

# File Systems

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## Reference: bwHPC Wiki

■ Most information given by this talk can be found at <https://wiki.bwhpc.de>

- select cluster
- then select File Systems

[https://wiki.bwhpc.de/e/Main\\_Page](https://wiki.bwhpc.de/e/Main_Page)

### HPC System Specific Documentation

bwHPC Clusters are dedicated to [specific research domains](#). Documentation differs between clusters:

<a href="#">bwUniCluster 2.0</a>	General Purpose, Teaching
<a href="#">bwForCluster JUSTUS 2</a>	Theoretical Chemistry, Condensed Matter Physics, Computational Humanities, Structural and Systems
<a href="#">bwForCluster Helix</a>	Neurosciences, Particle Physics, Materials Science, Bioinformatics, Geosciences and Astrophysics.
<a href="#">bwForCluster NEMO</a>	
<a href="#">bwForCluster BinAC</a>	

Further Compute Clusters in Baden-Württemberg (separate access policies):

- bwHPC tier 1: [Hawk](#) ([getting access](#))
- bwHPC tier 2: [HoreKa](#) ([getting access](#))

# Material: Slides & Scripts

- [https://indico.scc.kit.edu/e/hpc\\_course\\_2023-10-16](https://indico.scc.kit.edu/e/hpc_course_2023-10-16)
- BwUniCluster 2.0: /opt/bwhpc/common/workshops/2023-10-16/
- HoreKa: /software/all/workshop/2023-10-16/

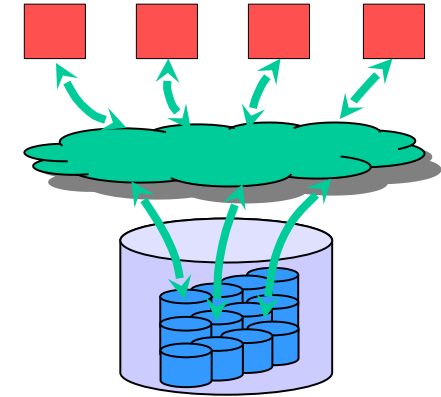
## How to read the following slides

Abbreviation/Colour code	Full meaning
<code>\$ command -option value</code>	<code>\$</code> = <b>prompt</b> of the interactive shell The full prompt may look like: <code>user@machine:path\$</code> The command has been entered in the interactive shell session
<code>&lt;integer&gt;</code> <code>&lt;string&gt;</code>	<code>&lt;&gt;</code> = Placeholder for integer, string etc
<code>foo, bar</code>	Metasyntactic variables

