CSE 484 / CSE M 584: Computer Security and Privacy

Cryptography [Finish Hash Functions; Start Asymmetric Cryptography]

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Admin

- Lab 1 due in a week
- Homework 2 (crypto) out now (due May 8)
- Looking ahead:
  - **Today+Monday:** Asymmetric Crypto
  - **Monday:** Start transition to web security
    - Lab 2 will be on web security

Which Property Do We Need?

- UNIX passwords stored as hash(password)
  - **One-wayness:** hard to recover the/a valid password
- Integrity of software distribution
  - **Weak collision resistance**
  - But software images are not really random… may need **full collision resistance** if considering malicious developers
- Private auction bidding
  - Alice wants to bid B, sends H(B), later reveals B
  - **One-wayness:** rival bidders should not recover B (this may mean that she needs to hash some randomness with B too)
  - **Collision resistance:** Alice should not be able to change her mind to bid B' such that H(B)=H(B')

Common Hash Functions

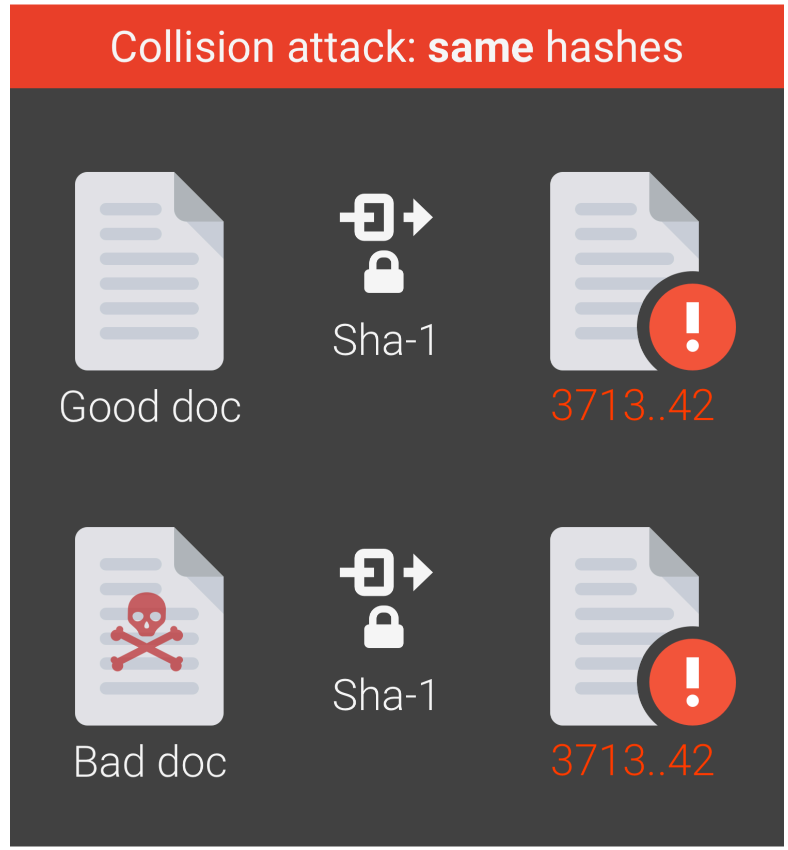
- MD5 – Don't Use!
  - 128-bit output
  - Designed by Ron Rivest, used very widely
  - Collision-resistance broken (summer of 2004)
- RIPEMD-160
  - 160-bit variant of MD5
- SHA-1 (Secure Hash Algorithm)
  - 160-bit output
  - US government (NIST) standard as of 1993-95
  - Theoretically broken 2005; practical attack 2017!
- SHA-256, SHA-512, SHA-224, SHA-384
- SHA-3: standard released by NIST in August 2015

SHA-1 Broken in Practice (2017)

Google just cracked one of the building blocks of web encryption (but don't worry)

