The Apache HBASE Book

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Abstract

This is the official book of Apache HBase, a distributed, versioned, column-oriented database built on top of Apache Hadoop and Apache ZooKeeper.

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Preface

This book aims to be the official guide for the HBase version it ships with. This document describes HBase version *0.91.0-SNAPSHOT*. Herein you will find either the definitive documentation on an HBase topic as of its standing when the referenced HBase version shipped, or this book will point to the location in javadoc, JIRA or wiki where the pertinent information can be found.

This book is a work in progress. Feel free to add to this book by adding a patch to an issue up in the HBase JIRA.

Heads-up

If this is your first foray into the wonderful world of Distributed Computing, then you are in for some interesting times. First off, distributed systems are hard; making a distributed system hum requires a disparate skillset that needs span systems (hardware and software) and networking. Your cluster' operation can hiccup because of any of a myriad set of reasons from bugs in HBase itself through misconfigurations -- misconfiguration of HBase but also operating system misconfigurations -- through to hardware problems whether it be a bug in your network card drivers or an underprovisioned RAM bus (to mention two recent examples of hardware issues that manifested as "HBase is slow"). You will also need to do a recalibration if up to this your computing has been bound to a single box. Here is one good starting point: Fallacies of Distributed Computing.

Chapter 1. Getting Started

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1.1. Introduction

Section 1.2, “Quick Start” will get you up and running on a single-node instance of HBase using the local filesystem. Chapter 2, *Configuration* describes setup of HBase in distributed mode running on top of HDFS.

1.2. Quick Start

This guide describes setup of a standalone HBase instance that uses the local filesystem. It leads you through creating a table, inserting rows via the HBase **shell**, and then cleaning up and shutting down your standalone HBase instance. The below exercise should take no more than ten minutes (not including download time).

1.2.1. Download and unpack the latest stable release.

Choose a download site from this list of Apache Download Mirrors. Click on suggested top link. This will take you to a mirror of *HBase Releases*. Click on the folder named `stable` and then download the file that ends in `.tar.gz` to your local filesystem; e.g. `hbase-0.91.0-SNAPSHOT.tar.gz`.

Decompress and untar your download and then change into the unpacked directory.

```
$ tar xfz hbase-0.91.0-SNAPSHOT.tar.gz
$ cd hbase-0.91.0-SNAPSHOT
```

At this point, you are ready to start HBase. But before starting it, you might want to edit `conf/hbase-site.xml` and set the directory you want HBase to write to, `hbase.rootdir`.

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<configuration>
  <property>
    <name>hbase.rootdir</name>
    <value>file:///DIRECTORY/hbase</value>
  </property>
</configuration>
```

Replace `DIRECTORY` in the above with a path to a directory where you want HBase to store its data. By default, `hbase.rootdir` is set to `/tmp/hbase-${user.name}` which means you'll lose all your data whenever your server reboots (Most operating systems clear `/tmp` on restart).

1.2.2. Start HBase

Now start HBase:

```
$ ./bin/start-hbase.sh
starting Master, logging to logs/hbase-user-master-example.org.out
```

You should now have a running standalone HBase instance. In standalone mode, HBase runs all daemons in the the one JVM; i.e. both the HBase and ZooKeeper daemons. HBase logs can be found in the `logs` subdirectory. Check them out especially if HBase had trouble starting.

Is java installed?

All of the above presumes a 1.6 version of Oracle java is installed on your machine and available on your path; i.e. when you type java, you see output that describes the options the java program takes (HBase requires java 6). If this is not the case, HBase will not start. Install java, edit `conf/hbase-env.sh`, uncommenting the `JAVA_HOME` line pointing it to your java install. Then, retry the steps above.

1.2.3. Shell Exercises

Connect to your running HBase via the **shell**.

```
$ ./bin/hbase shell
HBase Shell; enter 'help<RETURN>' for list of supported commands.
Type "exit<RETURN>" to leave the HBase Shell
Version: 0.90.0, r1001068, Fri Sep 24 13:55:42 PDT 2010

hbase(main):001:0>
```

Type **help** and then **<RETURN>** to see a listing of shell commands and options. Browse at least the paragraphs at the end of the help emission for the gist of how variables and command arguments are entered into the HBase shell; in particular note how table names, rows, and columns, etc., must be quoted.

Create a table named `test` with a single column family named `cf`. Verify its creation by listing all tables and then insert some values.

```
hbase(main):003:0> create 'test', 'cf'
0 row(s) in 1.2200 seconds
hbase(main):003:0> list 'table'
test
1 row(s) in 0.0550 seconds
hbase(main):004:0> put 'test', 'row1', 'cf:a', 'value1'
0 row(s) in 0.0560 seconds
hbase(main):005:0> put 'test', 'row2', 'cf:b', 'value2'
0 row(s) in 0.0370 seconds
hbase(main):006:0> put 'test', 'row3', 'cf:c', 'value3'
0 row(s) in 0.0450 seconds
```

Above we inserted 3 values, one at a time. The first insert is at `row1`, column `cf:a` with a value of `value1`. Columns in HBase are comprised of a column family prefix -- `cf` in this example -- followed by a colon and then a column qualifier suffix (`a` in this case).

Verify the data insert.

Run a scan of the table by doing the following

```
hbase(main):007:0> scan 'test'
ROW        COLUMN+CELL
row1       column=cf:a, timestamp=1288380727188, value=value1
row2       column=cf:b, timestamp=1288380738440, value=value2
row3       column=cf:c, timestamp=1288380747365, value=value3
3 row(s) in 0.0590 seconds
```

Get a single row as follows

```
hbase(main):008:0> get 'test', 'row1'
COLUMN      CELL
cf:a        timestamp=1288380727188, value=value1
1 row(s) in 0.0400 seconds
```

Now, disable and drop your table. This will clean up all done above.

```
hbase(main):012:0> disable 'test'
0 row(s) in 1.0930 seconds
hbase(main):013:0> drop 'test'
0 row(s) in 0.0770 seconds
```

Exit the shell by typing exit.

```
hbase(main):014:0> exit
```

1.2.4. Stopping HBase

Stop your hbase instance by running the stop script.

```
$ ./bin/stop-hbase.sh
stopping hbase...............
```

1.2.5. Where to go next

The above described standalone setup is good for testing and experiments only. Next move on to Chapter 2, *Configuration* where we'll go into depth on the different HBase run modes, requirements and critical configurations needed setting up a distributed HBase deploy.

Chapter 2. Configuration

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This chapter is the Not-So-Quick start guide to HBase configuration.

Please read this chapter carefully and ensure that all requirements have been satisfied. Failure to do so will cause you (and us) grief debugging strange errors and/or data loss.

HBase uses the same configuration system as Hadoop. To configure a deploy, edit a file of environment variables in `conf/hbase-env.sh` -- this configuration is used mostly by the launcher shell scripts getting the cluster off the ground -- and then add configuration to an XML file to do things like override HBase defaults, tell HBase what Filesystem to use, and the location of the ZooKeeper ensemble [1] .

When running in distributed mode, after you make an edit to an HBase configuration, make sure you copy the content of the `conf` directory to all nodes of the cluster. HBase will not do this for you. Use **rsync**.

2.1. Java

Just like Hadoop, HBase requires java 6 from Oracle. Usually you'll want to use the latest version available except the problematic u18 (u24 is the latest version as of this writing).

2.2. Operating System

2.2.1. ssh

ssh must be installed and **sshd** must be running to use Hadoop's scripts to manage remote Hadoop and HBase daemons. You must be able to ssh to all nodes, including your local node, using passwordless login (Google "ssh passwordless login").

2.2.2. DNS

HBase uses the local hostname to self-report it's IP address. Both forward and reverse DNS resolving should work.

If your machine has multiple interfaces, HBase will use the interface that the primary hostname resolves to.

If this is insufficient, you can set `hbase.regionserver.dns.interface` to indicate the primary interface. This only works if your cluster configuration is consistent and every host has the same network interface configuration.

Another alternative is setting `hbase.regionserver.dns.nameserver` to choose a different nameserver than the system wide default.

2.2.3. NTP

The clocks on cluster members should be in basic alignments. Some skew is tolerable but wild skew could generate odd behaviors. Run NTP on your cluster, or an equivalent.

If you are having problems querying data, or "weird" cluster operations, check system time!

2.2.4. `ulimit` and `nproc`

HBase is a database. It uses a lot of files all at the same time. The default ulimit -n -- i.e. user file limit -- of 1024 on most *nix systems is insufficient (On mac os x its 256). Any significant amount of loading will lead you to FAQ: Why do I see "java.io.IOException...(Too many open files)" in my logs?. You may also notice errors such as

```
      2010-04-06 03:04:37,542 INFO org.apache.hadoop.hdfs.DFSClient: Exception
increateBlockOutputStream java.io.EOFException
      2010-04-06 03:04:37,542 INFO org.apache.hadoop.hdfs.DFSClient: Abandoning block
blk_-6935524980745310745_1391901
```

Do yourself a favor and change the upper bound on the number of file descriptors. Set it to north of 10k. See the above referenced FAQ for how. You should also up the hbase users' `nproc` setting; under load, a low-nproc setting could manifest as `OutOfMemoryError` [2] [3].

To be clear, upping the file descriptors and nproc for the user who is running the HBase process is an operating system configuration, not an HBase configuration. Also, a common mistake is that administrators will up the file descriptors for a particular user but for whatever reason, HBase will be running as some one else. HBase prints in its logs as the first line the ulimit its seeing. Ensure its correct. [4]

2.2.4.1. `ulimit` on Ubuntu

If you are on Ubuntu you will need to make the following changes:

In the file `/etc/security/limits.conf` add a line like:

```
hadoop  -       nofile  32768
```

Replace `hadoop` with whatever user is running Hadoop and HBase. If you have separate users, you will need 2 entries, one for each user. In the same file set nproc hard and soft limits. For example:

```
hadoop soft/hard nproc 32000
```

.

In the file `/etc/pam.d/common-session` add as the last line in the file:

```
session required  pam_limits.so
```

Otherwise the changes in `/etc/security/limits.conf` won't be applied.

Don't forget to log out and back in again for the changes to take effect!

2.2.5. Windows

HBase has been little tested running on Windows. Running a production install of HBase on top of Windows is not recommended.

If you are running HBase on Windows, you must install Cygwin to have a *nix-like environment for the shell scripts. The full details are explained in the Windows Installation guide. Also search our user mailing list to pick up latest fixes figured by Windows users.

2.3. Hadoop

This version of HBase will only run on Hadoop 0.20.x. It will not run on hadoop 0.21.x (nor 0.22.x). HBase will lose data unless it is running on an HDFS that has a durable `sync`. Hadoop 0.20.2 and Hadoop 0.20.203.0 DO NOT have this attribute. Currently only the branch-0.20-append branch has this a working sync[5]. No official releases have been made from the branch-0.20-append branch up to now so you will have to build your own Hadoop from the tip of this branch. Michael Noll has written a detailed blog, Building an Hadoop 0.20.x version for HBase 0.90.2, on how to build an Hadoop from branch-0.20-append. Recommended [6].

Or rather than build your own, you could use the Cloudera or MapR distributions. Cloudera' CDH3 is Apache Hadoop 0.20.x plus patches including all of the 0.20-append additions needed to add a durable sync. Use the released version of CDH3 at least (They have just posted an update). MapR includes a commercial, reimplementation of HDFS. It has a durable sync as well as some other interesting features that are not yet in Apache Hadoop. Their M3 product is free to use and unlimited.

Because HBase depends on Hadoop, it bundles an instance of the Hadoop jar under its `lib` directory. The bundled Hadoop was made from the Apache branch-0.20-append branch at the time of the HBase's release. The bundled jar is ONLY for use in standalone mode. In distributed mode, it is *critical* that the version of Hadoop that is out on your cluster match what is under HBase. Replace the hadoop jar found in the HBase `lib` directory with the hadoop jar you are running on your cluster to avoid version mismatch issues. Make sure you replace the jar in HBase everywhere on your cluster. Hadoop version mismatch issues have various manifestations but often all looks like its hung up.

2.3.1. Hadoop Security

HBase will run on any Hadoop 0.20.x that incorporates Hadoop security features -- e.g. Y! 0.20S or CDH3B3 -- as long as you do as suggested above and replace the Hadoop jar that ships with HBase with the secure version.

2.3.2. `dfs.datanode.max.xcievers`

An Hadoop HDFS datanode has an upper bound on the number of files that it will serve at any one time. The upper bound parameter is called `xcievers` (yes, this is misspelled). Again, before doing any loading, make sure you have configured Hadoop's `conf/hdfs-site.xml` setting the `xceivers` value to at least the following:

```
<property>
  <name>dfs.datanode.max.xcievers</name>
  <value>4096</value>
</property>
```

Be sure to restart your HDFS after making the above configuration.

Not having this configuration in place makes for strange looking failures. Eventually you'll see a complain in the datanode logs complaining about the xcievers exceeded, but on the run up to this one manifestation is complaint about missing blocks. For example: `10/12/08 20:10:31 INFO hdfs.DFSClient: Could not obtain block blk_XXXXXXXXXXXXXXXXXXXXXX_YYYYYYYY from any node: java.io.IOException: No live nodes contain current block. Will get new block locations from namenode and retry...` [7]

2.4. HBase run modes: Standalone and Distributed

HBase has two run modes: Section 2.4.1, "Standalone HBase" and Section 2.4.2, "Distributed". Out of the box, HBase runs in standalone mode. To set up a distributed deploy, you will need to configure HBase by editing files in the HBase `conf` directory.

Whatever your mode, you will need to edit `conf/hbase-env.sh` to tell HBase which **java** to use. In this file you set HBase environment variables such as the heapsize and other options for the JVM, the preferred location for log files, etc. Set `JAVA_HOME` to point at the root of your **java** install.

2.4.1. Standalone HBase

This is the default mode. Standalone mode is what is described in the Section 1.2, "Quick Start" section. In standalone mode, HBase does not use HDFS -- it uses the local filesystem instead -- and it runs all HBase daemons and a local ZooKeeper all up in the same JVM. Zookeeper binds to a well known port so clients may talk to HBase.

2.4.2. Distributed

Distributed mode can be subdivided into distributed but all daemons run on a single node -- a.k.a *pseudo-distributed*-- and *fully-distributed* where the daemons are spread across all nodes in the cluster [8].

Distributed modes require an instance of the *Hadoop Distributed File System* (HDFS). See the Hadoop requirements and instructions for how to set up a HDFS. Before proceeding, ensure you have an appropriate, working HDFS.

Below we describe the different distributed setups. Starting, verification and exploration of your install, whether a *pseudo-distributed* or *fully-distributed* configuration is described in a section that follows, Section 2.4.3, "Running and Confirming Your Installation". The same verification script applies to both deploy types.

2.4.2.1. Pseudo-distributed

A pseudo-distributed mode is simply a distributed mode run on a single host. Use this configuration testing and prototyping on HBase. Do not use this configuration for production nor for evaluating HBase performance.

Once you have confirmed your HDFS setup, edit `conf/hbase-site.xml`. This is the file into which you add local customizations and overrides for <xreg></xreg> and Section 2.4.2.2.3, “HDFS Client Configuration”. Point HBase at the running Hadoop HDFS instance by setting the `hbase.rootdir` property. This property points HBase at the Hadoop filesystem instance to use. For example, adding the properties below to your `hbase-site.xml` says that HBase should use the `/hbase` directory in the HDFS whose namenode is at port 9000 on your local machine, and that it should run with one replica only (recommended for pseudo-distributed mode):

```
<configuration>
  ...
  <property>
    <name>hbase.rootdir</name>
    <value>hdfs://localhost:9000/hbase</value>
    <description>The directory shared by RegionServers.
    </description>
  </property>
  <property>
    <name>dfs.replication</name>
    <value>1</value>
    <description>The replication count for HLog and HFile storage. Should not be greater
than HDFS datanode count.
    </description>
  </property>
  ...
</configuration>
```

Note

Let HBase create the `hbase.rootdir` directory. If you don't, you'll get warning saying HBase needs a migration run because the directory is missing files expected by HBase (it'll create them if you let it).

Note

Above we bind to `localhost`. This means that a remote client cannot connect. Amend accordingly, if you want to connect from a remote location.

Now skip to Section 2.4.3, “Running and Confirming Your Installation” for how to start and verify your pseudo-distributed install. [9]

2.4.2.2. Fully-distributed

For running a fully-distributed operation on more than one host, make the following configurations. In `hbase-site.xml`, add the property `hbase.cluster.distributed` and set it to `true` and point the HBase `hbase.rootdir` at the appropriate HDFS NameNode and location in HDFS where you would like HBase to write data. For example, if you namenode were running at namenode.example.org on port 9000 and you wanted to home your HBase in HDFS at `/hbase`, make the following configuration.

```
<configuration>
  ...
  <property>
    <name>hbase.rootdir</name>
    <value>hdfs://namenode.example.org:9000/hbase</value>
    <description>The directory shared by RegionServers.
    </description>
  </property>
  <property>
    <name>hbase.cluster.distributed</name>
    <value>true</value>
    <description>The mode the cluster will be in. Possible values are
      false: standalone and pseudo-distributed setups with managed Zookeeper
      true: fully-distributed with unmanaged Zookeeper Quorum (see hbase-env.sh)
    </description>
  </property>
  ...
</configuration>
```

2.4.2.2.1. `regionservers`

In addition, a fully-distributed mode requires that you modify `conf/regionservers`. The Section 2.7.1.2, "`regionservers`" file lists all hosts that you would have running HRegionServers, one host per line (This file in HBase is like the Hadoop `slaves` file). All servers listed in this file will be started and stopped when HBase cluster start or stop is run.

2.4.2.2.2. ZooKeeper and HBase

See section Section 2.5, "ZooKeeper" for ZooKeeper setup for HBase.

2.4.2.2.3. HDFS Client Configuration

Of note, if you have made *HDFS client configuration* on your Hadoop cluster -- i.e. configuration you want HDFS clients to use as opposed to server-side configurations -- HBase will not see this configuration unless you do one of the following:

- Add a pointer to your `HADOOP_CONF_DIR` to the `HBASE_CLASSPATH` environment variable in `hbase-env.sh`.
- Add a copy of `hdfs-site.xml` (or `hadoop-site.xml`) or, better, symlinks, under `${HBASE_HOME}/conf`, or
- if only a small set of HDFS client configurations, add them to `hbase-site.xml`.

An example of such an HDFS client configuration is `dfs.replication`. If for example, you want to run with a replication factor of 5, hbase will create files with the default of 3 unless you do the above to make the configuration available to HBase.

2.4.3. Running and Confirming Your Installation

Make sure HDFS is running first. Start and stop the Hadoop HDFS daemons by running `bin/start-hdfs.sh` over in the `HADOOP_HOME` directory. You can ensure it started properly by testing the **put** and **get** of files into the Hadoop filesystem. HBase does not normally use the mapreduce daemons. These do not need to be started.

If you are managing your own ZooKeeper, start it and confirm its running else, HBase will start up ZooKeeper for you as part of its start process.

Start HBase with the following command:

```
bin/start-hbase.sh
```

Run the above from the `HBASE_HOME` directory.

You should now have a running HBase instance. HBase logs can be found in the `logs` subdirectory. Check them out especially if HBase had trouble starting.

HBase also puts up a UI listing vital attributes. By default its deployed on the Master host at port 60010 (HBase RegionServers listen on port 60020 by default and put up an informational http server at 60030). If the Master were running on a host named `master.example.org` on the default port, to see the Master's homepage you'd point your browser at `http://master.example.org:60010`.

Once HBase has started, see the Section 1.2.3, "Shell Exercises" for how to create tables, add data, scan your insertions, and finally disable and drop your tables.

To stop HBase after exiting the HBase shell enter

```
$ ./bin/stop-hbase.sh
stopping hbase...............
```

Shutdown can take a moment to complete. It can take longer if your cluster is comprised of many machines. If you are running a distributed operation, be sure to wait until HBase has shut down completely before stopping the Hadoop daemons.

2.5. ZooKeeper

A distributed HBase depends on a running ZooKeeper cluster. All participating nodes and clients need to be able to access the running ZooKeeper ensemble. HBase by default manages a ZooKeeper "cluster" for you. It will start and stop the ZooKeeper ensemble as part of the HBase start/stop process. You can also manage the ZooKeeper ensemble independent of HBase and just point HBase at the cluster it should use. To toggle HBase management of ZooKeeper, use the `HBASE_MANAGES_ZK` variable in `conf/hbase-env.sh`. This variable, which defaults to `true`, tells HBase whether to start/stop the ZooKeeper ensemble servers as part of HBase start/stop.

When HBase manages the ZooKeeper ensemble, you can specify ZooKeeper configuration using its native `zoo.cfg` file, or, the easier option is to just specify ZooKeeper options directly in `conf/hbase-site.xml`. A ZooKeeper configuration option can be set as a property in the HBase `hbase-site.xml` XML configuration file by prefacing the ZooKeeper option name with `hbase.zookeeper.property`. For example, the `clientPort` setting in ZooKeeper can be changed by setting the `hbase.zookeeper.property.clientPort` property. For all default values used by HBase, including ZooKeeper configuration, see Section 2.6.1.1, "HBase Default Configuration". Look for the `hbase.zookeeper.property` prefix [10]

You must at least list the ensemble servers in `hbase-site.xml` using the `hbase.zookeeper.quorum` property. This property defaults to a single ensemble member at `localhost` which is not suitable for a fully distributed HBase. (It binds to the local machine only and remote clients will not be able to connect).

How many ZooKeepers should I run?

You can run a ZooKeeper ensemble that comprises 1 node only but in production it is recommended that you run a ZooKeeper ensemble of 3, 5 or 7 machines; the more members an ensemble has, the more tolerant the ensemble is of host failures. Also, run an odd number of machines. There can be no quorum if the number of members is an even number. Give each ZooKeeper server around 1GB of RAM, and if possible, its own dedicated disk (A dedicated disk is the best thing you can do to ensure a performant ZooKeeper ensemble). For very heavily loaded clusters, run ZooKeeper servers on separate machines from RegionServers (DataNodes and TaskTrackers).

For example, to have HBase manage a ZooKeeper quorum on nodes *rs{1,2,3,4,5}.example.com*, bound to port 2222 (the default is 2181) ensure `HBASE_MANAGE_ZK` is commented out or set to `true` in `conf/hbase-env.sh` and then edit `conf/hbase-site.xml` and set `hbase.zookeeper.property.clientPort` and `hbase.zookeeper.quorum`. You should also set `hbase.zookeeper.property.dataDir` to other than the default as the default has ZooKeeper persist data under `/tmp` which is often cleared on system restart. In the example below we have ZooKeeper persist to `/user/local/zookeeper`.

