CIS 4360, Spring 2026

Digital Signature

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The slides are loosely based on those of Prof. Mihir Bellare, UC San Diego.

Agenda

1. High-level Overview

2. Building Signature Scheme

3. Application: DNSSEC

The Need For Signing Is Ubiquitous

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Brooklyn, NY, 12345

CHECK № 0007
DATE: Aug. 11, 2019

PAY TO THE ORDER OF: Mary Johnson $ 715,39
Seven hundred fifteen and 39/100 DOLLARS

PAYABLE AT
ALL LOREM BANK BRANCHES IN USA
ACCOUNT № 001234567

MEMO Monthly rent

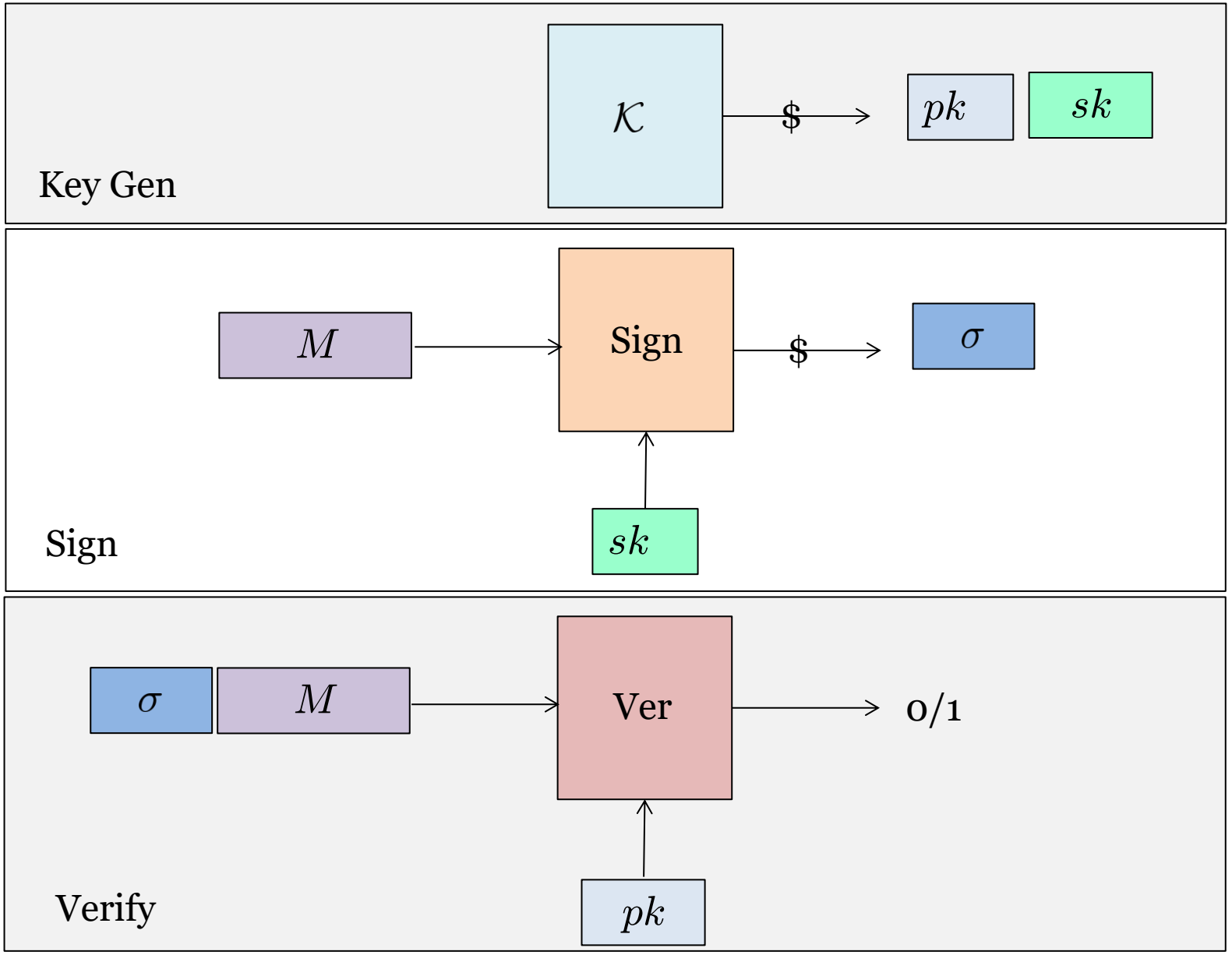
J. Smith
AUTHORIZED SIGNATURE

How To Sign Electronically?

