PBKDF2: performance matters

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1. Quick intro to PBKDF2

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Usage

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

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Performance

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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.

PBKDF2: how it was described

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

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and typically

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

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

Zoom, enhance

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Assumption: password and salt much shorter than SHA-256's 64-byte block size.

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block 2 : msg

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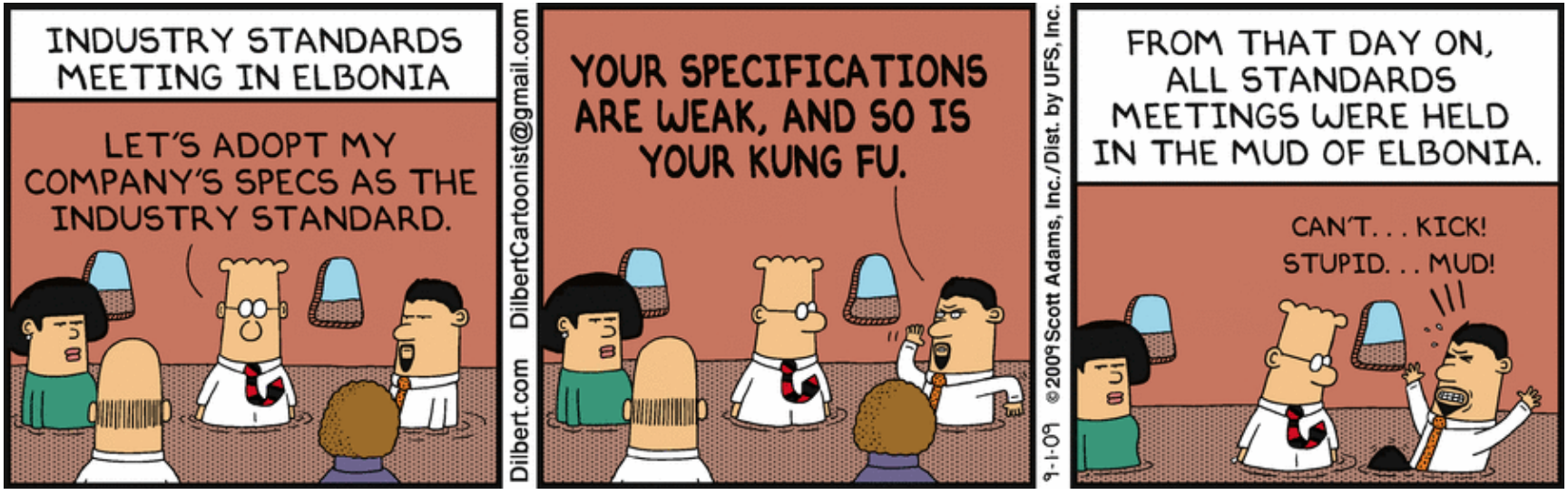
Therefore, we need to compute 4i SHA-256 blocks.

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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Selected performance measurements

- Question: how much practical difference does this make?

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- Let's measure PBKDF2-HMAC-SHA1 for large iteration count (2^{22})

