The security impact of a new cryptographic library

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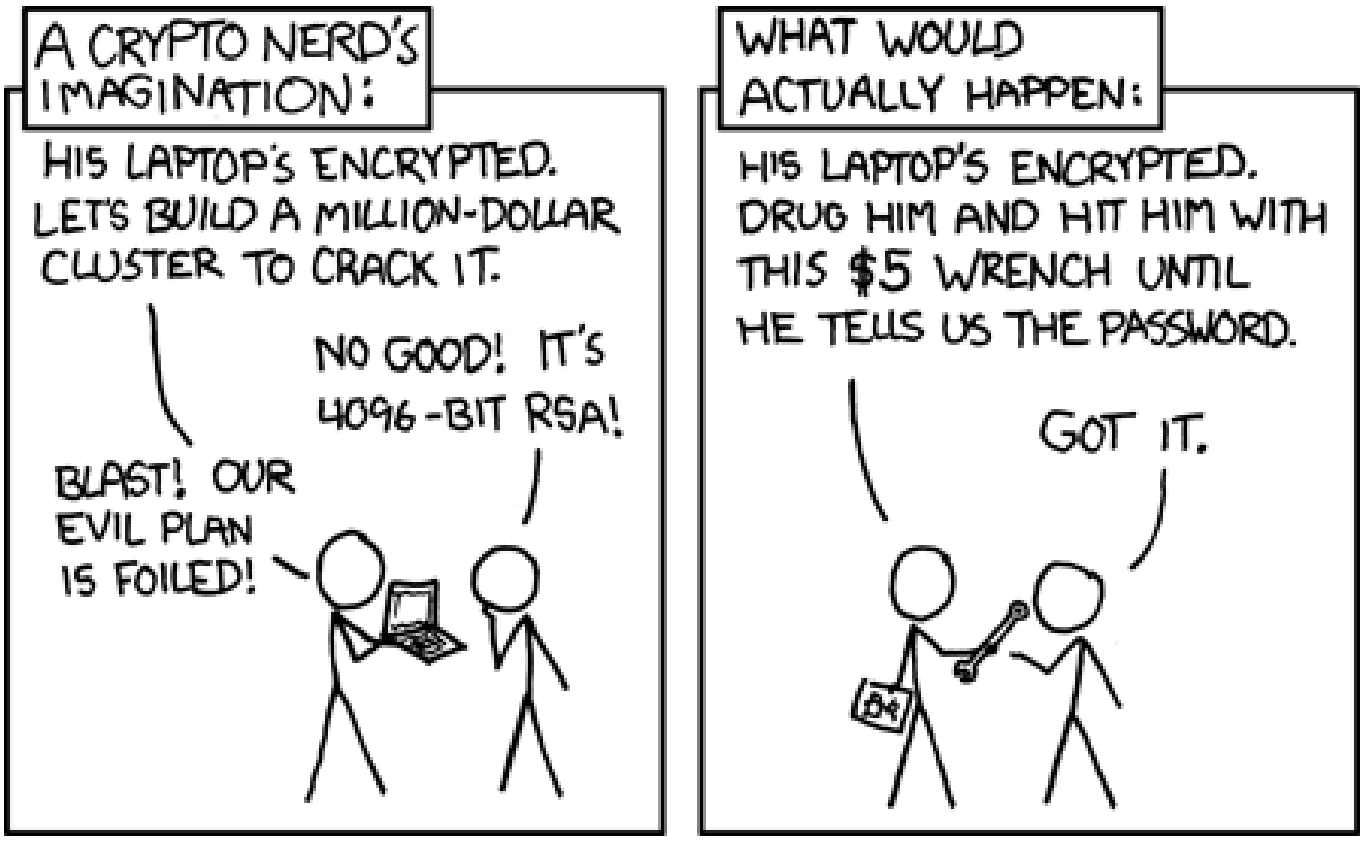

http://xkcd.com/538/

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are widely accepted standards.

Obviously infeasible to break
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But cryptography is still
a disaster! Complete failures
of confidentiality and integrity.

We have designed+implemented a new cryptographic library, NaCl ("salt"), to address the underlying problems.

nacl.cace-project.eu, nacl.cr.yp.to: source and extensive documentation.

Acknowledgments:
code contributions from Matthew Dempsky (Mochi Media), Niels Duif (Eindhoven), Emilia Käsper (Leuven), Adam Langley (Google), Bo-Yin Yang (Academia Sinica).

Most of the Internet
is cryptographically unprotected.
Primary goal of NaCl: Fix this.

Main task: **public-key authenticated encryption**.

Alice has a message m for Bob.

Uses Bob's public key and
Alice's secret key to compute
authenticated ciphertext c.
Sends c to Bob.

Bob uses Alice's public key
and Bob's secret key
to verify and recover m.

Alice using a
typical cryptographic library:

Generate random AES key.
Use AES key to encrypt packet.
Hash encrypted packet.
Read RSA key from wire format.
Use key to sign hash.
Read Bob's key from wire format.
Use key to encrypt signature etc.
Convert to wire format.

Plus more code:
allocate storage,
handle errors, etc.

