

PBKDF2: performance matters

Joseph Birr-Pixton

@jpixton

<https://jbp.io/>



1. Quick intro to PBKDF2





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2. The standard is bad





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3. Your implementation is bad





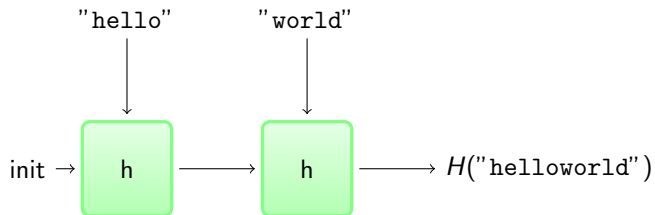
1. Quick intro to PBKDF2
2. The standard is bad
3. Your implementation is bad
4. A faster PBKDF2



Intro: Merkle-Damgård hash functions



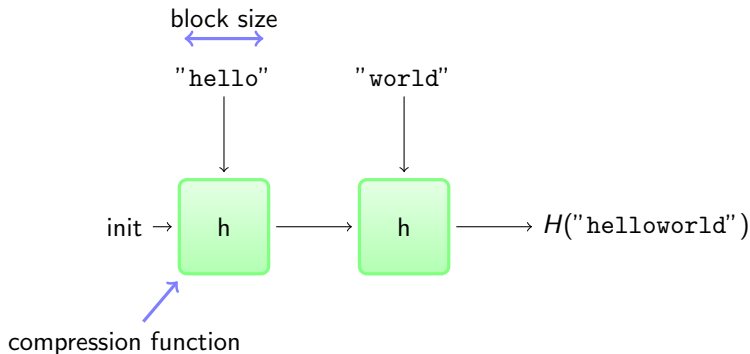
Basic construction of most hash functions: MD5, SHA-1, SHA-2.



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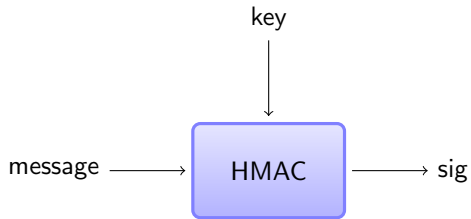
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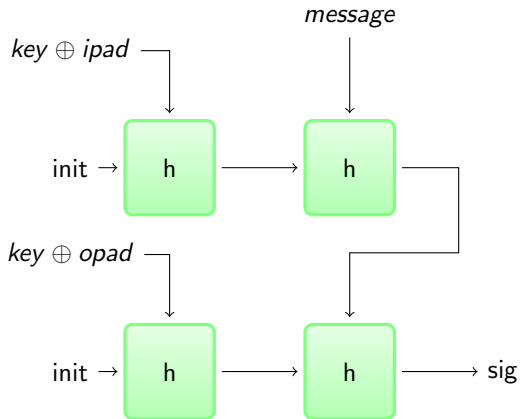
Intro: HMAC



Making secure symmetric signatures out of MD hash functions.



Intro: HMAC innards



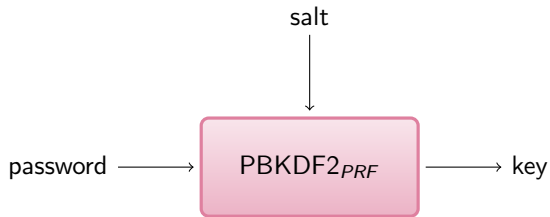
$$\text{HMAC-H}(key, message) := H((key \oplus opad) \parallel H((key \oplus ipad) \parallel message))$$

(for messages shorter than a block!)

Intro: PBKDF2



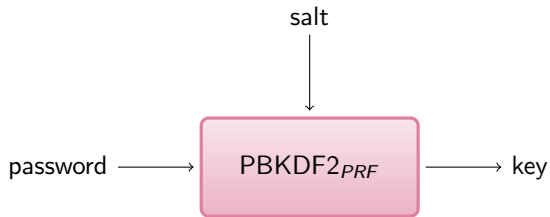
Slowly derive a key from a password and salt.



Intro: PBKDF2



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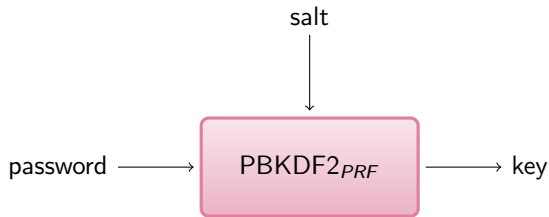


- ▶ Parameterised with a PRF, usually HMAC.

