PBKDF2: performance matters

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http://jbp.io/

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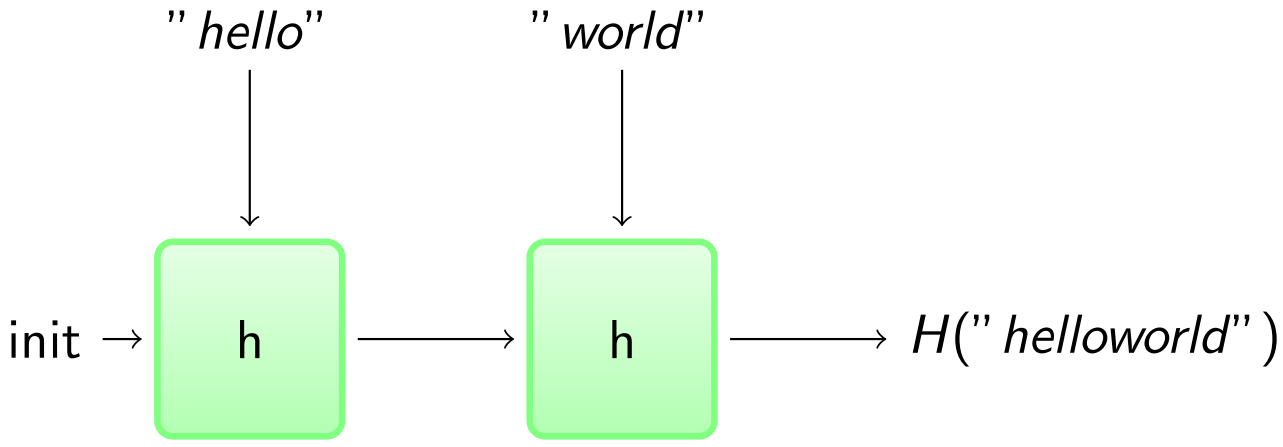
4. A faster PBKDF2

Intro: Merkle-Damgård hash functions

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



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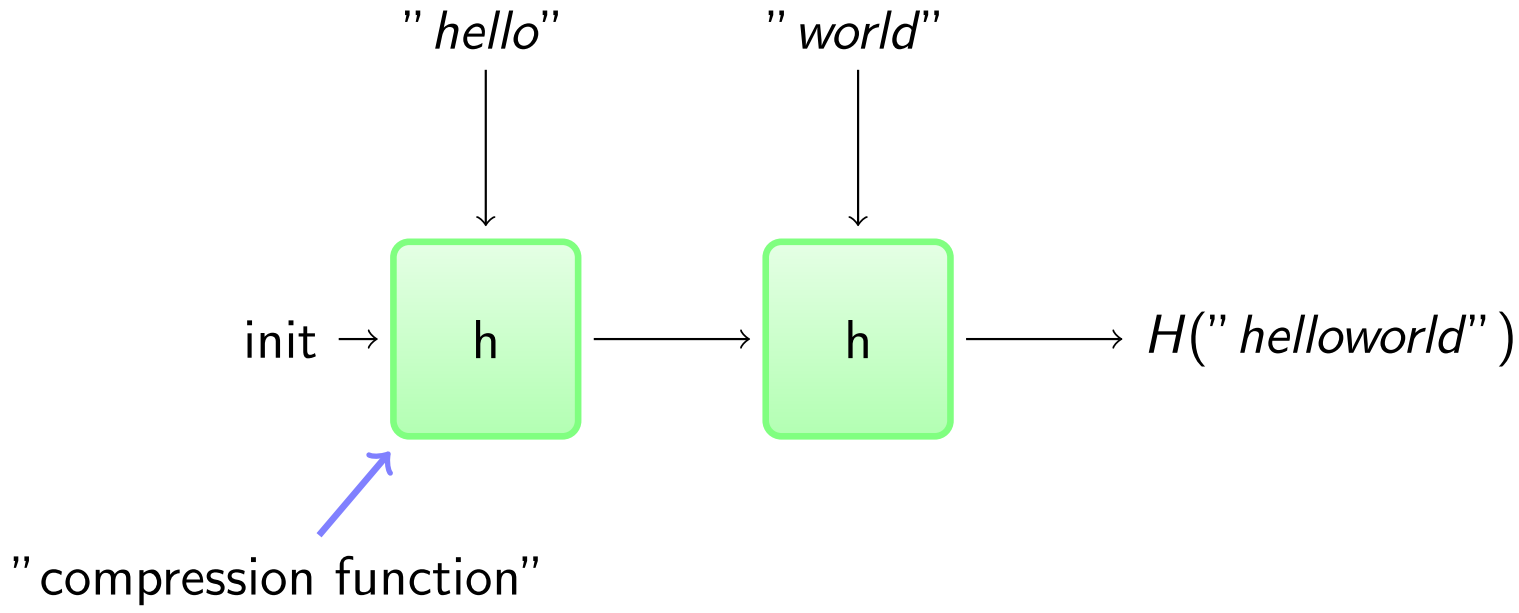
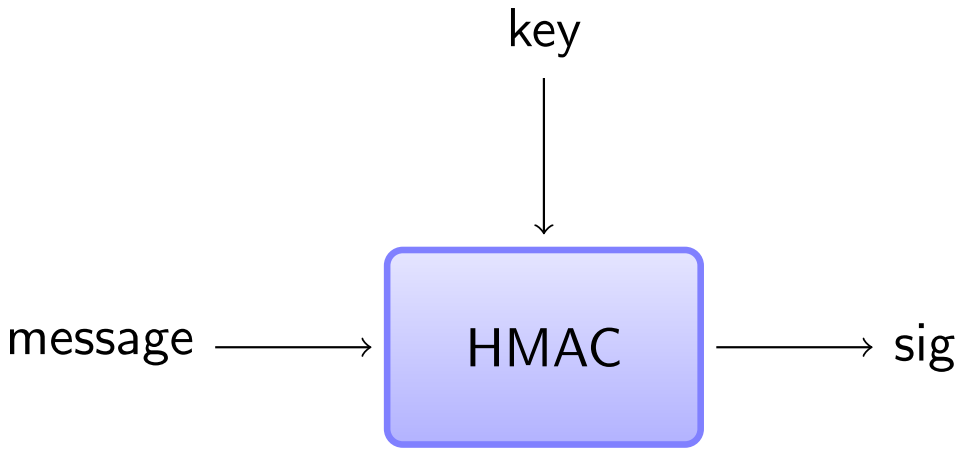


