ISIT312/ISIT912 Big Data Management

Spring 2023

HBase Design and Programming

In this practice, you will learn how to create HBase tables, how to load data, how to perform data manipulations, and how to search HBase tables using HBase shell commands. You will also learn how to use Java-based API to process HBase tables.

Warning: DO NOT attempt to copy the Linux commands in this document to your working Terminal, because it is error-prone. Type those commands by yourself or use the scripts when available.

Laboratory Instructions.

(0) Start Hadoop

Start five Hadoop services (see instructions in the earlier laboratory classes).

(1) How to start HBase server ?

It is possible to start HBase server from Terminal in the following way:

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

In order to interact with HBase, three HBase services must be running: **HMaster**, **HRegionServer** and **HQuorumPeer**. *(If you run into an error when using HBase, always check whether all three services are running.)*

Troubleshooting*. When working with HBase, if you see a message "ERROR: Can't get master address from ZooKeeper; znode data == null", use "jps" check whether HMaster is exited (this may happen from time to time). If HMaster is exited, re-process* `HBASE_HOME/bin/start-hbase.sh` *to re-start HMaster.*

(2) The HBase shell (command-line interface)

You can use the HBase command shell to interact with HBase. To use the shell, process the following command in a Terminal window:

```
$HBASE_HOME/bin/hbase shell
```

To ask about help …

```
help
```

The command `help` returns a pretty comprehensive information about the HBase commands.

(3) Some useful HBase commands

Processing of a command `version` returns the following messages.

```
1.2.6, rUnknown, Mon May 29 02:25:32 CDT 2017
```

Processing of a command `table_help` returns information about table-reference commands (see Appendix B in this document).

Command `status` returns the following message.

```
1 active master, 0 backup masters, 1 servers, 0 dead, 2.0000 average
load
```

Processing of a command `whoami` at the prompt returns the following message.

```
bigdata (auth:SIMPLE)
    groups: bigdata, adm, cdrom, sudo, dip, plugdev, lpadmin,
sambashare
```

(4) How to create a script file and how to process a script file (for HBase shell)?

To create HBase CLI script start `gedit` editor, type in the lines

```
status
whoami
```

and save a file as `script.hb`.

To process a script file type the following command at `hbase` prompt:

```
source('script.hb')
```

and press Enter key.

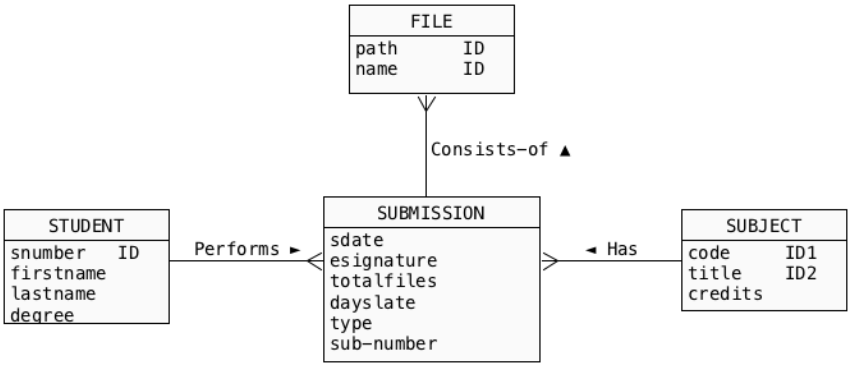
If you would like to process a script and save the results in a file then exit HBase CLI and in a Terminal window process the following command.

```
$HBASE_HOME/bin/hbase shell < script.hb > report.rpt
```

The command starts HBase shall that reads input from a file `script.hb` and outputs the results into a file `report.rpt`.

(5) How to design a HBase table ?

Consider the following conceptual schema.



We would like to implement a conceptual schema given above as a SINGLE HBase table. We shall create four column families: `STUDENT`, `SUBJECT`, `FILE`, and `SUBMISSION`. We shall distribute the rows over the column families in a way schematically presented below, which I would call as "a relational implementation style". We shall concatenate the names of entity types with the values of identifiers of entity instances and use it as the keys of rows in HBase table. The submitted files will be represented as column qualifiers. It means that a column family `FILE` will have a variable number of column qualifiers depending on the total number of submitted files.

```
                    STUDENT      SUBJECT        SUBMISSION   FILE
student:snumber1    xxxxxxxxxxx
student:snumber2    xxxxxxxxxxx
…
subject:code1                    xxxxxxxxxxx
subject:code2                    xxxxxxxxxxx
…
submission:skey1    xxx          xxx            xxxxxxxxxxx  xxxxxx
submission:skey2    xxx          xxx            xxxxxxxxxxx  xxx
…
```

where a submission `skey-n` consists of `snumber-n|code-n|sub-number-n`. The rows that describe submissions spread over all column families. The total number of overlaps determines what we call in the relational model as "denormalization" or simply speaking "redundancies" in HBase table.

