

RDM Embedded 10.1

C++ Interface Users Guide

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Introduction

The RDM Embedded database management system (DBMS) is designed to provide powerful, flexible, high-performance capabilities for developing embedded database applications. By combining the network and relational model technologies in a single system, RDM Embedded lets you organize and access information efficiently, regardless of the complexity of the data. The Native RDM Embedded C API provides an efficient low-level interface with a rich set of functionality.

The C++ interface to RDM Embedded is designed to augment the RDM Embedded navigation API by providing database specific sets of classes implementing higher-level abstractions of the Core API. These generated interfaces are built to fit your specific database schema using an object orientated approach. The C++ API is designed for ease of use, but by giving full access to both RDM Embedded's network and relational functionality for RDM Embedded, it is very powerful and can be used to create efficient database applications.

Interfaces

There are two main interfaces that comprise the RDM Embedded C++ API, the Db interface which encapsulates access to a particular database and the Cursor interface which encapsulates access to records within a database. These interfaces contain methods that are common to all databases and records and methods that are specific to a particular schema. By using these interfaces the C++ programmer is able to create applications that safely and efficiently query, insert, update, and delete data stored in an RDM Embedded database

The interfaces are implemented as smart pointers (http://en.wikipedia.org/wiki/Smart_pointer) to implementation objects. Therefore the interface objects should be passed by value not reference. There are explicit public methods for the default constructor, copy constructor, assignment operator, and destructor that implement the smart pointer. The developer only needs to know that whenever the last interface reference goes out of scope the database will automatically be closed and the implementation object will be de-allocated.

Db Interface

There is one Db interface class generated for each database access through the RDM C++ API. This database specific Db interface extends the base Db class and provides methods that allow the programmer to:

- Open the database
- Create a new records
- Obtain record scan cursors
- Obtain key scan cursors
- Start read transactions
- Start write transactions
- Pre-commit transaction
- Commit transactions
- Abort transactions
- Start a read-only snap shot

Cursor Interface

There is one Cursor interface class generated for each record defined in a schema. These Cursor classes extend the base Cursor class and provide methods that allow the programmer to:

- Delete Records
- Disconnect Records from a set owner
- Connect Records to a set owner
- Reconnect Records to a new set owner
- Navigate through the records in the cursor
- Obtain record scan cursors
- Obtain a key scan cursor
- Obtain a cursor contain member records
- Obtain a singleton cursor contain an owner record
- Update individual field values
- Update all field values
- Read individual field values
- Read all field values
- Find records by a key value
- Obtain a singleton cursor

Creating the C++ Interface

The C++ API is tailored to a specific schema and is optionally generated by the Data Definition Language Process (ddlp) utility when it processes a database schema definition file. As an example we will create a schema to support a hypothetical piece of equipment that stores readings from onboard sensors. Information on how to design a RDMes schema can be found in [section 4.2](#) of the RDMes User's Guide.

```
database measurements
{
  data file "measurements.d00" contains sensor;
  data file "measurements.d01" contains measurement;
  key file  "measurements.k00" contains sensor.name;
  blob file "measurements.b00" contains measurement.raw_data;

  record sensor {
    unique key char name[32];
    int32_t status;
  }

  record measurement {
    int32_t time;
    int32_t value;
    blob_id raw_data;
  }

  set sensor_measurement {
    order last;
    owner sensor;
    member measurement;
  }
}
```

We run the DDLP utility with the `-cpp` option to get a C++ API for the above schema.

```
ddlp -d -cpp measurement.ddl
```

This command will produce the source and header that comprise the RDMes C++ API for the measurements database

<code>measurements.h</code>	RDMes database header file
<code>measurements_api.h</code>	RDMes C++ interface header file
<code>measurements_api.cpp</code>	RDMes C++ interface implementation file

All source files that want to use the RDMes Embedded C++ API for the measurements database will need to include the `measurements_api.h` header file. The `measurements_api.cpp` source file will need to be compiled with the application code.

Access Methods

Cursors are used to navigate, read, update, create, and delete records within the C++ API. There are four main types of Cursors available each of which implements a different access method to data stored in a RDM Embedded database. While there are four types of Cursor each cursor implementation uses the exact same interface which simplifies the uses of these cursors.

Singleton Cursors

Singleton Cursors contain one and only one record instance. Singleton Cursors can be obtained by

- Creating a new record (`Db.New_recordname`)
- Asking for the owner of a set (`Cursor.Get_setname_owner`)
- Asking for a Singleton cursor from any cursor (`Cursor.GetThis`)

Singleton cursors can be useful if we want to save a reference to a particular record or if we wish to do multiple things to with the record and an operation may remove the record from the cursor.

Table Scan Cursors

Table scan cursors contain a collection of all the records in a table in no particular order. Table Scan Cursors are useful when you want to access all records in a table and the order of access is not important. For example if you wanted to calculate the total number of measurements taken by all sensors in our example database. Table Scan Cursors can be obtained from the Db Interface by the `Db->Get_recordname_records` method and from a Cursor interface by using the `Cursor->GetRecords` method. Obtaining a Cursor from the Db interface positions the cursor at the first cursor position. Obtaining a Cursor from another Cursor positions the new cursor at the same Cursor position.

Key Scan Cursors

Key scan cursors contain a collection of all records in a table in index order. Key Scan Cursor can be useful when you want to display records to a user in a particular order. Key Scan Cursors can be obtained from the Db Interface by the `Db.Get_recordname_recordsBy_indexname` method or from a Cursor interface by the `Cursor.GetRecordsBy_indexname` method. Obtaining a Cursor from the Db interface positions the cursor at the first cursor position. Obtaining a Cursor from another Cursor positions the new cursor at the same Cursor position.

Set Member Cursor

A Set Member Cursor contains a collection of records associated with a particular owner record. Set Member Cursors can be used to iterate through all of the measurements made by a particular sensor in our example database. Set Member Cursors can only be obtained from a Cursor by the `Cursor.Get_setname_members` and `Cursor.Get_setname_siblings` methods.

Operational Overview

The C++ API allows developers to create powerful embedded applications without needing to worry about the low-level details required by the RDM Embedded Navigation APIs. While the C++ API contains a large set of functionality it does not implement everything that is supported by the RDM Embedded Core API. In this sections we look at the operations that are supported by the C++ API.

Database Control Methods

There are methods implemented in the Db interface that allow the developer to Open, Create, Destroy and Initialize the database our C++ API classes encapsulate.

