MENDER

Cryptography basics for embedded developers

Embedded Linux Conference, San Diego, 2016

"If you think **cryptography is the solution** to your problem, then you **don't understand your problem**"

\- Roger Needham

Cryptography basics are important

- Misuse of cryptography is common source of vulnerabilities
  - “41 of the 100 apps selected [...] were vulnerable [...] due to various forms of SSL misuse.” *
- Understanding crypto basics will improve the security of devices
  - Important for anyone using cryptography (e.g. libraries)
- Think about security requirements for your product
  - Can it be attacked? Why would it? How?
  - Consider how cryptography can be applied correctly to support your requirements
- Reduce the risk of your product being compromised

* Source: “Why Eve and Mallory Love Android: An Analysis of Android SSL (In)Security” CCS’2012

About me

- Eystein Stenberg
  - CS/Crypto master's
  - 7 years in systems, security management
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  - Over-the-air updater project for Linux/Yocto
  - Under active development
  - Open Source
- Reach me after on email or exhibitor hall

The mandatory legal note

- Some use of cryptography / software has legal implications
- Most notably: export restrictions in the USA
- I will only consider technological aspects, not legal ones

Session overview

- Our goals
- Crypto basics and pitfalls
  - Encryption
  - Signatures & Message Authentication Codes
  - Secure hashing
  - Key management
- Crypto for embedded
  - Expensive operations
  - Alternatives

Attacker motivation

- Why would someone attack your product?
- Can someone *make money* from a compromise? How much?
- All crime starts with *a motive*

Your goal is to *lower attacker ROI*

- It is always *possible* to compromise

- Lower Return on Investment (ROI) for attacker; either
    - *Decrease value* of successful attack
    - *Increase cost* of successful attack

- Focus on increasing cost of attack in this session

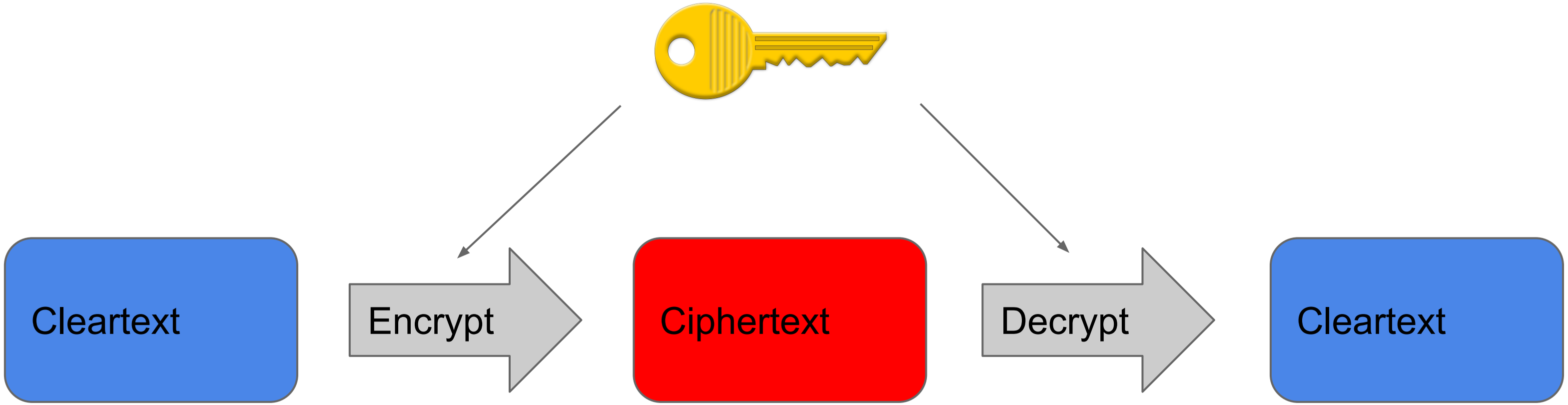
Decreasing value of attack can be effective too