(6) How to create a HBase table ?

To create an HBase table we must provide a name of a table and a name of at least one column family. Process the following command to create HBase table `COURSEWORK` with a column family `STUDENT`.

```
create 'COURSEWORK', 'STUDENT'
```

To verify a structure of HBase table use `describe` command.

```
describe 'COURSEWORK'
```

(7) How add new column families to an existing HBase table ?

Next, we use `alter` command add a column family `SUBJECT` to HBase table `COURSEWORK`.

```
alter 'COURSEWORK', {NAME=>'SUBJECT', VERSIONS=>'1'}
```

In our design we plan to represent each entity type as a separate column family. To add the column families FILE and SUBMISSION process the following commands.

```
alter 'COURSEWORK', {NAME=>'FILE', VERSIONS=>'2'}
alter 'COURSEWORK', {NAME=>'SUBMISSION', VERSIONS=>'1'}
```

Use describe command to verify the structures of HBase table COURSEWORK.

```
describe 'COURSEWORK'
```

(8) How to enter data into HBase table ?

It is possible to use a script dbload.hb available through Resources link on Moodle to process all put commands listed in this section. However, if you do not want to process all put commands in "one go" then it is still possible to use the script to copy/paste its individual sections.

First, we shall add few rows to a column family STUDENT. We shall use the values of attribute snumber prefixed with a string 'student' as a keys of rows in HBase table. The following commands add to a column family a row with key 'student:007', and the column qualifiers snumber, fname, lname, degree, and put the values into cells of HBase table.

```
put 'COURSEWORK','student:007','STUDENT:snumber','007'
put 'COURSEWORK','student:007','STUDENT:first-name','James'
put 'COURSEWORK','student:007','STUDENT:last-name','Bond'
put 'COURSEWORK','student:007','STUDENT:degree','MIT'
```

To verify the insertions use scan command.

```
scan 'COURSEWORK'
```

A sequence of put commands implements an insertion of a single row with a key 'student:007' into HBase table COURSEWORK.

Now, add all remaining data to a table COURSEWORK. The next sequence of put commands inserts the next row into column family STUDENT.

```
put 'COURSEWORK','student:666','STUDENT:snumber','666'
put 'COURSEWORK','student:666','STUDENT:firstname','Harry'
put 'COURSEWORK','student:666','STUDENT:lastname','Potter'
put 'COURSEWORK','student:666','STUDENT:degree','BCS'
```

Next, we insert two rows into a column family SUBJECT.

```
put 'COURSEWORK','subject:312','SUBJECT:code','312'
put 'COURSEWORK','subject:312','SUBJECT:title','Big Data'
put 'COURSEWORK','subject:312','SUBJECT:credits','6'
put 'COURSEWORK','subject:313','SUBJECT:code','313'
put 'COURSEWORK','subject:313','SUBJECT:title','Very Big Data'
put 'COURSEWORK','subject:313','SUBJECT:credits','12'
```

Next, we insert information about a submission performed by one of the students enrolled in one of the subjects.

```
put 'COURSEWORK','submission:007|312|1','SUBMISSION:sdate','01-APR-2017'
put 'COURSEWORK','submission:007|312|1','SUBMISSION:esignature','jb'
```

```
put 'COURSEWORK','submission:007|312|1','SUBMISSION:totalfiles','2'
put 'COURSEWORK','submission:007|312|1','SUBMISSION:dayslate','0'
put 'COURSEWORK','submission:007|312|1','STUDENT:snumbner','007'
put 'COURSEWORK','submission:007|312|1','SUBJECT:code','312'
put 'COURSEWORK','submission:007|312|1','FILE:fnumber1','path/file-name1-1'
put 'COURSEWORK','submission:007|312|1','FILE:fnumber2','path/file-name1-1'
```

Note, that a row with a key `'submission:007|312|1'` contributes to column families `SUBMISSION`, `STUDENT`, `SUBJECT`, `FILE`.