Opening

A database is opened by using one of the overloaded static open methods generated in the Db interface. Calling these static methods give the application the database specific Db interface that is used to access the RDM Embedded database throughout the application.

```
static Db_measurements Open (...) throw (rdme_exception&);
```

This method has two optional

name	The database name to use for the open call. The default value for this parameter is the name defined in the schema.
mode	The mode to open the database in. The default is multi-user shared mode ("s")

Initializing

A database can be initialized by using the Initialize method in the Db interface. The Initialize method will (re)create all data, key, index, and blob files defined in the database schema. Any existing data stored in the database will be lost when calling this method.

```
void Initialize (void) const throw (rdme_exception&);
```

Destroy

A database can be destroyed by using the Destroy method in the Db interface. The Destroy method will remove all data, key, index, blob, log, and dbd files that make up a database. All Db and Cursor interfaces referencing this database become invalid after calling Destroy. All data stored in the database is lost when calling this method.

```
void Destroy (void) const throw (rdme_exception&);
```

Close

There is no explicit method for closing a database. The smart pointer implementation will automatically close the database when all references to the Db interface are de-allocated, reassigned, explicitly released or go out of scope. When this happens all internal resources held for the Db interface will be freed.

Transaction Control Methods

The Db interface contains the methods providing transaction management functionality for the C++ API. When using the C++ API all read and write operations are executed within the context of a "read" or "write" transaction. This differs slightly from the convention of the core API where transactions are only required for "write" operations. The C++ API allows for simultaneous read transactions, but requires exclusive access to records for write transactions. This is similar to the core API except that in the C++ API lock management is encapsulated within transaction handling.

Update Transactions

All operations which may modify the contents of a database must be performed within the context of a "write" transaction. While the C++ interface will implicitly begin and end write transactions for the developer, it is considered poor programming practice to rely on these implicit transactions. Instead developers should explicitly start write transactions by using the `Db.BeginUpdate` method.

```
void BeginUpdate () const throw (rdme_exception&);
```

This method has two optional parameters

types	An array of recordType Identifiers to be locked
num	The number of recordType values in the array

If you do not provide parameters for the `BeginUpdate` method every record type and key file in the database will be write locked. In the following example both the measurement and sensor records will be locked by the Update method.

```
void add_measurement (
    Db_measurements    db,
    struct measurement *sensor_fields,
    Cursor_sensor      s) throw (rdme_exception&)
{
    Cursor_measurement m;
    db.BeginUpdate ();
    try
```

```
{
    m = db.New_measurement_recordWithFieldValues(sensor_fields);
    m.Connect_sensor_measurement(s);
    db.End();
}
catch (rdme_exception e)
{
    db.Abort();
}
}
```

If you only need to lock certain records for your operation you can specify those records using the `BeginUpdate` parameters.

```
Cursor_sensor add_sensor(
    Db_measurements db,
    struct sensor *sensor_fields) throw (rdme_exception&)
{
    Cursor_sensor s;
    recordType rtypes[] = {Cursor_sensor::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        s = db.New_sensor_recordWithFieldValues(sensor_fields);
        db.End();
    }
    catch (rdme_exception e)
    {
        db.Abort();
    }
    return s;
}
```

You can also use a special end marker in the array instead of specifying the number of record types.

```
Cursor_sensor add_sensor2(
    Db_measurements db,
    struct sensor *sensor_fields) throw (rdme_exception&)
{
    Cursor_sensor s;
    recordType rtypes[] = {Cursor_sensor::Type(), Cursor::NoMoreTypes()};
    db.BeginUpdate(rtypes);
    try
    {
        s = db.New_sensor_recordWithFieldValues(sensor_fields);
        db.End();
    }
    catch (rdme_exception e)
    {

```

```
        db.Abort();
    }
    return s;
}
```

Read Transactions

Read Transactions allow an application to read data from a database without blocking other readers. While it is legal to read data using Update Transactions those require exclusive access to the records and therefore do not promote parallelism to the same degree. The C++ interface will implicitly begin and end read transactions, but it is considered better programming to explicitly begin and end transactions.

```
void BeginRead () const throw (rdme_exception&);
```

If you do not provide parameters for the `BeginRead` method every record type and key file in the database will be read locked. In the following example both the measurement and sensor records will be locked by the `BeginRead` method.

```
void read_measurement(
    Db_measurements db,
    Cursor_measurement m,
    struct sensor *sensor_fields,
    struct measurement *measurement_fields) throw (rdme_exception&)
{
    db.BeginRead();
    try
    {
        m.GetFieldValues(measurement_fields);
        m.Get_sensor_measurement_owner().Get_name(sensor_fields->name);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

If you only need to lock certain records for your operation you can specify those records using the `BeginRead` parameters.

```
void read_sensor(
    Db_measurements db,
    Cursor_sensor s,
    struct sensor *sensor_fields) throw (rdme_exception&)
```

```
{
    recordType rtypes[]= {Cursor_sensor::Type()};
    db.BeginRead(rtypes, 1);
    try
    {
        s.GetFieldValues(sensor_fields);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

You can also use a special end marker in the array instead of specifying the number of record types.

```
void read_sensor2(
    Db_measurements db,
    Cursor_sensor s,
    struct sensor *sensor_fields) throw (rdme_exception&)
{
    recordType rtypes[]= {Cursor_sensor::Type(), Cursor::NoMoreTypes()};
    db.BeginRead(rtypes);
    try
    {
        s.GetFieldValues(sensor_fields);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Database Snapshots

While read transactions allow for multiple readers they block all potential writers. If you would like to read data from the database without blocking writers you can utilize database snapshots. These snapshots create a transaction consistent view of a database at a particular point in time. Any changes made by other database users will not be visible within the snapshot, however they will be available when snapshot ends. Database snapshots can greatly increase parallelism, however they require the engine to retain information about database changes, and this can require a significant amount of memory. It is recommended that snapshots be used for a limited duration especially on hardware with limited resources.

Database snapshots are created using the `db.BeginSnapshot` method.

```
void BeginSnapshot () const throw (rdme_exception&);
```

This method takes no parameters and creates a static read-only view of the database.