CIA concepts implemented with crypto primitives

- Confidentiality
  - Is there something **secret**?
  - Primitives: encryption
- Integrity
  - Should we detect **altering** of information?
  - Primitives: secure hashing, signatures, MAC
- Authenticity
  - Do we need to know **who** create/request information?
  - Primitives: signatures, MAC

not encryption

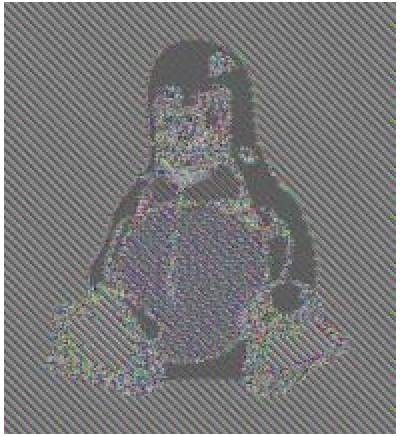
Symmetric encryption: one shared secret key



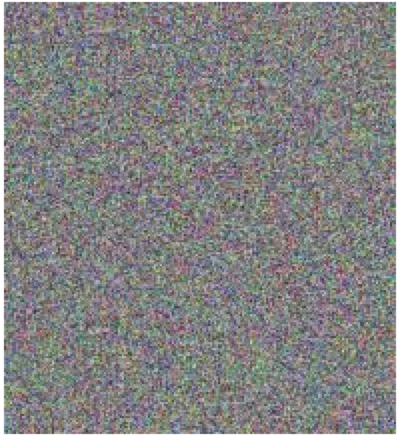
- Use for **confidentiality**
- Efficient, relatively low resource consumption
- Typical key & block sizes: 128, 192, 256 bit
- Difficult to keep **shared** things **secret**
- Note **block cipher mode** when encrypting large volumes of data with same key
- Example: AES (Advanced Encryption Standard) + CBC mode

