



(Super Wide Column Database)

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

The major differences “Super Wide Column Database” has to commonly known Wide Column Databases are SWC-DB does not have Tables nor Namespaces and while cell key as known to be in Wide Column Database structured in timestamp, row, column-family and column-family-qualifier in SWC-DB a cell key is a list of Fractions with timestamp. The differences in SQL structure, it is in-place of 'select columns from "table_name";' with SWC-DB It is 'select [where_clause [Columns-Intervals]]';'. Considering to structure a Wide-Column-DB in SWC-DB it can be in these forms key=[F(row), F(column-family), F(column-family-qualifier)] or the actual column is column-family with key=[F(row), F(column-family-qualifier)].

The Fractions in SWC-DB cell-key let numerous “qualifiers”, as known to be, with a range-locator able to respond with the ranges applicable to the fractions of a scan specs. As a result a scan-spec of key=[>“, >=“THIS”] will scan ranges that consist the “THIS” on comparator with a help of meta-column that include, additionally to the key-begin and key-end of a range, the minimal and maximum values of the fractions in an aligned manner. Hence the name “Super Wide Column” a column can have cells with one key [F(1st)] second key [F(1st), F(2nd)] third key [F(1st), F(2nd), F(3rd), ..] and the scan/select is possible on [F(1st)] and above that will return all the cells having fraction one equal “1st” and so as without further indexations to select cells with key [>F(), F(2nd)] returning the cells with second fraction equal “2nd”.

The comparators available in SWC-DB are **NONE**, **PF**, **GT**, **GE**, **EQ**, **LE**, **LT**, **NE**, **RE** while some have limitations for range-locator as regexp is evaluated as NONE being anything-match. Additionally the conditions of comparators applied on the corresponding “range-sequence” by column's schema that include **BITWISE**, **BITWISE_VOL**, **BITWISE_FCOUNT**, **BITWISE_VOL_FCOUNT** that define the sequence of cells in a range. If a prefix (PF) is desired than the choice will be the **BITWISE** or with **_FCOUNT** as **_VOL** (volumetric) will no correspond to the char-byte sequence while if desired to have for example a decimal sequence of 0, 1, 2 .. 11 the **_VOL** is the right choice whereas the **_FCOUNT** unlike tree-wise on fraction keeps the sequence of smaller key fractions-count at the beginning in the range.

SWC-DB use a self-explanatory master-ranges that define ranges to meta-ranges of data-ranges(cells-range) whereas on range-locator scan includes the Key comparison on the comparators of request, resulting in most narrowed ranges for the scan of cells. For the purpose SWC-DB have reserved columns 1: Ranges(sys_master) 2: Ranges(sys_meta) 3: Statistics(sys_stats). The Statistics column used for internal systems monitoring and it can be used like any other counter column (keeping for the purpose) with fraction of [period, role, instance, metric] with counter value

The storage-form in the SWC-DB on FS is based on column-id and range-id, that on path consist CellStores and CommitLog files while at any point one server is responsible for a range-id on column-id and of a path root. The CellStores are files storing Cells in serialized form that are after latest compaction whereas Commit-Log is Fragments of current added data, one fragment is written at a time on a threshold reach or on shutdown.

The Serialization of data in a CellStore/CommitLog file: (delimited with “|” for visual-representation of NONE)

| Blocks[Header | Compressor(Cells)] | Blocks-Index | CellStore-Trailer |

A Cell-Serialization, it is possible to use Binary data in key-fractions and cell-value

| Flag(i8) | Fractions-count(i8) | [Fraction(length(i32) | data)] | Control(i8) | Timestamp(i64) | Revision(i64) | Value-length(i32) | Value-Data |

The limitations that can be over-seen are:

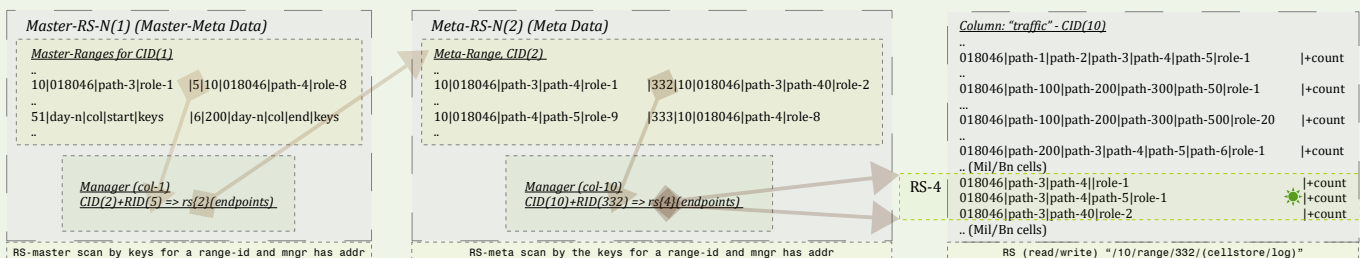
- ✗ Maximum number of columns, it is store-size of $\text{int64}(2^{64}) - 10$ (reserved cols) which can be improved by CID to be a string-type.
- ✗ Maximum size of Value or Key-Fraction(after serialization), it is 4GB, while for such data size other limitations apply.

