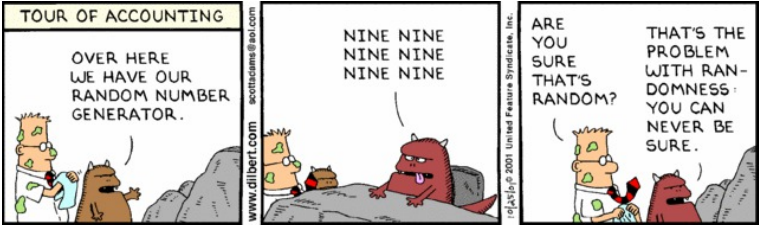

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- Bad-randomness attack: guess the right value

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Debian randomness disaster

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Sony randomness disaster

- "Bushing", Cantero, Boessenkool, Peter in 2010: Sony ignored ECDSA requirement of new randomness for each signature
- Signatures leaked PlayStation 3 code-signing key

Bad randomness II

Internet host randomness

- Heninger, Durumeric, Wustrow, Halderman in 2012: Obtain millions of TLS and SSH public keys
- Compute private keys for 0.5% of TLS and 1.06% of SSH public keys
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Taiwanese citizen cards

- Bernstein, Chang, Cheng, Chou, Heninger, Lange, and van Someren in 2013: Obtain public keys from Taiwanese "Citizen Digital Certificate" database
- Compute private keys of 184 Taiwanese citizens
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- Networking and Cryptography library (NaCl, pronounced “salt”)
- Offers all security features from previous slide
- Focus on protecting Internet communication
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http://nacl.cr.yp.to

Man in the middle

An https session (highly simplified)

- Browser connects to Server
- Server sends its public key
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- Compromise just one CA and you can do anything

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- You don't need the NSA for that, consider the EU

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From Article 5:

- data necessary to trace and identify the source of a communication
- data necessary to identify the destination of a communication

More on traffic data

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"Member States shall ensure that the categories of data specified in Article 5 are retained for periods of not less than six months and not more than two years from the date of the communication."

From Article 5:

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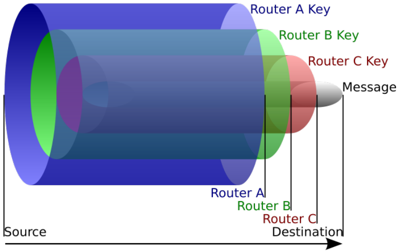
- data necessary to identify the location of mobile communication equipment

Anonymization with TOR

How can we hide traffic data?

- Most popular: TOR ("The Onion Router")
- Route data through (at least) three TOR nodes
- Use multiple layers of encryption:



- Open-source software available at http://torproject.org

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- Sounds good, but slides are from 2012, based on 2007 data
- How about today?

Attacks against TOR part I

Looking at the exit node

- Data that comes out of the exit node unencrypted

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- What if you access a website through TOR and type there

  "Hi, I'm Peter Schwabe, I'm sitting in Flórianopolis, Brazil.
  My IP address is 187.65.227.71."

Attacks against TOR part I

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- What if you access a website through TOR and type there

  "Hi, I'm Peter Schwabe, I'm sitting in Flórianopolis, Brazil. My IP address is 187.65.227.71."
- It can be more subtle: look for TOR users when they are not using TOR
- NSA on such attacks: *"Dumb Users (EPICFAIL)"*

Attacks against TOR part II

Controlling TOR nodes

- Attacker tries to control all nodes of a route
- NSA is known to run TOR nodes, unclear how many
- If NSA controls just 1% of the nodes, each route has a $1/1000000$ chance of being NSA controlled

Attacks against TOR part II

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- TOR changes routes every 15 minutes
- A matter of time until you're de-anonymized
- TOR has some ways to address these attacks

Attacks against TOR part III

"Tor ist tot. Tor basiert auf der Annahme, dass der Gegner nicht in der Lage ist, das gesamte Internet zu überwachen."
– Felix "Fefe" von Leitner (Aug 5, 2013)

Attacks against TOR part III

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Timing analysis of traffic

- Observe large amounts of Internet communication
- In particular: Traffic entering TOR network and exiting TOR network
- Use timing correlation to de-anonymize users
- In 2007 apparently infeasible for NSA

Attacks against TOR part IV

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- Good news: TOR is updating to 128-bit secure Curve25519

Wild speculation part I

Hardware trojans

- Your laptop is running on an Intel or AMD CPU
- Your smartphone has a Freescale, Qualcomm, Apple, TI, ... CPU
- Do you trust these US American companies to not have a trojan in the hardware?

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- David Johnston (Intel):

> *"...eliminate software PRNGs. Just use the output of the RDRAND instruction wherever you need a random number."*
>
> *"...we did RdRand the way we did, to bypass the OS, libraries, APIs, VMs, caches and memory and feed entropy directly to the register space of the running application."*

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- Becker, Regazzoni, Paar, and Burleson in 2013: Describe almost undetectable hardware trojan that can be used to create a backdoor in `rdrand`

Wild speculation part II

Quantum Computers

- Can't quantum computers break all crypto?

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- What then? :

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- What then? *Post-Quantum Cryptography* to the rescue:
  - Asymmetric cryptography that survives quantum attacks
  - Ongoing research effort to make it practical

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- Eliminate side-channel leakages
- Better anonymity (at acceptable performance) than TOR
- Obtain good randomness wherever and whenever it's needed
- Find a way to get rid of bad algorithms fast
- Make high-security crypto easy to use for everybody