The 9 Lives of Bleichenbacher's CAT: New Cache ATtacks on TLS Implementations

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מכון ויצמן למדע
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DATA 61

THE UNIVERSITY of ADELAIDE

Transport Layer Security (TLS)

- The most widely used cryptographic protocol
- Provides communication security (https, VPN, etc.)
  - TLS handshake is used for authentication and secure key exchange
  - TLS Record layer protects the communication
  - Allows for cryptographic agility using different cipher suites

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    - Supported for backwards compatibility

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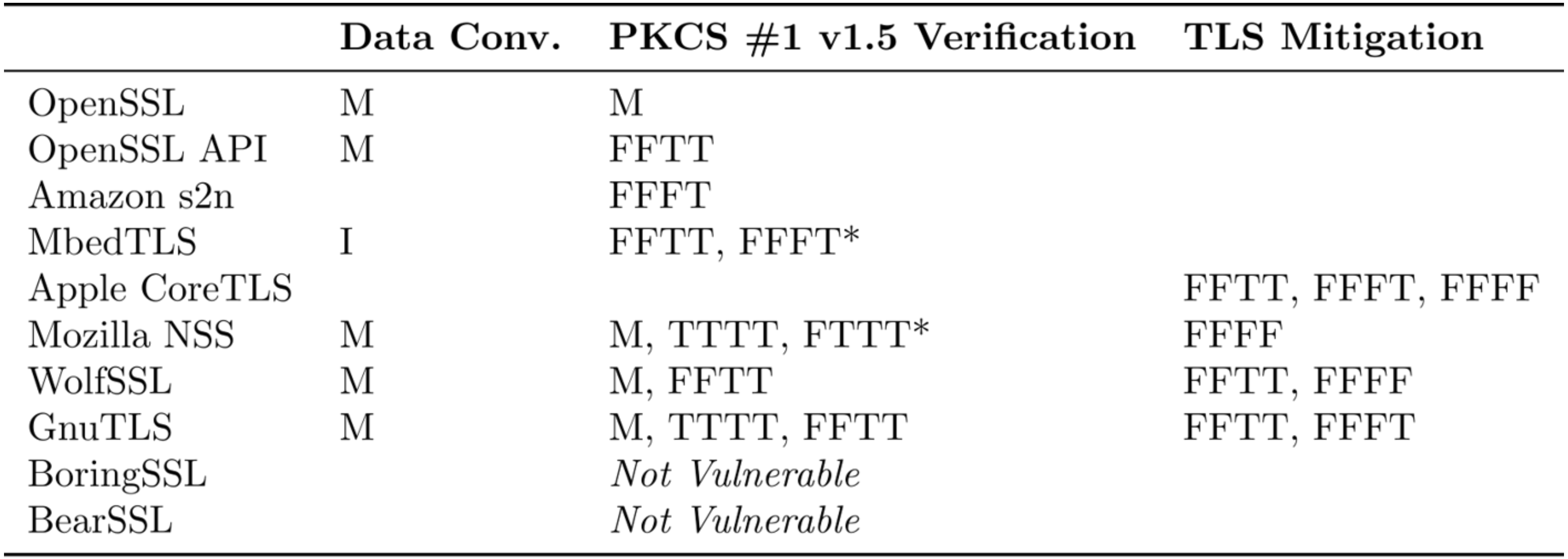
- 7 found vulnerable to new cache based RSA padding attacks
    - Multiple vulnerabilities in different layers of the protocol



	Data Conv.	PKCS #1 v1.5 Verification	TLS Mitigation
OpenSSL	M	M	
OpenSSL API	M	FFTT	
Amazon s2n		FFFT	
MbedTLS	I	FFTT, FFFT*	
Apple CoreTLS			FFTT, FFFT, FFFF
Mozilla NSS	M	M, TTTT, FTTT*	FFFF
WolfSSL	M	M, FFTT	FFTT, FFFF
GnuTLS	M	M, TTTT, FFTT	FFTT, FFFT
BoringSSL		*Not Vulnerable*	
BearSSL		*Not Vulnerable*	

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  - Works also if client doesn't support RSA KX

RSA Encryption

$$N = p \cdot q \qquad\qquad (p, q) \text{ are primes}$$
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  - There are several real world problems

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- Assume encryption of Yes/No – value 0 or 1
  - Vulnerable to dictionary attack
  - Easy to detect repetitions
  - m should be random

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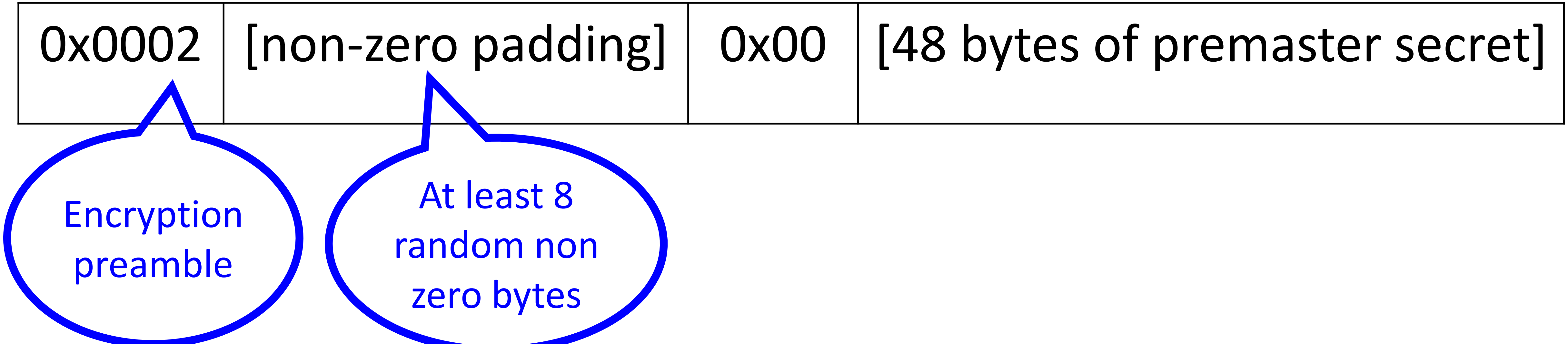

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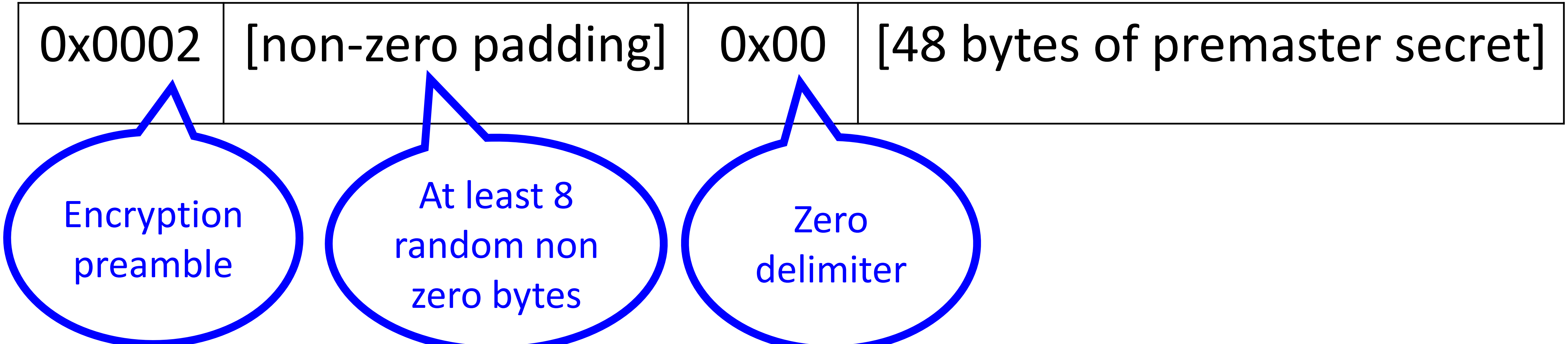