```
void list_sensors(
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
    struct sensor s_fields;
    db.BeginSnapshot();
    try
    {
        s = db.Get_sensor_records();
        for(s.First(); s != Cursor::GetAfterLast(); s++)
        {
            s.Get_name(s_fields.name);
            cout << s_fields.name << endl;
        }
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Transaction Commits

The `db.End` method will end an active transaction or snapshot. Calling `db.End` will

- Commit any modifications made in a write transaction
- Free locks obtained in a Write transaction
- Free locks obtained in a Read transaction
- Release a database snapshot

```
void End (void) const throw (rdme_exception&);
Cursor_sensor add_sensor(
    Db_measurements db,
    struct sensor *sensor_fields) throw (rdme_exception&)
{
    Cursor_sensor s;
    recordType rtypes[] = {Cursor_sensor::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        s = db.New_sensor_recordWithFieldValues(sensor_fields);
    }
}
```

```
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return s;
}
```

Transaction Aborts

If there is an exception in the processing of a transaction block you would normally abort the transaction instead of committing it. The `db.Abort` method is similar to the `db.End` method except that it rolls back changes made in a write transaction instead of persisting them. It is illegal to call `db.Abort` for a read transaction or snapshot.

```
void Abort (void) const throw (rdme_exception&);
Cursor_sensor add_sensor(
    Db_measurements db,
    struct sensor *sensor_fields) throw (rdme_exception&)
{
    Cursor_sensor s;
    recordType rtypes[]= {Cursor_sensor::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        s = db.New_sensor_recordWithFieldValues(sensor_fields);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return s;
}
```

Precommit

The RDMc C++ interface can be involved in multi-system transactions by the use of the `db.Precommit` method. In two-phase commit protocols there is a voting phase and a commit phase. The `db.Precommit` method is used in the voting phase to validate that a transaction is able to commit. Typically if `db.Precommit` does not throw an exception then `db.End` will not throw an exception. By using `db.Precommit` your application can check if the database is able to commit a transaction before issuing the actual `db.End` or `db.Abort` command.

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Consider our measurement example application, perhaps we want to periodically transfer readings from the device to an enterprise DBMS for data warehousing purposes. If the readings on the device are critical we may want to make sure that they are successfully entered in the enterprise DBMS before we delete them from the embedded database. We can do this by using a two phase-commit and having both the embedded database and the enterprise database confirm the ability to commit before actually ending the transaction.

```
void Precommit (void) const throw (rdme_exception&);
```

```
void delete_measurement(
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    bool b_do_commit = true;
    db.BeginUpdate();
    try
    {
        m.Disconnect_sensor_measurement();
        m.Delete();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }

    try
    {
        db.Precommit();
    }
    catch (rdme_exception e)
    {
        /* Send precommit failed message to transaction broker */
        db.Abort();
        throw e;
    }

    /* Send precommit succeeded message to transaction broker */

    /* Ask transaction broker if we should End or Abort */
    if(b_do_commit == true)
        db.End();
    else
        db.Abort();
}
```

New Methods

The Db interface provides a set of generated methods for adding new records to the database. Each record declared in the database schema will have two "New" methods - `New_recordname_record` and `New_recordname_recordWithFieldValues`. The first method creates a record with field values initialized to default values. The second method creates a record with values initialized with data that is provided to the method. These methods return a singleton cursor object for the newly created record and must be called within an Update transaction block. If a record has a unique key definition it is not possible to create more than one record with default values unless the unique key field of the created record is set to something else before the next record is created.

To create a new record with default values

```
Cursor_recname New_recname_record (void) const throw (rdme_exception&);
```

The caller of the function can use the cursor that is returned to set field values in the new record.

```
Cursor_sensor add_sensor2(
    struct sensor    *sensor_fields,
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
    recordType rtypes[]= {Cursor_sensor::Type(), Cursor::NoMoreTypes()};
    db.BeginUpdate(rtypes);
    try
    {
        s = db.New_sensor_record();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return s;
}
```

To create a new record with specified values

```
Cursor_recname New_recname_recordWithFieldValues (
    struct recname *fields) const throw (rdme_exception&);
```

```
Cursor_sensor add_sensor(
    struct sensor    *sensor_fields,
    Db_measurements db) throw (rdme_exception&)
```

```
{
    Cursor_sensor s;
    recordType rtypes[]= {Cursor_sensor::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        s = db.New_sensor_recordWithFieldValues(sensor_fields);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return s;
}
```

Delete Methods

The `Cursor` interface contains two methods to remove records from a database. The `Cursor.Delete` method is for deleting a record that is not actively connected to any sets. The `Cursor.DisconnectAndDelete` method will disconnect the record from any sets before it is deleted. Both methods require an active transaction context with locks on the cursor record, the `Cursor.DisconnectAndDelete` method also requires locks on any records related to the cursor record through a set.

```
Cursor Delete (void) const throw (rdme_exception&);
```

```
Cursor DisconnectAndDelete (void) const throw (rdme_exception&);
```

The first example shows how to use `Cursor.Delete` to remove a `Sensor` record that does not have any measurements related to it.

```
/* Note: this only works if the sensor has no associated measurements. If
 * the sensor has measurements then an exception will be thrown by the
 * s.Delete call
 */
void delete_sensor(
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[]= {s.Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
```

```
        s.Delete();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
}
```

The second example demonstrates how to use `Cursor.DisconnectAndDelete` to remove a Measurement record that is associated with a Sensor.

```
void delete_measurement2(
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[] = {Cursor_sensor::Type(), Cursor_measurement::Type()};
    db.BeginUpdate(rtypes, 2);
    try
    {
        m.DisconnectAndDelete();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
}
```

Get Methods

The Cursor interface has a set of generated methods for retrieving non-blob field data stored in record. There is a method for retrieving all of fields in a record (`Cursor.GetFieldData`) and methods to retrieve each field value individually (`Cursor.Get_fieldname`). These need to be run within a transaction block - Update, Read, or Snapshot.

```
void GetFieldValues (struct record_name *fields) const throw (rdme_exception&);
```

```
void Get_fieldname (<type> val) const throw (rdme_exception&);
```

This example shows how to retrieve all the field values from a `Cursor_measurement` object and just the name field from a `Cursor_sensor` object.

```
void read_measurement(
    struct measurement *measurement_fields,
    struct sensor      *sensor_fields,
    Cursor_measurement m,
    Db_measurements    db) throw (rdme_exception&)
{
    Cursor_sensor s;
    db.BeginRead();
    try
    {
        m.GetFieldValues(measurement_fields);
        m.Get_sensor_measurement_owner().Get_name(sensor_fields->name);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Set Methods

Updating data in the database is done through the Cursor interface's generated Set methods methods. There is a method for setting all the fields in a record (`Cursor.SetFieldData`) and methods to set each field value individually (`Cursor.Set_fieldname`). These need to be run within an Update transaction block.

```
void SetFieldValues (const struct recordname *fields) const throw (rdme_exception&);
```

```
void Set_fieldname (<type> val) const throw (rdme_exception&);
```

This example shows how to set all the field values from a `Cursor_sensor` object.

