Lecture 29

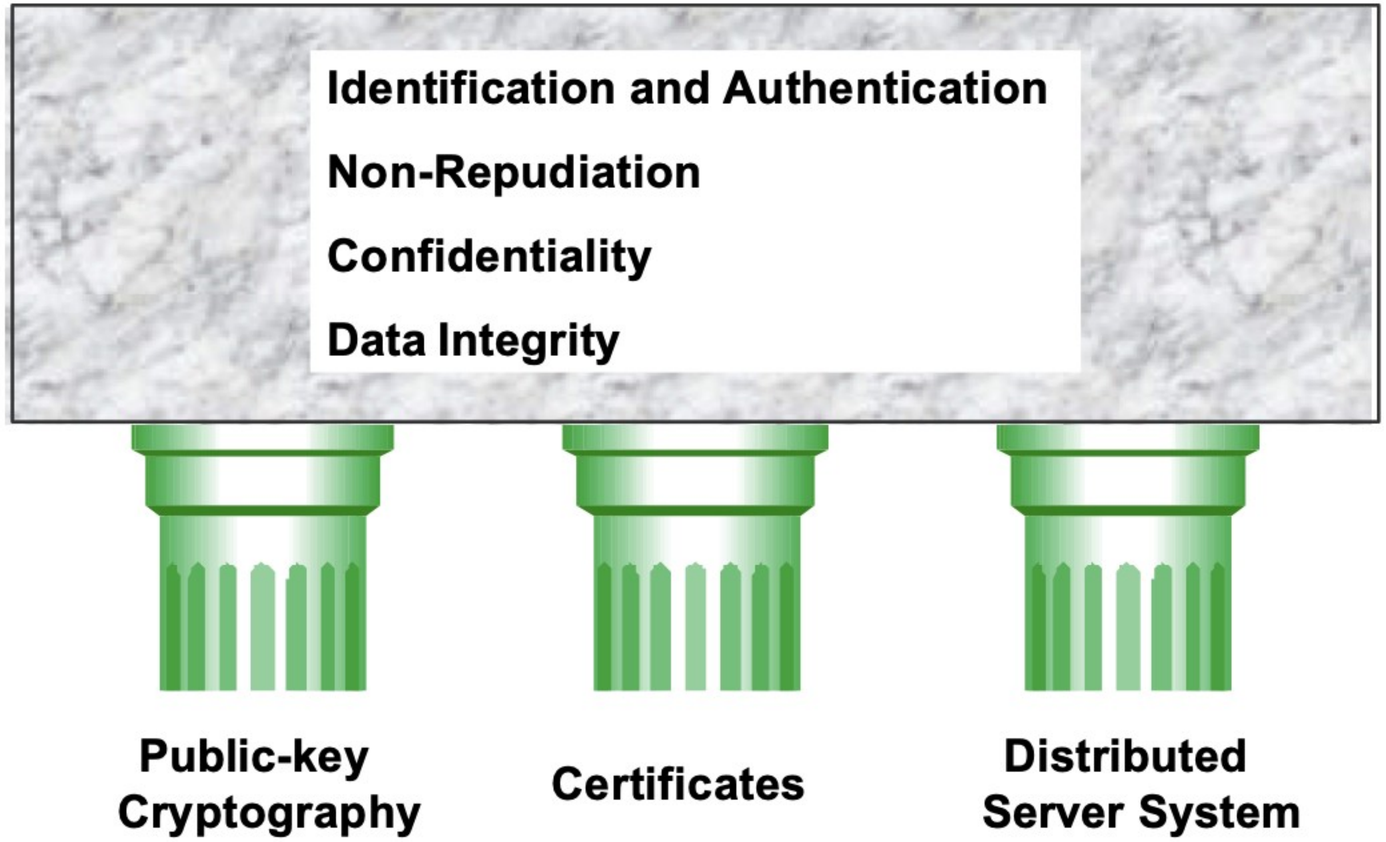
Key Distribution Using Asymmetric Encryption

PKI and Certificates

(Section 4.5)

What is PKI?

