CNT4406/5412 Network Security

Introduction to Cryptography

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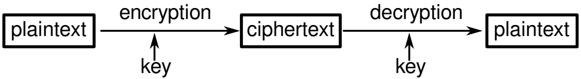
What is Cryptography

- Mangling data into unintelligible form in a manner allowing lossless unmangling
  - ➠ usually one-to-one in size (unlike compression)
  - ➠ RSA is different
  - ➠ other services: integrity check and authentication



Cryptography Caveats

- We normally cannot prove a cipher is secure, instead we assume it is secure until unproven
  - ➠ arms race of cryptographers and cryptanalysts (Fred) improves it
  - ➠ cryptography systems usually have an algorithm and a key
  - ➠ publish the algorithm while keeping the key secret

Fundamental Tenet of Cryptography

If lots of smart people have failed to solve a problem, then it probably won't be solved (soon).

Computational Difficulty

- Algorithm should be efficient to compute but significantly difficult for a brute-force cryptanalysis
  - ➠ Brute-force cryptanalysis: try all keys until “looks like” plaintext
  - ➠ a longer key means more work for brute-force cryptanalysis
  - ➠ encryption: O(N+1), brute-force: $O(2^{N+1})$

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- Advances in computing benefit cryptographer more, but make old uses of cryptography easier to break

  ➠ DES (56 bit key) was standardized in 1977. It took 56 hours to break it in 1998, less than 1 day in 2008

Breaking an Encryption Scheme

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- Chosen plaintext
  - ➠ Fred can choose a plaintext and have its ciphertext computed

Notation

Symbol	Meaning
$\oplus$	XOR, exclusive or
$\|$	concatenation (e.g., $ab\|cd = abcd$)
$K\{message\}$	encrypted with secret key K
$\{message\}_{Bob}$	encrypted with Bob's public key
$[message]_{Bob}$	signed by Bob with its private key

Trivial Ciphers

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  ➠ 26 possibilities
- Monoalphabetic cipher: arbitrary mapping of one letter to another
  ➠ 26! (about 4×10^{26}) possibilities
  ➠ letter frequencies is preserved, making it vulnerable to letter frequency analysis

Breaking Monoalphabetic Cipher

- Match high/low-frequency n-grams in the language to the ciphertext until a “recognizable plaintext” (n = 1, 2, 3)
  ➠ English: e, t, a, o, I, n, s, h, r...

Example:

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Si spy net work, big fedjaw iog link kyxogy
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To the bad guys, for making our jobs secure
```

Fun Fact about Words

- Scrambled words can still be parsed by the human brain

Aoccdrnig to rscheearch at Cmabrigde uinervtisy, it deosn't mttaer waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteres are at the rghit pclae. The rset can be a tatol mses and you cansitll raed it wouthit a porbelm. Tihs is bcuseae we do not raed ervey lteter by itslef but the wrod as a wlohe.

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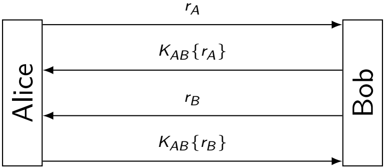
  ➠ one shared key
- Public key cryptography (asymmetric cryptography)
  ➠ two keys (public and private)

Secret Key Cryptography

- One key shared by both participators
  - ➠ one key, two operations (encryption and decryption)
  - ➠ how to securely agree on the key?
  - ➠ examples: DES, IDEA, AES...

Applications of SKC

- Transmitting data over insecure channel
  ➠ eavesdropping, modification, deletion



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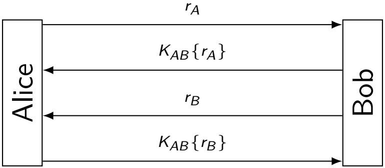
  ➠ Google deletes your (replicated) data by discarding the key



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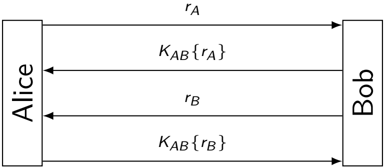

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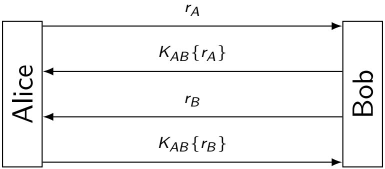
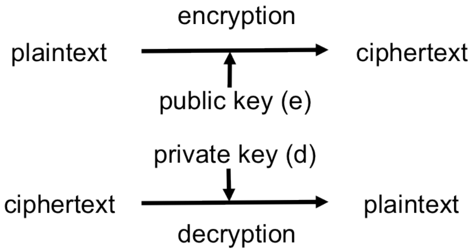
- Data integrity check to prevent forgery of data checksum
- Authentication: prove knowledge of the key w/o revealing it
  ➠ Trudy can impersonate Alice to Bob by reflection attack



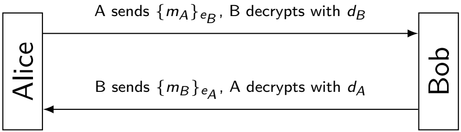
Public Key Cryptography

- Public key for encryption, and private key for decryption
  ➠ one operation (encryption), two keys (inverse of each other)
  ➠ anybody can encrypt a message, but only the owner of the private key can decrypt it



Applications of PKC

- Transmitting data over insecure channel


Alice
Bob
A sends $\{m_A\}_{e_B}$, B decrypts with d_B
B sends $\{m_B\}_{e_A}$, A decrypts with d_A

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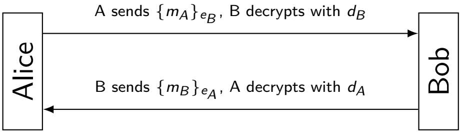
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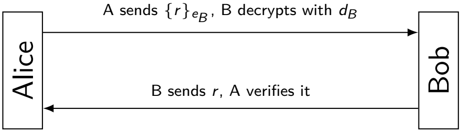
- Secure storage on insecure media
  ➠ generate a secret key for data encryption, then encrypt the key with PKC because PKC is slow

Applications of PKC

- Authentication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B sends r, A verifies it
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Applications of PKC

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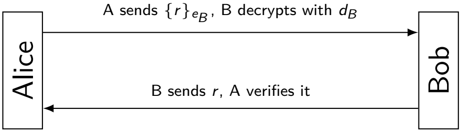
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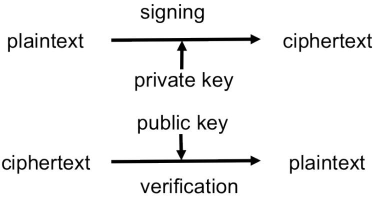
- Digital signature provides integrity and non-repudiation



Hash Function

- Hash function computes a fixed-length (short) number from a message of arbitrary length
  - ➠ given m, easy to compute $h(m)$
  - ➠ given $h(m)$, no easy way to find a m_1 that hashes to $h(m)$
  - ➠ computationally infeasible to find $h(m_1) = h(m_2)$

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- Message fingerprint and downline load security
  - ➠ publish with the data its md5 hash (download a copy of firefox)

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- Digital signature efficiency

  ➠ sign a hash of the message instead of the message itself (Public key encryption is inefficient)

Summary

- What is cryptograph
- Three ways to break cryptography
- Trivial ciphers
- Cryptographic functions and their applications

- Next lecture: secret key cryptography