Middleboxes, Cryptography, & Secure Protocols

CS640, 2014-04-30

Announcements

- Assign #5 due Thursday, May 7 @ 11pm

Outline

- Middleboxes
- Crypto algorithms
- Session keys
- Public key infrastructure
- Secure protocols

Middleboxes

- Systems in the "middle" of the network that examine and block packets and flows
    - Middle = on the path between pairs of communicating hosts
    - Packets forced to pass through middlebox -- based on physical topology, or using SDN
- Basic firewalls
    - Apply simple rules to decide whether to forward or block packets
    - Rules are based on fields in packet headers -- e.g., source/destination IPs, transport layer protocol, source/destination ports
    - Default rule to either forward or block if no other rules match
- Advanced firewalls
    - Maintain some state about active connections
        - E.g., current state of TCP connection -- SYN sent, SYN+ACK sent, established, FIN sent, etc.
        - Rules based on both packet headers and current state
    - Application-aware
        - Extra protection for services that should not be blocked (e.g., HTTP)
        - E.g., check if HTTP POST method is allowed
        - E.g., check if client is requesting a web page from a domain that is on a blacklist because it is known to host malware
        - Often acts as a proxy -- terminates TCP connection from client and establishes separate TCP connection to server
- Intrusion detection/prevention systems
    - Performs deep packet inspection
        - Look at payload of packet, not just headers, to decide if it should be blocked
        - Knows the format of packets for many different transport and application protocols -- HTTP, SSH, SSL/TLS, FTP, NFS, FTP, NTP, etc.
        - Cannot perform deep packet inspection on traffic that is encrypted!
    - Maintains state about active connections
        - Connection info such as src/dst IP, src/dst port, and TCP connection state
        - Reassembled payloads -- e.g., HTTP reply may be split among multiple packets, so the packets are reassembled into a single memory region that contains the entire reply

- Uses a set of signatures (i.e., rules) to detect malicious traffic
    - Specific sequences of packets -- e.g., TCP SYN+ACK after TCP FIN
    - Keywords in payloads -- e.g., "root"
    - MD5 sum of payload -- compare against database of MD5 sums for known malware
    - Large numbers of packets to one host in a short period of time
        - DoS
        - Port scan -- look for hosts which have sockets listening on a particular port and will accept connections; host may be running an outdated version of software that has a known vulnerability
- IDS just raises alerts, while IPS raises alerts and blocks traffic
- Speed of signature matching can significantly impact latency and throughput
    - Want efficient pattern matching algorithms
    - Sometimes use custom hardware
    - Can be easily parallelized

Basic Cryptography

- Encrypt/decrypt algorithm should be
    - Public -- inventing algorithms is hard, so we don't want to have to develop a new one if something is leaked
    - Easy to compute with the key -- efficient in software and hardware, and on mobile devices which have fewer resources
    - Hard to compute without the key -- computers keep getting more powerful
- Key should be
    - Secret
    - Long -- length of key often determines "level" of security
- Types of functions
    - Cryptographic hash -- no keys
    - Symmetric/secret key -- one shared key
    - Asymmetric/public key -- pair of keys: one public & one private

Cryptographic Hash

- Also known as "cryptographic checksum" -- used to detect if message has been tampered
- Take message *m* of any length, and produce smaller message *h(m)*
- Properties
    - Pre-image resistance -- hard to find *m* given *h(m)*; "one-way" function
    - Second pre-image resistance -- given a message *m*, it is hard to find a message *m'* that hashes to the same *h(m)*
    - Collision resistance -- hard to find any two messages *m* and *m'* such that *h(m)* = *h(m')*

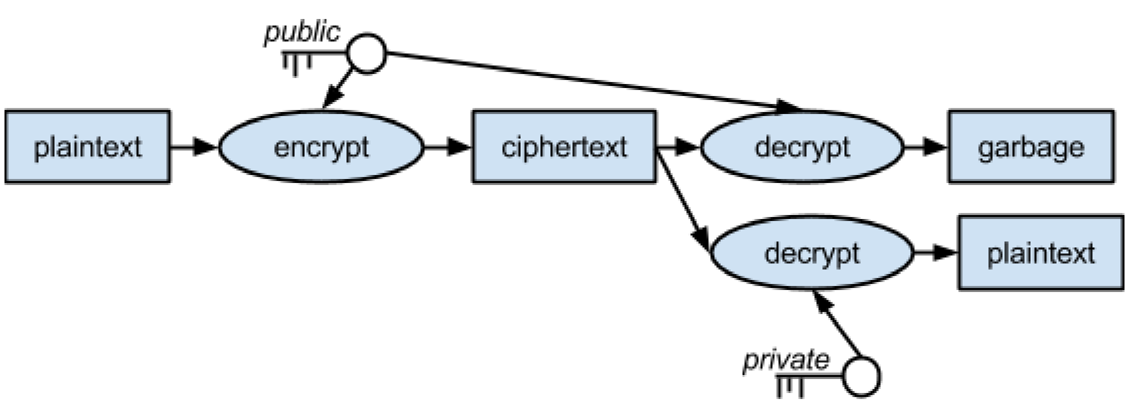
- How many bits for the hash?
  - If hash is *n* bits, it takes $2^{n/2}$ tries to find a collision
  - MD5 -- uses 128 bits; weakness known for a while
  - SHA-1 -- uses 160 bits; also not recommended for use
  - SHA-2 -- collection of six different hash functions; use 224, 256, 384 or 512 bits
  - SHA-3 -- emerging standard
- Example: self-certifying names
  - File-sharing software (e.g., BitTorrent) names files with h(file-data)
  - Verify h(downloaded-data) = name of file

