SWC DB: Abstract

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SWC DB (Super Wide Column Database)

https://github.com/kashirin-alex/swc-db

The database is structured in columns , not by Tables or Namespaces, as familiar SQL is '`select columns from “table_name”;`', with “Super Wide Column DB” It is '`select [where_clause [Columns-Intervals] ];`'.

The “Super Wide Column” comes to its meaning by the column's key is a list-set of keys eg. A column cell's key is keys=(k1,k2,k3,k4,kN), comparing to a “Wide Column” key that is row, column-family, column-family-qualifier in the “Super Wide Column DB” it is equal to keys=(k1(row),k2(cf),k3(cq)) or(similar) column=cf with keys=(k1(row),k3(cq)) . Majority of the developments are planned to be on bases of Hypertable (https://github.com/kashirin-alex/hypertable).

The storage-form in the “Super Wide Column DB” is based on column-id and range-id, which on path consist CellStores and CommitLogs files at any point one server is responsible for a range-id on column-id.

The CellStores are Files storing Cells in serialized form that are after latest compaction whereas CommitLogs are the open-file-descriptor to which current data is added.
The Serialization of data in a CellStore/CommitLog file: (delimited with “|” for visual-representation of NONE)
|Blocks(Header | Compressor(Cells)) | Fixed-Index | Variable-Index | CellStore-Trailer|
The Cell-Serialization: *|Key-length(int32)|Key-serialized| Value-length(int32)|Value-Data|*
Key serialization: *|Key-flag(int8)|Key-control(int8)|Keys-count(int8)|joined(Keys[N]\0)|Timestamp(int64)|Revision(int64)|*

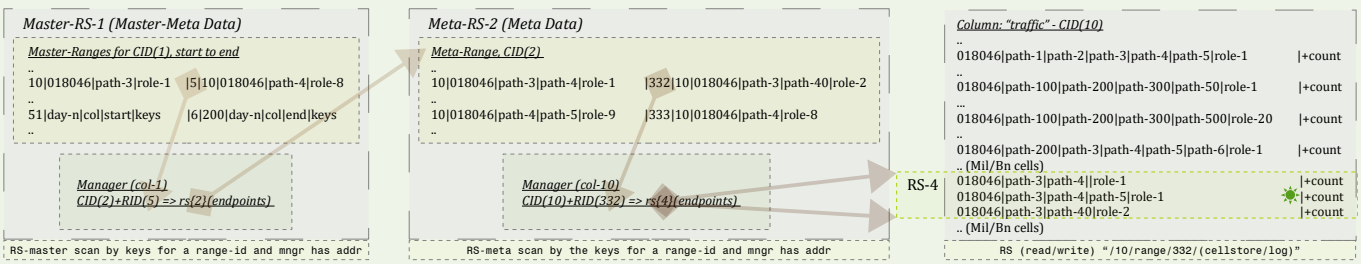
The Cells Ranges, a range is a Keys-begin to Keys-end, SWC DB use a self-explanatory master-ranges that define ranges to meta-ranges of data-ranges(cells-range) whereas on range-locator it includes the Keys comparison on the comparators of request, resulting in as most narrowed scan of cells-ranges.

System's reserved columns id[1-9],
1: IDENTIFIER a counter type column
2: RANGES
3: RID(RANGE-ID) to RS(N)
4: Column ID, Column Name and serialized Column-Scheme

The limitations that can be over-seen are:
- ✗ Maximum number of columns, it is store-size of int64(2^{64}) – 10(reserved cols) which can be improved by CID to be a string-type.
- ✗ Maximum size of Value or Key(after serialization), it is 4GB, while for such data size other limitations probably apply

The capabilities to expect:
- ✔ Supposing one server can handle 2bil cells with one cell is being keys(1024B) and value(1024B) a 4TB in volume over 1300 ranges, to apply such base to RS-master means there are 500k RS-meta with 667mil RS-data with cell value being just a 4KB, that makes a SWC DB cluster in total handling 5.7ZB(zettabyte) of data volume and more on a compression ratio.
- ✔ A client can read at 100%(while Client's and RS's are equivalent) bandwidth, considering a perfect scan case of each client is requesting on different ranges, number of clients at a given time can be by the number of RS-data using 100% bandwidth each.
- ✔ Maximum number of concurrent connections to a given server instance, it is the total available ports on the server by the number of configured IPv4 and IPv6 with support of multiple interfaces,