It is possible (but not necessary) to "de-normalise" the HBase table `COURSEWORK` by inserting the values into the cells labelled with the column qualifiers in `STUDENT` and `SUBJECT` to the rows that describe submissions. For example, the following commands add the first and the last name of a student who performed a submission.

```
put 'COURSEWORK','submission:007|312|1','STUDENT:firstname','James'
put 'COURSEWORK','submission:007|312|1','STUDENT:lastname','Bond'
```

Verify a structure of HBase table after all additions.

```
describe 'COURSEWORK'
```

Add all remaining data.

```
put 'COURSEWORK','submission:007|313|1','SUBMISSION:sdate','02-APR-2017'
put 'COURSEWORK','submission:007|313|1','SUBMISSION:esignature','jb'
put 'COURSEWORK','submission:007|313|1','SUBMISSION:totalfiles','2'
put 'COURSEWORK','submission:007|313|1','SUBMISSION:dayslate','0'
put 'COURSEWORK','submission:007|313|1','SUBMISSION:type','project'
put 'COURSEWORK','submission:007|313|1','STUDENT:snumbner','007'
put 'COURSEWORK','submission:007|313|1','SUBJECT:code','313'
put 'COURSEWORK','submission:007|313|1','FILE:fnumber1','path/file-name3-1'
put 'COURSEWORK','submission:666|312|3','SUBMISSION:sdate','01-APR-2017'
put 'COURSEWORK','submission:666|312|3','SUBMISSION:esignature','hp'
put 'COURSEWORK','submission:666|312|3','SUBMISSION:totalfiles','2'
put 'COURSEWORK','submission:666|312|3','SUBMISSION:dayslate','0'
put 'COURSEWORK','submission:666|312|3','SUBMISSION:type','assignment'
put 'COURSEWORK','submission:666|312|3','STUDENT:snumbner','666'
put 'COURSEWORK','submission:666|312|3','SUBJECT:code','312'
put 'COURSEWORK','submission:666|312|3','FILE:fnumber1','path/file-name1-1'
put 'COURSEWORK','submission:666|312|3','FILE:fnumber2','path/file-name1-1'
put 'COURSEWORK','submission:666|312|4','SUBMISSION:sdate','02-APR-2017'
put 'COURSEWORK','submission:666|312|4','SUBMISSION:esignature','hp'
put 'COURSEWORK','submission:666|312|4','SUBMISSION:totalfiles','2'
put 'COURSEWORK','submission:666|312|4','SUBMISSION:dayslate','0'
put 'COURSEWORK','submission:666|312|4','SUBMISSION:type','assignment'
put 'COURSEWORK','submission:666|312|4','STUDENT:snumbner','666'
put 'COURSEWORK','submission:666|312|4','SUBJECT:code','312'
put 'COURSEWORK','submission:666|312|4','FILE:fnumber1','path/file-name2-1'
put 'COURSEWORK','submission:666|312|4','FILE:fnumber2','path/file-name2-2'
put 'COURSEWORK','submission:666|313|2','SUBMISSION:sdate','02-APR-2017'
put 'COURSEWORK','submission:666|313|2','SUBMISSION:esignature','hp'
put 'COURSEWORK','submission:666|313|2','SUBMISSION:totalfiles','2'
put 'COURSEWORK','submission:666|313|2','SUBMISSION:dayslate','0'
put 'COURSEWORK','submission:666|313|2','SUBMISSION:type','project'
put 'COURSEWORK','submission:666|313|2','STUDENT:snumbner','666'
put 'COURSEWORK','submission:666|313|2','SUBJECT:code','313'
put 'COURSEWORK','submission:666|313|2','FILE:fnumber1','path/file-name3-1'
```

(9) How to replace a row ?

To replace a row use put command in the following way. *Note, that the replacements happens only for the cells with one version allowed. If some cells allow for more than one version then instead of the replacement a new version of a value in a cell is created*.

```
put 'COURSEWORK','student:007','STUDENT:snumber','008'
scan 'COURSEWORK'
```

(10) How to retrieve a row and a cell ?

