Exploring OpenSSH: Hands-On Workshop for Beginners

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Confidence 2024 Kraków

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William Robinet (Conostix S.A.) - 2024-05-27

About me

- Introduced to Open Source & Free Software around the end of the 90’s
- CompSci studies, work in IT at Conostix S.A. - AS197692
- ssldump improvements (build system, bug fixes, JSON output, IPv6 & ja3(s), …)
- asn1template: painless ASN.1 editing
- 🎸 🏃 🚵 🔭 ⏚

Before we begin

Workshop resources

Workshop repository: **https://github.com/wllm-rbnt/confidence-2024-openssh-workshop**

- HTML -> TODO tiny URLs
- PDF -> TODO tiny URLs

Slides are written in Markdown

Get the *PDF*/*HTML* or use *patat* to render the presentation

Go to release page **https://github.com/jaspervdj/patat/releases**

or

```
$ wget https://github.com/jaspervdj/patat/releases/download/v0.12.0.0/patat-v0.12.0.0-linux-x86_64.tar.gz
$ tar xzf patat-v0.12.0.0-linux-x86_64.tar.gz patat-v0.12.0.0-linux-x86_64/patat
$ patat-v0.12.0.0-linux-x86_64/patat confidence-2024-openssh-workshop.md
```

Labs Network Layout

```
┌─────────────────────┐          ┌──────────────────────────────────────────────┐
│ CONFidence 2024     │          │ Lab network                                  │
│                     │          │                                              │
│ ┌───────────────┐   │          │ ┌────────────┐          ┌──────────────────┐ │
│ │ local machine │   │<-------->│ │ lab-server │          │ internal-machine │ │
│ └───────────────┘   │"Internet"│ └────────────┘          └──────────────────┘ │
│                     │          │  Pub 172.18.0.2                              │
│                     │          │  Priv 172.19.0.2 <-LAN-> Priv 172.19.0.3     │
└─────────────────────┘          └──────────────────────────────────────────────┘
```

- *local machine* is your personal laptop or VM. It is located “somewhere on the Internet” It is able to reach *lab-server* on TCP port 22 (on 172.18.0.2)
- *Lab network* is a remote private LAN (172.19.0.0/16 in this case)
- On this remote LAN, *lab-server* is privately known as 172.19.0.2.
- *lab-server* is connected to another machine named *internal-machine* (172.19.0.3)

Usernames and Passwords

2 users exist on each VM: *root* and *user*.

Passwords are the same as usernames. *user* has sudo access on each machine.

Shell commands

Shell commands are prefixed by a prompt designating the machine on which the command shall be run:

```
(local)$ <local command>
(lab-server)$ <remote command on lab-server>
(internal-machine)$ <remote commandi on internal-machine>
```

IP addresses

- IP addresses are dynamically allocated when you execute `start_containers.sh`
- 3 IP addresses will appear during this workshop
    - lab-server_pub
    - lab-server_priv
    - internal-machine_priv

Labs Containers

- 2 containers will be used during this workshop, one for *lan-server* and a second for *internal-machine*
- Start containers with:

  ```
  (local)$ cd docker
  (local)$ ./start_containers.sh
  ```

- Stop containers with:

  ```
  (local)$ cd docker
  (local)$ ./stop_containers.sh
  ```

- Cleanup the whole docker setup: **WARNING this will remove all containers, images and networks from your local setup**

  ```
  (local)$ cd docker
  (local)$ ./docker_cleanup.sh
  (local)$ sudo systemctl restart docker
  ```

Illustration: Telnet is not secure

- A *telnet* server is listening on *lab-server*, TCP port 23
- Start a traffic capture on TCP port 23 in another terminal:

  ```
  (local)$ sudo apt install wireshark
  (local)$ sudo wireshark
  ```

or

```
(local)$ sudo apt install tcpdump
(local)$ sudo tcpdump -n -i any -XXX tcp and port 23
```

