

## ssh

### Keys Generation

#### Basic SSH-Keys Generation

NIST's standard recommendations for ssh keys encryption algorithms

Encryption Algorithm	Key length	Key generation command
ECDSA, EdDSA, DH, MQV	f=224-255 (and above)	ssh-keygen -t ed25519
RSA	k=2048 (and above)	ssh-keygen -t rsa -b 4096

```
# generate keys using ed25519
ssh-keygen -t ed25519
```

```
# generate keys using rsa
ssh-keygen -t rsa -b 4096
```

```
# copying over keys to remote system
cat $HOME/.ssh/id_ed25519.pub | ssh USERNAME@remote.system.ip "cat >> $HOME/.ssh/authorized_keys"
# alternatively one would use the ssh-copy-id command
ssh-copy-id -i $HOME/.ssh/id_ed25519.pub USERNAME@remote.system.ip
```

A typical output of the process of keys' generation would look like this,

```
$ ssh-keygen -t ed25519
Generating public/private ed25519 key pair.
Enter file in which to save the key (/home/USERNAME/.ssh/id_ed25519): $HOME/.ssh/system1_id_ed25519
Enter passphrase (empty for no passphrase): *****
Enter same passphrase again: *****
Your identification has been saved in system1_id_ed25519.
Your public key has been saved in system1_id_ed25519.pub.
The key fingerprint is:
SHA256:VrKTrH2EX+52KoKVbtIcPnzRlf21jo0vZU/Wf4IysjI local.USERNAME@local.machine
The key's randomart image is:
+--[ED25519 256]--+
|
|
|      . .   o |
|      . *   o o|
|      S.....=|
|      +++..o. +=|
|      .O..o...Boo|
|      E @.=.o+oo+|
|      =.* =oooo.|
+-----[SHA256]-----+
```

The next step would be to transfer the public part of recently generated key to the remote system,

```
$ ssh-copy-id -i $HOME/.ssh/system1_id_ed25519.pub USERNAME@remote.system.ip
```

## Keys Management

```
# transfer/copy keys to remote system
```

```
ssh-copy-id -i $HOME/.ssh/id_ed25519.pub USERNAME@remote.system.ip
```

```
# use of an specific key to access clusterX
```

```
ssh -i $HOME/.ssh/USER_clusterX_ed25519 USERNAME@clusterX.IP.address
```

```
# use of an specific key to access clusterY
```

```
ssh -i $HOME/.ssh/USER_clusterY_ed25519 USERNAME@clusterY.IP.address
```

```
# use of an specific key for remote access to clusterZ
```

```
ssh -i $HOME/.ssh/USER_clusterZ_ed25519 USERNAME@clusterZ.IP.address
```

**Adding Comments to your keys** One useful feature offered by the key generation command is the capability to associate comments to key, so that they can be used to remind us what a given key is being used for. Comments can be added to the key when created using the `-C` flag. For instance,

```
# key generation with comments and specified location
```

```
ssh-keygen -t ed25519 -C "USER@laptop cluster-X" -f $HOME/.ssh/USER_clusterX_ed25519
```

in this case, both the comment and the name for the keys files is being specified by the respective `-C` and `-f` flags. If one would like to modify the comment of an existent key, the `-c` (lower-case “c”) flag can be used instead.

**Using ssh-agent to remember your keys** Keys are quite powerful, they can substantially improve security and efficiency at the moment of connecting to work in remote systems. One really useful feature to help with productivity is requesting an ssh-agent program to recall our keys/passphrases combinations, in this way when a key is used to connect to a given system the *ssh-agent* will remember the passphrase entered for a given period of time avoiding to repeatedly prompt for it. The way to trigger this feature is to use `ssh-add key-file`. It is also possible to specify a timeout period (lifetime) for how long to remember the passphrase, using the `-t` flag.

## Some additional ssh-agent commands

ssh-agent command	description
ssh-add -l	Lists fingerprints of all identities currently represented by the agent

ssh-agent command	description
<code>ssh-add -D</code>	Delete all identities from the agent
<code>ssh-add -t life</code>	Sets the maximum time the agent will keep the given key

**Customizing SSH keys names** It is possible to specify the name of the file where to store the keys when generating them. By default ssh will search for predefined file names, such as `id_ed25519` or `id_rsa`. But if we are using a different name, then we should indicate ssh which file we are using as keys. For doing so, we will use the `-i` flag followed by the location (which is also standardized under `$HOME/.ssh`) and the actual filename. E.g.

```
# ssh using specific key file
ssh -i $HOME/.ssh/USER_clusterX_ed25519 USERNAME@clusterX.IP.address
```