# Parallel file systems

## ■ Most important parallel file systems

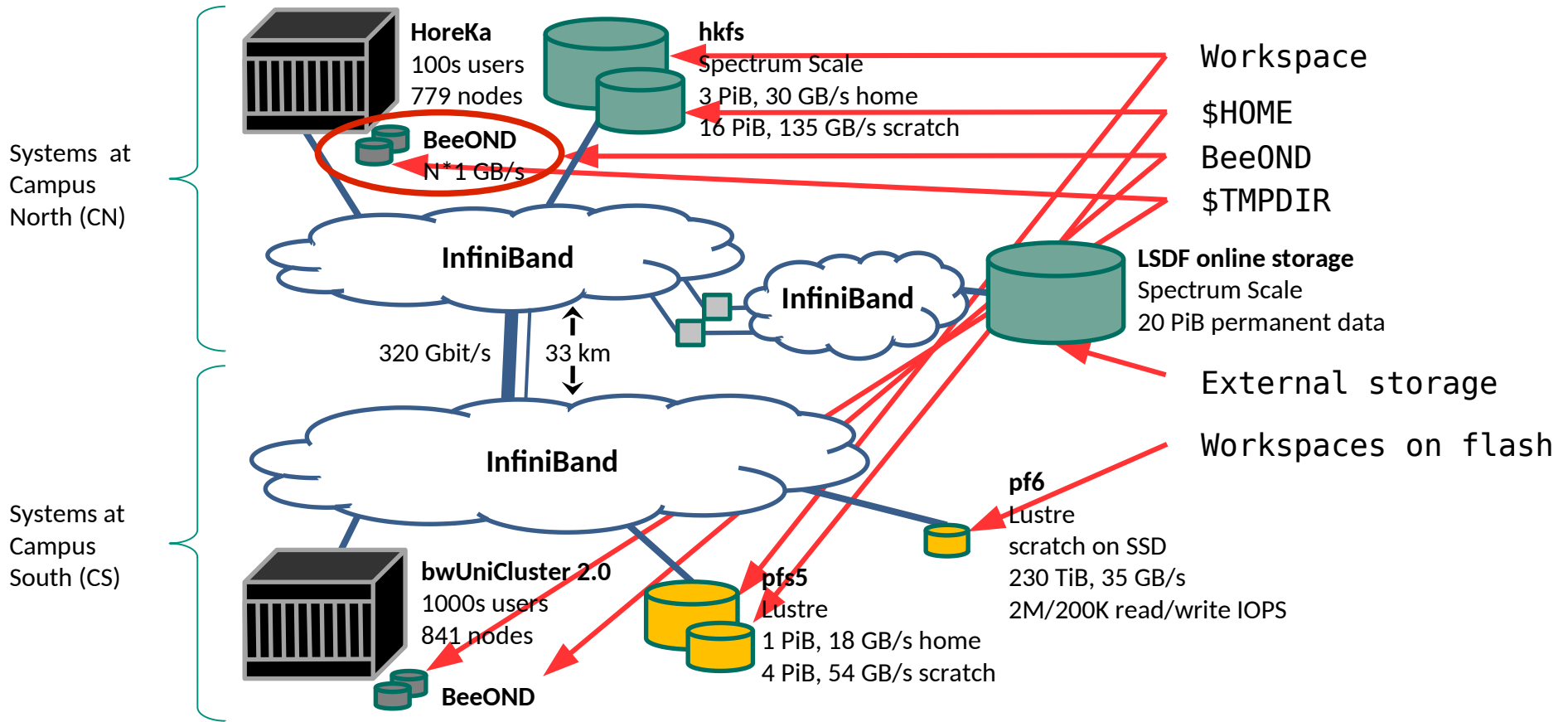
- Lustre
  - Used on most of the largest HPC systems
- IBM Spectrum Scale (aka GPFS)
  - Used in industry and on many HPC systems
- BeeGFS
  - Underlying file system for BeeGFS On Demand (BeeOND)



## ■ Lustre, GPFS, BeeGFS

- Follow POSIX standard, i.e. applications just work
- Offer large capacity and parallel access from many nodes
- Good performance for huge files and access with large chunks
- Dislike small files, random I/O, or many metadata (open, close, stat, create, remove) operations
  - Hence for some applications I/O on laptop with SSD might be faster
  - Reasons: communication over network, locking to guarantee consistency

# HPC clusters and file systems @ KIT



# How to use each File System (1)

- \$HOME = Home directory
  - Software, configuration files, final results
  - **Omit** heavy I/O
- Workspaces = Working directories with lifetime
  - Intermediate results, huge input/output data sets
  - Scratch data which needs to be shared between nodes
  - **Omit** small files, tiny block sizes, lots of metadata operations
    - If not possible to omit, KIT and HoreKa users can use [Workspaces on flash storage](#)
- \$TMPDIR = Separate file system on each node using local disks
  - Data is only available during job runtime on the local node
  - Possibly transfer data here within a batch job
  - **All** sorts of I/O **allowed**

