An introduction to SSH

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Administration de systèmes, réseaux et applications à base de logiciels libres

Outline

1. SSH basics
   - SSH 101
   - Public-key authentication
   - Checking the server's identity
   - Configuring SSH
2. Advanced usage
   - SSH as a communication layer for applications
   - Access remote filesystems over SSH: sshfs
   - SSH tunnels, X11 forwarding, and SOCKS proxy
   - VPN over SSH
   - Jumping through hosts
   - Triggering remote command execution securely
   - Escape sequences
   - Related tools
3. Conclusions

Introduction

- SSH = Secure SHell
- Standard network protocol and service (TCP port 22)
- Many implementations, including:
  - OpenSSH: Linux/Unix, Mac OS X ← this talk, mostly
  - Putty, MobaXterm: Windows, client only
  - Dropbear: small systems (routers, embedded)
- Unix command (`ssh`); server-side: `sshd`
- Establish a secure communication channel between two machines
- Relies on cryptography
- Most basic usage: get shell access on a remote machine
- Many advanced usages:
  - Data transfer (`scp`, `sftp`, `rsync`)
  - Connect to specific services (such as Git or SVN servers)
  - Dig secure tunnels through the public Internet
- Several authentication schemes: password, public key

Basic usage

- Connecting to a remote server:
  ```
  $ ssh login@remote-server
  ```
  $\rightsquigarrow$ Provides a shell on *remote-server*
- Executing a command on a remote server:
  ```
  $ ssh login@remote-server ls /etc
  ```
- Copying data (with `scp`, similar to `cp`):
  ```
  $ scp local-file login@remote-serv:remote-directory/
  $ scp login@remote-serv:remote-dir/file local-dir/
  ```
  Usual `cp` options work, e.g. `-r` (recursive)
- Copying data (with `rsync`, more efficient than `scp` with many files):
  ```
  $ rsync -avzP localdir login@server:path-to-rem-dir/
  ```
  Note: trailing slash on source matters with `rsync` (not with `cp`)
  - `rsync -a dir1 u@h:dir2` $\rightsquigarrow$ dir1 copied inside dir2
  - `rsync -a dir1/ u@h:dir2` $\rightsquigarrow$ content of dir1 copied to dir2

Public-key authentication

- General idea:
  - Asymmetric cryptography (or public-key cryptography):
    - The public key is used to encrypt something
    - Only the private key can decrypt it
  - User owns a private (secret) key, stored on the local machine
  - The server has the public key corresponding to the private key
  - Authentication = *<server> prove that you own that private key!*
- Implementation (*challenge-response authentication*):
  1. Server generates a nonce (random value)
  2. Server encrypts the nonce with the Client's public key
  3. Server sends the encrypted nonce (= the challenge) to client
  4. Client uses the private key to decrypt the challenge
  5. Client sends the nonce (= the response) to the Server
  6. Server compares the nonce with the response

Public-key authentication (2)

- Advantages:
  - The password does not need to be sent over the network
  - The private key never leaves the client
  - The same key can be used for many servers
  - The process can be automated
- However, the private key should be protected (what if your laptop gets stolen?)
  - Usually with a passphrase

Key-pair generation

```
$ ssh-keygen
Generating public/private rsa key pair.
Enter file in which to save the key (/home/user/.ssh/id_rsa): [ENTER]
Enter passphrase (empty for no passphrase): passphrase
Enter same passphrase again: passphrase
Your identification has been saved in /home/user/.ssh/id_rsa.
Your public key has been saved in /home/user/.ssh/id_rsa.pub.
The key fingerprint is:
f6:35:53:71:2f:ff:00:73:59:78:ca:2c:7c:ff:89:7b user@my.hostname.net
The key's randomart image is:
+--[ RSA 2048]----+
 ..o
(...)
 .o
+-----------------+
$
```

- Creates the key-pair:
  - `~/.ssh/id_rsa` (private key)
  - `~/.ssh/id_rsa.pub` (public key)

Copying the public key to the server

- Example public key:
  `ssh-rsa AAAAB3NX[. . . ]hpoR3/PLlXgGcZS4oR user@my.hostname.net`
- On the server, **~user/.ssh/authorized_keys** contains the list of public keys authorized to connect to the `user` account
- The key can be copied manually there
- Or use `ssh-copy-id` to automatically copy the key:
  ```
  client$ ssh-copy-id user@server
  ```
- Sometimes the public key needs to be provided using a web interface (e.g. on GitHub, FusionForge, Redmine, etc.)