To retrieve a row we use a row key and a command `get` in the following way.

```
get 'COURSEWORK','student:007'
```

To retrieve the contents of a cell we have to provide a full address of a cell that consists of `row key, column family: column qualifier`.

```
get 'COURSEWORK','student:007','STUDENT:snumber'
```

In the following way we can list up to 5 versions in a cell.

```
get 'COURSEWORK','student:007',{COLUMN=>'STUDENT:snumber',VERSIONS=>5}
```

(11) How to create a new version of a value in a cell ?

Assume that in one of existing submissions a student would like to submit a new version of a file `filenumber1`. A new version can be created because a column family `FILE` was created with value of parameter `VERSIONS` equal to `2` (see below). A new version is created by processing of the following `put` command.

```
alter 'COURSEWORK', {NAME=>'FILE', VERSIONS=>'2'}
```

A new version is created by processing the following `put` command.

```
put 'COURSEWORK','submission:007|313|1','FILE:fnumber1','path/file-name3-3'
```

The results can be verified with `get` command.

```
get 'COURSEWORK','submission:007|313|1',{COLUMN=>'FILE:fnumber1',VERSIONS=>2}
```

(12) How to retrieve many rows from a given column family ?

A `scan` command is equivalent to an operation of projection in the relational data model. It can be used to list the contents of entire HBase table, the contents of select column family, and the contents of cells in a given column family and in a given column qualifier (see below).

```
scan 'COURSEWORK',{COLUMN=>'STUDENT'}
scan 'COURSEWORK',{COLUMN=>'STUDENT:first-name'}
```

(13) How to list the names of created HBase tables ?

A column list displays the names of HBase tables created so far.

```
list
```

(14) How to drop HBase table ?

To drop HBase table we have disable it first with a command disable

```
disable 'COURSEWORK'
```

and then we can drop it with `drop` command.

```
drop 'COURSEWORK'
```

If you have performed `disable` but not `drop` yet, you can process `enable 'COURSEWORK'` to reverse `disable` and continue to work on the table.

(15) How to truncate HBase table ?

A command `truncate` can be used to delete the contents of HBASE table without changing its internal structure. The command preserves all column families and column qualifiers within the column families.

```
truncate 'COURSEWORK'
```

(16) How to exit HBase CLI (if you work with the HBase shell)?

To exit HBase CLI process at `hbase main: ...:0>` prompt a command `exit`.

```
exit
```

(17) How to use Java API to process HBase tables ? (optional)

Use `Resources` link to download `ListTable.java` from Moodle.

Use `gedit` editor and create a file `ListTable.java` with the following contents.

```
import org.apache.hadoop.conf.Configuration;
import org.apache.hadoop.hbase.HBaseConfiguration;
import org.apache.hadoop.hbase.HColumnDescriptor;
import org.apache.hadoop.hbase.HTableDescriptor;
import org.apache.hadoop.hbase.TableName;
import org.apache.hadoop.hbase.client.HBaseAdmin;

public class ListTables {
    public static void main(String[] args) throws Exception {
        Configuration conf = HBaseConfiguration.create();
        HBaseAdmin admin = new HBaseAdmin(conf);
// Get all the list of tables using HBaseAdmin object
      HTableDescriptor[] tableDescriptor = admin.listTables();

// Display the names of all tables
      System.out.println("HBase tables:");
```

```
        for (int i=0; i<tableDescriptor.length;i++ ){
        System.out.println(tableDescriptor[i].getNameAsString());}

    }
}
```

Assume your `ListTables.java` is on the Desktop. To compile `ListTables.java` and execute the implemented listing table function, use the following commands.

```
cd /home/bigdata/Desktop
javac -classpath .:/usr/share/hbase/lib/* ListTables.java
java -cp .:/usr/share/hbase/lib/* ListTables
```

(18) How to use the remaining example of HBase Java API ? (optional)

The following simple examples of HBase Java API are available on Moodle.

Creating HBase table	`CreateTable.java`
Inserting a row (cells)	`PutRow.java`
Retrieving a row (cells)	`GetRow.java`
Retrieving entire row with versions	`GetEntireRow.java`
Scanning a table	`ScanTable.java`
Deleting a row	`DelRow.java`
Dropping a table	`DropTable.java`

To compile and to process the remaining example of HBase Java API use `javac` and `java` commands in the same way as for `ListTables.java` example (see yellow highlighted fragments that should be replaced with the appropriate names).