- Then, in another shell, run the *telnet* client on your local machine:

  ```
  (local)$ sudo apt install telnet
  (local)$ telnet 172.18.0.2
  ```

- Login, *user* Password, *user*

Two main issues:

- Cleartext message exchange: vulnerable to traffic sniffing tcpdump/wireshark on traffic path (firewall, router)
- Insecure authentication: vulnerable to Man-In-The-Middle attack Ettercap (another machine on same LAN), proxy software on an intermediate router/firewall

Same goes for FTP, HTTP, SMTP, …

SSH History & Implementations

SSH stands for **S**ecure **SH**ell

Protocol Versions

- SSH-1.0 1995, by Tatu Ylönen, a researcher at Helsinki University of Technology
- SSH-2.0 2006, IETF Standardization RFC 4251-4256
- SSH-1.99 Retro-compatibility pseudo-version
- SSH3 Experimental implementation using HTTP/3 (QUIC)

Implementations

- OpenSSH on Unices, Client & server for GNU/Linux, *BSD, MacOS, …
- Dropbear, Lightweight implementation, for embedded-type Linux (or other Unices) systems
- On mobile: ConnectBot for Android, Termius for Apple iOS
- Terminal & File transfer clients for MS Windows: PuTTY, MobaXterm, WinSCP, FileZilla, …
- Network Appliances, OpenSSH or custom implementation

Focus on OpenSSH Tool suite

- Focus on the OpenSSH tool suite, a project started in 1999
- Clients & Server software
- This is the reference opensource version for many OSes
- It is based on modern cryptography algorithms and protocols
- It is widely available out-of-the-box
- It contains a wide range of tools (remote shell, file transfer, key management, …)
- Automation friendly (Ansible, or custom scripts)
- Main tools
  - *ssh* - Remote terminal access
  - *scp* - File transfer
  - *sftp* - FTP-like file transfer
- Helpers
  - *ssh-keygen* - Public/Private keypair generation
  - *ssh-copy-id* - Key deployment script
  - *ssh-agent* - Key management daemon (equivalent to PuTTY’s pageant.exe)
  - *ssh-add* - Key/Agent management tool

Documentation

Online manual pages

- Listing of **C**ommand **LI**ne man pages:

  ```
  $ man -k ssh
  ```

- Listing client's configuration options:

  ```
  $ man ssh_config
  ```

- Listing server's configuration options (the *openssh-server* package must be installed):

  ```
  $ man sshd_config
  ```

- CLI help, in your terminal, just type
  - `ssh` for the client
  - `/usr/sbin/sshd --help` for the server
  - `ssh-keygen --help` for the key management tool
  - …

First Login (1/2) - Commands, tcpdump & fingerprints

Syntax is: `ssh <username>@<host>`, where can be a hostname or an IP address

Username and password are the same as the one from the telnet example: - Username: *user* / Password: *user*

- Start a traffic capture on TCP port 22 in another terminal, traffic is **encrypted**:

  ```
  (local)$ sudo tcpdump -n -i docker0 -XXX tcp and port 22
  ```

TODO Retrieve the server keys fingerprints through a secure channel:

```
https://github.com/wllm-rbnt/confidence-2024-openssh-workshop/...
```

First Login (2/2) - Connection & host authentication

Type the following in a local terminal on your machine:

```
(local)$ ssh user@<lab-server_pub>
or
(local)$ ssh -o VisualHostKey=true user@<lab-server_pub>
The authenticity of host '172.18.0.2 (172.18.0.2)' can't be established.
ED25519 key fingerprint is SHA256:HFofTLfh2W/1IR3+g0sXGAcRs4ZnVsWwGKmbOzeMefk.
+--[ED25519 256]--+
|          . +B=*o|
|         o ooBX.o|
|        o oo=Oo=.|
|       + o..= o.*|
|      . S .o o o=|
|          o . o..|
|           = o   |
|          = *    |
|           + oE  |
+----[SHA256]-----+
This key is not known by any other names.
Are you sure you want to continue connecting (yes/no/[fingerprint])?
```