Avoiding typing the passphrase

- If the private key is not protected with a passphrase, the connection is established immediately:

```
*** login@laptop:~$ ssh rlogin@rhost  [ENTER]
*** rlogin@rhost:~$
```

- Otherwise, `ssh` asks for the passphrase:

```
*** login@laptop:~$ ssh rlogin@rhost  [ENTER]
Enter passphrase for key '/home/login/id_rsa': [passphrase+ENTER]
*** rlogin@rhost:~$
```

- An **SSH agent** can be used to store the decrypted private key
  - Most desktop environments act as SSH agents automatically
  - One can be started with `ssh-agent` if needed
  - Add keys manually with `ssh-add`

Checking the server identity: `known_hosts`

- Goal: detect hijacked servers
  What if someone replaced the server to steal passwords?
- When you connect to a server for the first time, `ssh` stores the server's public key in `~/.ssh/known_hosts`

```
*** login@laptop:~$ ssh rlogin@server [ENTER]
The authenticity of host 'server (10.1.6.2)' can't be established.
RSA key fingerprint is
94:48:62:18:4b:37:d2:96:67:c9:7f:2f:af:2e:54:a5.
Are you sure you want to continue connecting (yes/no)? yes [ENTER]
Warning: Permanently added 'server,10.1.6.2'(RSA) to the list of
known hosts.
rlogin@server's password:
```

Checking the server identity: known_hosts (2)

- During each following connection, ssh ensures that the key still matches, and warns the user otherwise

```
*** login@laptop:~$ ssh rlogin@server [ENTER]
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that a host key has just been changed.
The fingerprint for the RSA key sent by the remote host is
e3:94:03:90:5d:81:ed:bb:d5:d2:f2:de:ba:31:18:d8.
Please contact your system administrator.
Add correct host key in /home/login/.ssh/known_hosts to get rid of this message.
Offending RSA key in /home/login/.ssh/known_hosts:12
RSA host key for server has changed and you have requested strict checking.
Host key verification failed.
*** login@laptop:~$
```

- A truly outdated key can be removed with
  `ssh-keygen -R server`

Configuring SSH

- SSH gets configuration data from:
  1. command-line options (`-o ...`)
  2. the user's configuration file: `~/.ssh/config`
  3. the system-wide configuration file: `/etc/ssh/ssh_config`
- Options are documented in the `ssh_config(5)` man page
- `~/.ssh/config` contains a list of hosts (with wildcards)
- For each parameter, the first obtained value is used
  - Host-specific declarations are given near the beginning
  - General defaults at the end

Example: ~/.ssh/config

```
Host mail.acme.com
    User root

Host foo # alias/shortcut. 'ssh foo' works
    Hostname very-long-hostname.acme.net
    Port 2222

Host *.acme.com
    User jdoe
    Compression yes # default is no
    PasswordAuthentication no # only use public key
    ServerAliveInterval 60 # keep-alives for bad firewall

Host *
    User john
```

- Note: `bash-completion` can auto-complete using `ssh_config` hosts

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SSH as a communication layer for applications

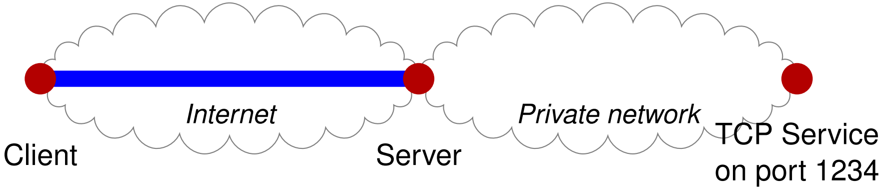
- Several applications use SSH as their communication (and authentication) layer
- `scp`, `sftp`, `rsync` (data transfer)
  - `lftp` (CLI) and `gftp` (GUI) support the SFTP protocol
- `unison` (synchronization)
- Subversion: `svn checkout svn+ssh://user@rhost/path/to/repo`
- Git: `git clone ssh://git@github.com/path-to/repository.git`
  Or: `git clone git@github.com:path-to/repository.git`

Access remote filesystems over SSH: sshfs

- `sshfs`: FUSE-based solution to access remote machines
- Ideal for remote file editing with a GUI, copying small amounts of data, etc.
- Mount a remote directory:
  ```
  sshfs root@server:/etc /tmp/local-mountpoint
  ```
  Unmount: `fusermount -u /tmp/local-mountpoint`
- Combine with `afuse` to auto-mount any machine:
  ```
  afuse -o mount_template="sshfs %r:/ %m" -o \
  unmount_template="fusermount -u -z %m" ~/.sshfs/
  ```
  $\leadsto$ `cd ~/.sshfs/rhost/etc/ssh`

