● CS344
Assignment-4
group-19

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Comparing Features of ZFS and ext4

- We compare the files systems ZFS and ext4 using vdbench.
- We created workloads to test 2 features -
  data compression and **management of large files** - on each file system.

Data Compression

● Data compression is a **reduction in the number of bits** needed to represent data.
● Compressing data can save storage capacity, speed up file transfer, and decrease costs for storage hardware and network bandwidth.

How compression works?

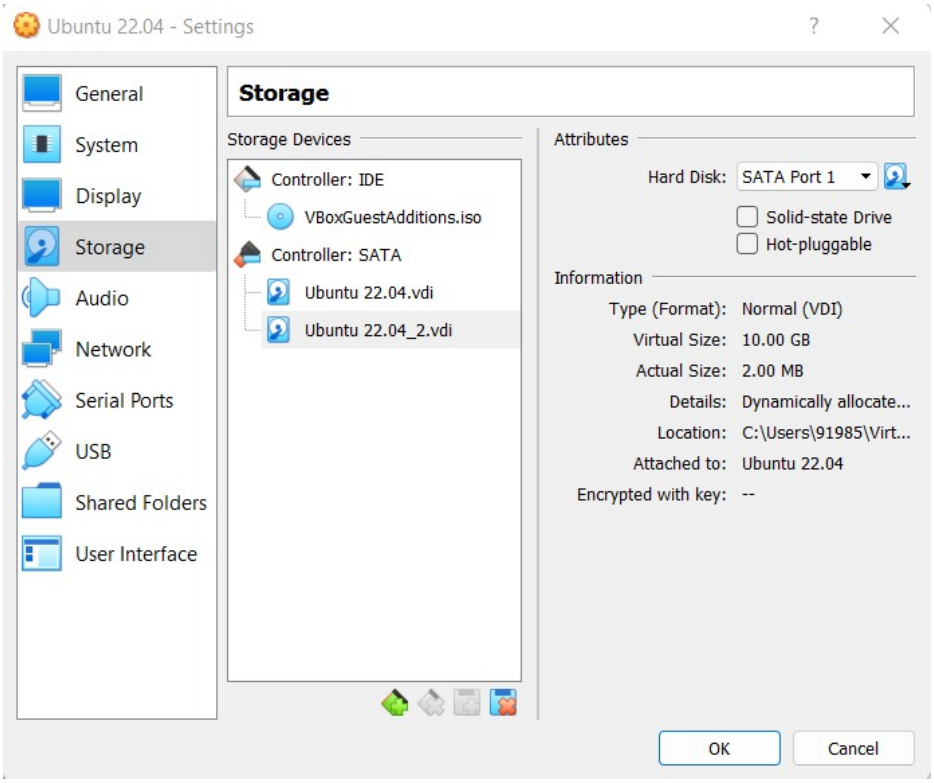
● Compression is performed by a program that uses a formula or algorithm to determine how to **shrink the size of the data.**
● For instance, an algorithm may represent a string of bits -- or 0s and 1s -- with a smaller string of 0s and 1s by using a dictionary for the conversion between them, or the formula may insert a reference or pointer to a string of 0s and 1s that the program has already seen.
● **Text compression** can be as simple as removing all unneeded characters, inserting a single repeat character to indicate a string of repeated characters and substituting a smaller bit string for a frequently occurring bit string. Data compression can reduce a text file to 50% or a significantly higher percentage of its original size.
● **Data compression** can be performed on the data content or on the entire transmission unit, including header data. When information is sent or received via the internet, larger files, either singly or with others as part of an archive file, may be transmitted in a ZIP, GZIP or other compressed format.

Management of Large files

● To manage large files the file system must have a support to handle large files.
● Ext4 uses extents (as opposed to the traditional block mapping scheme used by ext2 and ext3), which improves performance when using large files and reduces metadata overhead for large files but has a larger metadata overhead compared to ZFS.
● Ext4 uses 48-bit internal addressing, making it theoretically possible to allocate files up to 16 TiB on filesystems up to 1,000,000 TiB (1 EiB).

Creating a ZFS partition

1. We created a **ZFS pool** on an Ubuntu Virtual Machine.
2. First, we need to add an extra hard disk to our VM. In the VM settings, under the storage section, add an hard disk in the **Controller: SATA** section. Here, **NewVirtualDisk.vdi** is our added hard disk.