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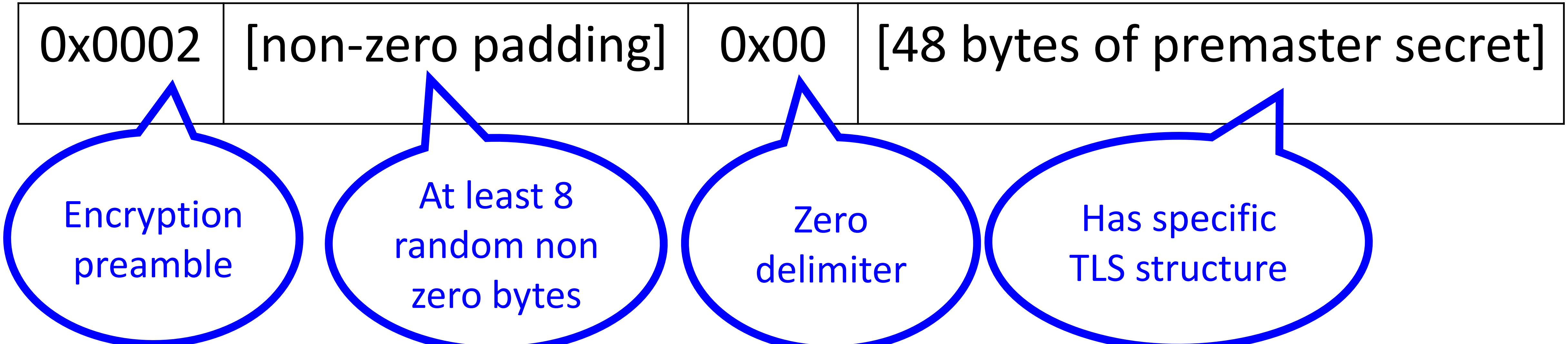

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Has specific TLS structure

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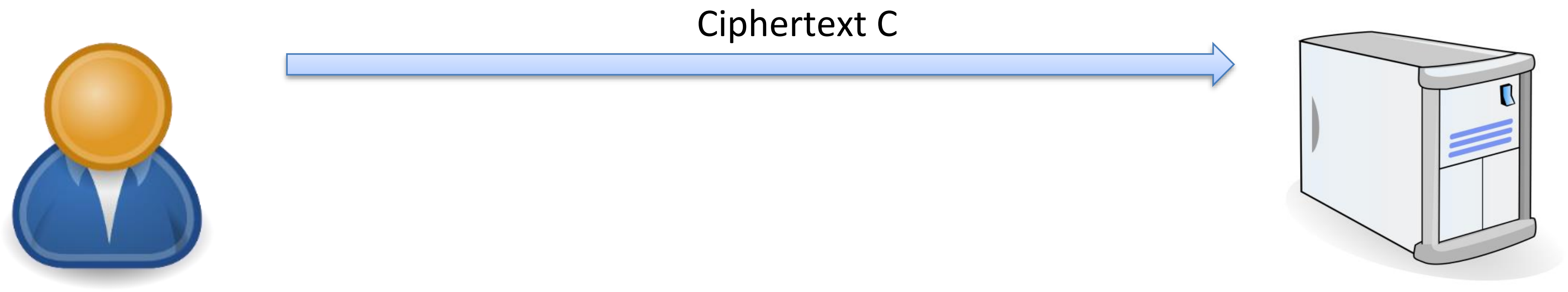

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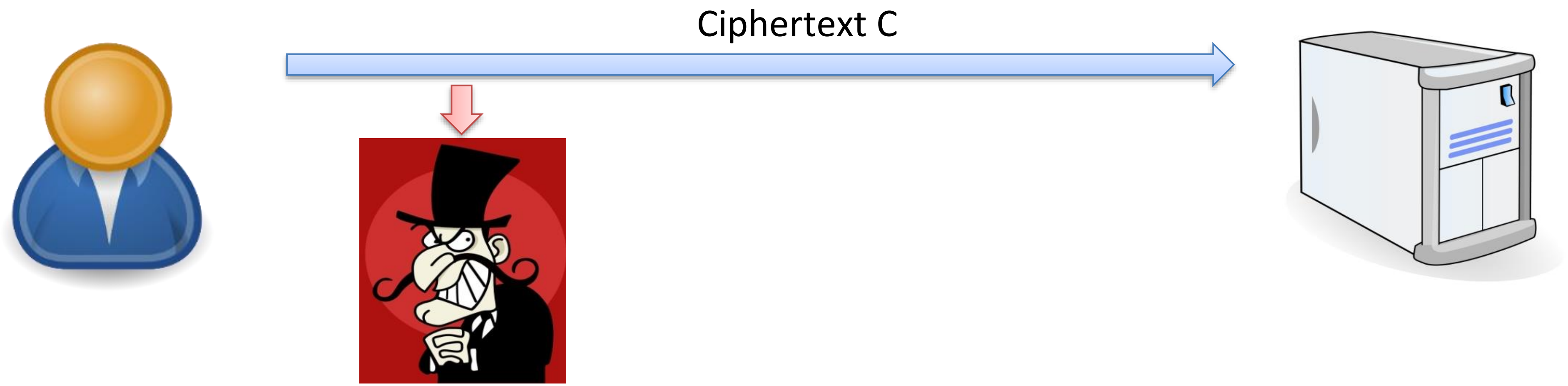

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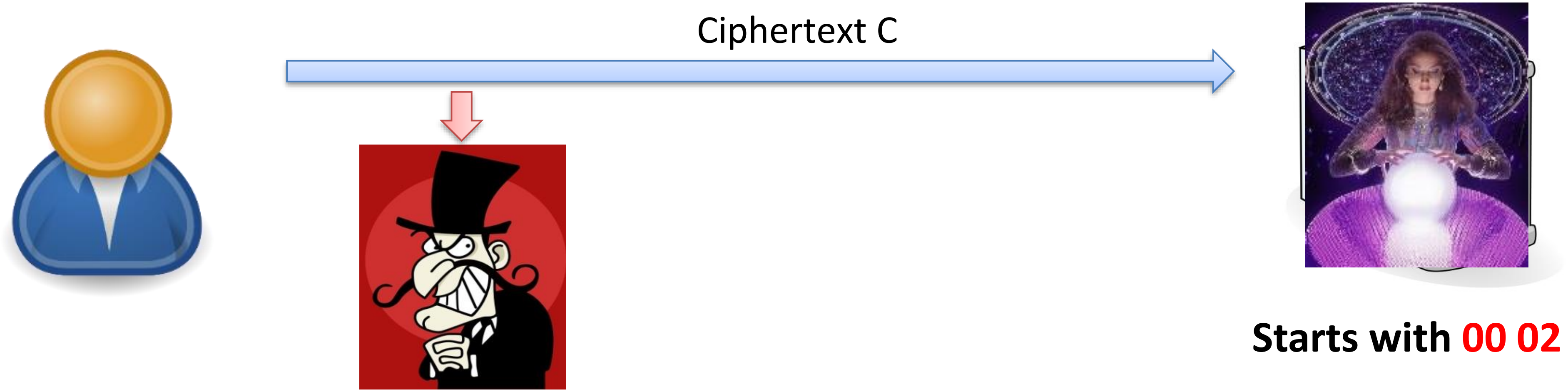

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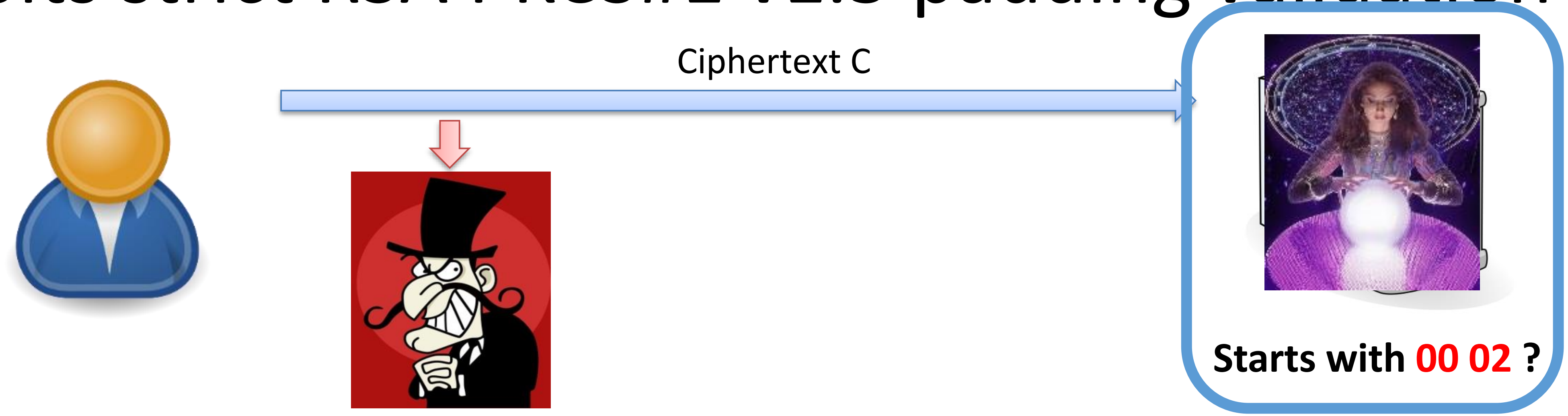