```
  <configuration>
    ...
    <property>
      <name>hbase.zookeeper.property.clientPort</name>
      <value>2222</value>
      <description>Property from ZooKeeper's config zoo.cfg.
      The port at which the clients will connect.
      </description>
    </property>
    <property>
      <name>hbase.zookeeper.quorum</name>
      <value>rs1.example.com,rs2.example.com,rs3.example.com,rs4.example.com,rs5.example.c
om</value>
      <description>Comma separated list of servers in the ZooKeeper Quorum.
      For example, "host1.mydomain.com,host2.mydomain.com,host3.mydomain.com".
      By default this is set to localhost for local and pseudo-distributed modes
      of operation. For a fully-distributed setup, this should be set to a full
      list of ZooKeeper quorum servers. If HBASE_MANAGES_ZK is set in hbase-env.sh
      this is the list of servers which we will start/stop ZooKeeper on.
      </description>
    </property>
    <property>
      <name>hbase.zookeeper.property.dataDir</name>
      <value>/usr/local/zookeeper</value>
      <description>Property from ZooKeeper's config zoo.cfg.
      The directory where the snapshot is stored.
      </description>
    </property>
    ...
  </configuration>
```

2.5.1. Using existing ZooKeeper ensemble

To point HBase at an existing ZooKeeper cluster, one that is not managed by HBase, set `HBASE_MANAGES_ZK` in `conf/hbase-env.sh` to false

```
  ...
  # Tell HBase whether it should manage it's own instance of Zookeeper or not.
  export HBASE_MANAGES_ZK=false
```

Next set ensemble locations and client port, if non-standard, in `hbase-site.xml`, or add a suitably configured `zoo.cfg` to HBase's `CLASSPATH`. HBase will prefer the configuration found in `zoo.cfg` over any settings in `hbase-site.xml`.

When HBase manages ZooKeeper, it will start/stop the ZooKeeper servers as a part of the regular start/stop scripts. If you would like to run ZooKeeper yourself, independent of HBase start/stop, you would do the following

```
${HBASE_HOME}/bin/hbase-daemons.sh {start,stop} zookeeper
```

Note that you can use HBase in this manner to spin up a ZooKeeper cluster, unrelated to HBase. Just make sure to set `HBASE_MANAGES_ZK` to `false` if you want it to stay up across HBase restarts so that when HBase shuts down, it doesn't take ZooKeeper down with it.

For more information about running a distinct ZooKeeper cluster, see the ZooKeeper Getting Started Guide. Additionally, see the ZooKeeper Wiki or the ZooKeeper documentation for more information on ZooKeeper sizing.

2.6. Configuration Files

2.6.1. `hbase-site.xml` and `hbase-default.xml`

Just as in Hadoop where you add site-specific HDFS configuration to the `hdfs-site.xml` file, for HBase, site specific customizations go into the file `conf/hbase-site.xml`. For the list of configurable properties, see Section 2.6.1.1, "HBase Default Configuration" below or view the raw `hbase-default.xml` source file in the HBase source code at `src/main/resources`.

Not all configuration options make it out to `hbase-default.xml`. Configuration that it is thought rare anyone would change can exist only in code; the only way to turn up such configurations is via a reading of the source code itself.

Currently, changes here will require a cluster restart for HBase to notice the change.

2.6.1.1. HBase Default Configuration

HBase Default Configuration

The documentation below is generated using the default hbase configuration file, `hbase-default.xml`, as source.

`hbase.rootdir`

> The directory shared by region servers and into which HBase persists. The URL should be 'fully-qualified' to include the filesystem scheme. For example, to specify the HDFS directory '/hbase'

where the HDFS instance's namenode is running at namenode.example.org on port 9000, set this value to: hdfs://namenode.example.org:9000/hbase. By default HBase writes into /tmp. Change this configuration else all data will be lost on machine restart.

Default: `file:///tmp/hbase-${user.name}/hbase`

`hbase.master.port`

The port the HBase Master should bind to.

Default: `60000`

`hbase.cluster.distributed`

The mode the cluster will be in. Possible values are false for standalone mode and true for distributed mode. If false, startup will run all HBase and ZooKeeper daemons together in the one JVM.

Default: `false`

`hbase.tmp.dir`

Temporary directory on the local filesystem. Change this setting to point to a location more permanent than '/tmp' (The '/tmp' directory is often cleared on machine restart).

Default: `/tmp/hbase-${user.name}`

`hbase.master.info.port`

The port for the HBase Master web UI. Set to -1 if you do not want a UI instance run.

Default: `60010`

`hbase.master.info.bindAddress`

The bind address for the HBase Master web UI

Default: `0.0.0.0`

`hbase.client.write.buffer`

Default size of the HTable clien write buffer in bytes. A bigger buffer takes more memory -- on both the client and server side since server instantiates the passed write buffer to process it -- but a larger buffer size reduces the number of RPCs made. For an estimate of server-side memory-used, evaluate hbase.client.write.buffer * hbase.regionserver.handler.count

Default: `2097152`

`hbase.regionserver.port`

The port the HBase RegionServer binds to.

Default: `60020`

`hbase.regionserver.info.port`

The port for the HBase RegionServer web UI Set to -1 if you do not want the RegionServer UI to run.

Default: `60030`

`hbase.regionserver.info.port.auto`

Whether or not the Master or RegionServer UI should search for a port to bind to. Enables automatic port search if hbase.regionserver.info.port is already in use. Useful for testing, turned off by default.

Default: `false`

`hbase.regionserver.info.bindAddress`

The address for the HBase RegionServer web UI

Default: `0.0.0.0`

`hbase.regionserver.class`

The RegionServer interface to use. Used by the client opening proxy to remote region server.

Default: `org.apache.hadoop.hbase.ipc.HRegionInterface`

`hbase.client.pause`

General client pause value. Used mostly as value to wait before running a retry of a failed get, region lookup, etc.

Default: `1000`

`hbase.client.retries.number`

Maximum retries. Used as maximum for all retryable operations such as fetching of the root region from root region server, getting a cell's value, starting a row update, etc. Default: 10.

Default: `10`

`hbase.client.scanner.caching`

Number of rows that will be fetched when calling next on a scanner if it is not served from (local, client) memory. Higher caching values will enable faster scanners but will eat up more memory and some calls of next may take longer and longer times when the cache is empty. Do not set this value such that the time between invocations is greater than the scanner timeout; i.e. hbase.regionserver.lease.period

Default: `1`

`hbase.client.keyvalue.maxsize`

Specifies the combined maximum allowed size of a KeyValue instance. This is to set an upper boundary for a single entry saved in a storage file. Since they cannot be split it helps avoiding that a region cannot be split any further because the data is too large. It seems wise to set this to a fraction of the maximum region size. Setting it to zero or less disables the check.

Default: `10485760`

`hbase.regionserver.lease.period`

HRegion server lease period in milliseconds. Default is 60 seconds. Clients must report in within this period else they are considered dead.

Default: `60000`

`hbase.regionserver.handler.count`

Count of RPC Listener instances spun up on RegionServers. Same property is used by the Master for count of master handlers. Default is 10.

Default: `10`

`hbase.regionserver.msginterval`

Interval between messages from the RegionServer to Master in milliseconds.

Default: `3000`

`hbase.regionserver.optionallogflushinterval`

Sync the HLog to the HDFS after this interval if it has not accumulated enough entries to trigger a sync. Default 1 second. Units: milliseconds.

Default: `1000`

`hbase.regionserver.regionSplitLimit`

Limit for the number of regions after which no more region splitting should take place. This is not a hard limit for the number of regions but acts as a guideline for the regionserver to stop splitting after a certain limit. Default is set to MAX_INT; i.e. do not block splitting.

Default: `2147483647`

`hbase.regionserver.logroll.period`

Period at which we will roll the commit log regardless of how many edits it has.

Default: `3600000`

`hbase.regionserver.hlog.reader.impl`

The HLog file reader implementation.

Default: `org.apache.hadoop.hbase.regionserver.wal.SequenceFileLogReader`

`hbase.regionserver.hlog.writer.impl`

The HLog file writer implementation.

Default: `org.apache.hadoop.hbase.regionserver.wal.SequenceFileLogWriter`

`hbase.regionserver.nbreservationblocks`

The number of resevoir blocks of memory release on OOME so we can cleanup properly before server shutdown.

Default: `4`

`hbase.zookeeper.dns.interface`

The name of the Network Interface from which a ZooKeeper server should report its IP address.

Default: `default`

`hbase.zookeeper.dns.nameserver`

The host name or IP address of the name server (DNS) which a ZooKeeper server should use to determine the host name used by the master for communication and display purposes.

Default: `default`

`hbase.regionserver.dns.interface`

The name of the Network Interface from which a region server should report its IP address.

Default: `default`

`hbase.regionserver.dns.nameserver`

The host name or IP address of the name server (DNS) which a region server should use to determine the host name used by the master for communication and display purposes.

Default: `default`

`hbase.master.dns.interface`

The name of the Network Interface from which a master should report its IP address.

Default: `default`

`hbase.master.dns.nameserver`

The host name or IP address of the name server (DNS) which a master should use to determine the host name used for communication and display purposes.

Default: `default`

`hbase.balancer.period`

Period at which the region balancer runs in the Master.

Default: `300000`

`hbase.regions.slop`

Rebalance if any regionserver has average + (average * slop) regions. Default is 20% slop.

Default: `0.2`

`hbase.master.logcleaner.ttl`

Maximum time a HLog can stay in the .oldlogdir directory, after which it will be cleaned by a Master thread.

Default: `600000`

`hbase.master.logcleaner.plugins`

A comma-separated list of LogCleanerDelegate invoked by the LogsCleaner service. These WAL/HLog cleaners are called in order, so put the HLog cleaner that prunes the most HLog files in front. To implement your own LogCleanerDelegate, just put it in HBase's classpath and add the fully qualified class name here. Always add the above default log cleaners in the list.

Default: `org.apache.hadoop.hbase.master.TimeToLiveLogCleaner` `hbase.regionserver.global.memstore.upperLimit`

Maximum size of all memstores in a region server before new updates are blocked and flushes are forced. Defaults to 40% of heap

Default: `0.4`

`hbase.regionserver.global.memstore.lowerLimit`

When memstores are being forced to flush to make room in memory, keep flushing until we hit this mark. Defaults to 35% of heap. This value equal to hbase.regionserver.global.memstore.upperLimit causes the minimum possible flushing to occur when updates are blocked due to memstore limiting.

Default: `0.35`

`hbase.server.thread.wakefrequency`

Time to sleep in between searches for work (in milliseconds). Used as sleep interval by service threads such as log roller.

Default: `10000`

`hbase.hregion.memstore.flush.size`

Memstore will be flushed to disk if size of the memstore exceeds this number of bytes. Value is checked by a thread that runs every hbase.server.thread.wakefrequency.

Default: `67108864`

`hbase.hregion.preclose.flush.size`

If the memstores in a region are this size or larger when we go to close, run a "pre-flush" to clear out memstores before we put up the region closed flag and take the region offline. On close, a flush is run under the close flag to empty memory. During this time the region is offline and we are not taking on any writes. If the memstore content is large, this flush could take a long time to complete. The preflush is meant to clean out the bulk of the memstore before putting up the close flag and taking the region offline so the flush that runs under the close flag has little to do.

Default: `5242880`

`hbase.hregion.memstore.block.multiplier`

Block updates if memstore has hbase.hregion.block.memstore time hbase.hregion.flush.size bytes. Useful preventing runaway memstore during spikes in update traffic. Without an upper-bound, memstore fills such that when it flushes the resultant flush files take a long time to compact or split, or worse, we OOME.

Default: `2`

`hbase.hregion.memstore.mslab.enabled`

Enables the MemStore-Local Allocation Buffer, a feature which works to prevent heap fragmentation under heavy write loads. This can reduce the frequency of stop-the-world GC pauses on large heaps.

Default: `true`

`hbase.hregion.max.filesize`

Maximum HStoreFile size. If any one of a column families' HStoreFiles has grown to exceed this value, the hosting HRegion is split in two. Default: 256M.

Default: `268435456`

`hbase.hstore.compactionThreshold`

If more than this number of HStoreFiles in any one HStore (one HStoreFile is written per flush of memstore) then a compaction is run to rewrite all HStoreFiles files as one. Larger numbers put off compaction but when it runs, it takes longer to complete.

Default: `3`

`hbase.hstore.blockingStoreFiles`

If more than this number of StoreFiles in any one Store (one StoreFile is written per flush of MemStore) then updates are blocked for this HRegion until a compaction is completed, or until hbase.hstore.blockingWaitTime has been exceeded.

Default: `7`

`hbase.hstore.blockingWaitTime`

The time an HRegion will block updates for after hitting the StoreFile limit defined by hbase.hstore.blockingStoreFiles. After this time has elapsed, the HRegion will stop blocking updates even if a compaction has not been completed. Default: 90 seconds.

Default: `90000`

`hbase.hstore.compaction.max`

Max number of HStoreFiles to compact per 'minor' compaction.

Default: `10`

`hbase.hregion.majorcompaction`

The time (in miliseconds) between 'major' compactions of all HStoreFiles in a region. Default: 1 day. Set to 0 to disable automated major compactions.

Default: `86400000`

`hbase.mapreduce.hfileoutputformat.blocksize`

The mapreduce HFileOutputFormat writes storefiles/hfiles. This is the minimum hfile blocksize to emit. Usually in hbase, writing hfiles, the blocksize is gotten from the table schema (HColumnDescriptor) but in the mapreduce outputformat context, we don't have access to the schema so get blocksize from Configuation. The smaller you make the blocksize, the bigger your index and the less you fetch on a random-access. Set the blocksize down if you have small cells and want faster random-access of individual cells.

Default: `65536`

`hfile.block.cache.size`

Percentage of maximum heap (-Xmx setting) to allocate to block cache used by HFile/StoreFile. Default of 0.2 means allocate 20%. Set to 0 to disable.

Default: `0.2`

`hbase.hash.type`

The hashing algorithm for use in HashFunction. Two values are supported now: murmur (MurmurHash) and jenkins (JenkinsHash). Used by bloom filters.

Default: `murmur`

`hfile.block.index.cacheonwrite`

This allows to put non-root multi-level index blocks into the block cache at the time the index is being written.

Default: `false`

`hfile.index.block.max.size`

When the size of a leaf-level, intermediate-level, or root-level index block in a multi-level block index grows to this size, the block is written out and a new block is started.

Default: `131072`

`hfile.format.version`

The HFile format version to use for new files. Set this to 1 to test backwards-compatibility. The default value of this option should be consistent with FixedFileTrailer.MAX_VERSION.

Default: `2`

`io.storefile.bloom.block.size`

The size in bytes of a single block ("chunk") of a compound Bloom filter. This size is approximate, because Bloom blocks can only be inserted at data block boundaries, and the number of keys per data block varies.

Default: `131072`

`io.storefile.bloom.cacheonwrite`

Enables cache-on-write for inline blocks of a compound Bloom filter.

Default: `false`

`hbase.rs.cacheblocksonwrite`

Whether an HFile block should be added to the block cache when the block is finished.

Default: `false`

`hbase.rpc.engine`

Implementation of org.apache.hadoop.hbase.ipc.RpcEngine to be used for client / server RPC call marshalling.

Default: `org.apache.hadoop.hbase.ipc.WritableRpcEngine`

`hbase.master.keytab.file`

Full path to the kerberos keytab file to use for logging in the configured HMaster server principal.

Default:

`hbase.master.kerberos.principal`

Ex. "hbase/_HOST@EXAMPLE.COM". The kerberos principal name that should be used to run the HMaster process. The principal name should be in the form: user/hostname@DOMAIN. If "_HOST" is used as the hostname portion, it will be replaced with the actual hostname of the running instance.

Default:

`hbase.regionserver.keytab.file`

Full path to the kerberos keytab file to use for logging in the configured HRegionServer server principal.

Default:

`hbase.regionserver.kerberos.principal`

Ex. "hbase/_HOST@EXAMPLE.COM". The kerberos principal name that should be used to run the HRegionServer process. The principal name should be in the form: user/hostname@DOMAIN. If "_HOST" is used as the hostname portion, it will be replaced with the actual hostname of the running instance. An entry for this principal must exist in the file specified in hbase.regionserver.keytab.file

Default:

`zookeeper.session.timeout`

ZooKeeper session timeout. HBase passes this to the zk quorum as suggested maximum time for a session (This setting becomes zookeeper's 'maxSessionTimeout'). See http://hadoop.apache.org/zookeeper/docs/current/zookeeperProgrammers.html#ch_zkSessions "The client sends a requested timeout, the server responds with the timeout that it can give the client. " In milliseconds.

Default: `180000`

`zookeeper.znode.parent`

Root ZNode for HBase in ZooKeeper. All of HBase's ZooKeeper files that are configured with a relative path will go under this node. By default, all of HBase's ZooKeeper file path are configured with a relative path, so they will all go under this directory unless changed.

Default: `/hbase`

`zookeeper.znode.rootserver`

Path to ZNode holding root region location. This is written by the master and read by clients and region servers. If a relative path is given, the parent folder will be ${zookeeper.znode.parent}. By default, this means the root location is stored at /hbase/root-region-server.

Default: `root-region-server`

`hbase.coprocessor.region.classes`

A comma-separated list of Coprocessors that are loaded by default on all tables. For any override coprocessor method, these classes will be called in order. After implementing your own Coprocessor, just put it in HBase's classpath and add the fully qualified class name here. A coprocessor can also be loaded on demand by setting HTableDescriptor.

Default:

`hbase.coprocessor.master.classes`

A comma-separated list of org.apache.hadoop.hbase.coprocessor.MasterObserver coprocessors that are loaded by default on the active HMaster process. For any implemented coprocessor methods, the listed classes will be called in order. After implementing your own MasterObserver, just put it in HBase's classpath and add the fully qualified class name here.

Default:

`hbase.zookeeper.quorum`

Comma separated list of servers in the ZooKeeper Quorum. For example, "host1.mydomain.com,host2.mydomain.com,host3.mydomain.com". By default this is set to localhost for local and pseudo-distributed modes of operation. For a fully-distributed setup, this should be set to a full list of ZooKeeper quorum servers. If HBASE_MANAGES_ZK is set in hbase-env.sh this is the list of servers which we will start/stop ZooKeeper on.

Default: `localhost`

`hbase.zookeeper.peerport`

Port used by ZooKeeper peers to talk to each other. See http://hadoop.apache.org/zookeeper/docs/r3.1.1/zookeeperStarted.html#sc_RunningReplicatedZooKeeper for more information.

Default: `2888`

`hbase.zookeeper.leaderport`

Port used by ZooKeeper for leader election. See http://hadoop.apache.org/zookeeper/docs/r3.1.1/zookeeperStarted.html#sc_RunningReplicatedZooKeeper for more information.

Default: `3888`

`hbase.zookeeper.property.initLimit`

Property from ZooKeeper's config zoo.cfg. The number of ticks that the initial synchronization phase can take.

Default: `10`

`hbase.zookeeper.property.syncLimit`

Property from ZooKeeper's config zoo.cfg. The number of ticks that can pass between sending a request and getting an acknowledgment.

Default: `5`

`hbase.zookeeper.property.dataDir`

Property from ZooKeeper's config zoo.cfg. The directory where the snapshot is stored.

Default: `${hbase.tmp.dir}/zookeeper`

`hbase.zookeeper.property.clientPort`

Property from ZooKeeper's config zoo.cfg. The port at which the clients will connect.

Default: `2181`

`hbase.zookeeper.property.maxClientCnxns`

Property from ZooKeeper's config zoo.cfg. Limit on number of concurrent connections (at the socket level) that a single client, identified by IP address, may make to a single member of the ZooKeeper ensemble. Set high to avoid zk connection issues running standalone and pseudo-distributed.

Default: `30`

`hbase.rest.port`

The port for the HBase REST server.

Default: `8080`

`hbase.rest.readonly`

Defines the mode the REST server will be started in. Possible values are: false: All HTTP methods are permitted - GET/PUT/POST/DELETE. true: Only the GET method is permitted.

Default: `false`

`hbase.defaults.for.version.skip`

Set to true to skip the 'hbase.defaults.for.version' check. Setting this to true can be useful in contexts other than the other side of a maven generation; i.e. running in an ide. You'll want to set this boolean to true to avoid seeing the RuntimException complaint: "hbase-default.xml file seems to be for and old version of HBase (@@@VERSION@@@), this version is X.X.X-SNAPSHOT"

Default: `false`

2.6.2. `hbase-env.sh`

Set HBase environment variables in this file. Examples include options to pass the JVM on start of an HBase daemon such as heap size and garbarge collector configs. You can also set configurations for HBase configuration, log directories, niceness, ssh options, where to locate process pid files, etc. Open the file at `conf/hbase-env.sh` and peruse its content. Each option is fairly well documented. Add your own environment variables here if you want them read by HBase daemons on startup.

Changes here will require a cluster restart for HBase to notice the change.

2.6.3. `log4j.properties`

Edit this file to change rate at which HBase files are rolled and to change the level at which HBase logs messages.

Changes here will require a cluster restart for HBase to notice the change though log levels can be changed for particular daemons via the HBase UI.

2.6.4. Client configuration and dependencies connecting to an HBase cluster

Since the HBase Master may move around, clients bootstrap by looking to ZooKeeper for current critical locations. ZooKeeper is where all these values are kept. Thus clients require the location of the ZooKeeper ensemble information before they can do anything else. Usually this the ensemble location is kept out in the `hbase-site.xml` and is picked up by the client from the `CLASSPATH`.

If you are configuring an IDE to run a HBase client, you should include the `conf/` directory on your classpath so `hbase-site.xml` settings can be found (or add `src/test/resources` to pick up the hbase-site.xml used by tests).

Minimally, a client of HBase needs the hbase, hadoop, log4j, commons-logging, commons-lang, and ZooKeeper jars in its `CLASSPATH` connecting to a cluster.

An example basic `hbase-site.xml` for client only might look as follows:

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<configuration>
  <property>
    <name>hbase.zookeeper.quorum</name>
    <value>example1,example2,example3</value>
    <description>The directory shared by region servers.
    </description>
  </property>
</configuration>
```

2.6.4.1. Java client configuration

The configuration used by a Java client is kept in an HBaseConfiguration instance. The factory method on HBaseConfiguration, `HBaseConfiguration.create();`, on invocation, will read in the content of the first `hbase-site.xml` found on the client's `CLASSPATH`, if one is present (Invocation will also factor in any `hbase-default.xml` found; an hbase-default.xml ships inside the `hbase.X.X.X.jar`). It is also possible to specify configuration directly without having to read from a `hbase-site.xml`. For example, to set the ZooKeeper ensemble for the cluster programmatically do as follows:

```
Configuration config = HBaseConfiguration.create();
config.set("hbase.zookeeper.quorum", "localhost");  // Here we are running zookeeper
locally
```

If multiple ZooKeeper instances make up your ZooKeeper ensemble, they may be specified in a comma-separated list (just as in the `hbase-site.xml` file). This populated `Configuration` instance can then be passed to an HTable, and so on.

