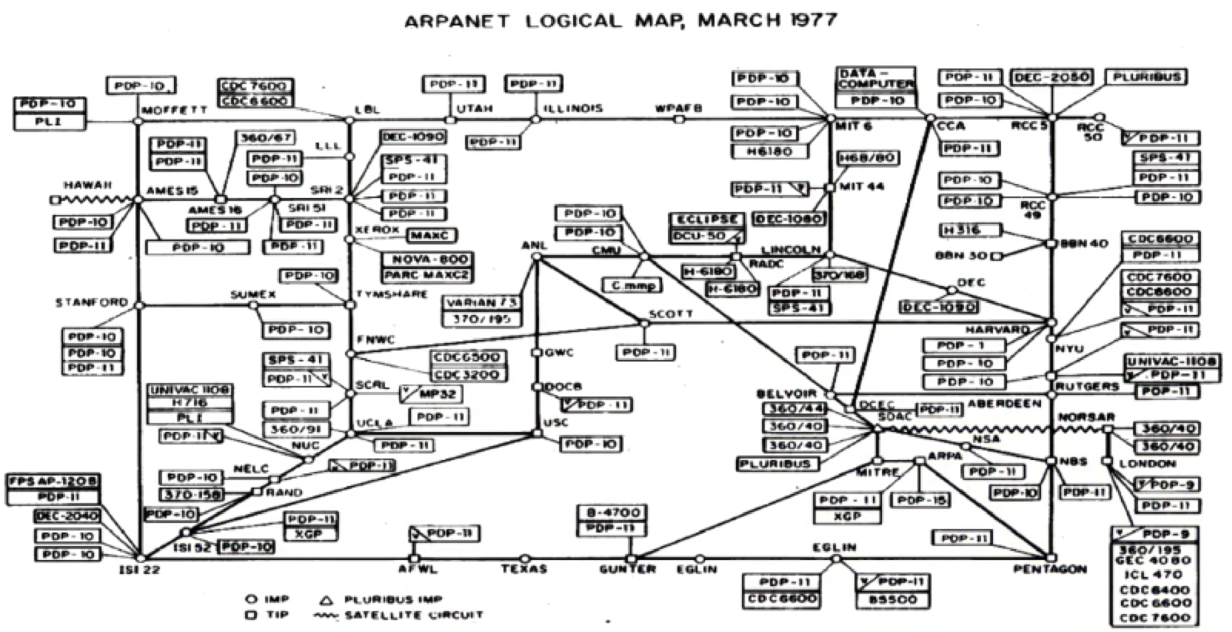
Information Security

Principles of Information Security

* Principles of Information Security Introduction
    - Introduction to terminologies pertaining to information security
    - Cryptographic techniques used to provide distributed authentication
        + Private key infrastructure
* Firsts from Computing Pioneers
    - First vision for a network of computers: 1963
    - First computer-computer communication: 1969
    - First email: 1971
    - Main frame: Contained CPU, memory, and I/O with CRT terminals to connect to the mainframe in 1975 (timesharing system)



All of the Computers in the World (1977)

* Terminologies
    - When to release information?
        + Privacy: When do individuals expect information to be protected or released?
        + Security: Concerned with protection and authentication (system)
    - Comprehensive set of security concerns
        + Unauthorized information release
        + Unauthorized information modification
        + Unauthorized denial of use (DOS attacks)
    - Goal of a secure system
        + Prevent all violations of the concerns above
        + Negative statement, impossible to achieve absolutely
        + At best, negative statement provides false sense of security
* Levels of Protection
    - Unprotected
        + MSDOS: Hooks for mistake prevention, not the same as security

- All or nothing
    + IBM VM-370: Only way to interact with one another is explicit I/O across virtual machines
- Controlled sharing
    + Access lists associated with files
- User programmed sharing controls
    + Unix-like semantics for files (owner, group, everyone else)
- Strings on information
    + "TOP SECRET" need to deal with dynamics of use

* Design Principles
    - Economy of mechanisms: Easy to verify whether it works or not
    - Fail safe defaults: Explicitly allow access -> default should not be no access (no way to guarantee information is protected)
    - Complete mediation: Security mechanism shouldn't take any shortcuts
        + Caching passwords is a bad idea
    - Open design: Publish the design but protect the keys
        + Must present keys to get information and breaking the keys should be computationally infeasible
        + Detection is easier than prevention (don't know what attacks are possible, so impossible to prevent all of them)
    - Separation of privelege: Two keys to open a vault
    - Least privilege: "Need to know" based controls
        + Require administrative priveleges for certain things
        + Origin for the idea of firewalls
    - Least common mechanism: Should mechanism be implemented in the kernel or as a library running on top?
    - Psychological acceptability: Good UI
    - Important takeaways
        1. All of the principles are positive statements
        2. All of the principles are still relevant to today's systems, despite being theorized at a time when computers weren't networked
        3. Difficult to crack protection boundary (computationally infeasible)
        4. Detection rather than prevention
* Principles of Information Security Conclusion
    - Paper by SALSA is a classic
    - Visionary ideas, thought of at a time when computers were independent