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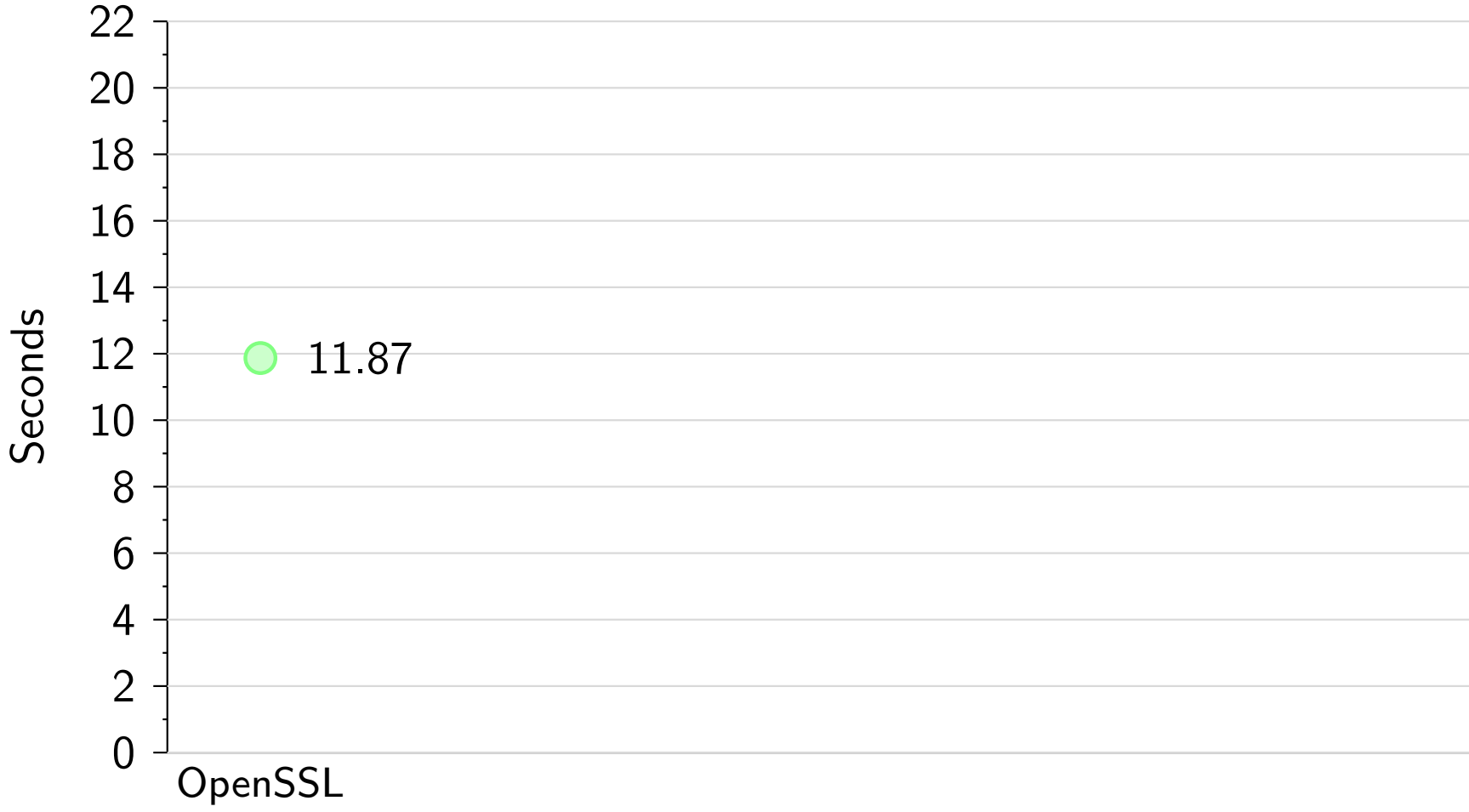

