On the Security of TLS 1.3 (and QUIC) Against Weaknesses in PKCS#1 v1.5 Encryption

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RSA-PKCS#1 v1.5 Encryption

- **Most frequently used** key transport mechanism in TLS **before v1.3**
  - "Textbook-RSA encryption" with additional **randomized padding**
  - A ciphertext is "valid", if it contains a **correctly padded** message

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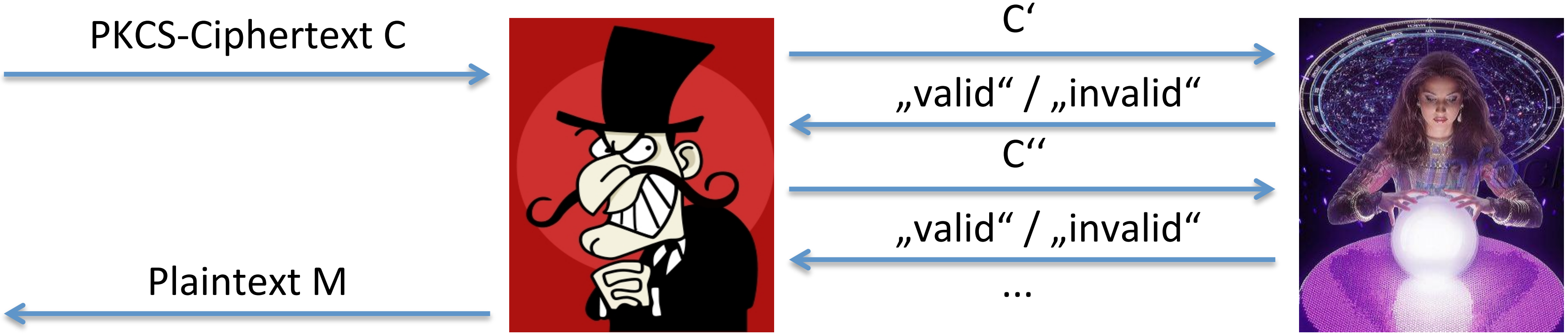
  - "Textbook-RSA encryption" with additional **randomized padding**
  - A ciphertext is "valid", if it contains a **correctly padded** message
- **Deprecated** in TLS 1.3
  - Vulnerable: **Bleichenbacher's attack** (CRYPTO `98)
  - **Sufficient to protect against its weaknesses?**

Bleichenbacher’s Attack

(CRYPTO 1998)



PKCS-Ciphertext C

C‘

„valid“ / „invalid“

C‘‘

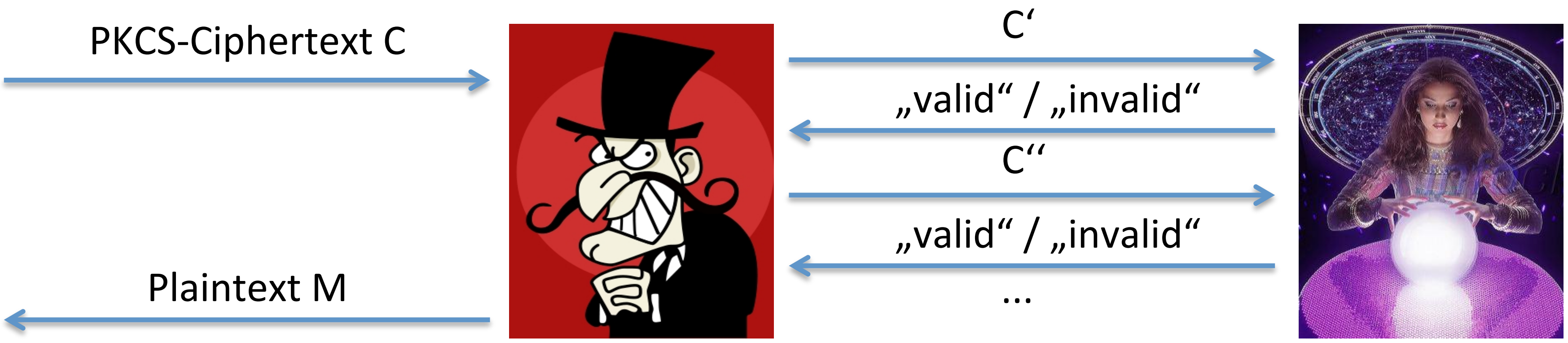
„valid“ / „invalid“

...

Plaintext M

Bleichenbacher’s Attack

(CRYPTO 1998)



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  - **Error message** if ciphertext is invalid
  - Other **side channels, like timing**

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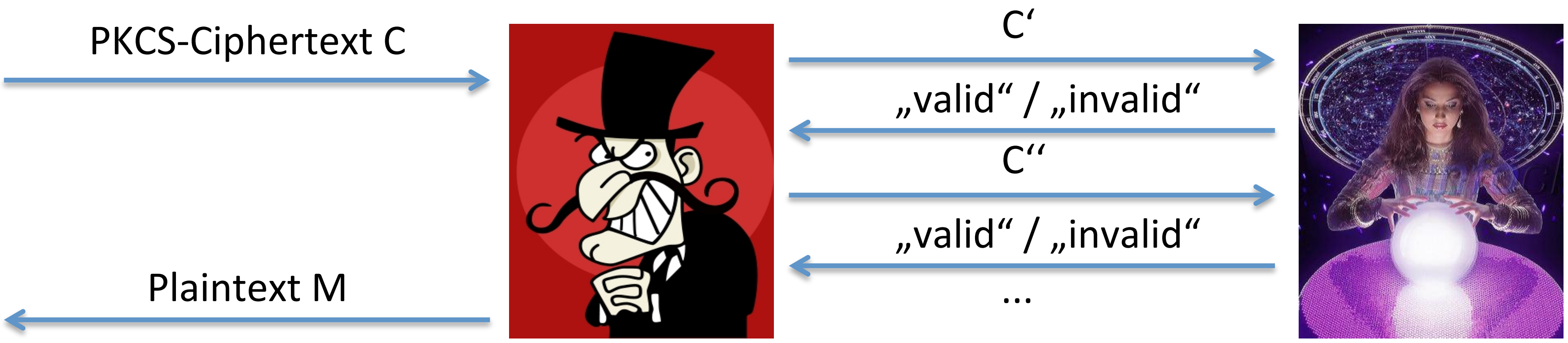

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Plaintext M

- Oracle usually provided by a server:
  - **Error message** if ciphertext is invalid
  - Other **side channels, like timing**
- Allows to perform **RSA secret key operation**
  - Decrypt RSA-PKCS#1 v1.5 ciphertexts
  - Compute digital RSA signatures