Alice using NaCl:

```
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`c = crypto_box(m,n,pk,sk)`

32-byte secret key `sk`.

32-byte public key `pk`.

24-byte nonce `n`.

`c` is 16 bytes longer than `m`.

All objects are C++

`std::string` variables

represented in wire format,

ready for storage/transmission.

C NaCl: similar, using pointers;

no memory allocation, no failures.

Bob verifying, decrypting:

```
m=crypto_box_open(c,n,pk,sk)
```

Initial key generation:

```
pk = crypto_box_keypair(&sk)
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Can instead use **signatures**
for public messages:

```
pk = crypto_sign_keypair(&sk)
```

64-byte secret key,
32-byte public key.

```
sm = crypto_sign(m,sk)
```

64 bytes overhead.

```
m = crypto_sign_open(sm,pk)
```

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Examples of applications
using NaCl’s `crypto_box`:

Several implementations of
DNSCurve, high-security
authenticated encryption for DNS
queries; deployed by OpenDNS.

QuickTun, VPN from Ivo Smits.

Ethos, OS from Jon Solworth.

Prototype implementation
of CurveCP: high-security
cryptographic version of TCP.

No secret load addresses

2005 Osvik–Shamir–Tromer:
65ms to steal Linux AES key
used for hard-disk encryption.
Attack process on same CPU
but without privileges.

Almost all AES implementations
use fast lookup tables.
Kernel's secret AES key
influences table-load addresses,
influencing CPU cache state,
influencing measurable timings
of the attack process.
65ms to compute influence^{-1}.

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still use secret load addresses
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NaCl systematically avoids
all loads from addresses
that depend on secret data.
Eliminates this type of disaster.

2010 Langley `ctgrind`:
verify this automatically.

No secret branch conditions

2011 Brumley–Tuveri:
minutes to steal another
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No padding oracles

1998 Bleichenbacher:
Decrypt SSL RSA ciphertext
by observing server responses
to $\approx 10^6$ variants of ciphertext.

SSL first inverts RSA,
then checks for "PKCS padding"
(which many forgeries have).
Subsequent processing applies
more serious integrity checks.

Server responses reveal
pattern of PKCS forgeries;
pattern reveals plaintext.

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try to hide differences
between padding checks and
subsequent integrity checks.

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NaCl does not decrypt
unless message is authenticated.
Verification procedure rejects
all forgeries in constant time.
Attacks are further constrained
by per-nonce key separation
and standard nonce handling.

Centralizing randomness

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NaCl uses `/dev/urandom`,
the OS random-number generator.
Reviewing this kernel code
is much more tractable than
reviewing separate RNG code
in every security library.

Avoiding unnecessary randomness

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NaCl has *deterministic* `crypto_box` and `crypto_sign`. Randomness only for `keypair`. Eliminates this type of disaster.

Also simplifies testing. NaCl uses automated test battery from eBACS (ECRYPT Benchmarking of Cryptographic Systems).

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Fact: By 1996, a few years after the introduction of MD5, Preneel and Dobbertin were calling for MD5 to be scrapped.

NaCl *pays attention to cryptanalysis* and makes very conservative choices of cryptographic primitives.

Speed

Crypto performance problems
often lead users to reduce
cryptographic security levels
or give up on cryptography.

Example 1:
Google SSL uses RSA-1024.

Security note:
Analyses in 2003 concluded
that RSA-1024 was breakable;
e.g., 2003 Shamir–Tromer
estimated 1 year, $\approx 10^7$ USD.
RSA Labs and NIST response:
Move to RSA-2048 by 2010.

Example 2: Tor uses RSA-1024.

Example 3: DNSSEC uses RSA-1024: "tradeoff between the risk of key compromise and performance. . ."

Example 4: OpenSSL continues to use secret AES load addresses.

Example 5:
https://sourceforge.net/account
is protected by SSL but
https://sourceforge.net/develop
redirects browser to
http://sourceforge.net/develop,
turning off the cryptography.

NaCl has no low-security options.

e.g. `crypto_box` always
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Remaining risk:
Users find NaCl too slow $\Rightarrow$
switch to low-security libraries
or disable crypto entirely.

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How NaCl avoids this risk:
NaCl is exceptionally fast.
Much faster than other libraries.
Keeps up with the network.

NaCl operations per second
for any common packet size,
using AMD Phenom II X6 1100T
CPU, 164€ on kieskeurig.nl:

`crypto_box`: >80000.

`crypto_box_open`: >80000.

`crypto_sign_open`: >70000.

`crypto_sign`: >180000.

Putting this into perspective:
80000 50-byte packets/second
would consume 32 Mbps
plus per-packet overhead.

But wait, it's even faster!

1. Pure secret-key crypto
for any packet size:
80000 1500-byte packets/second
fill up a 1 Gbps link.

2. Pure secret-key crypto
for many packets
from same public key,
if application splits
`crypto_box` into
`crypto_box_beforenm` and
`crypto_box_afternm`.

3. Very fast rejection
of forged packets
under known public keys:
no time spent on decryption.

(This doesn't help much
for forgeries under *new* keys,
but flooded server can
continue providing fast service
to *known* keys.)

4. Fast batch verification,
doubling speed of
`crypto_sign_open`
for valid signatures.

Cryptographic details

The main work we did:
achieve these speeds
without compromising security.

ECC, not RSA:
much stronger security record.
Curve25519, not NSA/NIST
curves: twist-security et al.
Salsa20, not AES:
much larger security margin.
Poly1305, not HMAC:
information-theoretic security.
EdDSA, not ECDSA:
collision-resilience et al.