- Use of public-key cryptography and X.509 certificates in a distributed server system to establish secure domains and trusted relationships



Identification and Authentication

Non-Repudiation

Confidentiality

Data Integrity

Public-key Cryptography

Certificates

Distributed Server System

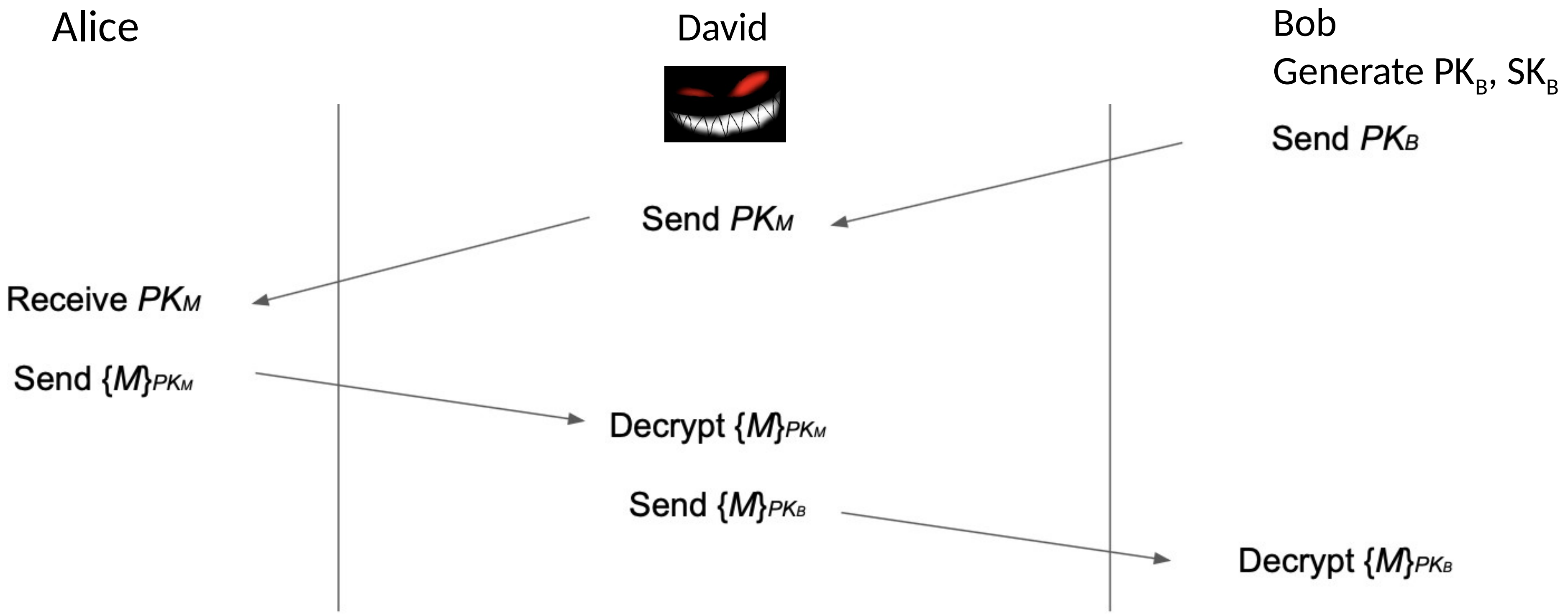
Why use public-key cryptography?

- Review: Public-key cryptography is great! We can communicate securely without a shared secret
  - Public-key encryption: Everybody encrypts with the public key, but only the owner of the private key can decrypt
  - Digital signatures: Only the owner of the private key can sign, but everybody can verify with the public key

Problem: Distributing Public Keys

- Public-key cryptography alone is not secure against man-in-the-middle attacks
- Scenario
  - Alice wants to send a message to Bob
  - Alice asks Bob for his public key
  - Bob sends his public key to Alice
  - Alice encrypts her message with Bob’s public key and sends it to Bob
- What can David do?
  - Replace Bob's public key with David’s public key
  - Now Alice has encrypted the message with David’s public key, and David can read it!

Problem: Distributing Public Keys



Alice

David

Bob

Generate PK_B, SK_B

Send PK_B

Send PK_M

Receive PK_M

Send $\{M\}_{PK_M}$

Decrypt $\{M\}_{PK_M}$

Send $\{M\}_{PK_B}$

Decrypt $\{M\}_{PK_B}$

Man-in-the-Middle Attack

Solution: Distributing Public Keys

- Idea: Sign Bob’s public key to prevent tampering
- Problem
    - If Bob signs his public key, we need his public key to verify the signature
    - But Bob’s public key is what we were trying to verify in the first place!
    - Circular problem: Alice can never trust any public key she receives
- You cannot gain trust if you trust nothing. You need a root of trust!
    - **Trust anchor**: Someone that we implicitly trust
    - From our trust anchor, we can begin to trust others