3. Start the VM, and then open the terminal.
4. To install ZFS, run the following command:

```
sudo apt install zfsutils-linux
```

5. To check if ZFS has been successfully installed, run the following command:

```
whereis zfs
```

6. To create the storage pool, first check the availables disks using the following command:

```
sudo  fdisk -l
```

We will use **/dev/sdb** to create our ZFS pool.

```
Disk /dev/sdb: 10 GiB, 10737418240 bytes, 20971520 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

7. To create the striped pool, run the following command:

```
sudo zpool create new-pool /dev/sdb
```

Here, **new-pool** is the name of our ZFS pool

8. We have now successfully created a ZFS pool

Creating an ext4 Partition

1. We created an **ext4** pool on an Ubuntu Virtual Machine.
2. First, we need to add an extra hard disk to our VM. Refer step 2 of creating a zfs partition.
3. Start the VM, and then open the terminal.
4. As **ext4** is the default file system of ubuntu, we don't need to install it explicitly. To create the storage pool, first check the availables disks using the following command:

sudo fdisk -l

We will use /dev/sdc to create our ext4 pool.

```
Disk /dev/sdc: 10 GiB, 10737418240 bytes, 20971520 sectors
Disk model: VBOX HARDDISK
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

5. We now use the **parted** command to configure our selected disk partition:

parted /dev/sdc

6. Now we will label the new partition using **mklabel** in parted and then create a partition using the **mkpart** command and specify the parameters.
7. To format the file system properly with ext4 file system we execute the following command:

. *mkfs.ext4 /dev/s*

8. We label the partition using e2label command:

e2label /dev/sdc old-pool

9. To create a mount point for our new partition, we create a new directory using the mkdir command:

mkdir old-pool

10. We will mount our partition to the mount point using the mount command:

mount /dev/sdc old-pool

11. We have successfully created an ext4 pool.

Checking the file system in the directories

We have mounted :

1. **ZFS** filesystem on the new-pool directory
2. **ext4** filesystem on the old-pool directory

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Setting up vdbench

Vdbench has three basic definitions in the configuration file.

1. **FSD or filesystem definitio**n: This defines what filesystem to use for the testing.

2. **FWD or filesystem workload definition**: This defines the workload parameter for the testing.
3. **RD or run definition**: This defines storage, workload and run duration.

Filesystem Definition

FSD defines the filesystem storage used for the testing.
The FSD name should be unique.
FSD parameters include:

1. fsd=name : Unique name for this File System Definition
2. anchor=/dir : The name of the directory where the directory structure will be created
3. depth=nn : How many levels of directories to create under the anchor.
4. files=nn : How many files to create in the lowest level of directories
5. width=nn : How many directories to create in each new directory
6. sizes=(nn,nn,…..) : Specifies the size(s) of the files that will be created.

Filesystem Workload Definition

FWD defines the filesystem workload used for the testing.
The FWD name should be unique. FWD parameters include:

1. fwd=name : Unique name for this Filesystem Workload Definition
2. fsd=(xx,….) : Name(s) of Filesystem Definitions to use.
3. operation=xxxx : Specifies a single file system operation that must be done for this workload. 4. fileio=sequential : How file I/O will be done: random or sequential
5. fileselect=random/seq : How to select file names or directory names for processing.
6. threads=nn : How many concurrent threads to run for this workload.
7. xfersize=(nn,…) : Specifies the data transfer size(s) to use for read and write operations.

Run Definition

RD defines what storage and workload will be run together and for how long.
Each run definition name must be unique.
RD parameters include:

1. fwd=(xx,yy,..) : Name(s) of Filesystem Workload Definitions to use.
2. format : ‘format=yes’ causes the directory structure to be completely created, including initialization of all files to the requested size.
3. elapsed : How long to run in seconds.
4. interval : Statistics collection interval in seconds.
5. fwdrate=nn : Run a workload of nn operations per second

Data Compression

vdbench code

```
Line 1 compratio=10
Line 2 fsd=fsd1,anchor=/dir,depth=2,width=2,files=2,size=100m
```

Line 3 fwd=fwd1,fsd=fsd1,operation=read,xfersize=4k,fileio=sequential,fileselect=random, threads=2
Line 4 rd=rd1,fwd=fwd1,fwdrate=100,format=yes,elapsed=10,interval=1