The capabilities to expect:

- ✓ A Manager-Root with definitions of $1K^2$ ranges (a use of 1 GB RAM) is a definition of $1K^4$ Meta-Ranges that sums-down to $1K^8$ Data-Ranges, with range-size configuration to 10GB that makes a total storage volume for a cell size average of 256KB to be a quarter of Yotta Byte.
- ✓ A client can read at 100%(while Client's and Ranger'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 data Rangers 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 multi-homed / 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.rgr.Range (defaults)

.CellStore.count.max=10, .CellStore.size.max=1GB, .block.size=64MB, .block.encoding=snappy, .compaction.size.percent=33

Ranger (#):

Column (#):

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

Range Definer (range.data):

- **Header:** (13-byte)
Version(i8), Data-Length(i32), Data-Checksum(i32), Header-Checksum(i32)
- **Data:**
CellStores-count(i32), [CellStore-ID(i32), Keys-Interval Begin + End]

Commit Log, Fragment(#):

- **Header:** (7-byte)
Version(i8), Extension-Length(i32), Checksum(i32)
- **Extension:**
Interval, Encoder(i8), Enc-Data-Length(i32), Data-Length(i32), Cells-count(i32)
- **Data:**
Cells (serialized)

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

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

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

- **Header:** (17-byte)
Encoder, Data-Enc-Length, Data-Length, Cells-count, Checksum
- **Data:**
Cells (serialized)

..

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

..