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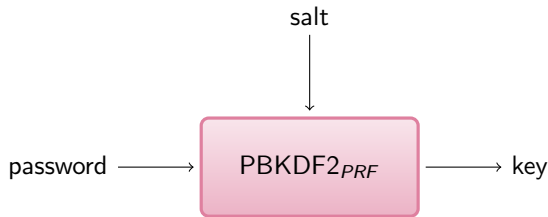


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- ▶ Tunable computation cost, with iteration count.

Intro: PBKDF2



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- ▶ 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



Iteration count choice

1. Choose computation budget (say, 50ms).
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Performance

Performance profile is *important* for defenders. Aim: to maximise attacker work for defender computation budget.

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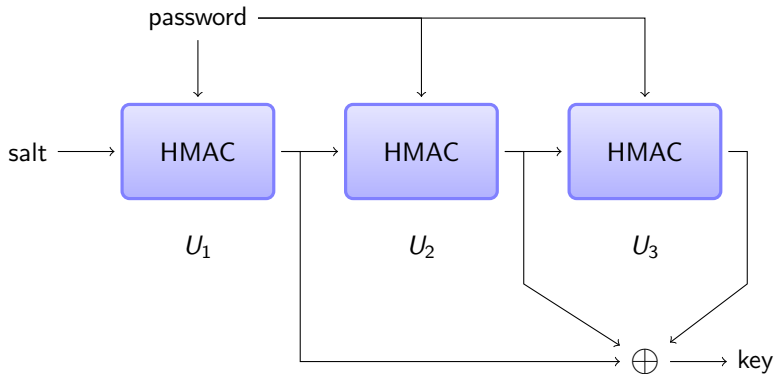
Performance

Performance profile is *important* for defenders. Aim: to maximise attacker work for defender computation budget.

For simplicity

Assume salts, passwords are less than block size. Assume output length is not more than hash output size.

Intro: PBKDF2_{HMAC} with 3 iterations



$$\text{PBKDF2}_{\text{HMAC}}(\text{password}, \text{salt}, i) := U_1 \oplus U_2 \oplus \dots \oplus U_i$$

where

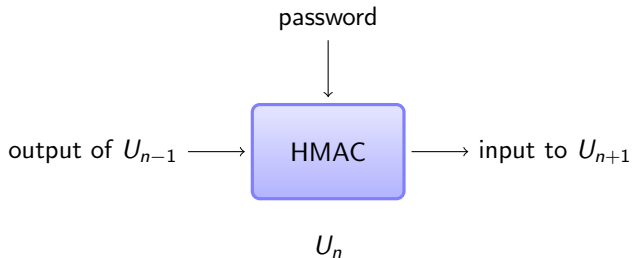
$$U_1 := \text{HMAC}(\text{password}, \text{salt})$$

$$U_n := \text{HMAC}(\text{password}, U_{n-1})$$

PBKDF2: perf vs. iteration count

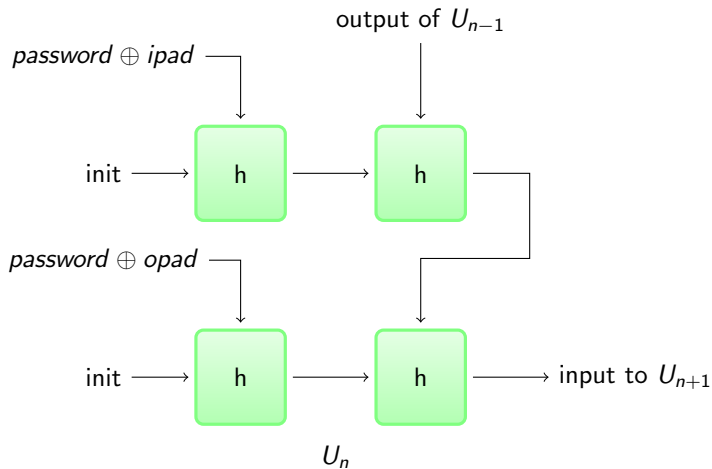


One HMAC per iteration.