- Type *yes* to accept and go on with user authentication, or *no* to refuse and disconnect immediately
- or type the *fingerprint* you received from the secure channel If the fingerprint you entered matches the one that is printed, the system will proceed with user authentication

Known hosts fingerprint databases

Remote Host Authentication is performed only on first connection

`~/.ssh/known_hosts` is then populated with host reference and corresponding key fingerprint

`/etc/ssh/ssh_known_hosts` can be used as a system-wide database of know hosts

Hosts references can be stored as clear text (IP or hostname) or the corresponding hash (see *HashKnownHosts* option)

Host keys location on OpenSSH server

```
(lab-server)$ ls -l /etc/ssh/ssh_host\*pub
-rw------- 1 root root  513 May 23 12:39 /etc/ssh/ssh_host_ecdsa_key
-rw-r--r-- 1 root root  179 May 23 12:39 /etc/ssh/ssh_host_ecdsa_key.pub
-rw------- 1 root root  411 May 23 12:39 /etc/ssh/ssh_host_ed25519_key
-rw-r--r-- 1 root root   99 May 23 12:39 /etc/ssh/ssh_host_ed25519_key.pub
-rw------- 1 root root 2602 May 23 12:39 /etc/ssh/ssh_host_rsa_key
-rw-r--r-- 1 root root  571 May 23 12:39 /etc/ssh/ssh_host_rsa_key.pub
```

Computing fingerprints of host keys

```
(lab-server)$ for i in $(ls -1 /etc/ssh/ssh_host\*pub); do ssh-keygen -lf $i; done
256 SHA256:gbF30TEqv4ucpI3VFIEjq0dnrji5woxacnPe+N9mFX8 root@460a6cac3a3c (ECDSA)
256 SHA256:/hUAOroJsQzhM4f9qSZxcBLqEYqmoPi03pVX2fQUxrg root@460a6cac3a3c (ED25519)
3072 SHA256:D0gvg+2kFzvrLjqi0OEZ23tnQN3H/+oB3cqm0VZHWiQ root@460a6cac3a3c (RSA)
```

Note: use `ssh-keygen -lvf <public_key>` to generate the visual ASCII art representation of a key

Configuration (1/2)

Configuration files

Client:

- Per-user client configuration: `~/.ssh/config`
- System-wide client configuration: `/etc/ssh/ssh_config`
- System-wide local configuration: `/etc/ssh/ssh_config.d/*`

Server:

- Server configuration: `/etc/ssh/sshd_config`
- Server local configuration: `/etc/ssh/sshd_config.d/*`

Configuration options

- Client configuration options: `$ man ssh_config`
- Server configuration options: `$ man sshd_config`

Configuration (2/2) - Per host client configuration

Client configuration options can be specified per host

Example:

Type following in your local `~/.ssh/config`:

```
Host lab-server
    Hostname <lab-server_pub>
    User user
```

Tips: Printing the “would be applied” configuration

The `-G` parameter cause `ssh` to print the configuration that would be applied for a given connection (without actually connecting)

```
(local)$ ssh -G lab-server
```

The following command should output your username:

```
(local)$ ssh -G lab-server | grep user
user user
```

Tips

Increase verbosity

Launch ssh commands with -v parameter in order to increase verbosity, and help with debugging

Example:

```
(local)$ ssh -v user@<lab-server_pub>
OpenSSH_8.4p1 Debian-5+deb11u2, OpenSSL 1.1.1w  11 Sep 2023
debug1: Reading configuration data /home/user/.ssh/config
debug1: Reading configuration data /etc/ssh/ssh_config
[...]
```

Escape character

The escape character can be used to pass out-of-band commands to ssh client

- By default ~, must be at beginning of a line
- Repeat char in order to type it (~~)
- Commands:
    - Quitting current session ~.
    - List Forwarded connections ~#

