TCIPG TRUSTWORTHY CYBER INFRASTRUCTURE FOR THE POWER GRID | TCIPG.ORG

KEY MANAGEMENT

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What are Keys?

- A **key** is the variable used as part of encryption and decryption algorithms in cryptographic systems
- During **encryption**, a key transforms **plaintext** into **ciphertext**
- During **decryption**, a key performs the reverse operation and converts ciphertext into plaintext
- <u>Motive</u>: large-scale systems need a way to manage keys

Key Management: Generation

- How can many keys be generated given that they may be needed for different purposes?
- Varying levels of security needed depending on application
- Varying levels of trustworthiness when generating keys:
  - Key ceremony: generation of root keys for a chain of trust requiring specific procedures to ensure integrity (in a certificate authority)

Types of Key Algorithms

Symmetric

- One key used for both encryption and decryption
- Concept of **shared secret**
- Shorter lengths (e.g. 128 bits)
- Algorithms
  - Data Encryption Standard (DES)
  - Advanced Encryption Standard (AES)
  - Triple DES (3DES)

Asymmetric

- One key used to encrypt (**public key**) and one key used to decrypt (**private key**)
- Public key infrastructure (PKI)
- Longer lengths (e.g. 2048 or 3072 bits)
- Algorithms
  - Diffie-Hellman Key Exchange
  - RSA

Diffie-Hellman Key Exchange (Video)

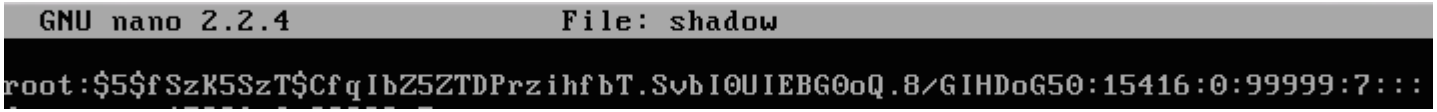
Key Management: Storage

- How should keys be stored such that only those with the correct authority be able to access them?
- Best practice: “Ensure that any secret key is protected from unauthorized access”
  - Separate where keys and data are stored
  - Encrypt keys themselves (passphrase)
  - Use key vaults
  - Store in trusted platform modules and/or hardware security modules

Source: https://www.owasp.org/index.php/Cryptographic_Storage_Cheat_Sheet

Hashing

- Used for: authentication, non-repudiation, integrity
- “Digital Fingerprint” of an input: unique and irreversible
- MD5 and SHA: commonly used hashing algorithms.
- Applications:
  - Password security
  - File/memory integrity
  - Message Authentication



```
  GNU nano 2.2.4                File: shadow

root:$5$fSzK5SzT$CfqIbZ5ZTDPrzihfbT.SvbI0UIEBG0oQ.8/GIHDoG50:15416:0:99999:7:::
```

Digital Signatures

- Technique to guarantee authenticity
- Steps involved:
  - Generate secure hash
  - Encrypt hash with private key
  - Hash + Message = Signature
  - Receiver calculates hash of message
  - Decrypt signature using public key
  - Compare decrypted signature to hash
- Authenticity: Only I can generate my signature
- Non-repudiation

Key Management: Exchange

- How can keys be efficiently exchanged with concern given to scalability and trustworthiness?
- **Direct trust**: trust since origin is known
- **Hierarchical trust**: trust CAs and root CAs
- **Web of trust** (distributed): trust based on others whom you trust; mix of above two
- Public key server
  - Access others' public keys
  - Difficult to remove old keys
  - Example: PGP Global Directory