Some examples:
- Search indexing at https://thither.direct/opensearch/ with Wide Column it is being row=”sequences-of-words:domain:path” cf=”lang” whereas with Super Wide Column it can be changed to keys=[“sequences-of-words”, “domain”, “path”, “lang”], makes the scan-select much optimized, especially if to query words-data of a domain & path, it would go on to ranges that start with domain & path skipping the seek through ranges of several other many domains that as well include the same word-sequences. While to have the same query on a Wide Column would require tripling the volume of data by using more indexes of word-sequences on a domain (and path) such as. row=”domain:sequences:path” & row=”domain:path:sequences”. At current period the “open-search” on Thither.Direct does not offer querying data(words) on a site:domain or info:url-path as it is unreasonable over the data-volume overheads.
- A theoretical requirement for a building security tracking. Track of how many(an atomic-counter) personnel passed in an area of a building by role on a day:



SWC DB: Data topology

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Configuration Settings:

swc.rs.Range

.CellStore: *.count.max=10 , .size.min=32MB , .size.max=1GB , .size.win=256MB , .block.size=8MB (default) , .compressor=snappy (default)*

.CommitLog: *.roll.size=128MB , .compressor=snappy , .prune.min=1GB , .prune.max=0 , .prune.max.mem.%=50*

RangeServer (#):

Column (#):

Range (#), (Keys Begin <= interval < Keys End):

Range Definer (range.data):

- Header: (12-byte)
  - Size
  - Number of Intervals
- Keys Intervals: Begin + End: CellStore (#)

Commit Log, Fragment(#):

- Header: (17-byte), Compressor(Type), Uncompressed(Length), Compressed(Length), Data-Checksum(value)
- Cells: (serialized)

Fragment (#) ++ >= (swc.rs.Range.CommitLog.*roll.size*)

CellStore (#), (Keys Begin <= interval < Keys End):

Block (#), (Keys Begin <= interval < Keys End):

Header: (17-byte)

- Compressor: Type
- Uncompressed: Length
- Compressed: Length
- Data-Checksum: value

Cells: (*serialized*)

k
.
k1,k5,k5,k4

. .

Block (#) ++ <= (swc.rs.Range.CellStore.size.max / .DefaultBlockSize)

Blocks Index:

- Compressor: Type
- Uncompressed: Length
- Checksum: value
- Intervals: count
- Keys Intervals:

Begin()	-	End(k1,k5,k5,k5) :	CS position offset
Begin(k5,k5,k5,k5)	-	End(k1,k7,k7,k7) :	CS position offset

Trailer:

- CS Keys Interval: Begin + End
- Blocks-Index: CS position offset
- Blocks-Index size: Length
- Trailer-Start: CS position offset
- CS Version: Value(1)

. .

CellStore (#) ++ <= (swc.rs.Range.CellStore.count.max)

. .

Range (#) ++

. .

Column (#) ++

. .

RangeServer (#) ++

SWC DB: Applications

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Range-Server-Manager{N} (*dbManager*)

One or Many with standbys: manage ranges on columns ID range or all
Configuration, default columns all, default port 15000:

```
swc.mngr.host=[1-9]|IPv4,IPv4,IPv6|PORT
swc.mngr.host=[1-9]|IPv4,IPv4,IPv6|PORT
swc.mngr.host=[10-]|hostname-1|PORT
swc.mngr.host=[10-]|hostname-2|PORT
```

OR

```
swc.mngr.host=hostname-1
swc.mngr.host=IP-2
```

* handle rs{N} endpoints of a CID(column id) + RID(range id)
* on-interval > check-ranges assignments and load balance (unload/assign Ranges)
* a broker to RS(Master/Meta) requests for get-range of meta or data
* notified by Range-Server on handled columns scheme updates and add/remove column
* notify Range-Servers handle ranges of updated column schemes or removed column