**Configuration Details** The preevious process can be simplified even a bit more, by adding some of theese details to the configuration file used by ssh. Such a configuration file resides in the `$HOME/.ssh/` directory and is named `config`. An example of an entry in this file is shown below,

### Single Host

```
HOST clusterX
    HostName clusterX.IP.address
    User USERNAME
    IdentityFile ~/.ssh/USER_clusterX_ed25519
```

**Multiple Hosts** One could even envision the possibility of including mutiple hosts by adding entries in the `~/.ssh/config` file.

```
HOST clusterX
    HostName clusterX.IP.address
    User USERNAMEonclusterX
    IdentityFile ~/.ssh/USER_clusterX_ed25519
```

```
HOST clusterY
    HostName clusterY.IP.address
    User USERNAMEonclusterY
    IdentityFile ~/.ssh/USER_clusterY_ed25519
```

```
HOST clusterZ
    HostName clusterZ.IP.address
    User USERNAMEonclusterZ
    IdentityFile ~/.ssh/USER_clusterZ_ed25519
```

in this way, the user would just use the commands `ssh clusterX` or `ssh clusterY` for connecting to any of the corresponding remote systems.

## Troubleshooting Keys Configurations

A couple of options to consider when finding troubles with the keys setup in a remote system can be generically considered.

Firstly, if for what ever reason the `ssh-copy-id` command is not found or available in the local system where the keys were generated, an alternative way to transfer the public key to the remote system could be achieved by using the following command,

```
cat $HOME/.ssh/id_ed25519.pub | ssh USERNAME@remote.system.ip "cat >> $HOME/.ssh/authorized_keys"
```

this assumes that the public key named `id_ed25519.pub` is located at `$HOME/.ssh/` directory and it will be placed in the `remote.system.ip` space of a user named `USERNAME`.

## Permission Attributes

Another issue that may arise when transferring the private keys, is related to an improper setup of the file permissions. The `$HOME/.ssh` directory must only be accessible by the owner, and the various key files must not be writable (or in some cases, readable) by anyone else. This is how the `$HOME/.ssh` directory should look like,

```
# look at ~/.ssh permissions
ls -ld $HOME/.ssh
```

```
drwx----- 2 USERNAME GROUPNAME 7 Aug  9 15:43 /home/USERNAME/.ssh
```

To fix improper set permissions, the following command may be used:

```
# fix permissions in ~/.ssh
chmod -R go= $HOME/.ssh/
```

## Debugging/Verbose Mode

Additionally, if we find problems when trying to `ssh` into a system which we either know the authentication procedure (either keys, password, or MFA) is not behaving or working as expected, we can use the following options when using the `ssh` command to obtain more verbose detail of the connections,

```
# -v activates the "verbose mode": resulting in printing debugging messages
# helpful in diagnosing connection, authentication, and configuration problems
# Multiple -v options increase the verbosity, the maximum is 3.
```

```
ssh -v USERNAME@remote.system.ip
```

```
ssh -vv USERNAME@remote.system.ip
ssh -vvv USERNAME@remote.system.ip
```

## Multiplexing: ControlMaster

Multiplexing is the ability to send more than one signal over a single line or connection. In OpenSSH, multiplexing can re-use an existing outgoing TCP connection for multiple concurrent SSH sessions to a remote SSH server, avoiding the overhead of creating a new TCP connection and **reauthenticating each time**.

ssh has an option called **ControlMaster** that enables the sharing of multiple sessions over one single network connection. This means that you can connect to the remote system once, enter your credentials, and have all other subsequent ssh sessions utilizing the initial connection without need for re-authentication. It is possible to establish this **ControlMaster** setup manually each time on the command line, but instead it's easiest to put it in the ssh client configuration file so that it applies every time that a connection is launched to the corresponding system.

```
HOST clusterX
  HostName clusterX.IP.address
  User USERNAMEonclusterX
  IdentityFile ~/.ssh/USER_clusterX_ed25519
  ControlMaster auto
  ControlPath ~/.ssh/controlmasters/%r@%h:%p
```

When ssh is instructed to use **ControlMaster**, it will look for the special file (a socket) in the `~/.ssh/controlmasters/` directory that is maintaining a connection to the cluster. If it already exists and is open, it'll use it to create a connection without re-authenticating; if it doesn't exist, it'll authenticate and create the file for subsequent use.