Intro: HMAC

Making secure symmetric signatures out of MD hash functions.



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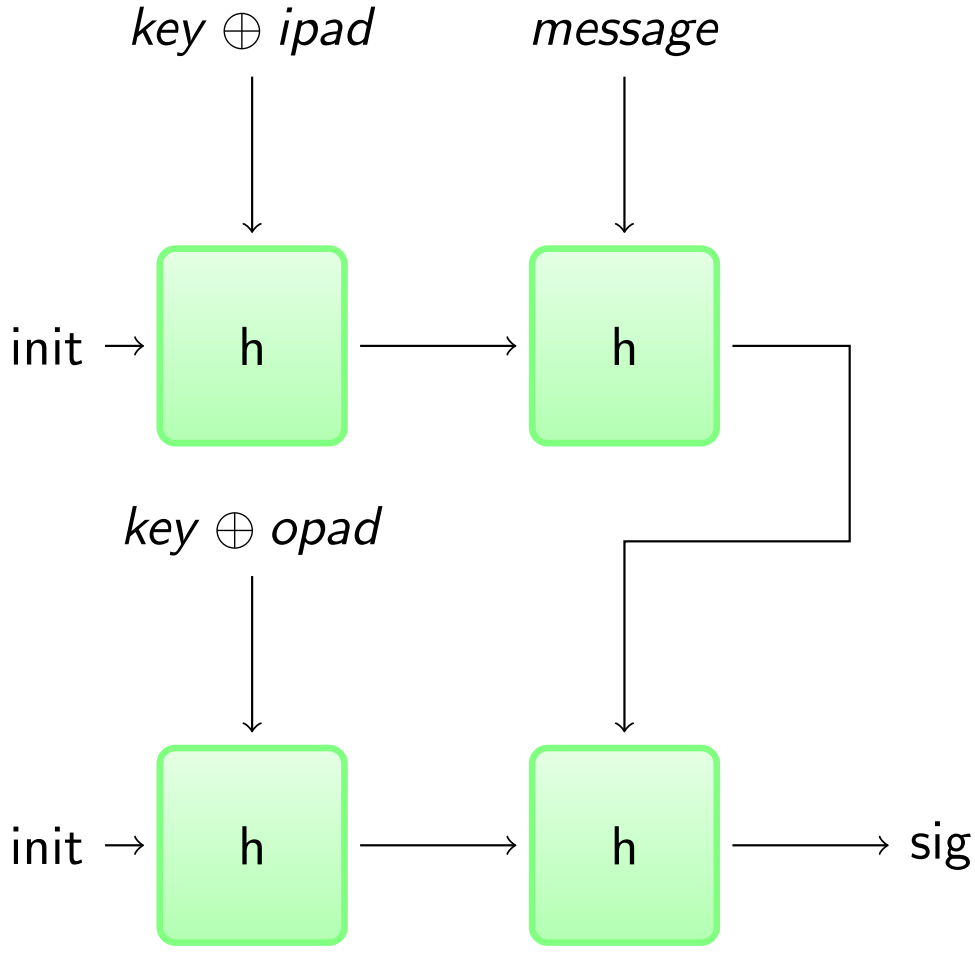
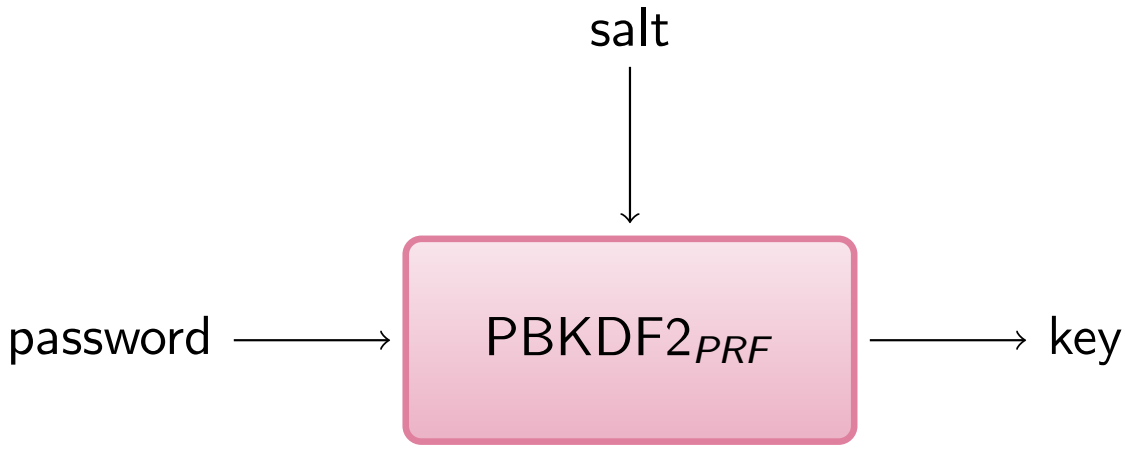


