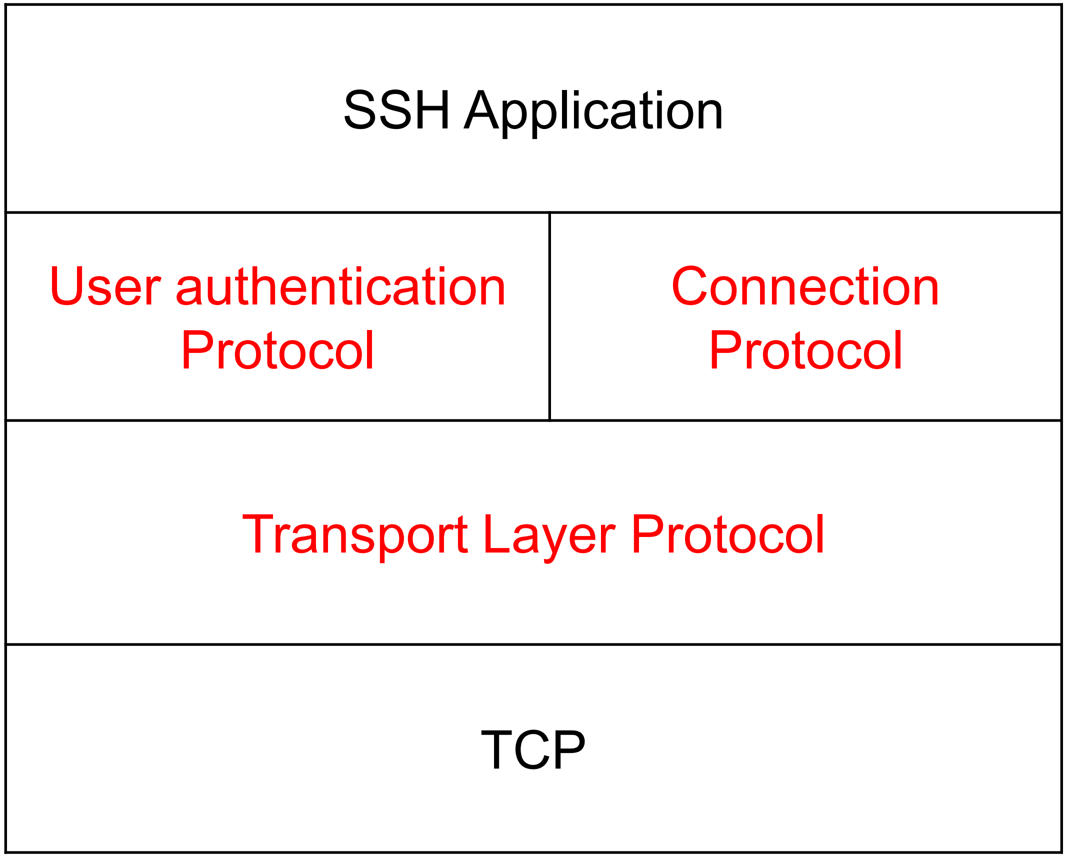
SSH: Secure Shell

- Readings
  - RFC 4251- RFC 4254
  - Manual page of ssh command

What is SSH?

- SSH – Secure Shell
  - Program vs. company vs. protocol
  - Will concentrate on SSH-2 protocol
- SSH is a protocol for secure remote login and other secure network services over an insecure network
  - Replacement for telnet, rsh, rlogin, etc
- Developed by SSH Communications, Finland
- Specified in a set of Internet drafts
- Two distributions are available:
  - Commercial version
  - Freeware (www.openssh.com)

