UNIX Introduction

Cluster Computing in Frankfurt

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Motivation

The Terminal
The Command Line
Unix
Linux
Shell Scripting
Bash

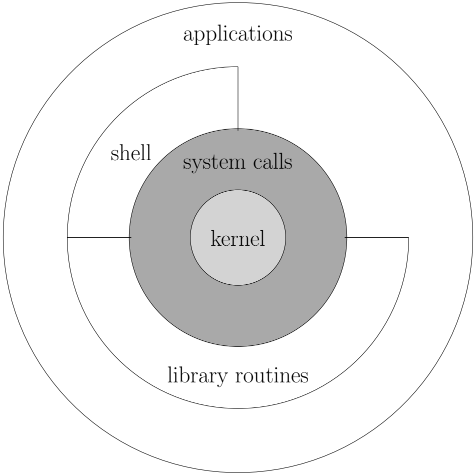
Operating System
UNIX Structure

- UNIX
  - is an operating system specification.
  - has many implementations (Linux, Mac OS X, Free BSD, etc.)
  - it controls the hardware, run programs, manage resources & communicate with other computers.
- The kernel
  - is the heart of the operating system.
  - handles memory management, input & output requests, & program scheduling.
  - interacts with hardware & most of the tasks like memory management, task scheduling & file management.
  - Users communicate with the kernel through system calls with the help of shell, libraries & other applications (e.g. Graphical User Interface)
- The shell is a command line interpreter.

Operating System
UNIX Structure

- Hardware provides basic computing resources.
  - CPU
  - RAM
  - I/O
  - PMC
- Utility Programs assists in system management & software development.
- Application Programs defines the ways in which the system resources are used to solve the computing problems of the users.
  - compilers
  - database systems
  - business programs

Operating System
UNIX Structure



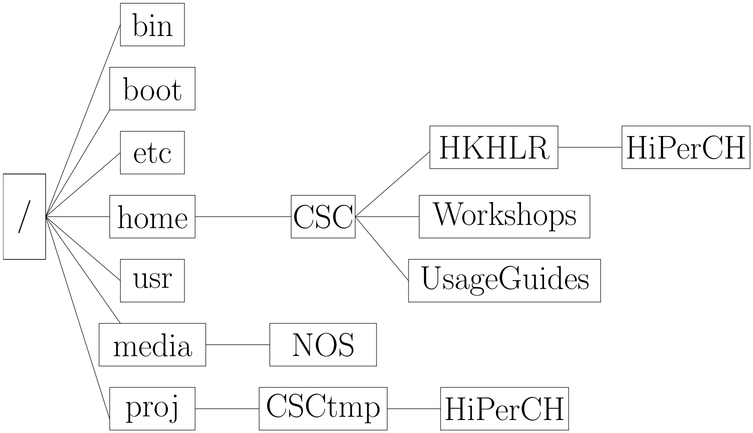
Operating System
UNIX Structure

- UNIX has files & processes.

processes	executing program identified by a unique PID. PID - process identifier
files	are a collection of data & organized into directories. everything is a file, e.g.

- modem
- keyboard
- hard-drive
- gpu

File System Basics
Directory Structure



File System Basics
Directory Structure

`/`	root directory of the file system
`/boot`	boot mechanism for programs & configuration files
`/bin`	system executables
`/lib`	essential libraries
`/etc`	system configuration files & scripts
`/var`	files that may change often, e.g. log files
`/media`	default mount point for removable devices

File System Basics
Directory Structure

`/home`	contains user home directories
`/root`	is the home directory for the `root` account
`/dev`	has device nodes
`/proc`	system state and kernel options
`/opt`	contains locally installed software
`/usr`	additional programs & resources
`/tmp`	contains temporary files, may be automatically cleared

UNIX Terminal
Terminal Usage

copy & paste in terminals

copy:	Highlight the text you want, make a copy …
paste:	…and paste at the desired location with a click of the mouse wheel (or with `Shift-Insert`).

filename completion

By typing part of the name of a command, filename or a directory & pressing the `Tab` key, the shell will complete as much as possible.

