

CNT 5412, SPRING 2025

DIGITAL SIGNATURE

VIET TUNG HOANG

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

THE CHEQUE PAPER CONTAINS COLORED MICROPRINTING AND WATERMARK. PROTECTED BY THE LAW OF THE UNITED STATES.

John Smith

765 Dolor sit Amet APT B5
Brooklyn, NY, 12345

CHECK N° 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 N° 001234567

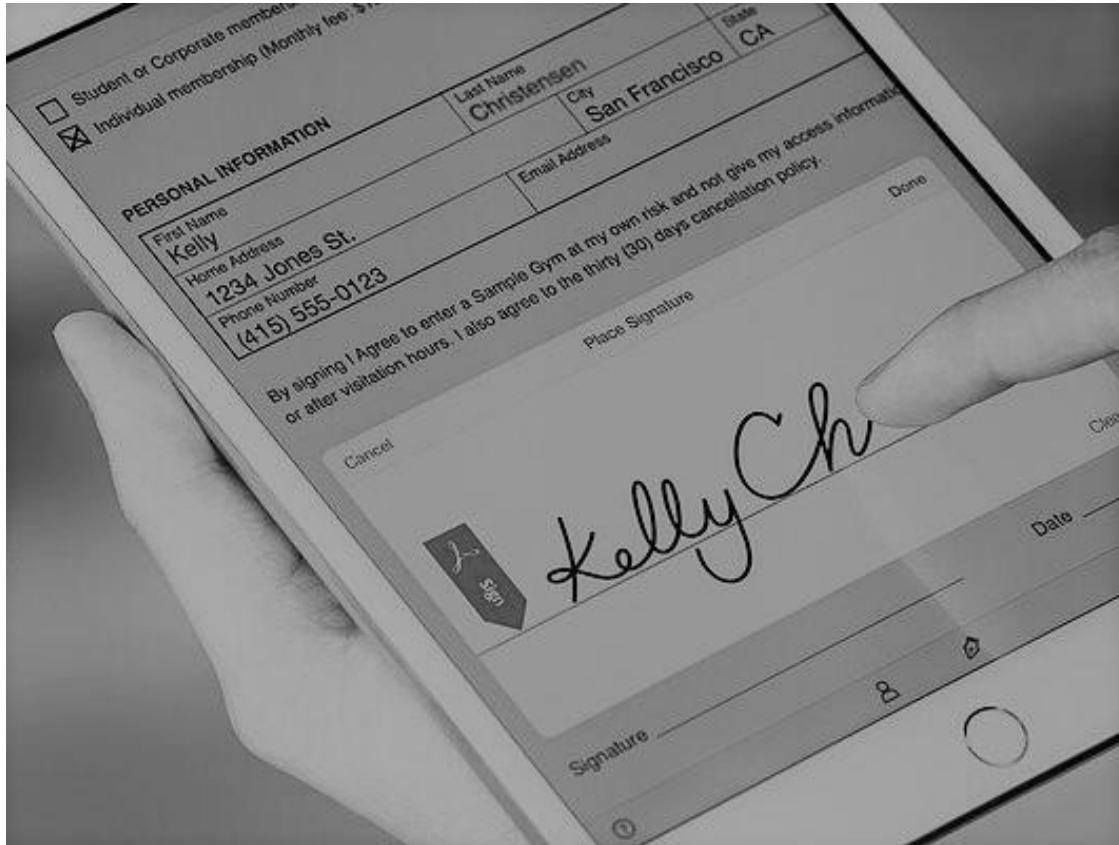
MEMO Monthly rent

J. Smith
AUTHORIZED SIGNATURE

Adobe Stock | #263107953



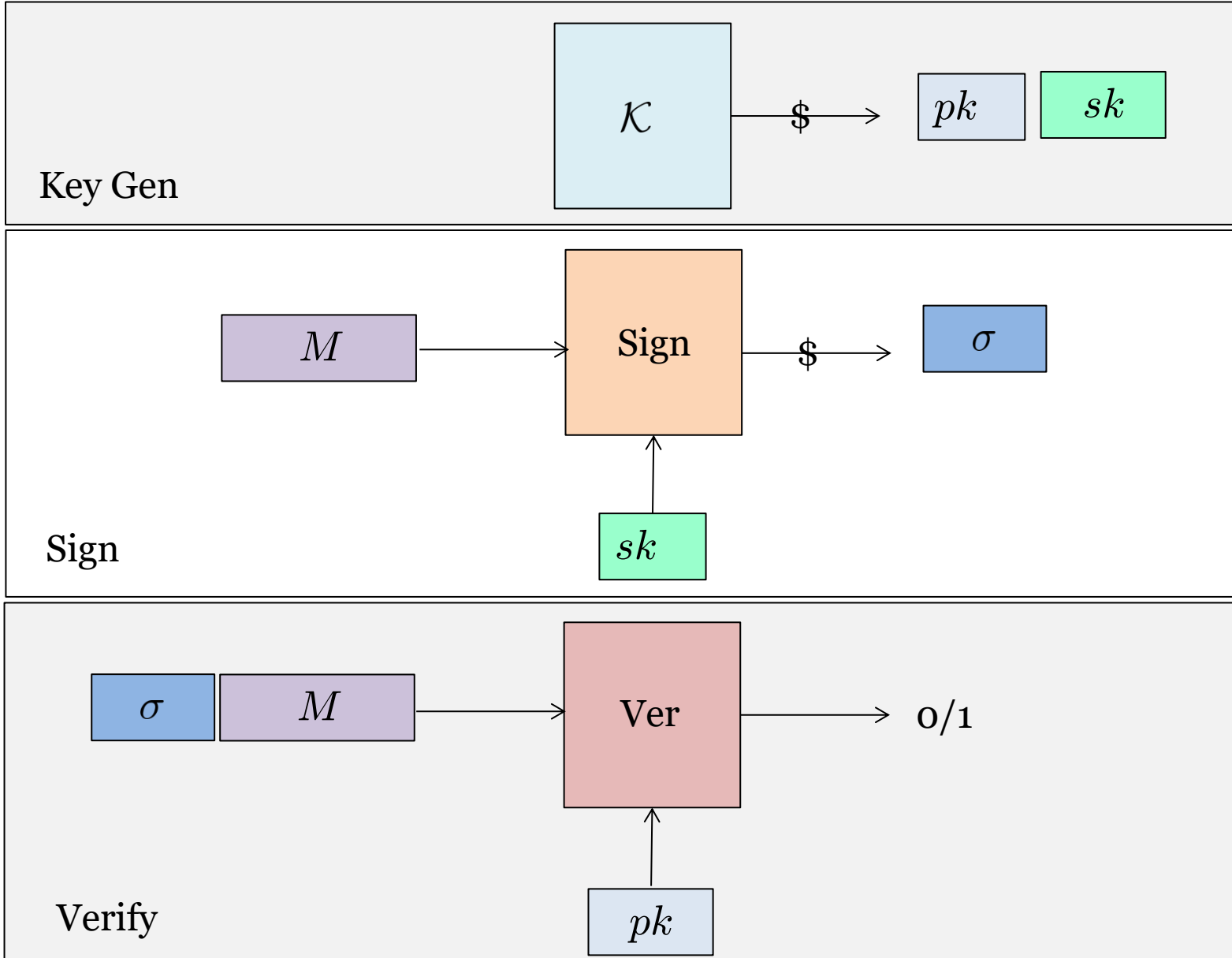
How To Sign Electronically?