Note that all subsequent connections are dependent on the initial connection — if you exit or kill the initial connection all other ones die, too. This can obviously be annoying if it happens accidentally. It's easily avoided by setting up a master connection in the background:

```
ssh -CX -o ServerAliveInterval=30 -fN remoteServer
```

in this case the `-fN` flag puts the process in background and sit idle, after authenticating; `-C` is for using compression and `X` for X-forwarding, `ServerAliveInterval` is used to specify a time interval to keep the sessions open when inactive.

## Tunneling

*Tunneling* is a method for transporting data across a network using protocols that are not supported by that network. Tunneling works by *encapsulating*

packets, i.e. wrapping packets inside of other packets. There are many different ways of tunneling, for instance, VPN, ssh tunneling, etc.

In tunneling, or port forwarding, a local port is connected to a port on a remote host or vice versa. So connections to the port on one machine are in effect connections to a port on the other machine.

Typically the options `-f` (go to background), `-N` (do not execute a remote program) and `-T` (disable pseudo-tty allocation) can be useful for connections that are used only for creation of tunnels.

In regular port forwarding, connections to a local port are forwarded to a port on a remote machine. This is a way of **securing an insecure protocol or of making a remote service appear as local**.

```
ssh -L localPortNbr:localhost:remotePortNbr -l username remote.server.ip
```

In that way connections on the local machine made to the forwarded port will in effect be connecting to the remote machine.

An application of this is the usual utilization of ssh-tunnels to establish VNC connections to remote locations.

## Graphics Forwarding

Also known as X11 forwarding or just X-forwarding, is the ability to forward graphical output from the remote system to the local host connected via ssh. This sometimes can be handy and useful but in most of the cases could also be slow.

ssh offers two options to enable X-forwarding: `-X` and `-Y`, and this alternatives are related to security concerns.

From ssh's documentation (see <https://man.openbsd.org/ssh.1#X>):

- `-X`        Enables X11 forwarding. This can also be specified on a per-host basis in a configuration file.  
  
X11 forwarding should be enabled with caution. Users with the ability to bypass local restrictions can access the X11 connection to the remote host (for the user's X authorization database) can access the local X11 connection. An attacker may then be able to perform activities such as keystroke recording or window grabbing.  
  
For this reason, X11 forwarding is subjected to X11 SECURITY extension restrictions to the ssh `-Y` option and the `ForwardX11Trusted` directive in `ssh_config(5)` for more details.  
  
`-x`        Disables X11 forwarding.  
  
`-Y`        Enables trusted X11 forwarding. Trusted X11 forwardings are not subjected to the security extensions on X11.
-

## References

- ssh summary
- <https://en.wikibooks.org/wiki/OpenSSH>

---

*Last Modified: Oct. 12, 2022* – v 0.1

## Multi-Factor Authentication (MFA)

- Google Authenticator – <https://github.com/google/google-authenticator>
- DUO
- YubiKeys
- PrivacyIdea – <https://www.privacyidea.org/>

References: - <https://datatracker.ietf.org/doc/html/rfc6143>

*Last Modified: Oct. 12, 2022* – v 0.1 Although not extrictely linked to *remote computing* many different aspects in our day-to-day operations involve remote transferring of information, as well as, remote access, trust, etc. Among one of the most relevant tools and commodities employed nowadays is eletronic-mail, e-mail.

## Email

In the same way that it is important to validate the integrity and validity of our connections to remote systems, it would also be for other types of communications, such as electronic messages, or email. In particular, for *email* a tool called **Pretty Good Privacy** (PGP) can be used to ensure the confidentiality %of the messages exchanged, as well as validate the identity of the sender. PGP is an encryption method that provides cryptographic privacy and authentication for data communication. The basic idea is to encrypt the communication (similar to how using *ssh-keys* would do it) and sign it so that the message received at the other end of the communication channel can be decrypted, validated and authenticated.

### Refs.

- [https://en.wikipedia.org/wiki/Pretty\\_Good\\_Privacy](https://en.wikipedia.org/wiki/Pretty_Good_Privacy)

## Cyber-security Checklist

- In your *local system*:
  - ☐ use an anti-virus

- ☐ keep software up-to-date with the latest patches, including the ones for the Operating System (OS)
- ☐ be mindful of emails, malicious attachments and links:
  - ☐ do not enter sensitive data in unknown websites,
  - ☐ verify for https connections and SSL certificates
- ☐ do not plug any type of device of unknown origin or source, e.g. USB-devices, memory sticks, memory cards, etc.
- ☐ use a password manager, do not store passwords in plain-text and use a different password for each service
- ☐ encrypt sensitive data
- When connecting to *remote systems*:
  - ☐ use ssh keys, with passphrases
  - ☐ use MFA
  - ☐ use VPN
  - ☐ check the information provided by the remote system (usually at the moment of logging in), about when have you connected and from which locations
  - ☐ consider using “private browsing” and set restrictions on *cookies* policies in your web browser and when visiting websites with tracking and third party cookies

---

Cyber-security *checklist*: main elements to take into consideration to enhance the cyber-security in your local and remote work spaces.