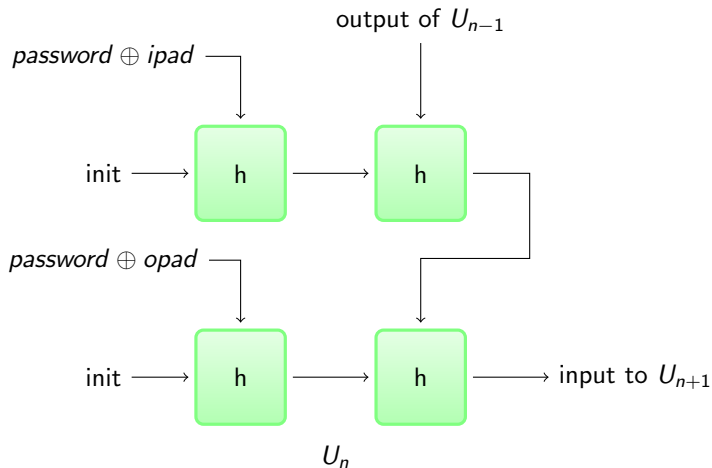


How many compression function applications?

PBKDF2: perf vs. iteration count



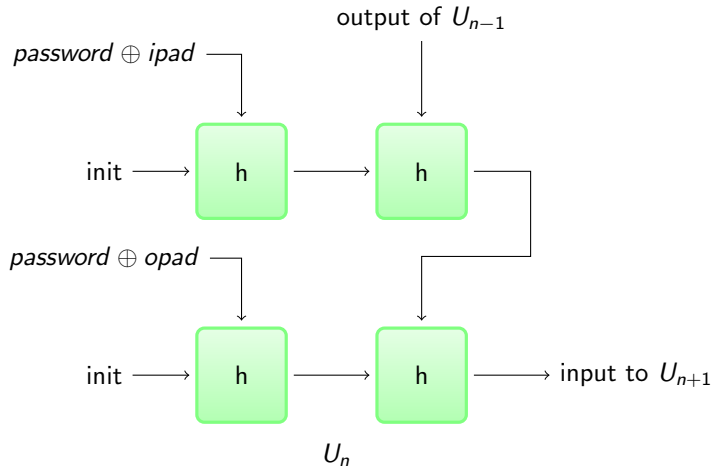
PBKDF2: perf vs. iteration count



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

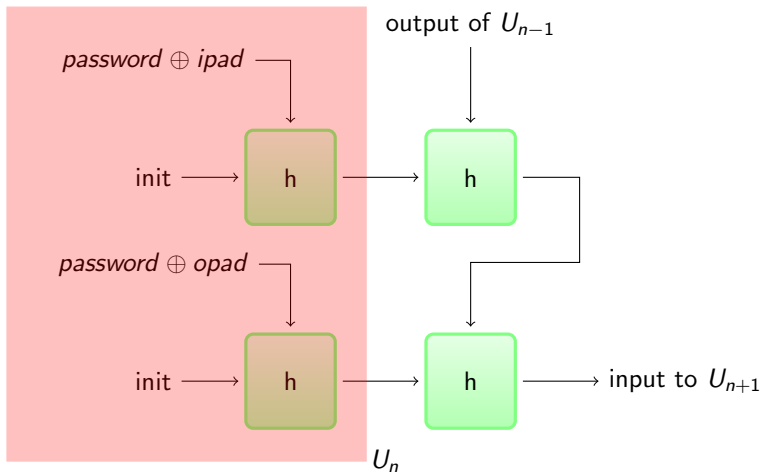
Nope!

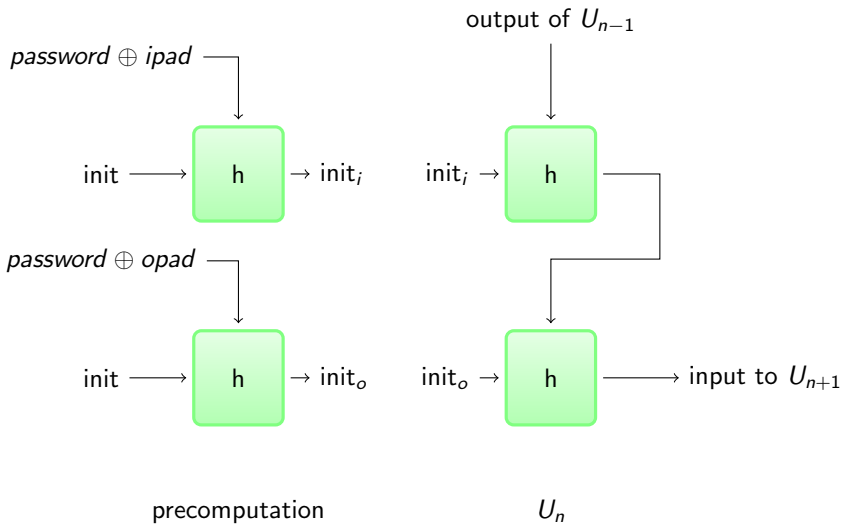
This is suboptimal. Neither of the standards mention this, or even describe the expected performance :(