Getting Help

man

`man <command>` views the man pages

man cp

```
NAME
      cp - copy files and directories
SYNOPSIS
      cp [OPTION]... [-T] SOURCE DEST
      cp [OPTION]... SOURCE... DIRECTORY
      cp [OPTION]... -t DIRECTORY SOURCE...
DESCRIPTION
Copy SOURCE to DEST, or multiple SOURCE(s)to DIRECTORY.
      <options>
```

Documentation

- https://ubuntudanmark.dk/filer/fwunixref.pdf
- http://cheatsheetworld.com/programming/unix-linux-cheat-sheet/
- http://www.mathcs.emory.edu/~valerie/courses/fall10/155/resources/unix_cheatsheet.html
- http://www.cyberciti.biz/tips/linux-unix-commands-cheat-sheets.html
- http://www.tutorialspoint.com/unix/unix-using-variables.htm
- www.ee.surrey.ac.uk/Teaching/Unix/books-uk.html
- www.tldp.org

Filename Conventions

- all characters allowed **but** `/` and `\0` (the *null character*) should be avoided in file names
- for portability the official recommendation is use only `a-z` `A-Z` `0-9` `.` `-` `_`

Wildcards

wildcards

the * wildcard `list*` will list all files in the current directory starting with `list...`

`*list` will list all files in the current directory ending with `...list`

the ? wildcard the character `?` will match exactly one character

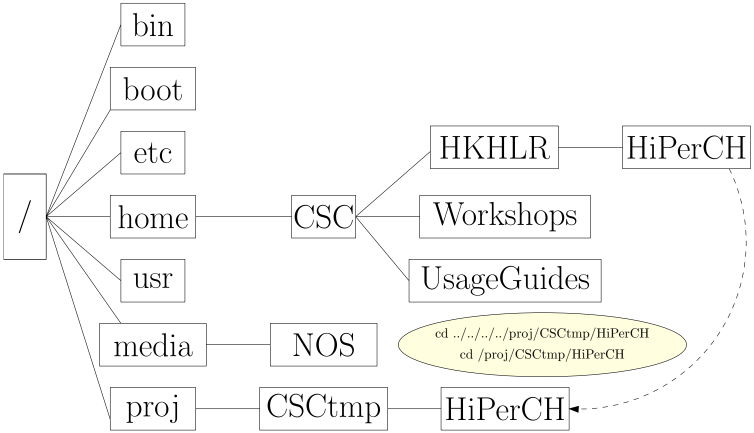
example for `?ist`:

```
List
list
gist
.ist
```

Paths

- any file can be found following a path
- **.** current directory
- **..** parent directory
- **~** home directory of current user
- case sensitive file names
- absolute paths always start with /
- relative paths refers to the current working directory

Elementary Commands
Absolute vs. Relative Paths



```
cd ../../../../proj/CSCtmp/HiPerCH
cd /proj/CSCtmp/HiPerCH
```

Elementary Commands
Listing Files and Directory

`ls`

`ls` lists the contents of a directory

Syntax: `ls <options>`

`-a`	view hidden files, **with** `.` and `..`
`-A`	view hidden files, **without** `.` and `..`
`-d`	list directories with `*/`
`-F`	list files & directories with special characters at the end
`-h`	human readable units
`-l`	list directory information
`-g`	list directory information, but do not list owner
`-1`	display one file per line

Elementary Commands

Listing Files and Directory

ls

`ls` lists the contents of a directory

Syntax: `ls <options>`

`-r`	list files in reverse order
`-R`	list subdirectories recursively
`-s`	print the allocated size of each file, in blocks
`-S`	sort by file size
`-t`	open last edited file
`-lag`	list access rights for all files
`-ltr`	reverse output order
`-lSrh`	sort files by file size

Elementary Commands
Making Directories

`mkdir`

`mkdir <directory>` creates an new `directory` in the current directory

Example for `mkdir`

`mkdir foo/bar` $\longrightarrow$ Error!