Lots of apps to digitize signatures

Problem: A digitized signature is easily copied → forgery

Digital Signature Scheme: Syntax



Digital Signature versus MAC

MAC

- Verifier needs to share a secret key with signer

- Verifier can impersonate signer

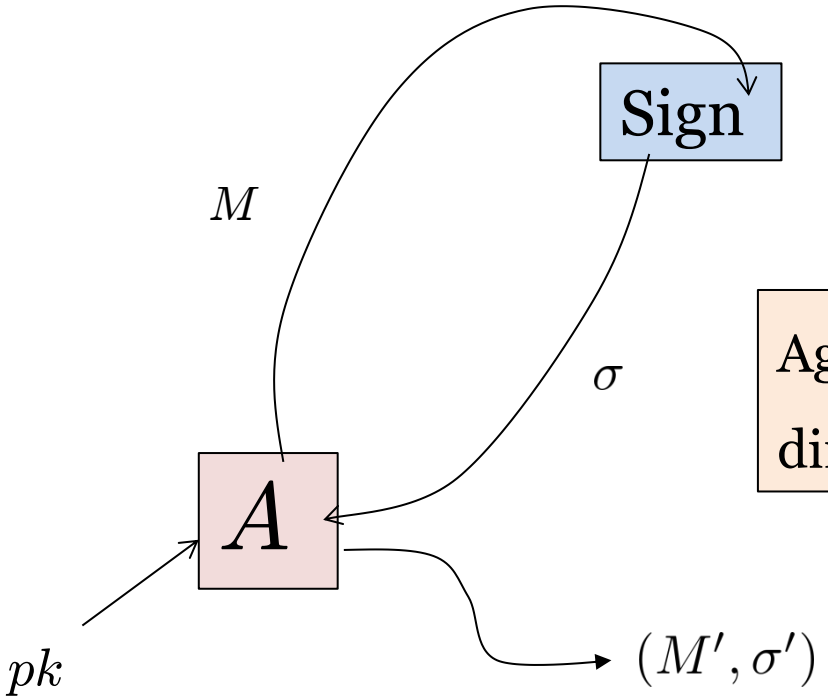
Digital Signature

- Verifier needs no secret

- Verifier cannot impersonate signer

Digital Signature: Unforgeability Security

- Similar to MAC security
- **Difference**: The adversary is given the public key



Again, digital signature doesn't directly thwart replay attack.

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A Bad Scheme: Plain RSA Signature

Key generation: Like RSA encryption

Sign:

- To sign a message, “decrypt” it:

Verify:

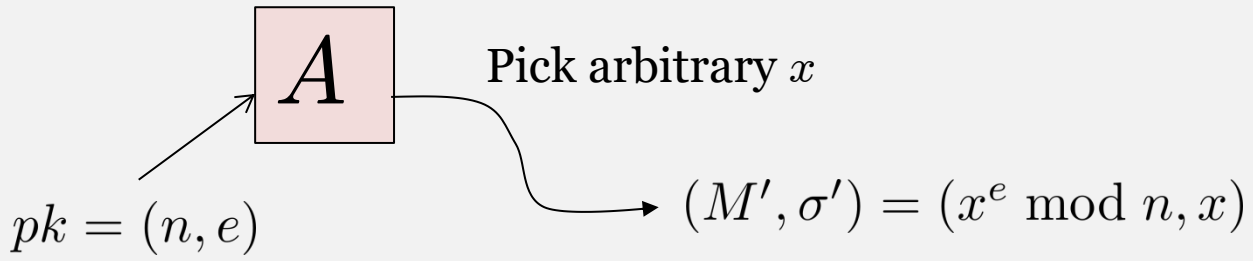
- To verify a signature, “encrypt” it and compare with the message

Issues with Plain RSA Signature

- **Feasibility**: Can sign only short messages

- **Security**: Can easily break unforgeability security

No sign query needed!