SSH Layers



SSH Application

User authentication Protocol

Connection Protocol

Transport Layer Protocol

TCP

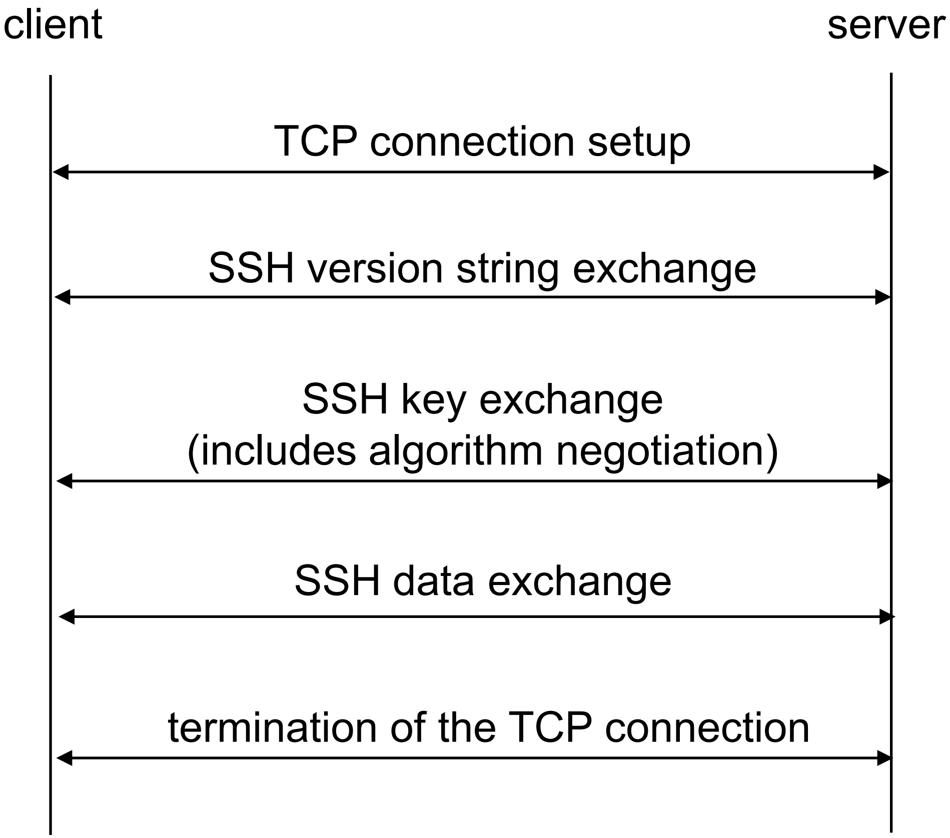
Major SSH Components

- SSH Transport Layer Protocol
  - Provides server authentication, confidentiality, and integrity services
  - May provide compression too
  - Runs on top of any reliable transport layer (e.g., TCP)
- SSH User Authentication Protocol
  - Provides client-side user authentication
  - Runs on top of the SSH Transport Layer Protocol
- SSH Connection Protocol
  - Multiplexes multiple logical channels into secure tunnel provided by Transport Layer and User Authentication Protocols
  - Logical channels can be used for a wide range of purposes
    - Secure interactive shell sessions
    - Forwarding X11 connections
    - TCP port forwarding