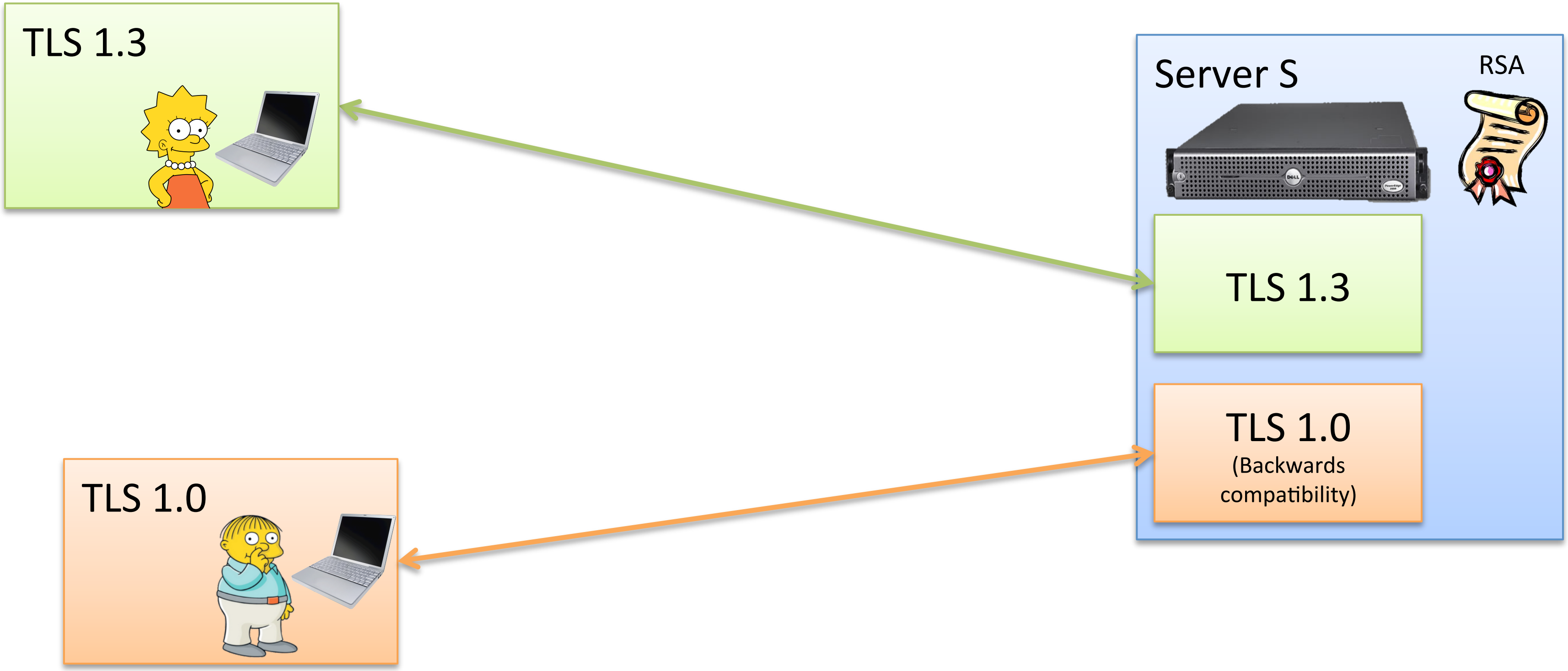
Bleichenbacher attacks over and over

- Bleichenbacher (CRYPTO 1998)
- Klima et al. (CHES 2003)
- Jager et al. (ESORICS 2012)
- Degabriele et al. (CT-RSA 2012)
- Bardou et al. (CRYPTO 2012)
- Zhang et al. (ACM CCS 2014)
- Meyer et al. (USENIX Security 2014)
- …

Many different techniques to construct the required oracle

Assumption: Bleichenbacher-like attacks remain a realistic threat

Typical use of TLS 1.3 in practice



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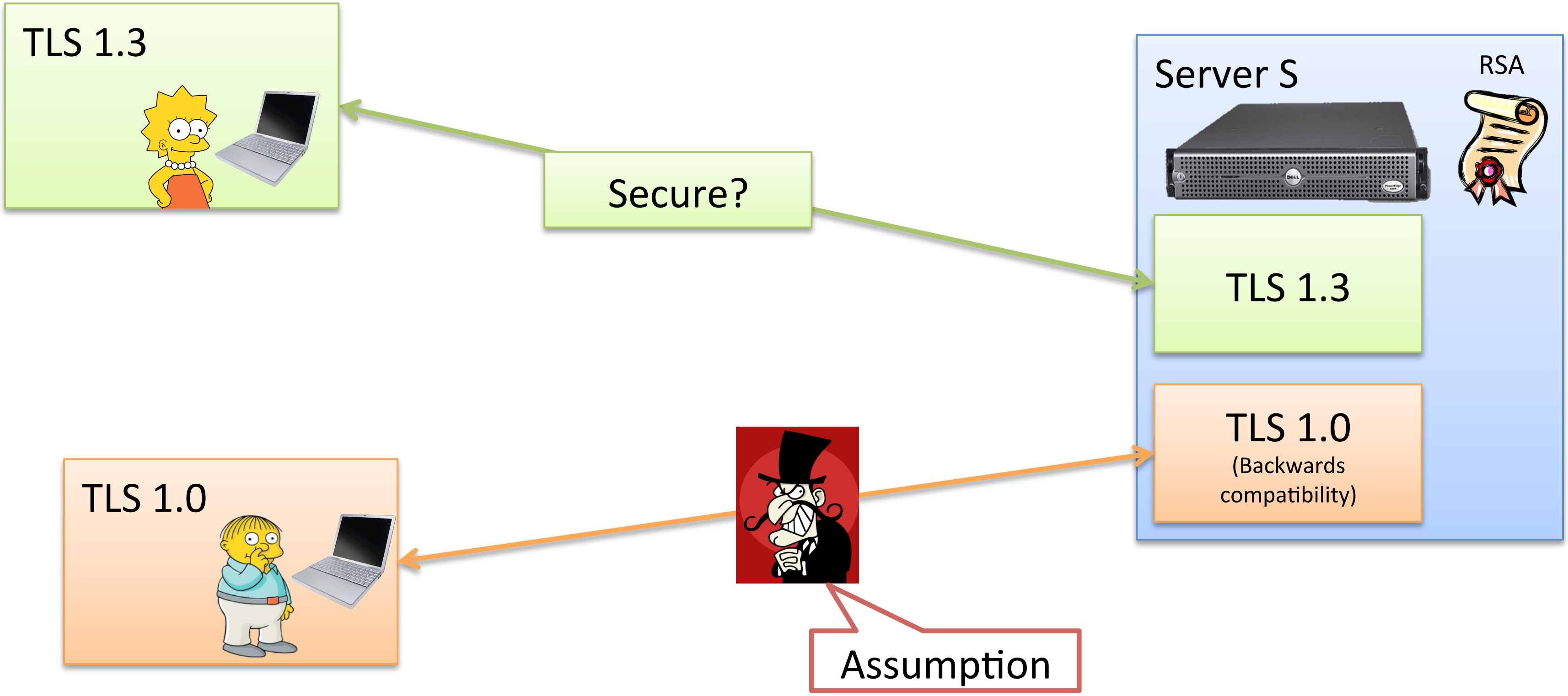


TLS 1.3

Secure?