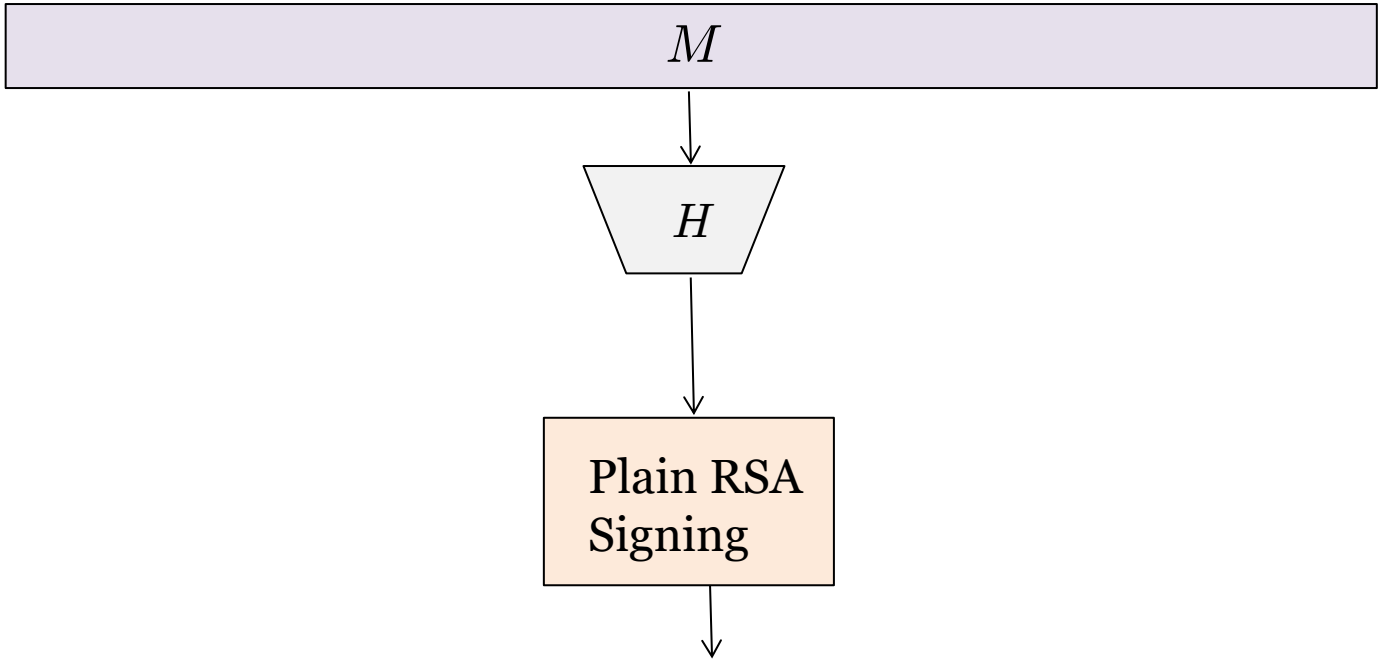


Hash-then-Sign Paradigm

Plain RSA Signature → Full Domain Hash (FDH)

Key generation: Like Plain RSA

Sign: To sign message M



Question: How to verify?

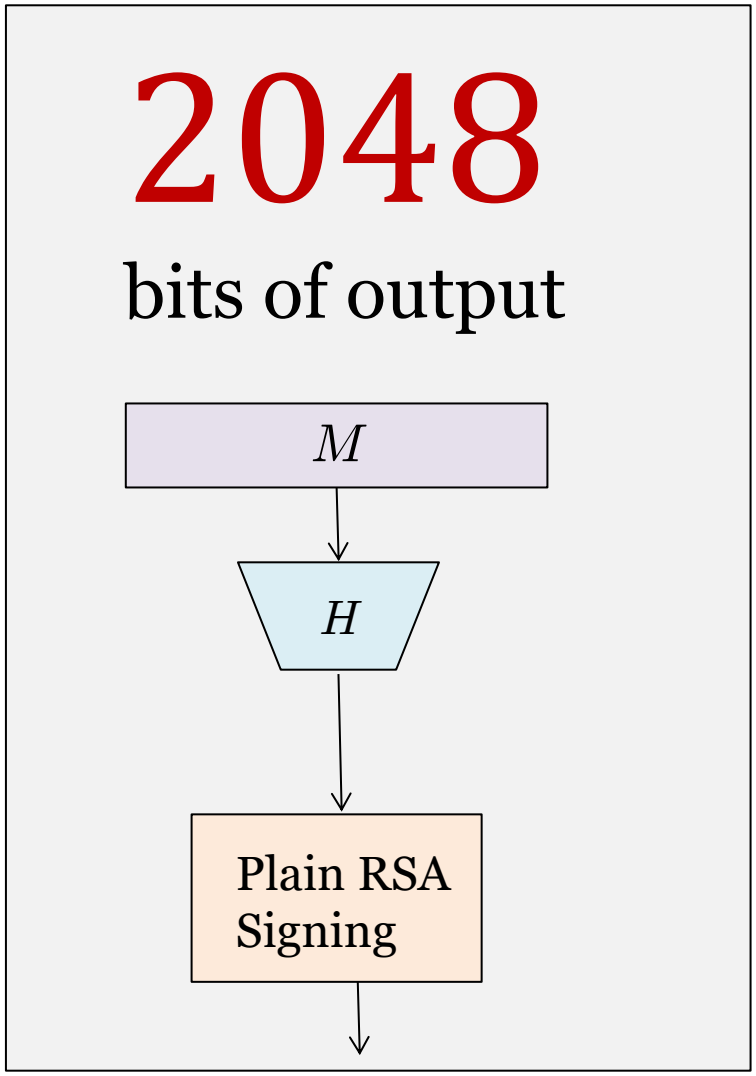
Security Requirement for Hash Function

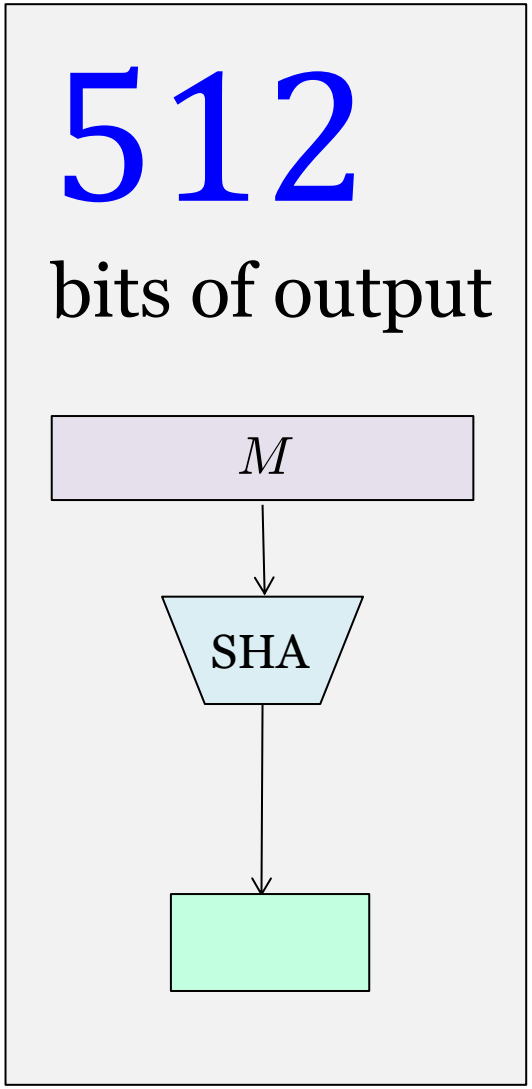
What intuition suggests: Hash must be collision-resistant