HMAC-H(*key*, *message*) := H(*key* ⊕ opad ‖ H(*key* ⊕ ipad ‖ *message*))

(for messages shorter than a block!)

Intro: PBKDF2

Slowly derive a key from a password and salt.



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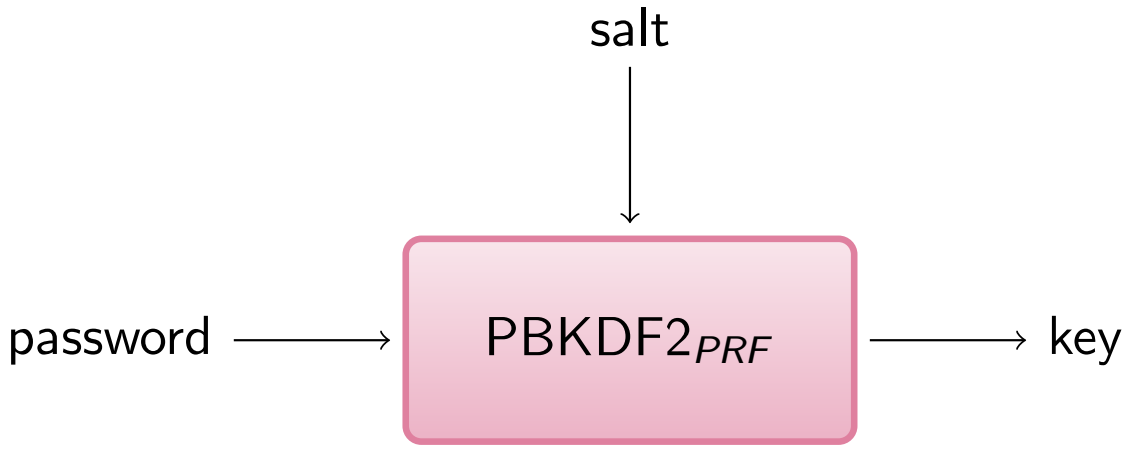