Requires Side Channel

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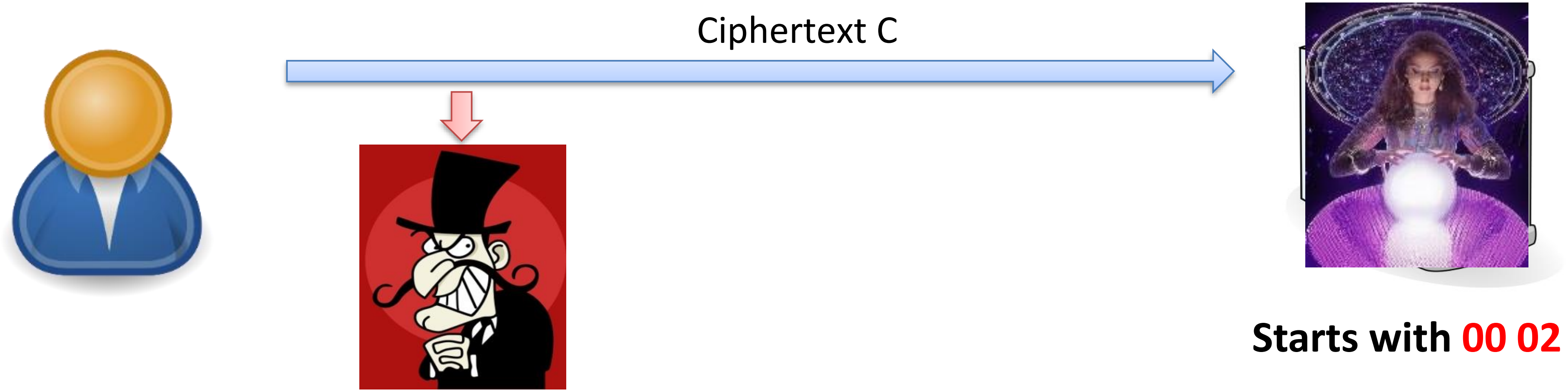

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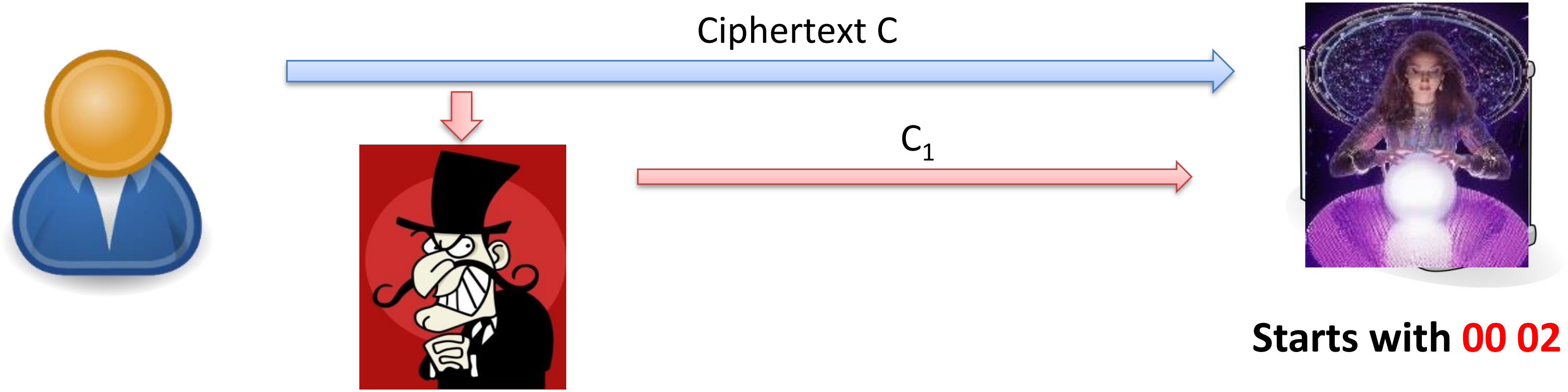

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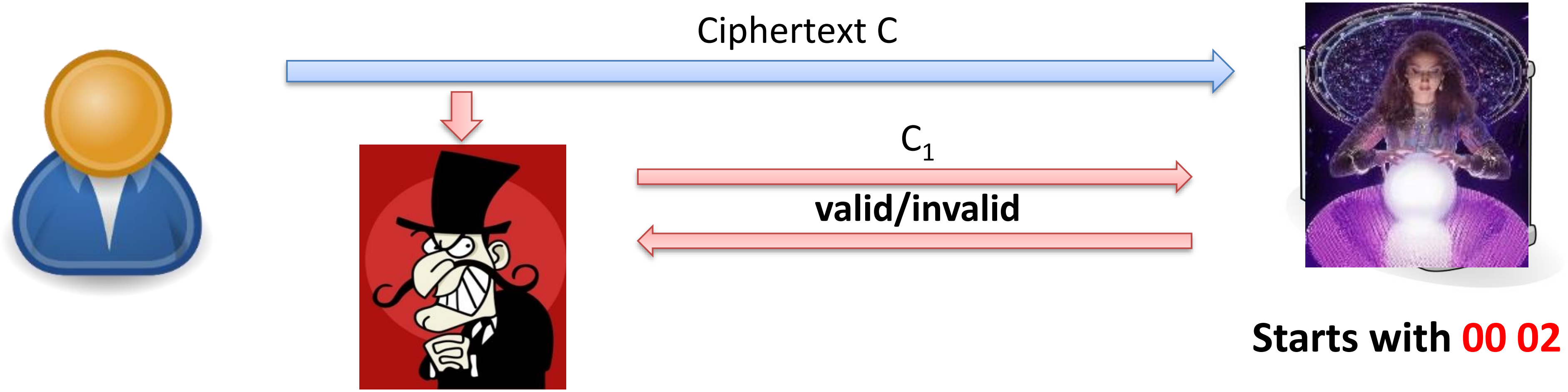

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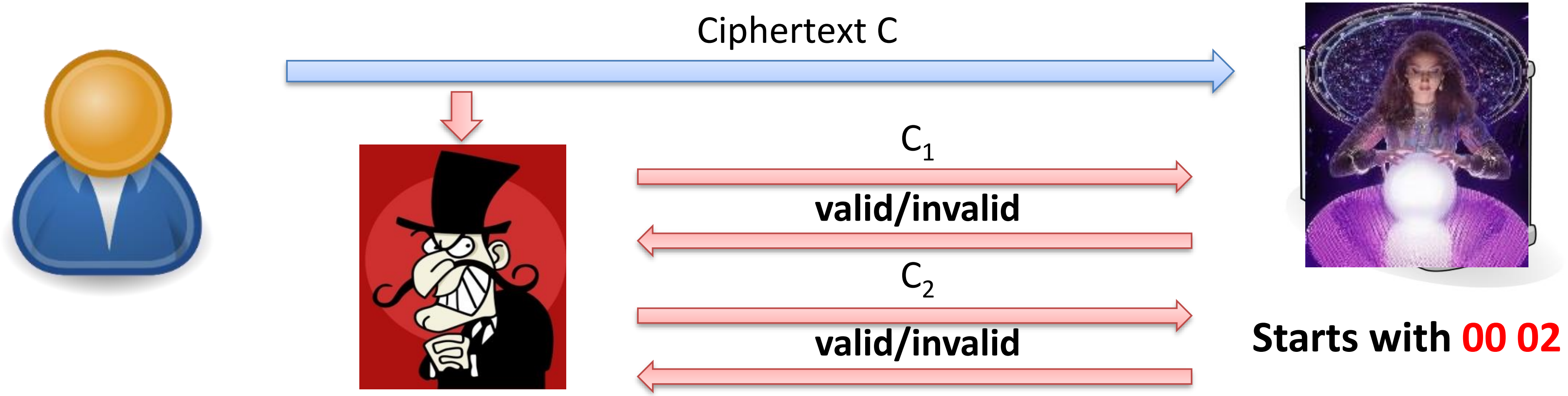