SSH tunnels with -L and -R

- Goal: transport traffic through a secure connection
  - Work-around network filtering (firewalls)
  - Avoid sending unencrypted data on the Internet
  - But only works for TCP connections
- **-L**: access a remote service behind a firewall (Intranet server)
  - `ssh -L 12345:service:1234 server`
  - Still on *Client*: `telnet localhost 12345`
  - *Server* establishes a TCP connection to *Service*, port 1234
  - The traffic is tunnelled inside the SSH connection to *Server*



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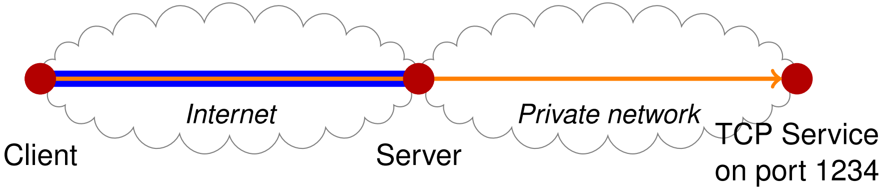
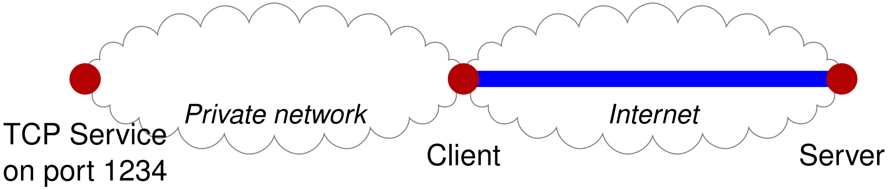


SSH tunnels with -L and -R

- **-R**: provide remote access to a local private service
  - `ssh -R 12345:service:1234 server`
  - On *Server*: `telnet localhost 12345`
  - *Client* establishes a TCP connection to *Service*, port 1234
  - The traffic is tunnelled inside the SSH connection to *Client*



- Notes:
  - SSH tunnels don't work very well for HTTP, because IP+port are not enough to identify a website (`Host:` HTTP header)
  - By default, tunnels are only bound to localhost. Use `-g` (gateway) to allow remote hosts to connect to local forwarded ports

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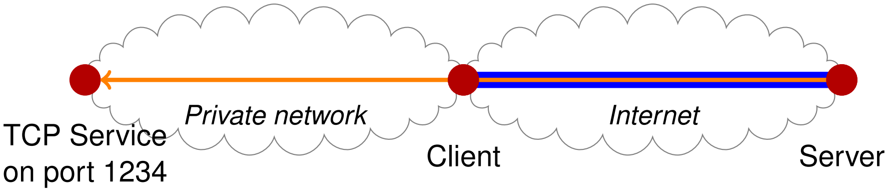

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X11 forwarding with -X: GUI apps over SSH

- Run a graphical application on a remote machine, display locally
- Similar to VNC, but on a per-application basis
- `ssh -X server`
- `$DISPLAY` will be set by SSH on the server:
  ```
  $ echo $DISPLAY
  localhost:10.0
  ```
- Then start GUI applications on server (e.g. `xeyes`)
- Troubleshooting:
  - `xauth` must be installed on the remote machine
  - The local Xorg server must allow TCP connections
    - `pgrep -a Xorg` $\leadsto$ `-nolisten` must not be included
    - Can be configured in your login manager
  - Does not work very well over slow or high-latency connections

SOCKS proxy with -D

- SOCKS: protocol to proxy TCP connections via a remote machine
- SSH can act as a SOCKS server: `ssh -D 1080 server`
- Use case similar to tunnelling with -L, but more flexible
  - Set up the proxy once, use for multiple connections
- Usage:
  - Manual: configure applications to use the SOCKS proxy
  - Transparent: use `tsocks` to re-route connections via SOCKS

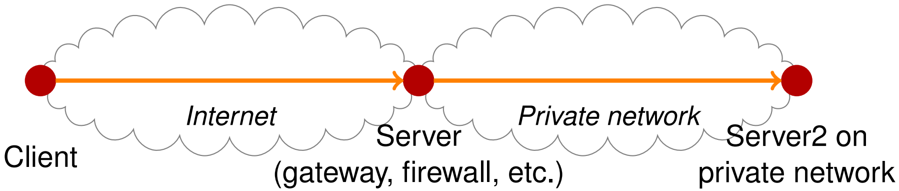
```
$ cat /etc/tsocks.conf
server = 127.0.0.1
server_type = 5
server_port = 1080 # then start ssh with -D 1080
$ tsocks pidgin # tunnel application through socks
```