`mkdir -p foo/bar`

Syntax: `mkdir <options> <directory>`

`-p`	creating a whole path

Elementary Commands

Print Working Directory & Changing to a different Directory

`pwd`

`pwd` displays the current directory

`cd`

`cd` changes the current directory

Elementary Commands
Print Working Directory & Changing to a different Directory

Syntax: `cd <path>`

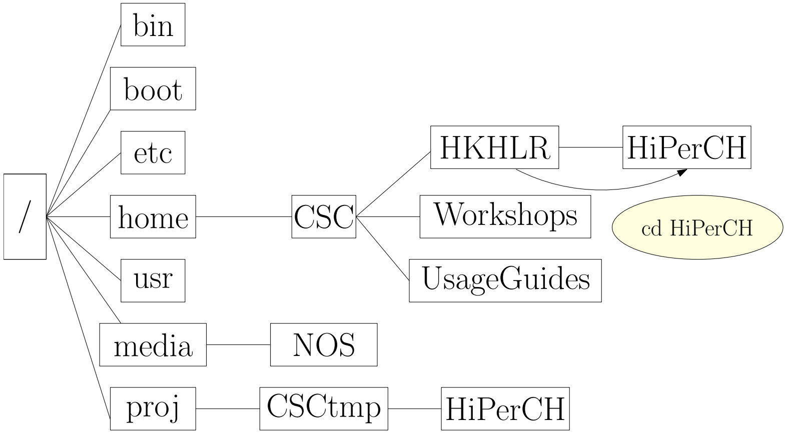
Example for `cd` & `pwd`

```
cd foo
pwd

cd bar
pwd

cd
pwd

cd foo/bar
pwd
```

Example for `cd` & `pwd`

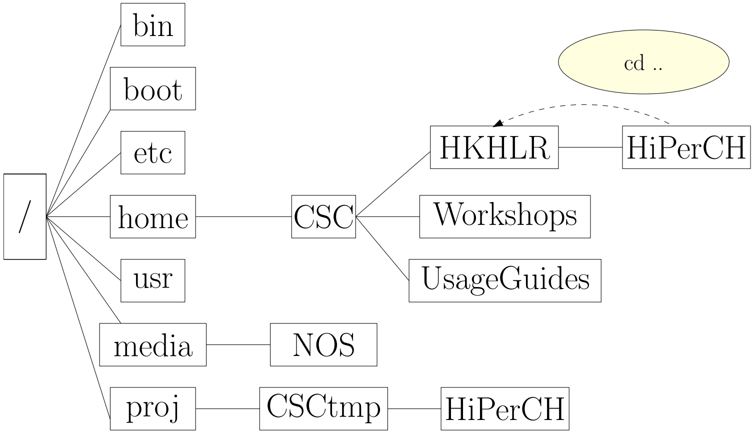
```
cd ..
pwd

cd .
pwd

cd ~
pwd
```

Elementary Commands
Changing to a different Directory

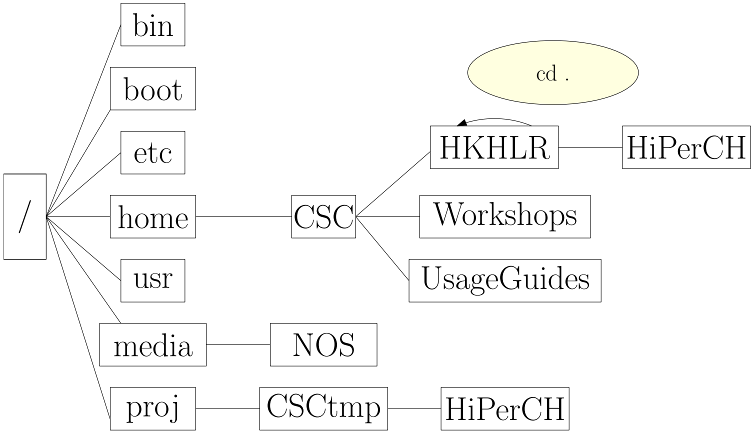


Elementary Commands

Changing to parent Directory



Elementary Commands
Current Directory



Elementary Commands
Copying Files

cp

`cp <source> <destination>` copies one or more files or directories from `source` to `destination`

Syntax: `cp <source> <destination>`

`-i`	confirm before overwriting (interactive mode)
`-r` | `-R`	copy directories recursively
`-p`	preserve attributes of file or directory while copying
`-l`	create hard link to a file or directory
`-s`	create soft link to a file or directory
`-v`	explain what is being done

Elementary Commands

Copying Files

Example for `cp`

```
cd foo
cp ~/some_file.text bar
ls -l
ls bar
cp -p ~/some_file.text .
ls -l
cp bar baz
cp -r bar baz
ls bar baz
```

Elementary Commands

Moving Files

`mv`

`mv <source> <destination>` moves & rename files & directories

Example for `mv`

```
mv oldname newname
mv filename /dest/dir
```

Syntax: `mv <source> <target>`

`-f`	do not prompt before overwriting existing files
`-i`	prompt before overwriting each existing destination file
`-n`	do not overwrite any existing file
`-u`	update

Elementary Commands

Removing Files and Directories

rm

`rm` deletes files & directories

Solution

backup your data

Warning!

`rm` deletes **without** further inquiry! There is no such thing as the trash!

`rm -rf <file/directory>`

removes everything!

