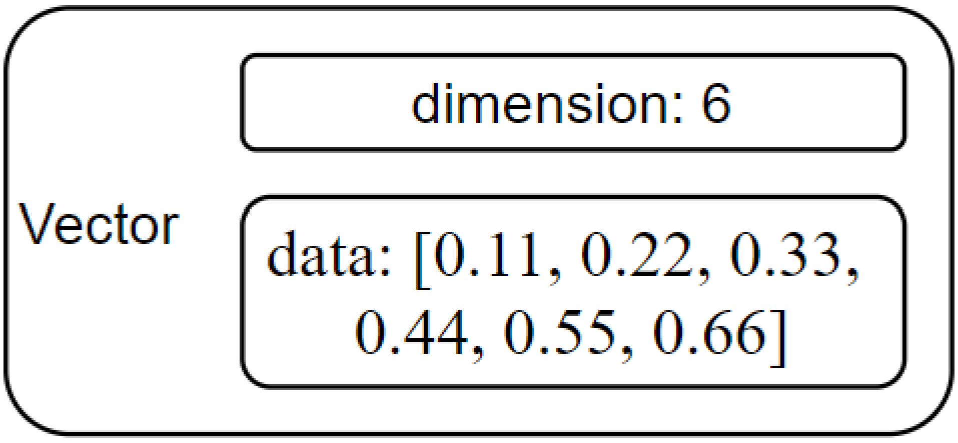
The Implementation of Vector Type in Nebula Graph

1. Implement vector value type and property type and do the unit test for vector type
   - Add new value type: VECTOR
   - Modify RocksEngine to support multiple column family of RocksDB
2. Implement serialization and deserialization for vector type: Graphd to Storaged by thrift
   - Add thrift operation for vector type
   - Encoding of vector type key
   - RowWriter and RowReader for vector type
3. Modify Schema to simply support original column and vector column
   - Separate vector column and original column in schema
   - Modify RowWriter and RowReader to support vector column
4. Add vector distance expression in expression system
   - Implement vector distance expression in expression system
   - TODO: Add vector distance expression in query engine
5. Implement Create Tag Sentence For Vector Type
   - Create tag with vector type property
6. Implement Add Vertex with Vector Type Property
   - Add vertex with vector type property
   - TODO: Pass tck tests

Design Notes

Vector Value Type

The VECTOR type can be used as a property type. For storage, the actual data content of the vector is placed at the end of the encoded data block. We then use an offset and a length to specify the exact memory region where the vector's content is located.

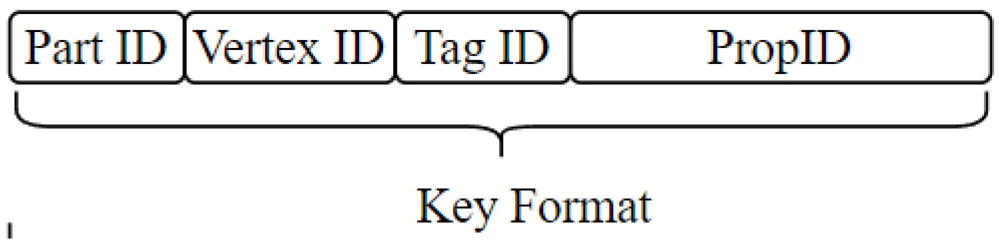


Storage for Vector Data

Specifically, Vertex data is stored in RocksDB in the form of KV pairs. We use RocksDB's Column Family to separate storage of VECTOR attributes and other graph attributes. We should add read and write method for RowReader and RowWriter.

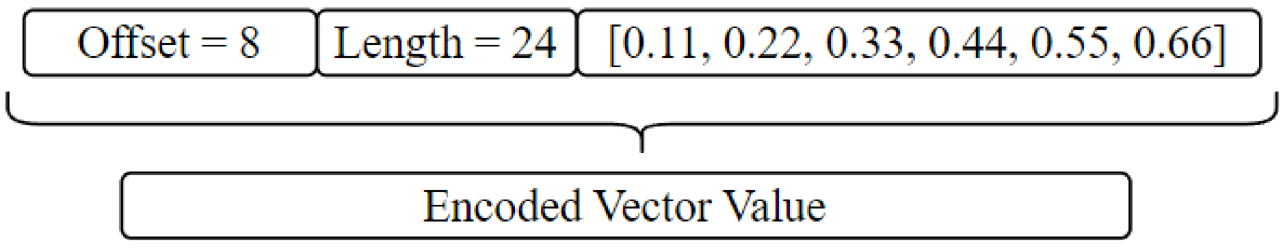
Key of Vector Type

The key of vector attributes is PartitionID + VertexID + TagID + PropID, Value is serialized vector data.