Server S

RSA

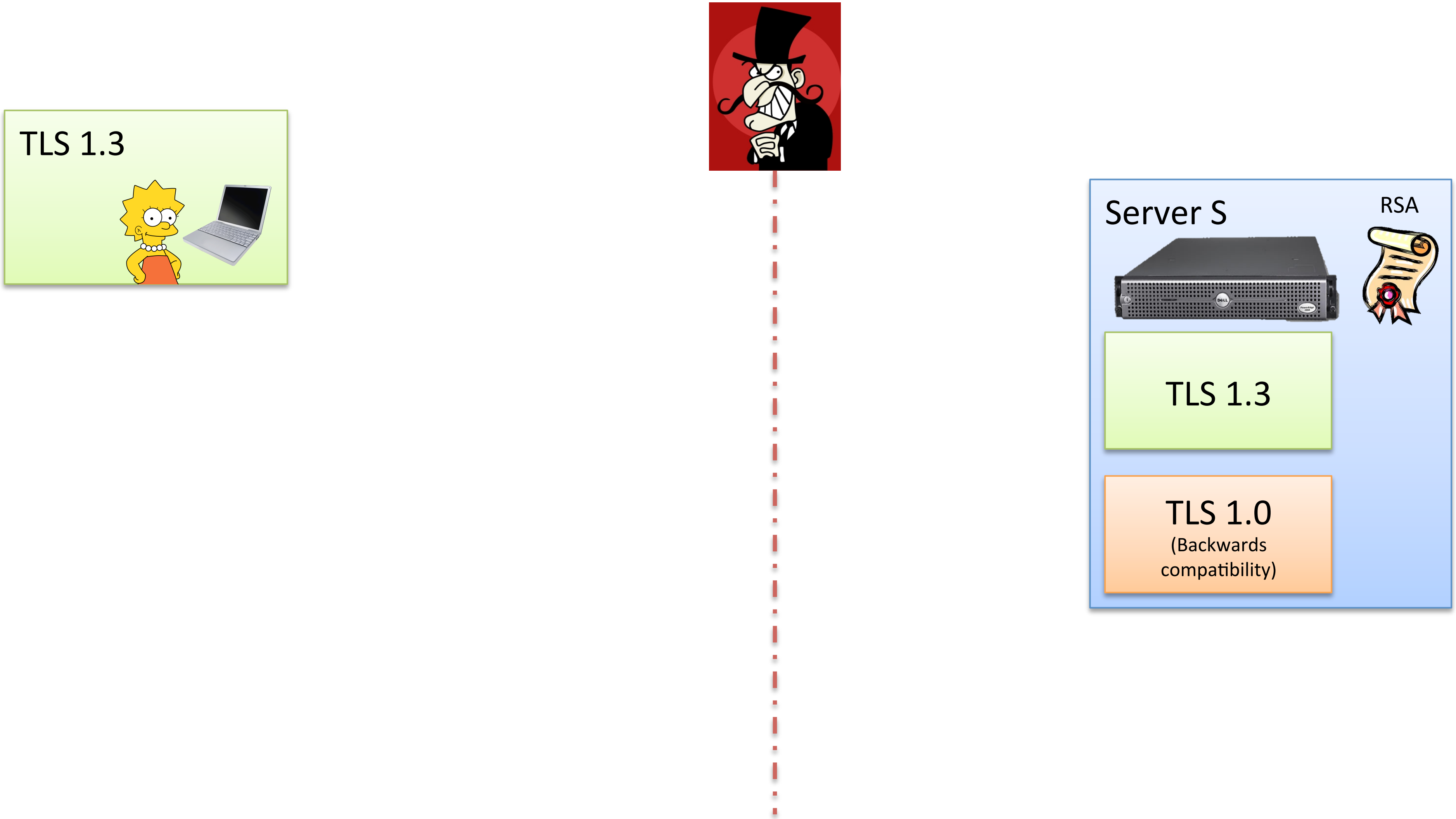
TLS 1.3

TLS 1.0
(Backwards compatibility)

TLS 1.0

Assumption

High-level Attack Description



TLS 1.3

Server S

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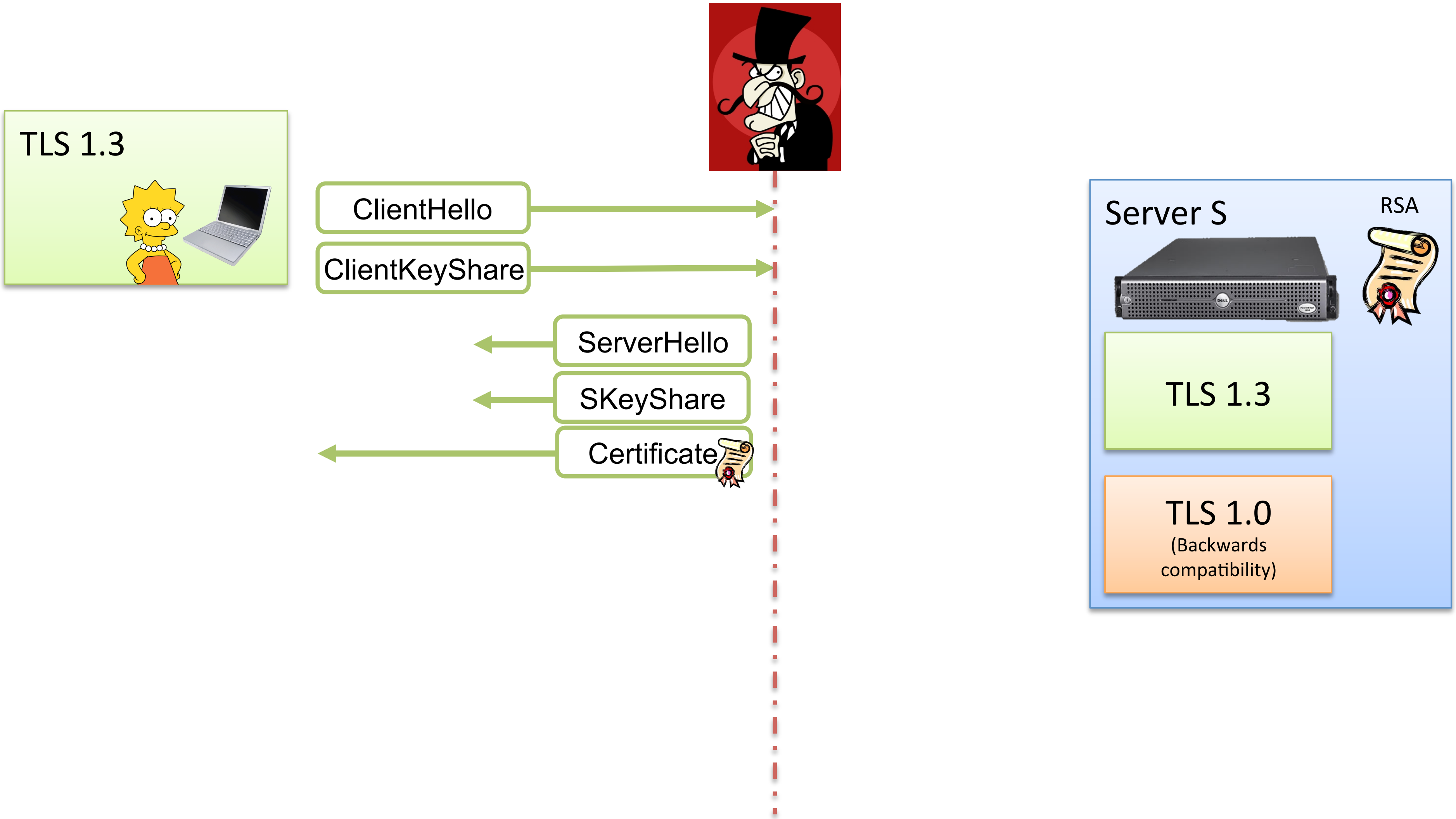