Pitfall: Use insecure symmetric block cipher *mode*

Original



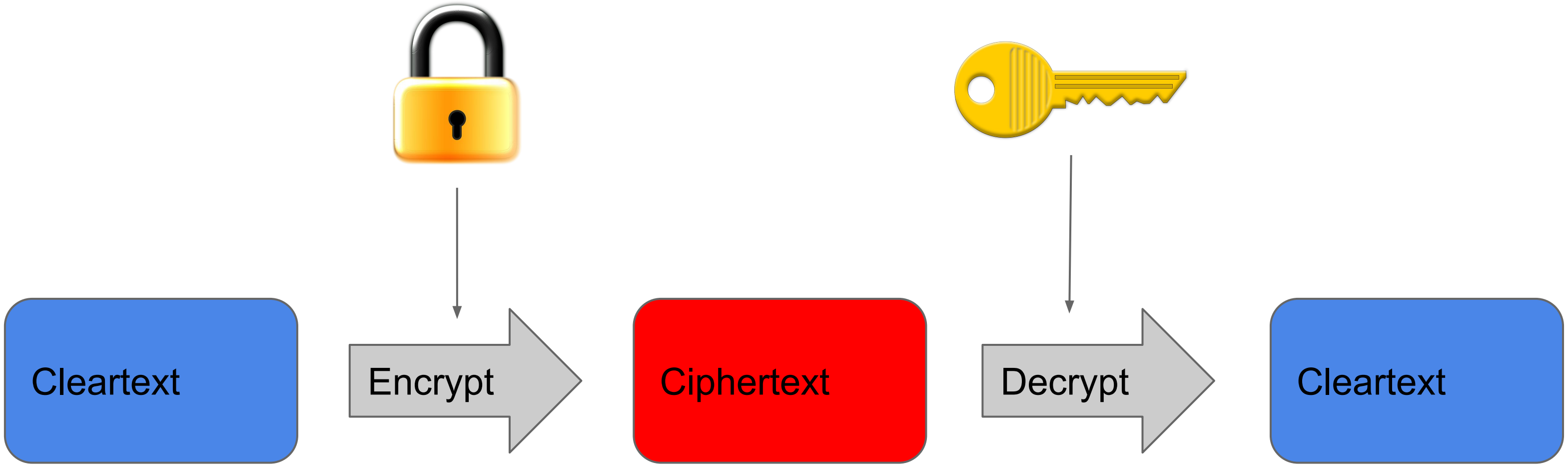
Encrypted with ECB mode



Encrypted with CBC mode

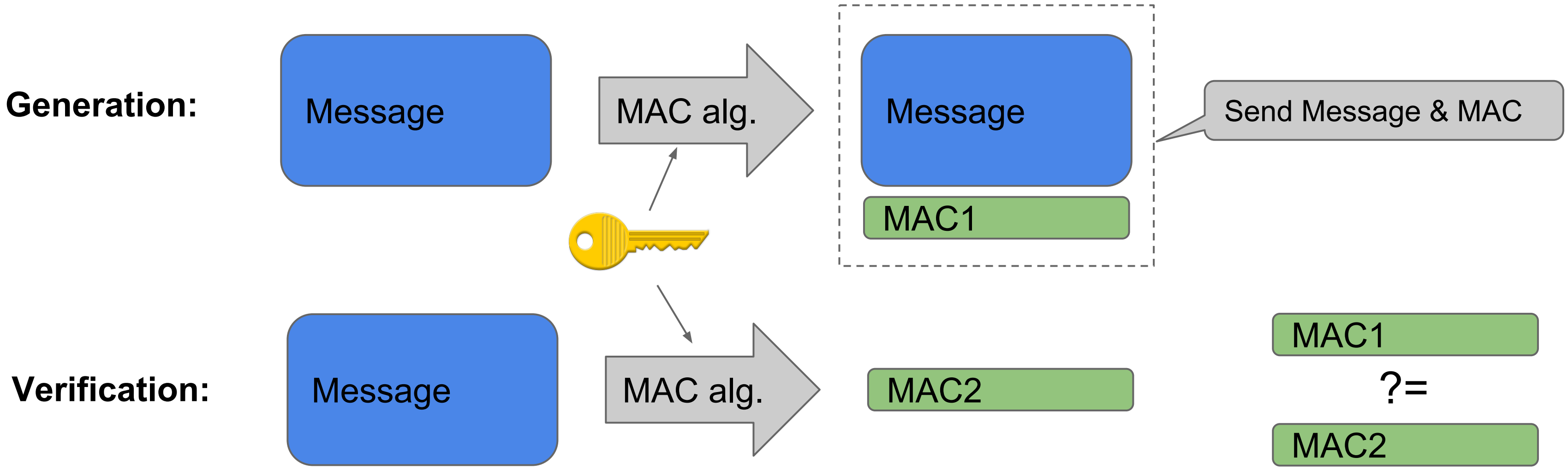
Source: Larry Ewing

Asymmetric encryption: public and private key



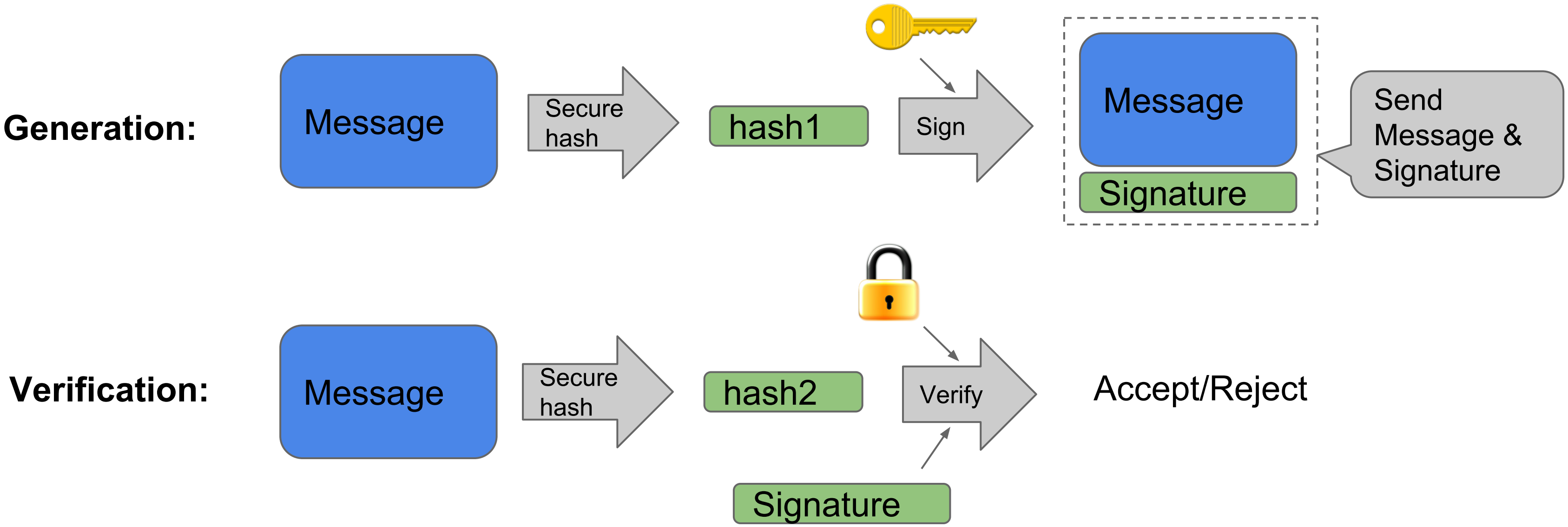
- Use for **confidentiality of little data** (e.g. symmetric key) with multiple parties
  - Very compute-intensive operation (~1000 x symmetric)
  - Large volume of ciphertext can leak information about private key
- Advantage over symmetric: safe to share public key with anyone
- Examples: RSA (key/block size ~4096 bits), Elliptic Curve (key/block size ~256 bits)