SSH Security Features

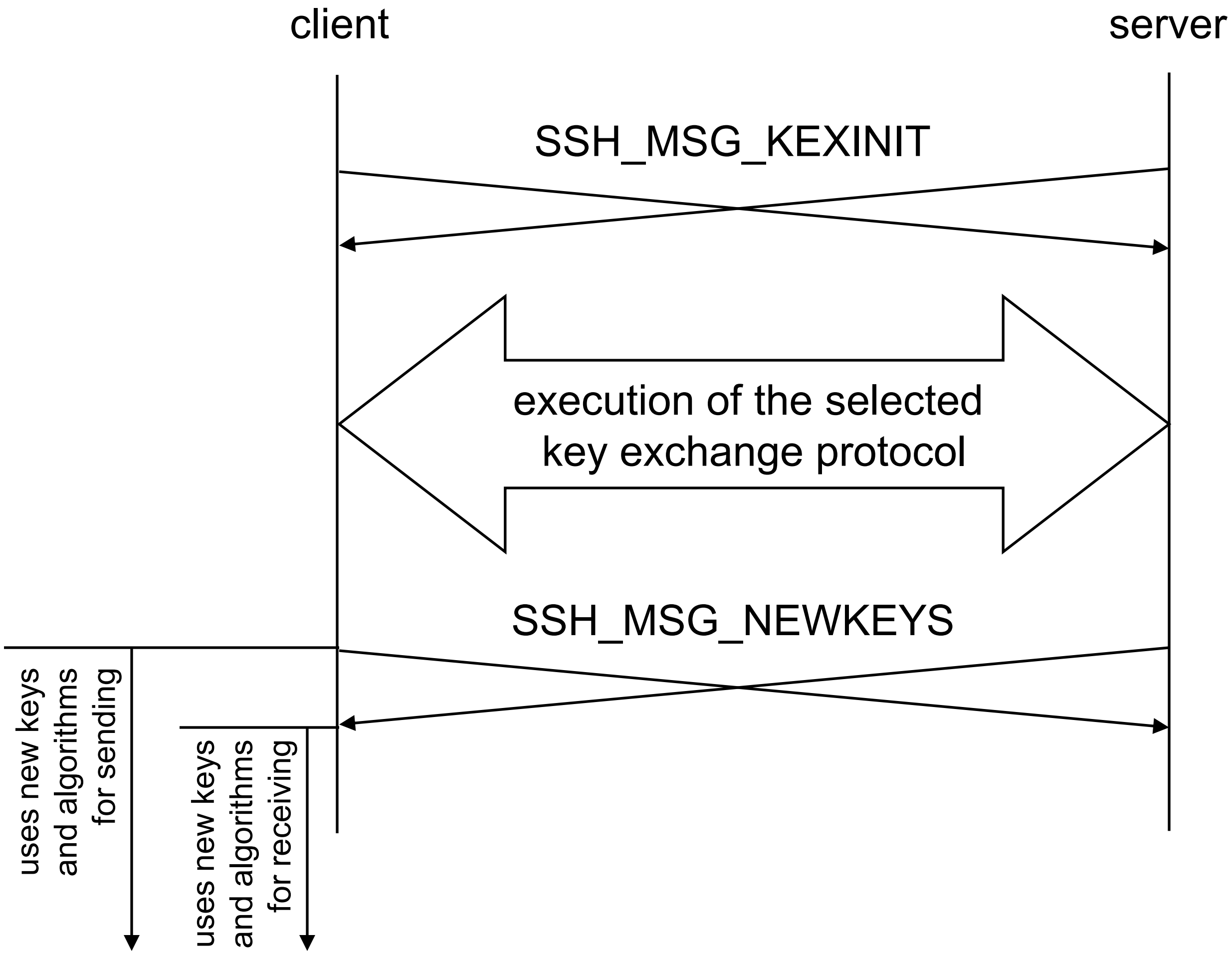
- Strong algorithms
  - Uses well established strong algorithms for encryption, integrity, key exchange, and public key management
- Large key size
  - Requires encryption to be used with at least 128 bit keys
  - Supports larger keys too
- Algorithm negotiation
  - Encryption, integrity, key exchange, and public key algorithms are negotiated
  - It is easy to switch to some other algorithm without modifying the base protocol

SSH Transport Layer Protocol – Overview



client
server
TCP connection setup
SSH version string exchange
SSH key exchange
(includes algorithm negotiation)
SSH data exchange
termination of the TCP connection

Key Exchange - Overview


client
server
SSH_MSG_KEXINIT
execution of the selected key exchange protocol
SSH_MSG_NEWKEYS
uses new keys and algorithms for sending
uses new keys and algorithms for receiving

Diffie-Hellman Key Exchange (with Explicit Server Authentication)

1.
   - Client generates a random number x and computes e = g^x mod p
   - Client sends e to the server
2.
   - Server generates a random number y and computes f = g^y mod p
   - Server receives e from the client
   - It computes K = e^y mod p = g^{xy} mod p and H = HASH(client version string | server version string | client kex init msg | server kex init msg | server host key K_{srv} | e | f | K)
   - It generates a signature s on H using the private part of the server host key (may involve additional hash computation on H)
   - It sends (K_{srv} | f | s) to the client
3.
   - Client verifies that K_{srv} is really the host key of the server
   - Client computes K = f^x mod p = g^{xy} mod p and the exchange hash H
   - Client verifies the signature s on H

Deriving Keys and IVs

- Any key exchange algorithm produces two values
  - a shared secret K
  - an exchange hash value H
- H from the first key exchange is used as the session ID
- Keys and IVs are derived from K and H as follows:
  - IV client to server = HASH(K | H | “A” | session ID)
  - IV server to client = HASH(K | H | “B” | session ID)
  - encryption key client to server = HASH(K | H | “C” | session ID)
  - encryption key server to client = HASH(K | H | “D” | session ID)
  - MAC key client to server = HASH(K | H | “E” | session ID)
  - MAC key server to client = HASH(K | H | “F” | session ID)