Lots of apps to digitize signatures

Problem: A digitized signature is easily copied → forgery

Digital Signature Scheme: Syntax



Digital Signature versus MAC

MAC

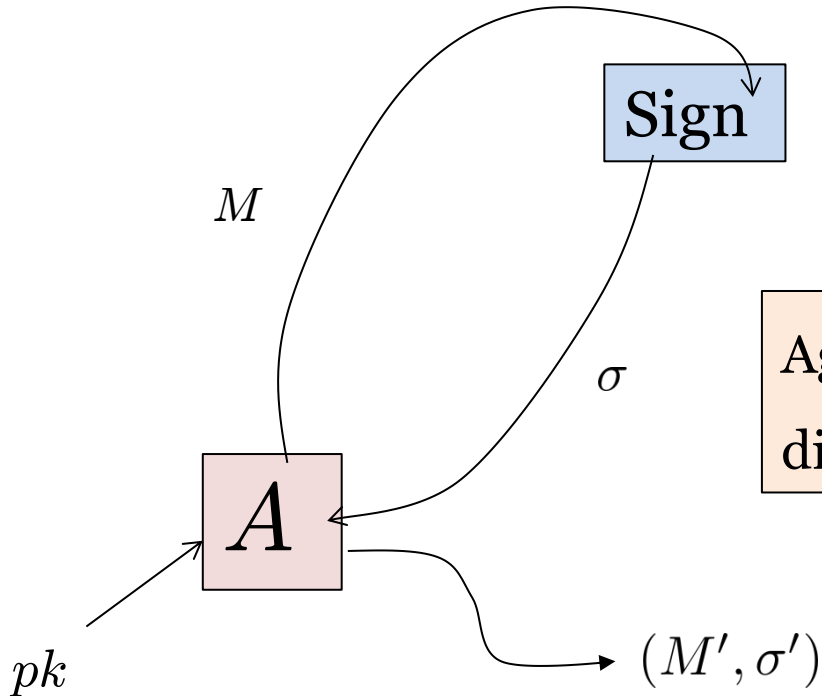
- Verifier needs to share a secret key with signer
- Verifier can impersonate signer

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.

Agenda

1. High-level Overview

2. Building Signature Scheme

3. Application: DNSSEC

A Bad Scheme: Plain RSA Signature

Key generation: Like RSA encryption

Sign:

- To sign a message, “decrypt” it:

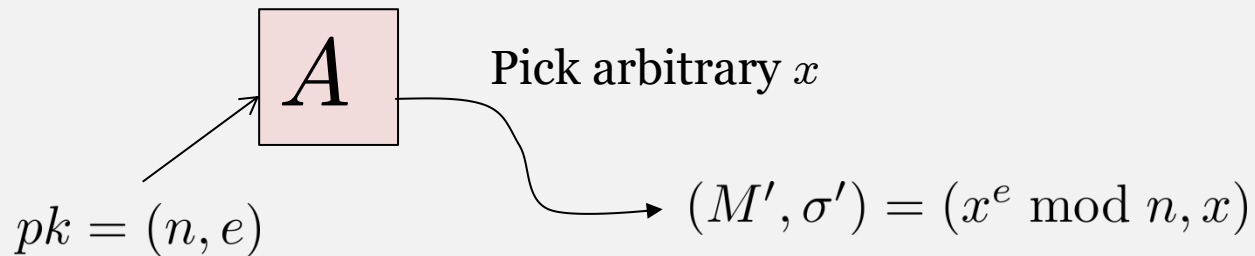
Verify:

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

Issues with Plain RSA Signature

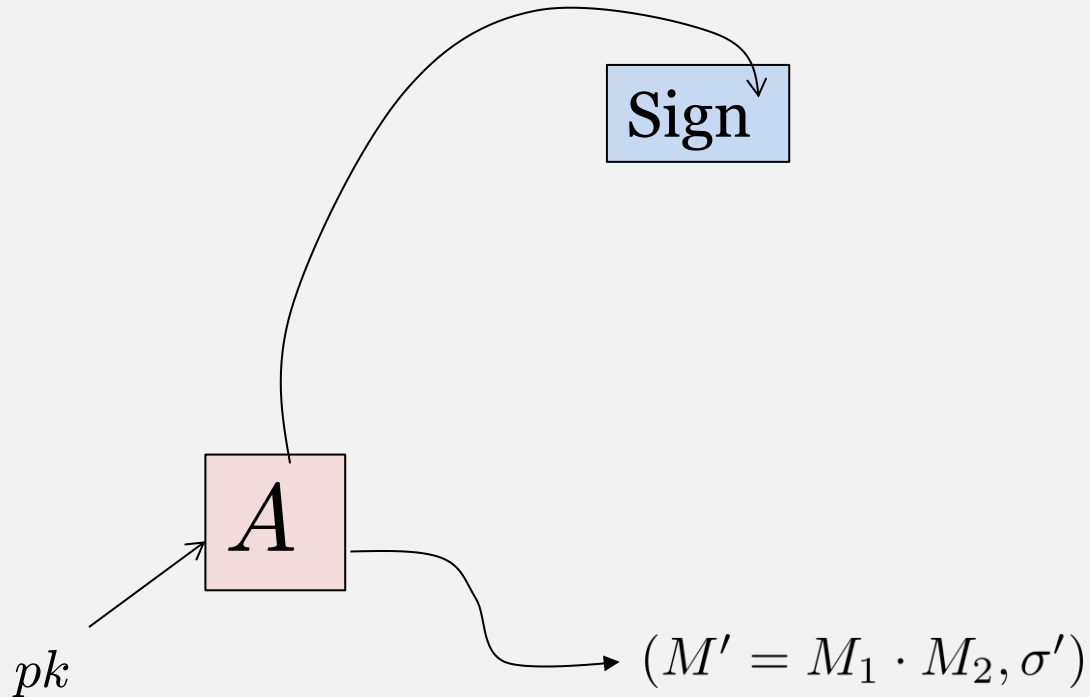
- **Feasibility:** Can sign only short messages
- **Security:** Can easily break unforgeability security

No sign query needed!



Exercise: Forging Plain RSA For Targeted Msg

Goal: The forged message must be a **specific** one

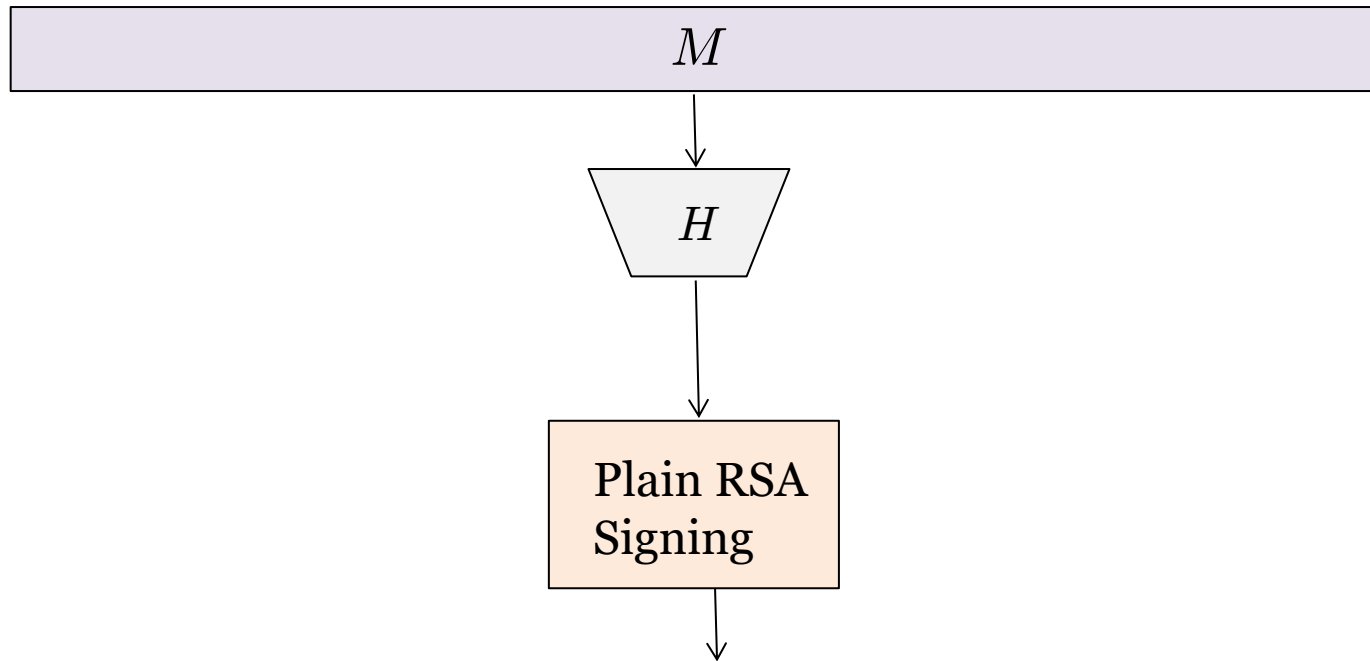


Hash-then-Sign Paradigm

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

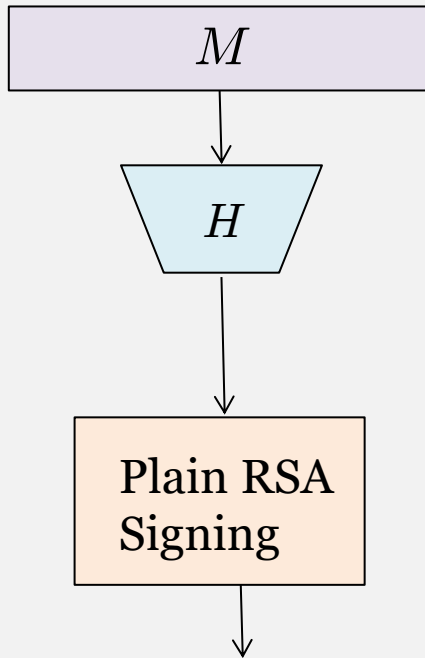
If $H(M) = H(M')$ then M and M' have the same signature