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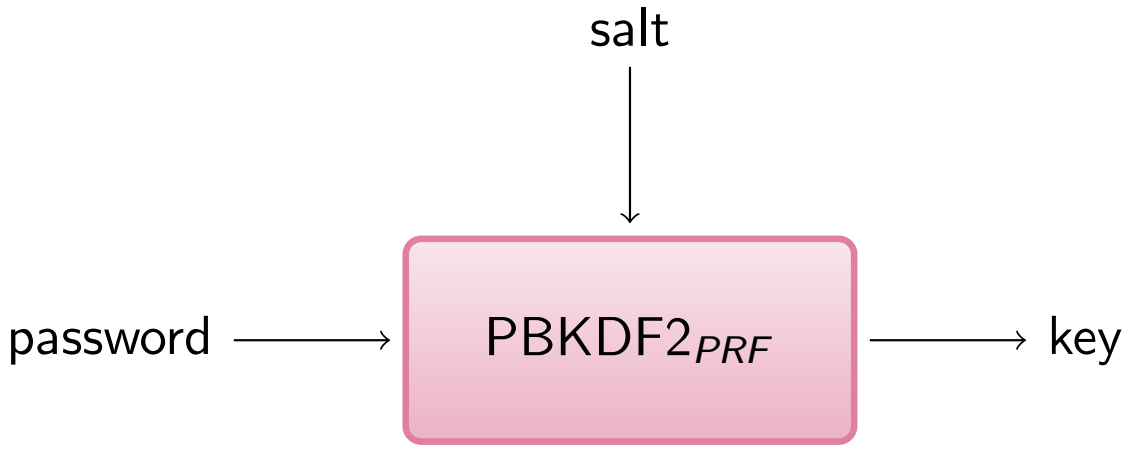
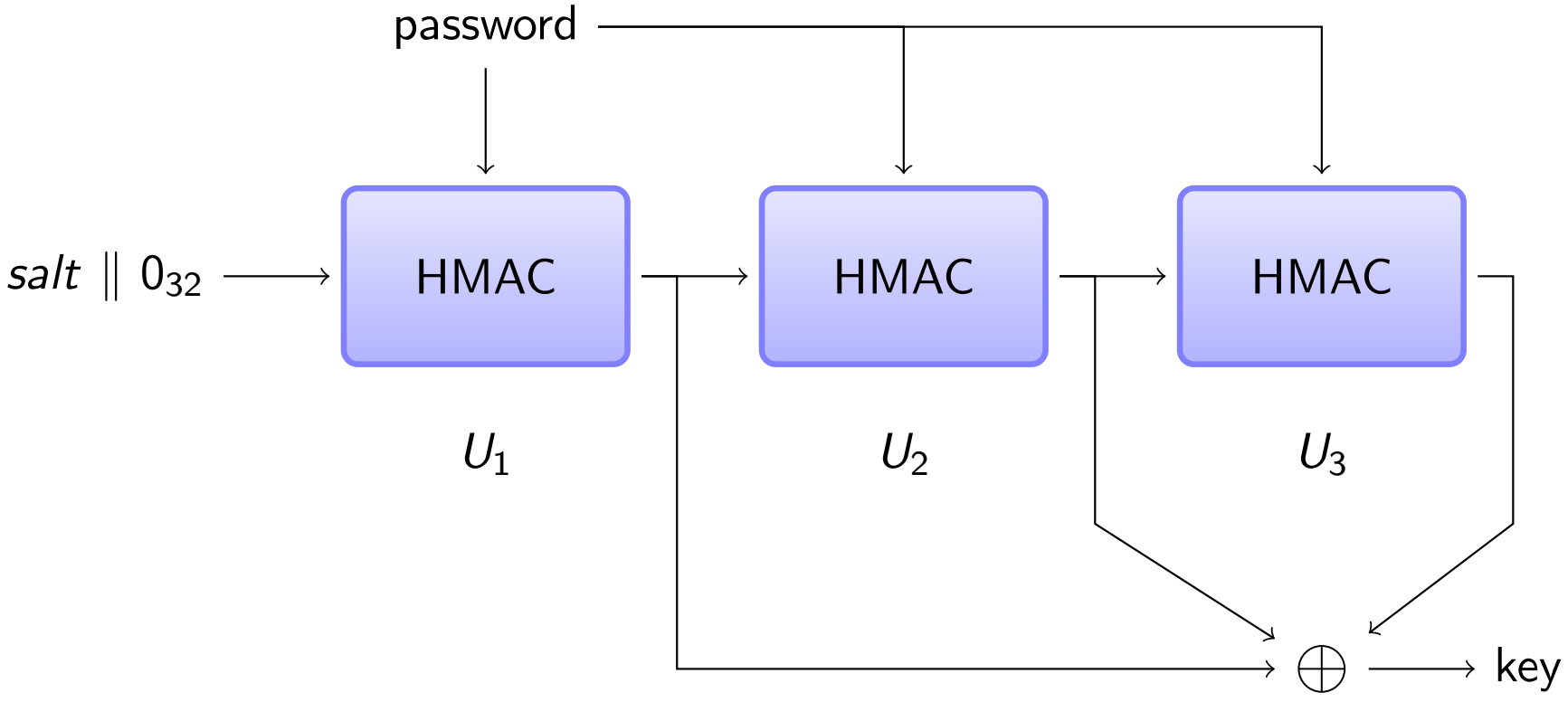


- Parametised with a PRF, usually HMAC.
- Tunable computation cost, with iteration count.

Intro: PBKDF2_{HMAC} with 3 iterations



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

where

$$U_1 := \text{HMAC}(\text{pw}, \text{salt} \parallel 0_{32})$$

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RSA labs, 1999. Described in PKCS#5 and then RFC2898

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Usage

- Password verification (web sites, network services, etc.)
- Key derivation (disk encryption, key management, etc.)

PBKDF2: quick intro

Performance

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

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Simplification

PBKDF2 can produce arbitrary length output.
We're going to ignore this capability from here on in: only considering the first block of output.