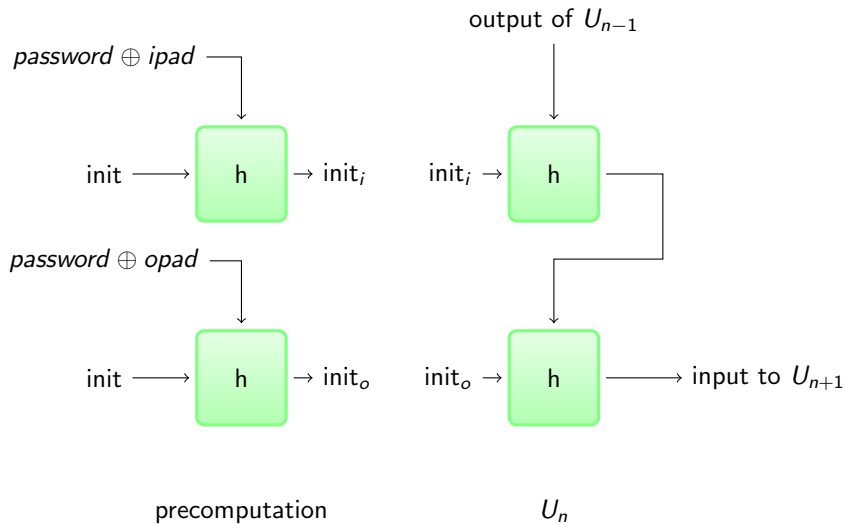


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Actually $2 + 2i$ compression function applications for i iterations.

Survey of defender implementations

I looked at the following PBKDF2s:

Survey of defender implementations

- ▶ FreeBSD 10
- ▶ GRUB 2.0
- ▶ Truecrypt 7.1a
- ▶ Android (disk encryption)
- ▶ Android BouncyCastle fork
- ▶ Django
- ▶ OpenSSL
- ▶ Python core (≥ 3.4)
- ▶ Python (pypi pbkdf2)
- ▶ Ruby (pbkdf2 gem)
- ▶ Go (go.crypto)
- ▶ Apple CoreCrypto (disassembly)
- ▶ OpenBSD
- ▶ PolarSSL/mbedTLS
- ▶ CyaSSL/wolfSSL
- ▶ SJCL
- ▶ Java (OpenJDK)
- ▶ Common Lisp (ironclad)
- ▶ Perl (Crypt::PBKDF2)
- ▶ PHP5
- ▶ .NET framework
- ▶ scrypt/yescript¹
- ▶ BouncyCastle

¹never called for scrypt/yescript with iterations $\neq 1$

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Don't blame implementors for bad crypto standards



Selected performance measurements

- ▶ Question: how much practical difference does this make?