Server Authentication

- Based on the server's host key K_{srv}
- Client must check K_{srv} is really host key of server
- Models
  - Client has a local database that associates each host name with the corresponding public host key
  - Host name – to – key association is certified by a trusted CA and server provides the necessary certificates or client obtains them from elsewhere
  - Check fingerprint of key over an external channel (e.g., phone)
  - Best effort:
    - accept host key without check when connecting first time to server
    - save the host key in the local database, and
    - check against the saved key on all future connections to the same server

Key Re-Exchange

- It is recommended to change keys after each gigabyte of transmitted data or after each hour of connection time
- key re-exchange is processed identically to the initial key exchange
  - except for the session ID, which will remain unchanged
  - algorithms may be changed
  - keys and IVs are recomputed

Service Request

- After key exchange the client requests a service
- Services
  - ssh-userauth
  - ssh-connection
- When the service starts, it has access to the session ID established during the first key exchange

SSH – User Authentication Protocol

- Protocol assumes that the underlying transport protocol provides integrity and confidentiality (e.g., SSH Transport Layer Protocol)
  - Protocol has access to the session ID
- Three authentication methods are supported
  - publickey
  - password
  - hostbased

The “publickey” Method

- All implementations must support this method
- However, most local policies will not require authentication with this method in the near future, as users don’t have public keys
- Authentication is based on demonstration of the knowledge of the private key (the client signs with the private key)
- Server verifies that
  - the public key really belongs to the user specified in the authentication request
  - the signature is correct

The “password” Method

- All implementations should support this method
  - User account
  - password
- This method is likely the most widely used

The “hostbased” Method

- Authentication is based on the host where the user is coming from
  - This method is optional
- Client sends a signature that has been generated with the private host key of the client
- Server verifies that
  - The public key really belongs to the host specified in the authentication request
  - The signature is correct

Hostbased: Try the Following

- To access or run command on remote machine without typing password.
- Remote ssh from machine A to machine B

  Step 1: at machine A: ssh-keygen –t rsa

  (do not enter any pass phrase, just keep typing "enter")

  Step 2: append A:.ssh/id_rsa.pub to B:.ssh/authorized_keys
- After these steps, (without typing password)
  - You should be able to access remote machine
    - On machine A: ssh user@B
  - you should be able to run remote command.
    - On machine A: ssh user@B "command"
- We do not recommend this
  - Breaking into one machine, breaking into all machines

SSH – Connection Protocol

- Provides
  - interactive login sessions
  - remote execution of commands
  - forwarded TCP/IP connections
  - forwarded X11 connections
- All these applications are implemented as “channels”
- All channels are multiplexed into the single encrypted tunnel provided by the SSH Transport Layer Protocol
- Channels are identified by channel numbers at both ends of the connection
  - Channel numbers for the same channel at the client and server sides may differ

SSH Port Forwarding or Tunneling

- Frequently as an alternative to a full-fledged VPN
  - A (non-secure) TCP/IP connection of an external application is redirected to the SSH program (client or server)
    - Forwards it to the other SSH party (server or client)
    - In turn forwards the connection to the desired destination host
- Forwarded connection is encrypted and protected on the path between the SSH client and server only
- Primarily useful for tunneling connections through firewalls
  - Ordinarily block that type of connection
  - Encrypting protocols which are not normally encrypted (e.g. VNC).

TCP/IP Port Forwarding Example

- Real server on remote machine
  - I want to listen on port 5110 on this machine; all packets arriving here get sent to mailserver, port 110:
  - ssh –L 5110:mailserver:110 mailserver

- Real server on this machine
  - All web traffic to my firewall should be redirected to the web server running on port 8000 on my machine instead:
  - ssh –R 80:MyMachine:8000 firewall

X Windows Forwarding

- No setup – already done!
- Run the X Windows application in the terminal window:
  - xclock &
  - The screen display shows up on your computer, and any keystrokes and mouse movements are sent back, all encrypted.

SSL/TLS vs. SSH

- Developed around the same time (mid 90s)
- SSH Transport Layer Protocol roughly equivalent to SSL/TLS
  - SSH could have been implemented using SSL/TLS
- They do have different origins and targeted applications
- SSL/TLS, developed by Netscape for web application
  - Authenticating server is critical
- SSH targets to replace plaintext remote login
  - Authenticating both server and client is critical

Reading Assignment

- Reviewing for final exam