Encoded Value

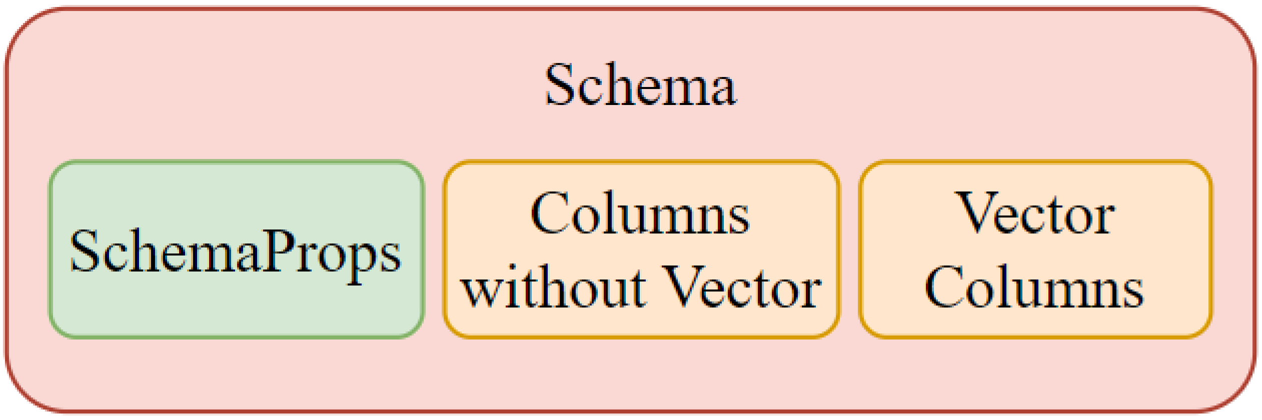
The encoded value of vector is consist of metadata and original data. Metadata is offset and length of original data, and original data is at last of whole value.