```
void update_sensor(
    struct sensor *sensor_fields,
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[] = {Cursor_sensor::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        s.SetFieldValues(sensor_fields);
    }
}
```

```
catch (rdme_exception e)
{
    db.Abort();
    throw e;
}
db.End();
}
```

This example illustrates how to update the value field of a measurement record

```
void update_measurement_value(
    int32_t          value,
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[] = {Cursor_measurement::Type()};
    db.BeginUpdate(rtypes, 1);
    try
    {
        m.Set_value(value);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
}
```

Blob Methods

Blob fields are handled slightly differently from standard fields, in addition to the Cursor generated Get and Set methods there are methods generated for retrieving and setting the size of the blob field. If you set the blob size to a value less than the current size the field will be truncated. If you set the size of a blob fields to a value larger than the existing size then the field will be padded with NULL bytes. As with standard fields Set Methods require and Update transaction and Get Methods require a Read transaction or Snapshot.

The `Cursor.Set` method is generated for each blob field to add or update data to a blob field. This method has more parameters than the `Cursor.Set` methods for standard fields. If you specify an offset in the middle of the existing data then the new data will overwrite any existing data.

```
void Set_blobfieldname (uint32_t offset, const void *buf, uint32_t size)
    const throw (rdme_exception&);
```

offset	The offset into the blob field to write the data
buf	The data to write to the blob
size	The size of the data to be written to the blob field

```
void add_measurement_raw_data(
    const void      *raw_data,
    uint32_t        size,
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    db.BeginUpdate();
    try
    {
        m.Set_raw_data(0, raw_data, size);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
}
```

There is a `Cursor.Get` method generated for each blob field to read data from a blob field. This method has more parameters than the `Get` methods for standard fields

```
void Get_blobfieldname (uint32_t offset, void *buf, uint32_t len, uint32_t *size=
NULL)
    const throw (rdme_exception&);
```

offset	The offset into the blob field to read data from
buf	A buffer to write the data read
len	The amount of data to read into buf
size	The amount of data that was read into buf

```
void read_measurement_raw_data(
    void      *raw_data,
    uint32_t  size,
    uint32_t  *bytes_read,
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    db.BeginRead();
    try
    {
        m.Get_raw_data(0, raw_data, size, bytes_read);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
}
```

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```
db.End();  
}
```

There is a `Cursor.Set_size` method generated for each blob field to change the size of the field. This can result in the field being truncated or padded with NULL bytes.

```
void Set_blobfieldname_size (uint32_t size) const throw (rdme_exception&);
```

There is a `Cursor.Get_size` method generated for each blob field to get the current size of the field.

size The new size for the blob field

```
void set_measurement_raw_data_size(  
    uint32_t          size,  
    Cursor_measurement m,  
    Db_measurements   db) throw (rdme_exception&)  
{  
    db.BeginUpdate();  
    try  
    {  
        m.Set_raw_data_size(size);  
    }  
    catch (rdme_exception e)  
    {  
        db.Abort();  
        throw e;  
    }  
    db.End();  
}
```

```
void Get_blobfieldname_size (uint32_t *size) const throw (rdme_exception&);
```

size The new size for the blob field

```
void get_measurement_raw_data_size(  
    uint32_t          *size,  
    Cursor_measurement m,  
    Db_measurements   db) throw (rdme_exception&)  
{  
    db.BeginRead();  
    try  
    {  
        m.Get_raw_data_size(size);  
    }  
    catch (rdme_exception e)  
    {
```

```
        db.End();
        throw e;
    }
    db.End();
}
```

Network Model Set Methods

The Cursor interface has generated methods to support connecting and disconnecting records to sets. Methods that deal with connecting or disconnecting records to sets require Update transactions and locks on both the owner and member record types. See the RDMc User's Guide for more information on Network Model Sets.

The `Cursor.Connect_setname` method connects a member to an owner's set chain.

```
void Connect_setname (const Cursor_ownertype &owner) const throw (rdme_exception&);
```

owner

A cursor positioned to the owner record the member will be connected to

```
Cursor_measurement add_measurement(
    struct measurement *measurement_fields,
    Cursor_sensor      s,
    Db_measurements    db) throw (rdme_exception&)
{
    Cursor_measurement m;
    db.BeginUpdate();
    try
    {
        m = db.New_measurement_recordWithFieldValues(measurement_fields);
        m.Connect_sensor_measurement(s);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return m;
}
```

The `Cursor.Disconnect_setname` method will remove a record from a set chain.

```
void Disconnect_sensor_measurement (void) const throw (rdme_exception&);
```

```
void delete_sensor2(
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[]= {s.Type(), Cursor_measurement::Type()};
    Cursor_measurement m;
    db.BeginUpdate(rtypes, 2);
    try
    {
        m = s.Get_sensor_measurement_members();
        while(m != Cursor::GetAfterLast())
        {
            m.Disconnect_sensor_measurement();
            m++;
        }
        s.Delete();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
}
```

The `Cursor.Reconnect_setname` method will remove a record from a set chain and add it to another set chain. This method is required when navigating set members via a `SetCursor` as the member record will drop out of the cursor when it is disconnected.

```
void Reconnect_sensor_measurement (const Cursor_sensor &owner) const throw (rdme_
exception&);
```

owner

A cursor positioned to the new owner record the member will be connected to

```
void move_measurement(
    Cursor_measurement m,
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    recordType rtypes[]= {s.Type(), Cursor_measurement::Type()};
    db.BeginUpdate(rtypes, 2);
    try
    {
        m.Reconnect_sensor_measurement(s);
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
}
```

```
    }  
    db.End();  
}
```

The `Cursor.Get_setname_count` method will return the number of members contained in a `SetCursor` collection. The function does not require a read transaction, but can potentially read old data without one.

```
int32_t Get_sensor_measurement_count (void) const throw (rdme_exception&);  
int32_t get_number_of_measurements(  
    Cursor_sensor s,  
    Db_measurements db) throw (rdme_exception&)  
{  
    int32_t member_count;  
    db.BeginRead();  
    try  
    {  
        member_count = s.Get_sensor_measurement_count();  
    }  
    catch (rdme_exception e)  
    {  
        db.End();  
        throw e;  
    }  
    db.End();  
    return member_count;  
}
```

Cursor Creation Methods

In the C++ interface record searching and navigation is done through Cursor interfaces. There are four types of Cursors supported by RDMe - table scan cursors, key scan cursors, and set member cursors, and singleton cursors. These cursors have a common interface and therefore can be interchanged. This section covers the generated methods that give you cursors containing a single record or groups of records.

Table Scan Cursors

A table scan cursor provides the ability to navigate all the records of a particular record type in sequential order. The exact ordering of those records will not be known to the application. In our example application this would be useful for a function that wants to find the average measurement value stored in the measurement record. The order in which the records are returned are not important in this calculation, but we do need to access every record instance.

A Table Scan cursor is returned from the Db interface with the `Db.Get_recname_records` method. There is no need for a transaction when calling `Db.Get_recname_records`, however a Read transaction or Snapshot is required to read data from a Cursor.

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```
Cursor_rectype Get_recname_records (void) const throw (rdme_exception&);
```

Returns: A table scan cursor contain a collection of all the *recname* records positioned at the first record instance.