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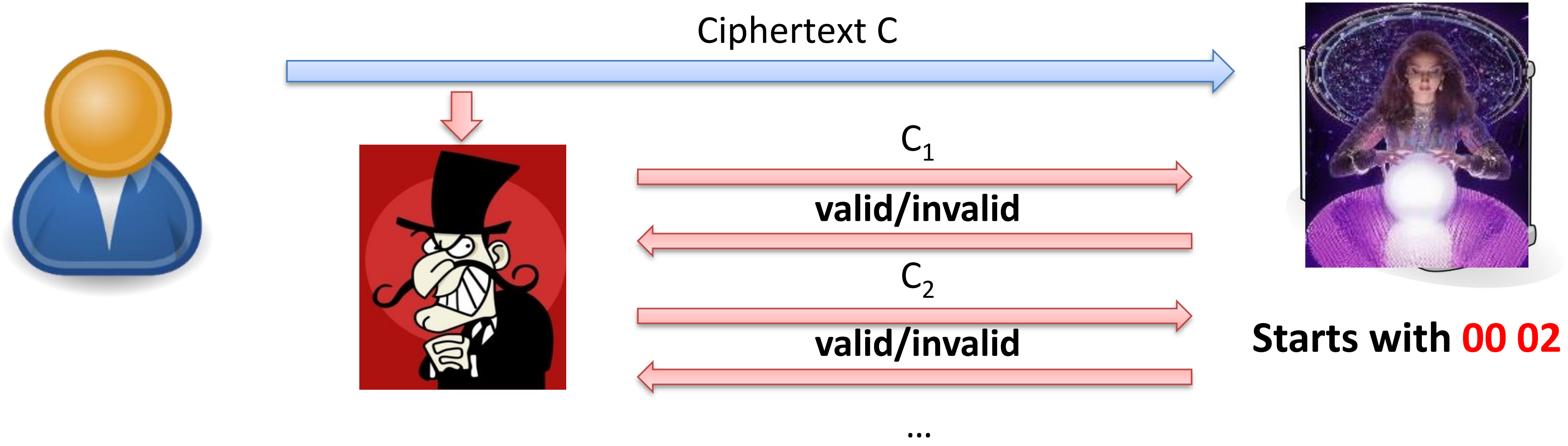

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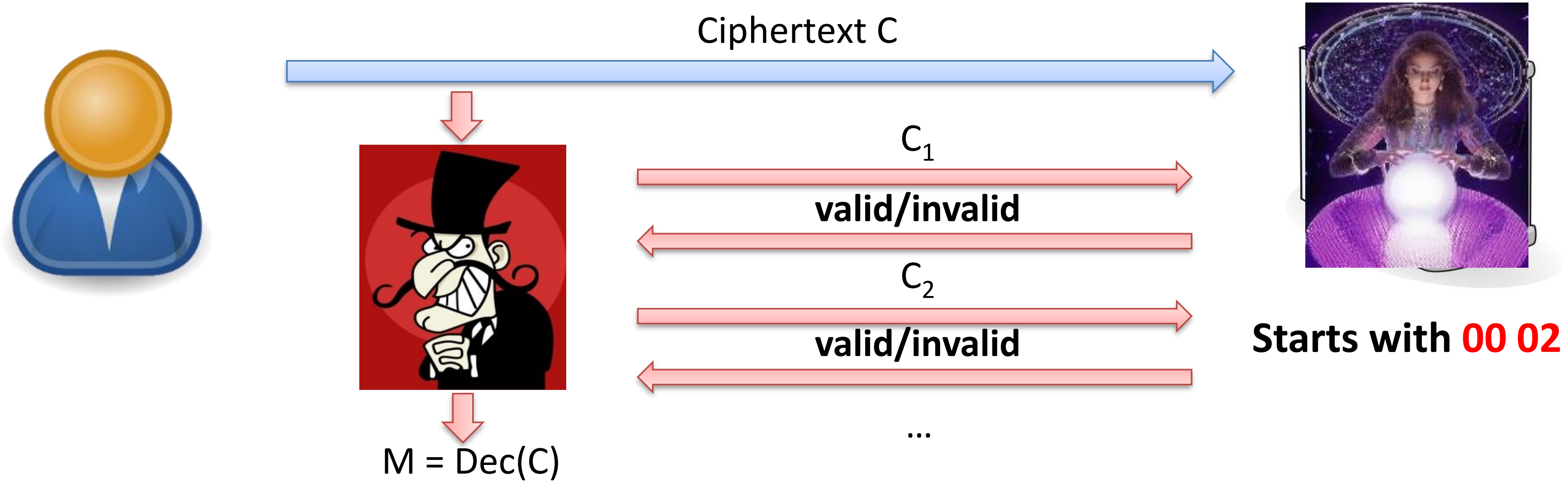

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M = Dec(C)

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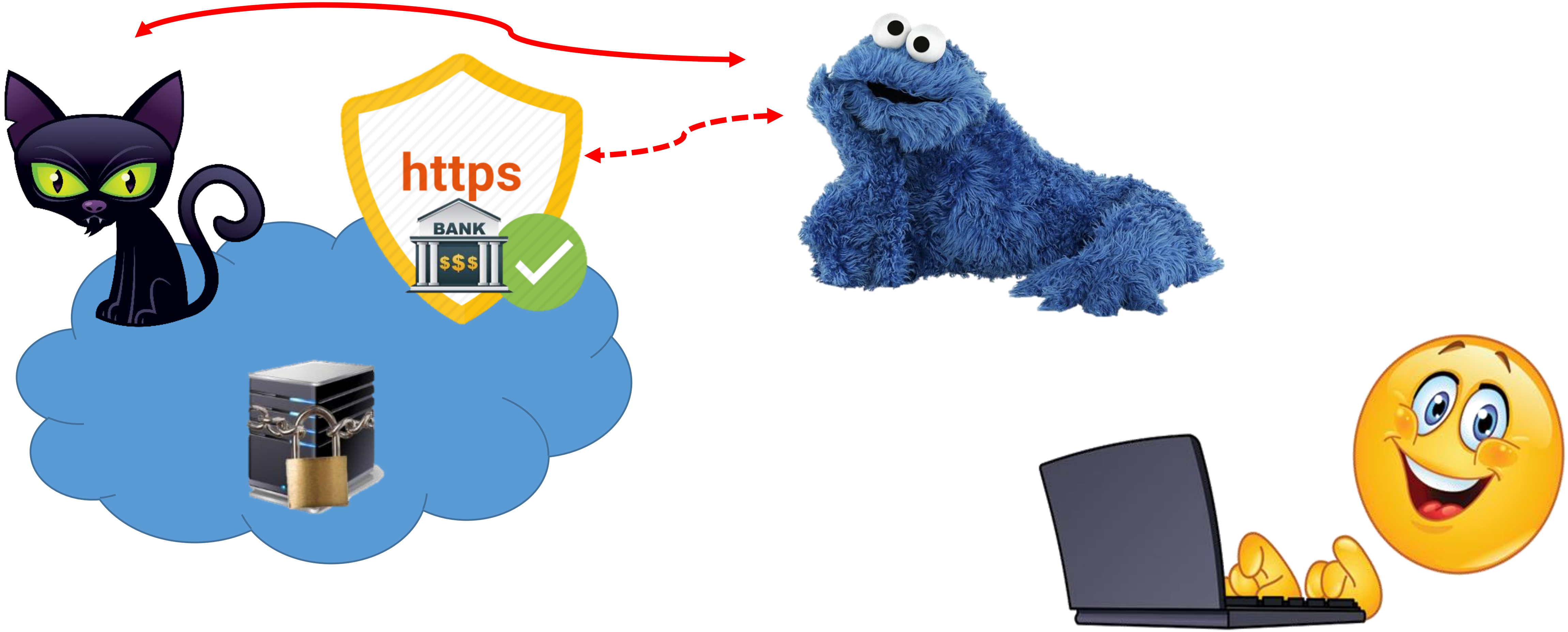