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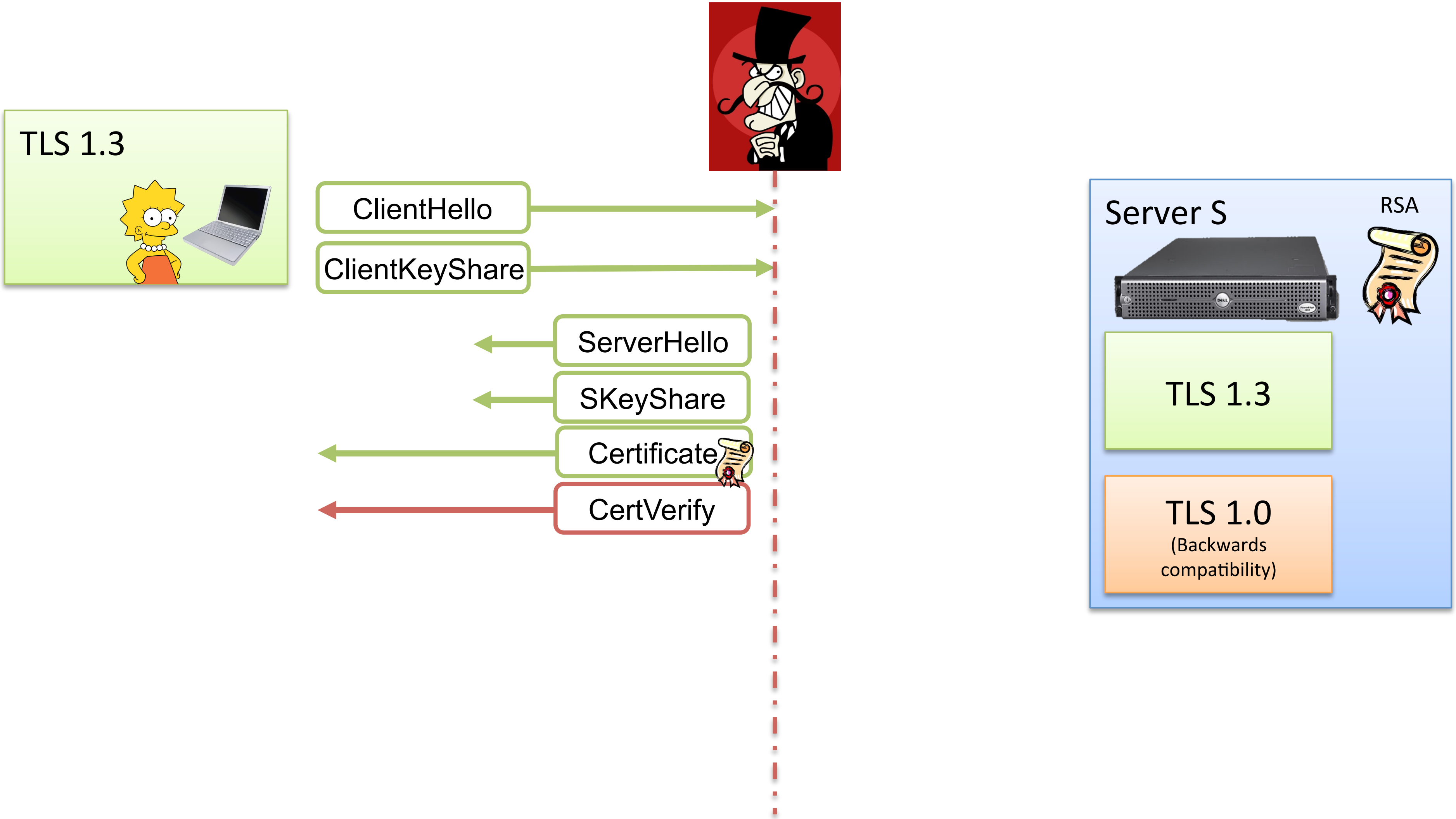


