HBase Key Design

Originals of Slides and Source Code for Examples:
http://www.coreservlets.com/hadoop-tutorial/

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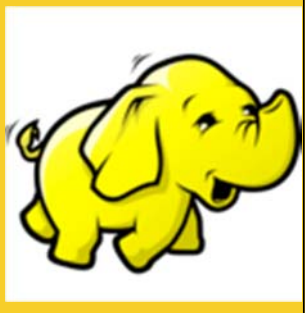


Agenda

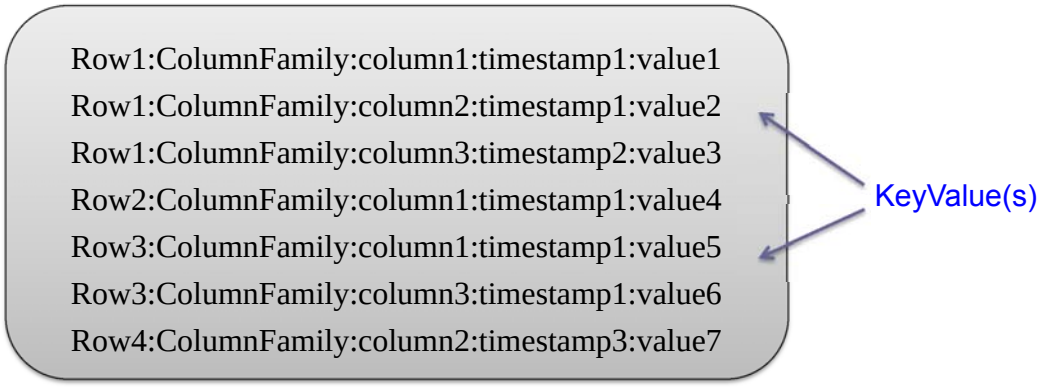
- **Storage Model**
- **Querying Granularity**
- **Table Design**
  - Tall-Narrow Tables
  - Flat-Wide Tables

Column Family – Storage Unit

- **Column family is how data is separated**
- **Not columns (unlike regular column database)**
- **For a family cells are stored in the same file (HFile) on HDFS**
- **Cells that are not set will not be stored**
  - Nulls are not stored – data must be explicitly set in order to be persisted
  - Coordinate of each cell are be persisted with the value

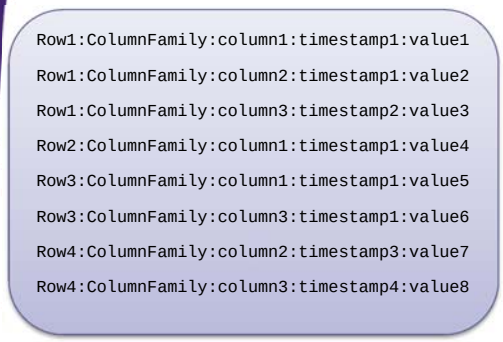
Column Family – Storage Unit

- **Rows are stored as a set of cells**
- **Cells are stored with their coordinates**
- **Ordered by Row-Id, and then by column qualifier**
- **Each cell is represented by KeyValue class**



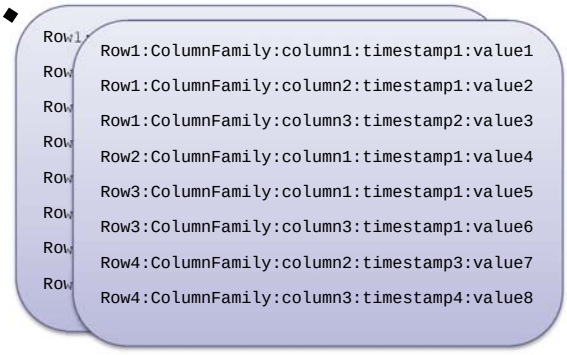
HFile “ColumnFamily/abcdef

HTable – Set of Column Families



HFile “Family1/abcdefU”

Table will be made of set of Column Families where each is stored in it’s own file.



HFile “Family1/abcdefU”

Querying Data From HBase

- **By Row-Id or range of Row Ids**
  - Only load the specific rows with the provided range of ids
  - Only touch the region servers with those ids
  - If no further criteria provided will load all the cells for all of the families which means loading multiple files of HDFS
- **By Column Family**
  - Eliminates the needs to load other storage files
  - Strongly suggested parameter if you know the needed families
- **By Timestamp/Version**
  - Can skip entire store files as the contained timestamp range within a file is considered