Message Authentication Code (symmetric)



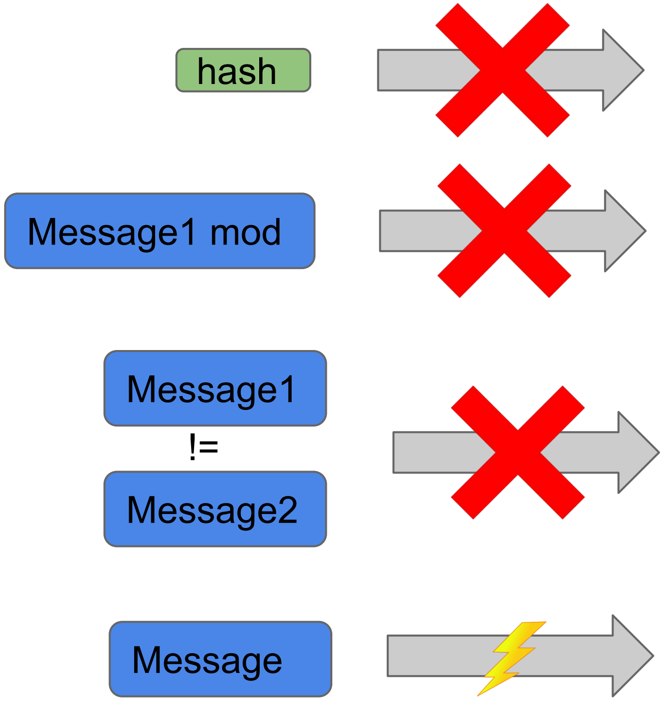
- Use for **authenticity**
- Efficient, typical key & MAC sizes: 160, 256 bit
- Difficult to keep **shared** things **secret**
- If you need confidentiality too, look at Authenticated Encryption (AE/AEAD)
- Example: HMAC-SHA256

Digital signature (asymmetric)



- Use for **authenticity**
- Less efficient than MAC (~1000x), but no shared secret
- Common misconception: “signing is encrypting with private key”
- Examples: DSA (key/block size ~4096 bits), ECDSA (key/block size ~256 bits)

Cryptographically secure hashing



Given hash, infeasible to generate a message that yields the hash.

Infeasible to modify a message in such a way that it generates the same hash.

Infeasible to find any two messages that yields the same hash.

Hash is efficient to compute.