2.7. Example Configurations

2.7.1. Basic Distributed HBase Install

Here is an example basic configuration for a distributed ten node cluster. The nodes are named `example0`, `example1`, etc., through node `example9` in this example. The HBase Master and the HDFS namenode are running on the node `example0`. RegionServers run on nodes `example1`-`example9`. A 3-node ZooKeeper ensemble runs on `example1`, `example2`, and `example3` on the default ports. ZooKeeper data is persisted to the directory `/export/zookeeper`. Below we show what the main configuration files -- `hbase-site.xml`, `regionservers`, and `hbase-env.sh` -- found in the HBase `conf` directory might look like.

2.7.1.1. `hbase-site.xml`

```
<?xml version="1.0"?>
<?xml-stylesheet type="text/xsl" href="configuration.xsl"?>
<configuration>
  <property>
    <name>hbase.zookeeper.quorum</name>
    <value>example1,example2,example3</value>
    <description>The directory shared by RegionServers.
    </description>
  </property>
  <property>
    <name>hbase.zookeeper.property.dataDir</name>
    <value>/export/zookeeper</value>
    <description>Property from ZooKeeper's config zoo.cfg.
    The directory where the snapshot is stored.
    </description>
  </property>
  <property>
    <name>hbase.rootdir</name>
    <value>hdfs://example0:9000/hbase</value>
    <description>The directory shared by RegionServers.
    </description>
  </property>
  <property>
    <name>hbase.cluster.distributed</name>
    <value>true</value>
    <description>The mode the cluster will be in. Possible values are
      false: standalone and pseudo-distributed setups with managed Zookeeper
      true: fully-distributed with unmanaged Zookeeper Quorum (see hbase-env.sh)
    </description>
  </property>
</configuration>
```

2.7.1.2. `regionservers`

In this file you list the nodes that will run RegionServers. In our case we run RegionServers on all but the head node `example1` which is carrying the HBase Master and the HDFS namenode

```
example1
example3
example4
example5
example6
example7
example8
example9
```

2.7.1.3. `hbase-env.sh`

Below we use a **diff** to show the differences from default in the `hbase-env.sh` file. Here we are setting the HBase heap to be 4G instead of the default 1G.

```
$ git diff hbase-env.sh
diff --git a/conf/hbase-env.sh b/conf/hbase-env.sh
index e70ebc6..96f8c27 100644
--- a/conf/hbase-env.sh
+++ b/conf/hbase-env.sh
@@ -31,7 +31,7 @@ export JAVA_HOME=/usr/lib//jvm/java-6-sun/
 # export HBASE_CLASSPATH=

 # The maximum amount of heap to use, in MB. Default is 1000.
-# export HBASE_HEAPSIZE=1000
+export HBASE_HEAPSIZE=4096

 # Extra Java runtime options.
 # Below are what we set by default.  May only work with SUN JVM.
```

Use **rsync** to copy the content of the `conf` directory to all nodes of the cluster.

2.8. The Important Configurations

Below we list what the *important* Configurations. We've divided this section into required configuration and worth-a-look recommended configs.

2.8.1. Required Configurations

Review the Section 2.2, “Operating System” and Section 2.3, “Hadoop” sections.

2.8.2. Recommended Configuations

2.8.2.1. `zookeeper.session.timeout`

The default timeout is three minutes (specified in milliseconds). This means that if a server crashes, it will be three minutes before the Master notices the crash and starts recovery. You might like to tune the timeout down to a minute or even less so the Master notices failures the sooner. Before changing this value, be sure you have your JVM garbage collection configuration under control otherwise, a long garbage collection that lasts beyond the ZooKeeper session timeout will take out your RegionServer (You might be fine with this -- you probably want recovery to start on the server if a RegionServer has been in GC for a long period of time).

To change this configuration, edit `hbase-site.xml`, copy the changed file around the cluster and restart.

We set this value high to save our having to field noob questions up on the mailing lists asking why a RegionServer went down during a massive import. The usual cause is that their JVM is untuned and they are running into long GC pauses. Our thinking is that while users are getting familiar with HBase, we'd save them having to know all of its intricacies. Later when they've built some confidence, then they can play with configuration such as this.

2.8.2.2. Number of ZooKeeper Instances

See Section 2.5, “ZooKeeper”.

2.8.2.3. `hbase.regionserver.handler.count`

This setting defines the number of threads that are kept open to answer incoming requests to user tables. The default of 10 is rather low in order to prevent users from killing their region servers when using large write buffers with a high number of concurrent clients. The rule of thumb is to keep this number low when the payload per request approaches the MB (big puts, scans using a large cache) and high when the payload is small (gets, small puts, ICVs, deletes).

It is safe to set that number to the maximum number of incoming clients if their payload is small, the typical example being a cluster that serves a website since puts aren't typically buffered and most of the operations are gets.

The reason why it is dangerous to keep this setting high is that the aggregate size of all the puts that are currently happening in a region server may impose too much pressure on its memory, or even trigger an OutOfMemoryError. A region server running on low memory will trigger its JVM's garbage collector to run more frequently up to a point where GC pauses become noticeable (the reason being that all the memory used to keep all the requests' payloads cannot be trashed, no matter how hard the garbage collector tries). After some time, the overall cluster throughput is affected since every request that hits that region server will take longer, which exacerbates the problem even more.

2.8.2.4. Configuration for large memory machines

HBase ships with a reasonable, conservative configuration that will work on nearly all machine types that people might want to test with. If you have larger machines -- HBase has 8G and larger heap -- you might the following configuration options helpful. TODO.

2.8.2.5. Compression

You should consider enabling ColumnFamily compression. There are several options that are near-frictionless and in most all cases boost performance by reducing the size of StoreFiles and thus reducing I/O.

See Appendix B, *Compression In HBase* for more information.

2.8.2.6. Bigger Regions

Consider going to larger regions to cut down on the total number of regions on your cluster. Generally less Regions to manage makes for a smoother running cluster (You can always later manually split the big Regions should one prove hot and you want to spread the request load over the cluster). By default, regions are 256MB in size. You could run with 1G. Some run with even larger regions; 4G or even larger. Adjust `hbase.hregion.max.filesize` in your `hbase-site.xml`.

2.8.2.7. Managed Splitting

Rather than let HBase auto-split your Regions, manage the splitting manually [11]. With growing amounts of data, splits will continually be needed. Since you always know exactly what regions you have, long-term debugging and profiling is much easier with manual splits. It is hard to trace the logs to understand region level problems if it keeps splitting and getting renamed. Data offlining bugs + unknown number of split regions == oh crap! If an `HLog` or `StoreFile` was mistakenly unprocessed by HBase due to a weird bug and you notice it a day or so later, you can be assured that the regions specified in these files are the same as the current regions and you have less headaches trying to restore/replay your data. You can finely tune your compaction algorithm. With roughly uniform data growth, it's easy to cause split / compaction storms as the regions all roughly hit the same data size at the same time. With manual splits, you can let staggered, time-based major compactions spread out your network IO load.

How do I turn off automatic splitting? Automatic splitting is determined by the configuration value `hbase.hregion.max.filesize`. It is not recommended that you set this to `Long.MAX_VALUE` in case you forget about manual splits. A suggested setting is 100GB, which would result in > 1hr major compactions if reached.

What's the optimal number of pre-split regions to create? Mileage will vary depending upon your application. You could start low with 10 pre-split regions / server and watch as data grows over time. It's better to err on the side of too little regions and rolling split later. A more complicated answer is that this depends upon the largest storefile in your region. With a growing data size, this will get larger over time. You want the largest region to be just big enough that the `Store` compact selection algorithm only compacts it due to a timed major. If you don't, your cluster can be prone to compaction storms as the algorithm decides to run major compactions on a large series of regions all at once. Note that compaction storms are due to the uniform data growth, not the manual split decision.

If you pre-split your regions too thin, you can increase the major compaction interval by configuring `HConstants.MAJOR_COMPACTION_PERIOD`. If your data size grows too large, use the (post-0.90.0 HBase) `org.apache.hadoop.hbase.util.RegionSplitter` script to perform a network IO safe rolling split of all regions.

2.8.2.8. Managed Compactions

A common administrative technique is to manage major compactions manually, rather than letting

HBase do it. By default, `HConstants.MAJOR_COMPACTION_PERIOD` is one day and major compactions may kick in when you least desire it - especially on a busy system. To "turn off" automatic major compactions set the value to `Long.MAX_VALUE`.

It is important to stress that major compactions are absolutely necessary for StoreFile cleanup, the only variant is when they occur. They can be administered through the HBase shell, or via HBaseAdmin.

---

[1] Be careful editing XML. Make sure you close all elements. Run your file through **xmllint** or similar to ensure well-formedness of your document after an edit session.

[2] See Jack Levin's major hdfs issues note up on the user list.

[3] The requirement that a database requires upping of system limits is not peculiar to HBase. See for example the section *Setting Shell Limits for the Oracle User* in Short Guide to install Oracle 10 on Linux.

[4] A useful read setting config on you hadoop cluster is Aaron Kimballs' Configuration Parameters: What can you just ignore?

[5] See CHANGES.txt in branch-0.20-append to see list of patches involved adding append on the Hadoop 0.20 branch.

[6] Praveen Kumar has written a complimentary article, Building Hadoop and HBase for HBase Maven application development.

[7] See Hadoop HDFS: Deceived by Xciever for an informative rant on xceivering.

[8] The pseudo-distributed vs fully-distributed nomenclature comes from Hadoop.

[9] See Pseudo-distributed mode extras for notes on how to start extra Masters and RegionServers when running pseudo-distributed.

[10] For the full list of ZooKeeper configurations, see ZooKeeper's `zoo.cfg`. HBase does not ship with a `zoo.cfg` so you will need to browse the `conf` directory in an appropriate ZooKeeper download.

[11] What follows is taken from the javadoc at the head of the `org.apache.hadoop.hbase.util.RegionSplitter` tool added to HBase post-0.90.0 release.

Chapter 3. Upgrading

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Review Chapter 2, *Configuration*, in particular the section on Hadoop version.

3.1. Upgrading to HBase 0.90.x from 0.20.x or 0.89.x

This version of 0.90.x HBase can be started on data written by HBase 0.20.x or HBase 0.89.x. There is no need of a migration step. HBase 0.89.x and 0.90.x does write out the name of region directories differently -- it names them with a md5 hash of the region name rather than a jenkins hash -- so this means that once started, there is no going back to HBase 0.20.x.

Be sure to remove the `hbase-default.xml` from your `conf` directory on upgrade. A 0.20.x version of this file will have sub-optimal configurations for 0.90.x HBase. The `hbase-default.xml` file is now bundled into the HBase jar and read from there. If you would like to review the content of this file, see it in the src tree at `src/main/resources/hbase-default.xml` or see Section 2.6.1.1, "HBase Default Configuration".

Finally, if upgrading from 0.20.x, check your `.META.` schema in the shell. In the past we would recommend that users run with a 16kb `MEMSTORE_FLUSHSIZE`. Run `hbase> scan '-ROOT-'` in the shell. This will output the current `.META.` schema. Check `MEMSTORE_FLUSHSIZE` size. Is it 16kb (16384)? If so, you will need to change this (The 'normal'/default value is 64MB (67108864)). Run the script `bin/set_meta_memstore_size.rb`. This will make the necessary edit to your `.META.` schema. Failure to run this change will make for a slow cluster [12] .

---

[12] See HBASE-3499 Users upgrading to 0.90.0 need to have their .META. table updated with the right MEMSTORE_SIZE

Chapter 4. The HBase Shell

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The HBase Shell is (J)Ruby's IRB with some HBase particular commands added. Anything you can do in IRB, you should be able to do in the HBase Shell.

To run the HBase shell, do as follows:

```
$ ./bin/hbase shell
```

Type **help** and then **<RETURN>** to see a listing of shell commands and options. Browse at least the paragraphs at the end of the help emission for the gist of how variables and command arguments are entered into the HBase shell; in particular note how table names, rows, and columns, etc., must be quoted.

See Section 1.2.3, "Shell Exercises" for example basic shell operation.

4.1. Scripting

For examples scripting HBase, look in the HBase `bin` directory. Look at the files that end in `*.rb`. To run one of these files, do as follows:

```
$ ./bin/hbase org.jruby.Main PATH_TO_SCRIPT
```

4.2. Shell Tricks

4.2.1. `irbrc`

Create an `.irbrc` file for yourself in your home directory. Add customizations. A useful one is command history so commands are save across Shell invocations:

```
                        $ more .irbrc
                        require 'irb/ext/save-history'
                        IRB.conf[:SAVE_HISTORY] = 100
                        IRB.conf[:HISTORY_FILE] = "#{ENV['HOME']}/.irb-save-history"
```

See the ruby documentation of `.irbrc` to learn about other possible confiurations.

4.2.2. LOG data to timestamp

To convert the date '08/08/16 20:56:29' from an hbase log into a timestamp, do:

```
                    hbase(main):021:0> import java.text.SimpleDateFormat
                    hbase(main):022:0> import java.text.ParsePosition
                    hbase(main):023:0> SimpleDateFormat.new("yy/MM/dd
HH:mm:ss").parse("08/08/16 20:56:29", ParsePosition.new(0)).getTime() => 1218920189000
```

To go the other direction:

```
                    hbase(main):021:0> import java.util.Date
                    hbase(main):022:0> Date.new(1218920189000).toString() => "Sat Aug 16
20:56:29 UTC 2008"
```

To output in a format that is exactly like that of the HBase log format will take a little messing with SimpleDateFormat.

4.2.3. Debug

4.2.3.1. Shell debug switch

You can set a debug switch in the shell to see more output -- e.g. more of the stack trace on exception -- when you run a command:

```
hbase> debug <RETURN>
```

4.2.3.2. DEBUG log level

To enable DEBUG level logging in the shell, launch it with the **-d** option.

```
$ ./bin/hbase shell -d
```

Chapter 5. HBase and MapReduce

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See HBase and MapReduce up in javadocs. Start there. Below is some additional help.

5.1. The default HBase MapReduce Splitter

When TableInputFormat, is used to source an HBase table in a MapReduce job, its splitter will make a map task for each region of the table. Thus, if there are 100 regions in the table, there will be 100 map-tasks for the job - regardless of how many column families are selected in the Scan.

5.2. HBase Input MapReduce Example

To use HBase as a MapReduce source, the job would be configured via TableMapReduceUtil in the following manner...

```
Job job = ...;
Scan scan = new Scan();
scan.setCaching(500);  // 1 is the default in Scan, which will be bad for MapReduce jobs
scan.setCacheBlocks(false);
// Now set other scan attrs
...

TableMapReduceUtil.initTableMapperJob(
  tableName,            // input HBase table name
  scan,                         // Scan instance to control CF and attribute selection
  MyMapper.class,               // mapper
  Text.class,           // reducer key
  LongWritable.class,   // reducer value
  job                   // job instance
  );
```

...and the mapper instance would extend TableMapper...

```
public class MyMapper extends TableMapper<Text, LongWritable> {
public void map(ImmutableBytesWritable row, Result value, Context context)
throws InterruptedException, IOException {
// process data for the row from the Result instance.
```

5.3. Accessing Other HBase Tables in a MapReduce Job

Although the framework currently allows one HBase table as input to a MapReduce job, other HBase tables can be accessed as lookup tables, etc., in a MapReduce job via creating an HTable instance in the setup method of the Mapper.

```
public class MyMapper extends TableMapper<Text, LongWritable> {
  private HTable myOtherTable;

  @Override
  public void setup(Context context) {
    myOtherTable = new HTable("myOtherTable");
  }
```

5.4. Speculative Execution

It is generally advisable to turn off speculative execution for MapReduce jobs that use HBase as a source. This can either be done on a per-Job basis through properties, on on the entire cluster. Especially for longer running jobs, speculative execution will create duplicate map-tasks which will double-write your data to HBase; this is probably not what you want.

Chapter 6. HBase and Schema Design

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A good general introduction on the strength and weaknesses modelling on the various non-rdbms datastores is Ian Varleys' Master thesis, No Relation: The Mixed Blessings of Non-Relational Databases. Recommended.

6.1. Schema Creation

HBase schemas can be created or updated with Chapter 4, *The HBase Shell* or by using HBaseAdmin in the Java API.

Tables must be disabled when making ColumnFamily modifications, for example..

```
Configuration config = HBaseConfiguration.create();
HBaseAdmin admin = new HBaseAdmin(conf);
String table = "myTable";

admin.disableTable(table);

HColumnDescriptor cf1 = ...;
admin.addColumn(table, cf1  );      // adding new ColumnFamily
HColumnDescriptor cf2 = ...;
admin.modifyColumn(table, cf2 );    // modifying existing ColumnFamily

admin.enableTable(table);
```

See Section 2.6.4, “Client configuration and dependencies connecting to an HBase cluster” for more information about configuring client connections.

6.2. On the number of column families

HBase currently does not do well with anything about two or three column families so keep the number of column families in your schema low. Currently, flushing and compactions are done on a per Region basis so if one column family is carrying the bulk of the data bringing on flushes, the adjacent families will also be flushed though the amount of data they carry is small. Compaction is currently triggered by the total number of files under a column family. Its not size based. When many column families the flushing and compaction interaction can make for a bunch of needless i/o loading (To be addressed by changing flushing and compaction to work on a per column family basis).

Try to make do with one column famliy if you can in your schemas. Only introduce a second and third column family in the case where data access is usually column scoped; i.e. you query one column family or the other but usually not both at the one time.

6.3. Monotonically Increasing Row Keys/Timeseries Data

In the HBase chapter of Tom White's book Hadoop: The Definitive Guide (O'Reilly) there is a an optimization note on watching out for a phenomenon where an import process walks in lock-step with all clients in concert pounding one of the table's regions (and thus, a single node), then moving onto the next region, etc. With monotonically increasing row-keys (i.e., using a timestamp), this will happen. See this comic by IKai Lan on why monotically increasing row keys are problematic in BigTable-like datastores: monotonically increasing values are bad. The pile-up on a single region brought on by monoticially increasing keys can be mitigated by randomizing the input records to not be in sorted order, but in general its best to avoid using a timestamp or a sequence (e.g. 1, 2, 3) as the row-key.

If you do need to upload time series data into HBase, you should study OpenTSDB as a successful example. It has a page describing the schema it uses in HBase. The key format in OpenTSDB is effectively [metric_type][event_timestamp], which would appear at first glance to contradict the previous advice about not using a timestamp as the key. However, the difference is that the timestamp is not in the *lead* position of the key, and the design assumption is that there are dozens or hundreds (or more) of different metric types. Thus, even with a continual stream of input data with a mix of metric types, the Puts are distributed across various points of regions in the table.

6.4. Try to minimize row and column sizes

Or why are my storefile indices large?

In HBase, values are always freighted with their coordinates; as a cell value passes through the system, it'll be accompanied by its row, column name, and timestamp. Always. If your rows and column names are large, especially compared to the size of the cell value, then you may run up against some interesting scenarios. One such is the case described by Marc Limotte at the tail of HBASE-3551 (recommended!). Therein, the indices that are kept on HBase storefiles (Section 10.3.4.2, “StoreFile (HFile)”) to facilitate random access may end up occupyng large chunks of the HBase allotted RAM because the cell value coordinates are large. Mark in the above cited comment suggests upping the block size so entries in the store file index happen at a larger interval or modify the table schema so it makes for smaller rows and column names. Compression will also make for larger indices. See the thread a question storefileIndexSize up on the user mailing list. `

6.5. Number of Versions

The number of row versions to store is configured per column family via HColumnDescriptor. The default is 3. This is an important parameter because as described in Chapter 9, *Data Model* section HBase does *not* overwrite row values, but rather stores different values per row by time (and qualifier). Excess versions are removed during major compactions. The number of versions may need to be increased or decreased depending on application needs.

6.6. Immutability of Rowkeys

Rowkeys cannot be changed. The only way they can be "changed" in a table is if the row is deleted and then re-inserted. This is a fairly common question on the HBase dist-list so it pays to get the rowkeys right the first time (and/or before you've inserted a lot of data).

6.7. Supported Datatypes

HBase supports a "bytes-in/bytes-out" interface via Put and Result, so anything that can be converted to an array of bytes can be stored as a value. Input could be strings, numbers, complex objects, or even images as long as they can rendered as bytes.

There are practical limits to the size of values (e.g., storing 10-50MB objects in HBase would probably be too much to ask); search the mailling list for conversations on this topic. All rows in HBase conform to the Chapter 9, *Data Model*, and that includes versioning. Take that into consideration when making your design, as well as block size for the ColumnFamily.

6.7.1. Counters

One supported datatype that deserves special mention are "counters" (i.e., the ability to do atomic increments of numbers). See Increment in HTable.

Synchronization on counters are done on the RegionServer, not in the client.

6.8. In-Memory ColumnFamilies

ColumnFamilies can optionally be defined as in-memory. Data is still persisted to disk, just like any other ColumnFamily. In-memory blocks have the highest priority in the Section 10.3.5, “Block Cache”, but it is not a guarantee that the entire table will be in memory.