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and typically

$$\text{PRF}(\text{pw}, \text{x}) = \text{HMAC-H}(\text{pw}, \text{x})$$

$$H = \text{SHA-1, SHA-256, SHA-512, or ...}$$

Zoom, enhance

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block 2 : msg

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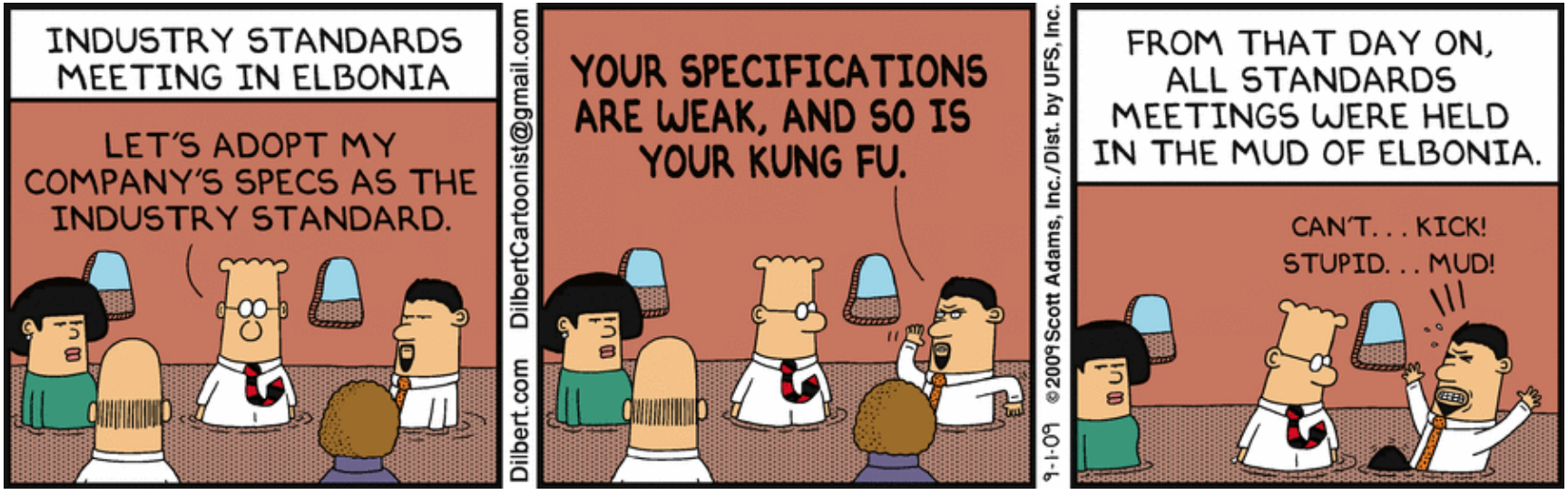
Therefore, we need to compute 4i SHA-256 blocks.

Nope!

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



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How many times?

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

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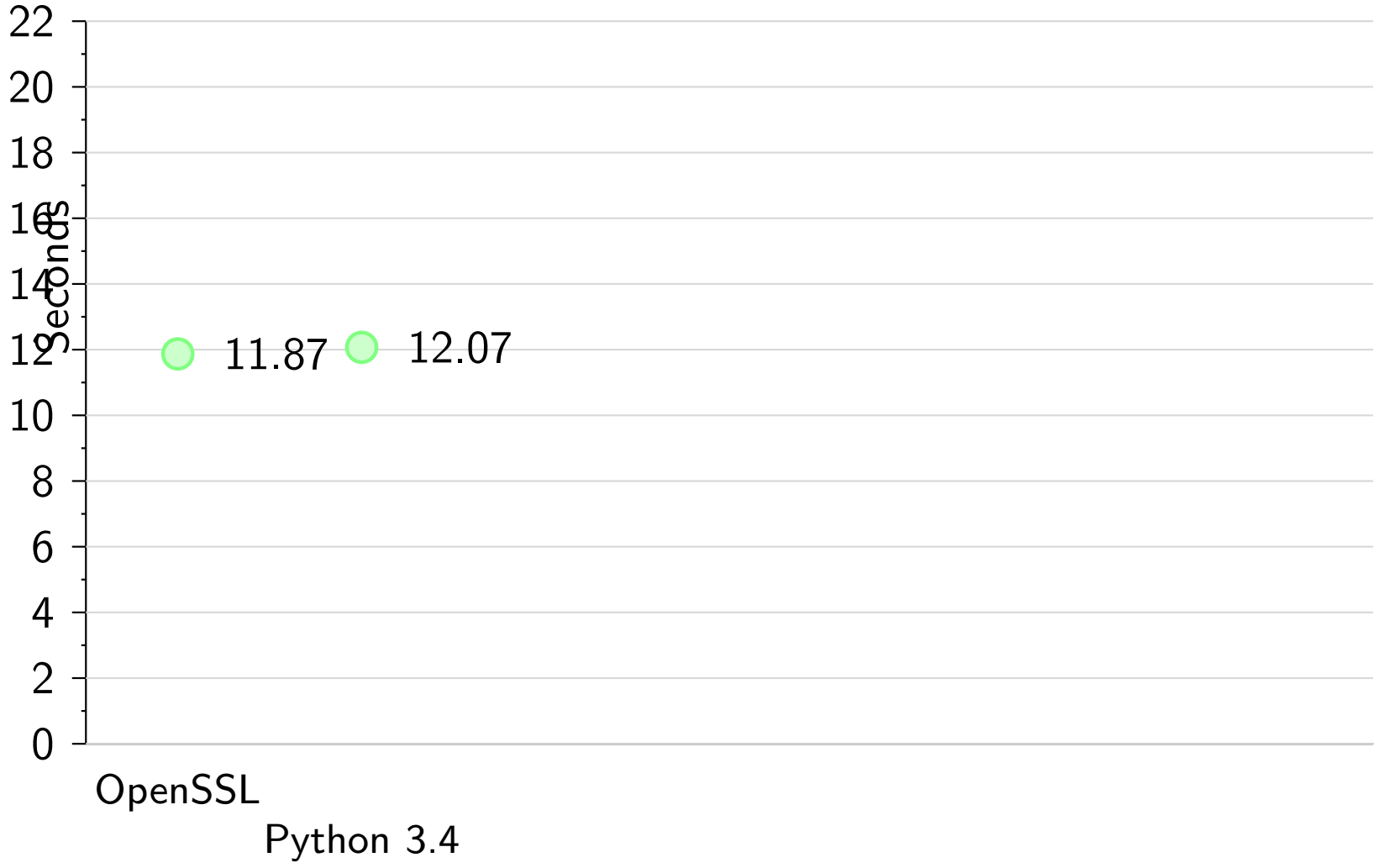