Public Key Authentication

Main Authentication Methods

- *Password* authentication
- *Public/Private key* authentication
  - Used for password-less authentication (passphrase may be required to unlock private key)

Lab

- Generate a new key pair on your local system (with or without a passphrase):

  ```
  (local)$ ssh-keygen -f ~/.ssh/my-ssh-key
  ```

- Install your public key on the remote server:

  ```
  (local)$ ssh-copy-id -i ~/.ssh/my-ssh-key.pub user@<lab-server_pub>
  ```

  Note: `ssh-copy-id` copies the public key from `~/.ssh/authorized_keys` to the remote machine

- Login again with your new key pair:

  ```
  (local)$ ssh -i ~/.ssh/my-ssh-key user@<lab-server_pub>
  ```

- Reference your key pair in your personal local configuration file (`~/.ssh/config`):

  Host lab-server Hostname User user IdentityFile ~/.ssh/my-ssh-key

Authentication Agent

The Authentication Agent can hold access to private keys, thus eliminating the need to enter passphrase at each use

Start the agent:

```
(local)$ ssh-agent | tee ssh-agent-env.sh
SSH_AUTH_SOCK=/tmp/ssh-KwTcl7ZieUKD/agent.1193973; export SSH_AUTH_SOCK;
SSH_AGENT_PID=1193974; export SSH_AGENT_PID;
echo Agent pid 1193974;
(local)$ source ssh-agent-env.sh
Agent pid 1193974
```

Load private key to the agent:

```
(local)$ ssh-add ~/.ssh/my-ssh-key
Enter passphrase for /home/user/.ssh/my-ssh-key: ********
Identity added: my-ssh-key (user@local)
```

Connect to remote machine:

```
(local)$ ssh user@<lab-server_pub>
```

Going further, keychain can be used to manage ssh-agent & keys across logins sessions

Remote Command Execution

Simple command execution:

```
(local)$ ssh user@<lab-server_pub> hostname
```

With redirection to local file:

```
(local)$ ssh user@<lab-server_pub> hostname > hostname.txt
```

With redirection to remote file:

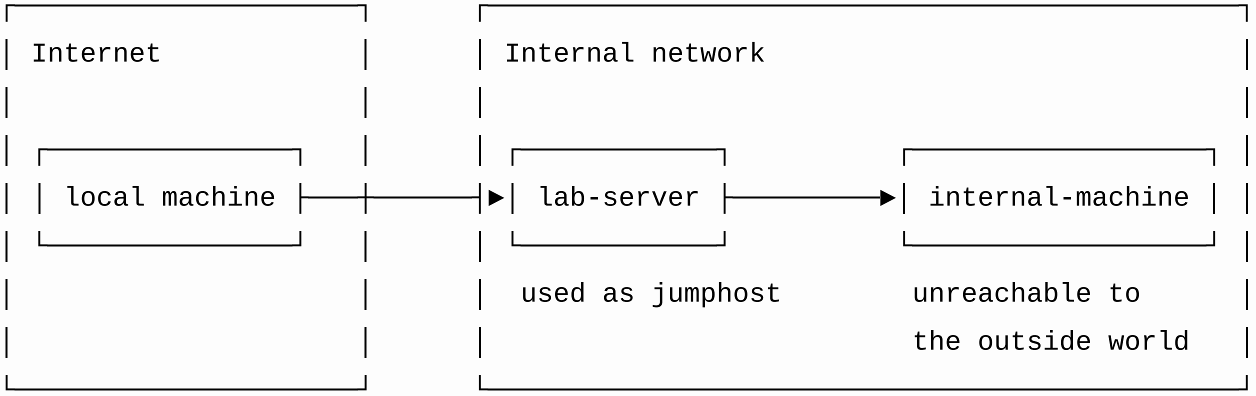
```
(local)$ ssh user@<lab-server_pub> "hostname > hostname.txt"
```