See HColumnDescriptor for more information.

6.9. Secondary Indexes and Alternate Query Paths

This section could also be titled "what if my table rowkey looks like *this* but I also want to query my table like *that*." A common example on the dist-list is where a row-key is of the format "user-timestamp" but there are are reporting requirements on activity across users for certain time ranges. Thus, selecting by user is easy because it is in the lead position of the key, but time is not.

There is no single answer on the best way to handle this because it depends on...

- Number of users
- Data size and data arrival rate
- Flexibility of reporting requirements (e.g., completely ad-hoc date selection vs. pre-configured ranges)
- Desired execution speed of query (e.g., 90 seconds may be reasonable to some for an ad-hoc report, whereas it may be too long for others)

... and solutions are also influenced by the size of the cluster and how much processing power you have to throw at the solution. Common techniques are in sub-sections below. This is a comprehensive, but not exhaustive, list of approaches.

It should not be a surprise that secondary indexes require additional cluster space and processing. This is precisely what happens in an RDBMS because the act of creating an alternate index requires both space and processing cycles to update. RBDMS products are more advanced in this regard to handle alternative index management out of the box. However, HBase scales better at larger data volumes, so this is a feature trade-off.

Pay attention to Chapter 11, *Performance Tuning* when implementing any of these approaches.

Additionally, see the David Butler response in this dist-list thread HBase, mail # user - Stargate+hbase

6.9.1. Filter Query

Depending on the case, it may be appropriate to use Section 10.1.3, “Filters”. In this case, no secondary index is created. However, don't try a full-scan on a large table like this from an application (i.e., single-threaded client).

6.9.2. Periodic-Update Secondary Index

A secondary index could be created in an other table which is periodically updated via a MapReduce job. The job could be executed intra-day, but depending on load-strategy it could still potentially be out of sync with the main data table.

See Chapter 5, *HBase and MapReduce* for more information.

6.9.3. Dual-Write Secondary Index

Another strategy is to build the secondary index while publishing data to the cluster (e.g., write to data table, write to index table). If this is approach is taken after a data table already exists, then bootstrapping will be needed for the secondary index with a MapReduce job (see Section 6.9.2, “ Periodic-Update Secondary Index ”).

6.9.4. Summary Tables

Where time-ranges are very wide (e.g., year-long report) and where the data is voluminous, summary tables are a common approach. These would be generated with MapReduce jobs into another table.

See Chapter 5, *HBase and MapReduce* for more information.

6.9.5. Coprocessor Secondary Index

Coprocessors act like RDBMS triggers. These are currently on TRUNK.

Chapter 7. Metrics

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7.1. Metric Setup

See Metrics for an introduction and how to enable Metrics emission.

7.2. RegionServer Metrics

7.2.1. `hbase.regionserver.blockCacheCount`

Block cache item count in memory. This is the number of blocks of storefiles (HFiles) in the cache.

7.2.2. `hbase.regionserver.blockCacheFree`

Block cache memory available (bytes).

7.2.3. `hbase.regionserver.blockCacheHitRatio`

Block cache hit ratio (0 to 100). TODO: describe impact to ratio where read requests that have cacheBlocks=false

7.2.4. `hbase.regionserver.blockCacheSize`

Block cache size in memory (bytes). i.e., memory in use by the BlockCache

7.2.5. `hbase.regionserver.compactionQueueSize`

Size of the compaction queue. This is the number of stores in the region that have been targeted for compaction.

7.2.6. `hbase.regionserver.fsReadLatency_avg_time`

Filesystem read latency (ms). This is the average time to read from HDFS.

7.2.7. `hbase.regionserver.fsReadLatency_num_ops`

TODO

7.2.8. `hbase.regionserver.fsSyncLatency_avg_time`

Filesystem sync latency (ms)

7.2.9. `hbase.regionserver.fsSyncLatency_num_ops`

TODO

7.2.10. `hbase.regionserver.fsWriteLatency_avg_time`

Filesystem write latency (ms)

7.2.11. `hbase.regionserver.fsWriteLatency_num_ops`

TODO

7.2.12. `hbase.regionserver.memstoreSizeMB`

Sum of all the memstore sizes in this RegionServer (MB)

7.2.13. `hbase.regionserver.regions`

Number of regions served by the RegionServer

7.2.14. `hbase.regionserver.requests`

Total number of read and write requests. Requests correspond to RegionServer RPC calls, thus a single Get will result in 1 request, but a Scan with caching set to 1000 will result in 1 request for each 'next' call (i.e., not each row). A bulk-load request will constitute 1 request per HFile.

7.2.15. `hbase.regionserver.storeFileIndexSizeMB`

Sum of all the storefile index sizes in this RegionServer (MB)

7.2.16. `hbase.regionserver.stores`

Number of stores open on the RegionServer. A store corresponds to a column family. For example, if a table (which contains the column family) has 3 regions on a RegionServer, there will be 3 stores open for that column family.

7.2.17. `hbase.regionserver.storeFiles`

Number of store filles open on the RegionServer. A store may have more than one storefile (HFile).

Chapter 8. Cluster Replication

See Cluster Replication.

Chapter 9. Data Model

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In short, applications store data into an HBase table. Tables are made of rows and columns. All columns in HBase belong to a particular column family. Table cells -- the intersection of row and column coordinates -- are versioned. A cell's content is an uninterpreted array of bytes.

Table row keys are also byte arrays so almost anything can serve as a row key from strings to binary representations of longs or even serialized data structures. Rows in HBase tables are sorted by row key. The sort is byte-ordered. All table accesses are via the table row key -- its primary key.

9.1. Conceptual View

The following example is a slightly modified form of the one on page 2 of the BigTable paper. There is a table called `webtable` that contains two column families named `contents` and `anchor`. In this example, `anchor` contains two columns (`anchor:cssnsi.com`, `anchor:my.look.ca`) and `contents` contains one column (`contents:html`).

Column Names

By convention, a column name is made of its column family prefix and a *qualifier*. For example, the column *contents:html* is of the column family `contents` The colon character (`:`) delimits the column family from the column family *qualifier*.

Table 9.1. Table `webtable`

Row Key	**Time Stamp**	**ColumnFamily `contents`**	**ColumnFamily `anchor`**
"com.cnn.www"	t9		`anchor:cnnsi.com` = "CNN"
"com.cnn.www"	t8		`anchor:my.look.ca` = "CNN.com"
"com.cnn.www"	t6	`contents:html` = "<html>..."	
"com.cnn.www"	t5	`contents:html` = "<html>..."	
"com.cnn.www"	t3	`contents:html` = "<html>..."	

9.2. Physical View

Although at a conceptual level tables may be viewed as a sparse set of rows. Physically they are stored on a per-column family basis. New columns (i.e., `columnfamily:column`) can be added to any column family without pre-announcing them.

Table 9.2. ColumnFamily `anchor`

Row Key	**Time Stamp**	**Column Family `anchor`**
"com.cnn.www"	t9	`anchor:cnnsi.com` = "CNN"
"com.cnn.www"	t8	`anchor:my.look.ca` = "CNN.com"

Table 9.3. ColumnFamily `contents`

Row Key	**Time Stamp**	**ColumnFamily "contents:"**
"com.cnn.www"	t6	`contents:html` = "<html>..."
"com.cnn.www"	t5	`contents:html` = "<html>..."
"com.cnn.www"	t3	`contents:html` = "<html>..."

It is important to note in the diagram above that the empty cells shown in the conceptual view are not stored since they need not be in a column-oriented storage format. Thus a request for the value of the `contents:html` column at time stamp `t8` would return no value. Similarly, a request for an `anchor:my.look.ca` value at time stamp `t9` would return no value. However, if no timestamp is supplied, the most recent value for a particular column would be returned and would also be the first one found since timestamps are stored in descending order. Thus a request for the values of all columns in the row `com.cnn.www` if no timestamp is specified would be: the value of `contents:html` from time stamp `t6`, the value of `anchor:cnnsi.com` from time stamp `t9`, the value of `anchor:my.look.ca` from time stamp `t8`.

9.3. Table

Tables are declared up front at schema definition time.

9.4. Row

Row keys are uninterrpreted bytes. Rows are lexicographically sorted with the lowest order appearing first in a table. The empty byte array is used to denote both the start and end of a tables' namespace.

9.5. Column Family

Columns in HBase are grouped into *column families*. All column members of a column family have the same prefix. For example, the columns *courses:history* and *courses:math* are both members of the *courses* column family. The colon character (`:`) delimits the column family from the . The column family prefix must be composed of *printable* characters. The qualifying tail, the column family *qualifier*, can be made of any arbitrary bytes. Column families must be declared up front at schema definition time whereas columns do not need to be defined at schema time but can be conjured on the fly while the table is up an running.

Physically, all column family members are stored together on the filesystem. Because tunings and storage specifications are done at the column family level, it is advised that all column family members have the same general access pattern and size characteristics.

9.6. Cells

A *{row, column, version}* tuple exactly specifies a `cell` in HBase. Cell content is uninterrpreted bytes

9.7. Versions

A *{row, column, version}* tuple exactly specifies a `cell` in HBase. Its possible to have an unbounded number of cells where the row and column are the same but the cell address differs only in its version dimension.

While rows and column keys are expressed as bytes, the version is specified using a long integer. Typically this long contains time instances such as those returned by `java.util.Date.getTime()` or `System.currentTimeMillis()`, that is: “the difference, measured in milliseconds, between the current time and midnight, January 1, 1970 UTC”.

The HBase version dimension is stored in decreasing order, so that when reading from a store file, the most recent values are found first.

There is a lot of confusion over the semantics of `cell` versions, in HBase. In particular, a couple questions that often come up are:

- If multiple writes to a cell have the same version, are all versions maintained or just the last?[13]
- Is it OK to write cells in a non-increasing version order?[14]

Below we describe how the version dimension in HBase currently works[15].

9.7.1. Versions and HBase Operations

In this section we look at the behavior of the version dimension for each of the core HBase operations.

9.7.1.1. Get/Scan

Gets are implemented on top of Scans. The below discussion of Get applies equally to Scans.

By default, i.e. if you specify no explicit version, when doing a `get`, the cell whose version has the largest value is returned (which may or may not be the latest one written, see later). The default behavior can be modified in the following ways:

- to return more than one version, see Get.setMaxVersions()
- to return versions other than the latest, see Get.setTimeRange()

  To retrieve the latest version that is less than or equal to a given value, thus giving the 'latest' state of the record at a certain point in time, just use a range from 0 to the desired version and set the max versions to 1.

9.7.1.2. Default Get Example

The following Get will only retrieve the current version of the row

```
        Get get = new Get(Bytes.toBytes("row1"));
        Result r = htable.get(get);
        byte[] b = r.getValue(Bytes.toBytes("cf"), Bytes.toBytes("attr"));  // returns
current version of value
```

9.7.1.3. Versioned Get Example

The following Get will return the last 3 versions of the row.

```
        Get get = new Get(Bytes.toBytes("row1"));
        get.setMaxVersions(3);  // will return last 3 versions of row
        Result r = htable.get(get);
        byte[] b = r.getValue(Bytes.toBytes("cf"), Bytes.toBytes("attr"));  // returns
current version of value
        List<KeyValue> kv = r.getColumn(Bytes.toBytes("cf"), Bytes.toBytes("attr"));  //
returns all versions of this column
```

9.7.1.4. Put

Doing a put always creates a new version of a `cell`, at a certain timestamp. By default the system uses the server's `currentTimeMillis`, but you can specify the version (= the long integer) yourself, on a per-column level. This means you could assign a time in the past or the future, or use the long value for non-time purposes.

To overwrite an existing value, do a put at exactly the same row, column, and version as that of the cell you would overshadow.

9.7.1.4.1. Implicit Version Example

The following Put will be implicitly versioned by HBase with the current time.

```
          Put put = new Put(Bytes.toBytes(row));
          put.add(Bytes.toBytes("cf"), Bytes.toBytes("attr1"), Bytes.toBytes( data));
          htable.put(put);
```

9.7.1.4.2. Explicit Version Example

The following Put has the version timestamp explicitly set.

```
          Put put = new Put( Bytes.toBytes(row ));
          long explicitTimeInMs = 555;  // just an example
          put.add(Bytes.toBytes("cf"), Bytes.toBytes("attr1"), explicitTimeInMs,
Bytes.toBytes(data));
          htable.put(put);
```

9.7.1.5. Delete

When performing a delete operation in HBase, there are two ways to specify the versions to be deleted

- Delete all versions older than a certain timestamp
- Delete the version at a specific timestamp

A delete can apply to a complete row, a complete column family, or to just one column. It is only in the last case that you can delete explicit versions. For the deletion of a row or all the columns within a family, it always works by deleting all cells older than a certain version.

Deletes work by creating *tombstone* markers. For example, let's suppose we want to delete a row. For this you can specify a version, or else by default the `currentTimeMillis` is used. What this means is “delete all cells where the version is less than or equal to this version”. HBase never modifies data in place, so for example a delete will not immediately delete (or mark as deleted) the entries in the storage file that correspond to the delete condition. Rather, a so-called *tombstone* is written, which will mask the deleted values[16]. If the version you specified when deleting a row is larger than the version of any value in the row, then you can consider the complete row to be deleted.

9.7.2. Current Limitations

There are still some bugs (or at least 'undecided behavior') with the version dimension that will be addressed by later HBase releases.

9.7.2.1. Deletes mask Puts

Deletes mask puts, even puts that happened after the delete was entered[17]. Remember that a delete writes a tombstone, which only disappears after then next major compaction has run. Suppose you do a delete of everything <= T. After this you do a new put with a timestamp <= T. This put, even if it happened after the delete, will be masked by the delete tombstone. Performing the put will not fail, but when you do a get you will notice the put did have no effect. It will start working again after the major compaction has run. These issues should not be a problem if you use always-increasing versions for new puts to a row. But they can occur even if you do not care about time: just do delete and put immediately after each other, and there is some chance they happen within the same millisecond.

9.7.2.2. Major compactions change query results

“...create three cell versions at t1, t2 and t3, with a maximum-versions setting of 2. So when getting all versions, only the values at t2 and t3 will be returned. But if you delete the version at t2 or t3, the one at t1 will appear again. Obviously, once a major compaction has run, such behavior will not be the case anymore...[18]”

[13] Currently, only the last written is fetchable.

[14] Yes

[15] See HBASE-2406 for discussion of HBase versions. Bending time in HBase makes for a good read on the version, or time, dimension in HBase. It has more detail on versioning than is provided here. As of this writing, the limiitation *Overwriting values at existing timestamps* mentioned in the article no longer holds in HBase. This section is basically a synopsis of this article by Bruno Dumon.

[16] When HBase does a major compaction, the tombstones are processed to actually remove the dead values, together with the tombstones themselves.

[17] HBASE-2256

[18] See *Garbage Collection* in Bending time in HBase

Chapter 10. Architecture

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10.1. Client

The HBase client HTable is responsible for finding RegionServers that are serving the particular row range of interest. It does this by querying the `.META.` and `-ROOT-` catalog tables (TODO: Explain). After locating the required region(s), the client *directly* contacts the RegionServer serving that region (i.e., it does not go through the master) and issues the read or write request. This information is cached in the client so that subsequent requests need not go through the lookup process. Should a region be reassigned either by the master load balancer or because a RegionServer has died, the client will requery the catalog tables to determine the new location of the user region.

Administrative functions are handled through HBaseAdmin

10.1.1. Connections

For connection configuration information, see Section 2.6.4, "Client configuration and dependencies connecting to an HBase cluster".

HTable instances are not thread-safe. When creating HTable instances, it is advisable to use the same HBaseConfiguration instance. This will ensure sharing of ZooKeeper and socket instances to the RegionServers which is usually what you want. For example, this is preferred:

```
HBaseConfiguration conf = HBaseConfiguration.create();
HTable table1 = new HTable(conf, "myTable");
HTable table2 = new HTable(conf, "myTable");
```

as opposed to this:

```
HBaseConfiguration conf1 = HBaseConfiguration.create();
HTable table1 = new HTable(conf1, "myTable");
HBaseConfiguration conf2 = HBaseConfiguration.create();
HTable table2 = new HTable(conf2, "myTable");
```

For more information about how connections are handled in the HBase client, see HConnectionManager.

10.1.1.1. Connection Pooling

For applications which require high-end multithreaded access (e.g., web-servers or application servers that may serve many application threads in a single JVM), see HTablePool.

10.1.2. WriteBuffer and Batch Methods

If Section 11.5.4, "HBase Client: AutoFlush" is turned off on HTable, `Put`s are sent to RegionServers when the writebuffer is filled. The writebuffer is 2MB by default. Before an HTable instance is discarded, either `close()` or `flushCommits()` should be invoked so Puts will not be lost.

Note: `htable.delete(Delete);` does not go in the writebuffer! This only applies to Puts.

For additional information on write durability, review the ACID semantics page.

For fine-grained control of batching of `Put`s or `Delete`s, see the batch methods on HTable.

10.1.3. Filters

Get and Scan instances can be optionally configured with filters which are applied on the RegionServer.

10.2. Daemons

10.2.1. Master

`HMaster` is the implementation of the Master Server. The Master server is responsible for monitoring all RegionServer instances in the cluster, and is the interface for all metadata changes.

10.2.1.1. Startup Behavior

If run in a multi-Master environment, all Masters compete to run the cluster. If the active Master loses it's lease in ZooKeeper (or the Master shuts down), then then the remaining Masters jostle to take over the Master role.

10.2.1.2. Interface

The methods exposed by `HMasterInterface` are primarily metadata-oriented methods:

- Table (createTable, modifyTable, removeTable, enable, disable)
- ColumnFamily (addColumn, modifyColumn, removeColumn)
- Region (move, assign, unassign)

For example, when the `HBaseAdmin` method `disableTable` is invoked, it is serviced by the Master server.

10.2.1.3. Processes

The Master runs several background threads:

- `LoadBalancer` periodically reassign regions in the cluster.
- `CatalogJanitor` periodically checks and cleans up the .META. table.

10.2.2. RegionServer

`HRegionServer` is the RegionServer implementation. It is responsible for serving and managing regions.

10.2.2.1. Interface

The methods exposed by `HRegionRegionInterface` contain both data-oriented and region-maintenance methods:

- Data (get, put, delete, next, etc.)
- Region (splitRegion, compactRegion, etc.)

For example, when the `HBaseAdmin` method `majorCompact` is invoked on a table, the client is actually iterating through all regions for the specified table and requesting a major compaction directly to each region.

10.2.2.2. Processes

The RegionServer runs a variety of background threads:

- `CompactSplitThread` checks for splits and handle minor compactions.
- `MajorCompactionChecker` checks for major compactions.
- `MemStoreFlusher` periodically flushes in-memory writes in the MemStore to StoreFiles.
- `LogRoller` periodically checks the RegionServer's HLog.

10.3. Regions

This chapter is all about Regions.

> **Note**
>
> Regions are comprised of a Store per Column Family.

10.3.1. Region Size

Region size is one of those tricky things, there are a few factors to consider:

- Regions are the basic element of availability and distribution.
- HBase scales by having regions across many servers. Thus if you have 2 regions for 16GB data, on a 20 node machine you are a net loss there.
- High region count has been known to make things slow, this is getting better, but it is probably better to have 700 regions than 3000 for the same amount of data.
- Low region count prevents parallel scalability as per point #2. This really cant be stressed enough, since a common problem is loading 200MB data into HBase then wondering why your awesome 10 node cluster is mostly idle.
- There is not much memory footprint difference between 1 region and 10 in terms of indexes, etc, held by the RegionServer.

Its probably best to stick to the default, perhaps going smaller for hot tables (or manually split hot regions to spread the load over the cluster), or go with a 1GB region size if your cell sizes tend to be largish (100k and up).

10.3.2. Region Splits

Splits run unaided on the RegionServer; i.e. the Master does not participate. The RegionServer splits a region, offlines the split region and then adds the daughter regions to META, opens daughters on the parent's hosting RegionServer and then reports the split to the Master. See Section 2.8.2.7, “Managed Splitting” for how to manually manage splits (and for why you might do this)

10.3.3. Region Load Balancer

Periodically, and when there are not any regions in transition, a load balancer will run and move regions around to balance cluster load. The period at which it runs can be configured.

10.3.4. Store

A Store hosts a MemStore and 0 or more StoreFiles (HFiles). A Store corresponds to a column family for a table for a given region.

10.3.4.1. MemStore

The MemStore holds in-memory modifications to the Store. Modifications are KeyValues. When asked to flush, current memstore is moved to snapshot and is cleared. HBase continues to serve edits out of new memstore and backing snapshot until flusher reports in that the flush succeeded. At this point the snapshot is let go.

10.3.4.2. StoreFile (HFile)

10.3.4.2.1. HFile Format

The *hfile* file format is based on the SSTable file described in the BigTable [2006] paper and on Hadoop's tfile (The unit test suite and the compression harness were taken directly from tfile). Schubert Zhang's blog post on HFile: A Block-Indexed File Format to Store Sorted Key-Value Pairs makes for a thorough introduction to HBase's hfile. Matteo Bertozzi has also put up a helpful description, HBase I/O: HFile.

10.3.4.2.2. HFile Tool

To view a textualized version of hfile content, you can do use the `org.apache.hadoop.hbase.io.hfile.HFile` tool. Type the following to see usage:

```
$ ${HBASE_HOME}/bin/hbase org.apache.hadoop.hbase.io.hfile.HFile
```

For example, to view the content of the file `hdfs://10.81.47.41:9000/hbase/TEST/1418428042/DSMP/4759508618286845475`, type the following:

```
 $ ${HBASE_HOME}/bin/hbase org.apache.hadoop.hbase.io.hfile.HFile -v -f
hdfs://10.81.47.41:9000/hbase/TEST/1418428042/DSMP/4759508618286845475
```

If you leave off the option -v to see just a summary on the hfile. See usage for other things to do with the `HFile` tool.

10.3.4.3. Compaction

There are two types of compactions: minor and major. Minor compactions will usually pick up a couple of the smaller adjacent files and rewrite them as one. Minors do not drop deletes or expired cells, only major compactions do this. Sometimes a minor compaction will pick up all the files in the store and in this case it actually promotes itself to being a major compaction. For a description of how a minor compaction picks files to compact, see the ascii diagram in the Store source code.