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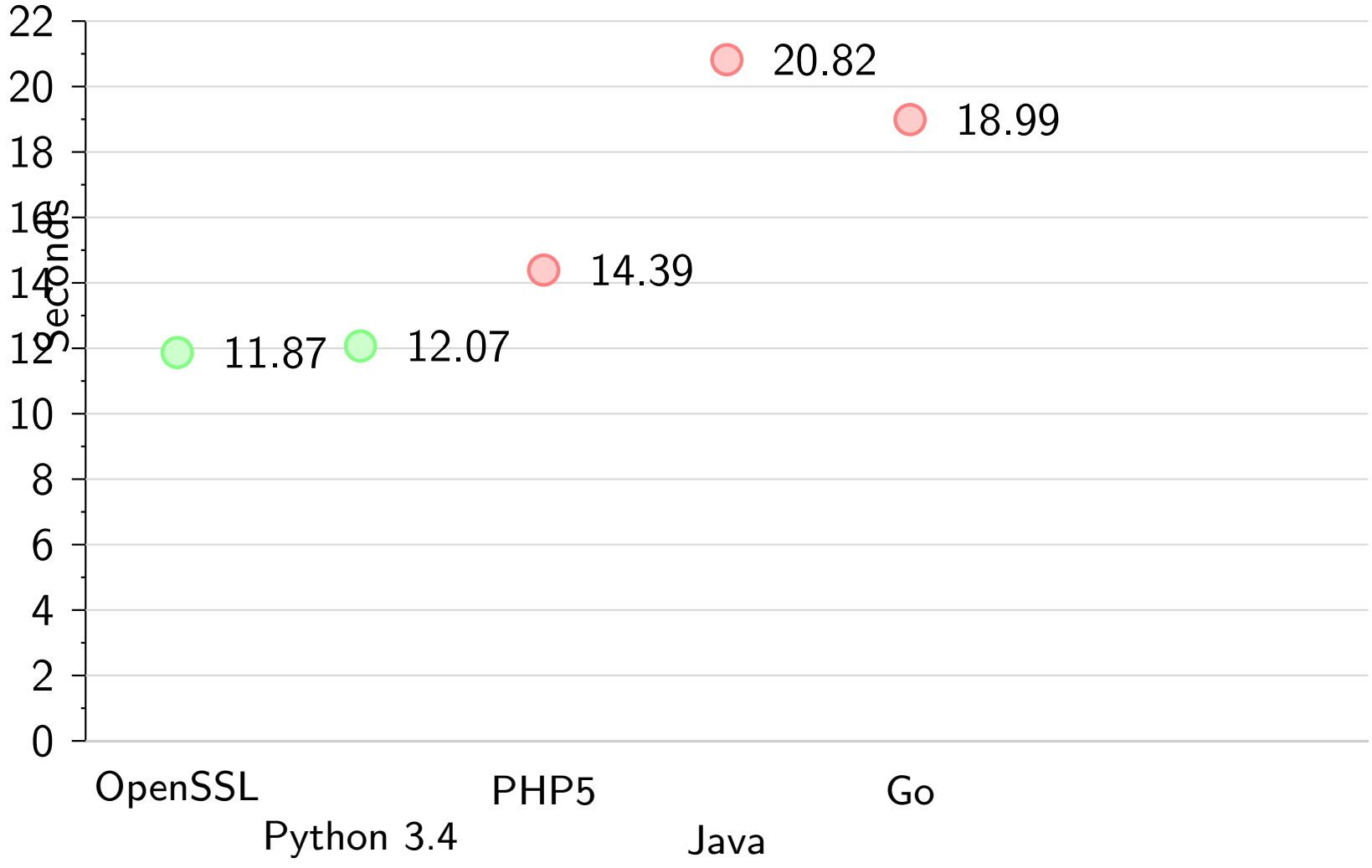