Trust-on-First-Use

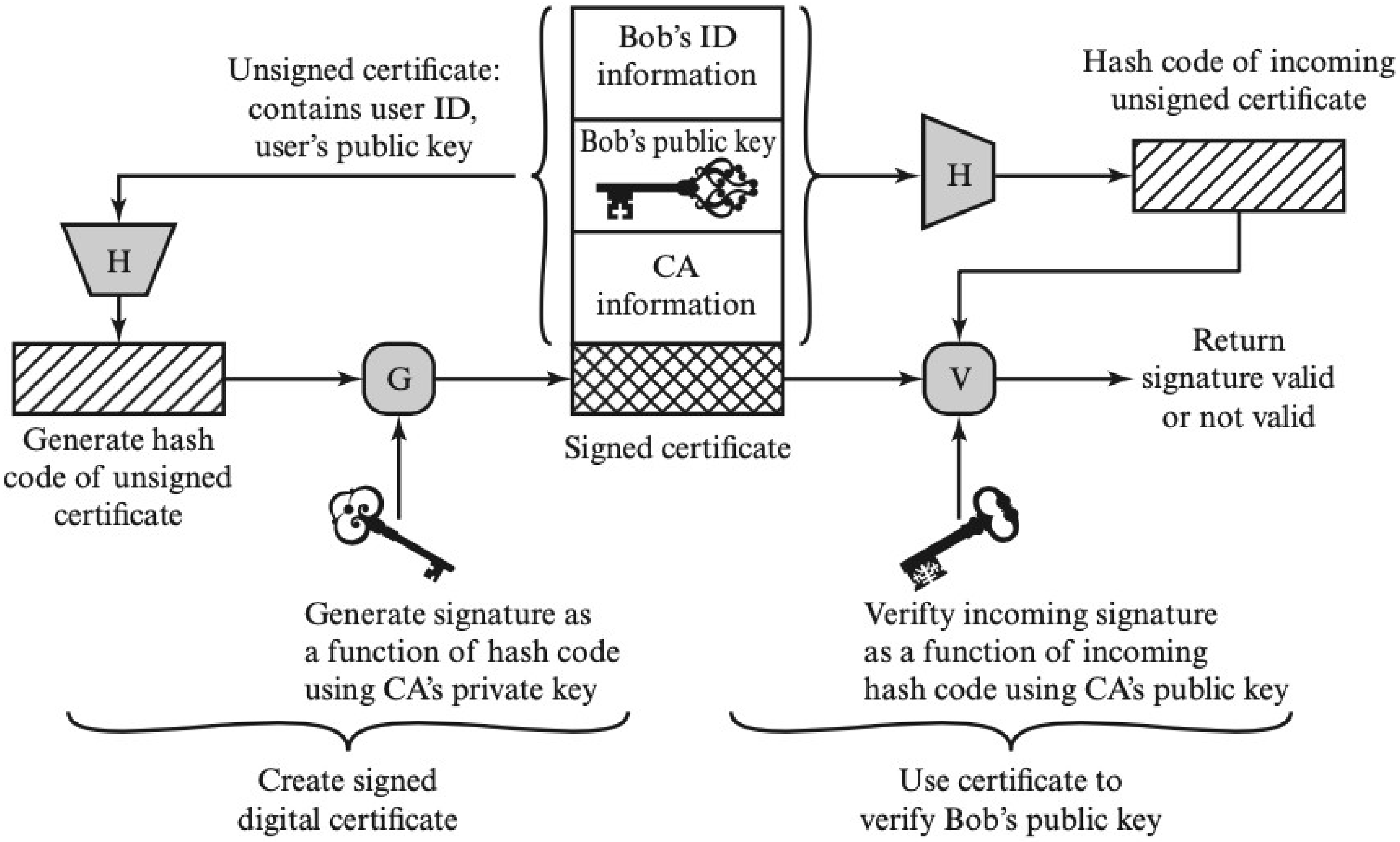
- **Trust-on-first-use**: The first time you communicate, trust the public key that is used and warn the user if it changes in the future
    - Used in SSH and a couple other protocols
    - Idea: Attacks aren't frequent, so assume that you aren't being attacked the first time communicate

Certificates

Certificates

- **Certificate**: A signed endorsement of someone's public key
  - A certificate contains at least two things: The **identity** of the person, and the **key**
- Abbreviated notation
  - Signing with a private key *SK*: $\{\text{“Message”}\}_{SK^{-1}}$
    - Recall: A signed message must contain the message along with the signature; you can't send the signature by itself!
- Scenario: Alice wants Bob's public key. Alice trusts Charlie (PK_C, SK_C)
  - Charlie is our trust anchor
- If we trust PK_C, a certificate we would trust is $\{\text{“Bob's public key is } PK_B\text{”}\}_{SK_C^{-1}}$

How do we use public-key certificate?