After a major compaction runs there will be a single storefile per store, and this will help performance usually. Caution: major compactions rewrite all of the stores data and on a loaded system, this may not be tenable; major compactions will usually have to be done manually on large systems. See Section 2.8.2.8, “Managed Compactions”.

10.3.5. Block Cache

The Block Cache contains three levels of block priority to allow for scan-resistance and in-memory ColumnFamilies. A block is added with an in-memory flag if the containing ColumnFamily is defined in-memory, otherwise a block becomes a single access priority. Once a block is accessed again, it changes to multiple access. This is used to prevent scans from thrashing the cache, adding a least-frequently-used element to the eviction algorithm. Blocks from in-memory ColumnFamilies are the last to be evicted.

For more information, see the LruBlockCache source

10.4. Write Ahead Log (WAL)

10.4.1. Purpose

Each RegionServer adds updates (Puts, Deletes) to its write-ahead log (WAL) first, and then to the Section 10.3.4.1, “MemStore” for the affected Section 10.3.4, “Store”. This ensures that HBase has durable writes. Without WAL, there is the possibility of data loss in the case of a RegionServer failure before each MemStore is flushed and new StoreFiles are written. HLog is the HBase WAL implementation, and there is one HLog instance per RegionServer.

The WAL is in HDFS in `/hbase/.logs/` with subdirectories per region.

For more general information about the concept of write ahead logs, see the Wikipedia Write-Ahead Log article.

10.4.2. WAL Flushing

TODO (describe).

10.4.3. WAL Splitting

10.4.3.1. How edits are recovered from a crashed RegionServer

When a RegionServer crashes, it will lose its ephemeral lease in ZooKeeper...TODO

10.4.3.2. `hbase.hlog.split.skip.errors`

When set to `true`, the default, any error encountered splitting will be logged, the problematic WAL will be moved into the `.corrupt` directory under the hbase `rootdir`, and processing will continue. If set to `false`, the exception will be propagated and the split logged as failed.[19]

10.4.3.3. How EOFExceptions are treated when splitting a crashed RegionServers' WALs

If we get an EOF while splitting logs, we proceed with the split even when `hbase.hlog.split.skip.errors` == `false`. An EOF while reading the last log in the set of files to split is near-guaranteed since the RegionServer likely crashed mid-write of a record. But we'll continue even if we got an EOF reading other than the last file in the set.[20]

---

[19] See HBASE-2958 When hbase.hlog.split.skip.errors is set to false, we fail the split but thats it. We need to do more than just fail split if this flag is set.

[20] For background, see HBASE-2643 Figure how to deal with eof splitting logs

Chapter 11. Performance Tuning

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11.1. Operating System

11.1.1. Memory

RAM, RAM, RAM. Don't starve HBase.

11.1.2. 64-bit

Use a 64-bit platform (and 64-bit JVM).

11.1.3. Swapping

Watch out for swapping. Set swappiness to 0.

11.2. Java

11.2.1. The Garbage Collector and HBase

11.2.1.1. Long GC pauses

In his presentation, Avoiding Full GCs with MemStore-Local Allocation Buffers, Todd Lipcon describes two cases of stop-the-world garbage collections common in HBase, especially during loading; CMS failure modes and old generation heap fragmentation brought. To address the first, start the CMS earlier than default by adding `-XX:CMSInitiatingOccupancyFraction` and setting it down from defaults. Start at 60 or 70 percent (The lower you bring down the threshold, the more GCing is done, the more CPU used). To address the second fragmentation issue, Todd added an experimental facility that must be explicitly enabled in HBase 0.90.x (Its defaulted to be on in 0.92.x HBase). See `hbase.hregion.memstore.mslab.enabled` to true in your `Configuration`. See the cited slides for background and detail.

For more information about GC logs, see Section 13.2.3, “JVM Garbage Collection Logs”.

11.3. Configurations

See Section 2.8.2, “Recommended Configuations”.

11.3.1. Number of Regions

The number of regions for an HBase table is driven by the Section 2.8.2.6, “Bigger Regions”. Also, see the architecture section on Section 10.3.1, “Region Size”

11.3.2. Managing Compactions

For larger systems, managing compactions and splits may be something you want to consider.

11.3.3. Compression

Production systems should use compression with their column family definitions. See Appendix B, *Compression In HBase* for more information.

11.3.4. `hbase.regionserver.handler.count`

See `hbase.regionserver.handler.count`. This setting in essence sets how many requests are concurrently being processed inside the RegionServer at any one time. If set too high, then throughput may suffer as the concurrent requests contend; if set too low, requests will be stuck waiting to get into the machine. You can get a sense of whether you have too little or too many handlers by Section 13.2.2.1, “Enabling RPC-level logging” on an individual RegionServer then tailing its logs (Queued requests consume memory).

11.3.5. `hfile.block.cache.size`

See `hfile.block.cache.size`. A memory setting for the RegionServer process.

11.3.6. `hbase.regionserver.global.memstore.upperLimit`

See `hbase.regionserver.global.memstore.upperLimit`. This memory setting is often adjusted for the RegionServer process depending on needs.

11.3.7. `hbase.regionserver.global.memstore.lowerLimit`

See `hbase.regionserver.global.memstore.lowerLimit`. This memory setting is often adjusted for the RegionServer process depending on needs.

11.3.8. `hbase.hstore.blockingStoreFiles`

See `hbase.hstore.blockingStoreFiles`. If there is blocking in the RegionServer logs, increasing this can help.

11.3.9. `hbase.hregion.memstore.block.multiplier`

See `hbase.hregion.memstore.block.multiplier`. If there is enough RAM, increasing this can help.

11.4. Number of Column Families

See Section 6.2, “ On the number of column families ”.

11.5. Writing to HBase

11.5.1. Batch Loading

Use the bulk load tool if you can. See Bulk Loads. Otherwise, pay attention to the below.

11.5.2. Table Creation: Pre-Creating Regions

Tables in HBase are initially created with one region by default. For bulk imports, this means that all clients will write to the same region until it is large enough to split and become distributed across the cluster. A useful pattern to speed up the bulk import process is to pre-create empty regions. Be somewhat conservative in this, because too-many regions can actually degrade performance. An example of pre-creation using hex-keys is as follows (note: this example may need to be tweaked to the individual applications keys):

```
public static boolean createTable(HBaseAdmin admin, HTableDescriptor table, byte[][]
splits)
throws IOException {
  try {
    admin.createTable( table, splits );
    return true;
  } catch (TableExistsException e) {
    logger.info("table " + table.getNameAsString() + " already exists");
    // the table already exists...
    return false;
  }
}

public static byte[][] getHexSplits(String startKey, String endKey, int numRegions) {
  byte[][] splits = new byte[numRegions-1][];
  BigInteger lowestKey = new BigInteger(startKey, 16);
  BigInteger highestKey = new BigInteger(endKey, 16);
  BigInteger range = highestKey.subtract(lowestKey);
  BigInteger regionIncrement = range.divide(BigInteger.valueOf(numRegions));
  lowestKey = lowestKey.add(regionIncrement);
  for(int i=0; i < numRegions-1;i++) {
    BigInteger key = lowestKey.add(regionIncrement.multiply(BigInteger.valueOf(i)));
    byte[] b = String.format("%016x", key).getBytes();
    splits[i] = b;
  }
  return splits;
}
```

11.5.3. Table Creation: Deferred Log Flush

The default behavior for Puts using the Write Ahead Log (WAL) is that `HLog` edits will be written immediately. If deferred log flush is used, WAL edits are kept in memory until the flush period. The benefit is aggregated and asynchronous `HLog`- writes, but the potential downside is that if the RegionServer goes down the yet-to-be-flushed edits are lost. This is safer, however, than not using WAL at all with Puts.

Deferred log flush can be configured on tables via HTableDescriptor. The default value of `hbase.regionserver.optionallogflushinterval` is 1000ms.

11.5.4. HBase Client: AutoFlush

When performing a lot of Puts, make sure that setAutoFlush is set to false on your HTable instance. Otherwise, the Puts will be sent one at a time to the RegionServer. Puts added via `htable.add(Put)` and `htable.add( <List> Put)` wind up in the same write buffer. If `autoFlush = false`, these messages are not sent until the write-buffer is filled. To explicitly flush the messages, call `flushCommits`. Calling `close` on the `HTable` instance will invoke `flushCommits`.

11.5.5. HBase Client: Turn off WAL on Puts

A frequently discussed option for increasing throughput on `Puts` is to call `writeToWAL(false)`. Turning this off means that the RegionServer will *not* write the `Put` to the Write Ahead Log, only into the memstore, HOWEVER the consequence is that if there is a RegionServer failure *there will be data loss*. If `writeToWAL(false)` is used, do so with extreme caution. You may find in actuality that it makes little difference if your load is well distributed across the cluster.

In general, it is best to use WAL for Puts, and where loading throughput is a concern to use bulk loading techniques instead.

11.5.6. HBase Client: Group Puts by RegionServer

In addition to using the writeBuffer, grouping `Puts` by RegionServer can reduce the number of client RPC calls per writeBuffer flush. There is a utility `HTableUtil` currently on TRUNK that does this, but you can either copy that or implement your own verison for those still on 0.90.x or earlier.

11.5.7. MapReduce: Skip The Reducer

When writing a lot of data to an HBase table from a MR job (e.g., with TableOutputFormat), and specifically where Puts are being emitted from the Mapper, skip the Reducer step. When a Reducer step is used, all of the output (Puts) from the Mapper will get spooled to disk, then sorted/shuffled to other Reducers that will most likely be off-node. It's far more efficient to just write directly to HBase.

For summary jobs where HBase is used as a source and a sink, then writes will be coming from the Reducer step (e.g., summarize values then write out result). This is a different processing problem than from the the above case.

11.5.8. Anti-Pattern: One Hot Region

If all your data is being written to one region at a time, then re-read the section on processing timeseries data.

Also, see Section 11.5.2, “ Table Creation: Pre-Creating Regions ”, as well as Section 11.3, “Configurations”

11.6. Reading from HBase

11.6.1. Scan Caching

If HBase is used as an input source for a MapReduce job, for example, make sure that the input Scan instance to the MapReduce job has `setCaching` set to something greater than the default (which is 1). Using the default value means that the map-task will make call back to the region-server for every record processed. Setting this value to 500, for example, will transfer 500 rows at a time to the client to be processed. There is a cost/benefit to have the cache value be large because it costs more in memory for both client and RegionServer, so bigger isn't always better.

11.6.2. Scan Attribute Selection

Whenever a Scan is used to process large numbers of rows (and especially when used as a MapReduce source), be aware of which attributes are selected. If `scan.addFamily` is called then *all* of the attributes in the specified ColumnFamily will be returned to the client. If only a small number of the available attributes are to be processed, then only those attributes should be specified in the input scan because attribute over-selection is a non-trivial performance penalty over large datasets.

11.6.3. Close ResultScanners

This isn't so much about improving performance but rather *avoiding* performance problems. If you forget to close ResultScanners you can cause problems on the RegionServers. Always have ResultScanner processing enclosed in try/catch blocks...

```
Scan scan = new Scan();
// set attrs...
ResultScanner rs = htable.getScanner(scan);
try {
  for (Result r = rs.next(); r != null; r = rs.next()) {
  // process result...
} finally {
  rs.close();  // always close the ResultScanner!
}
htable.close();
```

11.6.4. Block Cache

Scan instances can be set to use the block cache in the RegionServer via the `setCacheBlocks` method. For input Scans to MapReduce jobs, this should be `false`. For frequently accessed rows, it is advisable to use the block cache.

11.6.5. Optimal Loading of Row Keys

When performing a table scan where only the row keys are needed (no families, qualifiers, values or timestamps), add a FilterList with a `MUST_PASS_ALL` operator to the scanner using `setFilter`. The filter list should include both a FirstKeyOnlyFilter and a KeyOnlyFilter. Using this filter combination will result in a worst case scenario of a RegionServer reading a single value from disk and minimal network traffic to the client for a single row.

11.6.6. Concurrency: Monitor Data Spread

When performing a high number of concurrent reads, monitor the data spread of the target tables. If the target table(s) have too few regions then the reads could likely be served from too few nodes.

See Section 11.5.2, “ Table Creation: Pre-Creating Regions ”, as well as Section 11.3, “Configurations”

Chapter 12. Bloom Filters

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Bloom filters were developed over in HBase-1200 Add bloomfilters.[21][22]

12.1. Configurations

Blooms are enabled by specifying options on a column family in the HBase shell or in java code as specification on `org.apache.hadoop.hbase.HColumnDescriptor`.

12.1.1. `HColumnDescriptor` option

Use `HColumnDescriptor.setBloomFilterType(NONE | ROW | ROWCOL)` to enable blooms per Column Family. Default = `NONE` for no bloom filters. If `ROW`, the hash of the row will be added to the bloom on each insert. If `ROWCOL`, the hash of the row + column family + column family qualifier will be added to the bloom on each key insert.

12.1.2. `io.hfile.bloom.enabled` global kill switch

`io.hfile.bloom.enabled` in `Configuration` serves as the kill switch in case something goes wrong. Default = `true`.

12.1.3. `io.hfile.bloom.error.rate`

`io.hfile.bloom.error.rate` = average false positive rate. Default = 1%. Decrease rate by ½ (e.g. to .5%) == +1 bit per bloom entry.

12.1.4. `io.hfile.bloom.max.fold`

`io.hfile.bloom.max.fold` = guaranteed minimum fold rate. Most people should leave this alone. Default = 7, or can collapse to at least 1/128th of original size. See the *Development Process* section of the document BloomFilters in HBase for more on what this option means.

12.2. Bloom StoreFile footprint

Bloom filters add an entry to the `StoreFile` general `FileInfo` data structure and then two extra entries to the `StoreFile` metadata section.

12.2.1. BloomFilter in the `StoreFile` `FileInfo` data structure

12.2.1.1. `BLOOM_FILTER_TYPE`

`FileInfo` has a `BLOOM_FILTER_TYPE` entry which is set to `NONE`, `ROW` or `ROWCOL.`

12.2.2. BloomFilter entries in `StoreFile` metadata

12.2.2.1. `BLOOM_FILTER_META`

`BLOOM_FILTER_META` holds Bloom Size, Hash Function used, etc. Its small in size and is cached on `StoreFile.Reader` load

12.2.2.2. `BLOOM_FILTER_DATA`

`BLOOM_FILTER_DATA` is the actual bloomfilter data. Obtained on-demand. Stored in the LRU cache, if it is enabled (Its enabled by default).

[21] For description of the development process -- why static blooms rather than dynamic -- and for an overview of the unique properties that pertain to blooms in HBase, as well as possible future directions, see the *Development Process* section of the document BloomFilters in HBase attached to HBase-1200.

[22] The bloom filters described here are actually version two of blooms in HBase. In versions up to 0.19.x, HBase had a dynamic bloom option based on work done by the European Commission One-Lab Project 034819. The core of the HBase bloom work was later pulled up into Hadoop to implement org.apache.hadoop.io.BloomMapFile. Version 1 of HBase blooms never worked that well. Version 2 is a rewrite from scratch though again it starts with the one-lab work.

Chapter 13. Troubleshooting and Debugging HBase

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13.1. General Guidelines

Always start with the master log (TODO: Which lines?). Normally it’s just printing the same lines over and over again. If not, then there's an issue. Google or search-hadoop.com should return some hits for those exceptions you're seeing.

An error rarely comes alone in HBase, usually when something gets screwed up what will follow may be hundreds of exceptions and stack traces coming from all over the place. The best way to approach this type of problem is to walk the log up to where it all began, for example one trick with RegionServers is that they will print some metrics when aborting so grepping for *Dump* should get you around the start of the problem.

RegionServer suicides are "normal", as this is what they do when something goes wrong. For example, if ulimit and xcievers (the two most important initial settings, see Section 2.2.4, " `ulimit` and `nproc` ") aren't changed, it will make it impossible at some point for DataNodes to create new threads that from the HBase point of view is seen as if HDFS was gone. Think about what would happen if your MySQL database was suddenly unable to access files on your local file system, well it's the same with HBase and HDFS. Another very common reason to see RegionServers committing seppuku is when they enter prolonged garbage collection pauses that last longer than the default ZooKeeper session timeout. For more information on GC pauses, see the 3 part blog post by Todd Lipcon and Section 11.2.1.1, "Long GC pauses" above.

13.2. Logs

The key process logs are as follows... (replace <user> with the user that started the service, and <hostname> for the machine name)

NameNode: `$HADOOP_HOME/logs/hadoop-<user>-namenode-<hostname>.log`

DataNode: `$HADOOP_HOME/logs/hadoop-<user>-datanode-<hostname>.log`

JobTracker: `$HADOOP_HOME/logs/hadoop-<user>-jobtracker-<hostname>.log`

TaskTracker: `$HADOOP_HOME/logs/hadoop-<user>-jobtracker-<hostname>.log`

HMaster: `$HBASE_HOME/logs/hbase-<user>-master-<hostname>.log`

RegionServer: `$HBASE_HOME/logs/hbase-<user>-regionserver-<hostname>.log`

ZooKeeper: `TODO`

13.2.1. Log Locations

For stand-alone deployments the logs are obviously going to be on a single machine, however this is a development configuration only. Production deployments need to run on a cluster.

13.2.1.1. NameNode

The NameNode log is on the NameNode server. The HBase Master is typically run on the NameNode server, and well as ZooKeeper.

For smaller clusters the JobTracker is typically run on the NameNode server as well.

13.2.1.2. DataNode

Each DataNode server will have a DataNode log for HDFS, as well as a RegionServer log for HBase.

Additionally, each DataNode server will also have a TaskTracker log for MapReduce task execution.

13.2.2. Log Levels

13.2.2.1. Enabling RPC-level logging

Enabling the RPC-level logging on a RegionServer can often given insight on timings at the server. Once enabled, the amount of log spewed is voluminous. It is not recommended that you leave this logging on for more than short bursts of time. To enable RPC-level logging, browse to the RegionServer UI and click on *Log Level*. Set the log level to `DEBUG` for the package `org.apache.hadoop.ipc` (Thats right, for `hadoop.ipc`, NOT, `hbase.ipc`). Then tail the RegionServers log. Analyze.

To disable, set the logging level back to `INFO` level.

13.2.3. JVM Garbage Collection Logs

HBase is memory intensive, and using the default GC you can see long pauses in all threads including the *Juliet Pause* aka "GC of Death". To help debug this or confirm this is happening GC logging can be turned on in the Java virtual machine.

To enable, in `hbase-env.sh` add:

```
export HBASE_OPTS="-XX:+UseConcMarkSweepGC -verbose:gc -XX:+PrintGCDetails -XX:
+PrintGCTimeStamps -Xloggc:/home/hadoop/hbase/logs/gc-hbase.log"
```

Adjust the log directory to wherever you log. Note: The GC log does NOT roll automatically, so you'll have to keep an eye on it so it doesn't fill up the disk.

At this point you should see logs like so:

```
64898.952: [GC [1 CMS-initial-mark: 2811538K(3055704K)] 2812179K(3061272K), 0.0007360
secs] [Times: user=0.00 sys=0.00, real=0.00 secs]
64898.953: [CMS-concurrent-mark-start]
64898.971: [GC 64898.971: [ParNew: 5567K->576K(5568K), 0.0101110 secs] 2817105K-
>2812715K(3061272K), 0.0102200 secs] [Times: user=0.07 sys=0.00, real=0.01 secs]
```

In this section, the first line indicates a 0.0007360 second pause for the CMS to initially mark. This pauses the entire VM, all threads for that period of time.

The third line indicates a "minor GC", which pauses the VM for 0.0101110 seconds - aka 10 milliseconds. It has reduced the "ParNew" from about 5.5m to 576k. Later on in this cycle we see:

```
64901.445: [CMS-concurrent-mark: 1.542/2.492 secs] [Times: user=10.49 sys=0.33, real=2.49
secs]
64901.445: [CMS-concurrent-preclean-start]
64901.453: [GC 64901.453: [ParNew: 5505K->573K(5568K), 0.0062440 secs] 2868746K-
>2864292K(3061272K), 0.0063360 secs] [Times: user=0.05 sys=0.00, real=0.01 secs]
64901.476: [GC 64901.476: [ParNew: 5563K->575K(5568K), 0.0072510 secs] 2869283K-
>2864837K(3061272K), 0.0073320 secs] [Times: user=0.05 sys=0.01, real=0.01 secs]
64901.500: [GC 64901.500: [ParNew: 5517K->573K(5568K), 0.0120390 secs] 2869780K-
>2865267K(3061272K), 0.0121150 secs] [Times: user=0.09 sys=0.00, real=0.01 secs]
64901.529: [GC 64901.529: [ParNew: 5507K->569K(5568K), 0.0086240 secs] 2870200K-
>2865742K(3061272K), 0.0087180 secs] [Times: user=0.05 sys=0.00, real=0.01 secs]
```

```
64901.554: [GC 64901.555: [ParNew: 5516K->575K(5568K), 0.0107130 secs] 2870689K-
>2866291K(3061272K), 0.0107820 secs] [Times: user=0.06 sys=0.00, real=0.01 secs]
64901.578: [CMS-concurrent-preclean: 0.070/0.133 secs] [Times: user=0.48 sys=0.01,
real=0.14 secs]
64901.578: [CMS-concurrent-abortable-preclean-start]
64901.584: [GC 64901.584: [ParNew: 5504K->571K(5568K), 0.0087270 secs] 2871220K-
>2866830K(3061272K), 0.0088220 secs] [Times: user=0.05 sys=0.00, real=0.01 secs]
64901.609: [GC 64901.609: [ParNew: 5512K->569K(5568K), 0.0063370 secs] 2871771K-
>2867322K(3061272K), 0.0064230 secs] [Times: user=0.06 sys=0.00, real=0.01 secs]
64901.615: [CMS-concurrent-abortable-preclean: 0.007/0.037 secs] [Times: user=0.13
sys=0.00, real=0.03 secs]
64901.616: [GC[YG occupancy: 645 K (5568 K)]64901.616: [Rescan (parallel) , 0.0020210
secs]64901.618: [weak refs processing, 0.0027950 secs] [1 CMS-remark: 2866753K(3055704K)]
2867399K(3061272K), 0.0049380 secs] [Times: user=0.00 sys=0.01, real=0.01 secs]
64901.621: [CMS-concurrent-sweep-start]
```

The first line indicates that the CMS concurrent mark (finding garbage) has taken 2.4 seconds. But this is a _concurrent_ 2.4 seconds, Java has not been paused at any point in time.