With pipes:

```
(local)$ echo blabla | ssh user@<lab-server_pub> "cat - | tr 'a-z' 'A-Z'"
```

Jumphost <-

A Jump Host is a machine used as a relay to reach another, otherwise possibly unreachable, machine. This unreachable machine is named internal-machine



Lab objective: Connect to internal-machine from your local machine via SSH with a single command

Setup:

- First, copy your public key to the remote server (lab-server):

  ```
  (local)$ scp .ssh/my-ssh-key.pub user@<lab-server_pub>:
  ```

- Login to the remote server then copy your public key to the destination machine:

  ```
  (local)$ ssh user@<lab-server_pub> (lab-server)$ ssh-copy-id -f -i my-ssh-key.pub <internal-machine_priv>
  ```

- Connect to the remote machine with a single command:

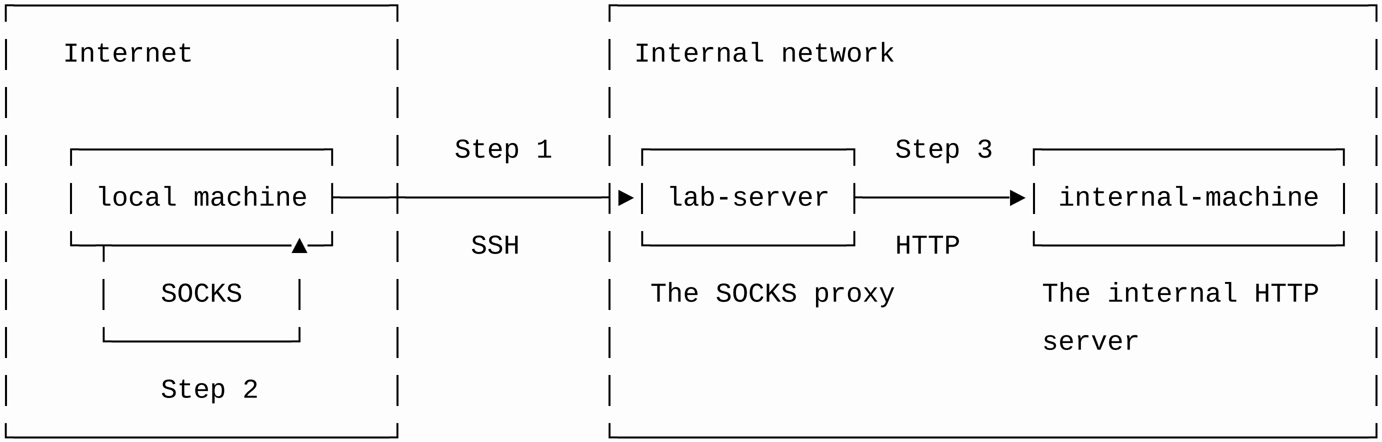
  ```
  (local)$ ssh -J user@<lab-server_pub> user@<internal-machine_prib>
  ```

TODO **Note**: *internal-machine* host key fingerprints available at https://github.com/wllm-rbnt/confidence-2024-openssh-workshop

SOCKS proxy (1/2)