Syntax: `rm <options> <file|directory>`

`-f`	delete file without prompting
`-r` | `-R`	remove directories and their contents recursively
`-i`	prompt before every removal
`-p`	delete nested directories

Elementary Commands

Removing Directories

rmdir

`rmdir <directory>` deletes the `directory` in the current directory

Warning!

`rmdir` deletes **only** empty directories!

Syntax: `rmdir <options> <directory>`

`-r`	delete directory recursively

Redirections

- $>$ symbol is used to redirect the output of a command.
  `<command> > <file>`
- $<$ symbol is used to redirect the input of a command.
  `<command> < <file>`
- $< \quad >$ get input from `file1` & write to `file2`
  `<command> < <file1> > <file2>`
  `sort < old.txt > new.txt` sorts old & saves as new.
- $>>$ appends the output to a file.
  `<command> >> <file>`
- $2>\&$ combine `stderr` and `stdout` into the `stdout` stream for further manipulation
- $|$ pipe symbol connects the output of `command1` directly to the input of `command2`

Redirections

Exercise

What is the difference between:

```
./a.out > outfile 2>& 1
./a.out 2>& 1 > outfile
```

Hint!

The shells process their command lines from left to right.

Displaying the Contents of a File on the Screen

`echo`

`echo <string>` prints the `<string>` passed to it as an argument

`cat`

`cat <file>` prints the contents of files passed to it as arguments & concatenate files together

Example for `cat`

```
cat file1.txt file2.txt > new.txt
```

Displaying the Contents of a File on the Screen

`clear`

`clear` clears the terminal screen

`head`

`head <file>` displays the first few lines of a file

`tail`

`tail <file>` displays the last few lines of a file

Syntax: `head` & `tail`

`-n num`	print the first `num` lines

Displaying the Contents of a File on the Screen

`more`

`more <file>` open files & display contents on the screen

`less`

`less <file>` open files & display contents on the screen

Warning!

If there are only strange characters are displayed after the output of a binary, type the command `reset`.

Searching the Contents of a File

grep

`grep 'keyword' <file>` search a file for keywords

Syntax: `grep`

`-A` | `-B` | `-C`	displaying lines before/after/around the match
`-c`	counting the number of matches
`-i`	case insensitive search
`-n`	precede each matching line with line number
`-o`	show only the matched string
`-v`	invert match
`-w`	search words
`-ivc`	print the number of lines without a particular words

Searching the Contents of a File

Example

```
grep Quark example.log > Quark.text
cat Quark.text
echo "These are the occurrences of Quark" >> Quark.
text
cat Quark.text
echo " in the log file" > Quark.text
cat Quark.text
```

Searching the Contents of a File

wc

`wc` count number of lines|words|characters in file

Syntax: `wc`

`-c` | `-m` | `-l` | `-w`	print the byte | character | newline | word counts
`-L`	print the length of the longest line

Example for `wc`

```
wc example.log wc -l example.log grep Quark example.
log grep Quark example.log | wc -l
```

Editing the Contents of a File

- Unix Editors are `vi`, `emacs` and `nano`.
- Midnight Commander `mc` is a directory browser/file manager for Unix-like operating systems.

File Access Permissions

There are 9 permission bits for each file divided in 3 categories.

	owner	group	other
	u	g	o
no rights	– – –	– – –	– – –
read	r – –	r – –	r – –
read & write	r w –	r w –	r w –
read & execute	r – x	r – x	r – x
read, write & execute	r w x	r w x	r w x

add permission	+
take away permission	–
execute & access directory	x

File Access Permissions

Warning!

A file should only be readable, writable and executable only for yourself in most cases.

```
- r w x - - - - - -
```

File Access Permissions
File Type

```
- rw - - - - - - -  1  gerbes  hkhlr  567  Okt 18 22:00  refsheet
```

`-`	normal file
`d`	directory
`l`	link
`Others`	various special files

File Access Permissions

Permissions

```
- rw - - - - - - -  1  gerbes  hkhlr  567  Okt 18 22:00  refsheet
```

`r`	read
`w`	write
`x`	execute
`others`	various special settings

File Access Permissions
Links

```
- rw - - - - - - - 1 gerbes hkhlr 567 Okt 18 22:00 refsheet
```

We will ignore links for now.

File Access Permissions
Users

```
- rw - - - - - - - 1 gerbes hkhlr 567 Okt 18 22:00 refsheet
```

The user that owns this file.

File Access Permissions
Groups

```
- rw - - - - - - -  1  gerbes  hkhlr  567  Okt 18 22:00  refsheet
```

The group that owns this file.