Security in Andrew

* Security in Andrew Introduction
    - Enable students at CMU to walk up to any workstation and use it (1988)
    - Access files from central server
    - Assume network was untrusted
    - Focus on security using a private key infrastructure
* State of Computing Circa 1988
    - Local disks served as efficient caches
    - Vision of Andrew file system and Coda (both from CMU)
        + Walk up to any workstation and log in
        + Your content magically appears
        + Similar to cloud and mobile devices today
* Andrew Architecture
    - Client workstation (virtues)
        + Unix
        + Connected to LAN through insecure network links

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    + Servers within a "vice" can communicate securely
  - Venus
    + Process on each virtue for user authentication and client caching
    + Users use RPC to transfer files from vice to virtue
    + RPC must be secure for passing parameters and receiving results
  - Client communication with servers must be encrypted
  - Server communication with each other does not
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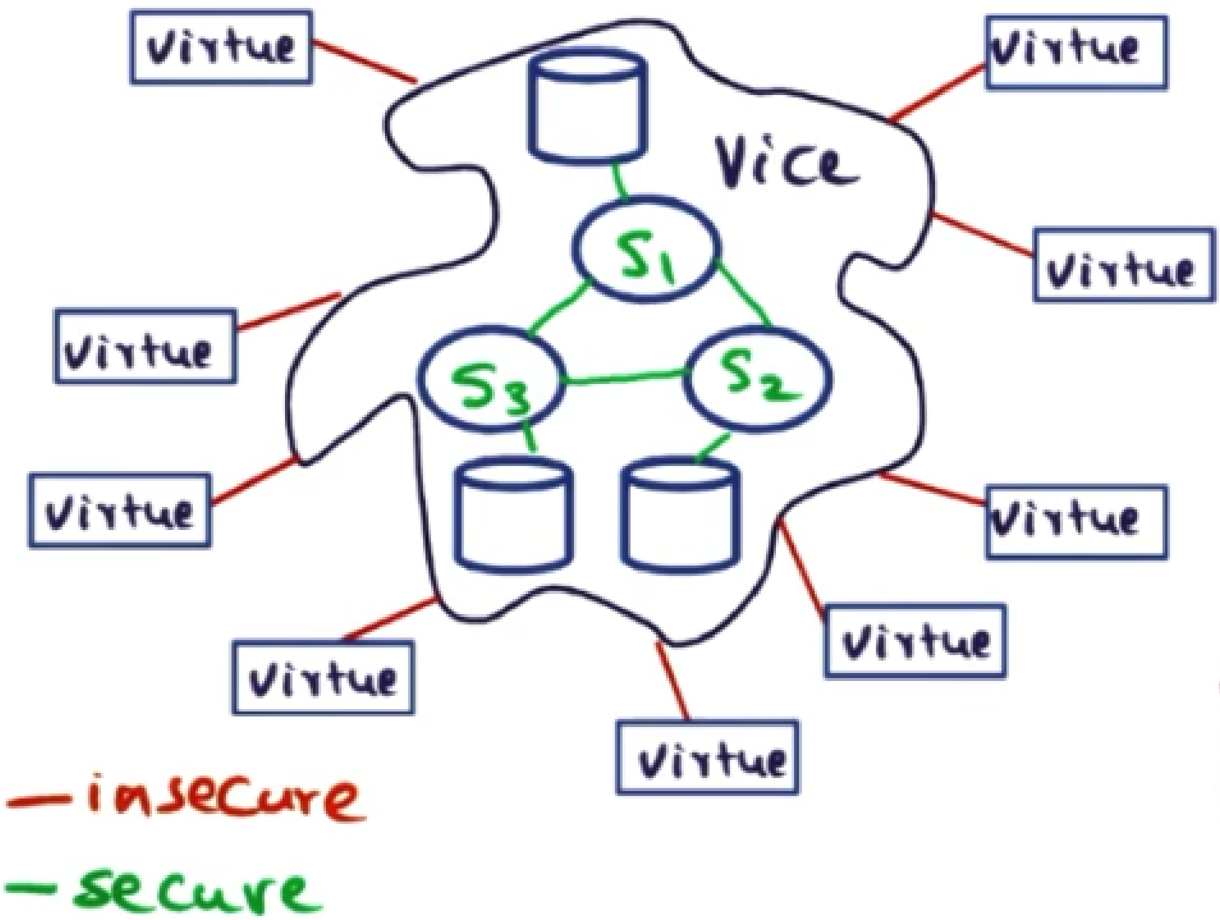