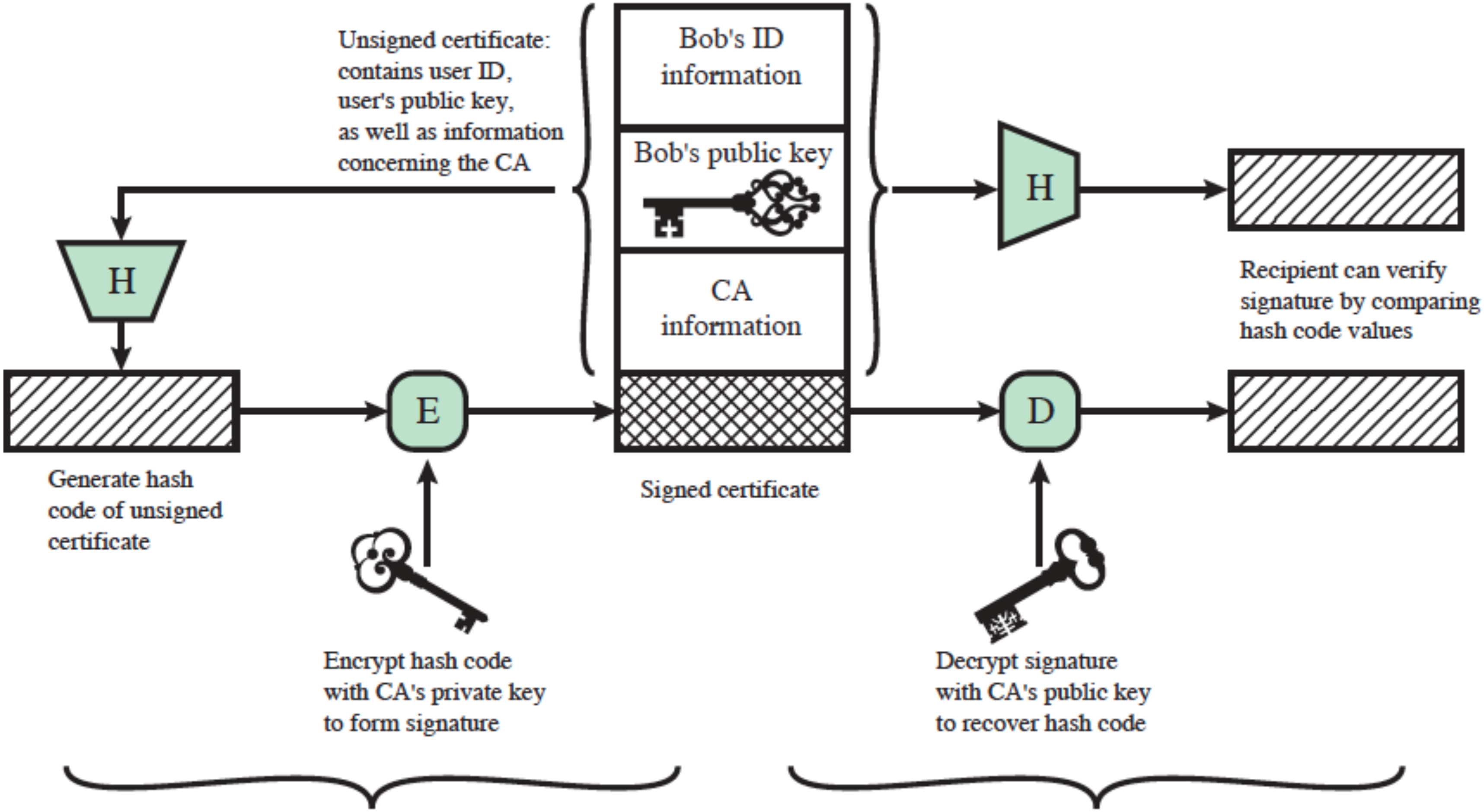
Public Key Certificates

- Problem: signatures can be forged
  - Anyone can claim to be me
  - Distribute their public key

- Certificate Authority
  - Trusted third party
  - DigiCert, Verisign

- X.509
  - Certificate standard for the internet
  - Establishes a chain of trust