```
void get_average_measurement(
    double          *avg,
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_measurement m;
    double total;
    int32_t cur_value;
    int64_t count;

    db.BeginSnapshot();
    try
    {
        for(m = db.Get_measurement_records(), count=0, total=0; m != Cur-
sor::GetAfterLast(); m++, count++)
        {
            m.Get_value(&cur_value);
            total += cur_value;
        }
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
    *avg = total / count;
}
```

The `Cursor` interface has a common method `Cursor.GetRecords` to obtain a table scan cursor for it's own record type. This method is similar to the generated method in the `Db` interface except that the resulting `Cursor` is not positioned at the first record instance, but rather at the location of the record that created the cursor - if that location is meaningful. Since table scan cursors are not ordered in a deterministic manner this method is of limited use.

```
Cursor GetRecords (void) const throw (rdme_exception&);
```

One potential use case would be to determine if a record was placed at the end of a file. Since RDMe recycles slots when records are deleted it is possible that a record could be placed in the middle of the file or at the end. The following example uses the `Cursor.GetRecords` method to determine if a newly inserted record was placed at the end of a file. It is also an example of how you can chain method calls together.

```
Cursor_measurement add_measurement2(
    bool                *b_rec_at_end,
    struct measurement *measurement_fields,
    Cursor_sensor       s,
    Db_measurements     db) throw (rdme_exception&)
{
    Cursor_measurement m;

    db.BeginUpdate();
    try
    {
        m = db.New_measurement_recordWithFieldValues(measurement_fields);
        m.Connect_sensor_measurement(s);
        *b_rec_at_end = m.GetRecords().Next().AfterLast();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
    db.End();
    return m;
}
```

Key Scan Cursors

Key Scan Cursors are similar to Table Scan cursors, except they are based on an b-tree index. A Key Scan Cursor allows an application to iterate through all of the records in a particular record type in index order. In addition Key Scan cursors add methods for direct record searches.

A *recname* Key Scan cursor is returned from the Db interface with the generated `Db.Get_recname_recordsBy_indexname` method. `Db.Get_recname_recordsBy_indexname` requires a Read Transaction or Snapshot, however the C++ API will implicitly create and release a Read Transaction if one is not active. RDMe best practices suggest explicitly creating transactions instead of solely relying on implicit transactions. The *recname* Key Scan cursor returned by `Db.Get_recname_recordsBy_indexname` will be positioned at the first record in the cursor collection.

```
Cursor_recname Get_recname_recordsBy_indexname (void) const throw (rdme_exception&);
```

The following example shows how to display a list of all the sensors in the database ordered by the sensor name.

```
void list_sensors_by_name(
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
    struct sensor s_fields;
```

```
db.BeginSnapshot();
try
{
    s = db.Get_sensor_recordsBy_name();
    for(s.First(); s != Cursor::GetAfterLast(); s++)
    {
        s.Get_name(s_fields.name);
        cout << s_fields.name << endl;
    }
}
catch (rdme_exception e)
{
    db.End();
    throw e;
}
db.End();
}
```

It is also possible to obtain a Key Scan Cursor directly from another cursor by using the generated method `Cursor.GetRecordsBy_indexname`. This result is similar to the method in the Db interface except that the resulting Cursor is not positioned at the first record instance, but at the location of the record from which we derived the new cursor from.

```
Cursor_recname GetRecordsBy_indexname() const throw (rdme_exception&);
```

The following example uses the `GetRecordsBy_indexname` from a Cursor to display all sensor readings that have occurred after the current reading in the cursor (based on the `k_reading` index).

```
void list_subsequent_measurements(
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_measurement m_later;
    struct measurement m_fields;
    db.BeginSnapshot();
    try
    {
        m_later = m.GetRecordsBy_k_reading();
        for(m_later.Next(); m_later != Cursor::GetAfterLast(); m_later++)
        {
            m_later.GetFieldValues(&m_fields);
            display_measurement(&m_fields);
        }
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
}
```

```
db.End();  
}
```

The Cursor interface also provides generated methods for performing searches on indexed fields. For each index defined in the database there will be a `Cursor.KeyFindBy_indexname` method generated. This method will reposition the cursor to the first occurrence of the key value in the cursor collection. This method repositions the cursor to the first occurrence of the key value in the cursor collection, but it does not change the Cursor type. If you call `KeyFindBy_indexname` from a Record Scan cursor any subsequent Next or Previous calls will be based on the Cursor order and not on the index order. `Cursor.KeyFindBy_indexname` requires a Read Transaction.

When calling `KeyFindBy_indexname` from a Key Scan cursor, if you do not get an exact match the Cursor will not be at a valid record, but it will be positioned at the index location where a match would have been located. Consider an integer index containing the values 1, 2, 7, and 8, a `KeyFindBy_indexname` with a value of 5 would result in a positioning the index to a point where a call to Previous would position the Cursor to the record with the '2' index value and a call to Next would position the Cursor to the record with the '7' index value. Attempted to read/write/delete from a Cursor that is not currently positioned at a record will result in a `rdme_not_at_record_exception` being thrown.

When working with a Set Member Cursor the `KeyFindBy_indexname` will only find records that are in the cursor. While Key Scan and Record Scan cursors contain all of the records in a table, Set Member cursors only contain member records associated with a particular owner.

Since a Singleton cursor by definition contains only a single record, the `KeyFindBy_indexname` method for a Singleton Cursor is not meaningful.

```
void KeyFindBy_indexname (field_type *field_value) const throw (rdme_exception&);
```

This method has one parameter

field_value The index value that will be used to position the cursor

This example shows how to position a Sensor cursor to a particular sensor record based on the indexed name field. For this function it does not matter if the cursor is a Record Scan or Key Scan cursor.

```
void lookup_sensor(  
    char *name,  
    Cursor_sensor s,  
    Db_measurements db) throw (rdme_exception&  
{  
    recordType rtypes[] = {s.Type()};  
    db.BeginRead(rtypes, 1);  
    try  
    {  
        s.KeyFindBy_name(name);  
    }  
    catch (rdme_exception e)  
    {
```

```
        db.End();
        throw e;
    }
    db.End();
}
```

Compound keys have an addition overloaded `Cursor.KeyFindBy_indexname` method

```
void KeyFindBy_indexname (int32_t nFields, uint32_t partialStrLen,
    field_type *field_value) const throw (rdme_exception&);
```

<code>nFields</code>	The number of fields to use in the search. If this parameter is zero, the function searches all fields. If this parameter is a non-zero value, the function uses only the number of fields indicated.
<code>partialStrLen</code>	The partial string length in bytes. If this parameter is a non-zero value, the function uses only this many bytes of the last field being considered (depending on <code>nFields</code> above).
<code>field_value</code>	The index value that will be used to position the cursor

This example shows how to position a Measurement cursor to a particular record based on the `k_reading` compound key. For this function it does not matter if the cursor is a Record Scan or Key Scan cursor.