Symmetric/Secret Key

- Sender and receiver share a common key
- None of the original structure of the plaintext should exist in the ciphertext
  - Otherwise, attackers could look for patterns -- e.g., commonly used letters in the English language; HTTP request starts with method (GET, POST, etc.)
- Variants
  - Data Encryption Standard (DES) -- 64-bit keys (8-bits are parity); easy to recover a key given today's processing power
  - Triple DES (3DES) -- 168-bit keys; encrypt using first 56-bits, decrypt using middle 56-bits, encrypt using last 56-bits (inverse for decryption); slow to implement in software
  - Advanced Encryption Standard (AES) -- 128, 192, or 256-bit keys; fast implementations in hardware or software and low memory footprint
- Challenge: key distribution
  - Physically deliver key -- not practical
  - Use existing key to deliver new key -- need unique key pair for each pair of endpoints ($n*(n-1)/2$ total keys for *n* endpoints)
  - Use key distribution center (KDC) -- KDC generates session keys and distributes them to pairs of endpoints that wants to communicate; need *n* master keys if you have *n* endpoints

Asymmetric/Public Key

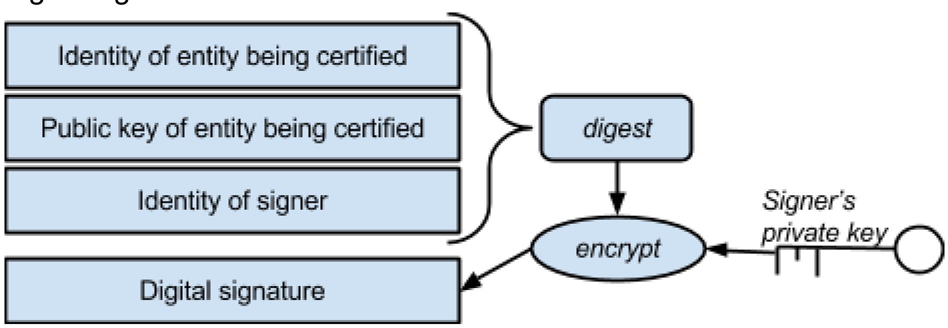
- Pair of keys
  - Public key given to many senders
  - Private key kept a secret by the receiver (i.e., owner)
  - The private key cannot be derived from the public key
- Data is encrypted using the public key, but can only be decrypted using the private key



- Data can also be encrypted using the private key and decrypted using the public key
  - Obviously not useful for sending confidential data
  - But, can be used to verify a message came from a specific entity, since only one entity should have the private key and the ability to encrypt a message using that key
- RSA (named after inventors Rivest Shamir, and Adleman)
  - Relies on the high computational cost of factoring large numbers
- Much slower than symmetric key, but key distribution is easier

Public Key Infrastructure

- Mechanism for certifying bindings between public keys and identities
  - Identities could be email address, domain name, etc.
  - Binding ensured using a digital signature
- Public key certificate
  - Identity of entity being certified
  - Public key of the entity being certified
  - Identity of the signer
  - Digital signature



    - Compute digest of identifies and public key using cryptographic hash
    - Encrypt digest using signer's private key
    - Anyone with signer's public key can decrypt the digest and compare it against a digest they compute
  - Identifier for digital signature algorithm -- Elliptic Curve Digital Signature Algorithm (ECDSA) is the current standard
  - Expiration timestamp
- Chain of trust -- e.g., X certifies public key for Y, and Y certifies public key for Z, then there is a chain of certificates from X to Z
- Certificate Authority (CA)
  - Verifies identities and issues public key certificates
  - Trusted organization (e.g., VeriSign)
  - Web browsers preconfigured with certificates for common CAs
  - Publish certificate revocation list -- digitally signed list of certificates that have been voided