If $H(M) = H(M')$ then M and M' have the same signature

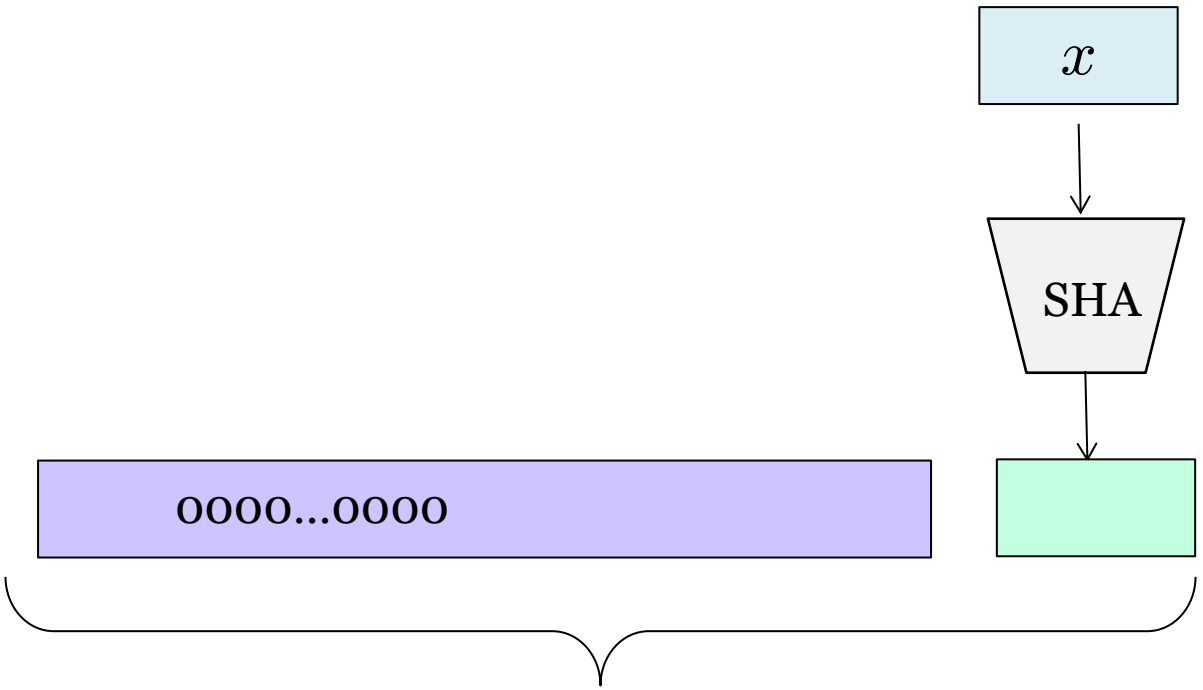
What proof requires: Hash is modeled as a random oracle

