PBKDF2: performance matters

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http://jbp.io/

1. Quick intro to PBKDF2

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3. Your implementation is bad

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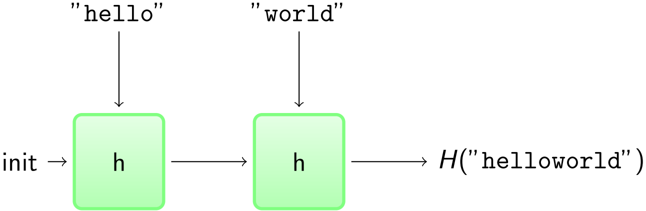
4. A faster PBKDF2

Intro: Merkle-Damgård hash functions

Basic construction of most hash functions: MD5, SHA-1, SHA-2.



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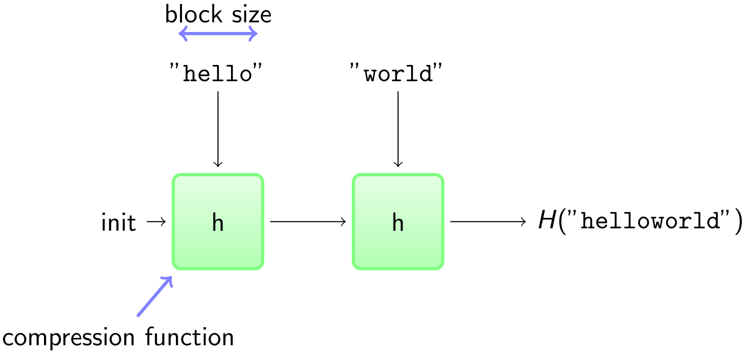
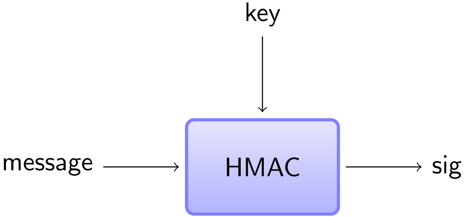
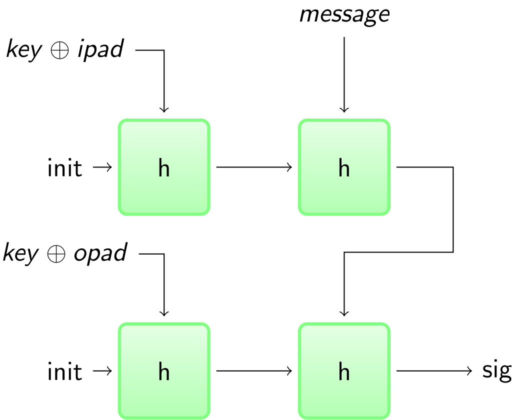


Intro: HMAC

Making secure symmetric signatures out of MD hash functions.



Intro: HMAC innards

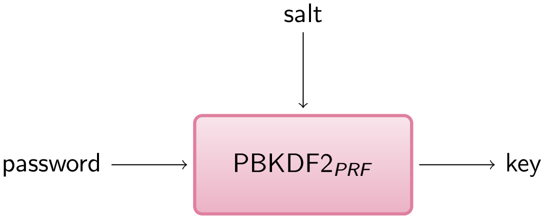


$$\text{HMAC-H}(\mathit{key}, \mathit{message}) := \text{H}(\mathit{key} \oplus \text{opad} \parallel \text{H}(\mathit{key} \oplus \text{ipad} \parallel \mathit{message}))$$

(for messages shorter than a block!)

Intro: PBKDF2

Slowly derive a key from a password and salt.



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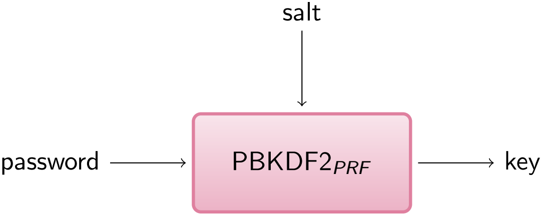

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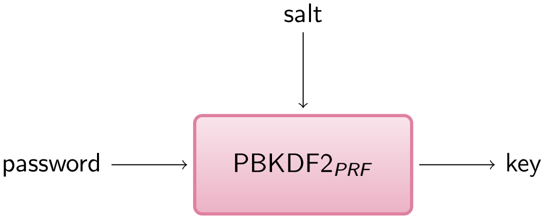