- Line 1 defines the compression ratio i.e the amount by which the files are going to be compressed in this case the files would be compressed by 10 times.
- Line 2 is the FSD i.e the filesystem definition.
- Line 3 are the FWD i.e the filesystem workload definition.
- Line 4 is the RD i.e the run definition.
- Here dir is new-pool for zfs and old-pool for ext4

Directory structure

Management of Large Files

vdbench code

Line1 fsd=fsd1,anchor=/dir,depth=1,width=1,files=3,size=500m
Line2 fwd=default,xfersize=4k,fileio=sequential,fileselect=seq,threads=2
Line3 fwd=fwd1,fsd=fsd1,operation=read
Line4 fwd=fwd2,fsd=fsd1,operation=write
Line5 rd=rd1,fwd=(fwd1,fwd2),fwdrate=100,format=yes,elapsed=10,interval=1

- **Line 1** is the FSD i.e the filesystem definition.
- **Lines 2,3,4** are the FWD i.e the filesystem workload definition.
- **Line 5** is the RD i.e the run definition.
- Here dir is new-pool for zfs and old-pool for ext4

Directory structure

Data Compression

Advantage:

ZFS has a data compression feature, which can be turned on using the following command:
sudo zfs compression=on new-pool
Using an identical workload to create **8 files**, each of size **100 MB**, we see that **new-pool** occupies only **71 MB** whereas **old-pool** occupies the full **801 MB** space. 8 files, each of size **100 MB**, will normally occupy **800 MB** plus some overhead, which is what happens in **ext4**. However, with compression feature turned on and compression ratio set to **10**, **ZFS** occupies a total size which is roughly **one-tenth** of the expected size.

Disadvantage:

ZFS has a very high average CPU utilisation (greater than **80**%) whereas **ext4** has a moderate average CPU utilisation (around **55**%). CPU usage is extensive because of file compression (results produced in **zfs_compression.html** and **ext4_compression.html** files).

Observations for Management of Large Files zfs ext4

26 intervals

..mb/sec...		mb/sec
read	write	total
0.00	161.2	161.25
0.00	32.12	32.12
0.00	1.38	1.38
0.00	0.00	0.00
0.00	154.6	154.62
0.00	73.50	73.50
0.00	38.88	38.88
0.00	117.5	117.50
0.00	65.00	65.00
0.00	58.62	58.62
0.00	101.1	101.12
0.00	0.00	0.00
0.00	35.00	35.00
0.00	164.0	164.00
0.00	0.00	0.00
0.00	135.0	135.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	81.88	81.88
0.00	0.00	0.00
0.00	74.00	74.00
0.00	0.00	0.00
0.00	86.88	86.88
0.00	0.00	0.00
0.00	93.12	93.12
0.00	25.88	25.88
0.00	53.54	53.54

zfs

15 intervals

..mb/sec...		mb/sec
read	write	total
0.00	316.8	316.88
0.00	195.6	195.62
0.00	159.1	159.12
0.00	126.3	126.38
0.00	126.1	126.12
0.00	79.00	79.00
0.00	71.75	71.75
0.00	66.38	66.38
0.00	62.62	62.62
0.00	90.25	90.25
0.00	50.50	50.50
0.00	59.75	59.75
0.00	39.75	39.75
0.00	34.62	34.62
0.00	21.25	21.25
0.00	84.51	84.51

ext4

Advantage:

ext4 is better equipped to create large files than **ZFS**. Here we design a workload to create 3 files, each of size **500** MB, for both the file systems. Since **ext4** handles large files more efficiently, **ext4** takes only **15 intervals** of one second each to write the files and **ZFS** takes as long as **26 intervals**. So, for writing the same amount of data, ext4 takes less time than ZFS and thus ext4 has a better throughput (observation from **ext4_largefiles**.html and **zfs_largefiles**.**html**, created in the output folder after running vdbench).

Disadvantage:

ext4 instead of storing a list of every individual block which makes up the file, the idea is to store just the address of the first and last block of each continuous range of blocks. These continuous ranges of data blocks (and the pairs of numbers which represent them) are called extents. Extents take a constant amount of space regardless of how big a range of blocks it describes and hence for smaller files **ext4** has a larger overhead of metadata compared to metadata in **ZFS**.

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In the above screenshot we have created 3 files of size 100 KB in both the file systems.
Hence the metadata overhead in case of ext4 is : 316-3*100=16KB
Hence the metadata overhead in case of ZFS is : 306-3*100=6KB
Hence the metadata overhead in case of ext4 for small files is larger than that of ZFS.