TLS 1.3

ClientHello

ClientKeyShare

ServerHello

SKeyShare

Certificate

CertVerify

Server S

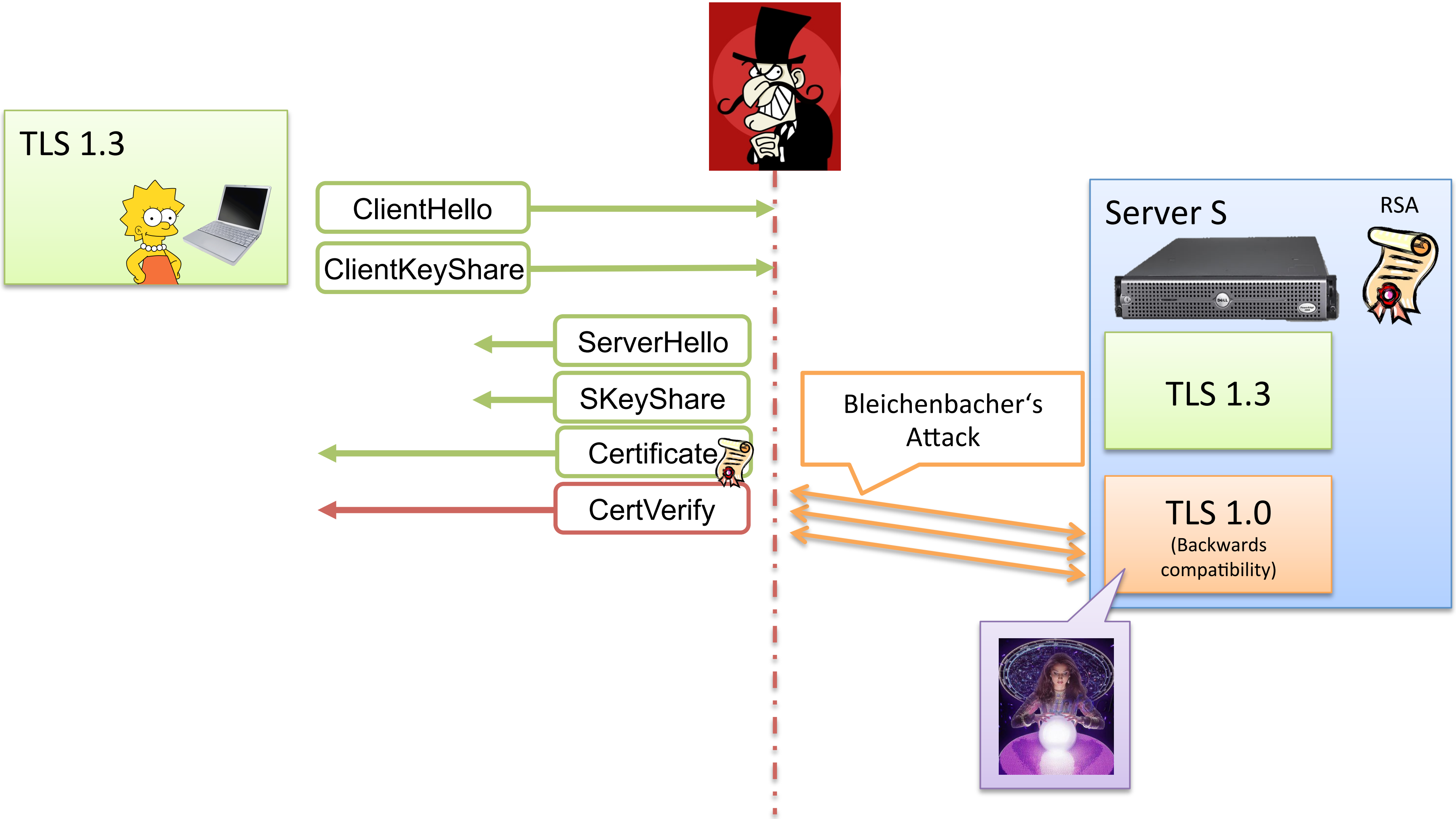
RSA

TLS 1.3

TLS 1.0

(Backwards compatibility)

High-level Attack Description



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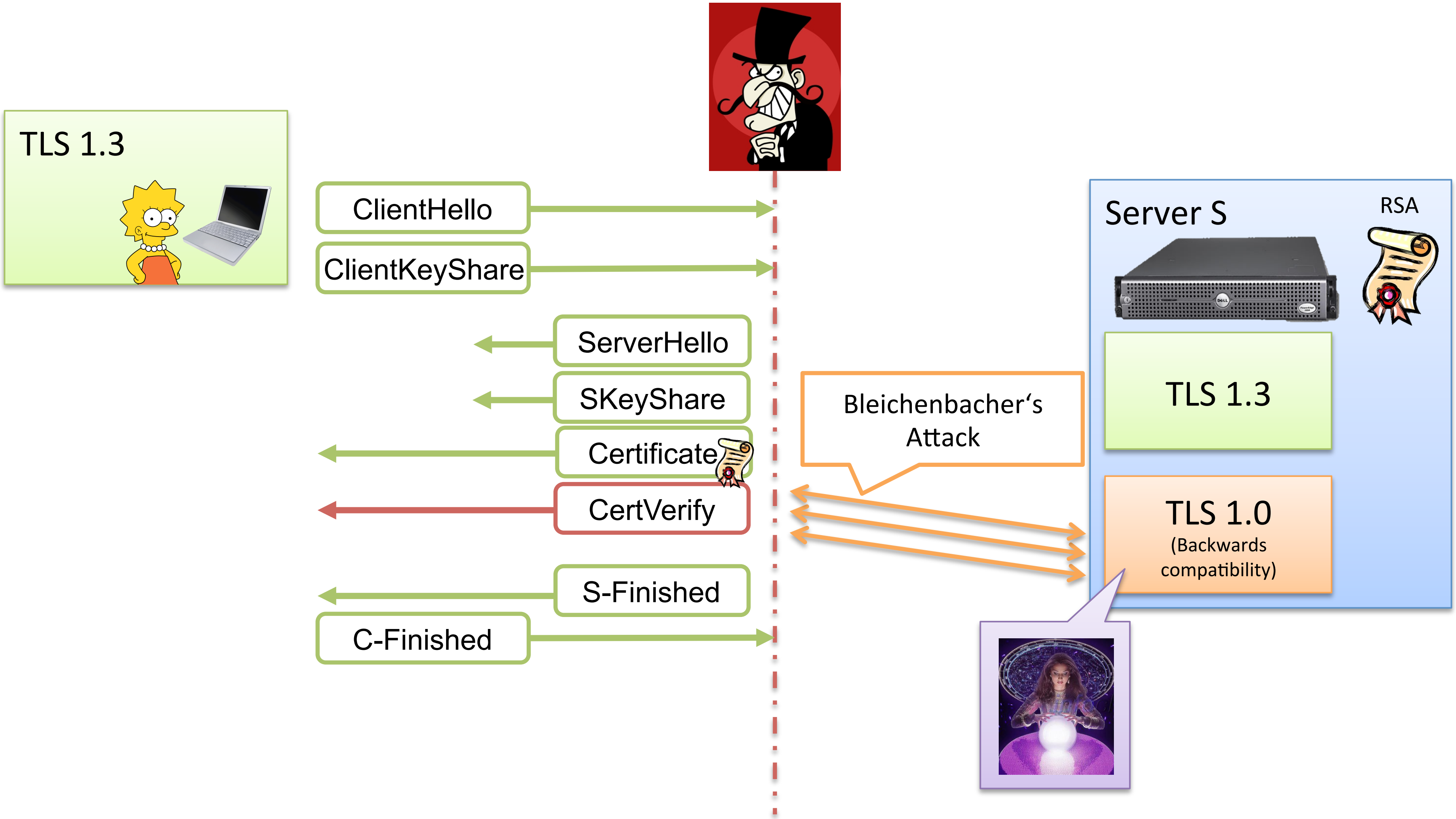