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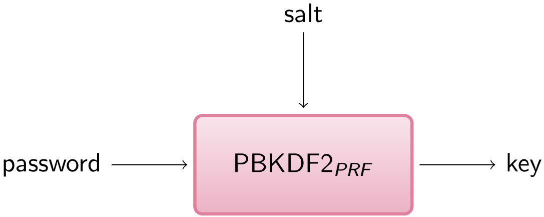

salt

password

PBKDF2$_{PRF}$

key

- Parameterised with a PRF, usually HMAC.
- Tunable computation cost, with iteration count.
- Origin: RSA labs, 1999. Described in PKCS#5 and then RFC2898.

Intro: PBKDF2

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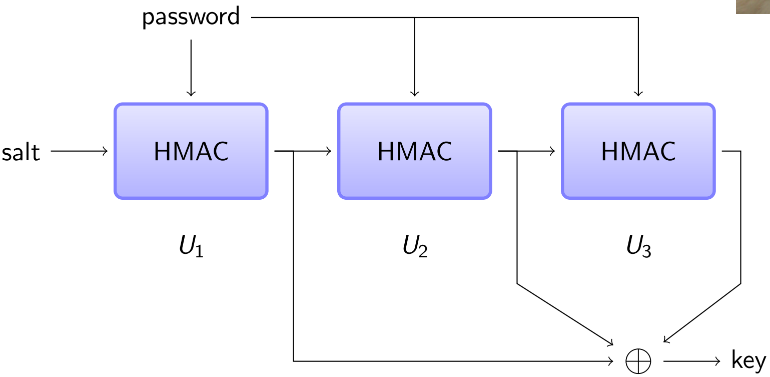
Simplification

PBKDF2 can produce arbitrary length output.
We're going to ignore this capability: assume it produces the same length output as the underlying hash.

Intro: PBKDF2$_{HMAC}$ with 3 iterations



$$\mathrm{PBKDF2}_{\mathrm{HMAC}}(\mathrm{password}, \mathrm{salt}, \mathrm{i}) := U_1 \oplus U_2 \oplus \cdots \oplus U_{\mathrm{i}}$$

where

$$U_1 := \mathrm{HMAC}(\mathrm{password}, \mathrm{salt})$$
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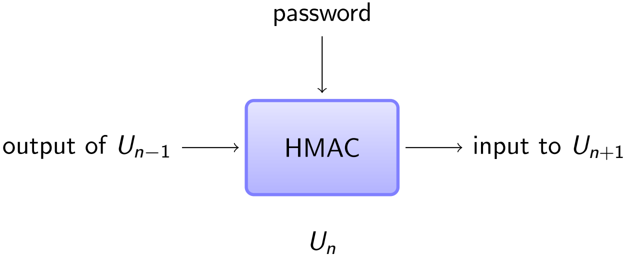
PBKDF2: perf vs. iteration count

One HMAC per iteration.



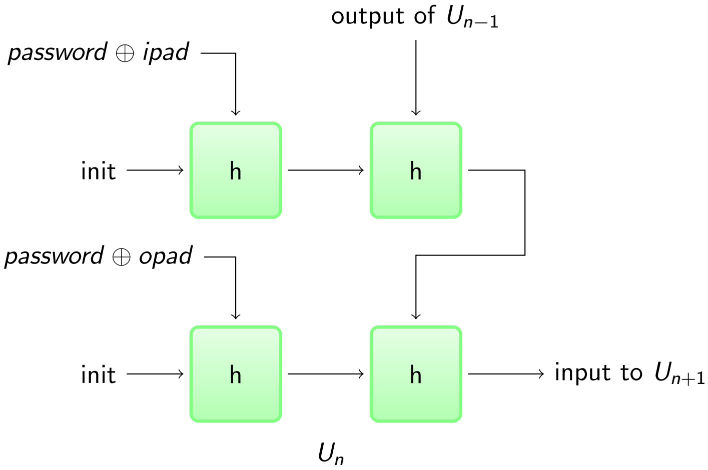
password

output of U_{n-1} ⟶ HMAC ⟶ input to U_{n+1}

U_n

How many compression function applications?

PBKDF2: perf vs. iteration count



Conclusion: $4i$ compression function applications for i iterations.