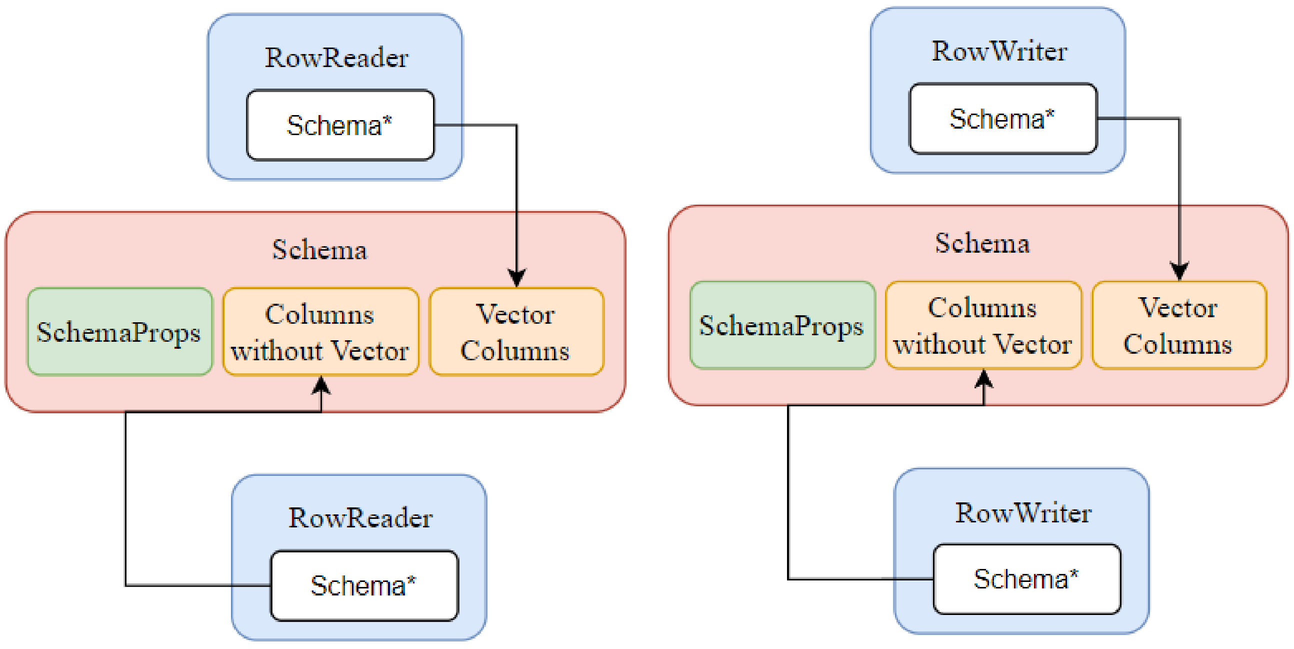
Schema Modification

To simply support original column and vector column, we need to modify the schema as follows:

1. Original columns (for other types except VECTOR type)
2. Vector columns (just for VECTOR type)
3. Schema Properties Options (TTL, TTL_COL, etc.)



Then, we also need to modify RowWriter and RowReader to support vector column. The RowWriter will write the vector data into the RocksDB "vector" column family, and the RowReader will read the vector data from the RocksDB "vector" column family.



Create Tag Sentence For Vector Type

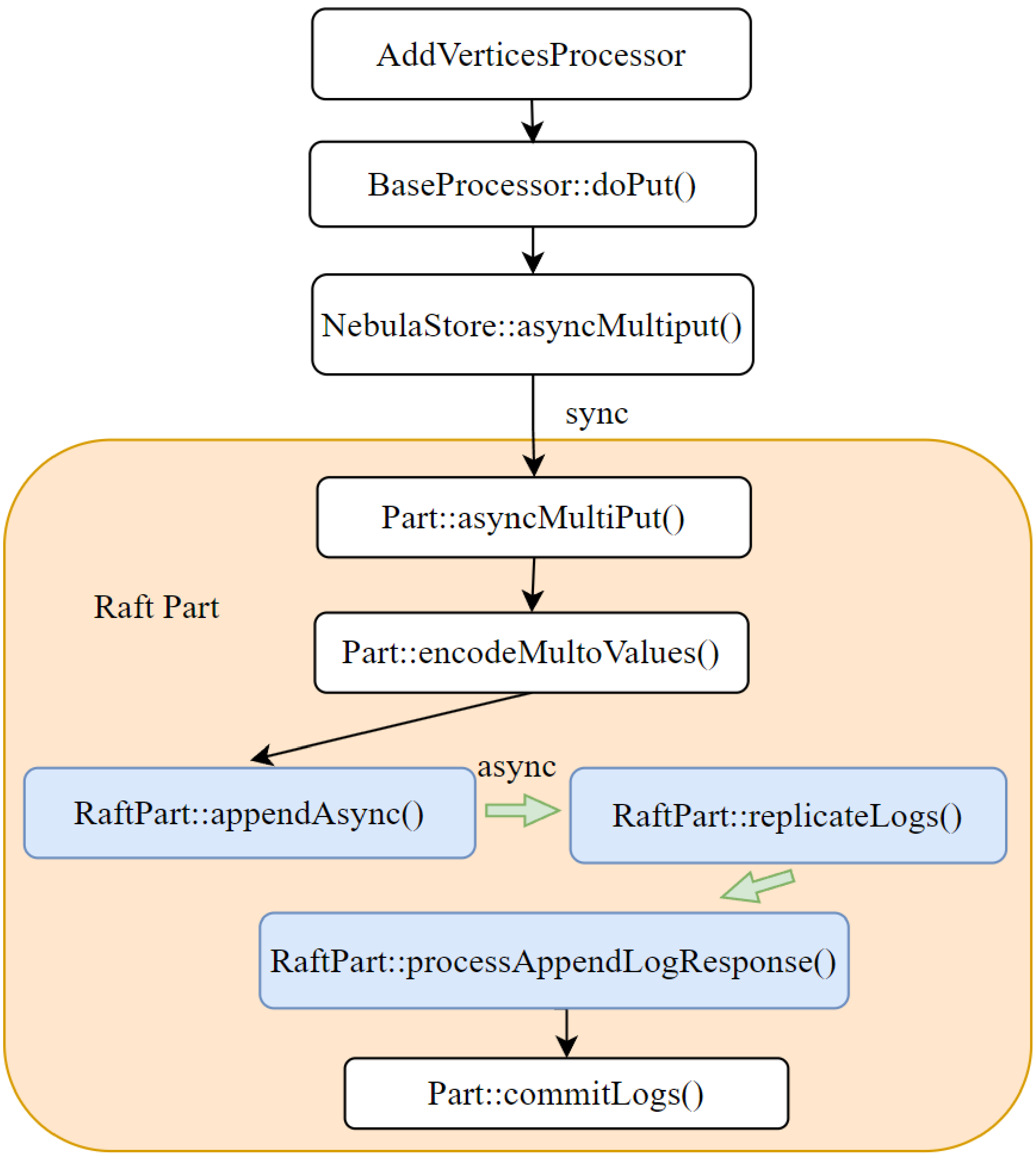
To create a tag with a vector type property, we can use the following sentence:

```
CREATE TAG IF NOT EXISTS test1(name string, embedding vector(3) DEFAULT
[1.0,2.0,3.0]) TTL_DURATION = 100, TTL_COL = "create_time";;
```