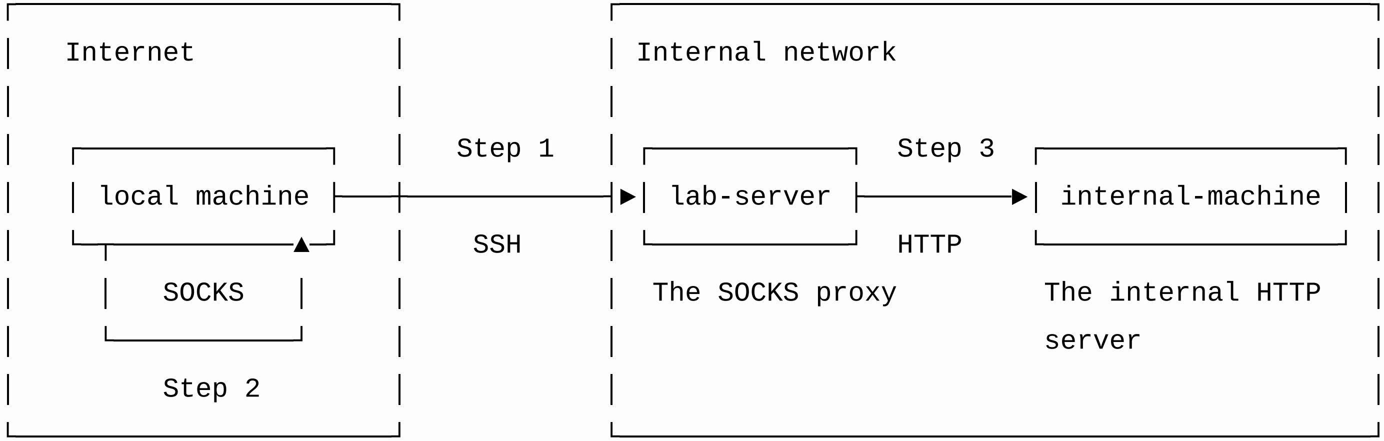
A *SOCKS server* proxies TCP connections to arbitrary IP addresses and ports

With SOCKS 5, DNS queries can be performed by the proxy on behalf of the client



Lab objective: Reach the internal HTTP server at http://secret-intranet (running on internal-machine) through a SOCKS proxy running on lab-server

SOCKS proxy (2/2)



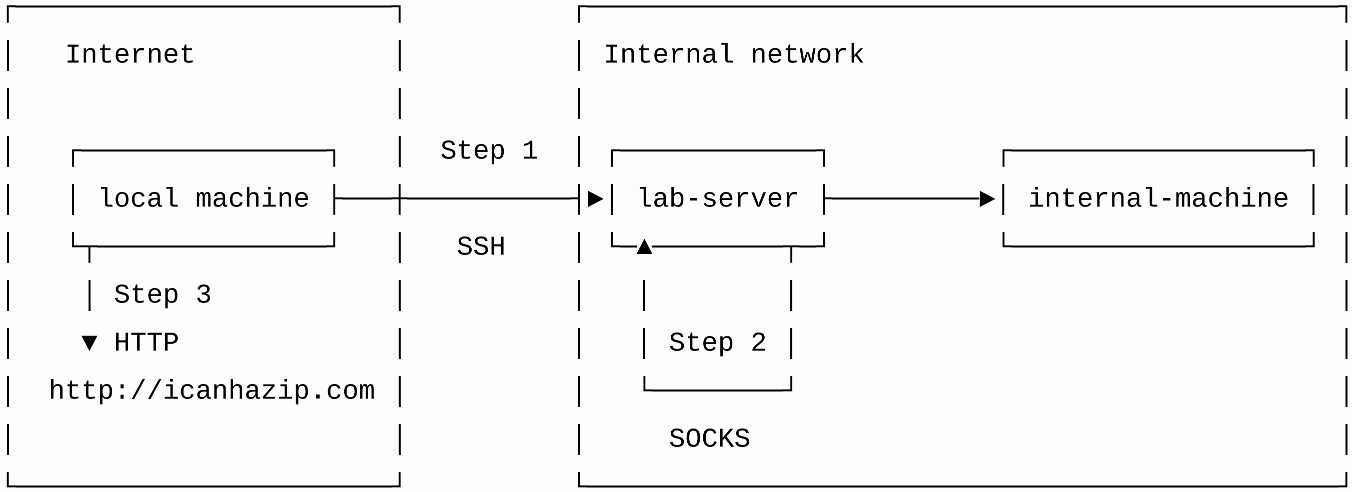
- Start a local SOCKS Proxy: `(local)$ ssh -D 1234 user@<lab-server_pub>` by establishing an SSH connection to lab-server with parameter `-D`
- Check, locally, for listening TCP port with `(local)$ ss -tpln | grep :1234`
- Configure your local browser to use local TCP port 1234 as a SOCKS proxy
- Configure your local browser to send DNS queries though the SOCKS proxy (tick the option in configuration)
- Point your browser to http://secret-intranet or Try it with curl:

```
(local)$ http_proxy=socks5h://127.0.0.1:1234 curl http://secret-intranet
Secret intranet server !
This is lab-server listening on 127.0.0.1 port 80.
```

