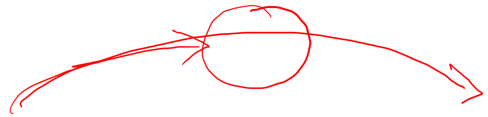
Design and Engineering of Computer Systems

Lecture 25: Network Security

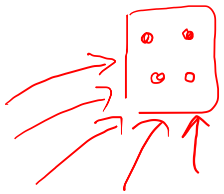
Mythili Vutukuru

IIT Bombay

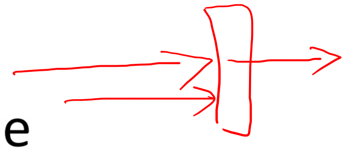
Network Security: Overview



- Many security problems can occur in a networked system
  - Man-in-the-middle attack: fake website impersonates real website and cheats users
  - Denial of Service attack: a large volume of traffic sent to server causes it to crash, service no longer available
  - Malware: malicious software designed to damage a computer system
  - Port scanning: probing traffic sent to various ports to find open ports/services
  - Tampering with data in transit, eavesdropping on confidential information

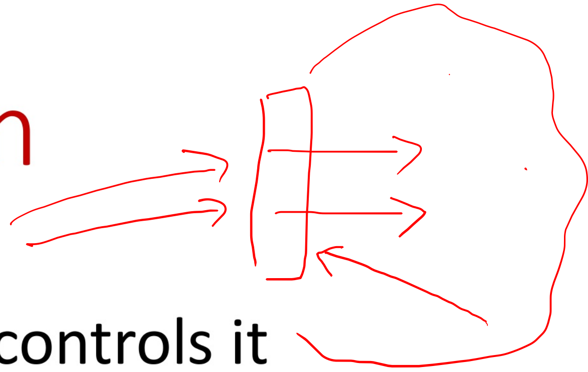


- Some good security properties we desire
  - Identify and filter out malicious traffic, attack traffic, malware
  - Origin authentication: guarantee that the website we are accessing is genuine
  - Data integrity: no one has tampered with content during transit over network
  - Confidentiality: no one has snooped on our traffic to steal private information



- In this lecture: key ideas to secure networked applications (basics only)

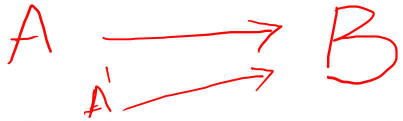
Firewall and intrusion detection system



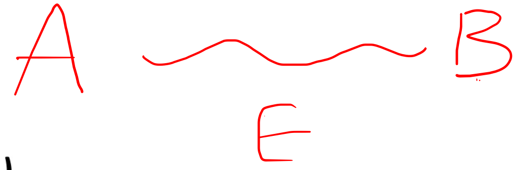
- Firewall: monitors incoming/outgoing traffic in a network and controls it according to various security rules
  - Can be a software program or hardware appliance
  - Filters packets based on rules (block incoming requests to some ports, disallow traffic from/to specific hosts)
- IDS (intrusion detection system): inspect incoming packets for malicious traffic
  - More sophisticated analysis than simple rules in firewalls
  - Detects anomalies in network traffic (too much traffic coming to specific hosts could be denial of service attack, too many connection requests could be port scanning attack)
  - Looks for signatures of well-known malwares, viruses in incoming traffic
  - Can raise alerts (intrusion detection) or block suspicious traffic (intrusion prevention)

Background: Public key cryptography

- Cryptography algorithms provide security properties using keys (strings of bits)
  - Based on hardness assumptions that some computations are hard to do
- Public key cryptography: a pair of keys used, one public, one private
  - Public key can be distributed in open, private key is kept secret with entity
- Cryptographic signatures for authentication
  - Alice generates *signature = sign(message, private key of Alice)* and sends it with message
  - Bob verifies message came from Alice by executing *verify(signature, public key of Alice)*

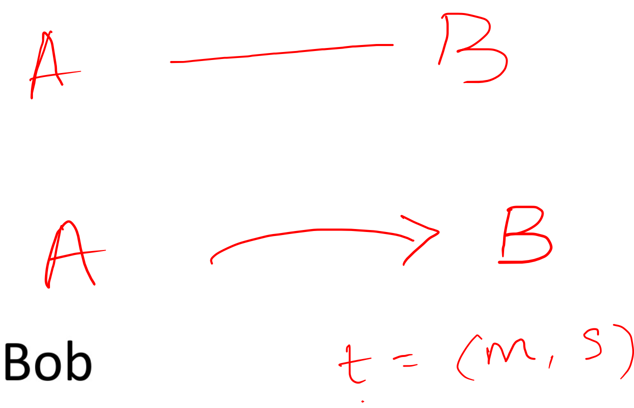


- Encryption for confidentiality
  - Alice sends *cipher = encrypt (message, public key of Bob)* to Bob
  - Bob can recover original message with *decrypt (cipher, private key of Bob)*