Figure : PBKDF2-HMAC-SHA1, one block output, 2^{22} iterations

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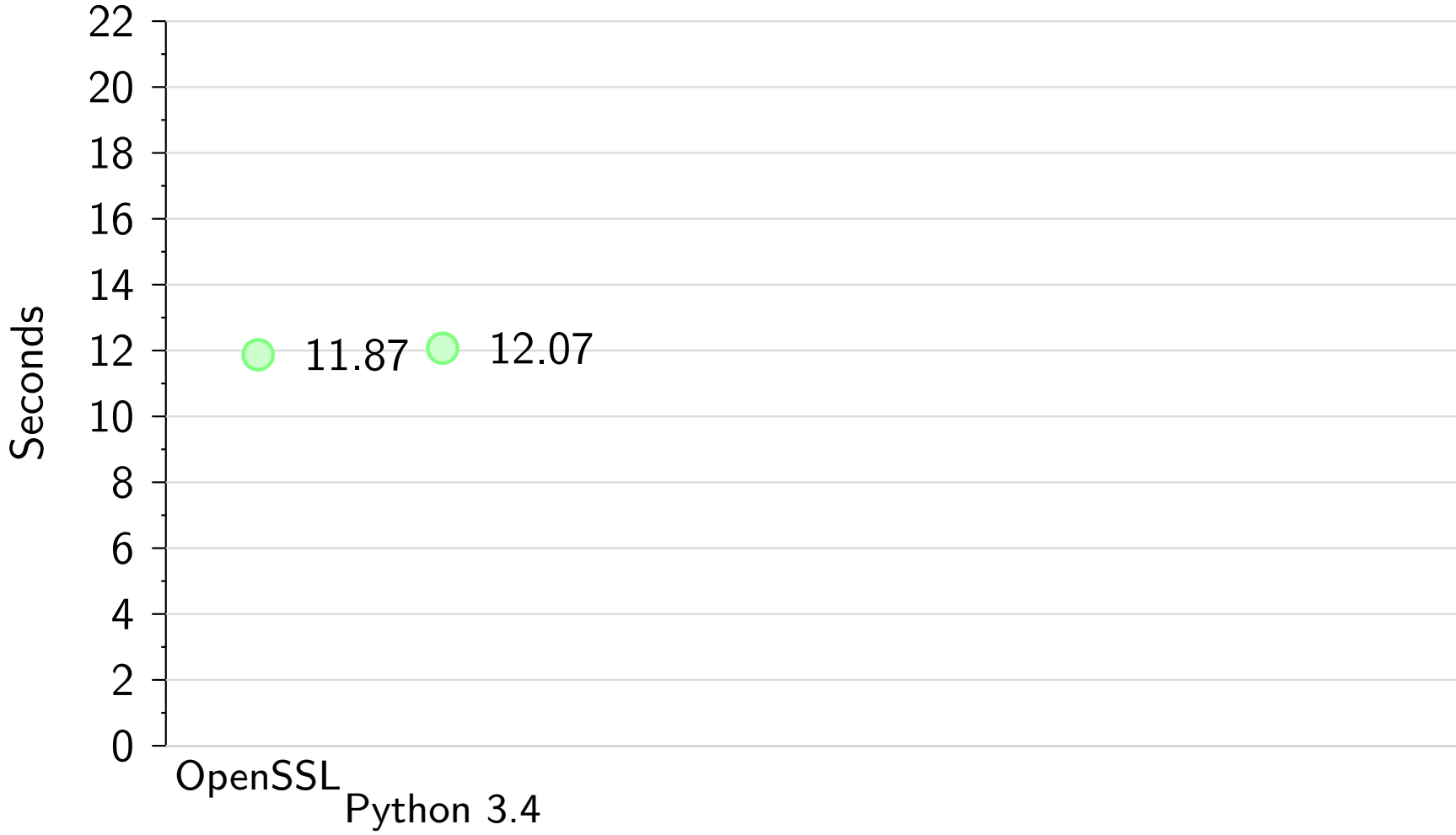

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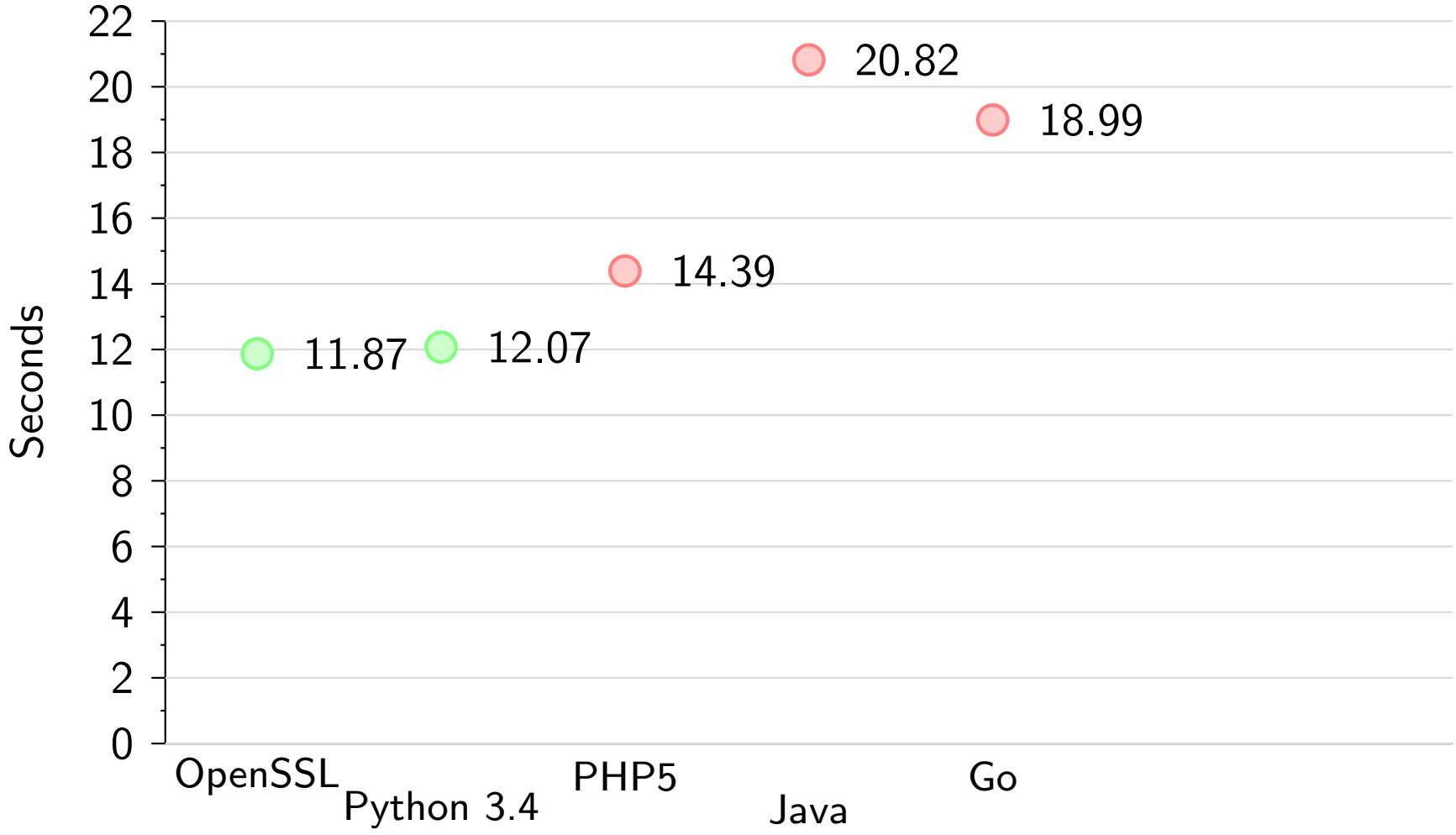