## How to use each File System (2)

- BeeOND = Private file system for batch job
  - Data is only available during job runtime on the batch job nodes
  - Possibly transfer data here within a batch job
  - **All** sorts of I/O **allowed**, only available on bwUniCluster 2.0 and HoreKa
- External storage
  - Archive scientific data, move data here when data sets become too large
  - Each organization has different solutions, example is LSDF at KIT
  - **Use** huge files or compressed archives
- Summary
  - Use \$HOME for permanent data
  - Use workspaces for huge files and sequential I/O
  - Use \$TMPDIR or BeeOND with many (> 10000) small files or random I/O

## File System properties of bw clusters and of HoreKa

Property	\$HOME	Workspace	\$TMPDIR	BeeOND <sup>1</sup>	LSDF <sup>1</sup>	WS on flash <sup>1</sup>
Visibility	all nodes	all nodes	local node	job nodes	login + job	all nodes
Lifetime	permanent	few weeks	job runtime	job runtime	permanent	few weeks
Usable capacity	40 GB - 10 TB	10 TB - 250 TB	128 GB - 7 TB	N * 750 GB	per project	1 TB
Usable inodes	2 mil - unlimited	1 mil - unlimited	unlimited	unlimited	per project	5 mil
Backup	yes, except Helix	no	no	no	yes	no
Total perf.	medium, 100s - 1000s MB/s	huge, 10s GB/s	100s MB/s per node	N * 100s MB/s	10s GB/s	huge, 10s GB/s

<sup>1</sup> Only available on bwUniCluster 2.0 and HoreKa



## \$HOME = Home directory

- \$HOME is visible on all nodes of a cluster
- Properties of \$HOME on different clusters

Cluster	Quota capacity limit	Quota file limit	Backup
JUSTUS 2	400 GB per user	2 mill. per user	Yes
Helix	200 GB per user	unlimited	No
NEMO	100 GB per user	unlimited	Yes
BinAC	40 GB per user	unlimited	Yes
BwUniCluster 2.0	1000 GB per user also limit per organization	10 mill. per user	Yes
HoreKa	10 TB per project	10 mill. per project	Yes

# \$HOME on bwUniCluster 2.0

## HowTo goto:

```
$ cd $HOME
```

```
$ cd
```

## User's quota usage and limits:

```
$ lfs quota -uh $(whoami) $HOME
```

```
Disk quotas for usr ab1234 (uid 9999):
```

Filesystem	used	quota	limit	grace	files	quota	limit	grace
/home/kit/scc/ab1234	9.904G	0k	1T	-	176849	0	10000000	-

## Organization quota usage and limits:

```
$ lfs quota -ph $(grep $(echo $HOME | sed -e "s|/[^/]*/[^/]*$||") \  
/pfs/data5/project_ids.txt | cut -f 1 -d\ ) $HOME
```

## \$HOME / \$PROJECT on HoreKa

- \$HOME and \$PROJECT are identical if your account is member of one project
  - Otherwise to change to another project which will also modify \$PROJECT:

```
$ newgrp <another_project_group>
```

- Project group quota usage and limits:

- First start an interactive job:

```
$ salloc -p dev_cpuonly -n 1 -t 20 --mem=500
```

- Show usage and limits of your project group on the \$HOME file system:

```
$ /usr/lpp/mmfs/bin/mmlsquota -j $PROJECT_GROUP --block-size G -C hkn.scc.kit.edu hkfs-home
```

		Block Limits			File Limits		
Filesystem	type	GB	quota	limit	files	quota	limit
home	FILESET	3467	10240	11264	4747501	10485760	11534336

current usage      soft limit      hard limit

# Workspaces = Working directories with lifetime

- **Workspace:** lifetime on allocated folder
  - Available on all clusters, visible on all nodes of a cluster
  - HowTo:
    - <https://wiki.bwhpc.de/e/Workspace>

<code>\$ ws_allocate foo 10</code>	Allocate workspace <i>foo</i> for 10 days
<code>\$ ws_list</code>	List your workspaces
<code>\$ ws_find foo</code>	Get absolute path of workspace <i>foo</i>
<code>\$ ws_extend foo 5</code>	Extend lifetime of your workspace <i>foo</i> by 5 days from now. Number of extensions depends on cluster.
<code>\$ ws_release foo</code>	Manually erase your workspace <i>foo</i>
<code>\$ ws_... -F ffuc ...</code>	Select non default workspace file system with -F (works for any command)