* GC on FS, in-case, ranges removed while cell-stores and logs remained

Root{1} – mngr - (Root Manager, manages columns 1-2)

* assign rs{N} to new RangeServer connection
* 1st RangeServer systematically assigned with column(1) - (Master-RS)
* handle next column id
* handle next range id for a column id
* assign rs{N} to new added columns

File System (*libSwcDbFS – lib:Local/Hdfs/Ceph/FsBroker*)

```
RANGE PATH:    ./Col-ID(path)/range/Range-ID(path)
COMMIT-LOGS:  (RANGE PATH)/log/{seq}/fragment{N}.log
CELLSTORES:   (RANGE PATH)/cs/{N}.cs
LAST_RS:       (RANGE PATH)/rs/current.data (addrs+rs{N})
```

lib-DB-Client (*libSwcDbClient*)

Handle Scan request (select/insert/delete):
  Scan requests (+ Range-Locator)
  Manage Communications to RangeServers and Managers
Handle column add, remove and scheme updates

Range-Server {N} (*dbRangeServer*)

Handle column rename and schemes updates
Notifying to corresponding Range-Server-Manager on columns changes
Handle range-scans
Handle compaction
Notify Range-Server-Manager on ranges change (add, remove, update)

Master {1} - RS

Handle master-ranges:
  column-1: range: (KEYS_START → KEYS_END)

Meta {N} - RS

Handle meta-ranges, as defined by Master-RS:
  column-2: range: (KEYS_START → KEYS_END)

(System Reserved columns ids [1-9] META_COLUMN)

Clients:

Range-Server (master, meta, manager)
ThriftBroker
Utilities
User Application

SWC DB: Failure Tolerance

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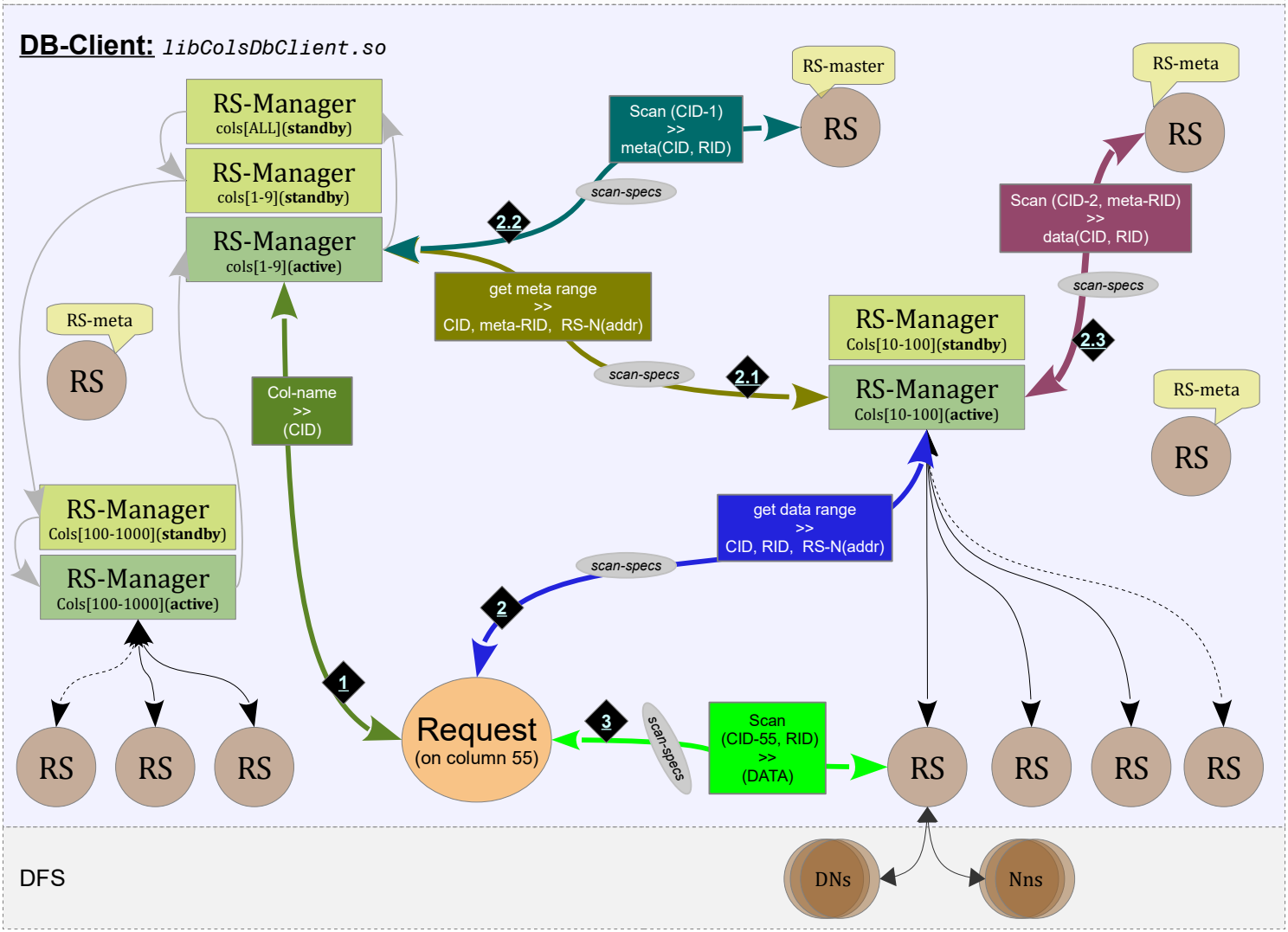
- ✔ A failed request to a RS-Manager is a connection fail-over to next in list from 'swc.mngr.host' configuration.
- ✔ A failed request to a RS(Master, Meta, Data)-N is fail-over to the new RS(addr) assign to RS-N by RS-Manager.
- ✔ RS-Manager, on interval or disconnection of a managed RS(either role), request to load ranges to another RS.
- ✔ RS-Master, as been a single instance, have connections only with It's RS-Manager. (in case, of only master-ranges)
- ✔ Distribute File System, depends on the system and it's feature of routing to a datanode .
- ✔ RS(any) in case a connection or file-descriptor failure try to reconnect to the DFS.
- ✔ Communication over-heads of a resolved-data to column-name, RID-location or RS-address are kept while connection and data discard by TTL or a notification from RS-Managers on changes.

  In worst case of outdated data being used with a request the RS return an error of a NOT_LOADED_RANGE.



SWC DB: LIB-DB-Client, Scan request (+ Range-Locator)

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Basic Process Flow of Scan request (+ Range-Locator)

Ranges Scan is done on per column base in-parallel(a client's max-range-locators config) with column's Scan Specifications

Scan-Specifications = cid, ScanSpecCellKeys(*keys_start, keys_finish*)

result = new_results = 0,

last_cell_keys = rid(meta) = 0,

keys_start(meta,data) = ScanSpec.keys_start

---

1 get column-ID by name => (cid)
Req. RS-MANAGER[cid-1](SCHEME-MNGR) – req, ([="ReqColName"]) => (cid)

```
DO get_ranges_data:
```

2 get range-data by (cid, *keys_start*(meta,data), *keys_finish*, rid(meta))
=> (cid,rid(data),rs{N}(addr), next_rid(meta,data)?, rid(meta))
Req. RS-MANAGER[cid]:
If not rid(meta):

2.1 get range-meta by (cid, *keys_start*(meta), *keys_finish*)
=> (cid, rid(meta), rs-meta{N}(addr), next_rid(meta)?):
Req. RS-MANAGER[cid-1]:

2.2 get range-master-meta => (rid(meta), next_rid(meta)?)
Req. RS-MASTER:
Scan-do (2-cell)(cid-1, [>="cid", *keys_start*(meta)], [<"cid", *keys_finish*]) = rid(meta)