```
void lookup_measurement(
    struct measurement_k_reading *reading,
    Cursor_measurement        m,
    Db_measurements           db) throw (rdme_exception&)
{
    recordType rtypes[] = {m.Type()};
    db.BeginRead(rtypes, 1);
    try
    {
        m.KeyFindBy_k_reading(2, 0, reading);
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Set Member Cursors

Set Member Cursors differ from Table Scan Cursors and Key Scan Cursors as they can only be obtained from another Cursor and they typically contain a subset of a table's total records. A Set Member Cursor allows an application to navigate network model set relationships. The Set Member Cursor contains a collection of all the member records that are associated with a particular owner record. There are two generated methods to obtain Set Member Cursors.

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Every record that is an "owner" in a set relationship will have a generated method called `Cursor.Get_setname_members`. This method will return a Set Member collection containing all of the member records associated with the current record in the owner's cursor collection. The cursor will be positioned at the first record in the collection.

```
Cursor_rectype Get_setname_members (void) const throw (rdme_exception&);
```

This example displays all of the measurements associated with a sensor through the `sensor_measurement` set.

```
void list_sensor_measurements(
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    int32_t ii;
    Cursor_measurement m;
    struct measurement m_fields;
    db.BeginRead();
    try
    {
        m = s.Get_sensor_measurement_members();
        for(m.First(), ii=0; m != Cursor::GetAfterLast(); m++, ii++)
        {
            m.GetFieldValues(&m_fields);
            cout << "Reading: " << ii << endl;
            cout << "Time: " << m_fields.time << endl;
            cout << "Value: " << m_fields.value << endl;
        }
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Every record that is a "member" in a set relationship will have a generated method called `Cursor.Get_setname_siblings`. This method will return a Set Member collection containing all of the member records with the same owner as the original cursor. The new cursor collection will be positioned at the location of the cursor from which we derived the new Set Member cursor and not the first member.

```
Cursor_rectype Get_setname_siblings (void) const throw (rdme_exception&);
```

In our test application sensors store their measurement readings using a set. This set will put all new readings at the end of the set chain. By using the `Get_sensor_measurement_siblings` method we can find all of sensor's readings that came before or after a particular reading without needing an index.

```
void list_prior_measurements_for_sensor(
    Cursor_measurement m,
    Db_measurements db) throw (rdme_exception&)
{
    int32_t ii;
    Cursor_measurement m_prior;
    struct measurement m_fields;
    db.BeginRead();
    try
    {
        m_prior = m.Get_sensor_measurement_siblings();
        for(m_prior.Prev(), ii=0; m_prior != Cursor::GetBeforeFirst(); m_prior--,
ii++)
        {
            m_prior.GetFieldValues(&m_fields);
            cout << "Reading: " << ii << endl;
            cout << "Time: " << m_fields.time << endl;
            cout << "Value: " << m_fields.value << endl;
        }
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
}
```

Singleton Cursors

The final type of cursor is a singleton cursor which can only contain one record. For convenience a singleton can be used just as any other type of cursor, however it will never yield more than one record.

When creating a new record the generated `Db.New_recordname_record` and `Db.New_recordname_recordWithFieldValues` methods return a **Singleton Cursor** containing the newly created record.

Each record that is defined as a member in a set relationship will have a method generated to obtain a singleton cursor containing the records "Owner".

```
Cursor_ownerrec Get_setname_owner (void) const throw (rdme_exception&);
```

Returns: A singleton cursor containing the owner record.

This example shows how to get a singleton cursor containing the related sensor record for any measurement stored in our sample database.

```
Cursor_sensor get_sensor_for_measurement(
    Cursor_measurement m,
```

```
Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
    db.BeginRead();
    try
    {
        s = m.Get_sensor_measurement_owner();
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
    return s;
}
```

Each cursor also contains a `Cursor.GetThis` method that will return a Singleton Cursor for the current record in the cursor collection. This allows an application to save a reference to a particular record for later use.

```
Cursor GetThis (void) const throw (rdme_exception&);
```

Returns: A singleton cursor containing the owner record.

Special Singletons

There are two special singletons 'BeforeFirst' and 'AfterLast' used for cursor navigation. These special singletons can be obtained using static methods in the Cursor interface and identify when a Cursor is positioned before the first record in the collection or after the final record in the collection.

```
static Cursor GetBeforeFirst (void) throw ();
```

Returns: The BeforeFirst special singleton

```
static Cursor GetAfterLast (void) throw ();
```

Returns: The AfterLast special singleton

This example demonstrates how to navigate through a cursor collection and uses the `GetAfterLast` singleton to identify when we have processed the final record in a cursor collection.

```
void list_sensors(
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
```

```
struct sensor s_fields;
db.BeginSnapshot();
try
{
    s = db.Get_sensor_records();
    for(s.First(); s != Cursor::GetAfterLast(); s++)
    {
        s.Get_name(s_fields.name);
        cout << s_fields.name << endl;
    }
}
catch (rdme_exception e)
{
    db.End();
    throw e;
}
db.End();
}
```

Cursor Navigation Methods

A Cursor obtained from a Db interface is always positioned to the first record in the sequence. A Cursor obtained from another Cursor is typically positioned to the same record as the originating Cursor. Once a Cursor had been obtained there are methods to navigate through the collections of records contained by the Cursor. All Cursors in the RDMc C++ Interface are considered live Cursors. Any changes made to the database will affect all active Cursors. If you need a Cursor to remain constant you must ensure a transaction is kept for the life of the Cursor.

First

It is possible to position a Cursor to the first record in the Cursor collection with the `Cursor.First` method. This method returns a copy of the Cursor which allows it to be chained in a series of method calls.

```
Cursor First (void) const throw (rdme_exception&);
```

Returns: The Cursor you are using positioned to the first record in the collection.

The following example demonstrates the use of the `Cursor.First` method in looping through all of the records in a Cursor collection.

```
void list_sensors(
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_sensor s;
    struct sensor s_fields;
    db.BeginSnapshot();
```

```
try
{
    s = db.Get_sensor_records();
    for(s.First(); s != Cursor::GetAfterLast(); s++)
    {
        s.Get_name(s_fields.name);
        cout << s_fields.name << endl;
    }
}
catch (rdme_exception e)
{
    db.End();
    throw e;
}
db.End();
}
```

Last

It is possible to position a `Cursor` to the last record in the `Cursor` collection with the `Cursor.Last` method. This method returns a copy of the `Cursor` which allows it to be chained in a series of method calls.