It's all over for SHA-1

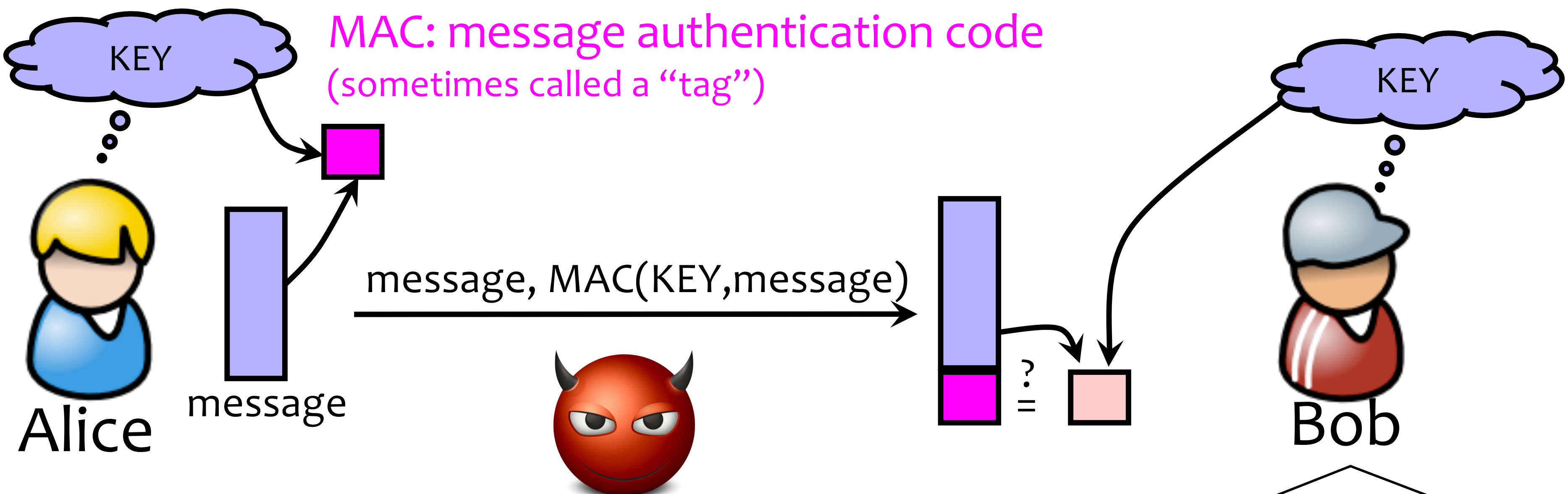
by Russell Brandom | @russellbrandom | Feb 23, 2017, 11:49am EST



https://shattered.io

Recall: Achieving Integrity

Message authentication schemes: A tool for protecting integrity.



Recomputes MAC and verifies whether it is equal to the MAC attached to the message

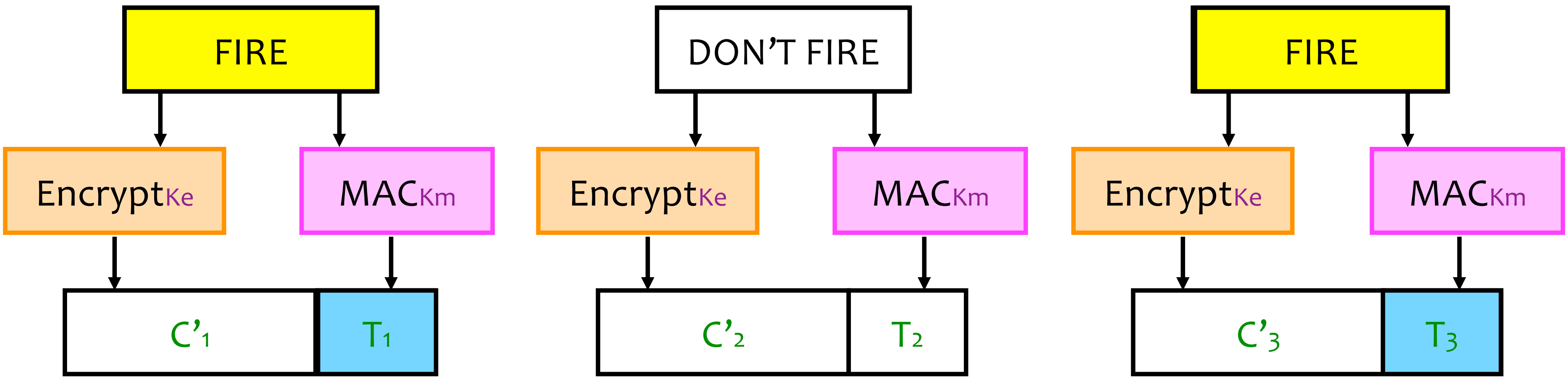
Integrity and authentication: only someone who knows KEY can compute correct MAC for a given message.