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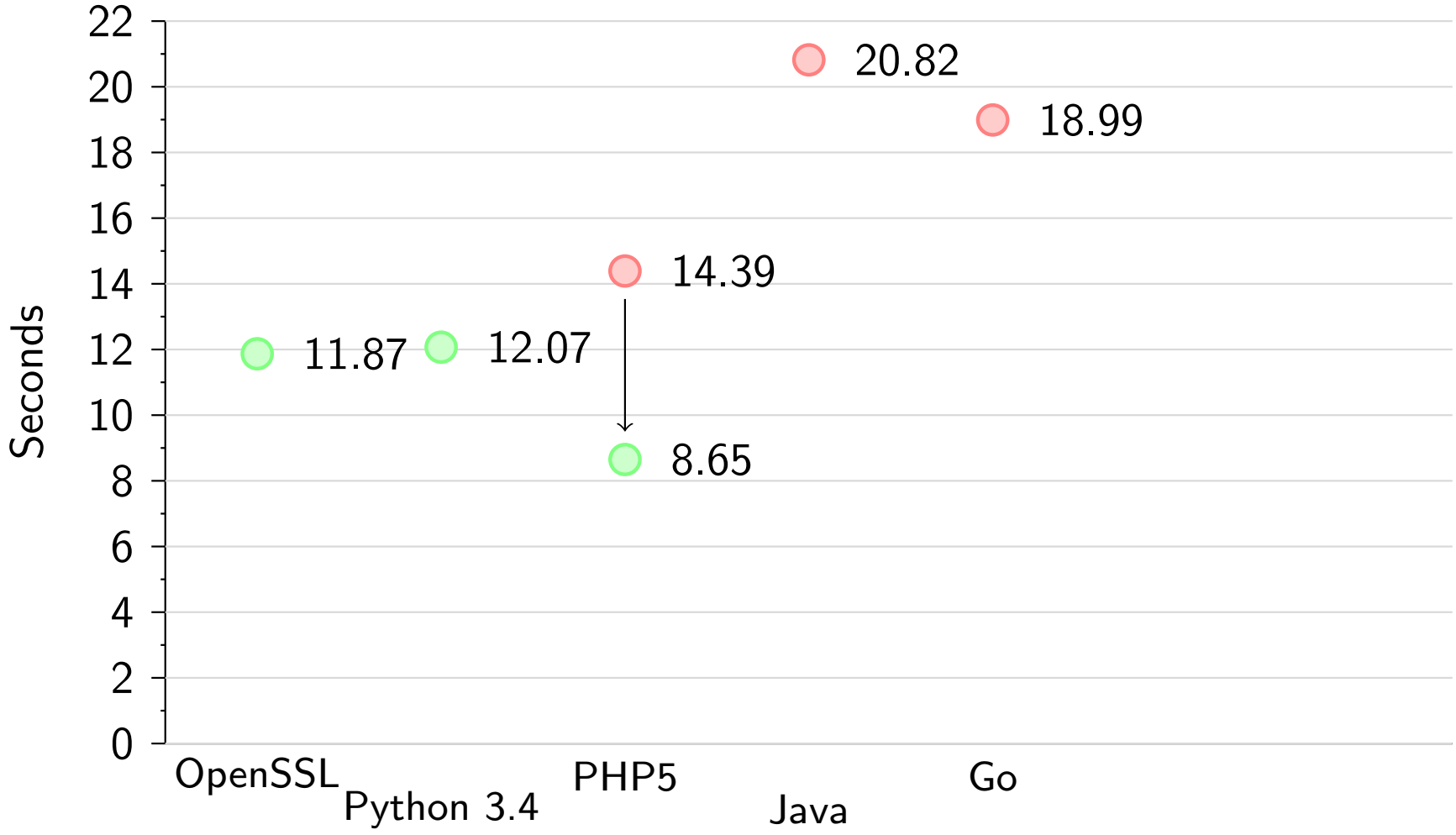