Add Vertex with Vector Type Property

Process for Adding Vertex with Vector Type Property

When adding a vertex with a VECTOR type property, the `AddVerticesProcessor` executor is responsible for processing the request. It packages the vertex data and metadata into raft-wal logs, which are then submitted to the Raft Part. The actual insertion into RocksDB occurs in the `Part::commitLogs()` method.



The actual data insertion into RocksDB occurs within the Part::commitLogs(std::unique_ptr iter, bool wait, bool needLock) method. The process can be summarized with the following pseudo-code:

```
auto batch = engine_->startBatchWrite();
while (iter->valid()) {
    // ...
    switch (log[sizeof(int64_t)]) {
      case OP_MULTI_PUT: {
        // Here, 'kvs' contains both keys and values, and potentially the column
family name.
        auto kvs = decodeMultiValues(log);
        // We iterate through key-value pairs.
        for (size_t i = 0; i < kvs.size(); i += 2) {
          // The column family name 'cfName' should be determined here before the
put.
          auto code = batch->put(kvs[i], kvs[i + 1], cfName);
        }
        break;
      }
    }
    ++(*iter);
}
engine_->commitBatchWrite(
      std::move(batch), FLAGS_rocksdb_disable_wal, FLAGS_rocksdb_wal_sync, wait);
```

To minimize modifications and maintain the integrity of the existing Raft log processing workflow, we propose adding some new log types like `OP_MULTI_PUT_VECTOR`, ``OP_MULTI_REMOVE_VECTOR`, etc. We can just solve vector data by adding a new switch case in `commitLogs`and add`cfName`field in`doPut` method. To fully support our new VECTOR type, we need to modify the entire data flow:

1. AddVerticesProcessor: Get vector columns from the schema and store them in the "vector" column family of RocksDB.
2. BaseProcessor::doPut: Update the doPut method to handle operations targeting the "vector" column family.
3. KVStore::asyncMultiPut: Extend the asyncMultiPut method to support writes to the "vector" column family.
4. Part Methods:
   - The asyncMultiPut method must be updated to support the "vector" column family.
   - The commitLogs method must also be adapted to correctly process log entries destined for the "vector" column family.
5. encodeMultiValues: Modify this function to correctly encode the "vector" column family name into the log entry.
6. KVEngine Interface: The KVEngine interface needs to be enhanced to support operations on the "vector" column family.

Addition of Interface for Vector Type

- Add a new interface for `WriteBatch` to support operations on specific column families.

```
class WriteBatch {
public:
  virtual nebula::cpp2::ErrorCode put(folly::StringPiece key,
                                      folly::StringPiece value,
                                      const std::string& cfName) = 0;
  virtual nebula::cpp2::ErrorCode remove(folly::StringPiece key, const
std::string& cfName) = 0;
  virtual nebula::cpp2::ErrorCode removeRange(folly::StringPiece start,
                                              folly::StringPiece end,
                                              const std::string& cfName) = 0;
};
```

- TODO(TEMP update):Add a new interface for `KVEngine` to support operations on specific column families.

```
class KVEngine {
public:
  virtual nebula::cpp2::ErrorCode get(const std::string& key,
                                      std::string* value,
                                      const std::string& cfName,
                                      const void* snapshot = nullptr) = 0;
};
```