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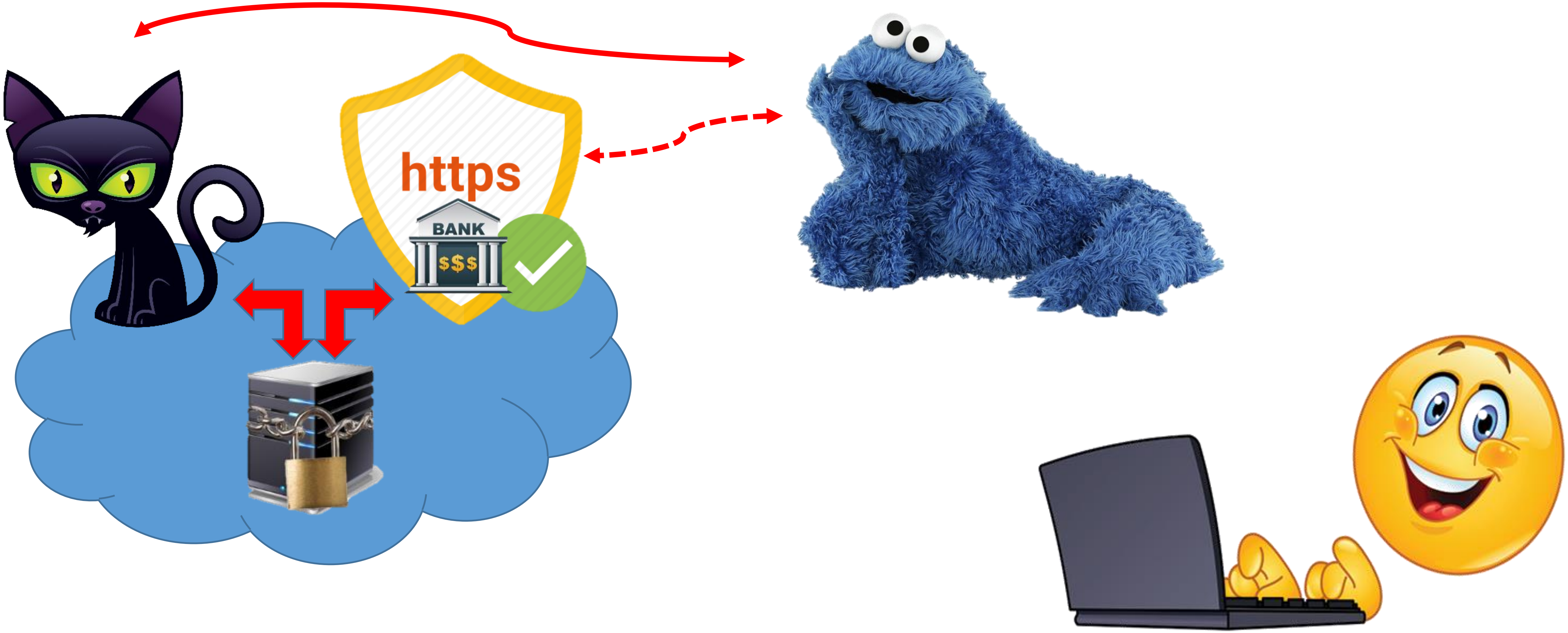

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  - Need many queries
  - Have time for < 600

Downgrade attack on Firefox

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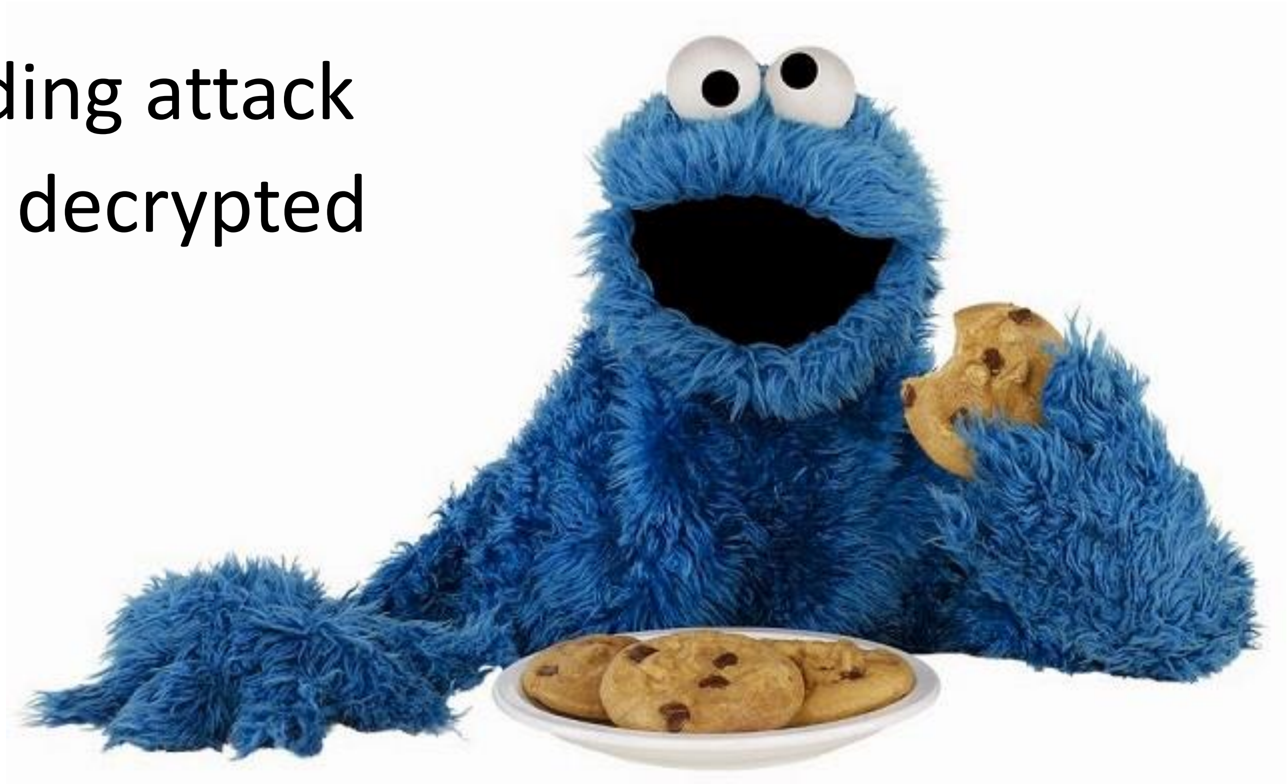

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  - Cookie?
- The user will notice the delay

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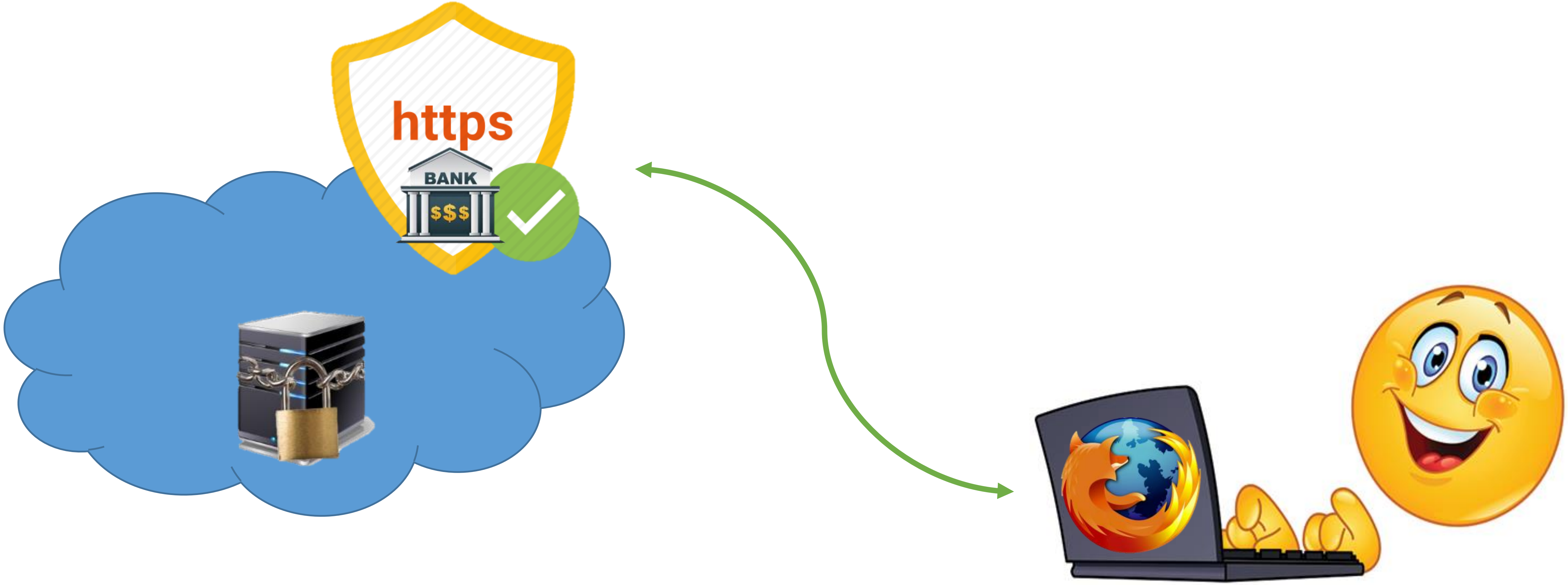

