06-06798 Distributed Systems

Lecture 14: Security

Overview

- What is security?
  - policies and mechanisms
  - threats and attacks
- Security of electronic transactions
  - secure channels
  - authentication and cryptography
- Security techniques
  - access control
  - firewalls
  - cryptographic algorithms

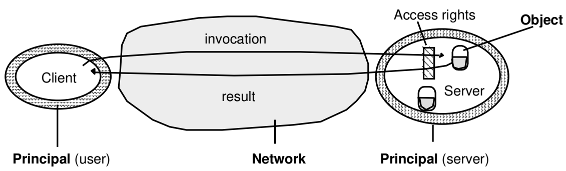
Security

- Definition
  - set of measures to guarantee the **privacy, integrity and availability** of resources:
    - objects, databases, servers, processes, channels, etc
  - involves protection of objects and securing processes and communication channels
- Security policies
  - specify who is authorised to access resources (e.g. file ownership)
- Security mechanisms
  - enforce security policy (e.g. file access control)

Security model

Object: intended for use by different clients, via remote invocation

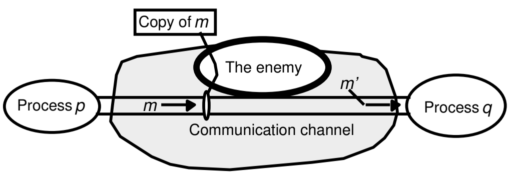
Principal: authority on whose behalf invocation is issued



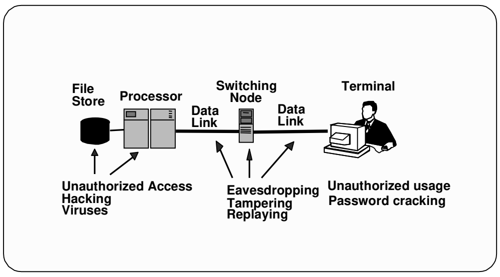
The enemy

Processes: encapsulate resources, interact by messages

Messages: exposed to attack by enemy



Security threats: what & where



Security threats: examples

- Online shopping/banking
  - intercept credit card information
  - purchase goods using stolen credit card details
  - replay bank transaction, e.g. credit an account
- Online stock market information service
  - observe frequency or timing of requests to deduce useful information, e.g. the level of stock
- Website
  - flooding with requests (denial of service)
- My computer
  - receive/download malicious code (virus)

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Types of security threats

- Eavesdropping
  - obtaining copies of messages without authority
- Masquerading
  - sending/receiving messages using the identity of another principal without their authority
- Message tampering
  - intercepting and altering messages
- Replaying
  - intercepting, storing and replaying messages
- Denial of service
  - flooding a channel with requests to deny access to others

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Defeating the enemy: how?

- Encryption (scrambling a message to hide its contents)
  - does not prove identity of sender
- Shared secrets (keys)
  - messages encrypted with the shared key
  - can only be decrypted if the key is known
- Identification (are you who you are?)
  - password protection, etc
- Authentication (are you who you say you are?)
  - include in message identity of principal/data, timestamp
  - encrypt with shared key

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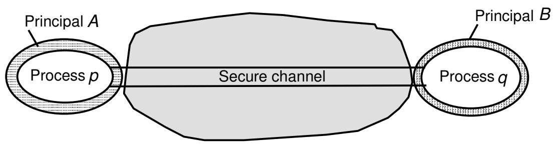
Secure channels

Processes: reliably know identity of principal

Messages: protected against tampering, timestamped to prevent replaying/reordering.



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Threats due to mobility...

- Mobile code (Java JVM)
  - applets, mobile agents (travel collecting information)
  - downloaded from server, run locally
- Security issues: what if the program...
  - illegally writes to a file?
  - writes over another program's memory?
  - crashes?
- Some solutions
  - stored separately from other classes
  - type-checking and code-validation (instruction subset)
  - still does not guard fully against programming errors...