## Properties of Workspaces on different clusters

Cluster	Capacity limit	File limit	Max lifetime	Max extensions
JUSTUS 2	20 TB per user	5 mill. per user	90 days	unlimited
Helix	10 TB per user	unlimited	30 days	10 times
NEMO	10 TB per user	1 mill. per user	100 days	99 times
BinAC	unlimited	unlimited	30 days	3 times
BwUniCluster 2.0	40 TB per user	30 mill. per user	60 days	3 times
HoreKa	250 TB per user	50 mill. per user	60 days	3 times

# File system on each node using local disks

## ■ Node local storage on SSDs

- Available on all clusters but **usage via different environment variables**
  - \$TMPDIR: HoreKa, bwuniCluster 2.0, Helix, NEMO, BinAC; \$SCRATCH: JUSTUS 2
- **Separate** private directory **on each node** of a batch job, created at job start and destroyed at job end
  - Make sure you have copied your data back to a workspace or \$HOME within your job
- HowTo:
  - [https://wiki.bwhpc.de/e/BwUniCluster2.0/Hardware\\_and\\_Architecture#.24TMPDIR](https://wiki.bwhpc.de/e/BwUniCluster2.0/Hardware_and_Architecture#.24TMPDIR)

## ■ Usage example

- Outside batch job create archive with compressed input dataset on a workspace:

```
$ tar -cvzf $(ws_find data-ssd)/dataset.tgz dataset/
```
- In batch script extract compressed input dataset to local SSD:

```
tar -C $TMPDIR/ -xvzf $(ws_find data-ssd)/dataset.tgz
```
- In batch script application reads data from dataset on SSD and writes results to SSD:

```
myapp -input $TMPDIR/dataset/myinput.csv -outputdir $TMPDIR/results
```
- In batch script save results to a workspace:

```
rsync -av $TMPDIR/results $(ws_find data-ssd)/results-${SLURM_JOB_ID}/
```

# BeeOND = Private file system for batch job

## ■ BeeOND (BeeGFS On-Demand)

- Available only on **bwUniCluster 2.0** and on **HoreKa**
- Private file system for batch job, created at job start and destroyed at job end
  - Make sure you have copied your data back to a workspace or \$HOME within your job
- Parallel file system, **visible on** nodes allocated to a **batch job**
- Uses local disks (SSDs) of each node to store the data
  - Capacity is limited: 750 GB \* *number of nodes used in batch job*
- Request creation in job script or on command line:

```
#SBATCH --constraint=BEEOND
```

```
$ sbatch -C BEEOND ...
```

- Use path below `/mnt/odfs/${SLURM_JOB_ID}` to access BeeOND, e.g.

```
$ cd /mnt/odfs/${SLURM_JOB_ID}/stripe_default
```

- HowTo:

→ [https://wiki.bwhpc.de/e/BwUniCluster\\_2.0\\_Hardware\\_and\\_Architecture#BeeOND\\_.28BeeGFS\\_On-Demand.29](https://wiki.bwhpc.de/e/BwUniCluster_2.0_Hardware_and_Architecture#BeeOND_.28BeeGFS_On-Demand.29)

# LSDF Online Storage = External storage for special users

## ■ LSDF Online Storage

- Available only on bwUniCluster 2.0 and on HoreKa **for special users**
  - intended usage for scientific measurement data and data-intensive scientific simulation results
    - <https://www.scc.kit.edu/en/services/11228.php>
  - **Visible** on login nodes and on batch job nodes **if access was requested**
    - Access from external with different protocols is also possible
  - Request access in job script or on command line:

```
#SBATCH --constraint=LSDF
```

```
$ sbatch -C LSDF ...
```