HMAC

- Construct MAC from a cryptographic hash function
  - Invented by Bellare, Canetti, and Krawczyk (1996)
  - Used in SSL/TLS, mandatory for IPsec
- Construction:
  - HMAC(k,m) = Hash((k⊕ipad) | Hash(k⊕opad | m))
- Why not block ciphers (at the time it was designed)?
  - Hashing is faster than block ciphers in software
  - Can easily replace one hash function with another
  - There used to be US export restrictions on encryption

Authenticated Encryption

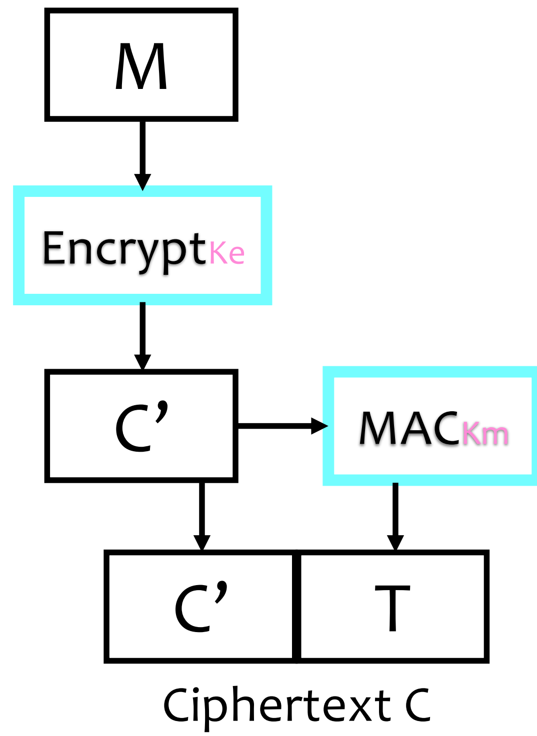
- What if we want both privacy and integrity?
- Natural approach: combine encryption scheme and a MAC.
- But be careful!
  - Obvious approach: Encrypt-and-MAC
  - Problem: MAC is deterministic! same plaintext → same MAC



Authenticated Encryption

- Instead:
  Encrypt *then* MAC.

- (Not as good:
  MAC-then-Encrypt)