File Access Permissions
Size

```
- rw - - - - - - - 1 gerbes hkhlr 567 Okt 18 22:00 refsheet
```

The size of this file, listed in bytes.

File Access Permissions

Last Change Date

```
- rw - - - - - - - 1 gerbes hkhlr 567 Okt 18 22:00 refsheet
```

The last time the file was changed.

File Access Permissions
Name

```
- rw - - - - - - -  1  gerbes  hkhlr  567  Okt 18 22:00  refsheet
```

The file name.

File Access Permissions

Changing Permissions

`chmod`

`chmod` changes a file mode. Only the owner of a file can use `chmod` to change the permissions of a file.

Syntax:	`chmod <options>`
`u+x <file>`	making the `<file>` executable
`go-w <file>`	`<file>` is no longer writeable
`u+rw <file>`	providing `r` & `w` access to a user
`u-w <file>`	removing execute permissions to a user
`a+rx <directory>`	adding `r` & `w` permissions to all directories
`a+r <directory>/*`	everybody can read the content of the `<directory>`

Process Management

Syntax	**Description**
`ps`	displays information about the process status of all processes
`top`	lists running processes
`bg | &`	moves the current process to the background
`fg`	moves the current process to the foreground
	typing `fg` with no job number foregrounds the last suspended process
`jobs`	lists background & suspended processes

Process Management

Syntax	Description
`kill | ctrl-C`	stop the process
	it is not possible to kill of others users' processes!
`kill -9`	non-catchable, non-ignorable kill
`ctrl-D`	ending terminal line input
`ctrl-Z`	suspend the current process

File System Basics

Command	**Description**
`file <filename>`	identifies the file type
`find <filename|dir>`	finds a file/directory
`apropos <command>`	searching for commands
`touch <filename>`	creates a blank file or modifies an existing files attributes
`whereis <filename>`	shows the location of a file
`which <filename>`	shows the location of a file if it is in your `PATH`

File System Basics
Disc Usage

`du`

`du` estimate file space usage

Syntax: `du <options>`

`<file>`	shows how much space has the `<file>`
`-h`	human readable units
`-s`	show occupied space as a sum

File System Basics

File System Disk Space Usage

`df`

`df` reports the amount of available disk space being used by file systems

Syntax:	`df <options>`
`-h`	human readable units

System Info
Environment Variables

printenv

`printenv` prints the values of the specified environment

System Variable	**Description**
`HOSTNAME`	your computers name
`HOME`	home directory of the current user
`PATH`	the search path for commands
`USER`	the ID of the current user
`PWD`	the current working directory

System Info
History of Commands

`history`

`history` shows command history list

System Variable	**Description**
`HISTFILE`	the files name which command history is saved
`HISTFILESIZE`	max number of lines contained in the history file
`HISTSIZE`	the number of commands to remember in the command history

System Info

Command	Description
`date`	to display & set system date time
`reset`	resets the terminal screen if is not displaying correctly
`uname`	print information about the current system

Tape Archive

`tar`

`tar` is an archiving file format

Syntax: `tar <options>`

`-A`	appends tar files to an archive
`-c`	creates a new archive
`-d`	shows the differences between archive & file system
`--delete`	deletes from the archive
`-f`	use archive file

Tape Archive

`tar`

`tar` is an archiving file format

Syntax: `tar <options>`

`-j`	`r` or `w` archives using the bzip2 compressor
`-r`	appends files to the end of a tar archive
`-t`	lists the contents of an archive
`-u`	updates the tar archive
`-x`	extracts files from a tar archive
`-z`	`r` or `w` archives through gzip

Tape Archive

Example for `tar`

```
tar -cf <archivename>.tar <directory>
```
will pack all files in a directory

```
tar -czf <archivename>.tar.gz <directory>
```
will pack & compress all files in a directory using gzip

```
tar -cjf <archivename>.tar.bz2 <directory>
```
will pack & compress all files in a directory using bzip2

```
tar -xfz <archivename>.tar.gz
```
to unpack (and uncompress) use `x` instead of `c`

Tape Archive

Example for `tar`

```
tar cvf stuff.tar example.log some_file.text Quark.
text
ls -ltrh
tar tf stuff.tar
rm stuff.tar
tar cvzf stuff.tar.gz example.log some_file.text
Quark.text
ls -ltrh
tar tf stuff.tar.gz
rm example.log some_file.text Quark.text
ls
tar xvzf stuff.tar.gz
ls
```