Hash function implementations

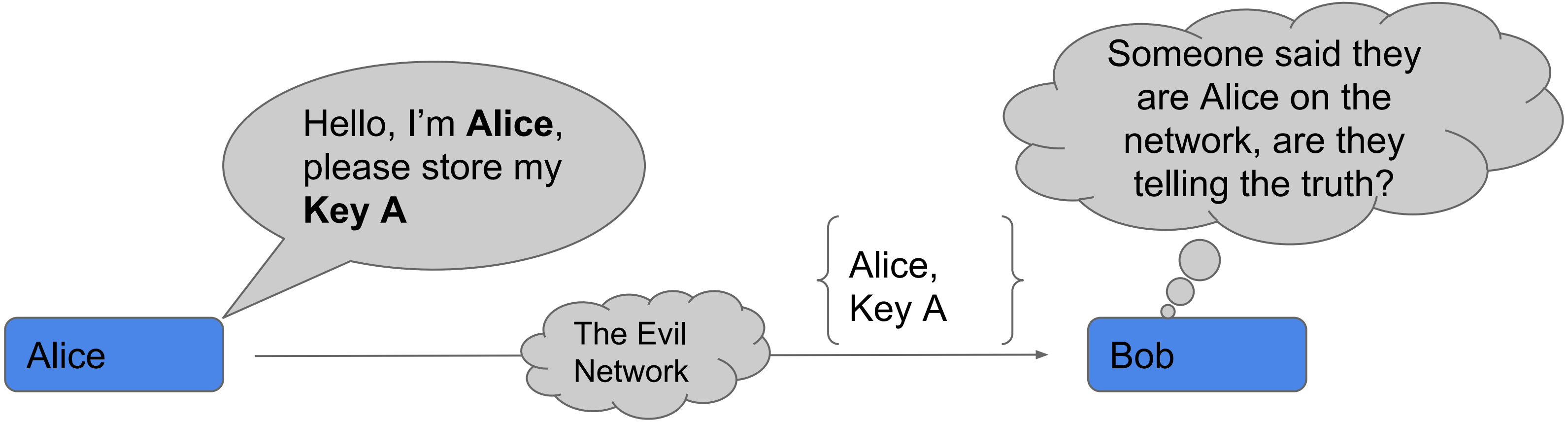
- Insecure if it does not meet all four criteria

- Secure hash algorithm (SHA) family
  - SHA-256, SHA-384, SHA-512 (number denotes bits of output)

- Insecure hash algorithms
  - MD5 (128 bits): Attack that can find two messages with **same hash in seconds**
  - SHA-1 (160 bits): Attack reduced collision to 63-bit operation (ideal is 160/2 = 80)

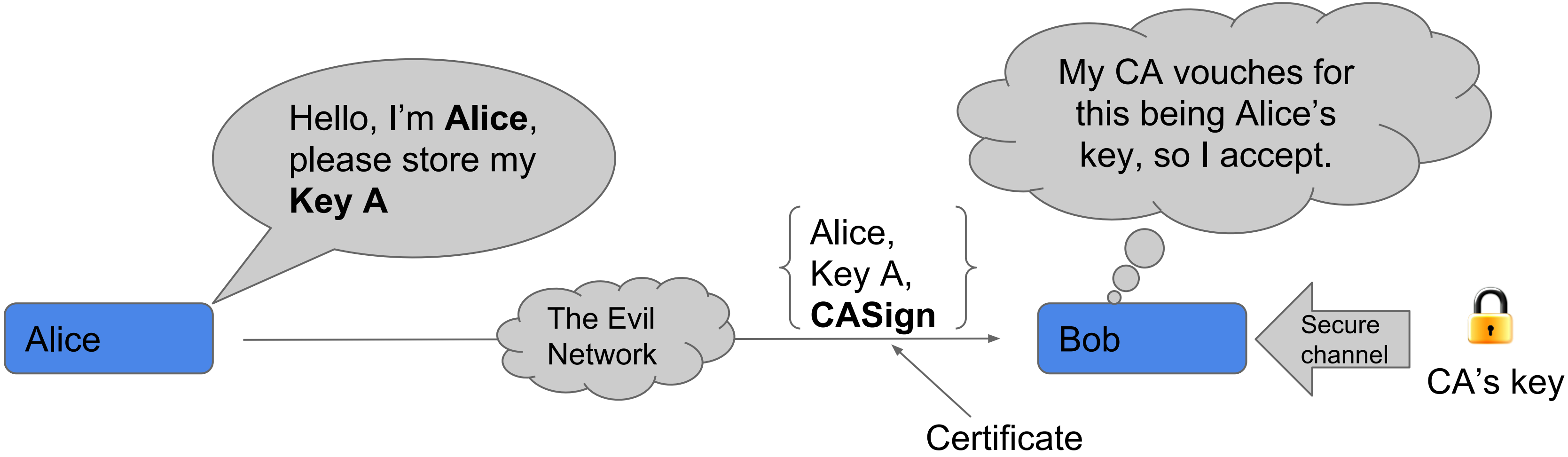
- Bottom line: use SHA-256 (or larger) if you use it for security