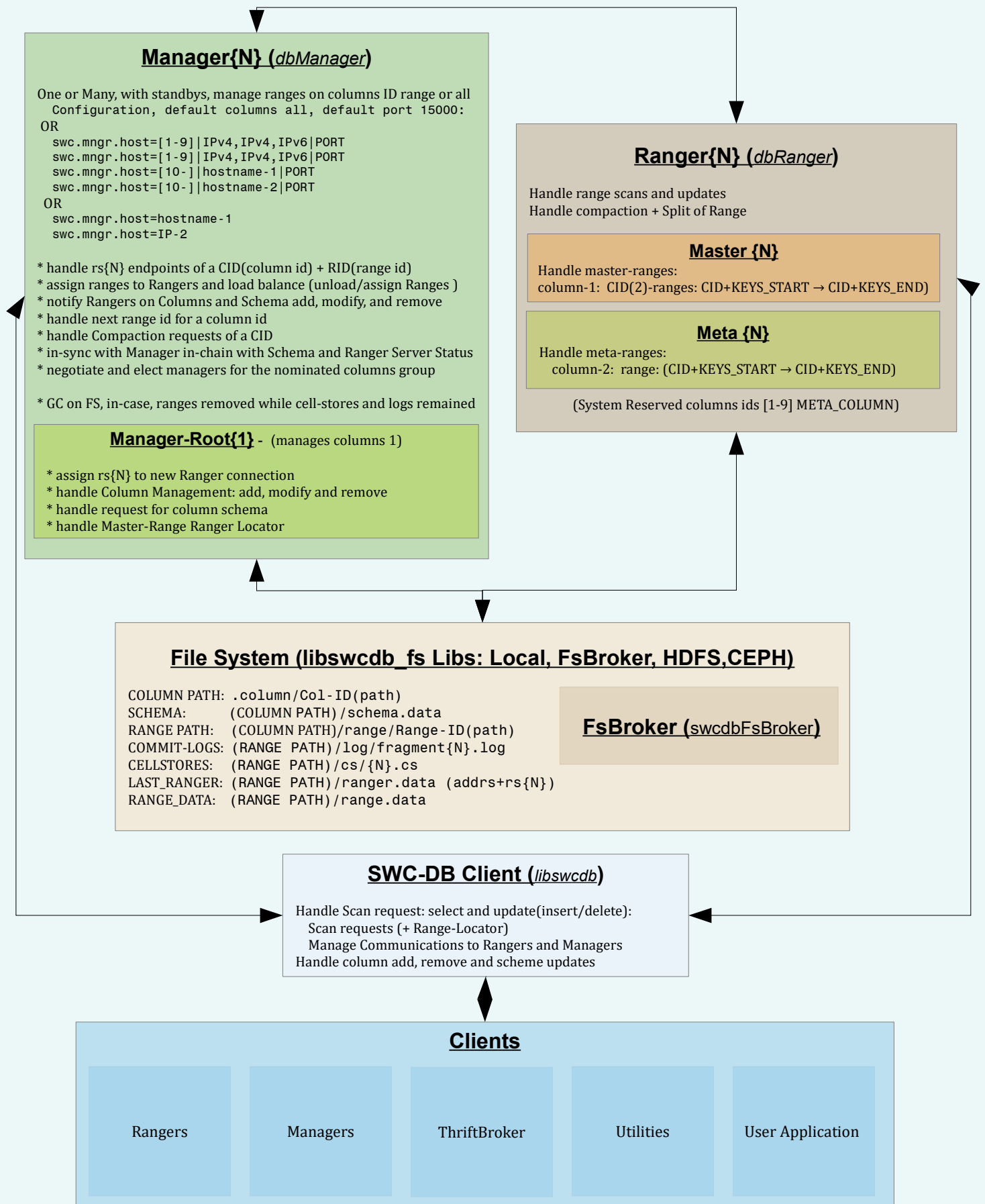
Range (#) ++

..

Column (#) ++

..