---

*Last Modified: Oct. 10, 2022 – v 0.1*

Action	Description	Mitigation
keep software up-to-date	keep your devices updated with all software updates, including OS and applications	zero-day exploits, bugs, known vulnerabilities – mitigates the risk of the remote computing system being compromised via the end user workstation
use ssh to connect to remote systems	de-facto tool to connect to remote systems using asymmetric encryption	MITM attacks, packet interception (sniffing)



Action	Description	Mitigation
use ssh-keys	more efficient and convenient way to authenticate	key-loggers, stolen credentials
use ssh-keys + MFA	enhanced way to authenticate	stolen private key
verify fingerprint of remote system	checks validity and authenticity of remote system by comparing system's fingerprints with publicly reported ones	MITM attacks, IP spoofing
connect through VPN	improves network protection and privacy by creating an encrypted channel over unsecured networks such as the Internet	MITM attacks, sensitive data exposure
firewall	“middle-ware” (hardware and/or software) to intercept and filter potential attacks	brute-force attacks, malicious network traffic
use an antivirus	local protection against wide spectrum of malware	multiple types of malware – mitigates the risk of the remote computing system being compromised via the end user workstation
use a passwords manager	specialized tool to more securely (i.e. using encryption) store passwords and generate strong passwords, which is useful if SSH keys as an authentication method is not available	password stealing, password brute-force
encrypted signed email (e.g. using PGP)	enhance authenticity and validity of email communications	MITM attacks, impersonation

Summary of some best practices for end users to enhance cybersecurity in remote computing.

## ssh Summary

A summary of the most relevant aspects is available [here](#).

---

*Last Modified: Oct. 10, 2022 – v 0.1 # SSH Summary*

## Connections, forwarding and tunneling

---

### Connections, forwarding and tunneling

---

connection to remote system	<code>ssh username@remote.system.IP</code>
	<code>ssh username@remote.system.IP -p PORTnbr</code>
with graphics-forwarding	<code>ssh -X username@remote.system.IP</code>
	<code>ssh -Y username@remote.system.IP</code>
tunneling	<code>ssh -R remPort:remote_host:locPort username@remote.system</code>
	<code>ssh -L locPort:remote_host:remPort username@remote.system</code>
	<code>ssh -fN -[R_or_L] port:remote_host:port username@remote</code>
remote execution	<code>ssh username@remote.system.IP "remote_cmd_to_exec"</code>

---

## Keys

### Generation

```
ssh-keygen -t ed25519
```

```
ssh-keygen -t rsa -b 4096
```

```
# key generation with comments and specified location
```

```
ssh-keygen -t ed25519 -C "USER@laptop cluster-X" -f $HOME/.ssh/USER_clusterX_ed25519
```

```
# ssh using specific key file
```

```
ssh -i $HOME/.ssh/USER_clusterX_ed25519 USERNAME@clusterX.IP.address
```

### Transfer

```
ssh-copy-id -i $HOME/.ssh/id_ed25519.pub USERNAME@remote.system.ip
```

```
# copying over keys to remote system
```

```
cat $HOME/.ssh/id_ed25519.pub | ssh USERNAME@remote.system.ip "cat >> $HOME/.ssh/authorized"
```

### Agent to recall key

```
ssh-add key-file
```

```
ssh-add key-file -t life
```

## Troubleshooting

### Debugging (verbose mode)

```
# -v activates the "verbose mode": resulting in printing debugging messages  
# helpful in diagnosing connection, authentication, and configuration problems  
# Multiple -v options increase the verbosity, the maximum is 3.
```

```
ssh -v USERNAME@remote.system.ip  
ssh -vv USERNAME@remote.system.ip  
ssh -vvv USERNAME@remote.system.ip
```

## Further References and Resources

- “High-Performance Computing (HPC) Security: Architecture, Threat Analysis, and Security Posture”, <https://csrc.nist.gov/publications/detail/sp/800-223/draft> Dated: Feb. 2023