What proof requires: Hash is modeled as a random oracle

A Gap of Demand and Supply

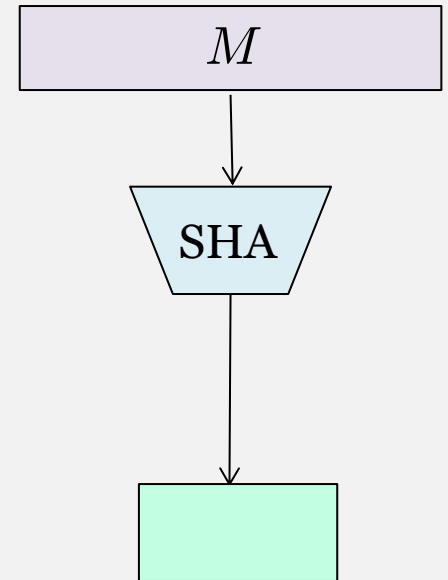
2048

bits of output

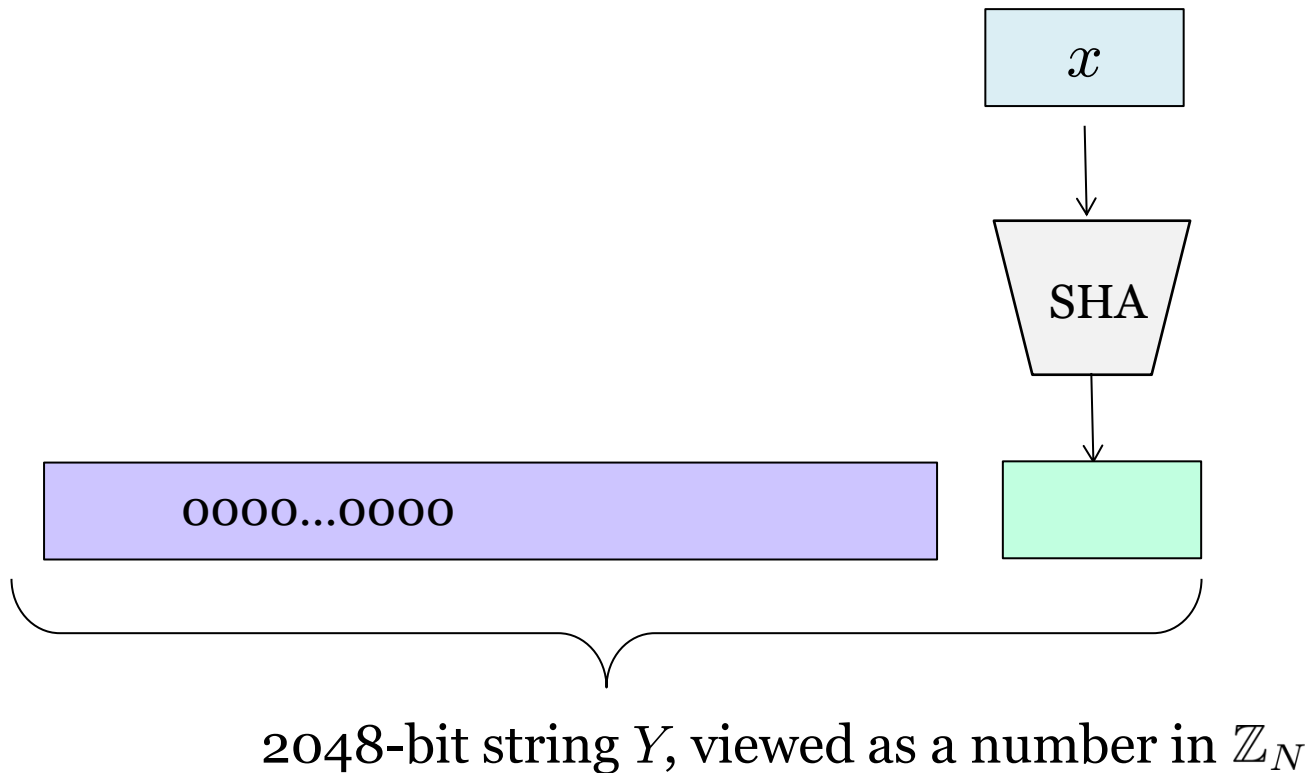


512

bits of output

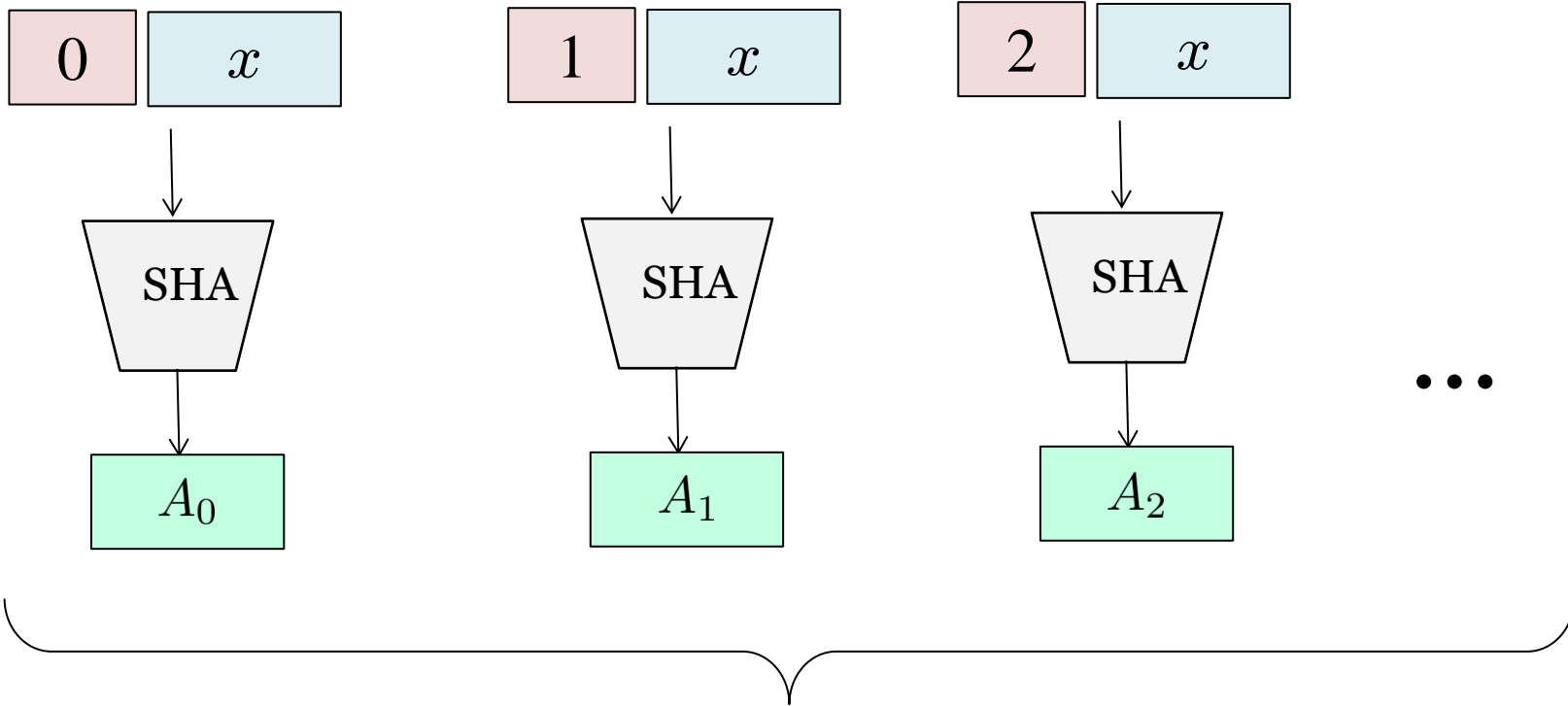


A Common Wrong Way to Hash



Broken by Desmedt and Odlyzko in 1985

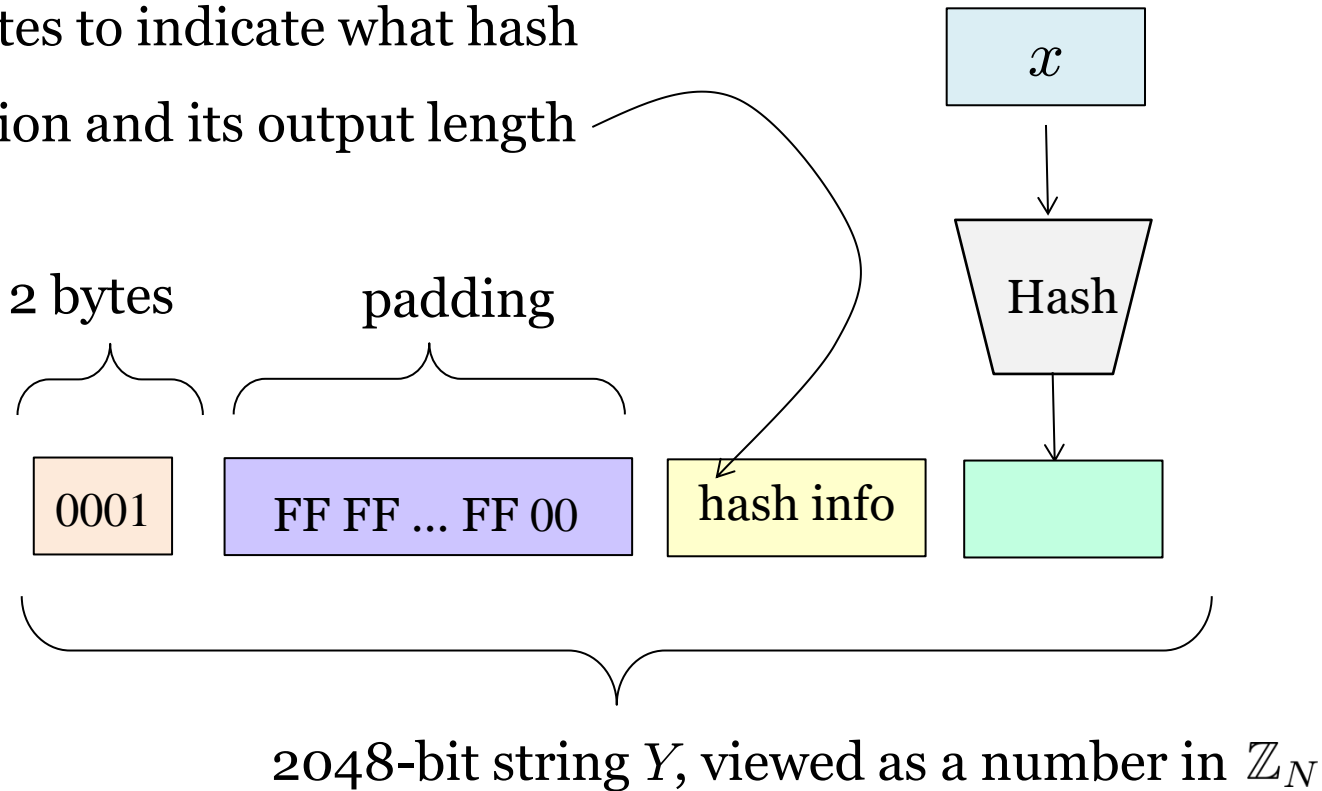