(19) How to stop HBase

Process the following command to stop HBase

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

Appendix A

```
hbase(main):001:0> help
HBase Shell, version 1.2.6, rUnknown, Mon May 29 02:25:32 CDT 2017
Type 'help "COMMAND"', (e.g. 'help "get"' -- the quotes are necessary) for help on a specific command.
Commands are grouped. Type 'help "COMMAND_GROUP"', (e.g. 'help "general"') for help on a command group.

COMMAND GROUPS:
  Group name: general
  Commands: status, table_help, version, whoami

  Group name: ddl
  Commands: alter, alter_async, alter_status, create, describe, disable, disable_all, drop, drop_all, enable, enable_all,
exists, get_table, is_disabled, is_enabled, list, locate_region, show_filters

  Group name: namespace
  Commands: alter_namespace, create_namespace, describe_namespace, drop_namespace, list_namespace,
list_namespace_tables

  Group name: dml
```

Commands: append, count, delete, deleteall, get, get_counter, get_splits, incr, put, scan, truncate, truncate_preserve

Group name: tools
Commands: assign, balance_switch, balancer, balancer_enabled, catalogjanitor_enabled, catalogjanitor_run, catalogjanitor_switch, close_region, compact, compact_rs, flush, major_compact, merge_region, move, normalize, normalizer_enabled, normalizer_switch, split, trace, unassign, wal_roll, zk_dump

Group name: replication
Commands: add_peer, append_peer_tableCFs, disable_peer, disable_table_replication, enable_peer, enable_table_replication, list_peers, list_replicated_tables, remove_peer, remove_peer_tableCFs, set_peer_tableCFs, show_peer_tableCFs

Group name: snapshots
Commands: clone_snapshot, delete_all_snapshot, delete_snapshot, list_snapshots, restore_snapshot, snapshot

Group name: configuration
Commands: update_all_config, update_config

Group name: quotas
Commands: list_quotas, set_quota

Group name: security
Commands: grant, list_security_capabilities, revoke, user_permission

Group name: procedures
Commands: abort_procedure, list_procedures

Group name: visibility labels
Commands: add_labels, clear_auths, get_auths, list_labels, set_auths, set_visibility

SHELL USAGE:
Quote all names in HBase Shell such as table and column names. Commas delimit
command parameters. Type <RETURN> after entering a command to run it.
Dictionaries of configuration used in the creation and alteration of tables are
Ruby Hashes. They look like this:

{'key1' => 'value1', 'key2' => 'value2', ...}

and are opened and closed with curley-braces. Key/values are delimited by the
'=>' character combination. Usually keys are predefined constants such as
NAME, VERSIONS, COMPRESSION, etc. Constants do not need to be quoted. Type
'Object.constants' to see a (messy) list of all constants in the environment.

If you are using binary keys or values and need to enter them in the shell, use
double-quote'd hexadecimal representation. For example:

hbase> get 't1', "key\x03\x3f\xcd"
hbase> get 't1', "key\003\023\011"
hbase> put 't1', "test\xef\xff", 'f1:', "\x01\x33\x40"

The HBase shell is the (J)Ruby IRB with the above HBase-specific commands added.
For more on the HBase Shell, see http://hbase.apache.org/book.html

Appendix B

```
hbase(main):003:0> table_help
Help for table-reference commands.

You can either create a table via 'create' and then manipulate the table via commands like 'put', 'get', etc.
See the standard help information for how to use each of these commands.

However, as of 0.96, you can also get a reference to a table, on which you can invoke commands.
For instance, you can get create a table and keep around a reference to it via:

   hbase> t = create 't', 'cf'

Or, if you have already created the table, you can get a reference to it:

   hbase> t = get_table 't'

You can do things like call 'put' on the table:

  hbase> t.put 'r', 'cf:q', 'v'

which puts a row 'r' with column family 'cf', qualifier 'q' and value 'v' into table t.

To read the data out, you can scan the table:

  hbase> t.scan

which will read all the rows in table 't'.

Essentially, any command that takes a table name can also be done via table reference.
Other commands include things like: get, delete, deleteall,
get_all_columns, get_counter, count, incr. These functions, along with
the standard JRuby object methods are also available via tab completion.

For more information on how to use each of these commands, you can also just type:

   hbase> t.help 'scan'

which will output more information on how to use that command.

You can also do general admin actions directly on a table; things like enable, disable,
flush and drop just by typing:

   hbase> t.enable
   hbase> t.flush
   hbase> t.disable
   hbase> t.drop

Note that after dropping a table, your reference to it becomes useless and further usage
is undefined (and not recommended).
```