```
Cursor Last (void) const throw (rdme_exception&);
```

Returns: The `Cursor` you are using positioned to the last record in the collection.

The following example demonstrates the use of the `Cursor.Last` method by displaying the last 5 records in a `Set` collection

```
void list_latest_sensor_measurements(
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    int32_t ii;
    Cursor_measurement m;
    struct measurement m_fields;
    db.BeginRead();
    try
    {
        m = s.Get_sensor_measurement_members();
        for(m.Last(), ii=0; m != Cursor::GetBeforeFirst() && ii < 5; m--, ii++)
        {
            m.GetFieldValues(&m_fields);
            cout << "Reading: " << ii << endl;
            cout << "Time: " << m_fields.time << endl;
            cout << "Value: " << m_fields.value << endl;
        }
    }
}
```

```
catch (rdme_exception e)
{
    db.End();
    throw e;
}
db.End();
}
```

Next

Position a Cursor to the next record in the collection by using the `Cursor.Next` method. The '++' operator can be used as a shortcut for the `Cursor.Next` method. This method returns a copy of the Cursor which allows it to be chained in a series of method calls.

```
Cursor Next (void) const throw (rdme_exception&);
```

```
Cursor operator ++ (void) const throw (rdme_exception&);
```

```
Cursor operator ++ (void) const throw (rdme_exception&);
```

Returns: The Cursor you are using positioned to the next record in the collection.

The following example demonstrates the use of chaining `Cursor.Next` method to determine if a record is the final record in a Cursor Collection

```
Cursor_measurement add_measurement2(
    bool *b_rec_at_end,
    struct measurement *measurement_fields,
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    Cursor_measurement m;

    db.BeginUpdate();
    try
    {
        m = db.New_measurement_recordWithFieldValues(measurement_fields);
        m.Connect_sensor_measurement(s);
        *b_rec_at_end = m.GetRecords().Next().AfterLast();
    }
    catch (rdme_exception e)
    {
        db.Abort();
        throw e;
    }
}
```

```
    }  
    db.End();  
    return m;  
}
```

Prev

Position a `Cursor` to the previous record in the collection by using the `Cursor.Prev` method. The `'--'` operator can be used as a shortcut for the `Cursor.Prev` method. This method returns a copy of the `Cursor` which allows it to be chained in a series of method calls.

```
Cursor Prev (void) const throw (rdme_exception&);
```

```
Cursor operator -- (void) const throw (rdme_exception&);
```

```
Cursor operator -- (int) const throw (rdme_exception&);
```

Returns: The `Cursor` you are using positioned to the previous record in the collection.

The following example demonstrates the use `Cursor.Prev` method and `'--'` operator to display prior measurements from a sensor.

```
void list_prior_measurements_for_sensor(  
    Cursor_measurement m,  
    Db_measurements db) throw (rdme_exception&  
{  
    int32_t ii;  
    Cursor_measurement m_prior;  
    struct measurement m_fields;  
    db.BeginRead();  
    try  
    {  
        m_prior = m.Get_sensor_measurement_siblings();  
        for(m_prior.Prev(), ii=0; m_prior != Cursor::GetBeforeFirst(); m_prior--,  
ii++)  
        {  
            m_prior.GetFieldValues(&m_fields);  
            cout << "Reading: " << ii << endl;  
            cout << "Time: " << m_fields.time << endl;  
            cout << "Value: " << m_fields.value << endl;  
        }  
    }  
    catch (rdme_exception e)  
    {
```

```
        db.End();
        throw e;
    }
    db.End();
}
```

Example 1: Cursor.Prev method

Count

Each cursor has a `GetCount` method which will return the number of items contained in the Cursor collection. By definition the `GetCount` method for a Singleton Cursor will always return 1. The `GetCount` method for the special Cursors (`BeforeFirst/AfterLast`) will always return 0.

A read transaction is not required for this method, but it is possible to retrieve out of data information without one.

```
uint64_t GetCount (void) const throw (rdme_exception&);
```

Returns: The number of items contained in the Cursor collection

The following example demonstrates the use `Cursor.GetCount` method to retrieve the number of sensors records in the database.

```
int64_t get_number_of_sensors(
    Cursor_sensor s,
    Db_measurements db) throw (rdme_exception&)
{
    int64_t sensor_count;
    db.BeginRead();
    try
    {
        sensor_count = s.GetCount();
    }
    catch (rdme_exception e)
    {
        db.End();
        throw e;
    }
    db.End();
    return sensor_count;
}
```

Cursor Comparison Methods

A cursor can be positioned at any record in the sequence, it can also be positioned before the first record or after the last record. At times we may want to compare the position of one cursor with the position of another. To

support this the C++ interface provide a set of methods and overloaded operators that compare cursor positions.

Equal

The '=' operator and the `Cursor.At` method perform a comparison for equality. They will return true only if the positions that are being compared represent the same record (or both are before the first record or after the last record). The cursors involved in the comparison do not need to be of the same type.

```
bool At (const Cursor& cursor) const throw (rdme_exception&);
```

```
bool operator == (const Cursor& cursor) const throw (rdme_exception&);
```

Not Equal

The '!=' operator and the `Cursor.NotAt` method perform a comparison for inequality. They will return true only if the positions that are being compared do not represent the same record. The cursors involved in the comparison do not need to be of the same type.

```
bool NotAt (const Cursor& cursor) const throw (rdme_exception&);
```

```
bool operator != (const Cursor& cursor) const throw (rdme_exception&);
```

Less Than

The '<' operator and the `Cursor.Before` method perform less than comparison for two cursors. They will return true only if the position in the left operand comes before the position in the right operand (as it is positioned in the left operands cursor sequence). The cursors involved in the comparison do not need to be of the same type.

A key scan cursor (`cursor1`) and a record scan cursor (`cursor2`) may contain the exact same set of records, but the records typically occur in different orders. A comparison between these cursors will be based on the order of the left operand. The means if `cursor1 < cursor2` (key order) it does not necessarily mean `cursor2 > cursor1` (record order)

```
bool Before (const Cursor& cursor) const throw (rdme_exception&);
```

```
bool operator < (const Cursor& cursor) const throw (rdme_exception&);
```

Less Than Or Equal

The '`<=`' operator and the `Cursor.BeforeAt` method perform a less than or equal comparison for two cursors. They will return true if the '`<`' operator or the '`==`' operator return true.

```
bool BeforeAt (const Cursor& cursor) const throw (rdme_exception&);
```

```
bool operator <= (const Cursor& cursor) const throw (rdme_exception&);
```

Greater Than

The '`>`' operator and the `Cursor.After` method perform greater than comparison for two cursors. They return the negated result of the '`<=`' operator.