2.3 get range-data by (cid, rid(meta), *keys_start*(data), *keys_finish*) => (cid, rid, rs{N}(addr), next_rid(data)?):
Req. RS-META - rs-meta{N}(addr):
Scan-do (2-cell)(cid-2, [>="cid", *keys_start*(data)], [<"cid", *keys_finish*]) = rid(data)

```
        If no range-data:
                goto finish
EXCEPT COMM:
        goto get_ranges_data
```

```
DO scan_range_data:

        scan range-data by (cid, rid(data), ScanSpecs)  => (new_results):
```

3 Req. RS-DATA – rs{N}(addr):

```
                Scan-do (cell-limit) (ScanSpecs) = results(data)

        if new_results
                (call_back) (available results), result+=new_results
                last_cell_keys=more_results[-1]

EXCEPT COMM, NOT_LOADED_RANGE:
        goto get_ranges_data
```

```
if result < limit(cell_limit):
        # Move Scan Offset by keys_start changed to last_cell_keys, setting -ge comparator to -gt
        if next_rid(data):
                start_keys(data) = last_cell_keys
                goto get_ranges_data

        if next_rid(meta):
                rid(meta) = 0
                start_keys(meta) = last_cell_keys
                goto get_ranges_data

DO finish:
        return result (call_back)
```

SWC DB: Query (SQL) scan

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select *[***where_clause** *[***Columns-Intervals** **or** **Cells-Intervals***]] [***Flags***(global-scope)];*

Columns-Intervals: *if not set, it is all columns from keys start to finish.*

```
col(column-name-a1) = ( [Cells-Intervals] [and] [Cells-Intervals] [and] .. [Cells-Intervals] )
[and] ..
col(column-name-b1, .., column-name-b2) = ( [Cells-Intervals] [and] [Cells-Intervals] [and] .. [Cells-Intervals] )
```

Cells-Intervals: *if not set, it is keys start to finish.*

```
cells = ( [Cells-Interval] Flags(interval-scope) )
[and]
cells = ( [Cells-Interval] Flags(interval-scope) )
[and]..
cells = ( [Cells-Interval] Flags(interval-scope) )
```

Cells-Interval:

```
[ Condition-Keys ] [and] [ Regexp-Condition-Keys ] [and] [ Condition-Value ] [and] [ Condition-Timestamp ]
```

Condition-Keys: *keys comparator apply to every key that do not have a dedicated comparator, exact-match is* keys=('k1', 'k2',,,'kN')

```
keys [comparator] ( [comparator] "str-1", [comparator] "str-2", [comparator] "str-3", [comparator] "str-N")

      or (in-range)

([comparator] "str-1",  [comparator] "str-N")      [ <=  or  < ]  keys  [ <=  or  < ]      ([comparator] "str-1",  [comparator] "str-N")
```

Condition-Value:

```
value [comparator] "string"

      or (for columns of counter type), not applicable comparators (prefix and regexp)

value [comparator] "int64_t(string)"
```

Condition-Timestamp: *not applicable comparators (prefix and regexp)*

```
timestamp [comparator] "YYYY/MM/DD HH:MM:ss.mmmuuunnn"

      or (in-range)

"YYYY/MM/DD HH:MM:ss.mmmuuunnn"  [ <=  or  < ]  timestamp  [ <=  or  < ]  "YYYY/MM/DD HH:MM:ss.mmmuuunnn"
```

Comparator:

```
[ =^ ]  :   prefix   (starts-with)
[ >  ]  :   -gt      (greater-than)
[ >= ]  :   -ge      (greater-equal)
[ =  ]  :   -eq      (equal)
[ <= ]  :   -le      (lower-equal)
[ <  ]  :   -lt      (lower-than)
[ != ]  :   -ne      (not-equal)
[ re ]  :   regexp   (regular-expression)

* -gt,-ge,-le,-lt are a bit-wise comparison
```

Flags: *at global-scope apply to Cells-Interval flags to which does not have flags definitions*

```
[ keys_only ]      =  TRUE on set            # default FALSE
[ return_deletes ] =  TRUE on set            # default FALSE
[ limit            =  NUMBER(uint32_t) ]     # default ALL
[ limit_by         =  "KEYS" or ".." ]       # default KEYS
[ offset           =  NUMBER(uint32_t) ]     # default 0
[ offset_by        =  "KEYS" or ".." ]       # default KEYS
[ max_versions     =  NUMBER(uint32_t) ]     # default ALL
```