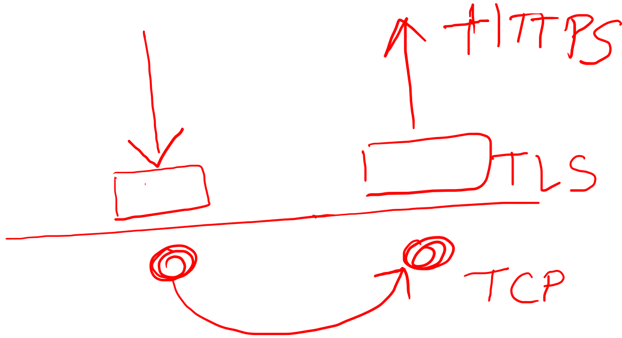


Background: Symmetric key cryptography

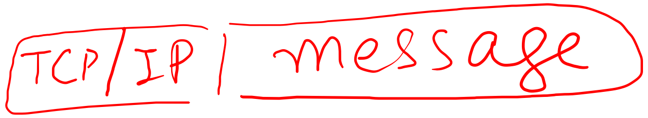
- Symmetric key cryptography: a shared secret key is used
  - Symmetric key algorithms are faster than public key algorithms
  - Mechanisms exist to agree on secret keys using public keys
- Message authentication codes (MAC) for data integrity
  - Alice sends message along with *tag = MAC(message, secret key)* to Bob
  - Bob can verify that message was not tampered with by regenerating tag, and verifying that it matches with received tag
  - If anyone tampered with message, recomputed tag will not match received tag
- Encryption for confidentiality with shared secret key
  - Alice sends *cipher = encrypt (message, secret key)* to Bob
  - Bob can recover original message with *decrypt (cipher, secret key)*



HTTPS (Secure HTTP)



- HTTP = requests and responses sent over regular TCP sockets
  - Anyone can snoop, tamper, pretend to be server
- HTTPS = requests and responses sent over TLS/SSL sockets
  - TLS (Transport Layer Security), also called Secure Sockets Layer (SSL), built over TCP, with additional messages exchanged for security during connection setup
  - Separate port number (443, not 80) for servers using secure sockets
  - If URL indicates "https" instead of http, request sent to secure HTTP server
- HTTP provides several security guarantees
  - Authentication: website is authenticated to be genuine
  - Data integrity: data sent inside HTTP messages is safe from tampering
  - Confidentiality: data is encrypted, no one can snoop on private information
- Only application layer security, outer TCP/IP headers are still visible



HTTPS: Details

- When we access a website, we want to know that the domain name, and associated information (e.g., public key) are all genuine
- How is this guaranteed? Using trusted certificate authorities (CA), whom we trust to verify information about websites
  - CA physically verifies and then signs information about a website (domain name, public key, …) with its private key
    (msg) sign
  - Website shares this SSL certificate with its clients during HTTPS setup
  - Client (browser) can verify certificate using CA's well-known public key (built into browsers)
- Website's public key is used to arrive at a temporary shared secret key
  - All HTTP request/response data is encrypted with shared secret key for confidentiality, then MAC added for data integrity

MAC[encrypt(HTTP data)]

Cryptographic hash functions

- Cryptographic hash functions: functions that map a large message to a small fixed size value (e.g., SHA-1, SHA-2, MD5)
  - Given message, compute hash(message) using hash function
  - Cannot invert function: cannot guess message by just looking at hash
  - Cannot easily generate another message that hashes to the same value
- Example: passwords in a computer system are stored as hashes
  - Do not store actual user password (privacy), instead store only the hash
  - No one can guess actual password by only looking at hash
  - When user enters password during login, hash it and verify match
- Example: websites post digests (hash) of large files (e.g., OS images). Users download image and verify digest to confirm integrity of data

Summary

- In this lecture:
  - Firewall, IDS to detect and filter malicious network traffic
  - HTTPS for authentication, integrity, confidentiality of HTTP data
  - Cryptographic hash functions
- Inspect traffic exchanged with a HTTPS website using Wireshark. Find out which information about packets is visible and which information is encrypted for confidentiality.