How to Hash Properly



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

Hashing in PKCS#1

19 bytes to indicate what hash function and its output length



Agenda

1. High-level Overview

2. Building Signature Scheme

3. Application: DNSSEC

Recap: DNS Cache Poisoning Attack

Kaminsky, 2008

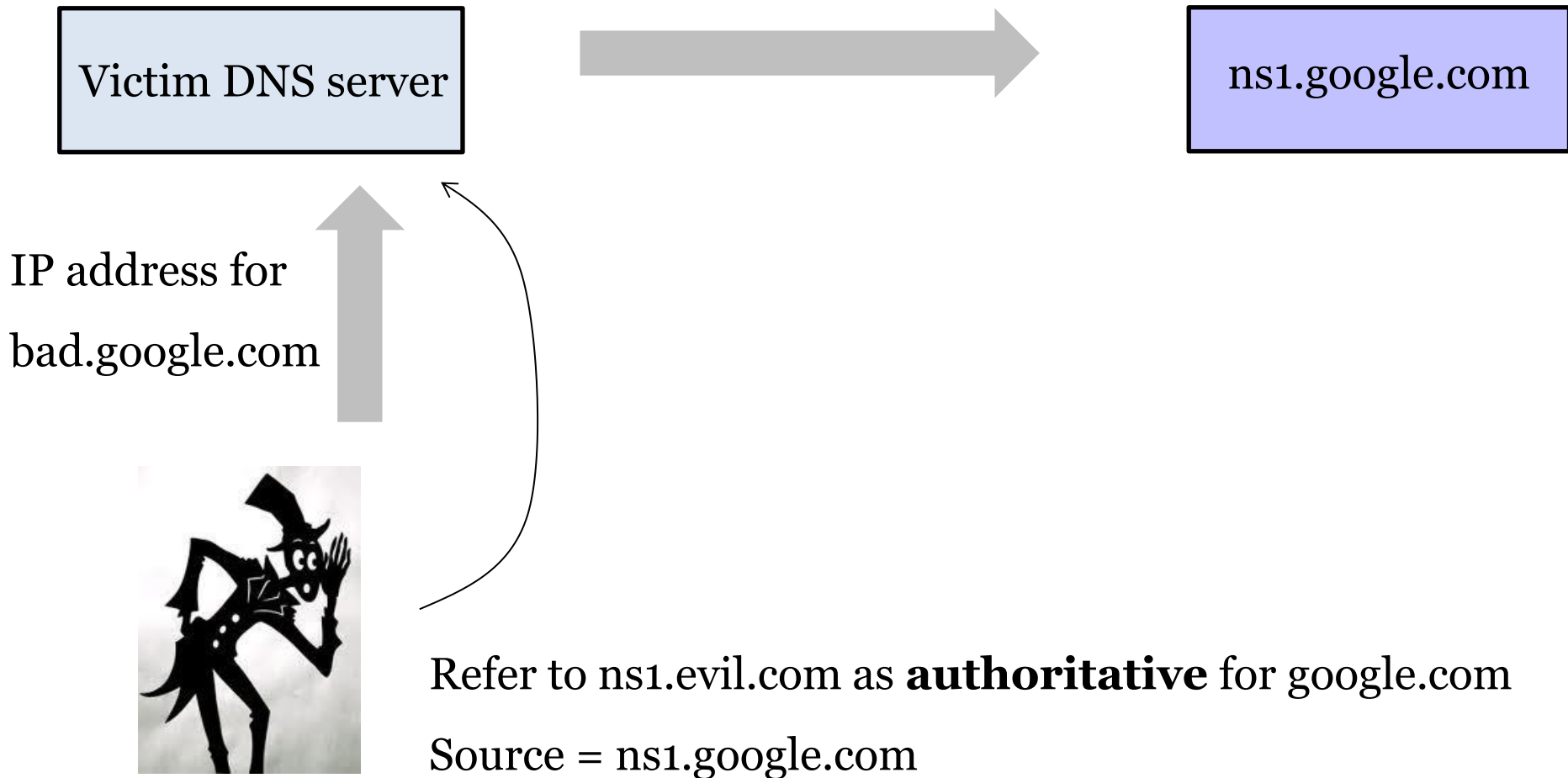