There are a few more minor GCs, then there is a pause at the 2nd last line:

```
64901.616: [GC[YG occupancy: 645 K (5568 K)]64901.616: [Rescan (parallel) , 0.0020210
secs]64901.618: [weak refs processing, 0.0027950 secs] [1 CMS-remark: 2866753K(3055704K)]
2867399K(3061272K), 0.0049380 secs] [Times: user=0.00 sys=0.01, real=0.01 secs]
```

The pause here is 0.0049380 seconds (aka 4.9 milliseconds) to 'remark' the heap.

At this point the sweep starts, and you can watch the heap size go down:

```
64901.637: [GC 64901.637: [ParNew: 5501K->569K(5568K), 0.0097350 secs] 2871958K-
>2867441K(3061272K), 0.0098370 secs] [Times: user=0.05 sys=0.00, real=0.01 secs]
...  lines removed ...
64904.936: [GC 64904.936: [ParNew: 5532K->568K(5568K), 0.0070720 secs] 1365024K-
>1360689K(3061272K), 0.0071930 secs] [Times: user=0.05 sys=0.00, real=0.01 secs]
64904.953: [CMS-concurrent-sweep: 2.030/3.332 secs] [Times: user=9.57 sys=0.26, real=3.33
secs]
```

At this point, the CMS sweep took 3.332 seconds, and heap went from about ~ 2.8 GB to 1.3 GB (approximate).

The key points here is to keep all these pauses low. CMS pauses are always low, but if your ParNew starts growing, you can see minor GC pauses approach 100ms, exceed 100ms and hit as high at 400ms.

This can be due to the size of the ParNew, which should be relatively small. If your ParNew is very large after running HBase for a while, in one example a ParNew was about 150MB, then you might have to constrain the size of ParNew (The larger it is, the longer the collections take but if its too small, objects are promoted to old gen too quickly). In the below we constrain new gen size to 64m.

Add this to HBASE_OPTS:

```
export HBASE_OPTS="-XX:NewSize=64m -XX:MaxNewSize=64m <cms options from above> <gc logging
options from above>"
```

For more information on GC pauses, see the 3 part blog post by Todd Lipcon and Section 11.2.1.1, “Long GC pauses” above.

13.3. Tools

13.3.1. Builtin Tools

13.3.1.1. Master Web Interface

The Master starts a web-interface on port 60010 by default.

The Master web UI lists created tables and their definition (e.g., ColumnFamilies, blocksize, etc.). Additionally, the available RegionServers in the cluster are listed along with selected high-level metrics (requests, number of regions, usedHeap, maxHeap). The Master web UI allows navigation to each RegionServer's web UI.

13.3.1.2. RegionServer Web Interface

RegionServers starts a web-interface on port 60030 by default.

The RegionServer web UI lists online regions and their start/end keys, as well as point-in-time RegionServer metrics (requests, regions, storeFileIndexSize, compactionQueueSize, etc.).

See Chapter 7, *Metrics* for more information in metric definitions.

13.3.2. External Tools

13.3.2.1. search-hadoop.com

search-hadoop.com indexes all the mailing lists and JIRA, it’s really helpful when looking for Hadoop/HBase-specific issues.

13.3.2.2. tail

`tail` is the command line tool that lets you look at the end of a file. Add the “-f” option and it will refresh when new data is available. It’s useful when you are wondering what’s happening, for example, when a cluster is taking a long time to shutdown or startup as you can just fire a new terminal and tail the master log (and maybe a few RegionServers).

13.3.2.3. top

`top` is probably one of the most important tool when first trying to see what’s running on a machine and how the resources are consumed. Here’s an example from production system:

```
top - 14:46:59 up 39 days, 11:55,  1 user,  load average: 3.75, 3.57, 3.84
Tasks: 309 total,   1 running, 308 sleeping,   0 stopped,   0 zombie
Cpu(s):  4.5%us,  1.6%sy,  0.0%ni, 91.7%id,  1.4%wa,  0.1%hi,  0.6%si,  0.0%st
Mem:  24414432k total, 24296956k used,   117476k free,     7196k buffers
Swap: 16008732k total,  14348k used, 15994384k free, 11106908k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
15558 hadoop    18  -2 3292m 2.4g 3556 S   79 10.4   6523:52 java
```

```
13268 hadoop    18  -2 8967m 8.2g 4104 S   21 35.1   5170:30 java
 8895 hadoop    18  -2 1581m 497m 3420 S   11  2.1   4002:32 java
…
```

Here we can see that the system load average during the last five minutes is 3.75, which very roughly means that on average 3.75 threads were waiting for CPU time during these 5 minutes. In general, the "perfect" utilization equals to the number of cores, under that number the machine is under utilized and over that the machine is over utilized. This is an important concept, see this article to understand it more: http://www.linuxjournal.com/article/9001.

Apart from load, we can see that the system is using almost all its available RAM but most of it is used for the OS cache (which is good). The swap only has a few KBs in it and this is wanted, high numbers would indicate swapping activity which is the nemesis of performance of Java systems. Another way to detect swapping is when the load average goes through the roof (although this could also be caused by things like a dying disk, among others).

The list of processes isn't super useful by default, all we know is that 3 java processes are using about 111% of the CPUs. To know which is which, simply type "c" and each line will be expanded. Typing "1" will give you the detail of how each CPU is used instead of the average for all of them like shown here.

13.3.2.4. jps

`jps` is shipped with every JDK and gives the java process ids for the current user (if root, then it gives the ids for all users). Example:

```
hadoop@sv4borg12:~$ jps
1322 TaskTracker
17789 HRegionServer
27862 Child
1158 DataNode
25115 HQuorumPeer
2950 Jps
19750 ThriftServer
18776 jmx
```

In order, we see a:

- Hadoop TaskTracker, manages the local Childs
- HBase RegionServer, serves regions
- Child, its MapReduce task, cannot tell which type exactly
- Hadoop TaskTracker, manages the local Childs
- Hadoop DataNode, serves blocks
- HQuorumPeer, a ZooKeeper ensemble member
- Jps, well… it's the current process
- ThriftServer, it's a special one will be running only if thrift was started
- jmx, this is a local process that's part of our monitoring platform (poorly named maybe). You probably don't have that.

You can then do stuff like checking out the full command line that started the process:

```
hadoop@sv4borg12:~$ ps aux | grep HRegionServer
```

```
hadoop   17789  155 35.2 9067824 8604364 ?     S<l  Mar04 9855:48
/usr/java/jdk1.6.0_14/bin/java -Xmx8000m -XX:+DoEscapeAnalysis -XX:+AggressiveOpts -XX:
+UseConcMarkSweepGC -XX:NewSize=64m -XX:MaxNewSize=64m
-XX:CMSInitiatingOccupancyFraction=88 -verbose:gc -XX:+PrintGCDetails -XX:
+PrintGCTimeStamps -Xloggc:/export1/hadoop/logs/gc-hbase.log
-Dcom.sun.management.jmxremote.port=10102 -Dcom.sun.management.jmxremote.authenticate=true
-Dcom.sun.management.jmxremote.ssl=false
-Dcom.sun.management.jmxremote.password.file=/home/hadoop/hbase/conf/jmxremote.password
-Dcom.sun.management.jmxremote -Dhbase.log.dir=/export1/hadoop/logs
-Dhbase.log.file=hbase-hadoop-regionserver-sv4borg12.log
-Dhbase.home.dir=/home/hadoop/hbase -Dhbase.id.str=hadoop -Dhbase.root.logger=INFO,DRFA
-Djava.library.path=/home/hadoop/hbase/lib/native/Linux-amd64-64 -classpath
/home/hadoop/hbase/bin/../conf:[many jars]:/home/hadoop/hadoop/conf
org.apache.hadoop.hbase.regionserver.HRegionServer start
```

13.3.2.5. jstack

`jstack` is one of the most important tools when trying to figure out what a java process is doing apart from looking at the logs. It has to be used in conjunction with jps in order to give it a process id. It shows a list of threads, each one has a name, and they appear in the order that they were created (so the top ones are the most recent threads). Here's a few example:

The main thread of a RegionServer that's waiting for something to do from the master:

```
      "regionserver60020" prio=10 tid=0x0000000040ab4000 nid=0x45cf waiting on condition
[0x00007f16b6a96000..0x00007f16b6a96a70]
   java.lang.Thread.State: TIMED_WAITING (parking)
                at sun.misc.Unsafe.park(Native Method)
                - parking to wait for  <0x00007f16cd5c2f30> (a
java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject)
                at java.util.concurrent.locks.LockSupport.parkNanos(LockSupport.java:198)
                at
java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject.awaitNanos(AbstractQ
ueuedSynchronizer.java:1963)
                at
java.util.concurrent.LinkedBlockingQueue.poll(LinkedBlockingQueue.java:395)
                at
org.apache.hadoop.hbase.regionserver.HRegionServer.run(HRegionServer.java:647)
                at java.lang.Thread.run(Thread.java:619)

                The MemStore flusher thread that is currently flushing to a file:
"regionserver60020.cacheFlusher" daemon prio=10 tid=0x0000000040f4e000 nid=0x45eb in
Object.wait() [0x00007f16b5b86000..0x00007f16b5b87af0]
   java.lang.Thread.State: WAITING (on object monitor)
                at java.lang.Object.wait(Native Method)
                at java.lang.Object.wait(Object.java:485)
                at org.apache.hadoop.ipc.Client.call(Client.java:803)
                - locked <0x00007f16cb14b3a8> (a org.apache.hadoop.ipc.Client$Call)
                at org.apache.hadoop.ipc.RPC$Invoker.invoke(RPC.java:221)
                at $Proxy1.complete(Unknown Source)
                at sun.reflect.GeneratedMethodAccessor38.invoke(Unknown Source)
                at
sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:25)
                at java.lang.reflect.Method.invoke(Method.java:597)
                at
org.apache.hadoop.io.retry.RetryInvocationHandler.invokeMethod(RetryInvocationHandler.java
:82)
                at
org.apache.hadoop.io.retry.RetryInvocationHandler.invoke(RetryInvocationHandler.java:59)
                at $Proxy1.complete(Unknown Source)
                at
org.apache.hadoop.hdfs.DFSClient$DFSOutputStream.closeInternal(DFSClient.java:3390)
                - locked <0x00007f16cb14b470> (a
org.apache.hadoop.hdfs.DFSClient$DFSOutputStream)
                at
org.apache.hadoop.hdfs.DFSClient$DFSOutputStream.close(DFSClient.java:3304)
                at
org.apache.hadoop.fs.FSDataOutputStream$PositionCache.close(FSDataOutputStream.java:61)
                at
org.apache.hadoop.fs.FSDataOutputStream.close(FSDataOutputStream.java:86)
                at org.apache.hadoop.hbase.io.hfile.HFile$Writer.close(HFile.java:650)
                at
org.apache.hadoop.hbase.regionserver.StoreFile$Writer.close(StoreFile.java:853)
                at
org.apache.hadoop.hbase.regionserver.Store.internalFlushCache(Store.java:467)
                - locked <0x00007f16d00e6f08> (a java.lang.Object)
                at org.apache.hadoop.hbase.regionserver.Store.flushCache(Store.java:427)
                at org.apache.hadoop.hbase.regionserver.Store.access$100(Store.java:80)
                at
org.apache.hadoop.hbase.regionserver.Store$StoreFlusherImpl.flushCache(Store.java:1359)
                at
org.apache.hadoop.hbase.regionserver.HRegion.internalFlushcache(HRegion.java:907)
                at
org.apache.hadoop.hbase.regionserver.HRegion.internalFlushcache(HRegion.java:834)
                at
org.apache.hadoop.hbase.regionserver.HRegion.flushcache(HRegion.java:786)
                at
org.apache.hadoop.hbase.regionserver.MemStoreFlusher.flushRegion(MemStoreFlusher.java:250)
                at
org.apache.hadoop.hbase.regionserver.MemStoreFlusher.flushRegion(MemStoreFlusher.java:224)
                at
org.apache.hadoop.hbase.regionserver.MemStoreFlusher.run(MemStoreFlusher.java:146)
```

A handler thread that’s waiting for stuff to do (like put, delete, scan, etc):

```
"IPC Server handler 16 on 60020" daemon prio=10 tid=0x00007f16b011d800 nid=0x4a5e waiting
on condition [0x00007f16afefd000..0x00007f16afefd9f0]
   java.lang.Thread.State: WAITING (parking)
                at sun.misc.Unsafe.park(Native Method)
                - parking to wait for  <0x00007f16cd3f8dd8> (a
java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject)
                at java.util.concurrent.locks.LockSupport.park(LockSupport.java:158)
                at
java.util.concurrent.locks.AbstractQueuedSynchronizer$ConditionObject.await(AbstractQueued
Synchronizer.java:1925)
                at
java.util.concurrent.LinkedBlockingQueue.take(LinkedBlockingQueue.java:358)
                at
org.apache.hadoop.hbase.ipc.HBaseServer$Handler.run(HBaseServer.java:1013)
```

And one that’s busy doing an increment of a counter (it’s in the phase where it’s trying to create a scanner in order to read the last value):

```
"IPC Server handler 66 on 60020" daemon prio=10 tid=0x00007f16b006e800 nid=0x4a90 runnable
[0x00007f16acb77000..0x00007f16acb77cf0]
   java.lang.Thread.State: RUNNABLE
                at
org.apache.hadoop.hbase.regionserver.KeyValueHeap.<init>(KeyValueHeap.java:56)
                at
org.apache.hadoop.hbase.regionserver.StoreScanner.<init>(StoreScanner.java:79)
                at org.apache.hadoop.hbase.regionserver.Store.getScanner(Store.java:1202)
                at
org.apache.hadoop.hbase.regionserver.HRegion$RegionScanner.<init>(HRegion.java:2209)
                at
org.apache.hadoop.hbase.regionserver.HRegion.instantiateInternalScanner(HRegion.java:1063)
                at
org.apache.hadoop.hbase.regionserver.HRegion.getScanner(HRegion.java:1055)
                at
org.apache.hadoop.hbase.regionserver.HRegion.getScanner(HRegion.java:1039)
                at
org.apache.hadoop.hbase.regionserver.HRegion.getLastIncrement(HRegion.java:2875)
                at
org.apache.hadoop.hbase.regionserver.HRegion.incrementColumnValue(HRegion.java:2978)
                at
org.apache.hadoop.hbase.regionserver.HRegionServer.incrementColumnValue(HRegionServer.java
:2433)
                at sun.reflect.GeneratedMethodAccessor20.invoke(Unknown Source)
                at
sun.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:25)
                at java.lang.reflect.Method.invoke(Method.java:597)
                at org.apache.hadoop.hbase.ipc.HBaseRPC$Server.call(HBaseRPC.java:560)
                at
org.apache.hadoop.hbase.ipc.HBaseServer$Handler.run(HBaseServer.java:1027)
```

A thread that receives data from HDFS:

```
"IPC Client (47) connection to sv4borg9/10.4.24.40:9000 from hadoop" daemon prio=10
tid=0x00007f16a02d0000 nid=0x4fa3 runnable [0x00007f16b517d000..0x00007f16b517dbf0]
   java.lang.Thread.State: RUNNABLE
                at sun.nio.ch.EPollArrayWrapper.epollWait(Native Method)
                at sun.nio.ch.EPollArrayWrapper.poll(EPollArrayWrapper.java:215)
                at sun.nio.ch.EPollSelectorImpl.doSelect(EPollSelectorImpl.java:65)
                at sun.nio.ch.SelectorImpl.lockAndDoSelect(SelectorImpl.java:69)
                - locked <0x00007f17d5b68c00> (a sun.nio.ch.Util$1)
                - locked <0x00007f17d5b68be8> (a java.util.Collections$UnmodifiableSet)
                - locked <0x00007f1877959b50> (a sun.nio.ch.EPollSelectorImpl)
                at sun.nio.ch.SelectorImpl.select(SelectorImpl.java:80)
                at
org.apache.hadoop.net.SocketIOWithTimeout$SelectorPool.select(SocketIOWithTimeout.java:332
)
                at
org.apache.hadoop.net.SocketIOWithTimeout.doIO(SocketIOWithTimeout.java:157)
                at
org.apache.hadoop.net.SocketInputStream.read(SocketInputStream.java:155)
                at
org.apache.hadoop.net.SocketInputStream.read(SocketInputStream.java:128)
                at java.io.FilterInputStream.read(FilterInputStream.java:116)
                at
org.apache.hadoop.ipc.Client$Connection$PingInputStream.read(Client.java:304)
                at java.io.BufferedInputStream.fill(BufferedInputStream.java:218)
                at java.io.BufferedInputStream.read(BufferedInputStream.java:237)
                - locked <0x00007f1808539178> (a java.io.BufferedInputStream)
                at java.io.DataInputStream.readInt(DataInputStream.java:370)
                at
org.apache.hadoop.ipc.Client$Connection.receiveResponse(Client.java:569)
                at org.apache.hadoop.ipc.Client$Connection.run(Client.java:477)
```

And here is a master trying to recover a lease after a RegionServer died:

```
"LeaseChecker" daemon prio=10 tid=0x00000000407ef800 nid=0x76cd waiting on condition
[0x00007f6d0eae2000..0x00007f6d0eae2a70]
--
   java.lang.Thread.State: WAITING (on object monitor)
                at java.lang.Object.wait(Native Method)
                at java.lang.Object.wait(Object.java:485)
                at org.apache.hadoop.ipc.Client.call(Client.java:726)
                - locked <0x00007f6d1cd28f80> (a org.apache.hadoop.ipc.Client$Call)
                at org.apache.hadoop.ipc.RPC$Invoker.invoke(RPC.java:220)
                at $Proxy1.recoverBlock(Unknown Source)
                at
org.apache.hadoop.hdfs.DFSClient$DFSOutputStream.processDatanodeError(DFSClient.java:2636)
                at
org.apache.hadoop.hdfs.DFSClient$DFSOutputStream.<init>(DFSClient.java:2832)
                at org.apache.hadoop.hdfs.DFSClient.append(DFSClient.java:529)
                at
org.apache.hadoop.hdfs.DistributedFileSystem.append(DistributedFileSystem.java:186)
                at org.apache.hadoop.fs.FileSystem.append(FileSystem.java:530)
                at org.apache.hadoop.hbase.util.FSUtils.recoverFileLease(FSUtils.java:619)
                at org.apache.hadoop.hbase.regionserver.wal.HLog.splitLog(HLog.java:1322)
                at org.apache.hadoop.hbase.regionserver.wal.HLog.splitLog(HLog.java:1210)
                at
org.apache.hadoop.hbase.master.HMaster.splitLogAfterStartup(HMaster.java:648)
                at org.apache.hadoop.hbase.master.HMaster.joinCluster(HMaster.java:572)
                at org.apache.hadoop.hbase.master.HMaster.run(HMaster.java:503)
```

13.3.2.6. OpenTSDB

OpenTSDB is an excellent alternative to Ganglia as it uses HBase to store all the time series and doesn't have to downsample. Monitoring your own HBase cluster that hosts OpenTSDB is a good exercise.

Here's an example of a cluster that's suffering from hundreds of compactions launched almost all around the same time, which severely affects the IO performance: (TODO: insert graph plotting compactionQueueSize)

It's a good practice to build dashboards with all the important graphs per machine and per cluster so that debugging issues can be done with a single quick look. For example, at StumbleUpon there's one dashboard per cluster with the most important metrics from both the OS and HBase. You can then go down at the machine level and get even more detailed metrics.

13.3.2.7. clusterssh+top

clusterssh+top, it's like a poor man's monitoring system and it can be quite useful when you have only a few machines as it's very easy to setup. Starting clusterssh will give you one terminal per machine and another terminal in which whatever you type will be retyped in every window. This means that you can type "top" once and it will start it for all of your machines at the same time giving you full view of the current state of your cluster. You can also tail all the logs at the same time, edit files, etc.

13.4. Client

13.4.1. ScannerTimeoutException

This is thrown if the time between RPC calls from the client to RegionServer exceeds the scan timeout. For example, if `Scan.setCaching` is set to 500, then there will be an RPC call to fetch the next batch of rows every 500 `.next()` calls on the ResultScanner because data is being transferred in blocks of 500 rows to the client. Reducing the setCaching value may be an option, but setting this value too low makes for inefficient processing on numbers of rows.

13.4.2. Shell or client application throws lots of scary exceptions during normal operation

Since 0.20.0 the default log level for `org.apache.hadoop.hbase.*`is DEBUG.

On your clients, edit `$HBASE_HOME/conf/log4j.properties` and change this: `log4j.logger.org.apache.hadoop.hbase=DEBUG` to this: `log4j.logger.org.apache.hadoop.hbase=INFO`, or even `log4j.logger.org.apache.hadoop.hbase=WARN`.

13.4.3. Long Client Pauses With Compression

This is a fairly frequent question on the HBase dist-list. The scenario is that a client is typically inserting a lot of data into a relatively un-optimized HBase cluster. Compression can exacerbate the pauses, although it is not the source of the problem.

See Section 11.5.2, " Table Creation: Pre-Creating Regions " on the pattern for pre-creating regions and confirm that the table isn't starting with a single region.

See Section 11.3, "Configurations" for cluster configuration, particularly `hbase.hstore.blockingStoreFiles`, `hbase.hregion.memstore.block.multiplier`, `MAX_FILESIZE` (region size), and `MEMSTORE_FLUSHSIZE.`

A slightly longer explanation of why pauses can happen is as follows: Puts are sometimes blocked on the MemStores which are blocked by the flusher thread which is blocked because there are too many files to compact because the compactor is given too many small files to compact and has to compact the same data repeatedly. This situation can occur even with minor compactions. Compounding this situation, HBase doesn't compress data in memory. Thus, the 64MB that lives in the MemStore could become a 6MB file after compression - which results in a smaller StoreFile. The upside is that more data is packed into the same region, but performance is achieved by being able to write larger files - which is why HBase waits until the flushize before writing a new StoreFile. And smaller StoreFiles become targets for compaction. Without compression the files are much bigger and don't need as much compaction, however this is at the expense of I/O.