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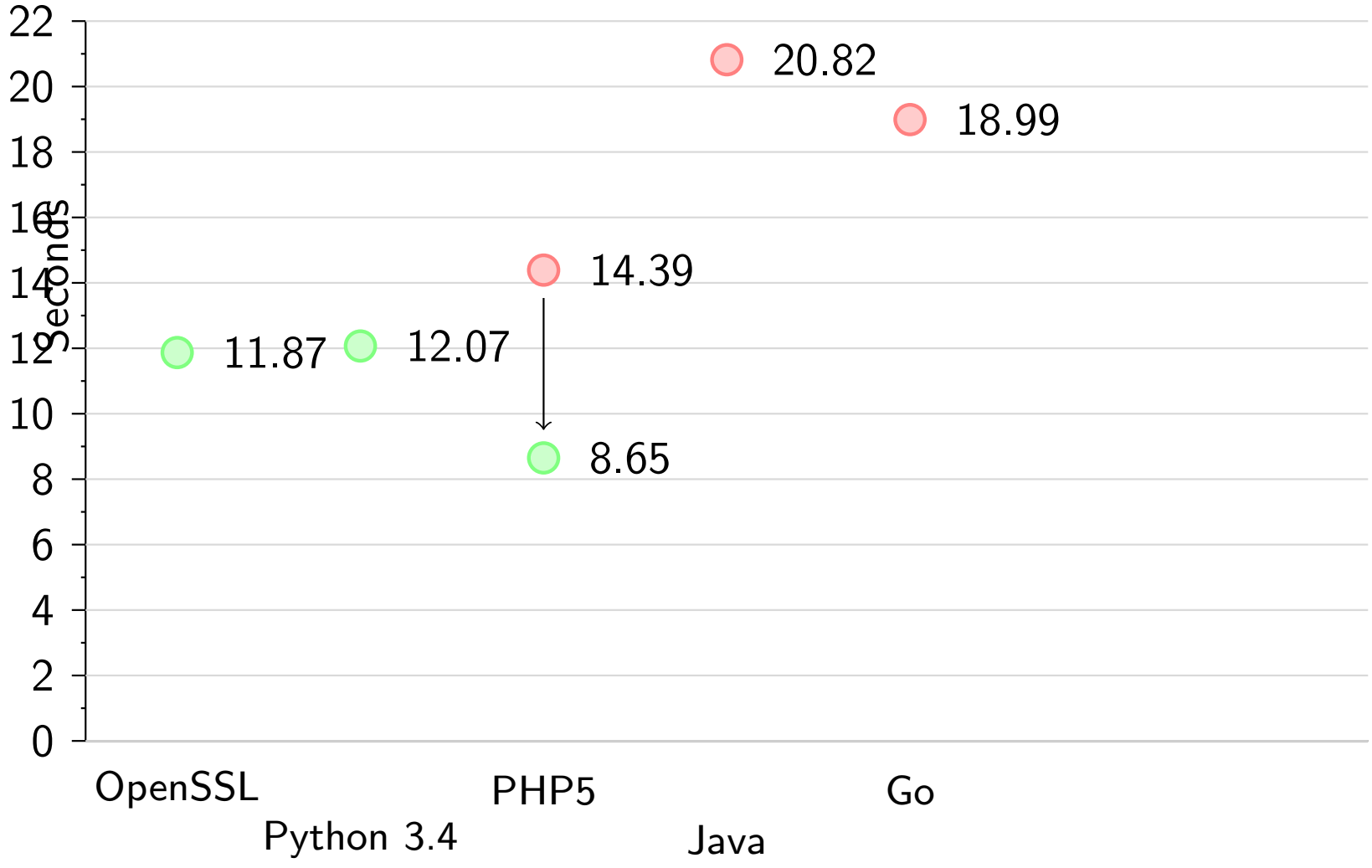

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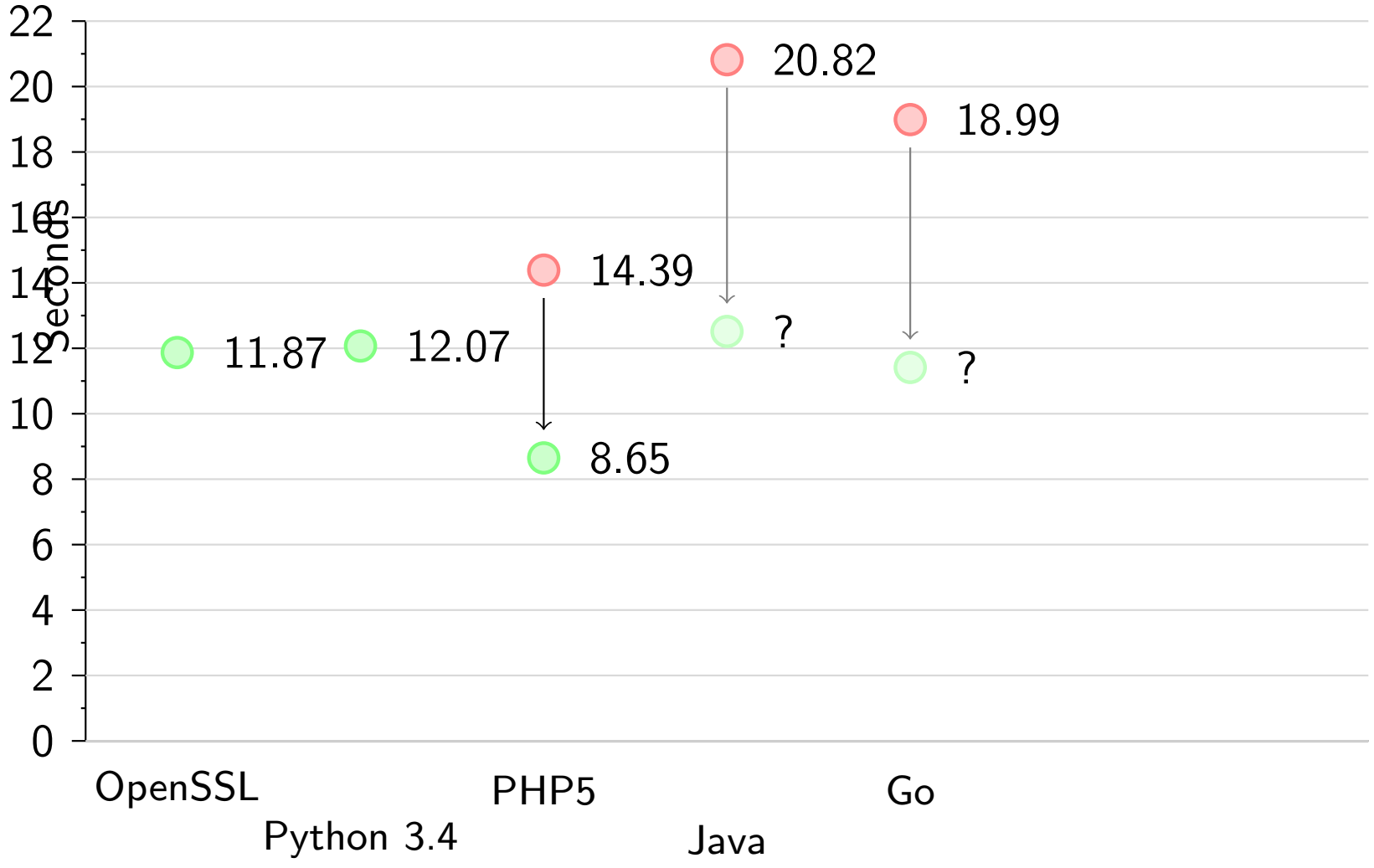

