CS 640 Introduction to Computer Networks

Lecture23

Today's lecture

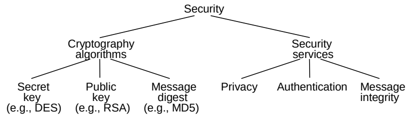
- Network security
  - Encryption Algorithms
  - Authentication Protocols
  - Message Integrity Protocols

Why do we care about Security?

- "Toto… I have a feeling we're not in Kansas anymore." Dorothy, *The Wizard of Oz*
- "The art of war teaches us to rely not on the likelihood of the enemy's not coming, but on our own readiness to receive him; not on the chance of his not attacking, but rather on the fact that we have made our position unassailable." *The Art of War*, Sun Tzu
- There **are** bad guys out there who can easily take advantage of you.
- Reference: *Cryptography and Network Security, Principles and Practice*, William Stallings, Prentice Hall

Overview

- Security services in networks
  - Privacy: preventing unauthorized release of information
  - Authentication: verifying identity of the remote participant
  - Integrity: making sure message has not been altered



- Cryptography algorithms – building blocks for security
  - Privacy/Authentication
    - Secret key (e.g., Data Encryption Standard (DES))
    - Public key (e.g., Rivest, Shamir and Adleman (RSA))
  - Integrity
    - Message digest/hash (e.g., Message Digest version 5 (MD5))

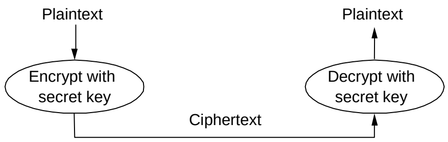
Issues in Security

- Threat models
  - How are bad guys trying to do bad things to you?
- Key distribution
  - How do folks get their keys?
- Implementation and verification
  - How can we be sure systems are secure?
- Non-goal: details of crypto algorithms
  - We are not going to focus on proving anything about crypto algorithms
    - See CS642

Crypto 101

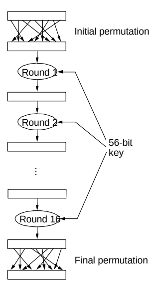
- Cryptographic algorithms determine how to generate encoded text (ciphertext) from plaintext using keys (string of bits)
  - Can only be decrypted by key holders
- Algorithms
  - Published and stable
  - Keys must be kept secret
  - Keys cannot be deduced
  - Large keys make breaking code VERY hard
  - Computational efficiency

Secret Key (DES)

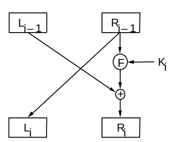


- Approach: Make algorithm so complicated that none of the original structure of plaintext exists in ciphertext

- Encrypt 64 bit blocks of plaintext with 64-bit key (56-bits + 8-bit parity)
- 16 rounds

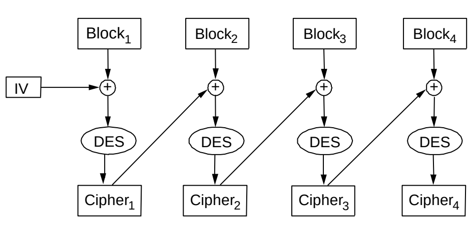


- Each Round

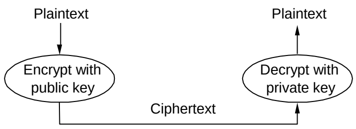


- L,R = 32 bit halves of 64 bit block
- K = 48 bits of 64 bit key
- F = combiner function
- + = XOR

- Encryption steps are the same as decryption
- Repeat for larger messages (cipher block chaining)
  - IV = initialization vector = random number generated by sender



Public Key (RSA)



- One of the coolest algorithms ever!
- Encryption
  - *ciphertext* $= c = m^e \mod n$ *($<e, n>$ = public key)*
- Decryption
  - *Message* $= m = c^d \mod n$ *($<d, n>$ = private key)*
- M < n
  - Larger messages treated as concatenation of multiple n sized blocks

RSA contd.

- Choose two large prime numbers *p* and *q* (each 256 bits)
- Multiply *p* and *q* together to get *n*
- Choose the encryption key *e*, such that *e* and $(p - 1) \times (q - 1)$ are relatively prime.
- Two numbers are relatively prime if they have no common factor greater than one
- Compute decryption key *d* such that

$$d = e^{-1} \mod ((p - 1) \times (q - 1))$$

- Construct public key as (*e*, *n*)
- Construct public key as (*d*, *n*)
- Discard (do not disclose) original primes *p* and *q*

RSA contd.

- See example in book for applying RSA
  - Many others as well
- Usage
  - for privacy encrypt with recipient's *public* key and he decrypts with *private* key
  - for authentication encrypt with your *private* key and the recipient decrypts with your *public* key
- Security based on premise that factoring is hard
  - The bigger the key the harder it is to factor
  - The bigger the key is more computationally expensive it is to encrypt/decrypt

Message Digest

- Cryptographic checksum
  - a fixed length sequence of bits which is used to protect the receiver from accidental changes to the message; a cryptographic checksum protects the receiver from malicious changes to the message.
- One-way function
  - given a cryptographic checksum for a message, it is virtually impossible to figure out what message produced that checksum; it is not computationally feasible to find two messages that hash to the same cryptographic checksum.
- Relevance
  - if you are given a checksum for a message and you are able to compute exactly the same checksum for that message, then it is highly likely this message produced the checksum you were given.

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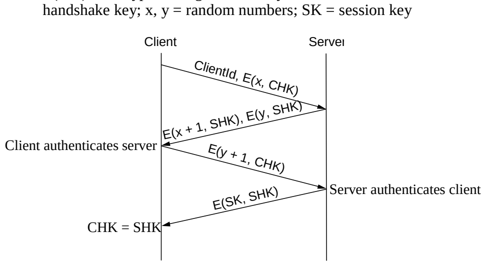
Authentication Protocols

- Three-way handshake (uses secret key - eg. password)
  - E(m,k) = encrypt message *m* with key *k;* C/SHK = client/server handshake key; x, y = random numbers; SK = session key



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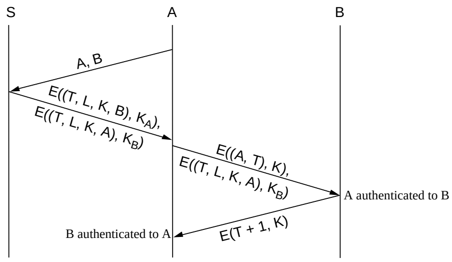
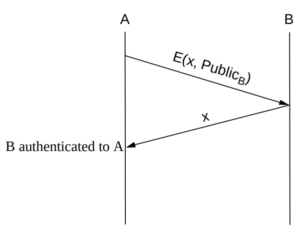
- Trusted third party (Kerberos)
  - A and B share secret keys (K_A, K_B) with trusted third party S
  - A,B =ID's; T = timestamp; L = lifetime, K = session key



- Public key authentication (using eg. RSA)



Message Integrity Protocols

- Digital signature using RSA
  - special case of a message integrity where the code can only have been generated by one participant
  - compute signature with private key and verify with public key
- Keyed MD5 (uses MD5 and RSA)
  - sender: m + MD5(m + k) + E(k, *private*) where k = random number
  - receiver
    - recovers random key using the sender's public key
    - applies MD5 to the concatenation of this random key message
- MD5 with RSA signature
  - sender: m + E(MD5(m), *private*)
  - receiver
    - decrypts signature with sender's public key
    - compares result with MD5 checksum sent with message