For additional information, see this thread on Long client pauses with compression.

13.4.4. ZooKeeper Client Connection Errors

Errors like this...

```
11/07/05 11:26:41 WARN zookeeper.ClientCnxn: Session 0x0 for server null,
 unexpected error, closing socket connection and attempting reconnect
 java.net.ConnectException: Connection refused: no further information
        at sun.nio.ch.SocketChannelImpl.checkConnect(Native Method)
        at sun.nio.ch.SocketChannelImpl.finishConnect(Unknown Source)
        at org.apache.zookeeper.ClientCnxn$SendThread.run(ClientCnxn.java:1078)
 11/07/05 11:26:43 INFO zookeeper.ClientCnxn: Opening socket connection to
 server localhost/127.0.0.1:2181
 11/07/05 11:26:44 WARN zookeeper.ClientCnxn: Session 0x0 for server null,
 unexpected error, closing socket connection and attempting reconnect
 java.net.ConnectException: Connection refused: no further information
        at sun.nio.ch.SocketChannelImpl.checkConnect(Native Method)
        at sun.nio.ch.SocketChannelImpl.finishConnect(Unknown Source)
        at org.apache.zookeeper.ClientCnxn$SendThread.run(ClientCnxn.java:1078)
 11/07/05 11:26:45 INFO zookeeper.ClientCnxn: Opening socket connection to
 server localhost/127.0.0.1:2181
```

... are either due to ZooKeeper being down, or unreachable due to network issues.

13.5. NameNode

13.5.1. HDFS Utilization of Tables and Regions

To determine how much space HBase is using on HDFS use the `hadoop` shell commands from the NameNode. For example...

```
hadoop fs -dus /hbase/
```

...returns the summarized disk utilization for all HBase objects.

```
hadoop fs -dus /hbase/myTable
```

...returns the summarized disk utilization for the HBase table 'myTable'.

```
hadoop fs -du /hbase/myTable
```

...returns a list of the regions under the HBase table 'myTable' and their disk utilization.

13.5.2. Browsing HDFS for HBase Objects

Somtimes it will be necessary to explore the HBase objects that exist on HDFS. These objects could include the WALs (Write Ahead Logs), tables, regions, StoreFiles, etc. The easiest way to do this is with the NameNode web application that runs on port 50070. The NameNode web application will provide links to the all the DataNodes in the cluster so that they can be browsed seamlessly.

The HDFS directory structure of HBase tables in the cluster is...

```
/hbase
     /<Table>             (Tables in the cluster)
```

```
          /<Region>           (Regions for the table)
               /<ColumnFamiy>      (ColumnFamilies for the Region for the table)
                    /<StoreFile>        (StoreFiles for the ColumnFamily for the Regions
for the table)
```

The HDFS directory structure of HBase WAL is..

```
/hbase
     /.logs
          /<RegionServer>    (RegionServers)
               /<HLog>           (WAL HLog files for the RegionServer)
```

13.5.2.1. Use Cases

Two common use-cases for querying HDFS for HBase objects is research the degree of uncompaction of a table. If there are a large number of StoreFiles for each ColumnFamily it could indicate the need for a major compaction. Additionally, after a major compaction if the resulting StoreFile is "small" it could indicate the need for a reduction of ColumnFamilies for the table.

13.6. RegionServer

13.6.1. Startup Errors

13.6.1.1. Master Starts, But RegionServers Do Not

The Master believes the RegionServers have the IP of 127.0.0.1 - which is localhost and resolves to the master's own localhost.

The RegionServers are erroneously informing the Master that their IP addresses are 127.0.0.1.

Modify `/etc/hosts` on the region servers, from...

```
# Do not remove the following line, or various programs
# that require network functionality will fail.
127.0.0.1               fully.qualified.regionservername regionservername
localhost.localdomain localhost
::1             localhost6.localdomain6 localhost6
```

... to (removing the master node's name from localhost)...

```
# Do not remove the following line, or various programs
# that require network functionality will fail.
127.0.0.1               localhost.localdomain localhost
::1             localhost6.localdomain6 localhost6
```

13.6.1.2. Compression Link Errors

Since compression algorithms such as LZO need to be installed and configured on each cluster this is a frequent source of startup error. If you see messages like this...

```
11/02/20 01:32:15 ERROR lzo.GPLNativeCodeLoader: Could not load native gpl library
java.lang.UnsatisfiedLinkError: no gplcompression in java.library.path
        at java.lang.ClassLoader.loadLibrary(ClassLoader.java:1734)
        at java.lang.Runtime.loadLibrary0(Runtime.java:823)
        at java.lang.System.loadLibrary(System.java:1028)
```

.. then there is a path issue with the compression libraries. See the Configuration section on LZO compression configuration.

13.6.2. Runtime Errors

13.6.2.1. RegionServer Hanging

Are you running an old JVM (< 1.6.0_u21?)? When you look at a thread dump, does it look like threads are BLOCKED but no one holds the lock all are blocked on? See HBASE 3622 Deadlock in HBaseServer (JVM bug?). Adding `-XX:+UseMembar` to the HBase `HBASE_OPTS` in `conf/hbase-env.sh` may fix it.

13.6.2.2. java.io.IOException...(Too many open files)

See the Getting Started section on ulimit and nproc configuration.

13.6.2.3. xceiverCount 258 exceeds the limit of concurrent xcievers 256

This typically shows up in the DataNode logs.

See the Getting Started section on xceivers configuration.

13.6.2.4. System instability, and the presence of "java.lang.OutOfMemoryError: unable to create new native thread in exceptions" HDFS DataNode logs or that of any system daemon

See the Getting Started section on ulimit and nproc configuration. The default on recent Linux distributions is 1024 - which is far too low for HBase.

13.6.2.5. DFS instability and/or RegionServer lease timeouts

If you see warning messages like this...

```
2009-02-24 10:01:33,516 WARN org.apache.hadoop.hbase.util.Sleeper: We slept xxx ms, ten
times longer than scheduled: 10000
2009-02-24 10:01:33,516 WARN org.apache.hadoop.hbase.util.Sleeper: We slept xxx ms, ten
times longer than scheduled: 15000
2009-02-24 10:01:36,472 WARN org.apache.hadoop.hbase.regionserver.HRegionServer: unable to
report to master for xxx milliseconds - retrying
```

... or see full GC compactions then you may be experiencing full GC's.

13.6.2.6. "No live nodes contain current block" and/or YouAreDeadException

These errors can happen either when running out of OS file handles or in periods of severe network problems where the nodes are unreachable.

See the Getting Started section on ulimit and nproc configuration and check your network.

13.6.2.7. ZooKeeper SessionExpired events

Master or RegionServers shutting down with messages like those in the logs:

```
WARN org.apache.zookeeper.ClientCnxn: Exception
closing session 0x278bd16a96000f to sun.nio.ch.SelectionKeyImpl@355811ec
java.io.IOException: TIMED OUT
       at org.apache.zookeeper.ClientCnxn$SendThread.run(ClientCnxn.java:906)
WARN org.apache.hadoop.hbase.util.Sleeper: We slept 79410ms, ten times longer than
scheduled: 5000
INFO org.apache.zookeeper.ClientCnxn: Attempting connection to server hostname/IP:PORT
INFO org.apache.zookeeper.ClientCnxn: Priming connection to
java.nio.channels.SocketChannel[connected local=/IP:PORT remote=hostname/IP:PORT]
INFO org.apache.zookeeper.ClientCnxn: Server connection successful
WARN org.apache.zookeeper.ClientCnxn: Exception closing session 0x278bd16a96000d to
sun.nio.ch.SelectionKeyImpl@3544d65e
java.io.IOException: Session Expired
       at
org.apache.zookeeper.ClientCnxn$SendThread.readConnectResult(ClientCnxn.java:589)
       at org.apache.zookeeper.ClientCnxn$SendThread.doIO(ClientCnxn.java:709)
       at org.apache.zookeeper.ClientCnxn$SendThread.run(ClientCnxn.java:945)
ERROR org.apache.hadoop.hbase.regionserver.HRegionServer: ZooKeeper session expired
```

The JVM is doing a long running garbage collecting which is pausing every threads (aka "stop the world"). Since the RegionServer's local ZooKeeper client cannot send heartbeats, the session times out. By design, we shut down any node that isn't able to contact the ZooKeeper ensemble after getting a timeout so that it stops serving data that may already be assigned elsewhere.

- Make sure you give plenty of RAM (in `hbase-env.sh`), the default of 1GB won't be able to sustain long running imports.
- Make sure you don't swap, the JVM never behaves well under swapping.
- Make sure you are not CPU starving the RegionServer thread. For example, if you are running a MapReduce job using 6 CPU-intensive tasks on a machine with 4 cores, you are probably starving the RegionServer enough to create longer garbage collection pauses.
- Increase the ZooKeeper session timeout

If you wish to increase the session timeout, add the following to your `hbase-site.xml` to increase the timeout from the default of 60 seconds to 120 seconds.

```
<property>
    <name>zookeeper.session.timeout</name>
    <value>1200000</value>
</property>
<property>
    <name>hbase.zookeeper.property.tickTime</name>
    <value>6000</value>
</property>
```

Be aware that setting a higher timeout means that the regions served by a failed RegionServer will take at least that amount of time to be transfered to another RegionServer. For a production system serving live requests, we would instead recommend setting it lower than 1 minute and over-provision your cluster in order the lower the memory load on each machines (hence having less garbage to collect per machine).

If this is happening during an upload which only happens once (like initially loading all your data into HBase), consider bulk loading.

See Section 13.8.2, “ZooKeeper, The Cluster Canary” for other general information about ZooKeeper troubleshooting.

13.6.2.8. NotServingRegionException

This exception is "normal" when found in the RegionServer logs at DEBUG level. This exception is returned back to the client and then the client goes back to .META. to find the new location of the moved region.

However, if the NotServingRegionException is logged ERROR, then the client ran out of retries and something probably wrong.

13.6.2.9. Regions listed by domain name, then IP

Fix your DNS. In versions of HBase before 0.92.x, reverse DNS needs to give same answer as forward lookup. See HBASE 3431 RegionServer is not using the name given it by the master; double entry in master listing of servers for gorey details.

13.6.3. Shutdown Errors

13.7. Master

13.7.1. Startup Errors

13.7.1.1. Master says that you need to run the hbase migrations script

Upon running that, the hbase migrations script says no files in root directory.

HBase expects the root directory to either not exist, or to have already been initialized by hbase running a previous time. If you create a new directory for HBase using Hadoop DFS, this error will occur. Make sure the HBase root directory does not currently exist or has been initialized by a previous run of HBase. Sure fire solution is to just use Hadoop dfs to delete the HBase root and let HBase create and initialize the directory itself.

13.7.2. Shutdown Errors

13.8. ZooKeeper

13.8.1. Startup Errors

13.8.1.1. Could not find my address: xyz in list of ZooKeeper quorum servers

A ZooKeeper server wasn't able to start, throws that error. xyz is the name of your server.

This is a name lookup problem. HBase tries to start a ZooKeeper server on some machine but that machine isn't able to find itself in the `hbase.zookeeper.quorum` configuration.

Use the hostname presented in the error message instead of the value you used. If you have a DNS server, you can set `hbase.zookeeper.dns.interface` and `hbase.zookeeper.dns.nameserver` in `hbase-site.xml` to make sure it resolves to the correct FQDN.

13.8.2. ZooKeeper, The Cluster Canary

ZooKeeper is the cluster's "canary in the mineshaft". It'll be the first to notice issues if any so making sure its happy is the short-cut to a humming cluster.

See the ZooKeeper Operating Environment Troubleshooting page. It has suggestions and tools for checking disk and networking performance; i.e. the operating environment your ZooKeeper and HBase are running in.

13.9. Amazon EC2

13.9.1. ZooKeeper does not seem to work on Amazon EC2

HBase does not start when deployed as Amazon EC2 instances. Exceptions like the below appear in the Master and/or RegionServer logs:

```
2009-10-19 11:52:27,030 INFO org.apache.zookeeper.ClientCnxn: Attempting
connection to server ec2-174-129-15-236.compute-1.amazonaws.com/10.244.9.171:2181
2009-10-19 11:52:27,032 WARN org.apache.zookeeper.ClientCnxn: Exception
closing session 0x0 to sun.nio.ch.SelectionKeyImpl@656dc861
java.net.ConnectException: Connection refused
```

Security group policy is blocking the ZooKeeper port on a public address. Use the internal EC2 host names when configuring the ZooKeeper quorum peer list.

13.9.2. Instability on Amazon EC2

Questions on HBase and Amazon EC2 come up frequently on the HBase dist-list. Search for old threads using Search Hadoop

Chapter 14. Building HBase

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This chapter will be of interest only to those building HBase from source.

14.1. Building in snappy compression support

<p>Pass `-Dsnappy` to trigger the snappy maven profile for building snappy native libs into hbase.</p>

14.2. Adding an HBase release to Apache's Maven Repository

Follow the instructions at Publishing Maven Artifacts. The 'trick' to making it all work is answering the questions put to you by the mvn release plugin properly, making sure it is using the actual branch AND before doing the **mvn release:perform** step, VERY IMPORTANT, hand edit the release.properties file that was put under `${HBASE_HOME}` by the previous step, **release:perform**. You need to edit it to make it point at right locations in SVN.

If you see run into the below, its because you need to edit version in the pom.xml and add `-SNAPSHOT` to the version (and commit).

```
[INFO] Scanning for projects...
[INFO] Searching repository for plugin with prefix: 'release'.
[INFO] ------------------------------------------------------------------------
[INFO] Building HBase
[INFO]    task-segment: [release:prepare] (aggregator-style)
[INFO] ------------------------------------------------------------------------
[INFO] [release:prepare {execution: default-cli}]
[INFO] ------------------------------------------------------------------------
[ERROR] BUILD FAILURE
[INFO] ------------------------------------------------------------------------
[INFO] You don't have a SNAPSHOT project in the reactor projects list.
[INFO] ------------------------------------------------------------------------
[INFO] For more information, run Maven with the -e switch
[INFO] ------------------------------------------------------------------------
[INFO] Total time: 3 seconds
[INFO] Finished at: Sat Mar 26 18:11:07 PDT 2011
[INFO] Final Memory: 35M/423M
[INFO] -----------------------------------------------------------------------
```

Chapter 15. Developing HBase

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This chapter will be of interest only to those developing HBase (i.e., as opposed to using it).

15.1. HBase Repositories

15.1.1. SVN

```
svn co http://svn.apache.org/repos/asf/hbase/trunk hbase-core-trunk
```

15.1.2. Git

```
git clone git://git.apache.org/hbase.git
```

15.2. IDEs

15.2.1. Eclipse

15.2.1.1. Code Formatting

See HBASE-3678 Add Eclipse-based Apache Formatter to HBase Wiki for an Eclipse formatter to help ensure your code conforms to HBase'y coding convention. The issue includes instructions for loading the attached formatter.

Also, no @author tags - that's a rule. Quality Javadoc comments are appreciated. And include the Apache license.

15.2.1.2. Subversive Plugin

Download and install the Subversive plugin.

Set up an SVN Repository target from Section 15.1.1, “SVN”, then check out the code.

15.2.1.3. HBase Project Setup

To set up your Eclipse environment for HBase, close Eclipse and execute...

```
mvn eclipse:eclipse
```

... from your local HBase project directory in your workspace to generate a new `.project` file. Then reopen Eclipse.

15.2.1.4. Maven Plugin

Download and install the Maven plugin. For example, Help -> Install New Software -> (search for Maven Plugin)

15.2.1.5. Maven Classpath Variable

The `M2_REPO` classpath variable needs to be set up for the project. This needs to be set to your local Maven repository, which is usually `~/.m2/repository`

If this classpath variable is not configured, you will see compile errors in Eclipse like this...

```
Description     Resource        Path    Location        Type
The project cannot be built until build path errors are resolved        hbase
Unknown Java Problem
Unbound classpath variable: 'M2_REPO/asm/asm/3.1/asm-3.1.jar' in project 'hbase'
hbase           Build path      Build Path Problem
Unbound classpath variable: 'M2_REPO/com/github/stephenc/high-scale-lib/high-scale-
lib/1.1.1/high-scale-lib-1.1.1.jar' in project 'hbase'       hbase           Build path
Build Path Problem
Unbound classpath variable: 'M2_REPO/com/google/guava/guava/r09/guava-r09.jar' in project
'hbase'       hbase           Build path      Build Path Problem
Unbound classpath variable: 'M2_REPO/com/google/protobuf/protobuf-java/2.3.0/protobuf-
java-2.3.0.jar' in project 'hbase'        hbase           Build path      Build Path
Problem Unbound classpath variable:
```

15.2.1.6. Eclipse Known Issues

Eclipse will currently complain about `Bytes.java`. It is not possible to turn these errors off.

```
Description     Resource        Path    Location        Type
Access restriction: The method arrayBaseOffset(Class) from the type Unsafe is not
accessible due to restriction on required library
/System/Library/Java/JavaVirtualMachines/1.6.0.jdk/Contents/Classes/classes.jar
Bytes.java      /hbase/src/main/java/org/apache/hadoop/hbase/util       line 1061
Java Problem
Access restriction: The method arrayIndexScale(Class) from the type Unsafe is not
accessible due to restriction on required library
/System/Library/Java/JavaVirtualMachines/1.6.0.jdk/Contents/Classes/classes.jar
Bytes.java      /hbase/src/main/java/org/apache/hadoop/hbase/util       line 1064
Java Problem
Access restriction: The method getLong(Object, long) from the type Unsafe is not
accessible due to restriction on required library
/System/Library/Java/JavaVirtualMachines/1.6.0.jdk/Contents/Classes/classes.jar
```

```
Bytes.java      /hbase/src/main/java/org/apache/hadoop/hbase/util       line 1111
Java Problem
```

15.3. Maven Build Commands

All commands executed from the local HBase project directory.

15.3.1. Compile

```
mvn compile
```

15.3.2. Run all Unit Tests

```
mvn test
```

15.3.3. Run a Single Unit Test

```
mvn test -Dtest=TestXYZ
```

15.4. Unit Tests

In HBase we use JUnit 4. If you need to run miniclusters of HDFS, ZooKeeper, HBase, or MapReduce testing, be sure to checkout the `HBaseTestingUtility`. Alex Baranau of Sematext describes how it can be used in HBase Case-Study: Using HBaseTestingUtility for Local Testing and Development (2010).

15.4.1. Mockito

Sometimes you don't need a full running server unit testing. For example, some methods can make do with a a `org.apache.hadoop.hbase.Server` instance or a `org.apache.hadoop.hbase.master.MasterServices` Interface reference rather than a full-blown `org.apache.hadoop.hbase.master.HMaster`. In these cases, you maybe able to get away with a mocked `Server` instance. For example:

15.5. Getting Involved

HBase gets better only when people contribute!

15.5.1. Mailing Lists

Sign up for the dev-list and the user-list. See the mailing lists page. Posing questions - and helping to answer other people's questions - is encouraged! There are varying levels of experience on both lists so patience and politeness are encouraged (and please stay on topic.)

15.5.2. Jira

Check for existing issues in Jira. If it's either a new feature request, enhancement, or a bug, file a ticket.

15.5.2.1. Jira Priorities

The following is a guideline on setting Jira issue priorities:

- Blocker: Should only be used if the issue WILL cause data loss or cluster instability reliably.
- Critical: The issue described can cause data loss or cluster instability in some cases.
- Major: Important but not tragic issues, like updates to the client API that will add a lot of much-needed functionality or significant bugs that need to be fixed but that don't cause data loss.
- Minor: Useful enhancements and annoying but not damaging bugs.
- Trivial: Useful enhancements but generally cosmetic.

15.5.3. Codelines

Most development is done on TRUNK. However, there are branches for minor releases (e.g., 0.90.1, 0.90.2, and 0.90.3 are on the 0.90 branch).

If you have any questions on this just send an email to the dev dist-list.

15.5.4. Submitting Patches

15.5.4.1. Create Patch

Patch files can be easily generated from Eclipse, for example by selecting "Team -> Create Patch".

Please submit one patch-file per Jira. For example, if multiple files are changed make sure the selected resource when generating the patch is a directory. Patch files can reflect changes in multiple files.

Make sure you review Section 15.2.1.1, "Code Formatting" for code style.

15.5.4.2. Patch File Naming

The patch file should have the HBase Jira ticket in the name. For example, if a patch was submitted for `Foo.java`, then a patch file called `Foo_HBASE_XXX.patch` would be acceptable where XXX is the HBase Jira number.

15.5.4.3. Unit Tests

Yes, please. Please try to include unit tests with every code patch (and especially new classes and large changes).

Also, please make sure unit tests pass locally before submitting the patch.

15.5.4.4. Attach Patch to Jira

The patch should be attached to the associated Jira ticket "More Actions -> Attach Files". Make sure you click the ASF license inclusion, otherwise the patch can't be considered for inclusion.

Once attached to the ticket, click "Submit Patch" and the status of the ticket will change. Committers will review submitted patches for inclusion into the codebase. Please understand that not every patch may get committed, and that feedback will likely be provided on the patch. Fear not, though, because the HBase community is helpful!

15.5.5. Committing Patches

Committers do this. See How To Commit in the HBase wiki.

Appendix A. Tools

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Here we list HBase tools for administration, analysis, fixup, and debugging.

A.1. HBase hbck

An *fsck* for your HBase install

To run hbck against your HBase cluster run

```
$ ./bin/hbase hbck
```

At the end of the commands output it prints *OK* or *INCONSISTENCY*. If your cluster reports inconsistencies, pass **-details** to see more detail emitted. If inconsistencies, run **hbck** a few times because the inconsistency may be transient (e.g. cluster is starting up or a region is splitting). Passing **-fix** may correct the inconsistency (This latter is an experimental feature).

A.2. HFile Tool

See Section 10.3.4.2.2, “HFile Tool”.

A.3. WAL Tools

A.3.1. `HLog` tool

The main method on `HLog` offers manual split and dump facilities. Pass it WALs or the product of a split, the content of the `recovered.edits`. directory.