The Key Exchange Problem: Using the right key



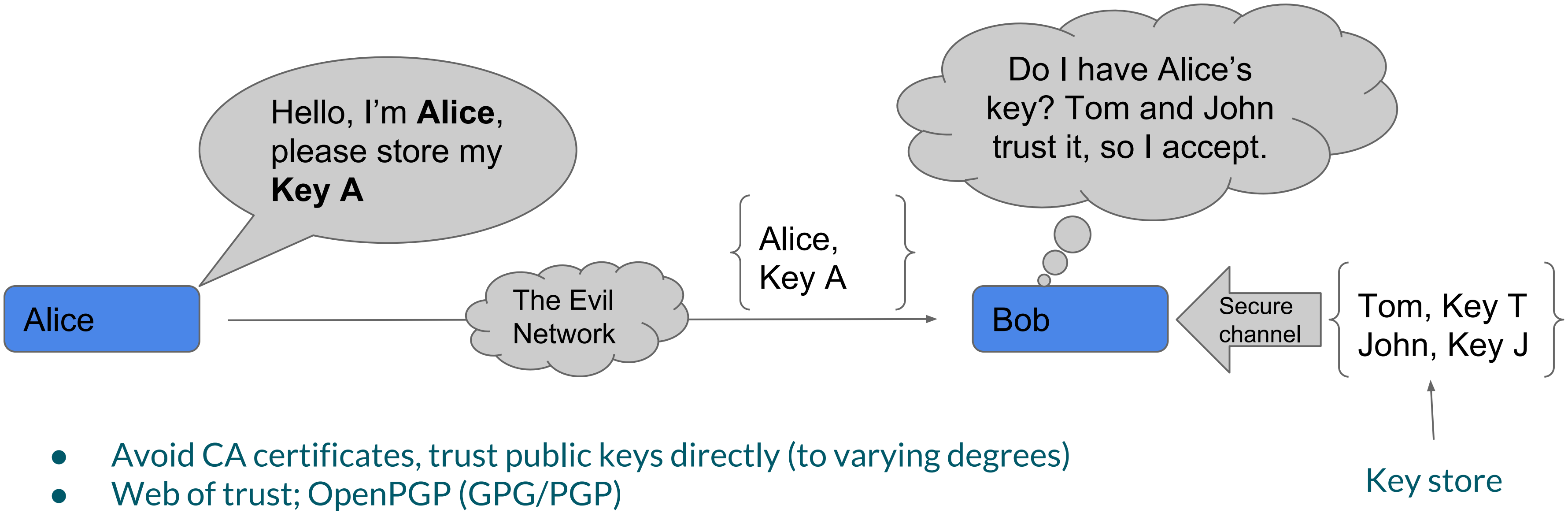
- All cryptography is based on **keys**
- If someone can make you use the **wrong key, security is broken**
    - Need secure **{ID, key} mappings**
- Secure key exchange **requires a pre-existing secure channel** (barring quantum crypto)
    - Typically inserted during **provisioning** (e.g. web-browsers, phone apps, ...)
- It is a notoriously hard problem, especially in **many-to-many conversations** (e.g. web)

Using the right key: Public Key Infrastructure (PKI)



- Most common way to "solve" the key exchange problem
- Delegate problem with **absolute trust** to one (or more) **Certificate Authority** (CA)
  - If CA says it's the right binding by **signing { ID, key }**, we will trust him
- Still need to **securely obtain CA's key** (pre-existing secure channel, e.g. provisioning)
- Introduces a **single point of compromise** for the entire system (CA's private key)
- Complex to manage (keep the CA secure, rekeying CA, cert issue, cert revocation, ...)