- Bonus: look at your local traffic with *tcpdump*, you shouldn’t see any DNS exchanges

Reverse SOCKS proxy

A reverse SOCKS proxy setup allows a remote machine to use your local machine as a SOCKS proxy



Lab objective: Reach the external HTTP server at http://icanhazip.com from lab-server through a SOCKS proxy running on your local machine

Setup:

- Start a remote SOCKS Proxy: `(local)$ ssh -R 1234 user@<lab-server_pub>` by establishing an SSH connection to lab-server with parameter -R
- Check, on lab-server, for listening TCP port with `(lab-server)$ ss -tpln | grep :1234`
- Point your curl on lab-server to http://icanhazip.com though the SOCKS proxy listening on 127.0.0.1🔢

  ```
  (lab-server_pub)$ http_proxy=socks5h://127.0.0.1:1234 curl http://icanhazip.com
  <Confidence conference Internet access public IP address>
  ```

LocalForward

A *LocalForward* creates a locally listening TCP socket that is connected over SSH to a TCP port reachable in the network scope of a remote machine

Lab objective: Create and connect local listening TCP socket on port 8888 to TCP port 80 on 127.0.0.1 in the context of *lab-server*

Setup:

- Configure the forwarding while connecting to *lab-server* through SSH with -L parameter: (local)$ ssh -L 8888:127.0.0.1:80 user@

- -L parameter syntax:

```
<local_port>:<remote_IP>:<remote_port>
```

can be extended to

```
<local_IP>:<local_port>:<remote_IP>:<remote_port>
```

- SSH is now listening on TCP port 8888 on your local machine, check with: `(local)$ ss -tpln`

- Point your browser to http://127.0.0.1:8888 You should see something like:

  Hello world ! This is lab-server listening on 127.0.0.1 port 80.

RemoteForward

A *RemoteForward* creates a listening TCP socket on a remote machine that is connected over SSH to a TCP port reachable in the network scope of the local machine

Lab objective: Create a TCP socket on *lab-server* on port 8123 and connect it to a locally listening netcat on TCP port 1234

Setup:

- Start a listening service on localhost on your local machine on TCP port 1234: `(local)$ nc -l -p 1234 127.0.0.1`
- Check that it's listening with `ss`: `(local)$ ss -tpln | grep 1234`
- Configure the forwarding on TCP port 8123 while connecting to *lab-server* with `-R` parameter:

  ```
  ssh -R 8123:127.0.0.1:1234 user@<lab-server_pub>
  ```

- `ssh` is now listening on TCP port 8123 on *lab-server*

-R parameter syntax:

`<remote_port>:<local_IP>:<local_port>`

can be extended to

`<remote_IP>:<remote_port>:<local_IP>:<local_port>`

- Check its listening status on lab-server: `(lab-server)$ netstat -tpln | grep 8123`
- Connect to the forwarded service on remote machine on port 8123 with netcat: `(lab-server)$ nc 127.0.0.1 8123`
- Both netcat instances, local & remote, should be able to communicate with each other

Note: reverse proxy SOCKS is a special use case of `-R`

X11 Forwarding

Lab objective: Start a graphical application on *lab-server*, and get the visual feedback locally

Setup:

- Connect to lab-server with `-X` parameter: `(local)$ ssh -X user@<lab-server_pub>`
- Then, start a graphical application on the remote machine:

```
(lab-server)$ xmessage "This is a test !" &!
```

or

```
(lab-server)$ xcalc &!
```

- Check processes with `(lab-server|local)$ ps auxf` on *lab-server* and *local machine*