Selected performance measurements

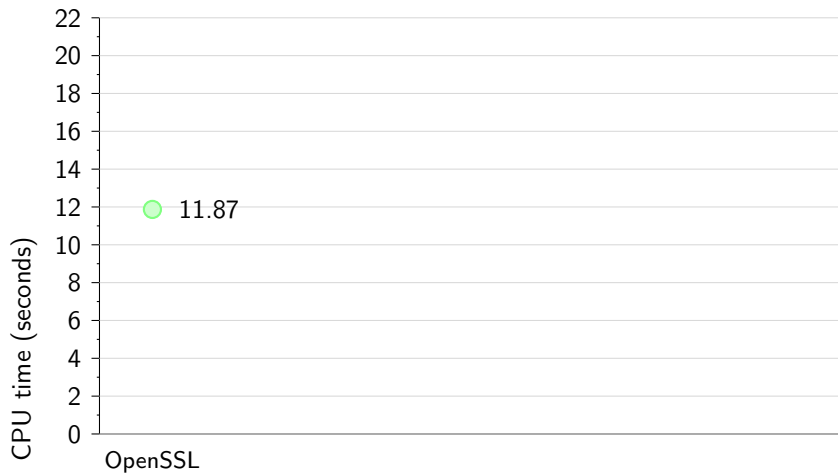
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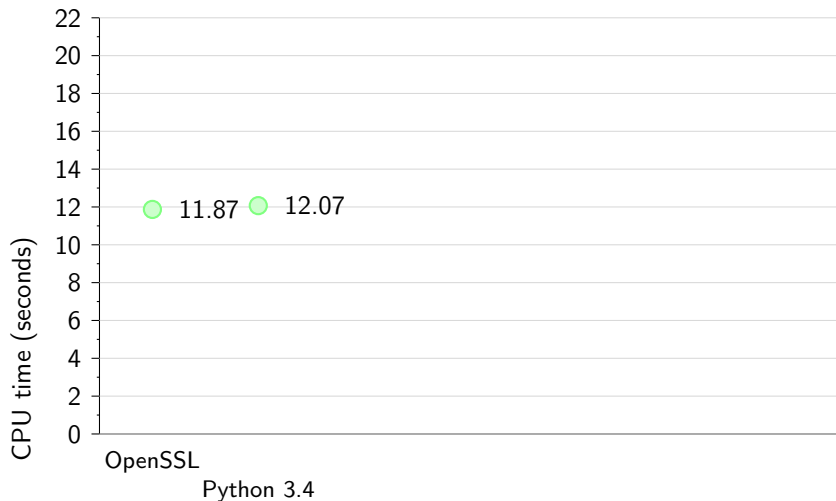
Measured on Intel Atom N2800 (1.86GHz), best of five runs, CPU time in user mode.

Selected performance measurements



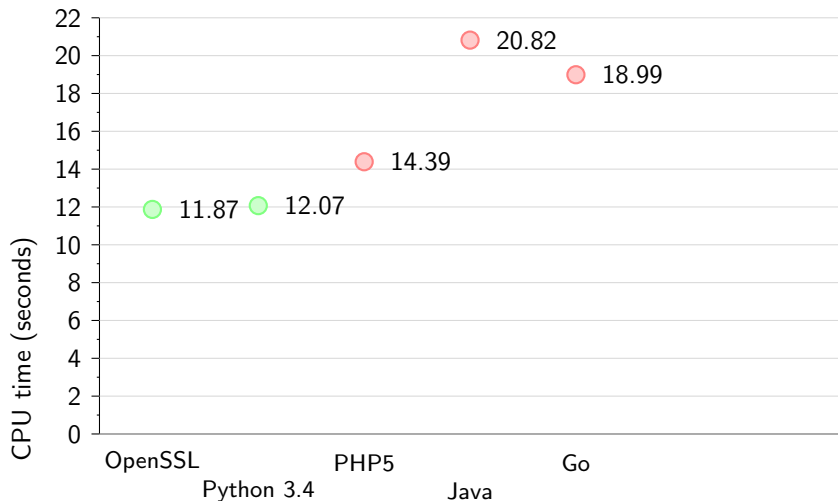
PBKDF2-HMAC-SHA1, one block output, 2^{22} iterations