- Use environment variables \$LSDF, \$LSDFPROJECTS, \$LSDFHOME to access, e.g.

```
$ cd ${LSDF}
```

- HowTo:

→ [https://wiki.bwhpc.de/e/BwUniCluster\\_2.0\\_Hardware\\_and\\_Architecture#LSDF\\_Online\\_Storage](https://wiki.bwhpc.de/e/BwUniCluster_2.0_Hardware_and_Architecture#LSDF_Online_Storage)



# Workspaces on flash storage

## ■ Workspaces on flash storage

- Available only on bwUniCluster 2.0 and on HoreKa **for KIT users** and **HoreKa users**
  - File system is visible on all nodes of both clusters
  - All storage devices are based on flash (no hard disks)
    - low access times and higher IOPS rates
- Use via workspace commands
  - Add switch **-F ffuc** on bwUniCluster 2.0 and **-F ffhk** on HoreKa
  - Path to each workspace is visible and can be used on both clusters
- Show quota usage and limits:

```
$ lfs quota -uh $(whoami) /pfs/work8
```

## ■ HowTo:

→ [https://wiki.bwhpc.de/e/BwUniCluster2.0/Hardware\\_and\\_Architecture#Workspaces\\_on\\_flash\\_storage](https://wiki.bwhpc.de/e/BwUniCluster2.0/Hardware_and_Architecture#Workspaces_on_flash_storage)

# Exercise 1

## ■ Allocate two workspaces

```
$ ws_allocate test 30
Info: could not read email from users config ~/.ws_user.conf.
Info: reminder email will be sent to local user account
Info: creating workspace.
/pfs/work7/workspace/scratch/myuser-test
remaining extensions : 3
remaining time in days: 30

$ ws_allocate -F ffuc scratch 50
Info: could not read email from users config ~/.ws_user.conf.
Info: reminder email will be sent to local user account
Info: creating workspace.
/pfs/work8/workspace/ffuc/scratch/myuser-scratch
remaining extensions : 3
remaining time in days: 50
```

## Exercise 2

### ■ List workspaces

```
$ ws_list
id: scratch
  workspace directory : /pfs/work8/workspace/ffuc/scratch/myuser-scratch
  remaining time     : 49 days 23 hours
  creation time      : Wed Oct  6 18:59:11 2021
  expiration date    : Thu Nov 25 17:59:11 2021
  filesystem name     : pfs6wor8
  available extensions : 3
id: test
  workspace directory : /pfs/work7/workspace/scratch/myuser-test
  remaining time     : 29 days 23 hours
  creation time      : Wed Oct  6 18:55:17 2021
  expiration date    : Fri Nov  5 17:55:17 2021
  filesystem name     : pfs5wor7
  available extensions : 3
```

## Exercise 3

- Find workspace path and switch to it

```
$ ws_find -F ffuc scratch
/pfs/work8/workspace/ffuc/scratch/myuser-scratch

$ ws_find test
/pfs/work7/workspace/scratch/myuser-test

$ cd $(ws_find test)
$ pwd
/pfs/work7/workspace/scratch/myuser-test
```

## Exercise 4

### ■ Extend the lifetime of a workspace

```
$ ws_extend test 60
Info: could not read email from users config ~/.ws_user.conf.
Info: reminder email will be sent to local user account
Info: extending workspace.
Info: changed mail address to myuser
Info: changed reminder setting.
/pfs/work7/workspace/scratch/myuser-test
remaining extensions : 2
remaining time in days: 60
$ ws_list test
id: test
    workspace directory : /pfs/work7/workspace/scratch/myuser-test
    remaining time      : 59 days 23 hours
    creation time       : Wed Oct  6 19:01:02 2021
    expiration date     : Sun Dec  5 18:01:02 2021
    filesystem name     : pfs5wor7
    available extensions : 2
```

## Exercise 5

### ■ Release workspaces

```
$ ws_release test
```

```
$ ws_release -F ffuc scratch
```

```
$ ws_list
```