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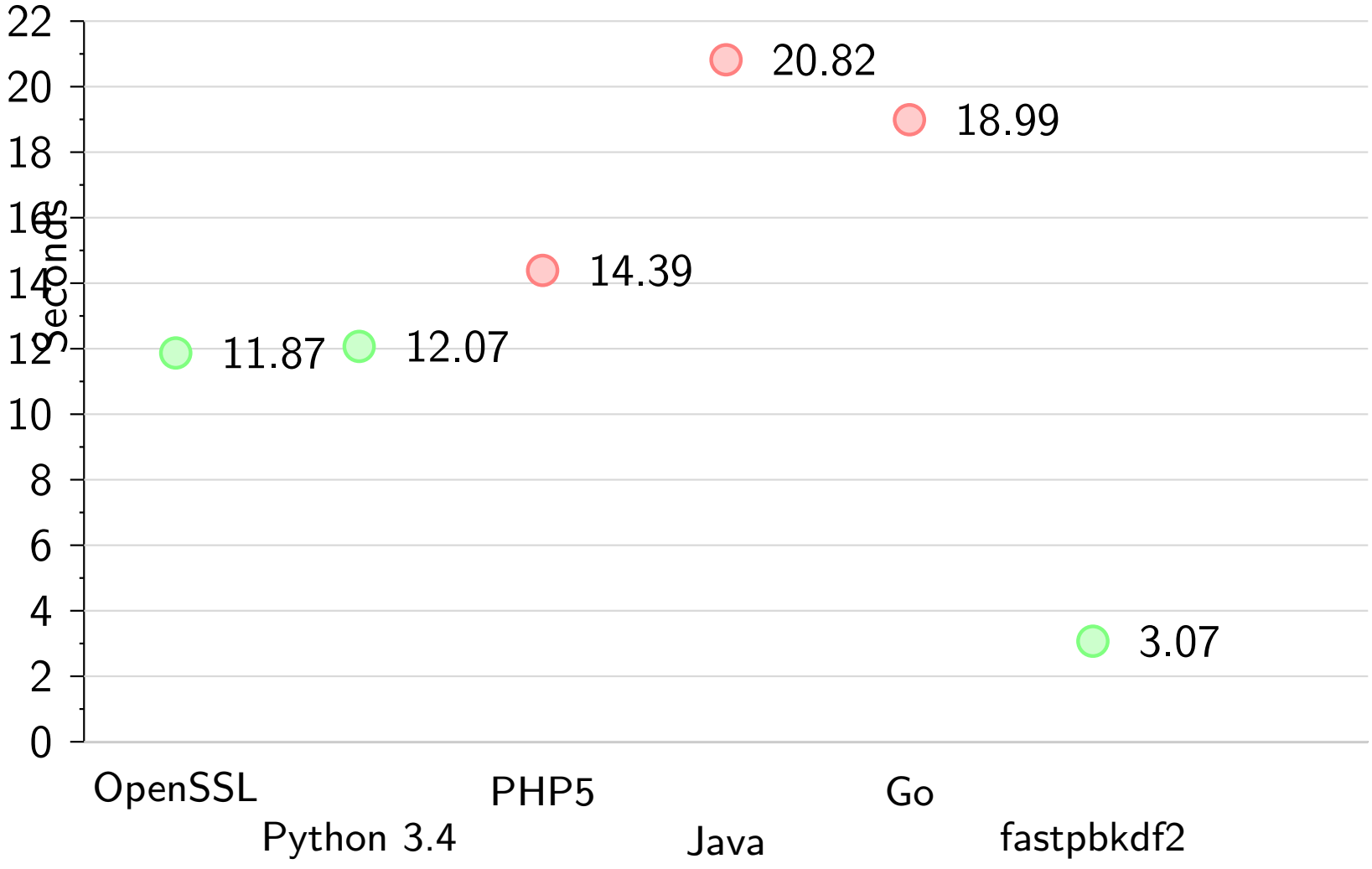

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A faster PBKDF2-HMAC-{SHA-1,SHA-256,SHA-512} for defenders.

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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/