Crypto libraries introduction

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Open source cryptographic libraries

- Linux environment – up to you:
    - Debian / VirtualBox VM (see course materials)
        - **some optional examples need OpenSSL 3.0 or gcrypt 1.10**
    - Your own distro – need to install development env.:
        - libgcrypt: Fedora: **libgcrypt-devel**; Debian/Ubuntu: **libgcrypt20-dev**
        - OpenSSL:Fedora: **openssl-devel**; Debian/Ubuntu: **libssl-dev**

          NOTE: OpenSSL3 is often not yet in stable releases
        - libsodium:Fedora: **libsodium-devel**; Debian/Ubuntu: **libsodium-dev**
    - aisa.fi.muni.cz (OpenSSL v1 only)
- All examples in C language
- Home assignments (10 points each)

Lab environment
VirtualBox image

- Unpack zip archive from IS
- Open VirtualBox (click **blue** icon – config file)
- Login and password is **pv181**
  (same for **sudo** and **root** password)
- Debian with upgraded OpenSSL and libgcrypt
- We will use only opensource tools
- Examples on gitlab (always **git pull** for updates)

```
git clone https://gitlab.fi.muni.cz/xbroz/pv181.git
make clean; make; ./example
```

Cryptographic libraries
Goals for this lab

- Crypto libraries and API / abstraction
- More practical and implementation view
- Why legacy code, compatibility and standards
- Coding practices – in C language
- Defensive approach: **It will fail, be prepared for it :-)**

Why not use a modern language with garbage collection and functional programming and free massages after lunch?
Here’s the answer: Pointers are real. They’re what the hardware understands. Somebody has to deal with them.
You can’t just place a LISP book on top of an x86 chip and hope that the hardware learns about lambda calculus by osmosis.
- James Mickens, https://www.usenix.org/system/files/1311_05-08_mickens.pdf

Why implementation matters

- It works, but …
- How many possible bugs do you see?

```c
/* Read a key from Linux RNG */
#include <string.h>
#include <unistd.h>
#include <fcntl.h>

int main(int argc, char *argv[])
{
   int fd;
   char key[32];

   fd = open("/dev/random", O_RDONLY);
   read(fd, key, 32);
   close(fd);
   /* Do something with the key[] */
   memset(key, 0, 32);
   return 0;
}
```

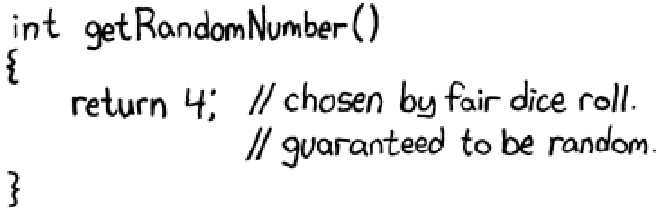
Why implementation matters

- How many possible bugs do you see?
  - *No check for return code, open(), read()*
  - *Posible reading from invalid fd (no random at all)*
  - *Partial read() is not detected*
  - *Failed read() is not detected (mandatory access control can block reading)*
  - *Magic numbers (one constant on several places)*
  - *Compiler can optimize memset() out (secret key remains in memory)*
  - *No error exit code, cannot check for failure*

Why implementation matters

- Fixes? Let’s see **example 0** in git.

- It is better to use a crypto library.
- Usually, maintainers implement it correctly :-)



```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

https://xkcd.com/221/

Secure implementation notes

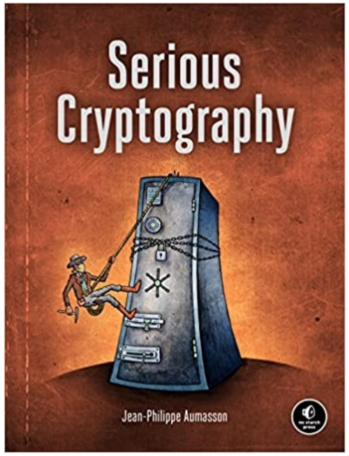
- Even C compilers can do many checks
  - Use -Wall option and **do not ignore warnings**
  - non-default warnings options
- User opensource static and dynamic code analyzers
  - clang scan-build
  - gcc -fanalyzer options
  - valgrind
  - cppcheck
- Fuzzing can be very powerfull
- Code review (it requires some skills)

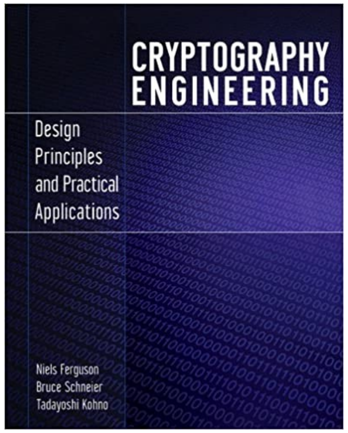
Practically oriented books

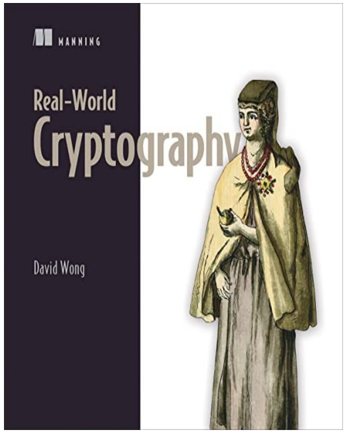
- *Jean-Phillipe Aumasson*
  Serious Cryptography:
  A Practical Introduction
  to Modern Encryption (2017)

- *Ferguson, Schneier, Kohno*
  Cryptography Engineering:
  Design Principles and Practical
  Applications (2010)

- *David Wong*
  Real-World Cryptography (2021)







Cryptographic libraries Introduction

- Open-source / Proprietary
- Static + embedded / dynamically linked
- Low or high level abstractions
- Multiplatform
- Stable API and ABI
- Policy (approved algorithms)
- Security or platform specific features
  - Safe memory use, side-channel resistance, …
  - HW acceleration support, “secure” HW support

Crypto libraries – algorithms

- Random Number Generator (RNG) access
- Hash, keyed-hash (HMAC, msg authentication)
- Symmetric ciphers and modes
- Asymmetric ciphers
- Certificate support, ASN.1, ...
- Key exchange, key derivation
- Helpers
  - secure memory
  - safe comparison
  - network / sockets
  - plugin support (like OpenSSL3 providers)
  - ...

Example libs (C and Linux) abstraction from low to high

- **Nettle**
- **libgcrypt**
- **OpenSSL / OpenSSL3**
  - LibreSSL (clone), BoringSSL (Google)
- **NSS**
  - Network Security Services (Mozilla)
- **NaCl** ("salt")
  - more common as **libsodium**

Examples in **gcrypt**, **OpenSSL / OpenSSL3** and **libsodium**