A Gap of Demand and Supply





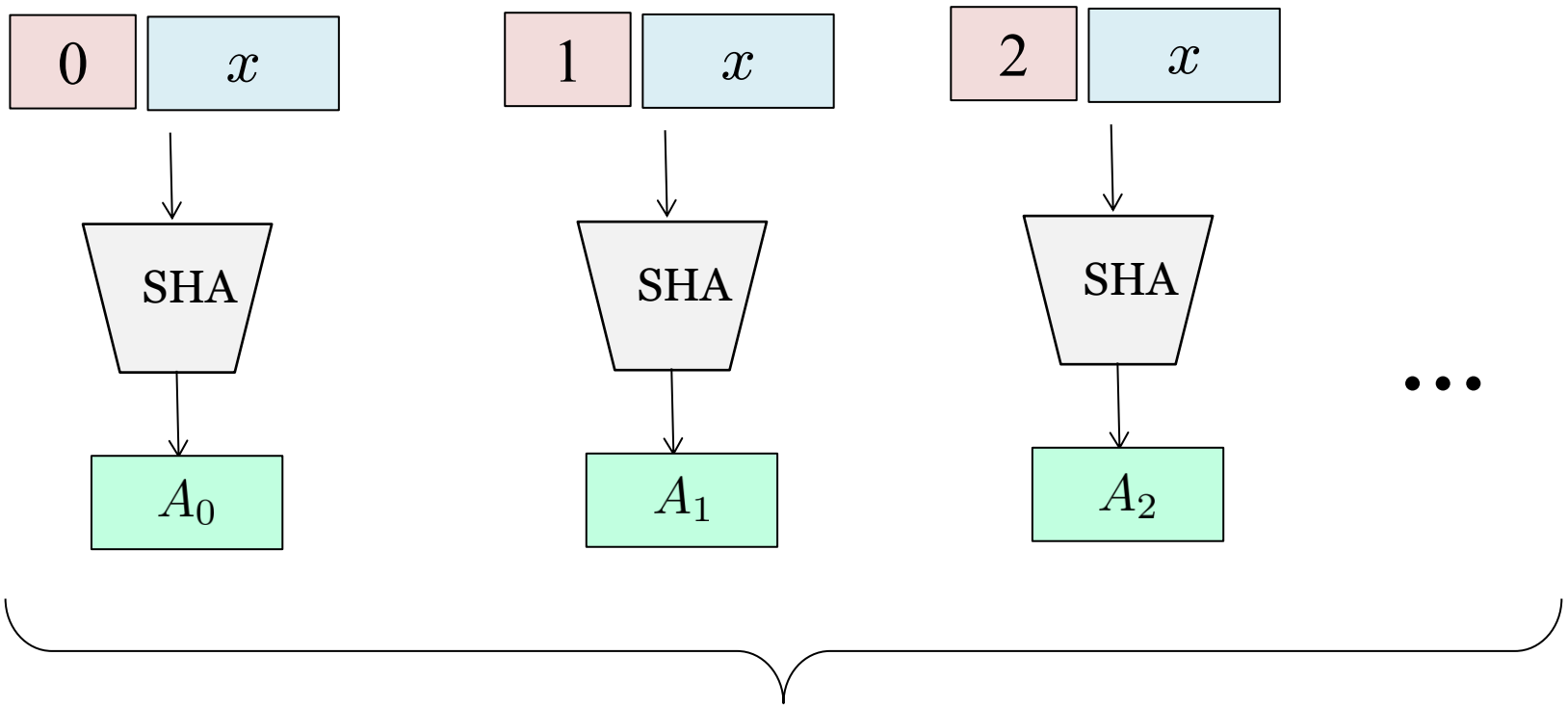
A Common Wrong Way to Hash



2048-bit string Y, viewed as a number in $\mathbb{Z}_N$