Using the right key: Trust-based



- Avoid CA certificates, trust public keys directly (to varying degrees)
- Web of trust; OpenPGP (GPG/PGP)
  - Like a distributed CA
  - "I trust T & J, T & J trusts A, so I trust A"
- Might be a better fit for **one-to-many** (e.g. clients w/ single server)
  - Simpler, avoids the run-your-own-CA complexities
  - Limited use of certificates anyway here (sent just to client and server)

Key management

- Some keys need to be exchanged
- All security breaks if secret keys are compromised
- The hardest part of implementing cryptography
- Some tips
  - Don’t share secret keys between many devices
  - Use asymmetric cryptography
  - Store secret keys on non-removable media with strict file permissions
  - Ensure that keys can be decommissioned / rotated
  - Consider hardware-assistance (only operations are available to software, not keys)

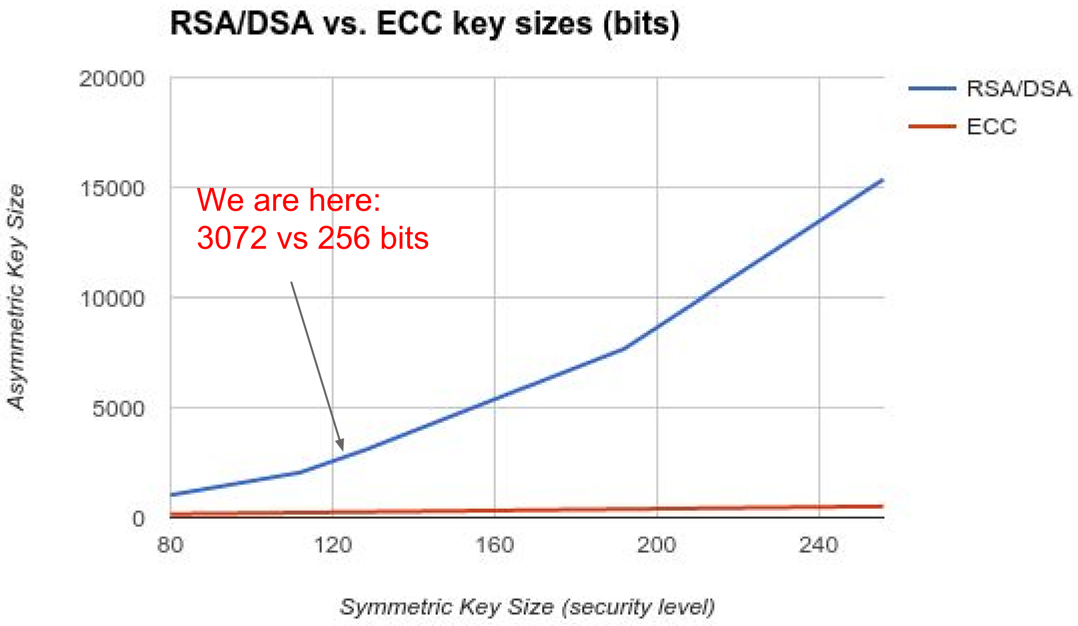
Implementing cryptography in embedded

- We need it to be efficient!
    - Cryptography is based on advanced mathematical operations

- Asymmetric cryptography is very expensive on CPU/memory
    - Order of 1000x of symmetric counterparts typically
    - Use it sparingly
    - Use Elliptic Curve Cryptography (ECC)

- Look for hardware support (crypto processor)

Use Elliptic Curve Cryptography over RSA/DSA



Source: NIST 800-57, Table 2

- Typically aim for 128-bit security level or higher today (but it's up to you)
- RSA/DSA requires 12x the key size at this level
- TLS with ECC is 3-10x faster (CPU time) at this level*

* Source: Performance Analysis of Elliptic Curve Cryptography for SSL, V. Gupta, S. Gupta, S. Chang

Cryptography basics that will improve your security

- Key management is hard
  - At least you are aware
  - Consider trust-based key exchange
  - Avoid putting a single secret all over the place

- Use industry standard libraries and high-level functions
  - Never ever ever implement your own cryptographic algorithms!

- Consider ECC over RSA for performance in asymmetric crypto

- Use SHA-256 (or higher) for secure hashing

Is there a secret backdoor?