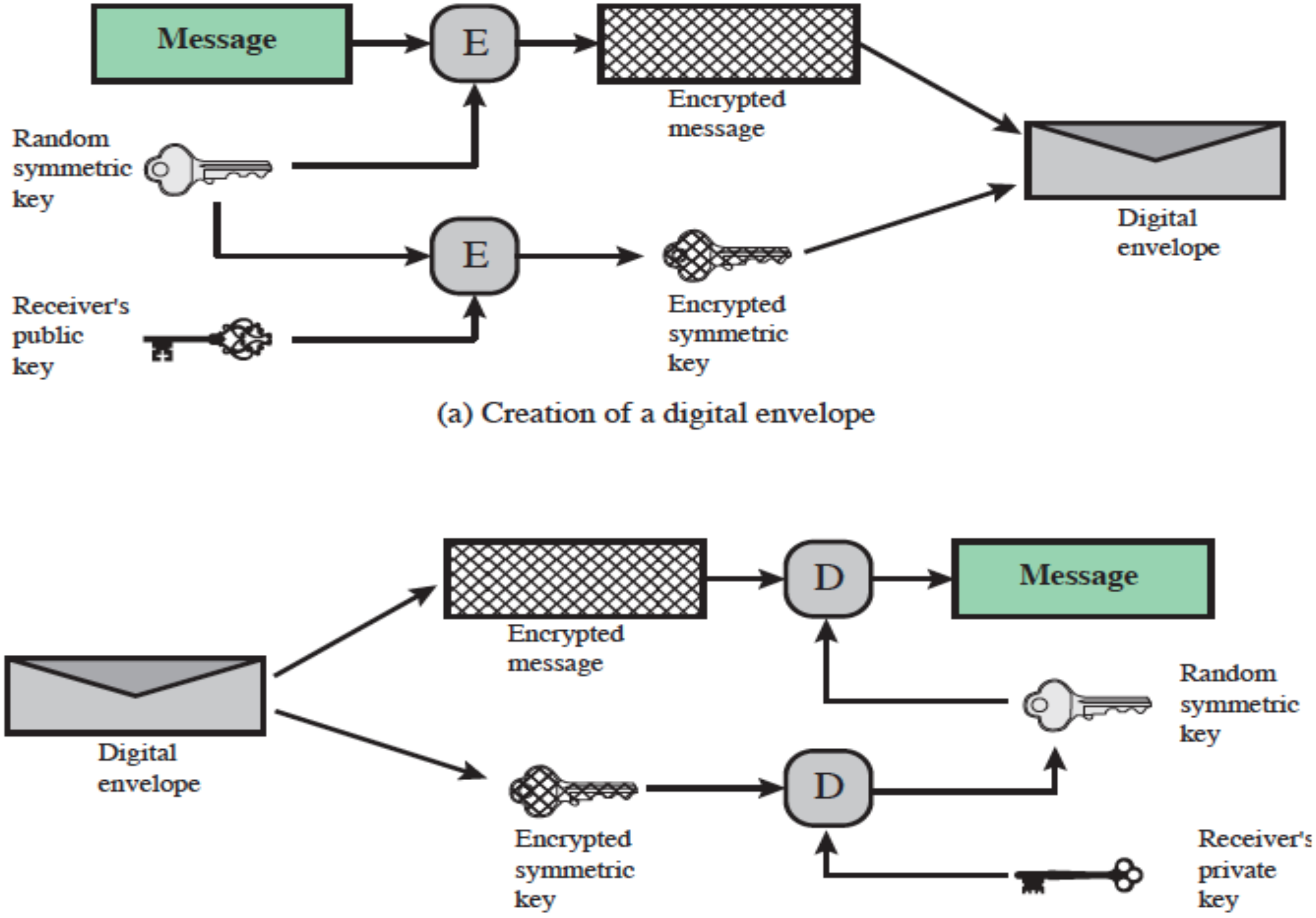
Public Key Certificates


Unsigned certificate:
contains user ID,
user's public key,
as well as information
concerning the CA
Bob's ID information
Bob's public key
CA information
H
H
E
D
Recipient can verify signature by comparing hash code values
Generate hash code of unsigned certificate
Signed certificate
Encrypt hash code with CA's private key to form signature
Decrypt signature with CA's public key to recover hash code

Create signed digital certificate

Use certificate to verify Bob's public key

Digital Envelope



(a) Creation of a digital envelope

(b) Opening a digital envelope

Key Management: Replacement

- What should the length of use be for a key?
- Is the key meant to last for one session, one week, one year, many years, etc.?
- Reasons for replacement:
  - Key has been revoked
  - Key has expired
  - Key has been compromised
    - Detected
    - Undetected
- Rekey encrypted data with new keys

Source: https://www.owasp.org/index.php/Cryptographic_Storage_Cheat_Sheet

Revocation of Certificates

- CRL: Certificate Revocation List
  - Published by CAs
  - Every certificate must be checked against the CAs CRL.
- Problem?
  - CRLs have gotten way too big
  - Overhead of checking is too high
  - Current solution: your browser does not check CRLs!!
  - One of the unsolved problems of security

SSL/TLS

- Provides secure connection over the internet
- Protects the application layer
- HTTPS: HTTP protected by TLS
- Session:
  - Create association between client and server
  - Established using a handshake
  - Defines the set of cryptographic parameters
- TLS Heartbeat Protocol
  - Heartbleed!