Andrew Architecture

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* Encryption Primer
  - Private key system
    + Symmetric keys to encrypt and decrypt (e.g. passwords to login)
    + Publish the design but protect the key (SALSA)
    + Key distribution is difficult as the organization grows
    + Sender: data -> encrypt(data, key) -> cyphertext
    + Receiver: cyphertext -> decrypt(cyphertext, key) -> data
  - Public key system
    + Asymmetric keys (pair of keys)
    + Public key published -> Encrypt
    + Private key -> Decrypt
    + Mathematical basis is a one-way function
    + Sender: Data -> encrypt(data, public key) -> cyphertext
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    + Receiver: Cyphertext -> decrypt(data, private key) -> data
* Private Key Encryption System in Action
  - With private key encryption
    + A and B have exchanged keys
    + B needs to know identity of send to know which key to use
    + The identity of the sender is sent in cleartext
    + KeyA can be the same as KeyB
* Challenges for Andrew System
  - Authenticate user
    + How can you verify the identity of the person logging in?
  - Authenticate server
    + How can you be sure the message is from the actual server?
  - Prevent replay attacks
    + A person sniffing packets from the wire shouldn't be able to
    resend a packet and fool the sender or receiver?
  - Isolate users
    + Community is shielded from the actions of other users
  - Andrew used a private key crypto system to protect RPC calls
    + Key distribution is not as big of a challenge
    + Identity of sender in cleartext
  - Traditional Unix: Username, password
    + Overuse of usernames and passwords results in a security hole
    + Violates the principle of protecting the keys
  - Dilemma: What to use as identity and private key?
* Andrew Solution
  - Username and password only for login
  - Use ephemeral ID and keys for subsequent Venus-vice communication
  - Three classes of client-server interaction
    1. Login: Username, password
    2. RPC session establishment: Open communication with file system
    3. File system access during session: Download files and work locally
  - 1 uses username and password
  - 2 and 3 uses ephemeral IDs and keys
* Login Process
  - User logs in with username and password to login server
    + Authentication server is separate from authentication server
    + Login process returns cleartoken and secrettoken
    + This communication is secure
  - Cleartoken: Data structure
    + Extract handshake key client (HKC)
    + Use HKC as private key for establishing a new RPC session
  - Secrettoken: Cleartoken encrypted with key known only to vice
    + Encryption is different from the HKC
    + Unique for this login session (just a bitstream)
    + Use as ephemeral client-id for this login session
    + Only vice knows how to decrypt
  - Venus throws away clear and secret tokens at the end of the session
  - Bind mechanism is at the core of the Andrew file system
    + Used for establishing secure communication
* RPC Session Establishment
  - After a user logs in, Venus establishes an RPC session on behalf of
  the client (bind client-server)
  - Client sends:
    + clientID, E[Xr,HKC]

        + Xr is a random number for each RPC
        + HKC is extracted from the cleartoken
    - Server sends:
        + E[(Xr+1,Yr),HKS] (HKC = HKS by design)
        + Xr+1 establishes that the server is genuine
        + Xr is encrpyted, so this authenticates the server and prevents replay attacks
        + Yr is another random number generated by the server
    - Client sends:
        + E[Yr+1,HKC]
        + Server checks if the value == Yr+1 to establish that the client is genuine and prevents replay attacks
    - Server only uses HKC for establishing a login session
        + Within an RPC session, a client may make many calls (open, read, write, close, etc)
        + After the server validates the ID of the client, it creates a session key (SK) and sends it to the client
    - Server sends:
        + E[(SK,num),HKS]
        + Client can extract the SK using its own HKC and use it for the duration of the session
        + num is the starting sequence number for RPC session (safeguard against replay attacks)
        + Use SK as handshake key for the rest of RPC session with server
* Sequence Establishment
    - The sequence client(Xr) -> server(Xr+1) -> client establishes that the server is genuine
    - The sequence server(Yr) -> client(Yr+1) -> server establishes that the client is genuine
* Login is a Special Case of Bind
    - Client/server validation is identical for login and bind
    - Password used as HKC
    - Username used for clientID
    - Get back two tokens
        + Secrettoken (encrypted with password)
        + Cleartoken (encrypted with password)
    - Tokens kept by Venus for this login session
* Putting it All Together
    - Login using username and password
    - Vice sends secret and clear tokens (1)
    - Venus establishes an RPC session on behalf of the client using secret token and HKC
    - Vice sends session key for this particular RPC session (2)
    - Venus uses secret token and session key to make file system calls (3)
    - Upshots:
        + username, password are only exposed once per login session
        + HKC used only for new RPC session establishment
        + SK used for all RPC calls to file system (valid for duration of RPC session)
* AFS Security Report Card
    - Mutual suspicion: Yes
        - Protection from fellow users
    - Protection from system for users: No
        + Users must trust system, so no protection

    - Confinement of resource usage: No
        + User can make many calls on server and consume bandwidth (DoS)
    - Authentication: Yes
        + Validation of client-server
    - Server integrity: No
        + Servers are within a firewall, so if somebody penetrated this, they could wreak havoc
        + Must physically and socially protect servers
* Security in Andrew Conclusion
    - Main takeaway: How do OS designers make the best decisions for information security to make a secure and usable distributed system?
        + Able to compare against the principles outlined by SALSA
    - Introduces notion of audit chain for system administrators modifying the system
    - Access lists for files with positive and negative rights