Note:

- On a Linux local client, the XOrg graphical server is used
- On a Windows machine use:
  - VcXsrv: https://sourceforge.net/~/vcxsrv/
  - or XMing: https://sourceforge.net/~/xming/

Connection to Legacy Systems (1/2)

Host key algorithm mismatch

“Unable to negotiate with 10.11.12.13 port 22: no matching host key type found. Their offer: ssh-rsa”

```
(local)$ ssh -o HostKeyAlgorithms=ssh-rsa <user>@<machine>
```

- Listing known host key algorithms: `(local)$ ssh -Q key`

Wrong key exchange algorithm

“Unable to negotiate with 10.11.12.13 port 22: no matching key exchange method found. Their offer: diffie-hellman-group-exchange-sha1”

```
(local)$ ssh -o KexAlgorithms=diffie-hellman-group1-sha1 <user>@<machine>
```

- Listing known key exchange algorithms: `(local)$ ssh -Q kex`

Connection to Legacy Systems (2/2)

Wrong cipher

“Unable to negotiate with 10.11.12.13 port 22: no matching cipher found. Their offer: aes128-cbc,3des-cbc,aes192-cbc,aes256-cbc”

```
(local)$ ssh -o Ciphers=aes256-cbc <user>@<machine>
```

- Listing known ciphers: `(local)$ ssh -Q cipher`

Wrong public key signature algorithm

“debug1: send_pubkey_test: no mutual signature algorithm” (with ssh -v)

```
$ ssh -o PubkeyAcceptedAlgorithms=ssh-rsa <user>@<machine>
```

- Listing known public key sig algorithm: `(local)$ ssh -Q key-sig` or `(local)$ ssh -Q PubkeyAcceptedAlgorithms`

SSH Tarpit

- The legitimate SSH server is running on port 22 on the remote server
- `endlessh`, a simple honeypot, is running on port 2222 on the remote server for demonstration purpose
- Try to connect to port 2222 with `ssh user@<lab-server_pub> -p 2222`
- Check both ports with `netcat`:

  ```
  (local)$ nc -nv 31.22.124.187 22
  (UNKNOWN) [31.22.124.187] 22 (ssh) open
  SSH-2.0-OpenSSH_9.2p1 Debian-2

  (local)$ nc -nv 31.22.124.187 2222
  (UNKNOWN) [31.22.124.187] 2222 (?) open
  XkZ?NK>-h5xs#/OSF
  SU6Jv
  6%n[;
  M5I'R8.W}wgE?"DhADl"jp"$x#4;Z
  wT%mJK_l5(Nf]Iw_
  $2'ZUmQ2YgdyXnI,
  \7_c.f4@bQHcY>N'y
  [...]
  ```

tmux - terminal multiplexer

tmux can be used to keep interactive shell tasks running while you’re disconnected

- Installation: `$ sudo apt install tmux`
- Create a tmux session: `$ tmux`
- List tmux sessions: `$ tmux ls`
- Attach to first session: `$ tmux a`
- Attach to session by index #: `$ tmux a -t 1`
- Commands inside a session:
  - `Ctrl-b d`: detach from session
  - `Ctrl-b c`: create new window
  - `Ctrl-b n` / `Ctrl-b p`: switch to next/previous window
  - `Ctrl-b %` / `Ctrl-b "`: split window vertically/horizontally
  - `Ctrl-b <arrow keys>`: move cursor across window panes
  - `Ctrl-[ + <arrow keys>`: browse current pane backlog, press return to quit
- Documentation: `$ man tmux`

References

- OpenSSH
- SSH History (Wikipedia)
- SSH Mastery by Michael W. Lucas
- SSH Mastery @BSDCAN 2012
- A Visual Guide to SSH Tunnels
- SSH Kung Fu
- The Hacker’s Choice SSH Tips & Tricks

Thanks for your attention