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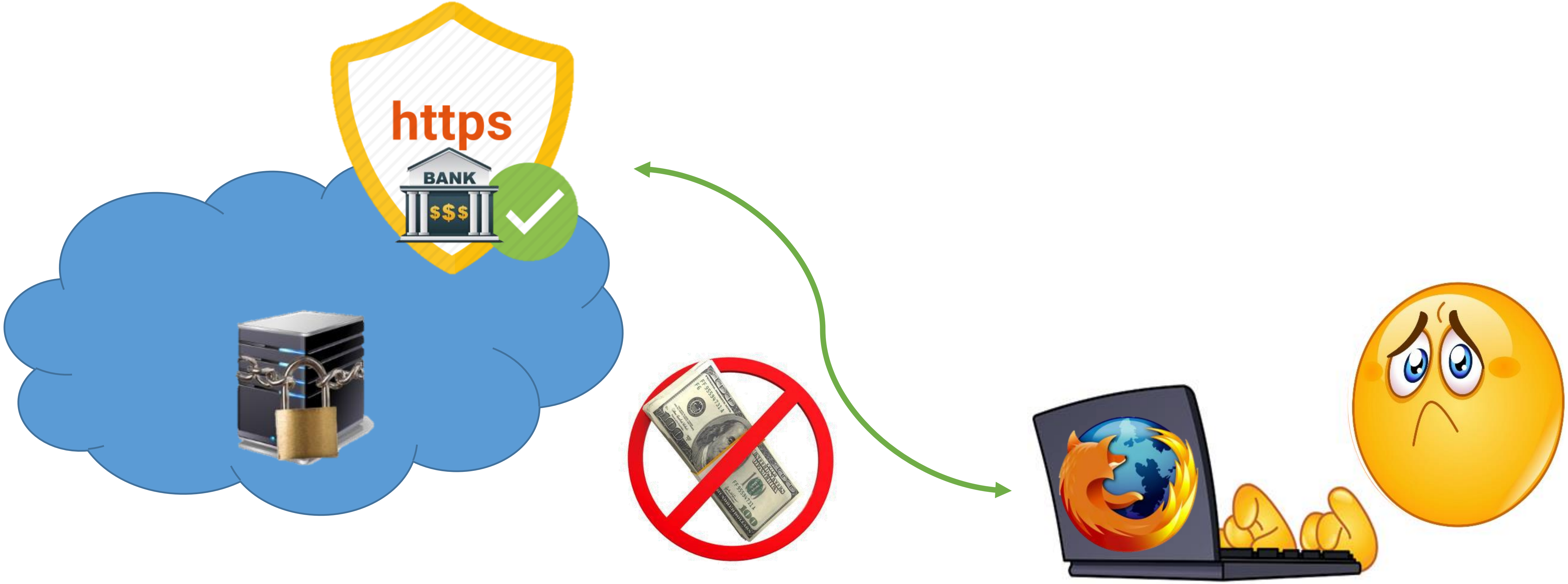

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https
BANK
$$$
Win Big Prizes .COM

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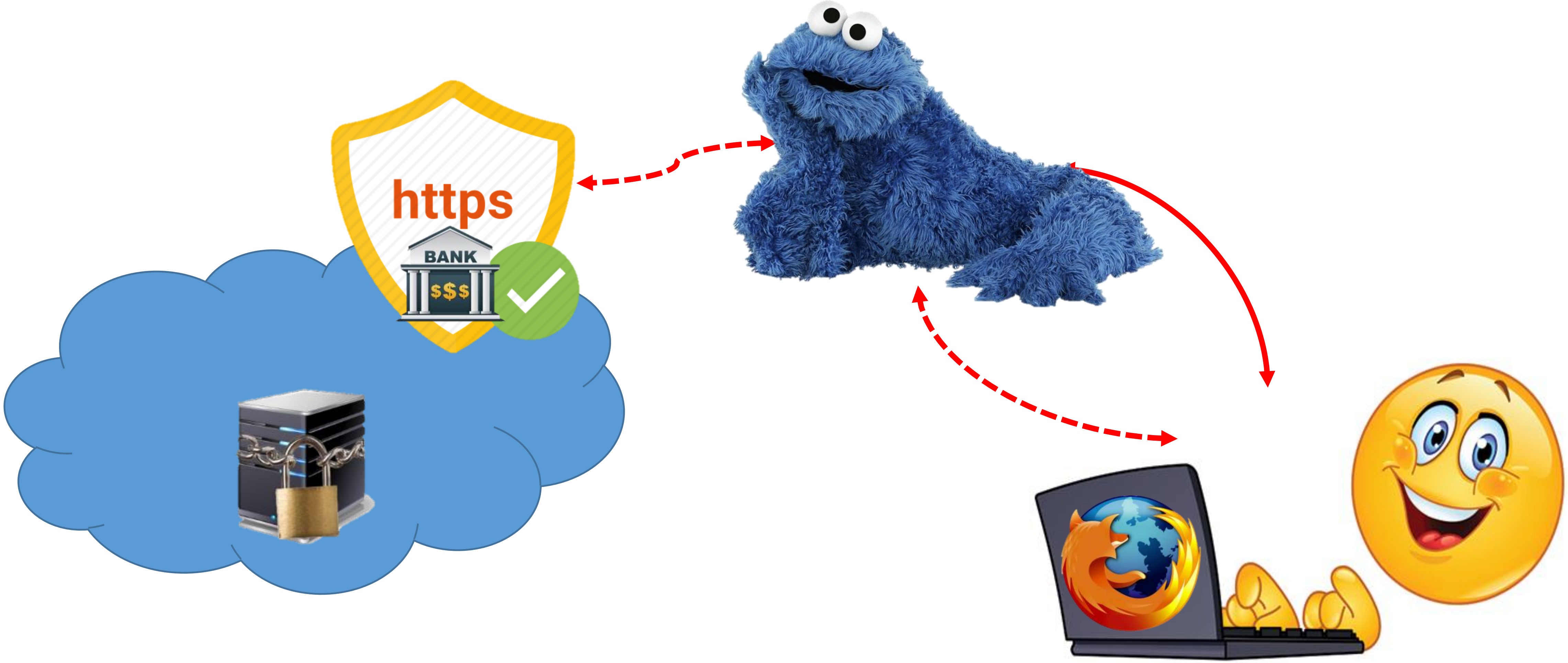