Ranger (#) ++

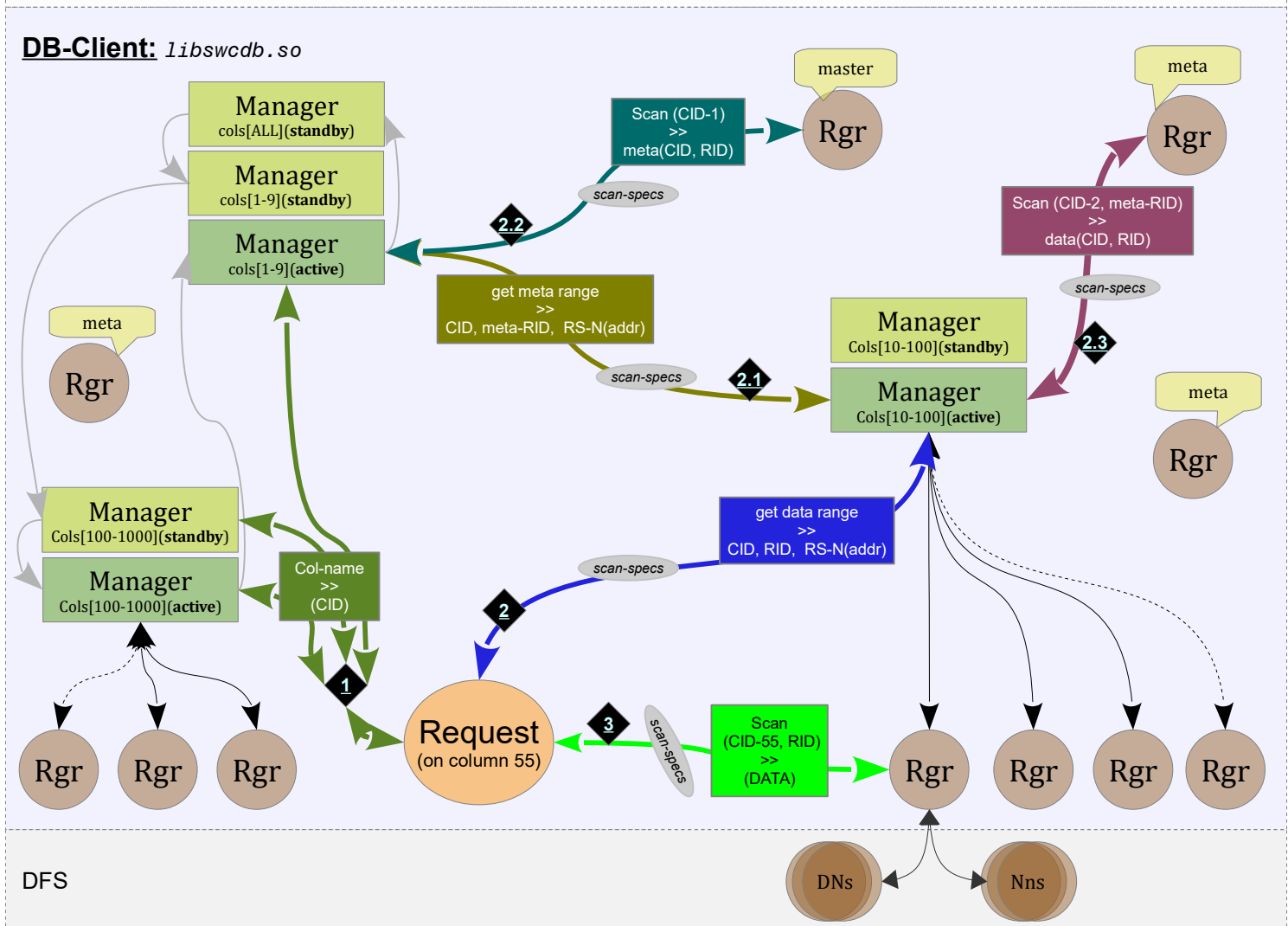


SWC DB: Failure Tolerance

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- ✓ A failed request to a Manager is a connection fail-over to next in list from 'swc.mngr.host' configuration.
- ✓ A failed request to a Ranger(Master, Meta, Data)-N is fail-over to the new newly assigned Ranger(addr) by Manager.
- ✓ Manager, on interval or shut-down state of a managed Ranger(either role), request to load ranges to another Ranger.
- ✓ Distribute File System, depends on the system and it's feature of routing to a datanode .
- ✓ Managers or Rangers in case of a connection or file-descriptor failure try to reconnect to the DFS.
- ✓ Communications security, SSL applicable between servers for non-secure networks.
- ✓ Communication over-heads of resolved-data of column-name, RID-location and Ranger-address are kept on TTL/KA.

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



SWC DB: LIB-DB, 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):
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) )
```

Cells-Interval:

```
[ Condition-Range ] [and] [ Condition-Key ] [and] [ Condition-Value ] [and] [ Condition-Timestamp ]
```

Condition-Range: The applicable ranges for a scan, comparators are always -ge or -le

```
Cell::Key [ <= ] range [ <= ] Cell::Key
```

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

```
Key [<|<=>|>|=] [ [comparator] "str-1", [comparator] "str-2", [comparator] "str-3", [comparator] "str-N" ]
or (an interval)
[[comparator] "str-1", [comparator] "str-N" ] [ <= ] key [ <= ] [[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 (an interval)
"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 volumetric bit-wise comparison

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

```
[ only_keys ] = TRUE on set # default FALSE
[ only_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 = ( range >= ['1-'] and ( [>='1-'] <= key = [<='1-1-', "1"] and value = "Value-Data-1" and timestamp > "2010/05/29" limit=10 limit_by="KEYS" )
)
and
col(ColNameB1, ColNameB2) = (
cells = ( [>='2-'] <= key = [<='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:

SpecsScan (

```
Columns  columns;
Flags    flags;
```

)

SpecsColumn (

```
int64_t  cid;
Intervals intervals;
```

)

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

SpecsInterval (

```
Cell::Key range_begin, range_end;
Key        key_start, key_finish;
Value      value;
Timestamp  ts_start, ts_finish;
Flags      flags;
```

```
Cell::Key  offset_key;
int64_t    offset_rev;
```

)

SpecsKey (

```
uint32_t count;
uint32_t size;
uint8_t* data(serial);
```

)

SpecsTimestamp (

```
int64_t  value;
Condition::Comp comp;
```

)

SpecsValue (

```
uint8_t* data;
uint32_t size;
Condition::Comp comp;
```

)

SpecsFlags (

```
uint32_t limit, offset, max_versions;
uint8_t  options;
```

)

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 (

```
list<c-array> key
int64_t       timestamp
c-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.

Configuration Options:

The following configurations available in the Column-Schema:

- COLUMN-LEVEL:
 - NAME: (string) - column-name
 - CID: (uint64_t) - column-id
 - TYPE: (enum) - plain/counter_i8/counter_i16/counter_i32/counter_i64, default - PLAIN
- CELL-LEVEL:
 - TTL: (uint32_t) - Time To Live in seconds
 - MAX_VERSIONS: (uint32_t) - default 1 - not applicable with COUNTER
- BLOCK-LEVEL:
 - ENCODING: (enum) - none/snappy/zlib (...zstd/bmz/lzo/quicklz)
 - BLOCKSIZE: (uint32_t) - size of a block
 - CELLS: (uint32_t) - number of cells in a block
- CELLSTORE-LEVEL:
 - REPLICATION: (int8_t) - replication factor applied to the DFS supporting file-replication, default 3
 - SIZE: (int32_t) - max allowed cellstore size in bytes
- RANGE-LEVEL:
 - CS-MAX: (int8_t) - number of cellstores allowed in a range before range-split
 - COMPACT-%: (int8_t) - relative percentage to cellstores-volume allowed without compaction