You can get a textual dump of a WAL file content by doing the following:

```
 $ ./bin/hbase org.apache.hadoop.hbase.regionserver.wal.HLog --dump
hdfs://example.org:9000/hbase/.logs/example.org,60020,1283516293161/10.10.21.10%3A60020.12
83973724012
```

The return code will be non-zero if issues with the file so you can test wholesomeness of file by redirecting `STDOUT` to `/dev/null` and testing the program return.

Similarily you can force a split of a log file directory by doing:

```
 $ ./bin/hbase org.apache.hadoop.hbase.regionserver.wal.HLog --split
hdfs://example.org:9000/hbase/.logs/example.org,60020,1283516293161/
```

A.4. Compression Tool

See Section A.4, “Compression Tool”.

A.5. Node Decommission

You can stop an individual RegionServer by running the following script in the HBase directory on the particular node:

```
$ ./bin/hbase-daemon.sh stop regionserver
```

The RegionServer will first close all regions and then shut itself down. On shutdown, the RegionServer's ephemeral node in ZooKeeper will expire. The master will notice the RegionServer gone and will treat it as a 'crashed' server; it will reassign the nodes the RegionServer was carrying.

Disable the Load Balancer before Decommissioning a node

If the load balancer runs while a node is shutting down, then there could be contention between the Load Balancer and the Master's recovery of the just decommissioned RegionServer. Avoid any problems by disabling the balancer first. See Load Balancer below.

A downside to the above stop of a RegionServer is that regions could be offline for a good period of time. Regions are closed in order. If many regions on the server, the first region to close may not be back online until all regions close and after the master notices the RegionServer's znode gone. In HBase 0.90.2, we added facility for having a node gradually shed its load and then shutdown itself down. HBase 0.90.2 added the `graceful_stop.sh` script. Here is its usage:

```
$ ./bin/graceful_stop.sh
Usage: graceful_stop.sh [--config &conf-dir>] [--restart] [--reload] [--thrift] [--rest]
&hostname>
 thrift      If we should stop/start thrift before/after the hbase stop/start
 rest        If we should stop/start rest before/after the hbase stop/start
 restart     If we should restart after graceful stop
 reload      Move offloaded regions back on to the stopped server
 debug       Move offloaded regions back on to the stopped server
 hostname    Hostname of server we are to stop
```

To decommission a loaded RegionServer, run the following:

```
$ ./bin/graceful_stop.sh HOSTNAME
```

where `HOSTNAME` is the host carrying the RegionServer you would decommission.

On `HOSTNAME`

The `HOSTNAME` passed to `graceful_stop.sh` must match the hostname that hbase is using to identify RegionServers. Check the list of RegionServers in the master UI for how HBase is referring to servers. Its usually hostname but can also be FQDN. Whatever HBase is using, this is what you should pass the `graceful_stop.sh` decommission script. If you pass IPs, the script is not yet smart enough to make a hostname (or FQDN) of it and so it will fail when it checks if server is currently running; the graceful unloading of regions will not run.

The `graceful_stop.sh` script will move the regions off the decommissioned RegionServer one at a time to minimize region churn. It will verify the region deployed in the new location before it will moves the next region and so on until the decommissioned server is carrying zero regions. At this point, the `graceful_stop.sh` tells the RegionServer **stop**. The master will at this point notice the RegionServer gone but all regions will have already been redeployed and because the RegionServer went down cleanly, there will be no WAL logs to split.

Load Balancer

It is assumed that the Region Load Balancer is disabled while the **graceful_stop** script runs (otherwise the balancer and the decommission script will end up fighting over region deployments). Use the shell to disable the balancer:

```
hbase(main):001:0> balance_switch false
true
0 row(s) in 0.3590 seconds
```

This turns the balancer OFF. To reenable, do:

```
hbase(main):001:0> balance_switch true
false
0 row(s) in 0.3590 seconds
```

A.5.1. Rolling Restart

You can also ask this script to restart a RegionServer after the shutdown AND move its old regions back into place. The latter you might do to retain data locality. A primitive rolling restart might be effected by running something like the following:

```
$ for i in `cat conf/regionservers|sort`; do ./bin/graceful_stop.sh --restart --reload
--debug $i; done &> /tmp/log.txt &
```

Tail the output of `/tmp/log.txt` to follow the scripts progress. The above does RegionServers only. Be sure to disable the load balancer before doing the above. You'd need to do the master update separately. Do it before you run the above script. Here is a pseudo-script for how you might craft a rolling restart script:

1. Untar your release, make sure of its configuration and then rsync it across the cluster. If this is 0.90.2, patch it with HBASE-3744 and HBASE-3756.
2. Run hbck to ensure the cluster consistent

   ```
   $ ./bin/hbase hbck
   ```

   Effect repairs if inconsistent.
3. Restart the Master:

   ```
   $ ./bin/hbase-daemon.sh stop master; ./bin/hbase-daemon.sh start master
   ```

4. Disable the region balancer:

   ```
   $ echo "balance_switch false" | ./bin/hbase
   ```

5. Run the `graceful_stop.sh` script per RegionServer. For example:

   ```
   $ for i in `cat conf/regionservers|sort`; do ./bin/graceful_stop.sh --restart
   --reload --debug $i; done &> /tmp/log.txt &
   ```

   If you are running thrift or rest servers on the RegionServer, pass --thrift or --rest options (See usage for `graceful_stop.sh` script).
6. Restart the Master again. This will clear out dead servers list and reenable the balancer.
7. Run hbck to ensure the cluster is consistent.

A.6. CopyTable

CopyTable is a utility that can copy part or of all of a table, either to the same cluster or another cluster. The usage is as follows:

```
$ bin/hbase org.apache.hadoop.hbase.mapreduce.CopyTable [--rs.class=CLASS] [--
rs.impl=IMPL] [--starttime=X] [--endtime=Y] [--new.name=NEW] [--peer.adr=ADR] tablename
```

Options:

- `rs.class` hbase.regionserver.class of the peer cluster. Specify if different from current cluster.
- `rs.impl` hbase.regionserver.impl of the peer cluster.
- `starttime` Beginning of the time range. Without endtime means starttime to forever.
- `endtime` End of the time range. Without endtime means starttime to forever.
- `new.name` New table's name.
- `peer.adr` Address of the peer cluster given in the format hbase.zookeeper.quorum:hbase.zookeeper.client.port:zookeeper.znode.parent
- `families` Comma-separated list of ColumnFamilies to copy.

Args:

- tablename Name of table to copy.

Example of copying 'TestTable' to a cluster that uses replication for a 1 hour window:

```
$ bin/hbase org.apache.hadoop.hbase.mapreduce.CopyTable
--rs.class=org.apache.hadoop.hbase.ipc.ReplicationRegionInterface
```

```
--rs.impl=org.apache.hadoop.hbase.regionserver.replication.ReplicationRegionServer
--starttime=1265875194289 --endtime=1265878794289
--peer.adr=server1,server2,server3:2181:/hbase TestTable
```

Appendix B. Compression In HBase

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B.1. CompressionTest Tool

HBase includes a tool to test compression is set up properly. To run it, type `/bin/hbase org.apache.hadoop.hbase.util.CompressionTest`. This will emit usage on how to run the tool.

B.2. `hbase.regionserver.codecs`

To have a RegionServer test a set of codecs and fail-to-start if any code is missing or misinstalled, add the configuration `hbase.regionserver.codecs` to your `hbase-site.xml` with a value of codecs to test on startup. For example if the `hbase.regionserver.codecs` value is `lzo,gz` and if lzo is not present or improperly installed, the misconfigured RegionServer will fail to start.

Administrators might make use of this facility to guard against the case where a new server is added to cluster but the cluster requires install of a particular coded.

B.3. LZO

Unfortunately, HBase cannot ship with LZO because of the licensing issues; HBase is Apache-licensed, LZO is GPL. Therefore LZO install is to be done post-HBase install. See the Using LZO Compression wiki page for how to make LZO work with HBase.

A common problem users run into when using LZO is that while initial setup of the cluster runs smooth, a month goes by and some sysadmin goes to add a machine to the cluster only they'll have forgotten to do the LZO fixup on the new machine. In versions since HBase 0.90.0, we should fail in a way that makes it plain what the problem is, but maybe not.

See Section B.2, “ `hbase.regionserver.codecs` ” for a feature to help protect against failed LZO install.

B.4. GZIP

GZIP will generally compress better than LZO though slower. For some setups, better compression may be preferred. Java will use java's GZIP unless the native Hadoop libs are available on the CLASSPATH; in this case it will use native compressors instead (If the native libs are NOT present, you will see lots of *Got brand-new compressor* reports in your logs; see Q:).

B.5. SNAPPY

If snappy is installed, HBase can make use of it (courtesy of hadoop-snappy [23]).

1. Build and install snappy on all nodes of your cluster.
2. Use CompressionTest to verify snappy support is enabled and the libs can be loaded ON ALL NODES of your cluster:

   ```
   $ hbase org.apache.hadoop.hbase.util.CompressionTest hdfs://host/path/to/hbase
   snappy
   ```

3. Create a column family with snappy compression and verify it in the hbase shell:

   ```
   $ hbase> create 't1', { NAME => 'cf1', COMPRESSION => 'SNAPPY' }
   hbase> describe 't1'
   ```

   In the output of the "describe" command, you need to ensure it lists "COMPRESSION => 'SNAPPY'"

---

[23] See Alejandro's note up on the list on difference between Snappy in Hadoop and Snappy in HBase

Appendix C. FAQ

C.1. General

Are there other HBase FAQs?

Are there other HBase FAQs?

See the FAQ that is up on the wiki, HBase Wiki FAQ.

Does HBase support SQL?

Not really. SQL-ish support for HBase via Hive is in development, however Hive is based on MapReduce which is not generally suitable for low-latency requests. See the Chapter 9, *Data Model* section for examples on the HBase client.

How does HBase work on top of HDFS?

HDFS is a distributed file system that is well suited for the storage of large files. It's documentation states that it is not, however, a general purpose file system, and does not provide fast individual record lookups in files. HBase, on the other hand, is built on top of HDFS and provides fast record lookups (and updates) for large tables. This can sometimes be a point of conceptual confusion. See the Chapter 9, *Data Model* and Chapter 10, *Architecture* sections for more information on how HBase achieves its goals.

Can I change a table's rowkeys?

No. See Section 6.6, “ Immutability of Rowkeys ”.

Why are logs flooded with '2011-01-10 12:40:48,407 INFO org.apache.hadoop.io.compress.CodecPool: Got brand-new compressor' messages?

Because we are not using the native versions of compression libraries. See HBASE-1900 Put back native support when hadoop 0.21 is released. Copy the native libs from hadoop under hbase lib dir or symlink them into place and the message should go away.

C.2. EC2

Why doesn't my remote java connection into my ec2 cluster work?

See Andrew's answer here, up on the user list: Remote Java client connection into EC2 instance.

C.3. Building HBase

When I build, why do I always get `Unable to find resource 'VM_global_library.vm'`?

Ignore it. Its not an error. It is officially ugly though.

C.4. Runtime

I'm having problems with my HBase cluster, how can I troubleshoot it?

See Chapter 13, *Troubleshooting and Debugging HBase*.

How can I improve HBase cluster performance?

See Chapter 11, *Performance Tuning*.

C.5. How do I...?

Secondary Indexes in HBase?

See Section 6.9, “ Secondary Indexes and Alternate Query Paths ”

Store (fill in the blank) in HBase?

See Section 6.7, “ Supported Datatypes ”.

Back up my HBase Cluster?

See HBase Backup Options over on the Sematext Blog.

Appendix D. YCSB: The Yahoo! Cloud Serving Benchmark and HBase

TODO: Describe how YCSB is poor for putting up a decent cluster load.

TODO: Describe setup of YCSB for HBase

Ted Dunning redid YCSB so its mavenized and added facility for verifying workloads. See Ted Dunning's YCSB.

Appendix E. HFile format version 2

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E.1. Motivation

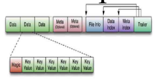
We found it necessary to revise the HFile format after encountering high memory usage and slow startup times caused by large Bloom filters and block indexes in the region server. Bloom filters can get as large as 100 MB per HFile, which adds up to 2 GB when aggregated over 20 regions. Block indexes can grow as large as 6 GB in aggregate size over the same set of regions. A region is not considered opened until all of its block index data is loaded. Large Bloom filters produce a different performance problem: the first get request that requires a Bloom filter lookup will incur the latency of loading the entire Bloom filter bit array.

To speed up region server startup we break Bloom filters and block indexes into multiple blocks and write those blocks out as they fill up, which also reduces the HFile writer's memory footprint. In the Bloom filter case, "filling up a block" means accumulating enough keys to efficiently utilize a fixed-size bit array, and in the block index case we accumulate an "index block" of the desired size. Bloom filter blocks and index blocks (we call these "inline blocks") become interspersed with data blocks, and as a side effect we can no longer rely on the difference between block offsets to determine data block length, as it was done in version 1.

HFile is a low-level file format by design, and it should not deal with application-specific details such as Bloom filters, which are handled at StoreFile level. Therefore, we call Bloom filter blocks in an HFile "inline" blocks. We also supply HFile with an interface to write those inline blocks.

Another format modification aimed at reducing the region server startup time is to use a contiguous “load-on-open” section that has to be loaded in memory at the time an HFile is being opened. Currently, as an HFile opens, there are separate seek operations to read the trailer, data/meta indexes, and file info. To read the Bloom filter, there are two more seek operations for its “data” and “meta” portions. In version 2, we seek once to read the trailer and seek again to read everything else we need to open the file from a contiguous block.

E.2. HFile format version 1 overview

As we will be discussing the changes we are making to the HFile format, it is useful to give a short overview of the previous (HFile version 1) format. An HFile in the existing format is structured as follows: 

[24]

E.2.1. Block index format in version 1

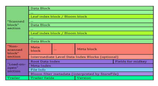
The block index in version 1 is very straightforward. For each entry, it contains:

1. Offset (long)
2. Uncompressed size (int)
3. Key (a serialized byte array written using Bytes.writeByteArray)
    a. Key length as a variable-length integer (VInt)
    b. Key bytes

The number of entries in the block index is stored in the fixed file trailer, and has to be passed in to the method that reads the block index. One of the limitations of the block index in version 1 is that it does not provide the compressed size of a block, which turns out to be necessary for decompression. Therefore, the HFile reader has to infer this compressed size from the offset difference between blocks. We fix this limitation in version 2, where we store on-disk block size instead of uncompressed size, and get uncompressed size from the block header.

E.3. HBase file format with inline blocks (version 2)

E.3.1. Overview

The version of HBase introducing the above features reads both version 1 and 2 HFiles, but only writes version 2 HFiles. A version 2 HFile is structured as follows: 

E.3.2. Unified version 2 block format

In the version 2 every block in the data section contains the following fields:

1. 8 bytes: Block type, a sequence of bytes equivalent to version 1's "magic records". Supported block types are:
    a. DATA – data blocks
    b. LEAF_INDEX – leaf-level index blocks in a multi-level-block-index
    c. BLOOM_CHUNK – Bloom filter chunks
    d. META – meta blocks (not used for Bloom filters in version 2 anymore)
    e. INTERMEDIATE_INDEX – intermediate-level index blocks in a multi-level blockindex
    f. ROOT_INDEX – root>level index blocks in a multi>level block index
    g. FILE_INFO – the "file info" block, a small key>value map of metadata
    h. BLOOM_META – a Bloom filter metadata block in the load>on>open section
    i. TRAILER – a fixed>size file trailer. As opposed to the above, this is not an HFile v2 block but a fixed>size (for each HFile version) data structure
    j. INDEX_V1 – this block type is only used for legacy HFile v1 block
2. Compressed size of the block's data, not including the header (int).

    Can be used for skipping the current data block when scanning HFile data.
3. Uncompressed size of the block's data, not including the header (int)

    This is equal to the compressed size if the compression algorithm is NON
4. File offset of the previous block of the same type (long)

    Can be used for seeking to the previous data/index block
5. Compressed data (or uncompressed data if the compression algorithm is NONE).

The above format of blocks is used in the following HFile sections:

1. Scanned block section. The section is named so because it contains all data blocks that need to be read when an HFile is scanned sequentially. Also contains leaf block index and Bloom chunk blocks.
2. Non-scanned block section. This section still contains unified-format v2 blocks but it does not have to be read when doing a sequential scan. This section contains "meta" blocks and intermediate-level index blocks.

We are supporting "meta" blocks in version 2 the same way they were supported in version 1, even though we do not store Bloom filter data in these blocks anymore.

E.3.3. Block index in version 2

There are three types of block indexes in HFile version 2, stored in two different formats (root and non-root):

1. Data index — version 2 multi-level block index, consisting of:
    a. Version 2 root index, stored in the data block index section of the file

   b. Optionally, version 2 intermediate levels, stored in the non%root format in the data index section of the file. Intermediate levels can only be present if leaf level blocks are present
   c. Optionally, version 2 leaf levels, stored in the non%root format inline with data blocks
2. Meta index — version 2 root index format only, stored in the meta index section of the file
3. Bloom index — version 2 root index format only, stored in the "load-on-open" section as part of Bloom filter metadata.

E.3.4. Root block index format in version 2

This format applies to:

1. Root level of the version 2 data index
2. Entire meta and Bloom indexes in version 2, which are always single-level.

A version 2 root index block is a sequence of entries of the following format, similar to entries of a version 1 block index, but storing on-disk size instead of uncompressed size.

1. Offset (long)

   This offset may point to a data block or to a deeper>level index block.
2. On-disk size (int)
3. Key (a serialized byte array stored using Bytes.writeByteArray)
   a. Key (VInt)
   b. Key bytes

A single-level version 2 block index consists of just a single root index block. To read a root index block of version 2, one needs to know the number of entries. For the data index and the meta index the number of entries is stored in the trailer, and for the Bloom index it is stored in the compound Bloom filter metadata.

For a multi-level block index we also store the following fields in the root index block in the load-on-open section of the HFile, in addition to the data structure described above:

1. Middle leaf index block offset
2. Middle leaf block on-disk size (meaning the leaf index block containing the reference to the "middle" data block of the file)
3. The index of the mid-key (defined below) in the middle leaf-level block.

These additional fields are used to efficiently retrieve the mid-key of the HFile used in HFile splits, which we define as the first key of the block with a zero-based index of (n – 1) / 2, if the total number of blocks in the HFile is n. This definition is consistent with how the mid-key was determined in HFile version 1, and is reasonable in general, because blocks are likely to be the same size on average, but we don't have any estimates on individual key/value pair sizes.

When writing a version 2 HFile, the total number of data blocks pointed to by every leaf-level index block is kept track of. When we finish writing and the total number of leaf-level blocks is determined, it is clear which leaf-level block contains the mid-key, and the fields listed above are computed. When reading the HFile and the mid-key is requested, we retrieve the middle leaf index block (potentially from the block cache) and get the mid-key value from the appropriate position inside that leaf block.

E.3.5. Non-root block index format in version 2

This format applies to intermediate-level and leaf index blocks of a version 2 multi-level data block index. Every non-root index block is structured as follows.

1. numEntries: the number of entries (int).
2. entryOffsets: the "secondary index" of offsets of entries in the block, to facilitate a quick binary search on the key (numEntries + 1 int values). The last value is the total length of all entries in this index block. For example, in a non-root index block with entry sizes 60, 80, 50 the "secondary index" will contain the following int array: {0, 60, 140, 190}.
3. Entries. Each entry contains:
    a. Offset of the block referenced by this entry in the file (long)
    b. On>disk size of the referenced block (int)
    c. Key. The length can be calculated from entryOffsets.

E.3.6. Bloom filters in version 2

In contrast with version 1, in a version 2 HFile Bloom filter metadata is stored in the load-on-open section of the HFile for quick startup.

1. A compound Bloom filter.
    a. Bloom filter version = 3 (int). There used to be a DynamicByteBloomFilter class that had the Bloom filter version number 2
    b. The total byte size of all compound Bloom filter chunks (long)
    c. Number of hash functions (int
    d. Type of hash functions (int)
    e. The total key count inserted into the Bloom filter (long)
    f. The maximum total number of keys in the Bloom filter (long)
    g. The number of chunks (int)
    h. Comparator class used for Bloom filter keys, a UTF>8 encoded string stored using Bytes.writeByteArray
    i. Bloom block index in the version 2 root block index format

E.3.7. File Info format in versions 1 and 2

The file info block is a serialized HbaseMapWritable (essentially a map from byte arrays to byte arrays) with the following keys, among others. StoreFile-level logic adds more keys to this.

hfile.LASTKEY	The last key of the file (byte array)
hfile.AVG_KEY_LEN	The average key length in the file (int)
hfile.AVG_VALUE_LEN	The average value length in the file (int)

File info format did not change in version 2. However, we moved the file info to the final section of the file, which can be loaded as one block at the time the HFile is being opened. Also, we do not store comparator in the version 2 file info anymore. Instead, we store it in the fixed file trailer. This is because we need to know the comparator at the time of parsing the load-on-open section of the HFile.

E.3.8. Fixed file trailer format differences between versions 1 and 2

The following table shows common and different fields between fixed file trailers in versions 1 and 2. Note that the size of the trailer is different depending on the version, so it is “fixed” only within one version. However, the version is always stored as the last four-byte integer in the file.

Version 1	Version 2
File info offset (long)	
Data index offset (long)	loadOnOpenOffset (long) *The offset of the section that we need toload when opening the file.*
Number of data index entries (int)	
metaIndexOffset (long) This field is not being used by the version 1 reader, so we removed it from version 2.	uncompressedDataIndexSize (long) The total uncompressed size of the whole data block index, including root-level, intermediate-level, and leaf-level blocks.
Number of meta index entries (int)	
Total uncompressed bytes (long)	
numEntries (int)	numEntries (long)
Compression codec: 0 = LZO, 1 = GZ, 2 = NONE (int)	
	The number of levels in the data block index (int)
	firstDataBlockOffset (long) The offset of the first first data block. Used when scanning.

	lastDataBlockEnd (long) The offset of the first byte after the last key/value data block. We don't need to go beyond this offset when scanning.
Version: 1 (int)	Version: 2 (int)

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[24] Image courtesy of Lars George, hbase-architecture-101-storage.html.

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