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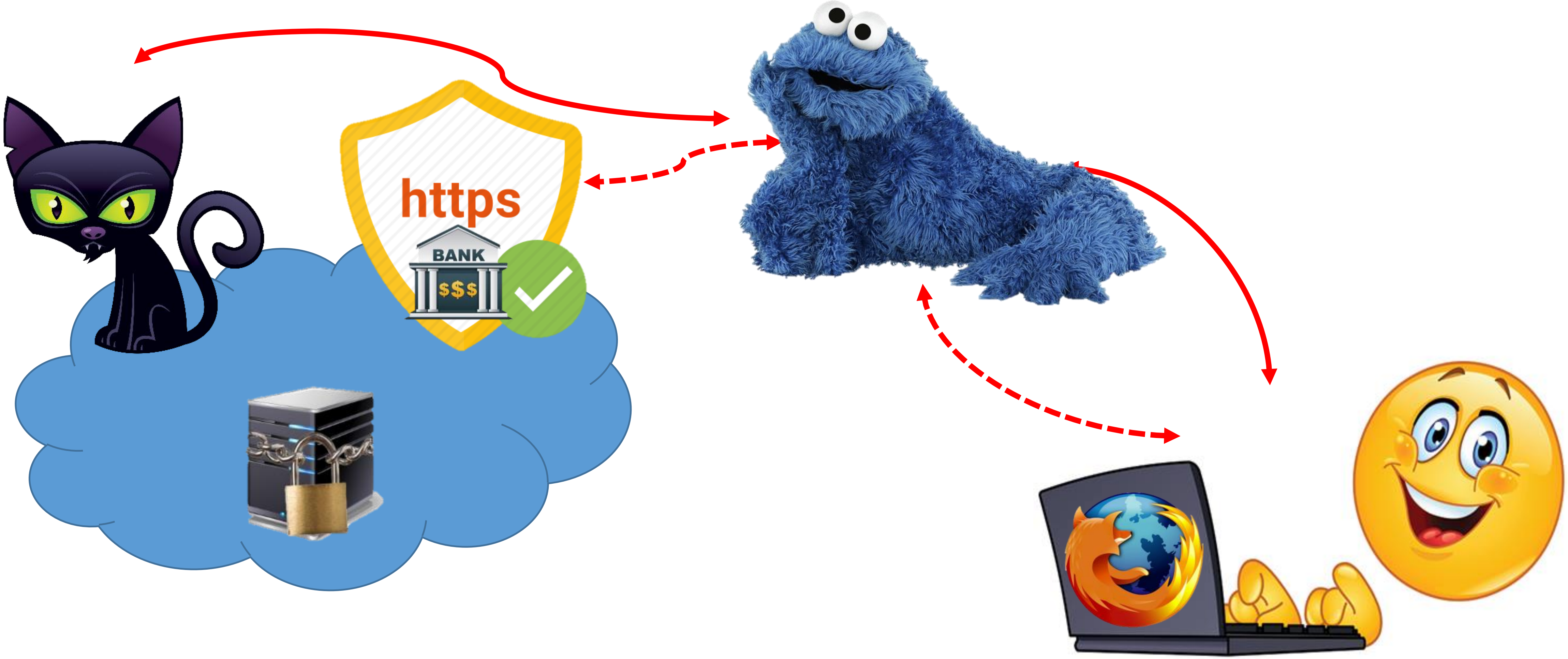

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  - Cookie?
- Need at least 2048 sequential adaptive queries
  - Have time for < 600

A little Manger background

- Assume we have the following Manger oracle

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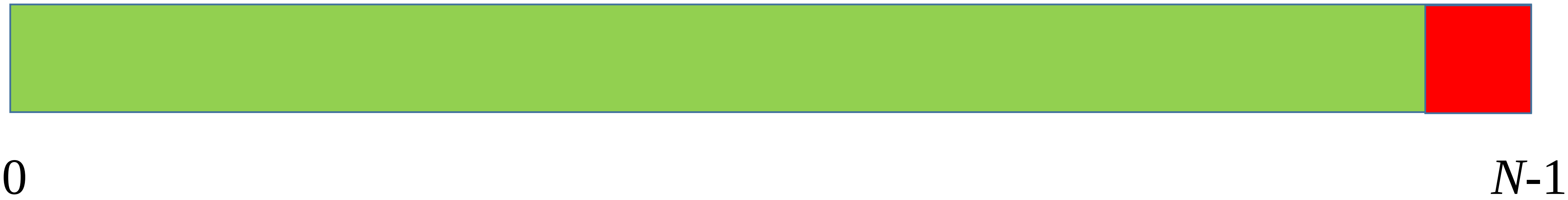

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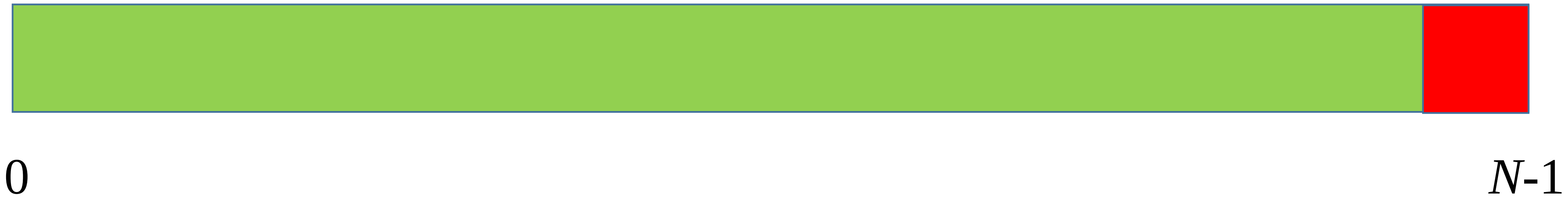

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- Iteratively reduce size of possible interval
- After additional i sequential queries we learn that

$$m \cdot s \mod N \in [a_i, b_i]$$

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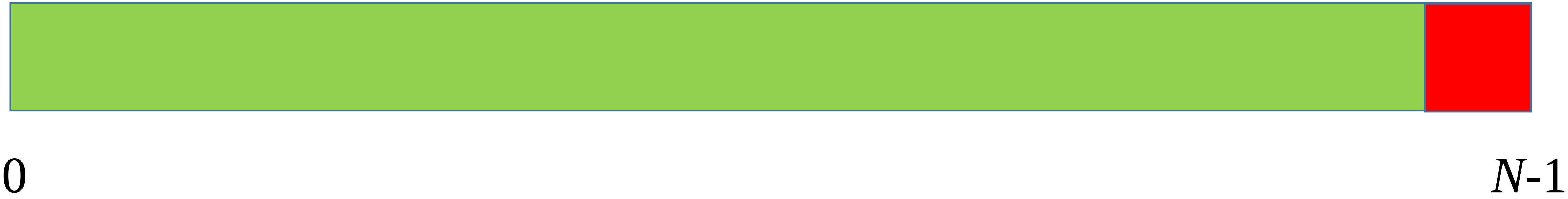

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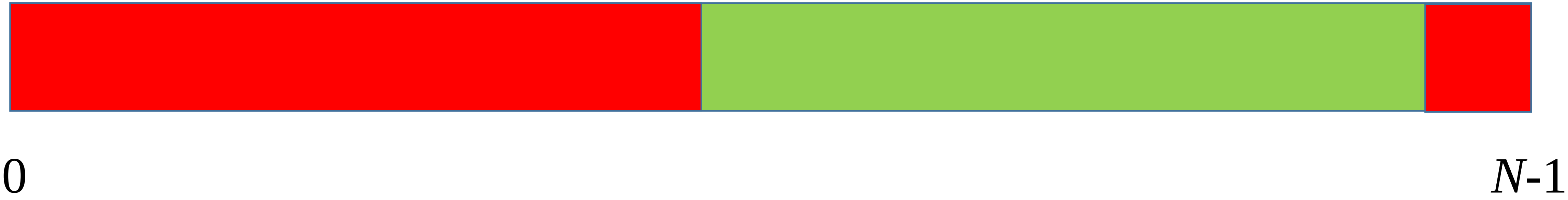

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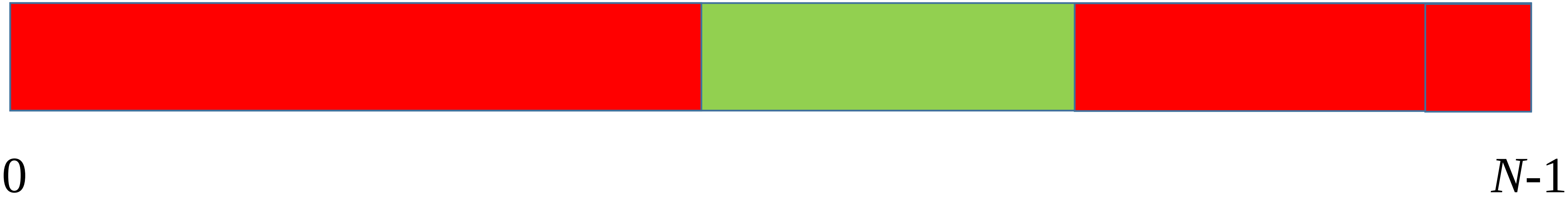