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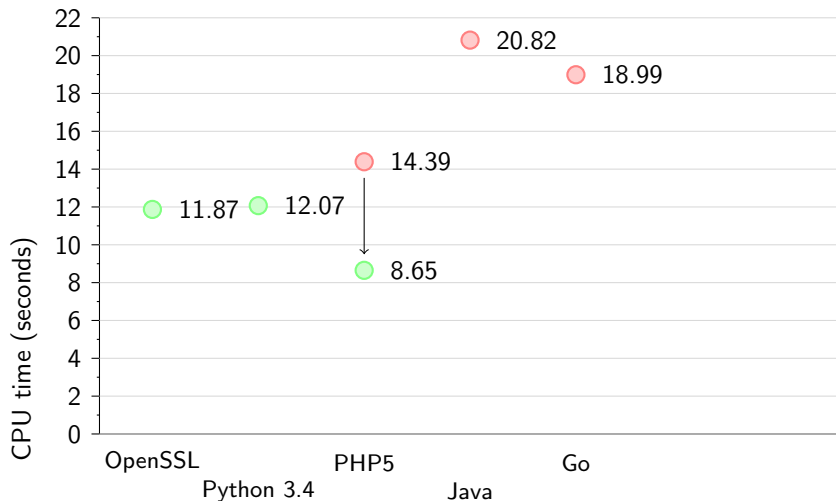
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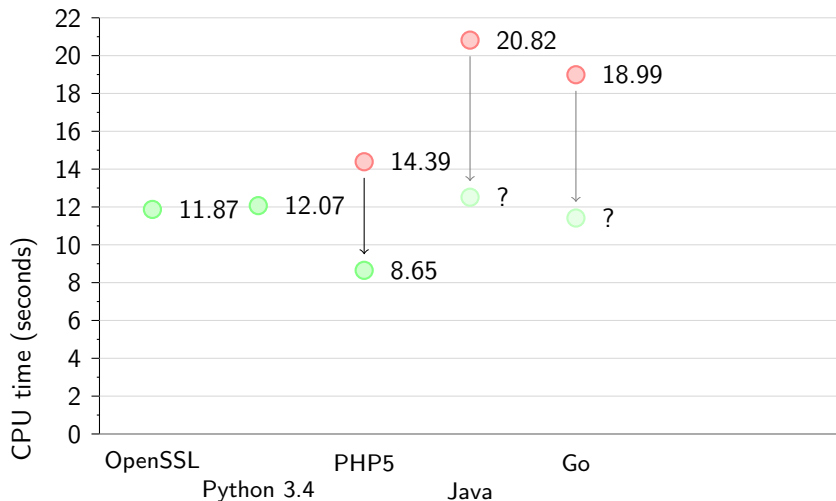
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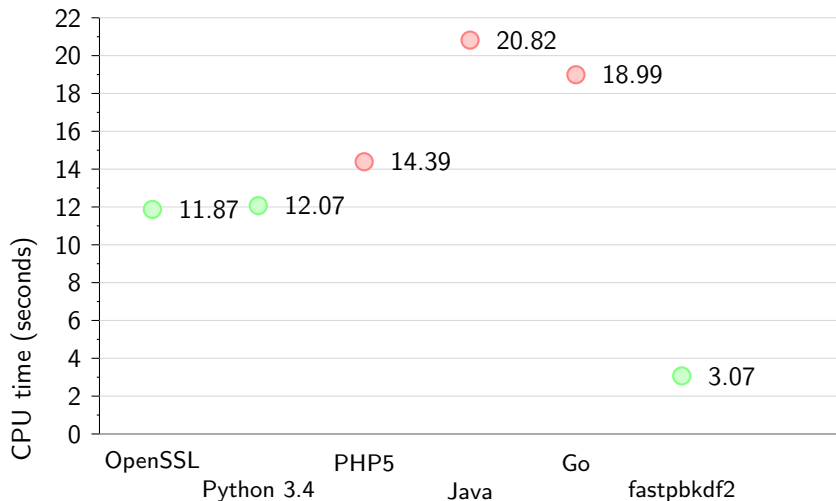
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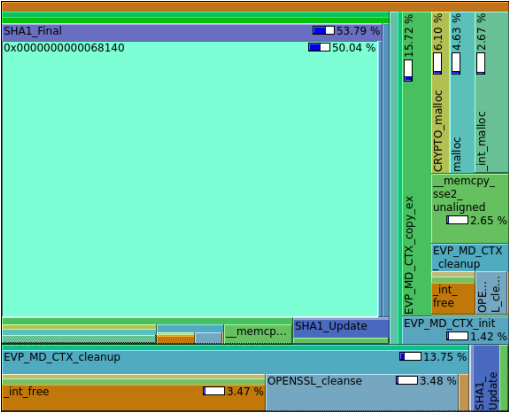
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- ▶ <https://github.com/ctz/fastpbkdf2/>