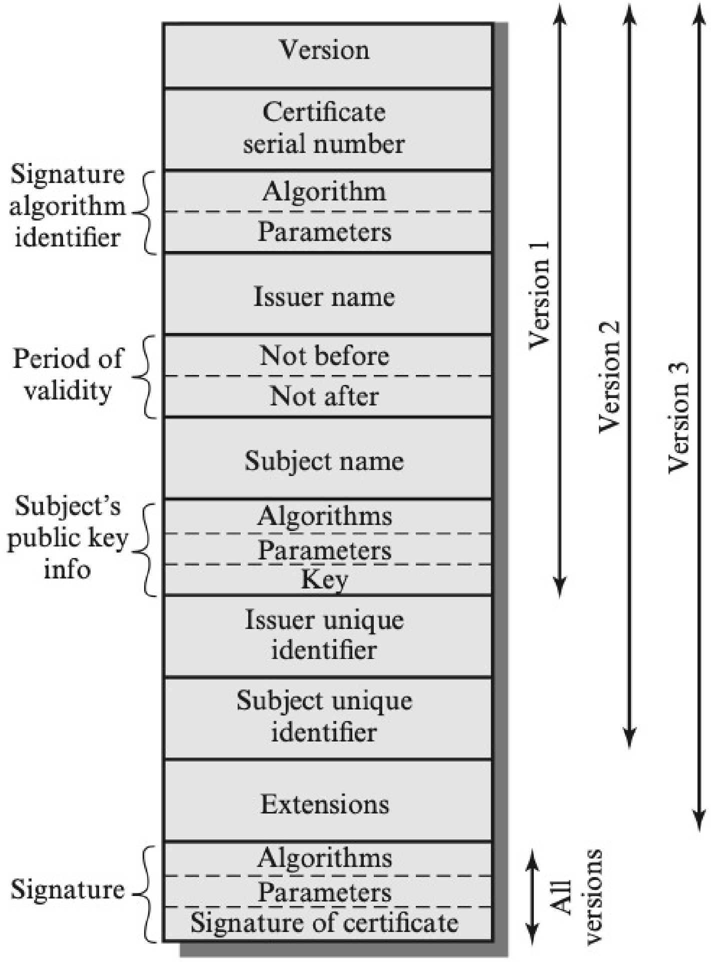


Unsigned certificate: contains user ID, user's public key
Bob's ID information
Bob's public key
CA information
Hash code of incoming unsigned certificate
H
H
G
V
Generate hash code of unsigned certificate
Signed certificate
Return signature valid or not valid
Generate signature as a function of hash code using CA's private key
Verifty incoming signature as a function of incoming hash code using CA's public key
Create signed digital certificate
Use certificate to verify Bob's public key

X.509 Certificates

- Certificate serial # - SN
- Period validity - T^A
- Subject’s public key info - Ap
- Signature signed by CA’s private key
- Math notation:

$$CA \ll A \gg \; = CA\,\{V, SN, AI, CA, UCA, A, UA, Ap, T^{A}\}$$



Version

Certificate serial number

Signature algorithm identifier: Algorithm, Parameters

Issuer name

Period of validity: Not before, Not after

Subject name

Subject’s public key info: Algorithms, Parameters, Key

Issuer unique identifier

Subject unique identifier

Extensions

Signature: Algorithms, Parameters, Signature of certificate

readings

- Barnes, R.; Hoffman-Andrews, J.; McCarney, D.; Kasten, J. (March 2019). *Automatic Certificate Management Environment (ACME) RFC 8555.* IETF
- Internet Security Research Group, “Annual Report”, https://www.abetterinternet.org/annual-reports/
- Minkyu Kim, “A Survey of Kerberos V and Public-Key Kerberos Security”, https://www.cse.wustl.edu/~jain/cse571-09/ftp/kerb5/index.html