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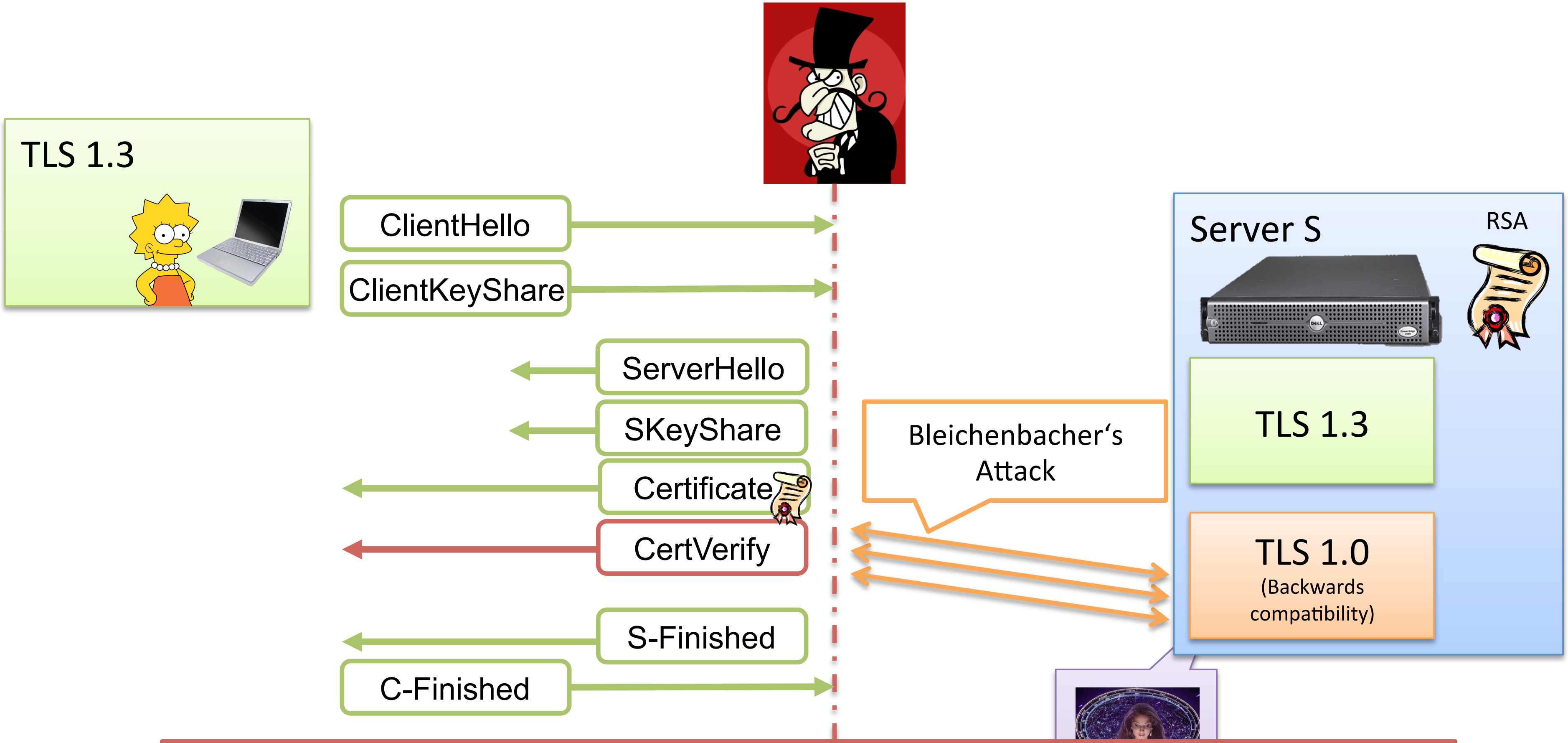

TLS 1.3 may be vulnerable to Bleichenbacher's attack, **even though PKCS#1 v1.5 encryption is not used**!

Practical Impact

- Practical impact on TLS 1.3 is **rather limited**
  - Typical Bleichenbacher-attacks take **hours or days**
  - **Would Lisa wait that long?**
  - Machine-to-machine communication?

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  - Typical Bleichenbacher-attacks take **hours or days**
  - **Would Lisa wait that long?**
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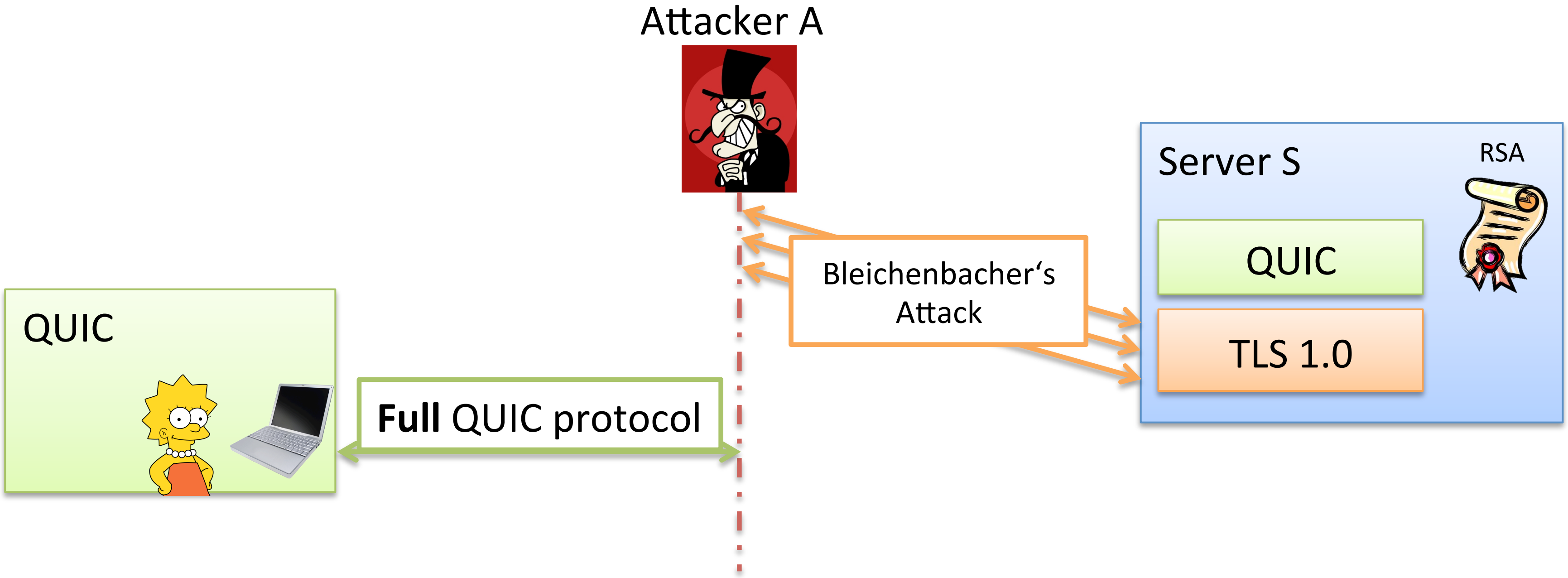
- Nevertheless:
  - **Backwards compatibility** must be considered
    - Cf. Jager, Paterson, Somorovsky (NDSS 2013)
  - Future **improvements of Bleichenbacher's** attack?