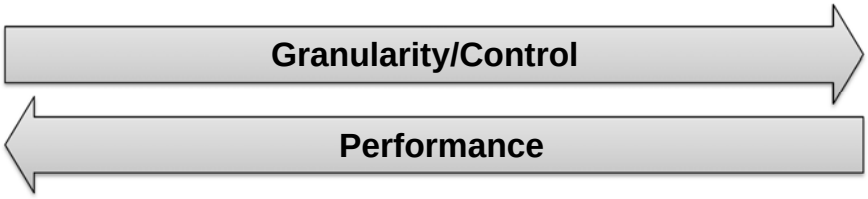
Querying Data From HBase

- **By Column Name/Qualifier**
  - Will not eliminate the need to load the storage file
  - Will however eliminate the need to transfer the unwanted data
- **By Value**
  - Can skip cells by using filters
  - The slowest selection criteria
  - Will examine each cell
- **Filters can be applied to each selection criteria**
  - rows, families, columns, timestamps and values
- **Multiple querying criteria can be provided**
  - And most of the time should be provided

Querying Granularity vs. Performance

Cells Coordinates

	Row	Column Family	Column Name	Timestamp	Value
Skip Rows	√	X	X	X	X
Skip Store Files	√	√	X	√	X



Source: Lars, George. HBase The Definitive Guide. O'Reilly Media. 2011

Designing to Store Data in Tables

- **Two options: Tall-Narrow OR Flat-Wide**
- **Tall-Narrow**
  - Small number of columns
  - Large number of rows
- **Flat-Wide**
  - Small number of rows
  - Large number of columns
- **Tall Narrow is generally recommended**
  - Store parts of cell data in the row id
    - Faster data retrieval
    - HBase splits on row boundaries

Real World Problem: Blog App

- **Let's say we are implementing a Blog management application**
  - Users will enter blogs
  - Some users will have many blogs and some few
  - You'll want to query by user and date range
- **We will implement simple DataFacade to store and access Blog objects**

Real World Problem: Blog App

```
public class Blog {
   private final String username;
   private final String blogEntry;
   private final Date created;
   public Blog(String username, String blogEntry, Date created) {
          this.username = username;
          this.blogEntry = blogEntry;
          this.created = created;
   }
   public String getUsername() {
          return username;
   }
   public String getBlogEntry() {
          return blogEntry;
   }
   public Date getCreated() {
          return created;
   }
   @Override
   public String toString() {
           return this.username + "(" + created + "): " + blogEntry ;
   }
}
```

**Encapsulates username, Blog entry and the date the blog was created

Real World Problem: Blog App

- **Two ways to arrange your data**
  - Flat-Wide: each row represents a single user
  - Tall-Narrow: each row represents a single blog, multiple rows will represent a single user
- **Lets assume a simple interface:**

```
public interface DataFacade {
  public List<Blog> getBlogs(String userId,
      Date startDate, Date endDate) throws IOException;
  public void save(Blog blog) throws IOException;
  public void close() throws IOException;
}
```


1: Flat-Wide Solution

- **All blogs are stored in a single row and family**
- **Each blog is stored in its own column (timestamp1 … timestamp)**

Flat

Row id	entry:t1	entry:t2	…	entry:tN
userid1	Blah blah blah...	Important news..	…	Interesting stuff...
userid2	Interesting stuff...	Blah blah blah...	…	Important news..
userid3	Important news...	Interesting stuff...	…	Blah blah blah...

Wide

- **Columns are ordered**
- **Can use filter to select sub-set of columns or page through**

1: Flat-Wide Solution FlatAndWideTableDataFacade.java

```
public class FlatAndWideTableDataFacade implements DataFacade {

  private final HTable table;
  private final static byte [] ENTRY_FAMILY = toBytes("entry");

  public FlatAndWideTableDataFacade(Configuration conf)
                      throws IOException{
     table = new HTable(conf, "Blog_FlatAndWide");
  }

  @Override
  public void close() throws IOException{
     table.close();
  }
…
…
```


1: Flat-Wide Solution FlatAndWideTableDataFacade.java

```
@Override
public void save(Blog blog) throws IOException {
        Put put = new Put(toBytes(blog.getUsername()));
        put.add(ENTRY_FAMILY, toBytes(dateToColumn(blog.getCreated())),
                        toBytes(blog.getBlogEntry()));
        table.put(put);
}

private String dateToColumn(Date date ){
        String reversedDateAsStr= Long.toString(Long.MAX_VALUE-date.getTime());
        StringBuilder builder = new StringBuilder();
        for ( int i = reversedDateAsStr.length(); i < 19; i++){
                builder.append('0');
        }
        builder.append(reversedDateAsStr);
        return builder.toString();
}
public Date columnToDate(String column){
        long reverseStamp = Long.parseLong(column);
        return new Date(Long.MAX_VALUE-reverseStamp);
}
```

entry:timestamp format, each blog is stored in it's own column; for a user all blogs are stored in the same row

Encode and decode date into a column name; columns are ordered,reversing timestamp and padding will force latest records to be retrieved first