Cipher Suite

- Named combination of cryptographic primitives:
  - key exchange algorithm (RSA/Diffie Hellman)
  - authentication algorithm (RSA, ECDSA)
  - bulk encryption algorithm (eg: AES/3DES)
  - message authentication (eg: HMAC-MD5)

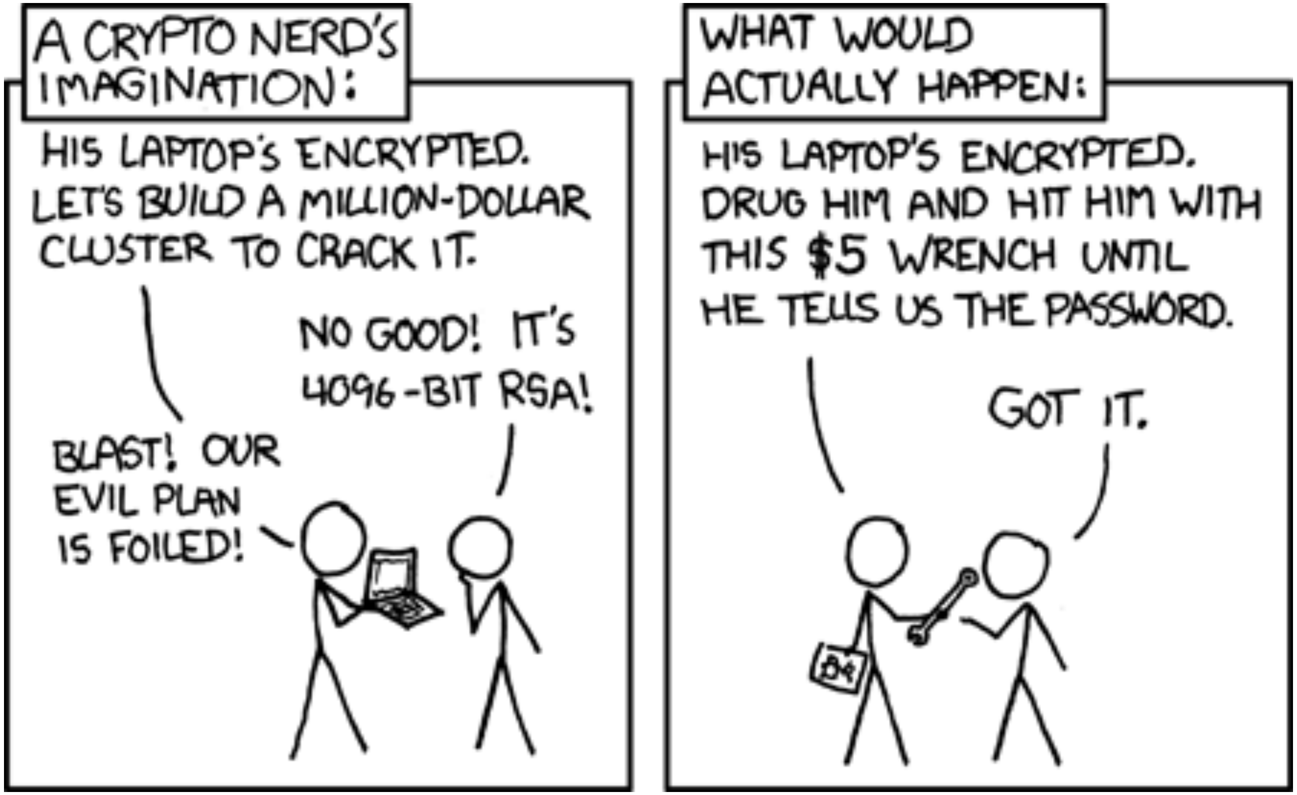
- Examples:
  - RSA-RSA-AES-SHA
  - DH-RSA-DES-SHA

Key Management in the Internet of Things

- Challenges:
  - Large number of devices
  - Limited processor and memory resources
  - Scaling difficulty with manual configuration
  - SSH as an example: What privileges can SSH access give you on a device?
- Specific challenges to the smart grid:
  - Sensitive information about devices and their electricity use

Source: http://www.iab.org/wp-content/IAB-uploads/2011/03/Turner.pdf

Thanks!


A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.