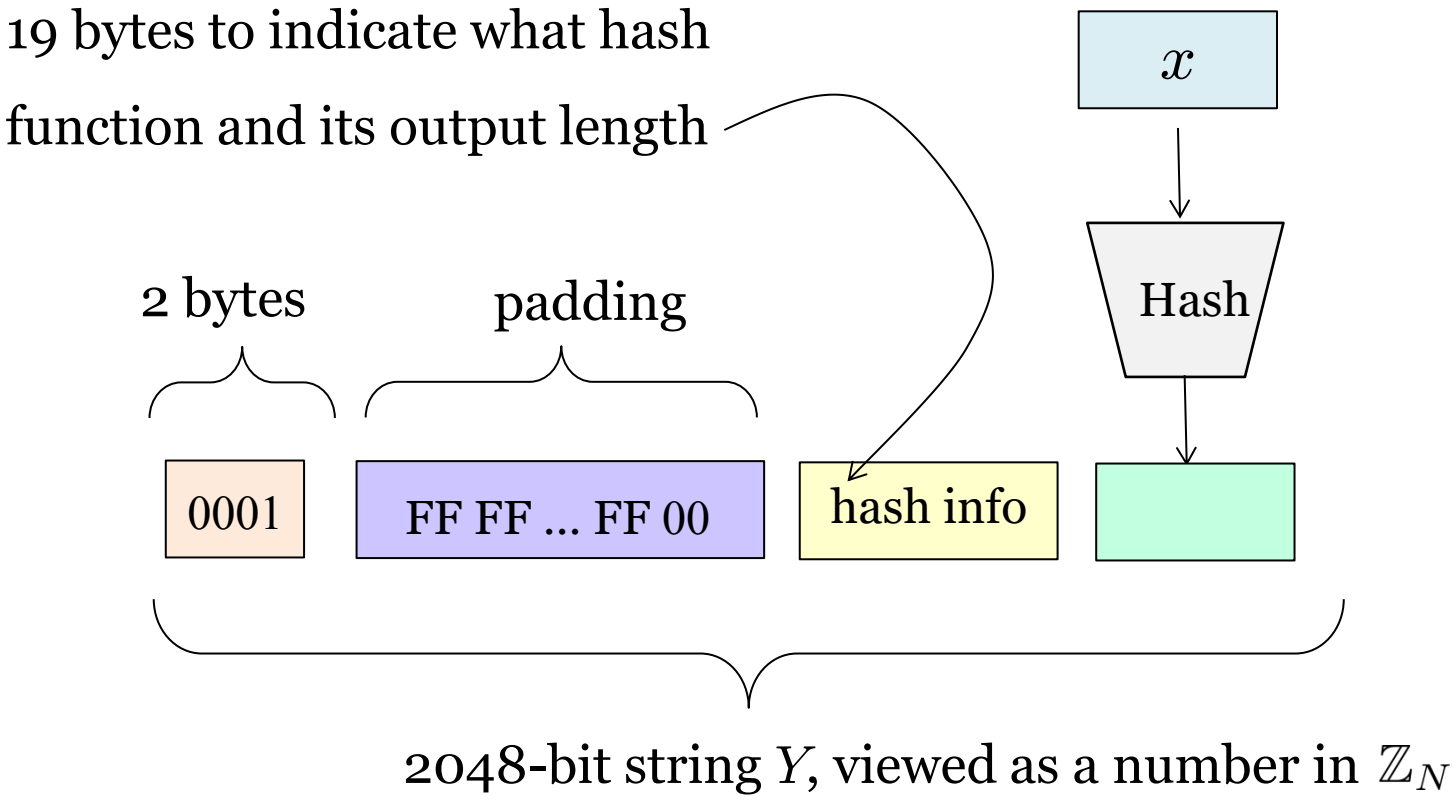
Broken by Desmedt and Odlyzko in 1985

How to Hash Properly



Use the first $m = \lceil \log_2(N) \rceil$ bits and take mod N

Hashing in PKCS#1