1: Flat-Wide Solution FlatAndWideTableDataFacade.java

```
@Override
public List<Blog> getBlogs(String userId, Date startDate, Date endDate) throws IOException {
        Get get = new Get(toBytes(userId));

        FilterList filters = new FilterList();
        filters.addFilter(new QualifierFilter(CompareOp.LESS_OR_EQUAL,
                new BinaryComparator(toBytes(dateToColumn(startDate)))));
        filters.addFilter(new QualifierFilter(CompareOp.GREATER_OR_EQUAL,
                new BinaryComparator(toBytes(dateToColumn(endDate)))));
        get.setFilter(filters);

        Result result = table.get(get);
        Map<byte[], byte[]> columnValueMap = result.getFamilyMap(ENTRY_FAMILY);

        List<Blog> blogs = new ArrayList<Blog>();
        for (Map.Entry<byte[], byte[]> entry : columnValueMap.entrySet()){
                Date createdOn = columnToDate(Bytes.toString(entry.getKey()));
                String blogEntry = Bytes.toString(entry.getValue());
                blogs.add(new Blog(userId, blogEntry, createdOn));
        }
        return blogs;
}
```

Get row by user id

Utilize filter mechanism to only retrieve provided date range; this works because timestamp is encoded in the column name

2: Tall-Narrow Solution

- **1 blog per row**
- **Row id will be comprised of user and timestamp**

Tall

Row id	entry:blog
userid1_t1	Blah blah blah...
userid1_t2	Interesting stuff...
...	...
userid1_tN	Important news...
….	...
….	...
userid3_500	Blah blah blah...
userid3_501	Blah blah blah...

Narrow

2: Tall-Narrow Solution TallAndNarrowTableDataFacade.java

```
public class TallAndNarrowTableDataFacade implements DataFacade {

  private final HTable table;
  private final static byte [] ENTRY_FAMILY = toBytes("entry");
  private final static byte [] BLOG_COLUMN = toBytes("blog");
  private final static byte [] CREATED_COLUMN = toBytes("created");
  private final static byte [] USER_COLUMN = toBytes("user");

  private final static char KEY_SPLIT_CHAR = '_';
  public TallAndNarrowTableDataFacade(Configuration conf)
          throws IOException{
        table = new HTable(conf, "Blog_TallAndNarrow");
  }

  @Override
  public void close() throws IOException {
        table.close();
  }

…
…
```


2: Tall-Narrow Solution TallAndNarrowTableDataFacade.java

```
@Override
public void save(Blog blog) throws IOException {

   Put put = new Put(toBytes(blog.getUsername() + KEY_SPLIT_CHAR +
               convertForId(blog.getCreated())));
```

Encode username and creation timestamp into key

```
  put.add(ENTRY_FAMILY, USER_COLUMN, toBytes(blog.getUsername()));
  put.add(ENTRY_FAMILY, BLOG_COLUMN, toBytes(blog.getBlogEntry()));
  put.add(ENTRY_FAMILY, CREATED_COLUMN,
               toBytes(blog.getCreated().getTime()));
```

Store blog in and other metadata in column(s)

```
  table.put(put);
}
```

Save one blog per row

2: Tall-Narrow Solution TallAndNarrowTableDataFacade.java

```
private String convertForId(Date date ){
      return convertForId(date.getTime());
}


private String convertForId(long timestamp){
      String reversedDateAsStr=
                  Long.toString(Long.MAX_VALUE-timestamp);
      StringBuilder builder = new StringBuilder();
      for ( int i = reversedDateAsStr.length(); i < 19; i++){
            builder.append('0');
      }
      builder.append(reversedDateAsStr);
      return builder.toString();
}
```

Encode date into a string to be used for row_id; ids are ordered, reversing timestamp and padding will force latest records to be retrieved first

2: Tall-Narrow Solution TallAndNarrowTableDataFacade.java

```
@Override
public List<Blog> getBlogs(String userId, Date startDate,
                    Date endDate) throws IOException {
  List<Blog> blogs = new ArrayList<Blog>();

  Scan scan = new Scan(toBytes(userId + KEY_SPLIT_CHAR +
       convertForId(endDate)), toBytes(userId + KEY_SPLIT_CHAR +
       convertForId(startDate.getTime()-1)));

  scan.addFamily(ENTRY_FAMILY);

  ResultScanner scanner = table.getScanner(scan);
  for (Result result : scanner){
    String user = Bytes.toString(
              result.getValue(ENTRY_FAMILY, USER_COLUMN));
    String blog = Bytes.toString(
              result.getValue(ENTRY_FAMILY, BLOG_COLUMN));
    long created = toLong(
              result.getValue(ENTRY_FAMILY, CREATED_COLUMN));
    blogs.add(new Blog(user, blog, new Date(created)));
  }
  return blogs;
}
```

Carefully construct start and stop keys of the scan; recall that row id is userId+reversed timestamp