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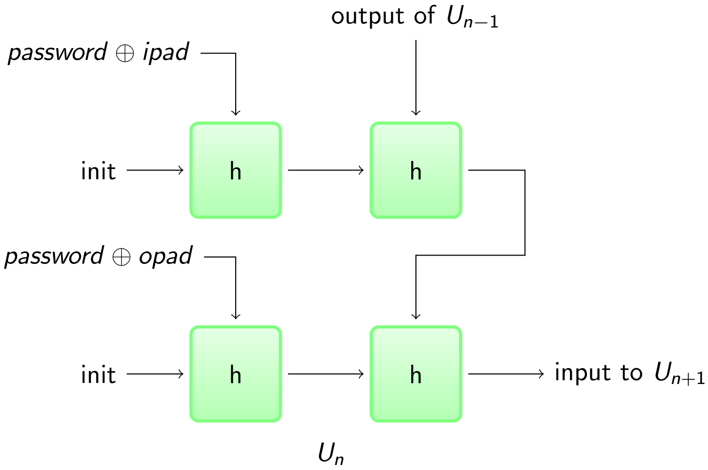

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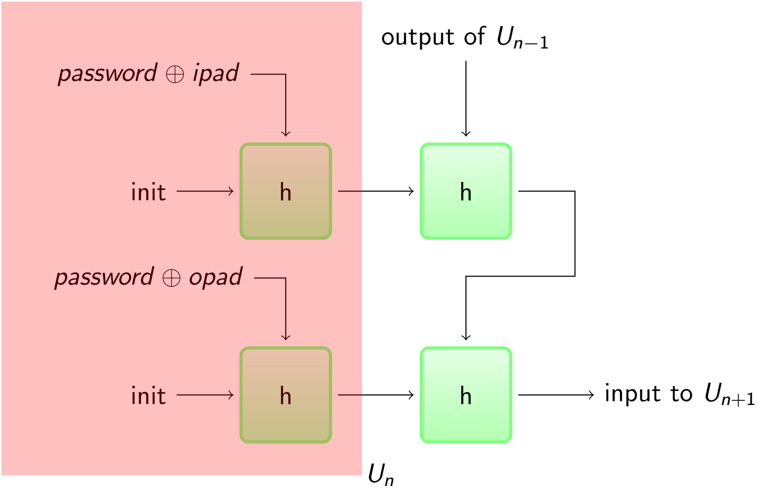

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$$\text{block } 2 : \mathit{msg}$$

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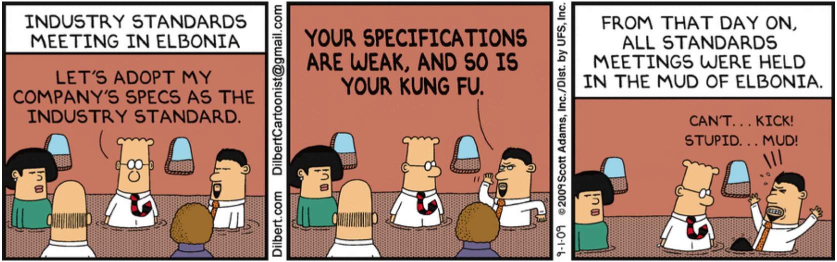
Therefore, we need to compute 4i SHA-256 blocks.

Nope!

This is suboptimal. Neither of the standards mention this, or even describe the expected performance :(


INDUSTRY STANDARDS MEETING IN ELBONIA
LET'S ADOPT MY COMPANY'S SPECS AS THE INDUSTRY STANDARD.
Dilbert.com DilbertCartoonist@gmail.com
YOUR SPECIFICATIONS ARE WEAK, AND SO IS YOUR KUNG FU.
9-1-09 ©2009 Scott Adams, Inc./Dist. by UFS, Inc.
FROM THAT DAY ON, ALL STANDARDS MEETINGS WERE HELD IN THE MUD OF ELBONIA.
CAN'T... KICK! STUPID... MUD!

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Actually, we only need compute $2 + 2i$ SHA-256 blocks.

Survey of defender implementations

I looked at the following PBKDF2s:

- FreeBSD 10
- GRUB 2.0
- Truecrypt 7.1a
- Android (disk encryption)
- Android (BouncyCastle)
- Django
- OpenSSL
- Python core ($\geq$3.4)
- Python (pypi pbkdf2)
- Ruby (pbkdf2 gem)
- Go (go.crypto)
- OpenBSD
- PolarSSL/mbedTLS
- CyaSSL/wolfSSL
- SJCL
- Java
- Common Lisp (ironclad)
- Perl (Crypt::PBKDF2)
- PHP5
- .NET framework
- scrypt/yescrypt[1]
- BouncyCastle

[1] never called for scrypt/yescrypt with iterations != 1

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Measured on Intel Atom N2800 (1.86GHz), best of five runs, CPU time in user mode.