fastpbkdf2



OpenSSL



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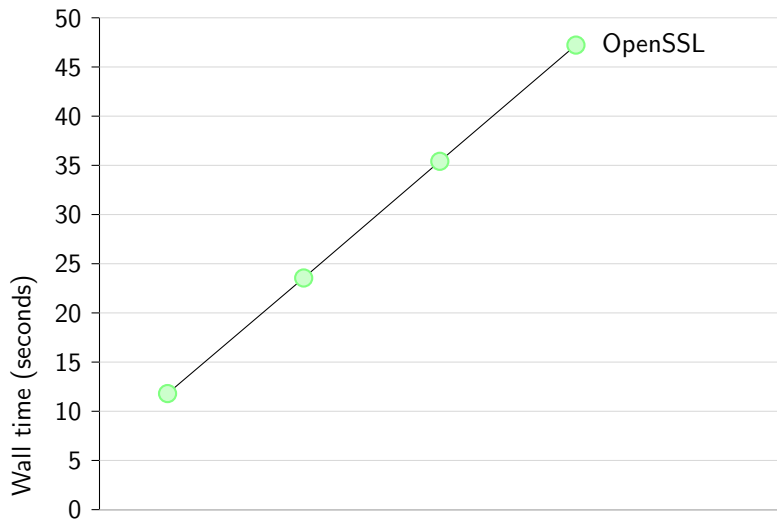
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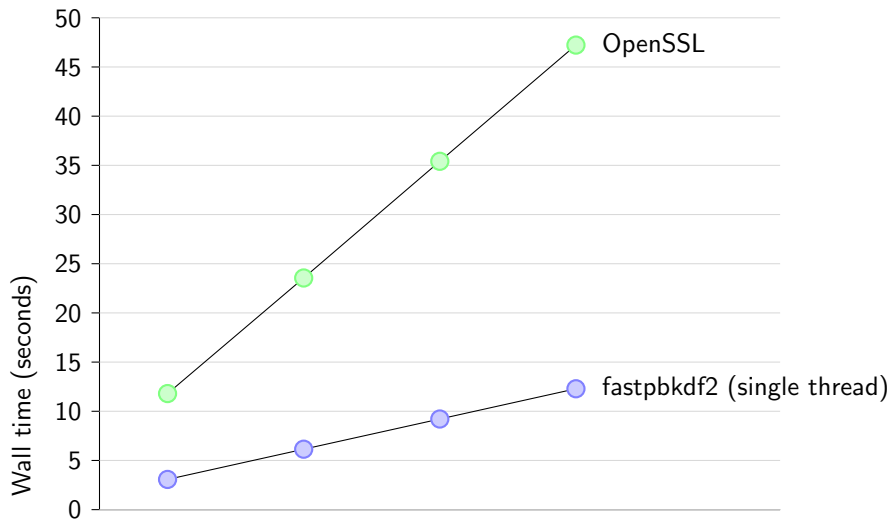
But, in any case, `fastpbkdf2` optionally parallelises this.

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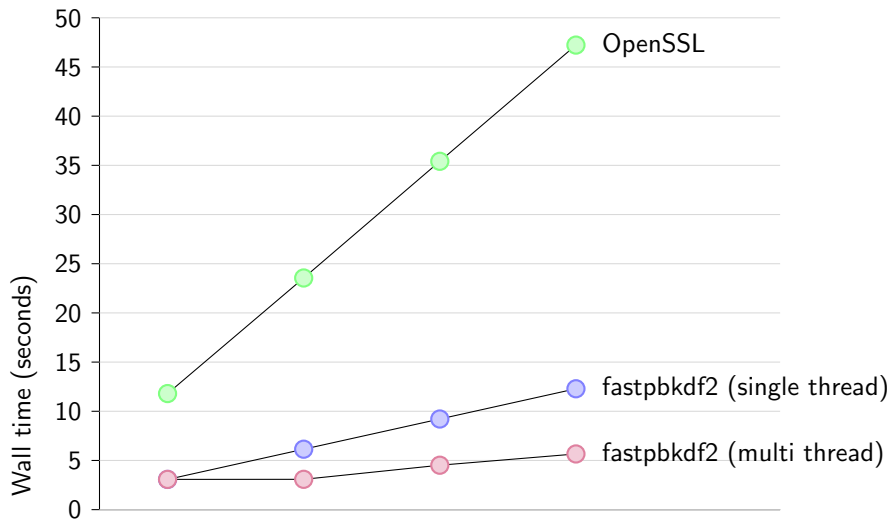
PBKDF2-HMAC-SHA1, one-four blocks output, 2^{22} iterations, two cores + HT

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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.)

Thank you!

Questions?

Twitter:

@jpixton

Mail:

jbp@jbp.io

Web:

<https://jbp.io/>

Slides and notes:

<https://github.com/ctz/talks/>

fastpbkdf2:

<https://github.com/ctz/fastpbkdf2/>