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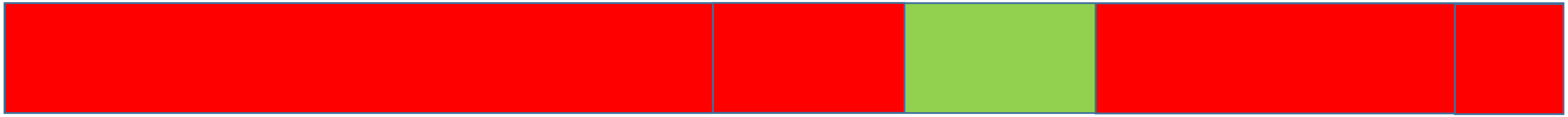

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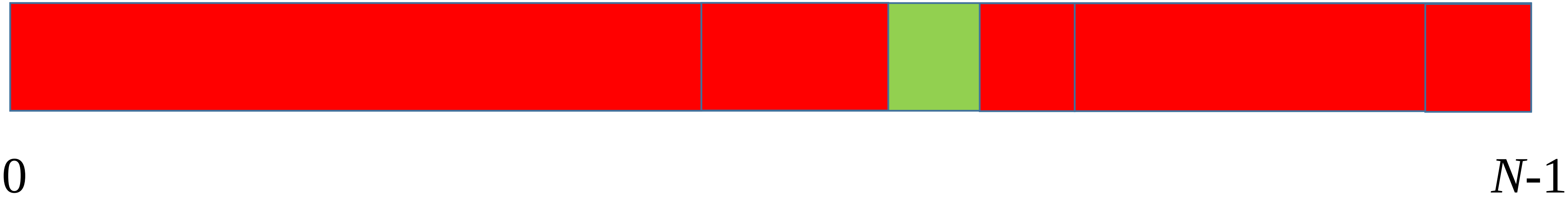

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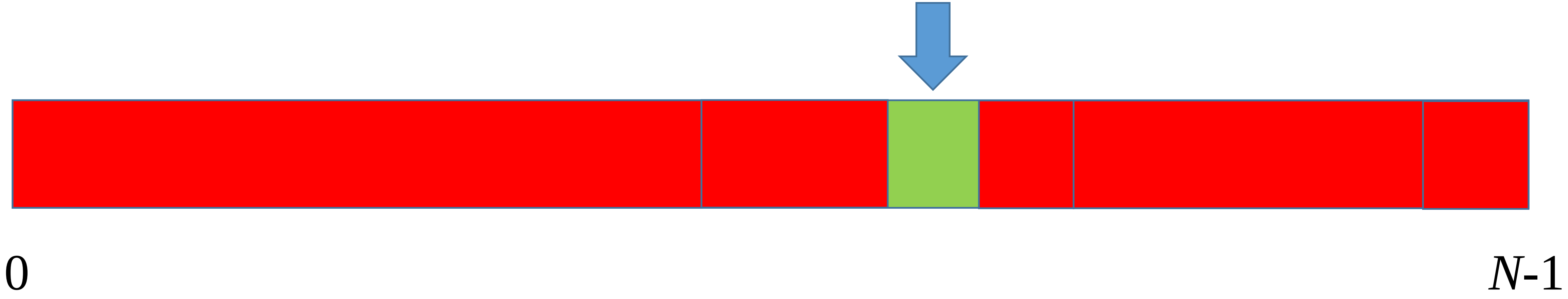

The Cookie Lattice

- Run k attacks in parallel with i sequential queries each

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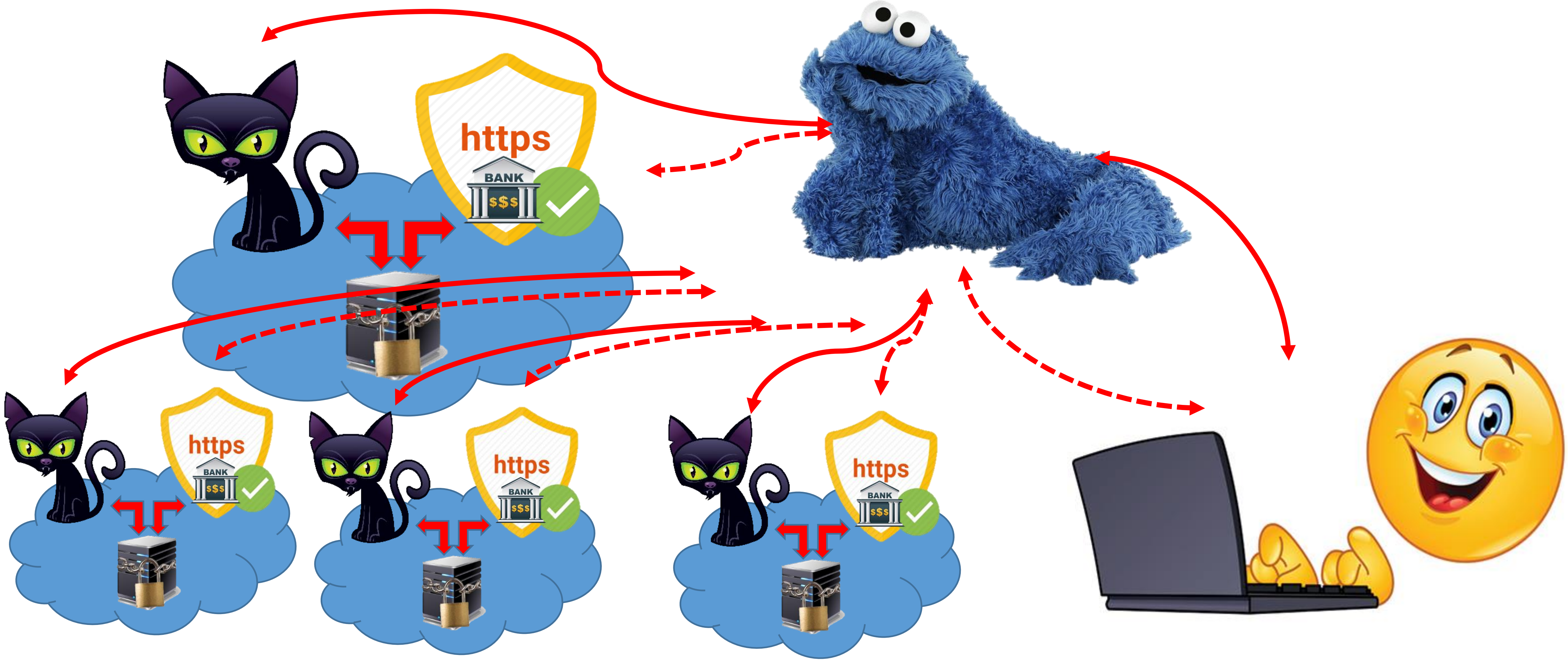
  - Allows us to finish attack in less than 30 seconds

Attack Scenario Parallel: MiTM + Cache timing side channel



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- Parallelization for downgrade attack
  - PoC for Manger parallelization using LLL

99% OF THE WORLDS COOKIES ARE CONSUMED BY 1% OF THE MONSTERS
LIFE
# OCCUPY SESAME STREET

Disclosure

- We disclosed to:
  - OpenSSL, Mozilla’s NSS, Amazon’s s2n, Apple’s CoreTLS, mbed TLS, wolfSSL, GnuTLS
- All have patched their code, with various levels of success
- Lots of stories…

Recommendation

- Many recommendations for several layers of mitigations in the paper
  - Bottom line **Don’t use RSA KX**
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- Many recommendations for several layers of mitigations in the paper
  - Bottom line **Don’t use RSA KX**
  - It has failed us too many times
- If you really really really must
  - Separate your certificates!
  - …

Questions?

- Paper website
  https://cat.eyalro.net

- Any questions?