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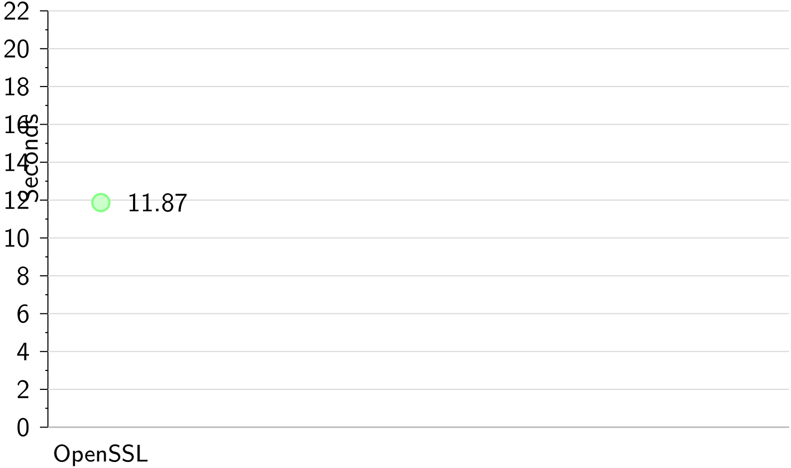

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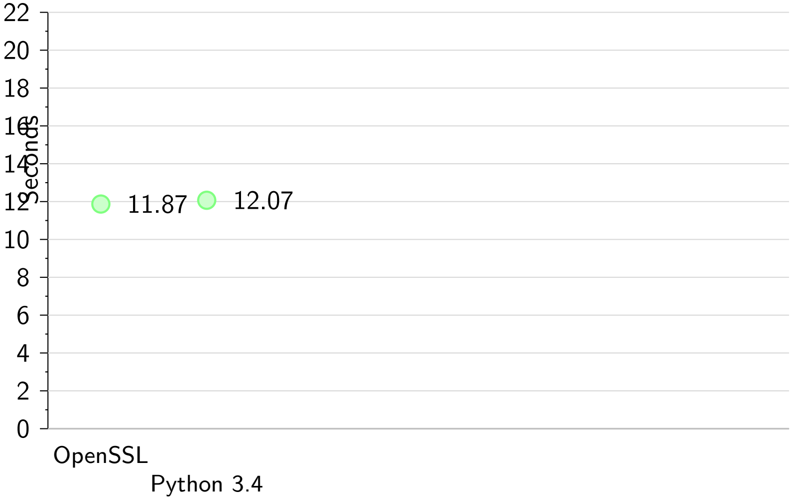

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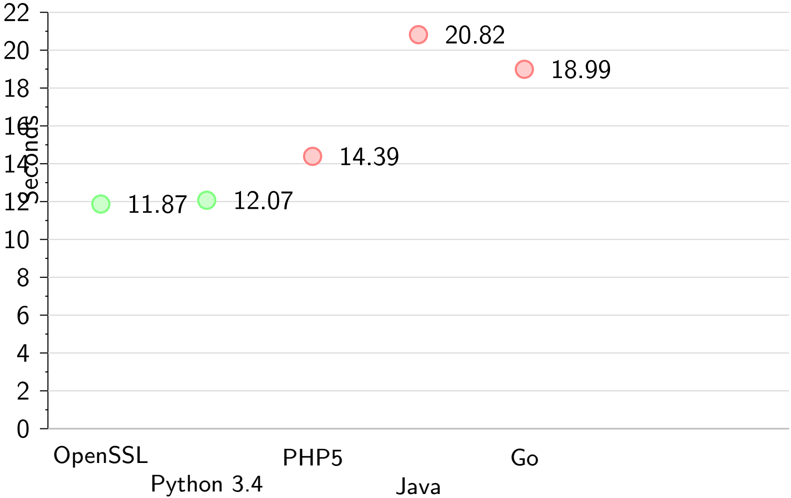