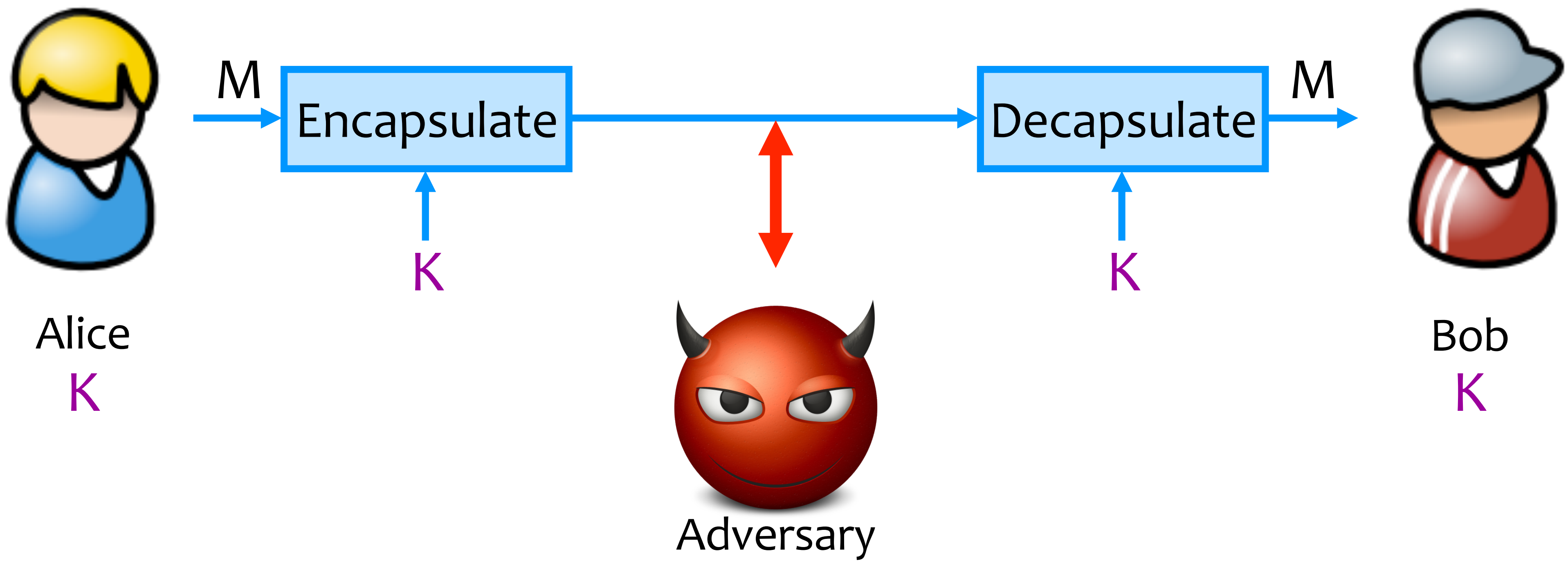
Encrypt-then-MAC

Stepping Back: Flavors of Cryptography

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.