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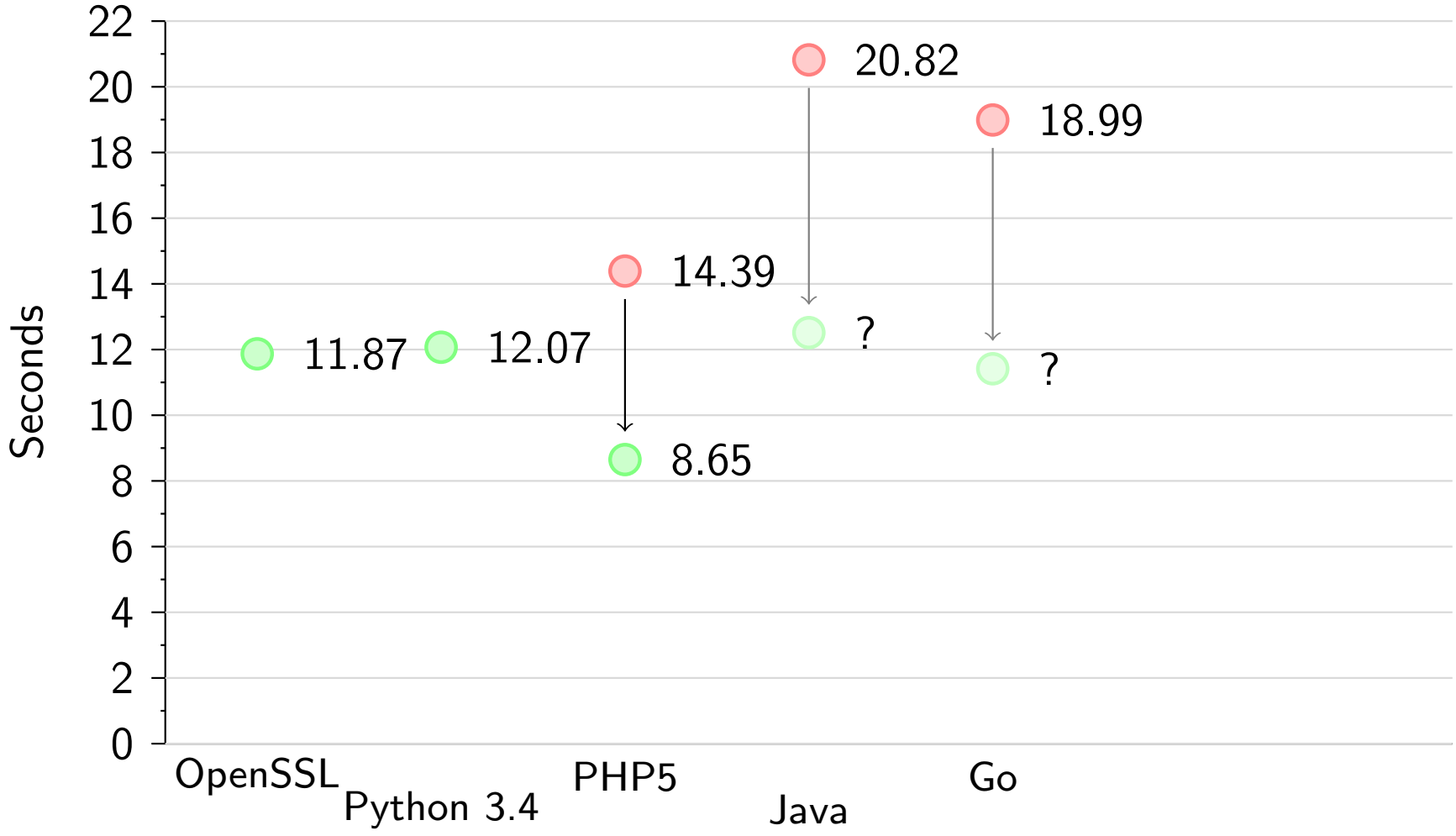