  - Another transparent proxifier is `redsocks` (uses `iptables` rules to redirect to a local daemon instead of `LD_PRELOAD`)

VPN over SSH

- Built-in support for tun-based VPN
  - `PermitTunnel yes` required on server (disabled by default)
  - `ssh -w 0:0 root@server` (0, 0 are the tun device numbers)
  - Then configure IP addresses and routing on both sides
- `sshuttle`: another VPN over SSH solution
  - Root access not required on the server side
  - Idea similar to `slirp`
  - Uses `iptables` rules to redirect traffic to VPN
  - (as root:) `sshuttle -r user@server 0/0 -vv`
  - Limitation: does not support tunnelling UDP or ICMP traffic

Jumping through hosts with ProxyCommand



- Problem: to connect to Server2, you need to connect to Server
  - Can you do that in a single step? (required for data transfer, tunnels, X11 forwarding)
- Combines two SSH features:
  - `ProxyCommand` option: command used to connect to host; connection available on standard input & output
  - `ssh -W host:port` $\leadsto$ establish a TCP connection, provide it on standard input & output (suitable for `ProxyCommand`)

Jumping through hosts with ProxyCommand (2)

- Example configuration:

```
Host server2 # ssh server2 works
    ProxyCommand ssh -W server2:22 server
```

- Also works with wildcards

```
Host *.priv # ssh host1.priv works
    ProxyCommand ssh -W $(basename %h .priv):%p server
```

- `-W` only available since OpenSSH 5.4 (circa 2010), but the same can be achieved with `netcat`:

```
Host *.priv
    ProxyCommand ssh serv nc -q 0 $(basename %h .priv) %p
```

- More generic version: `https://glandium.org/blog/?p=3631`
- Similar solution to connect via a proxy:
  - SOCKS: `connect-proxy -4 -S myproxy:1080 rhost 22`
  - HTTP (with CONNECT): `corkscrew myproxy 1080 rhost 22`
  - When CONNECT requests are forbidden, set up `httptunnel` on a remote server, and use `htc` and `hts`

Jumping through hosts with ProxyJump

- Available since OpenSSH 7.3
- A simpler way to write ProxyCommand configuration:

```
Host server2 # ssh server2 works
    ProxyJump server
```

- Or on the command line:

```
ssh -J server server2
```

Triggering remote command execution securely

- Goal: notify Server2 that something finished on Server1
  - But Server1 must not have full shell access on Server2
- Method: limit to a single command in `authorized_keys`
  - Also known as SSH triggers
- Example `authorized_keys` on Server2:

```
from="server1.acme.com",command="tar czf - /home",no-pty,
no-port-forwarding ssh-rsa AAAA[...]oR user@my.host.net
```

Escape sequences

- Goal: interact with an already established SSH connection
  - Add tunnels or SOCKS proxy, kill unresponsive connection
- Escape sequences start with '~', at the beginning of a line
  - So press `[enter]`, then `~`, then e.g. '?'
- Main sequences (others documented in `ssh(1)`):
  - `~.` – disconnect (for unresponsive connections)
  - `~?` – show the list of escape sequences
  - `~C` – open SSH command-line. e.g. `~C -D 1080`
  - `~&` – logout and background SSH while waiting for forwarded connections or X11 sessions to terminate

Related tools

- `screen` and `tmux`: provide virtual terminals on remote machines where you can start long-running commands, disconnect, and reconnect later
- `mosh`: SSH alternative suited for Wi-Fi, cellular and long distance links
- `autossh`: checks an SSH session every 10 minutes, and restart it if needed
  `autossh -t server 'screen -RD'`: maintain a screen session open despite network disconnections
- `concierge`: manage your SSH configuration using a template system
- `clustershell`: parallel SSH (execute the same command on several machines)

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Conclusions

- The Swiss-army knife of remote administration
- Very powerful tool, many useful features
- Practical session: test everything mentioned in this presentation
  1. `scp`, `rsync`
  2. Key-based authentication
  3. Using an SSH agent
  4. aliases in SSH configuration
  5. `sshfs`, `sftp`
  6. SSH tunnels
  7. X11 forwarding
  8. SOCKS proxy with `tsocks`
  9. Jumping through hosts
  10. Escape sequences
  11. ...