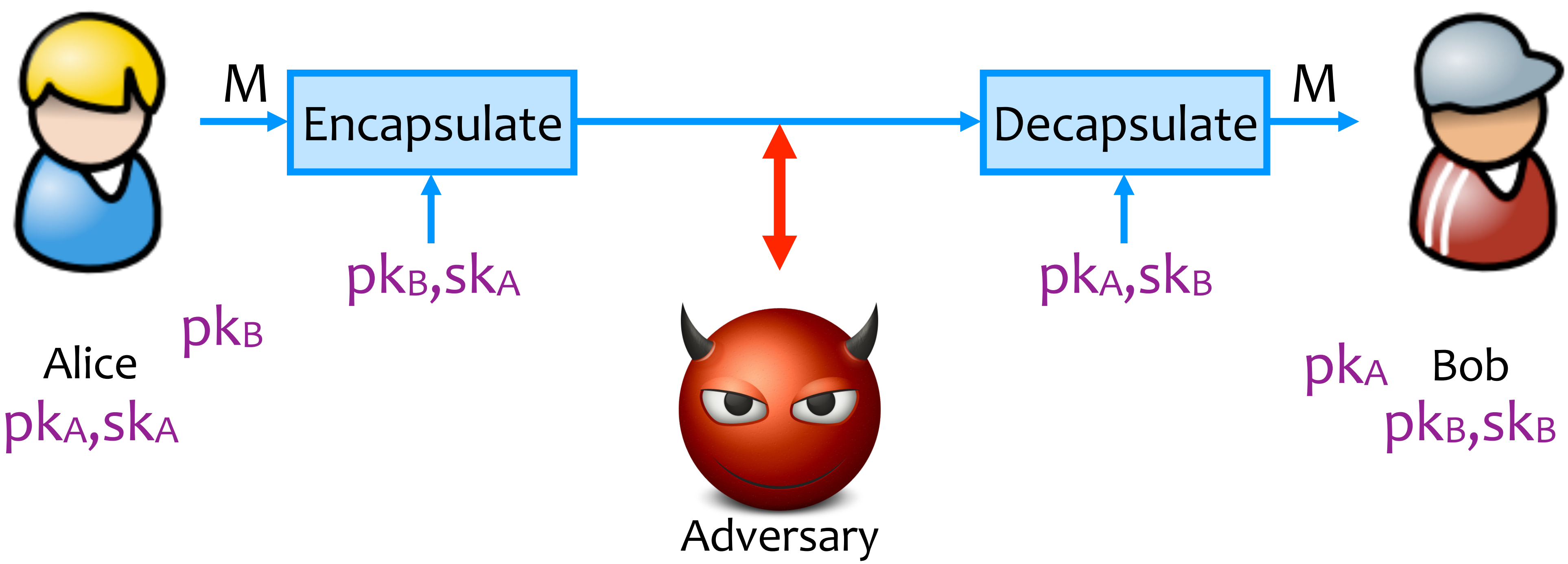
Symmetric Setting

Both communicating parties have access to a shared random string K, called the key.

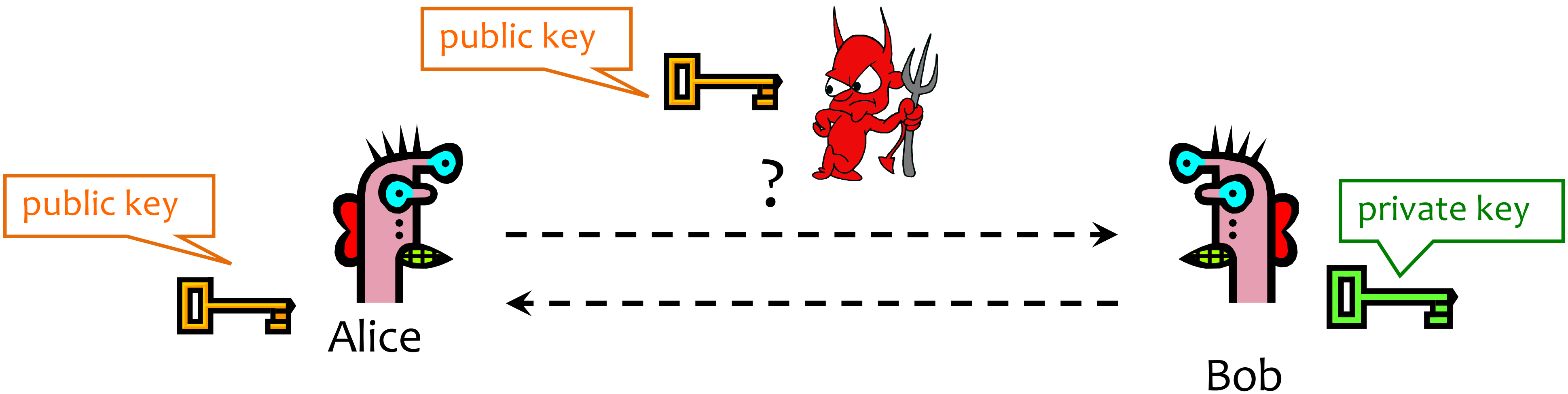


Asymmetric Setting

Each party creates a public key pk and a secret key sk.



Public Key Crypto: Basic Problem



Ignore for now: How do we know it's REALLY Bob's??

Given: Everybody knows Bob's public key
Only Bob knows the corresponding private key

Goals: 1. Alice wants to send a secret message to Bob
2. Bob wants to authenticate himself

Applications of Public Key Crypto

- Encryption for confidentiality
  - Anyone can encrypt a message
    - With symmetric crypto, must know secret key to encrypt
  - Only someone who knows private key can decrypt
  - Key management is simpler (or at least different)
    - Secret is stored only at one site: good for open environments
- Digital signatures for authentication
  - Can "sign" a message with your private key
- Session key establishment
  - Exchange messages to create a secret session key
  - Then switch to symmetric cryptography (why?)