Each row equals a blog

TableDesignExample.java

```
public class TableDesignExample {
        private final static DateFormat DATE_FORMAT = new
            SimpleDateFormat("yyyy.MM.dd hh:mm:ss");

        public static void main(String[] args) throws IOException {
                List<Blog> testBlogs = getTestBlogs();
                Configuration conf = HBaseConfiguration.create();


                DataFacade facade = new FlatAndWideTableDataFacade(conf);
                printTestBlogs(testBlogs);
                exerciseFacade(facade, testBlogs);
                facade.close();


                facade = new TallAndNarrowTableDataFacade(conf);
                exerciseFacade(facade, testBlogs);
                facade.close();
        }
```

Try both facades by running through the same code

TableDesignExample.java

```
private static void printTestBlogs(List<Blog> testBlogs) {
        System.out.println("----------------");
        System.out.println("Test set has [" +
                        testBlogs.size() + "] Blogs:");
        System.out.println("----------------");
        for (Blog blog : testBlogs){
                System.out.println(blog);
        }
}

private static List<Blog> getTestBlogs(){
        List<Blog> blogs = new ArrayList<Blog>();
        blogs.add(new Blog("user1", "Blog1", new Date(11111111)));
        blogs.add(new Blog("user1", "Blog2", new Date(22222222)));
        blogs.add(new Blog("user1", "Blog3", new Date(33333333)));
        blogs.add(new Blog("user2", "Blog4", new Date(44444444)));
        blogs.add(new Blog("user2", "Blog5", new Date(55555555)));
        return blogs;
}
```

TableDesignExample.java

```
public static void exerciseFacade(DataFacade facade,
             List<Blog> testBlogs) throws IOException{

       System.out.println("----------------");
       System.out.println("Running aggainst facade: " +
        facade.getClass());
       System.out.println("----------------");

       for (Blog blog : testBlogs){
             facade.save(blog);
       }

       getBlogs(facade, "user1",
        new Date(22222222), new Date(33333333));
       getBlogs(facade, "user2",
        new Date(55555555), new Date(55555555));
}
```


TableDesignExample.java

```
private static void getBlogs(DataFacade facade,
       String user, Date start, Date end)throws IOException {

  System.out.println("Selecting blogs for user [" + user + "] " +
              "between [" + DATE_FORMAT.format(start) + "] " +
              "and [" + DATE_FORMAT.format(end) + "]");

  for ( Blog blog : facade.getBlogs(user, start, end)){
       System.out.println("  " + blog);
  }
}
```

Run TableDesignExample

```
$ yarn jar $PLAY_AREA/HadoopSamples.jar \
    hbase.tableDesign.TableDesignExample
```


TableDesignExample's Output

```
Test set has [5] Blogs:
----------------
[Blog1] by [user1] on [1969.12.31 10:05:11]
[Blog2] by [user1] on [1970.01.01 01:10:22]
[Blog3] by [user1] on [1970.01.01 04:15:33]
[Blog4] by [user2] on [1970.01.01 07:20:44]
[Blog5] by [user2] on [1970.01.01 10:25:55]
----------------
Running aggainst facade: class hbase.tableDesign.FlatAndWideTableDataFacade
----------------
Selecting blogs for user [user1] between [1970.01.01 01:10:22] and [1970.01.01 04:15:33]
  [Blog3] by [user1] on [1970.01.01 04:15:33]
  [Blog2] by [user1] on [1970.01.01 01:10:22]
Selecting blogs for user [user2] between [1970.01.01 10:25:55] and [1970.01.01 10:25:55]
  [Blog5] by [user2] on [1970.01.01 10:25:55]
----------------
Running aggainst facade: class hbase.tableDesign.TallAndNarrowTableDataFacade
----------------
Selecting blogs for user [user1] between [1970.01.01 01:10:22] and [1970.01.01 04:15:33]
  [Blog3] by [user1] on [1970.01.01 04:15:33]
  [Blog2] by [user1] on [1970.01.01 01:10:22]
Selecting blogs for user [user2] between [1970.01.01 10:25:55] and [1970.01.01 10:25:55]
  [Blog5] by [user2] on [1970.01.01 10:25:55]
```

Flat-Wide vs. Tall-Narrow

- **Tall Narrow has superior query granularity**
  - query by rowid will skip rows, store files!
  - Flat-Wide has to query by column name which won't skip rows or storefiles
- **Tall Narrow scales better**
  - HBase splits at row boundaries meaning it will shard at blog boundary
  - Flat-Wide solution only works if all the blogs for a single user can fit into a single row
- **Flat-Wide provides atomic operations**
  - atomic on per-row-basis
  - There is no built in concept of a transaction for multiple rows or tables

Wrap-Up

Summary

- **We learned**
  - How Data Stored
  - Querying Granularity
  - Tall-Narrow Tables
  - Flat-Wide Tables

Questions?