An Example:

```
select
  where
    col(ColNameA1) = (
      cells = ( (>='1-') <= keys = (<='1-1-',="1") and value = "Value-Data-1" and timestamp > "2010/05/29" limit=10 limit_by="KEYS" )
    )
  and
    col(ColNameB1, ColNameB2) = (
      cells = ( (>='2-') <= keys = (<='2-2-',"1") and value = "Value-Data-2" and timestamp > "2010/05/29" )
      and
      cells = ( keys = (<='21-',"1") and timestamp > "2010/05/29" )
    )
  max_versions=1;
```

SWC DB: Scan Specs & Results

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Scan Specs, lib-DB-Client:

ScanSpec *(*

```
    ListColumns    columns;
    Flags          flags;
```

)

ColumnIntervals *(*

```
    int64_t           cid
    ListCellsInterval cells_intervals
```

)

The object-type is applied to the range-locator (Client)

CellsInterval *(*

```
    Keys       keys_start, keys_finish;
    Value      value;
    Timestamp  ts_start, ts_finish;
    Flags      flags;
```

)

Keys *(*

```
    ListKeys   keys;
```

)

Flags *(*

```
    uint32_t    limit, offset, max_versions;
    LimitType   limit_by, offset_by;
    bool        return_deletes, keys_only;
```

)

Key *(*

```
    const char*  key;
    size_t       key_len;
    Comparator   comp;
```

)

Value *(*

```
    const char*  value;
    size_t       value_len;
    Comparator   comp;
```

)

Timestamp *(*

```
    int64_t     ts;
    Comparator  comp;
```

)

Scan Response, lib-DB-Client:

Result *(*

```
    List<Col>   cols
    // ResponseFlag status = OK/PARTIAL/ERROR
    // Strings error_rs = ["N",]
```

)

Col *(*

```
    String      name
    String      id
    List<Cell>  cells
```

)

Cell *(*

```
    Strings     keys
    int64_t     timestamp
    char-array  value
    uint32_t    value_len
```

)

SWC DB: Column Schema & Actions on Columns

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Although, there are schemas in the SWC-DB these can be considered as schema-less, exception to TTL, Counter and Max-Versions at the Cells level.

Location of Schema and Column-Name to ID:

Reserved Column-ID 4 with cell:
Keys = ("FLAG" "Col-Name", "CID")
Value = (value-serialized)version(int8)
|counter(int8)|ttl(int32)|compression(int8)|bloomfilter(int8)|max_versions(int32)|time_order(int8)|replication(int8)|blocksize(int32)

Configuration Options:

The following configurations available in the Column-Schema:

- CELL-LEVEL:
  - TTL: (int32_t) seconds
  - COUNTER: (bool), default False
  - MAX_VERSIONS: (int32_t), default 1 - not applicable with COUNTER
  - TIME_ORDER: ASC/DESC, default ASC – applied to order of MAX_VERSIONS
- BLOCK-LEVEL:
  - COMPERSSION: none/snappy/zlib/zstd/bmz/lzo/quicklz
  - BLOCKSIZE: (int32_t)
- CELLSSTORE-LEVEL:
  - REPLICATION: (int8_t) – replication factor applied to the DFS supporting file-replication , default 3
  - BLOOMFILTER: (int8_t) – none/all-keys

Adding a Column

SQL:

```
add column (
      NAME="string",
      COUNTER=bool,
      MAX_VERSIONS=number,
      TTL=number,
      COMPRESSION="string",
      BLOCKSIZE=number,
      REPLICATION=number,
      BLOOMFILTER="string"
);
```

lib-DB-Client:

```
ColumnSpec (
      String           name
      int64_t          cid
      Bool             counter
      int32_t          max_versions
      int32            ttl
      Compressor::ENUM compression
      int8_t           replication
      BloomFilter      bloomfilter(TYPE::ENUM, factor, functions)
)
```