Victim DNS server

IP address for
bad.google.com



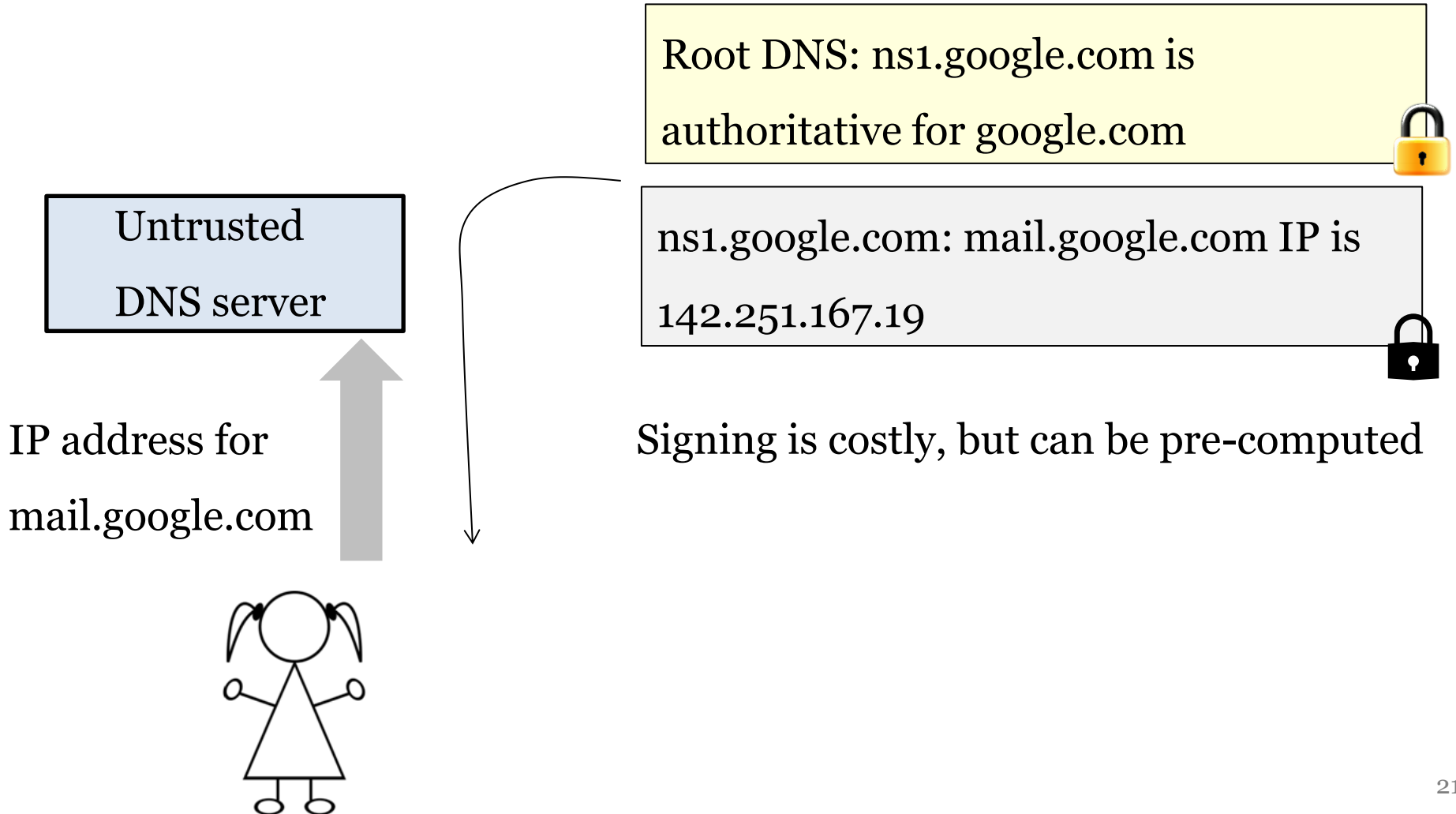
Recap: DNS Cache Poisoning Attack

Kaminsky, 2008

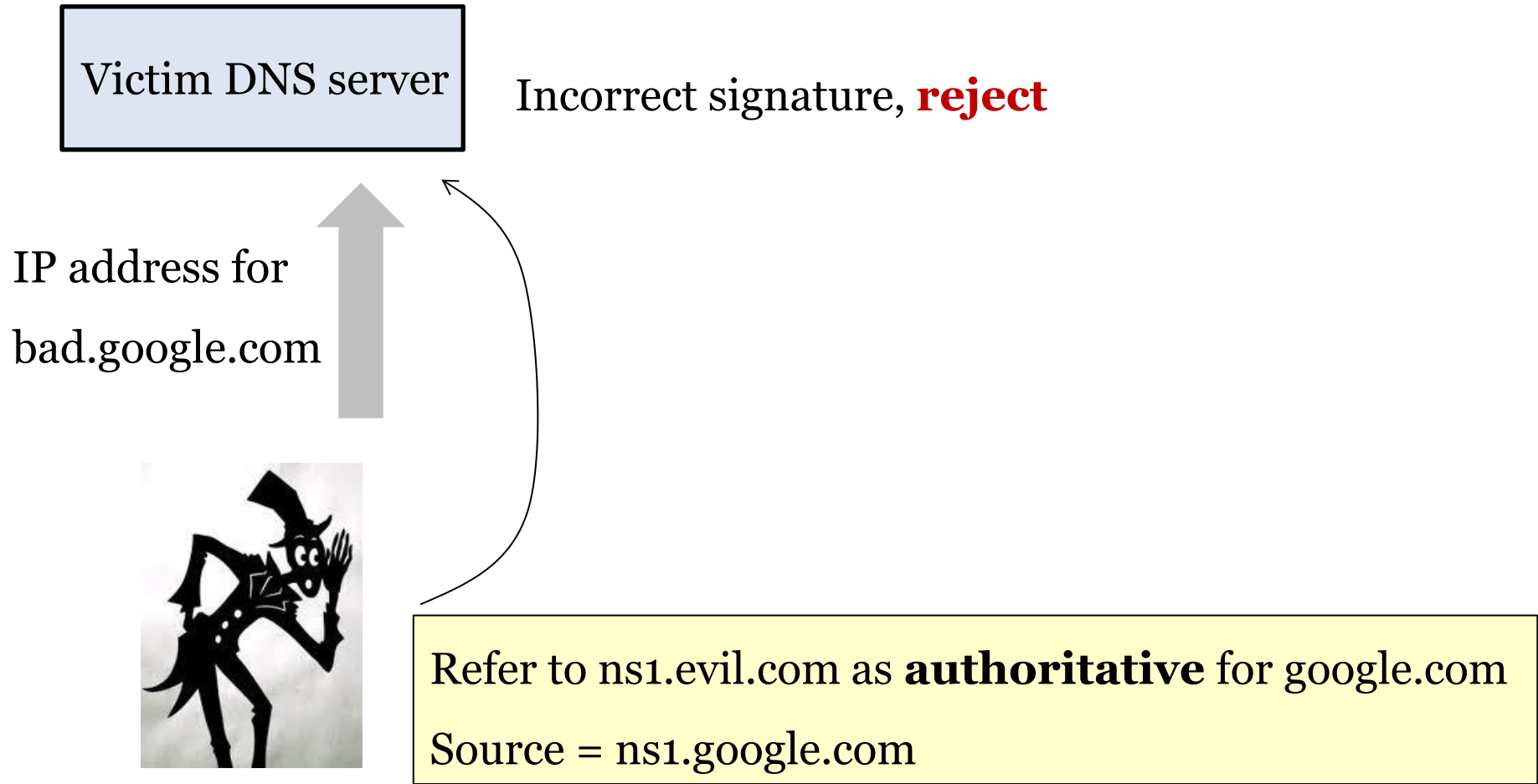


The Fix: DNSSEC

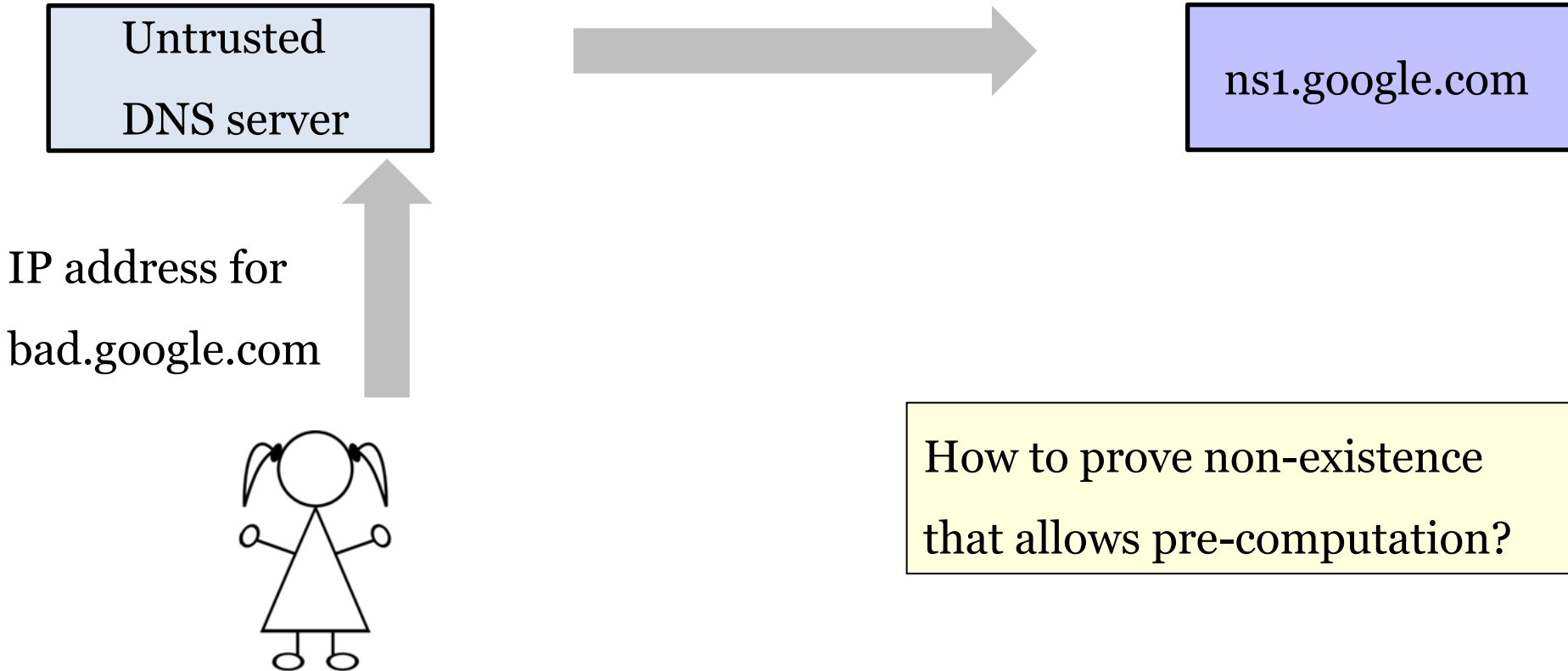
DNS replies need to be signed by authority



Thwarting Cache Poisoning Attack

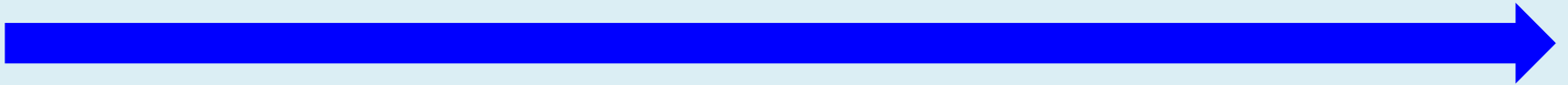


Issue: Prove Non-Existence



Proving Non-Existence: Precomputation


Google sorts its subdomain names alphabetically




account chrome mail policies site

Sign every consecutive pairs

| | | |
|------------|---------------------|---|
| google.com | account .google.com |  |
|------------|---------------------|---|

| | | |
|--------------------|--------------------|---|
| account.google.com | chrome .google.com |  |
|--------------------|--------------------|---|

| | | |
|-------------------|------------------|---|
| chrome.google.com | mail .google.com |  |
|-------------------|------------------|---|

Proving Non-Existence: Respond to Query

Unsuccessful Binary Search