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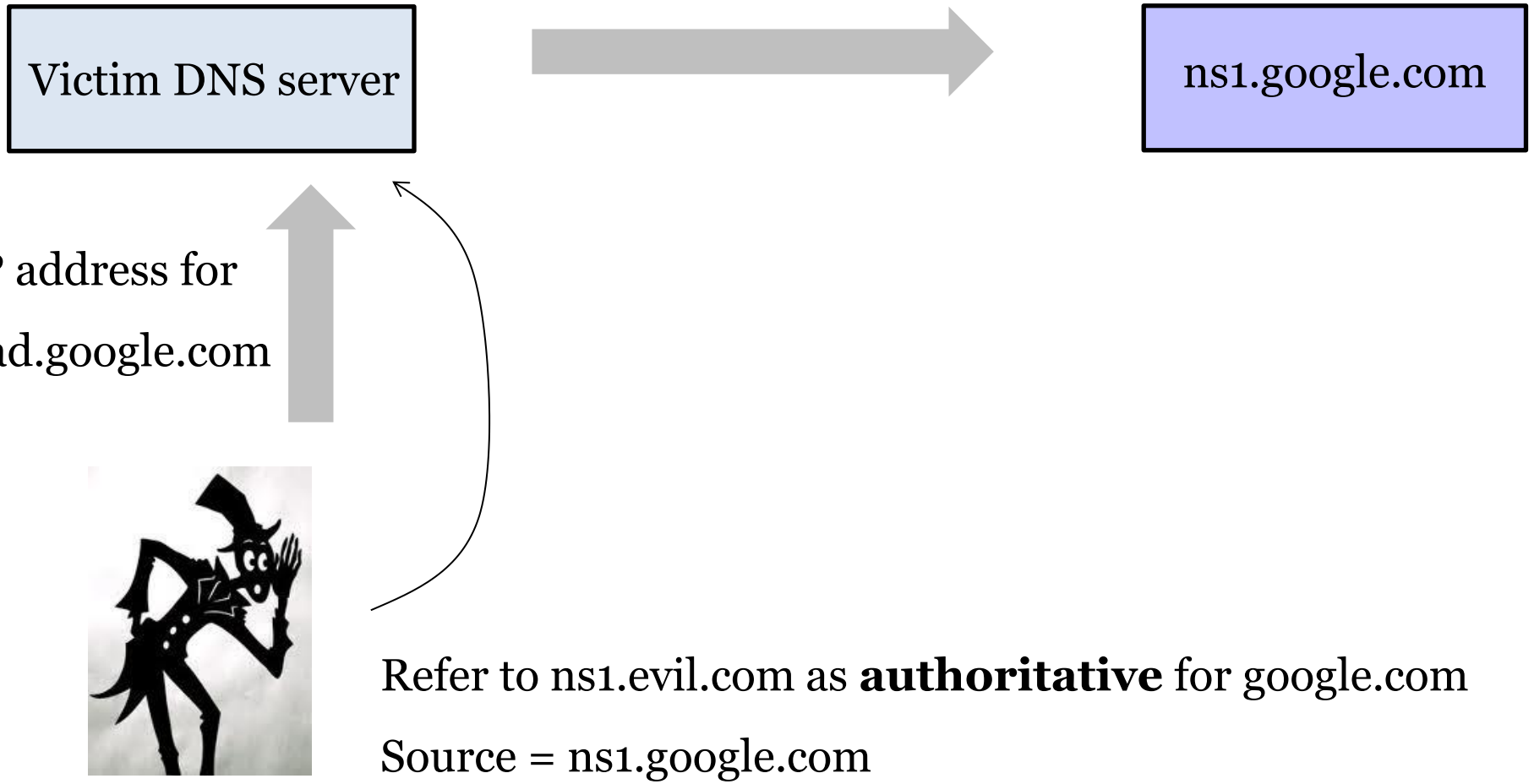
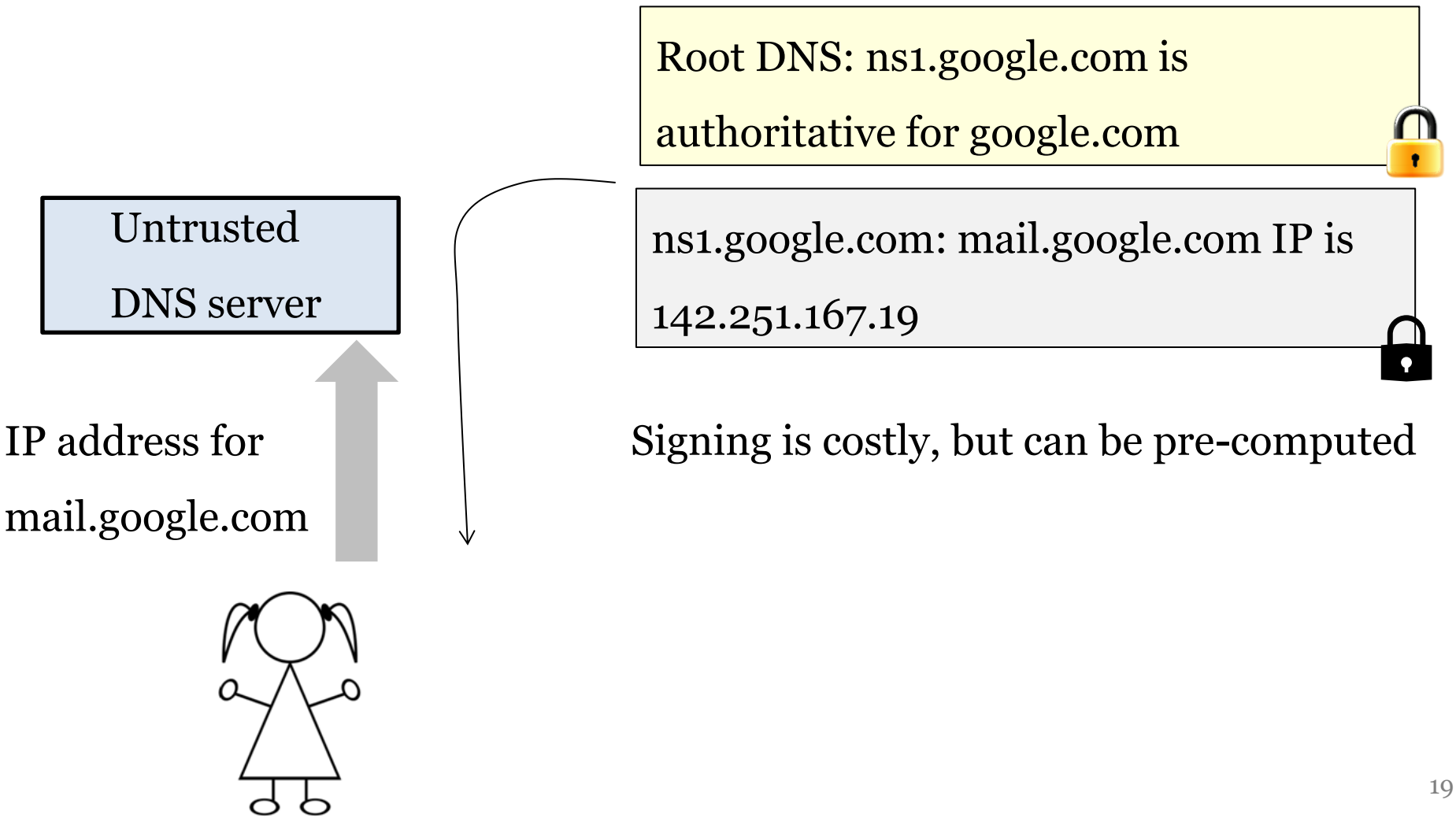
Recap: DNS Cache Poisoning Attack