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Designing secure systems

- Basic message
  - networks are insecure
  - interfaces are exposed
- Threat analysis
  - assume worst-case scenario
  - list all threats - complex scenarios!!!
- Design guidelines
  - log at points of entry so that violations detected
  - limit the lifetime and scope of each secret
  - publish algorithms, restrict access to shared keys
  - minimise trusted base

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Main security techniques

- Access control
  - implement resource protection, e.g. file protection
  - essential in distributed systems (remote login)
- Firewalls
  - monitor traffic into and out of intranet
- Cryptographic algorithms
  - ciphers
  - authentication
  - digital signatures

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Access control

- Definition
  - ensure that users/processes access computer resources in a controlled and authorised manner
- Protection domain
  - is a set of rights for each resource, e.g. Unix files
  - associated with each principal
- Two implementations of protection domains
  - Capabilities
    - request accompanied by key, simple access check
    - open to key theft, or key retained when person left company
  - Access control lists
    - list of rights stored with each resource
    - request requires authentication of principal

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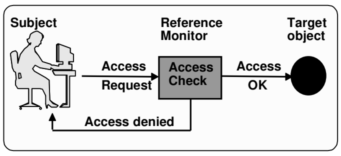
Access control



How it works: Reference Monitor
- intercepts all access attempts
- authenticates request and principal's credentials
- applies access control
  - if Yes, access proceeds
  - if No, access is denied, error message returned to the subject

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Firewalls

- Monitor and control all communication into and out of an intranet.
- Service control:
  - filter requests for services on internal hosts
  - e.g. reject HTTP request unless to official webserver
- Behaviour control
  - prevent illegal or anti-social behaviour
  - e.g. filter 'spam' messages
- User control:
  - allow access to authorised group of users
  - e.g. dial-up services

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How does it work...

A set of processes, at different protocol levels:
- IP packet filtering
  - screening of source & destination, only 'clean' packets proceed
  - performed in OS kernel of router
- TCP gateway
  - monitors TCP connection requests
- Application-level gateway
  - runs proxy for an application on TCP gateway, e.g. Telnet
- Bastion
  - separate computer within intranet
  - protected by IP packet filtering, runs TCP/application gateway

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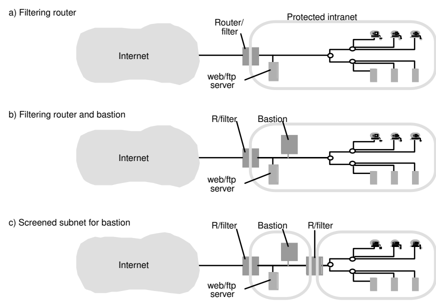
Firewall configurations



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Cryptographic algorithms

- Encryption
  - apply rules to transform *plaintext* to *ciphertext*
  - defined with a function F and key K
  - denote message M encrypted with K by

    $F_K(M) = \{M\}_K$
- Decryption
  - uses inverse function

    $F^{-1}_K(\{M\}_K) = M$
  - can be symmetric (based on secret key known to both parties)
  - or asymmetric (based on public key)

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Symmetric cryptography

- One-way functions
  - encryption function F_K easy to compute
  - decryption function F^{-1}_K hard, not feasible in practice
- Idea
  - difficult to discover F_K given $\{M\}_K$
  - difficulty increases with K, to prevent brute-force attack
  - combine blocks of *plaintext* with key through series of XOR, bit shifting, etc, obscuring bit pattern
- Examples
  - several algorithms: TEA, DES
  - secure secret key size 128 bits

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Asymmetric cryptography

- Trap-door functions
  - pair of keys (e.g. large numbers)
  - encryption function easy to compute (e.g. multiply keys)
  - decryption function infeasible unless secret known (e.g. factorise the product if one key not known)
- Idea
  - two keys produced: encryption key made public, decryption key kept secret
  - anyone can encrypt messages, only participant with decryption key can operate the trap door
- Examples
  - a few practical schemes: RSA

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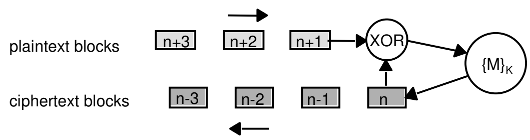
Block ciphers



- How it works
  - message divided into fixed size blocks (64 bits), padded
  - encryption block by block
- Cipher block chaining
  - combine each *plaintext* block with preceding *ciphertext* block using XOR before encryption

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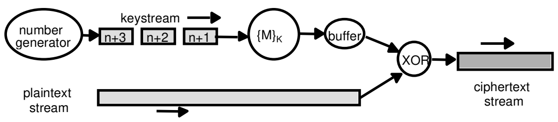
Stream ciphers

- How it works
  - used when no block structure (e.g. voice)
  - encryption performed bit by bit
  - generate sequence of numbers, concatenate into secure bit stream



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Lecture summary

- Security
  - achieves privacy, integrity and availability of distributed systems
- Main techniques
  - access control
  - firewalls
  - cryptography
- Design issues
  - consider worst-case scenario of threats
  - balance cost versus risk
  - log and detect

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