Attack on the QUIC protocol

Google



Attacker A

QUIC

Full QUIC protocol

Bleichenbacher‘s Attack

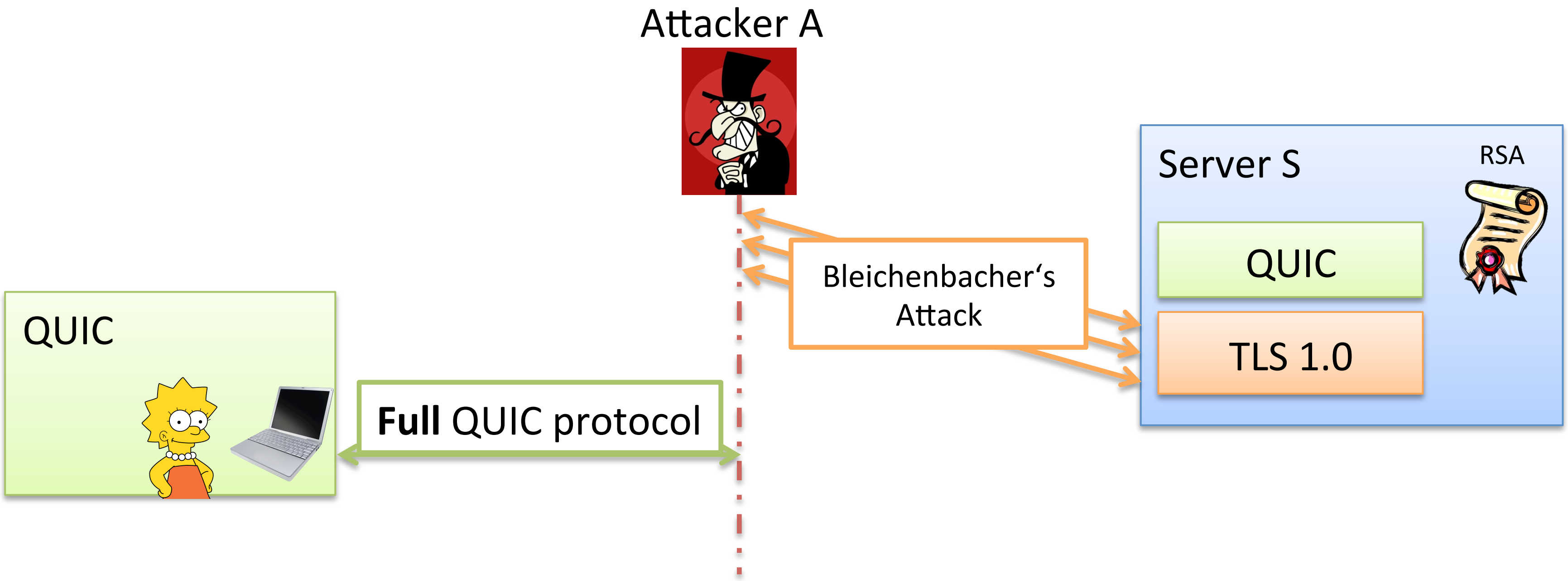
Server S

RSA

QUIC

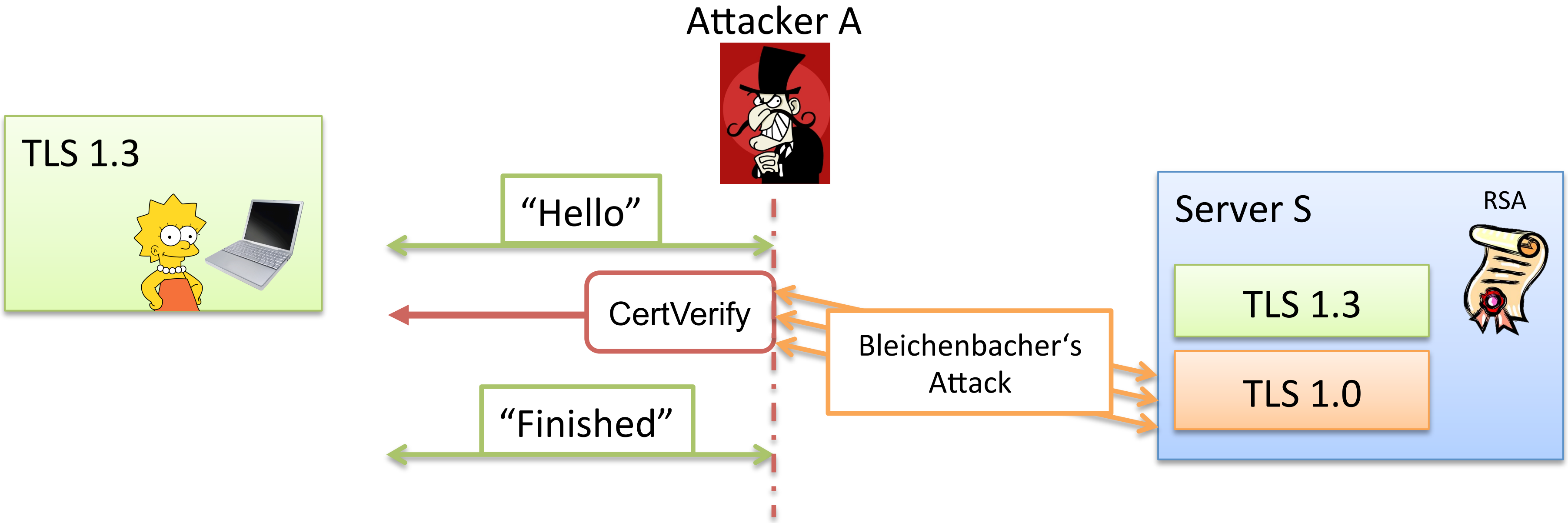
TLS 1.0

Attack on the QUIC protocol



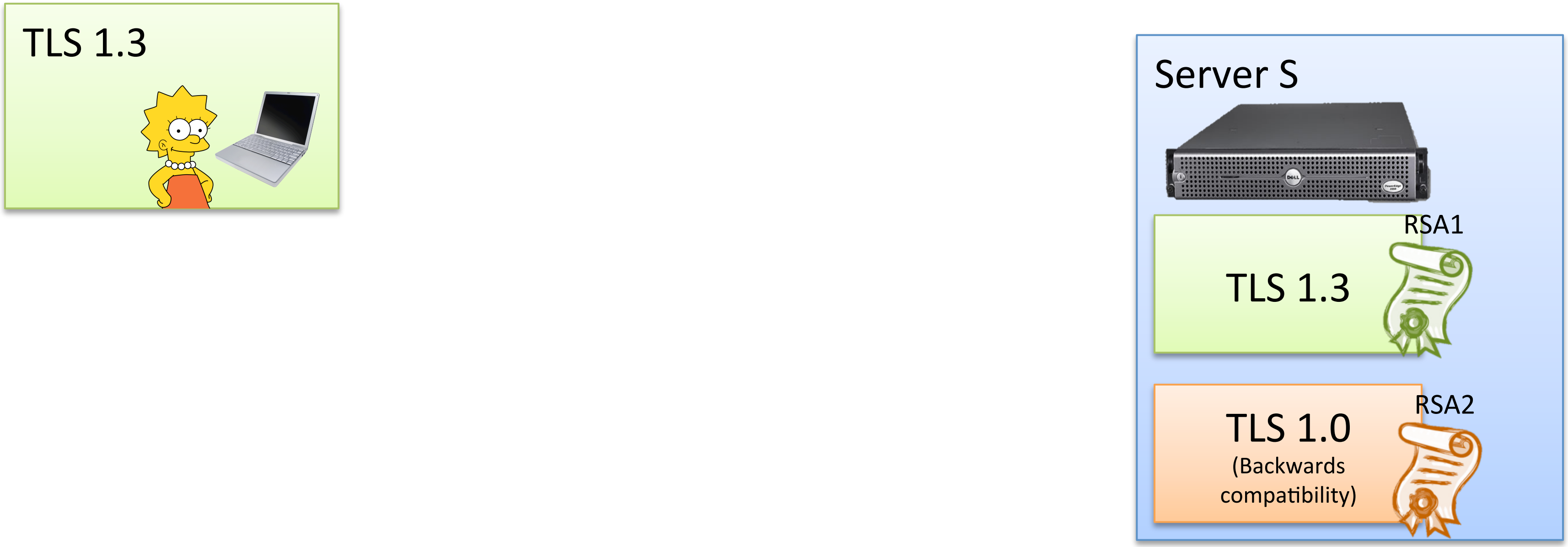
- A can run Bleichenbacher’s attack **before** Lisa connects to S
- **One signature** is equivalent to **the secret key** of S
- **Practical,** even if attack takes weeks!