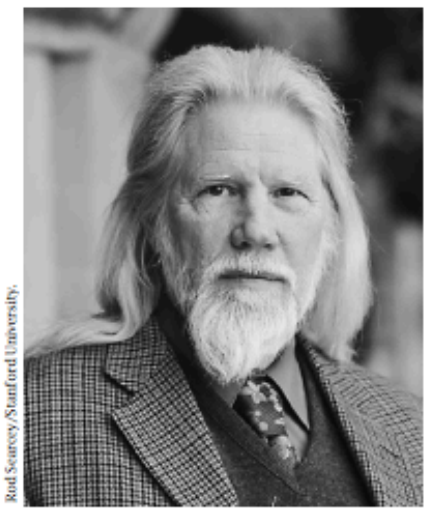
Session Key Establishment

Modular Arithmetic

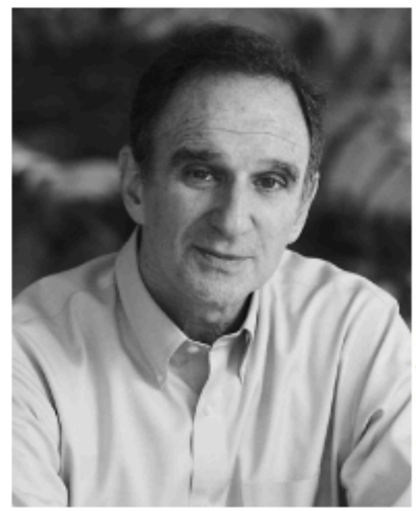
- Refresher in section yesterday
- Given g and prime p, compute:
  g^1 mod p, g^2 mod p, … g^{100} mod p
  - For p=11, g=10
    - 10^1 mod 11 = 10, 10^2 mod 11 = 1, 10^3 mod 11 = 10, …
    - Produces cyclic group {10, 1} (order=2)
  - For p=11, g=7
    - 7^1 mod 11 = 7, 7^2 mod 11 = 5, 7^3 mod 11 = 2, …
    - Produces cyclic group {7,5,2,3,10,4,6,9,8,1} (order = 10)
    - g=7 is a "generator" of Z_{11}*

Diffie-Hellman Protocol (1976)

Diffie and Hellman Receive 2015 Turing Award



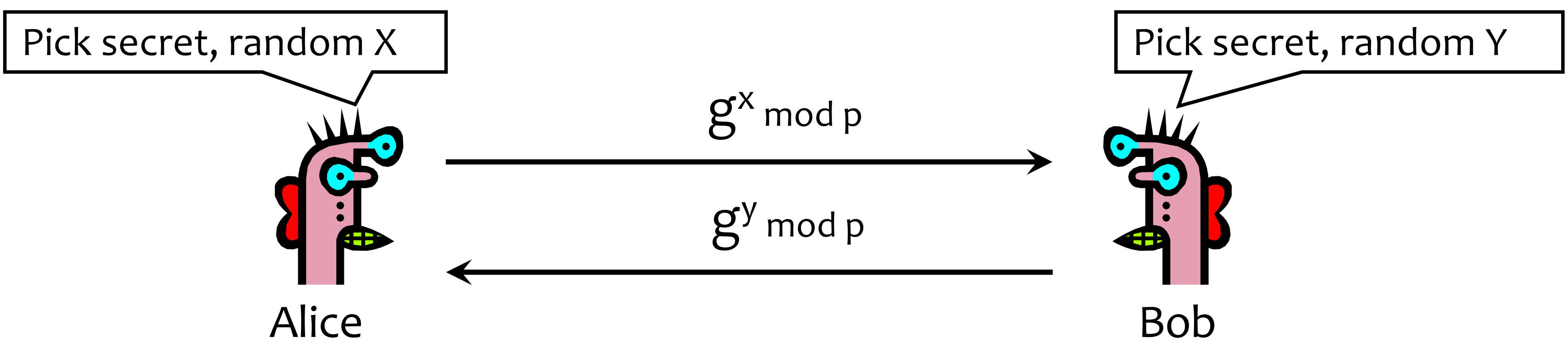
Whitfield Diffie



Martin E. Hellman

Diffie-Hellman Protocol (1976)

- Alice and Bob never met and share no secrets
- Public info: p and g
  - – p is a large prime, g is a **generator** of Z_p*
    - $Z_p^* = \{1, 2 \ldots p-1\}$; $\forall a \in Z_p^* \;\; \exists i$ such that $a = g^i \bmod p$
    - Modular arithmetic: numbers "wrap around" after they reach p



Compute $k=(g^y)^x=g^{xy} \bmod p$

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Example Diffie Hellman Computation