Secure Connections with `ssh`

Password Authentication

- $\substack{\text{user}\\\text{system}}$ is authenticated to the $\substack{\text{system}\\\text{user}}$ using password only
- all transmitted data is encrypted
- host authentication is performed via fingerprint comparison (user responsibility)

`ssh`

```
ssh <username>@<remote-host> <command>
```

Syntax: `ssh <options>`

`-f` sends `ssh` to background

Example for `ssh`

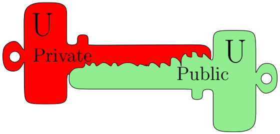
```
ssh loewe
ssh loewe ls
```

Generating Keys

`ssh-keygen`

`ssh-keygen -l` calculates the fingerprint of a public key

`ssh-keygen -t dsa | ssh-keygen -t rsa` generates a key pair

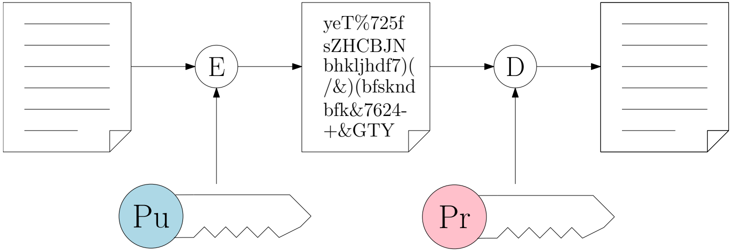


Authentication using Public Key

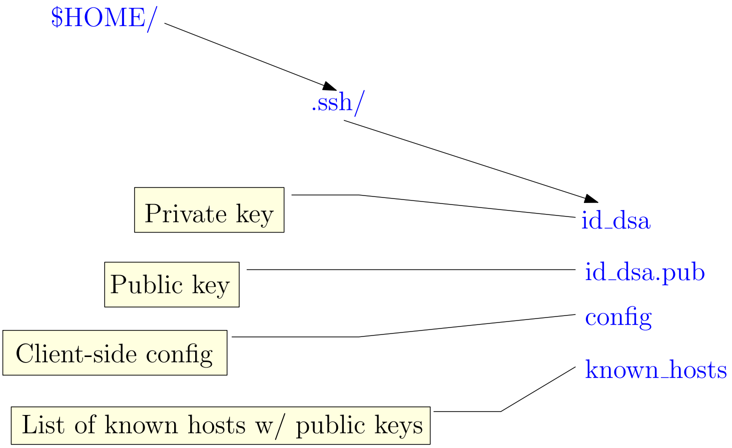
- every user owns a pair of keys, one private & one public
- public key can be known to everybody & allows to commmunicate with the user
- private key must be secret
- when the user’s public key is deposited at the remote host, the user can be authenticated without a password
- only the private key fits the corresponding public key

Authentication using Public Key

- a message will be encrypted with one of the keys & can only be decrypted with the corresponding other key
- with ssh, the session key is negotiated & authentication is performed using this mechanism



User Configuration, Client Side

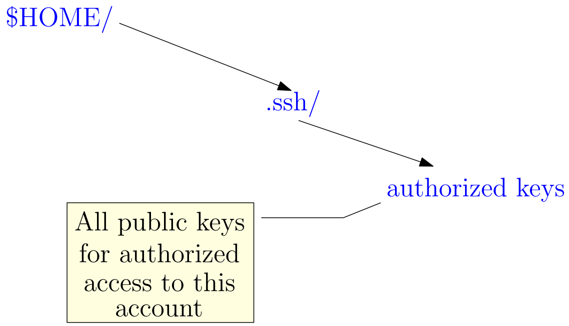


User Configuration, Client Side

Example for User Configuration

```
Host        loewe
Hostname    loewe-csc.hhlr-gu.de

Host        other_host
Hostname    other.host.name.org
User        anja

Host        yah
Hostname    yet.another.host.org
Port        45667
```

User Configuration, Server Side



Data Transfer

Secure Copy

`scp`

`scp <source> <destination>` copies files over a secure, encrypted network connection

- remote source or destination:

  `<username>@<remote-host>:<path>`
- wildcards are allowed

Syntax: `scp <options>`

`-r`	allows recursive copying into subfolders

Data Transfer

Remote Synchronization

rsync

`rsync <source> <destination>` is a tool for data transfer & synchronization of data between remote systems

- `rsync` uses `ssh` by default

Syntax: `rsync <options>`

`-a`	archive mode
`-e`	specify the remote shell to use
`-v`	increase verbosity
`-z`	compress file data during the transfer
`--stats`	give some file-transfer statistics