Limited Impact on TLS 1.3



- A can impersonate S only in a **single** TLS session
- Only practical with **very fast** Bleichenbacher attack

The difficulty of preventing such attacks (example)



TLS 1.3

Server S

RSA1

TLS 1.3

RSA2

TLS 1.0

(Backwards compatibility)

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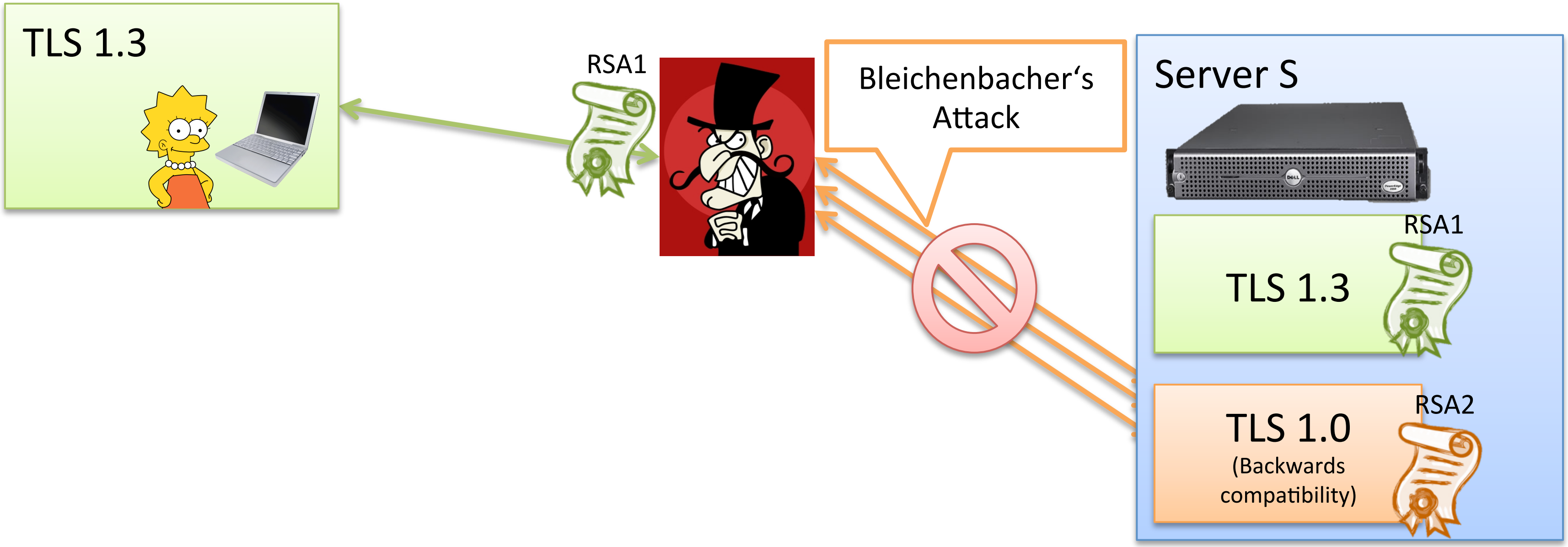

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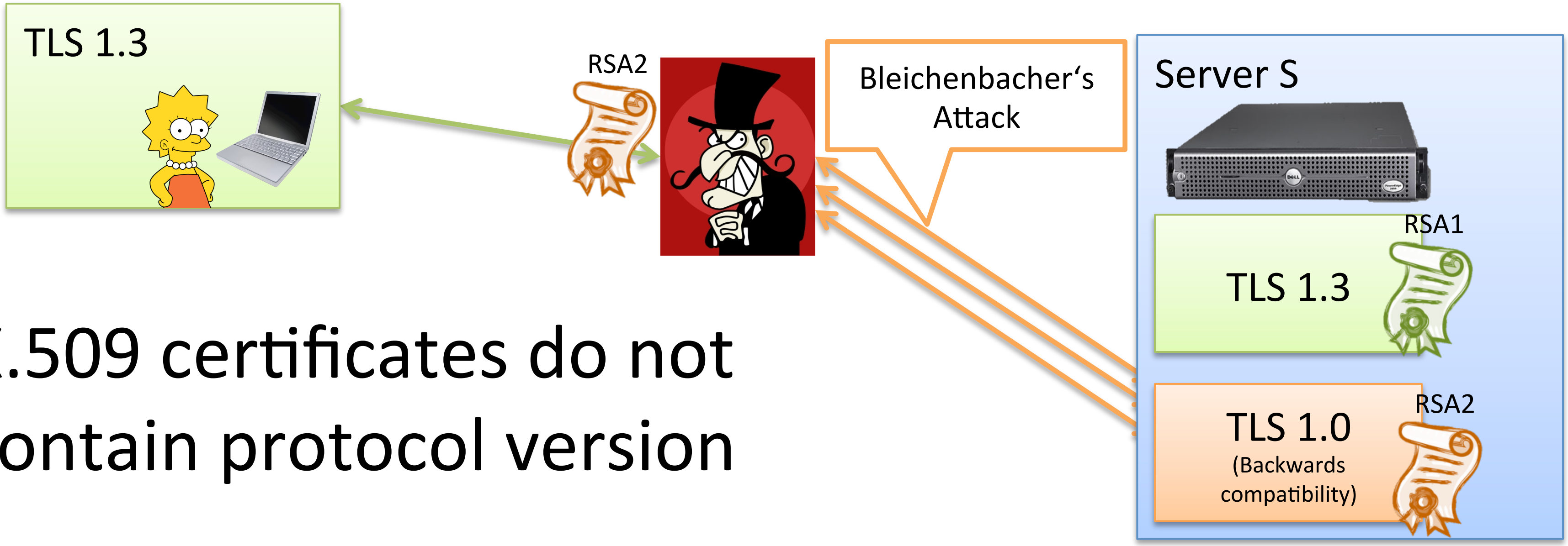

- X.509 certificates do not contain protocol version

Further difficulties

- Key separation **not supported** by major server implementations
- Certificates **cost money** (extended validation)
- X.509 supports “sign/encrypt-only” certs
  - “Sign-only” keys for TLS >= 1.3
  - “Encrypt-only” keys for TLS <= 1.2
    - **No Forward Secrecy** for versions <= 1.2 ☹
  - Do browsers really check this?

Summary and recommendations

- Removing RSA-PKCS#1 v1.5 from TLS is an **excellent decision**
  - Not sufficient to protect **completely** against weakness
- TLS 1.3 is more **"robust"** than QUIC
  - But **not immune**
  - Signing **ephemeral values** is a good idea
- Recommendation for future TLS versions: **promote key separation**
  - Talk to X.509 and software developers