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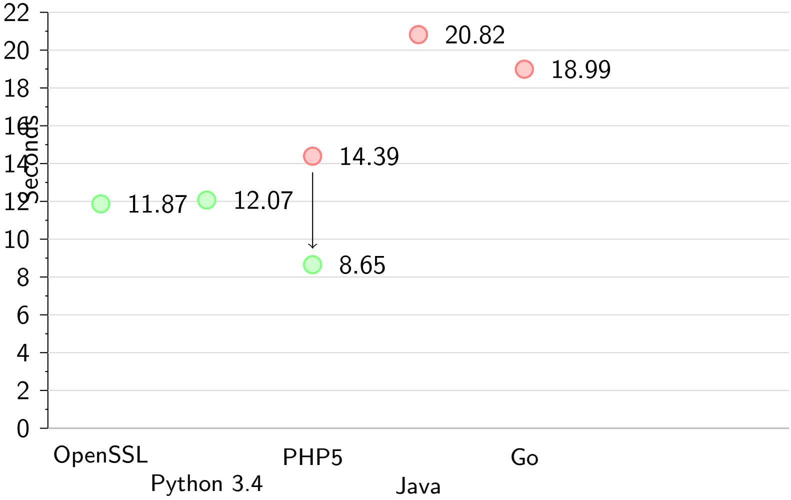

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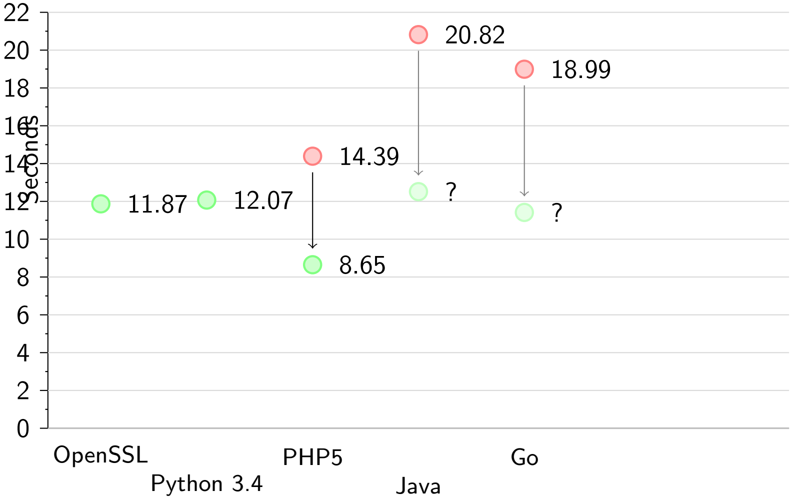

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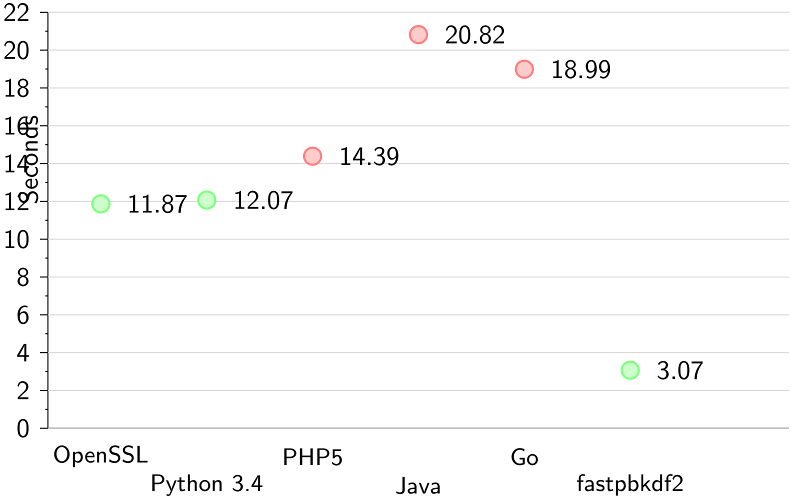

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A faster PBKDF2-HMAC-{SHA-1,SHA-256,SHA-512} for defenders.

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- https://github.com/ctz/fastpbkdf2/

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- Most implementations waste time and power.
- If you use PBKDF2, you can probably drop in a faster implementation and either increase security margin, or improve time/power performance.
- Please try not to use PBKDF2 any more.

Thank you!

Questions?

Twitter: @jpixton
Mail: jbp@jbp.io
Web: https://jbp.io/
Slides and benchmarking code: https://github.com/ctz/talks/