Kaminsky, 2008



The Fix: DNSSEC

DNS replies need to be signed by authority



Thwarting Cache Poisoning Attack

Victim DNS server

Incorrect signature, **reject**

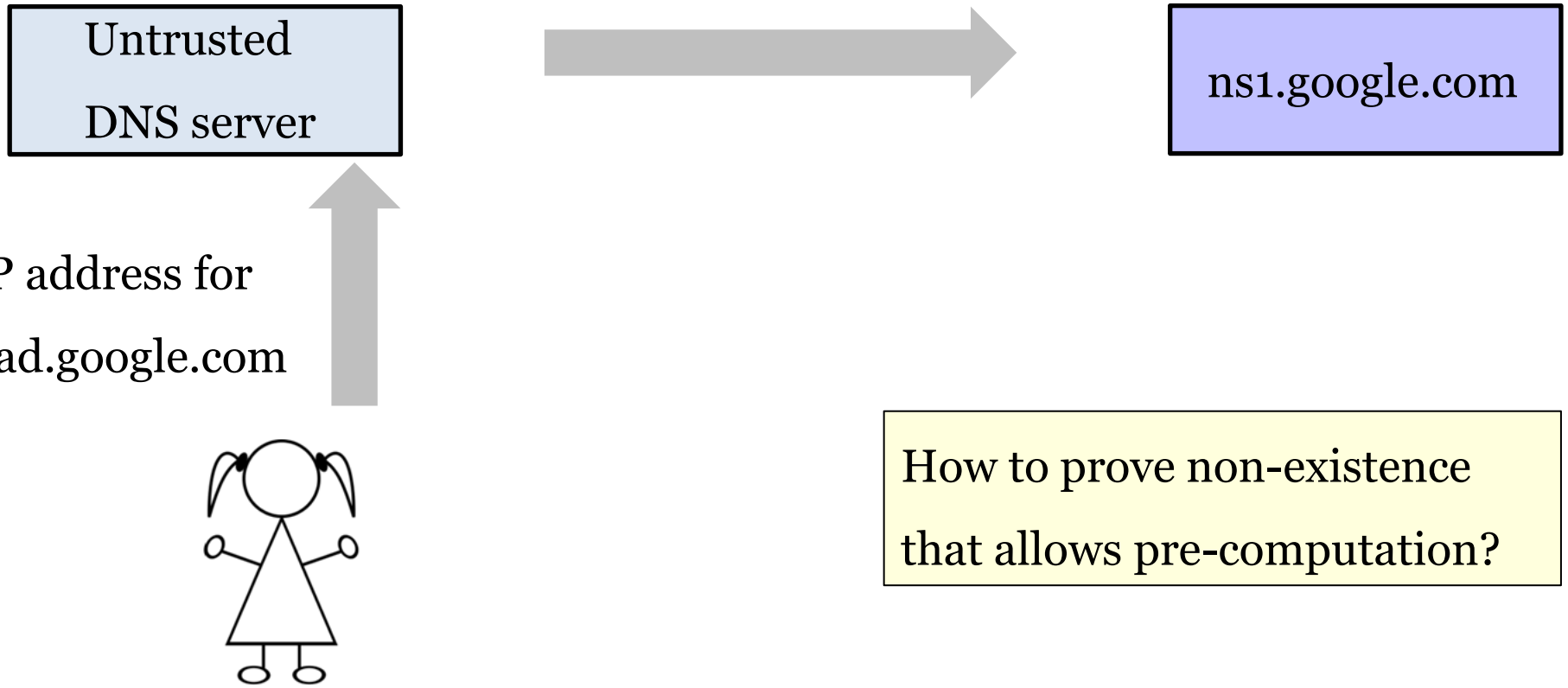
IP address for

bad.google.com

Refer to ns1.evil.com as **authoritative** for google.com

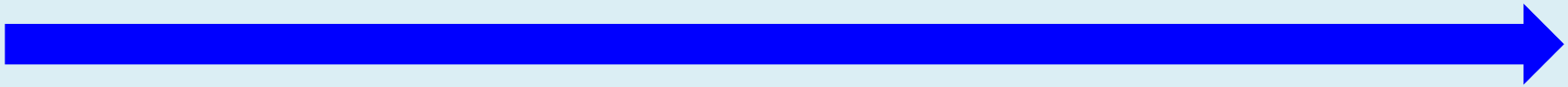
Source = ns1.google.com

Issue: Prove Non-Existence



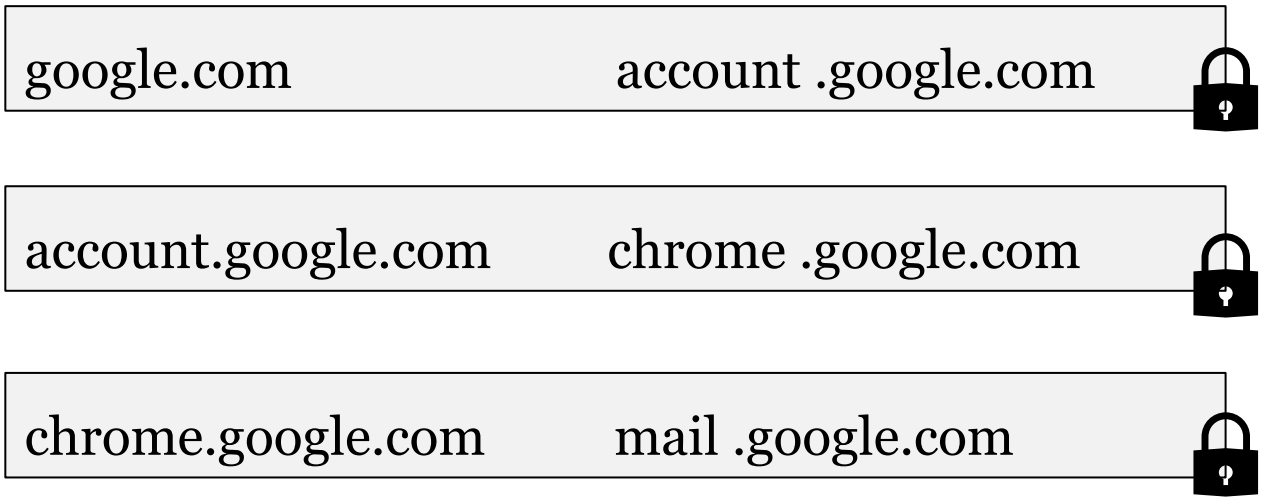
Proving Non-Existence: Precomputation

Google sorts its subdomain names alphabetically



account chrome mail policies site

Sign every consecutive pairs



Proving Non-Existence: Respond to Query

Unsuccessful Binary Search