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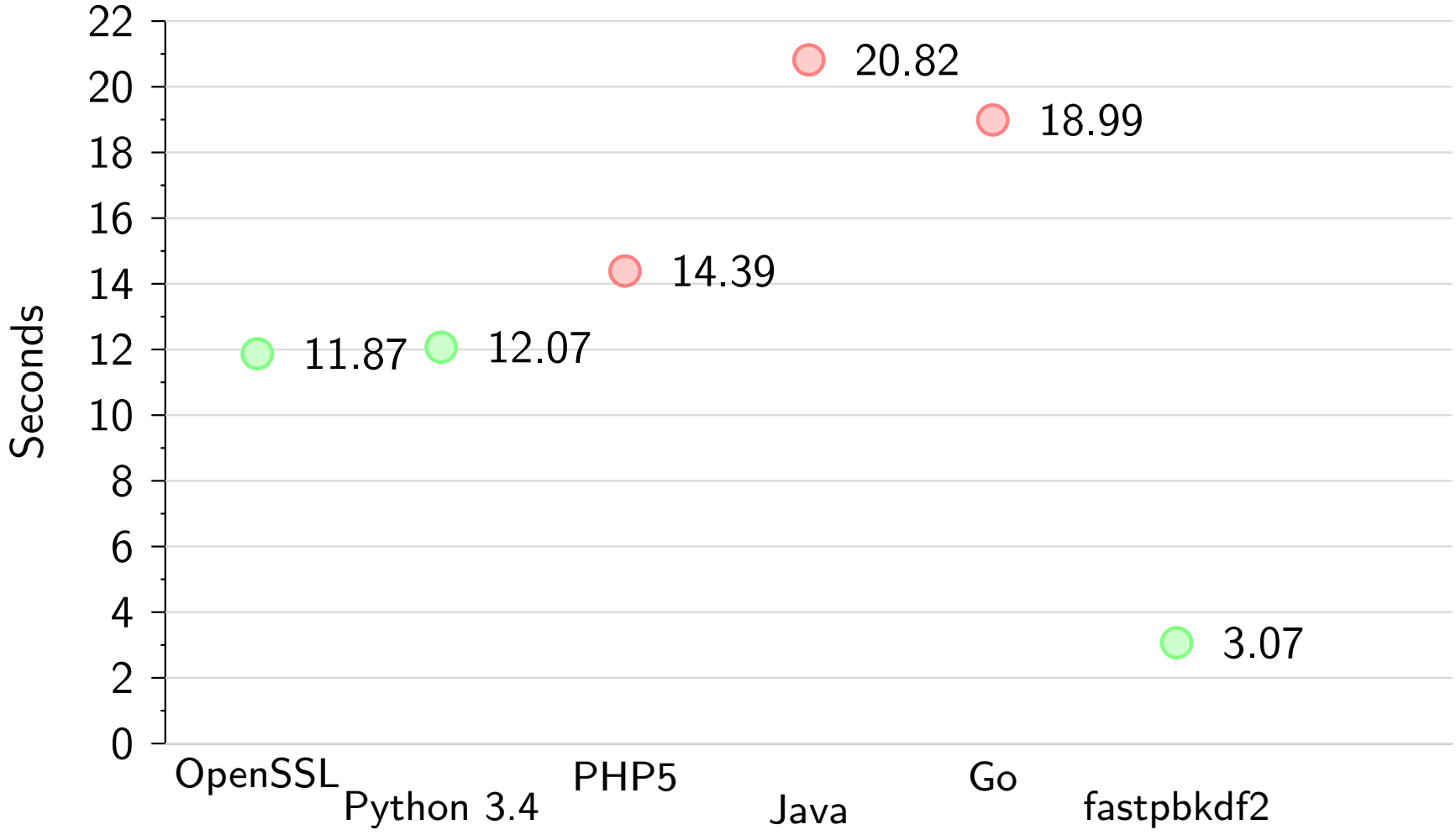

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A faster PBKDF2-HMAC-{SHA-1,SHA-256,SHA-512} for defenders.

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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/