```
bool After (const Cursor& cursor) const throw (rdme_exception&);
```

```
bool operator > (const Cursor& cursor) const throw (rdme_exception&);
```

Greater Than Or Equal

The '`>=`' operator and the `Cursor.FasterAt` method perform a greater than or equal comparison for two cursors. They will return the negated result of the '`<`' operator.

Error Handling

Very simple applications can get away without any error handling, if an error occurs an exception will be thrown and the application will terminate. For non-trivial applications this approach is not appropriate, the application needs to check for errors and take appropriate actions when errors are detected.

In the RDMc C++ interface there are two kinds of errors, expected errors and unexpected errors. Expected errors come from the use of the C++ API and an application must be coded to handle them. An example of an expected error is the inability to start a 'write transaction' because of locking contention. Only one thread is allowed to have a write transaction for a specific table, so an application that is requesting a write transaction must expect that their request may timeout and an error will occur. In this case the application may want to write some information out to a log file and then attempt to restart the transactions. Unexpected errors are more difficult to handle and may require the program to terminate. This would be the case if the application runs out of memory or if a database is corrupted due to a hardware error or software bug.

Exceptions

Error handling in the C++ interface is done through the use of exceptions. The C++ interface defines the `rdme_exception` class for all interface specific errors. Expected errors throw a class derived from `rdme_exception` while unexpected errors throw the base `rdme_exception` class. The following example demonstrates how we can use exception handling to verify the type of record a cursor collection contains. In the try block we attempt to cast a generic `Cursor` to record specific `Cursor_sensor`. The `Cursor_sensor` copy constructor will instantiate a `Cursor_sensor` with the `Cursor` as the template. The copy constructor will throw an `rdme_invalid_type_exception` if the `Cursor` is not a sensor cursor. Any other type of exception is not handled by the `is_sensor` function will need to be handled by the caller.

```
bool is_sensor(
    Cursor c)
{
    try
    {
        (Cursor_sensor) c;
    }
    catch (rdme_invalid_type_exception e)
    {
        return false;
    }
    return true;
}
```



Examples

Bill of Materials Benchmark (cppbom)

The bill-of-materials example class demonstrates the differences between relational and network model databases as well as API differences in implementing a solution to the same problem.

The CPPBOM program takes advantage of RDM's network model capabilities. The CPPBOM program use the RDM C++ API.

Execution

```
cppbomExample [-h] [-l #] [-m #]
```

Options

-h	Display usage information
-l #	Set number of levels of parts matrix to #. If not specified, the program will prompt for the information.
-m #	Set number of members (components) per level for the parts matrix to #. If not specified, the program will prompt for the information.

Example

```
C:\Raima\RDM\10.1\GettingStarted\examples\cppbom>cppbomExample -l 5 -m 6

CPP Network Model BOM Benchmark Example
RDM Embedded 10.1.0 Build 1000 [12-30-2010] http://www.raima.com/
Copyright (c) 2010 Raima Inc., All rights reserved.

Document Root: C:\Raima\RDM\10.1\GettingStarted\examples\cppbom\

Started dbkeep module
Create BOM with 5 levels and 6 members per level
  Building bill of materials
    millisecs: 353
  rolling up cost
    total rolled up cost = 7776
    millisecs: 135
Ended dbkeep module

Press RETURN to exit.
```

Summary

The RDM API offers a rich set of choices to application developers. It supports all three major data models: hierarchical, network, and relational. The choice of data model can be mixed to satisfy the requirements of virtually any application.

The bill-of-materials application was developed to compare the relative performance between pointer-based network and relational data model implementations in a common business application. The graphs in this report depict the tradeoffs between performance and database size.

The database definitions (schema) for the BOM application using different data models are provided in appendixes to this report. C source code for the applications is provided.

Problem

Many manufacturing firms build products assembled from components and subassemblies. These products range from something as simple as a ball-point pen with half a dozen parts to a Boeing 747 aircraft with over four million parts. To be competitive, modern manufacturers must rely on computer systems to accurately control parts inventories. These systems supply the production management staff with accurate, finished-product cost information and can regulate component purchases and manufacturing schedules to guarantee a predictable flow of finished product with minimum parts inventory. Material Requirements Planning (MRP II) is the ultimate realization of a production control system. The MRP II system automatically issues purchase orders and production orders in response to customer orders and sales forecasts.

The RDM benchmark builds a bill-of-materials database on disk, simulating an actual manufacturer's specification of the multi-level parts interrelationship for a product such as a power lawnmower. The benchmark then executes a Cost Roll-up in order to calculate the cost of the finished lawnmower, from the current costs of all the component parts.

Bill of Materials Structure

Figure 1 shows a diagram of the component structure for a power lawnmower. Note that there are many levels corresponding to assemblies and subassemblies, with discrete components at the bottom. Sometimes there are multiple instances of a component item (wheels, for example) connected to a parent item. Also, the same component (a screw, for example) could be used in several subassemblies, and there could be several finished-good items (different lawnmower models) using common subassemblies.

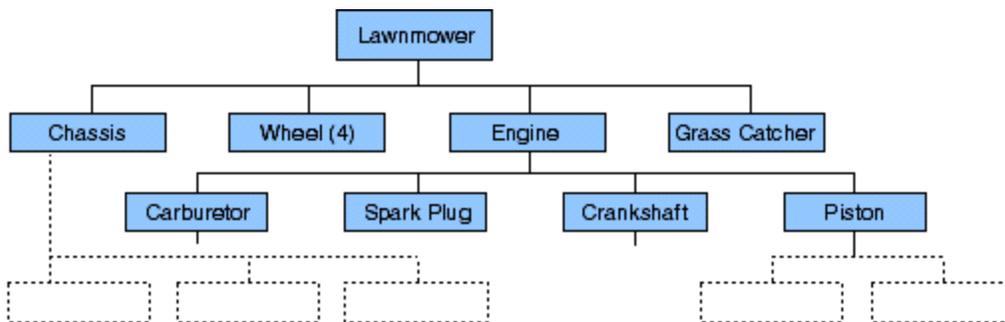


Figure 1: Lawnmower Component Structure (Partial illustration)

Different Approaches: Relational and Pointer-based Network Database Models

How can we model the bill of materials with a database structure? Consider first the relational approach. We need two tables, one for item records and the other for the connection records we call bill records. One item record exists for each unique part, between a parent item and component item. We need an item-ID index for the item table and a parent-ID/sequence-number index for the bill table. Given the item ID, we can find the item record and all the bill records that have the specified item as a parent. For each bill record we can get the component ID, and so on. [Figure 2](#) shows these tables.

ITEM RELATIONAL				
ID_CODE	DESCRIPTION	COST	COUNT	
ABC-110	Lawnmower Model 110	--	4	
XJ7-223	Wheel Assembly	--	4	
XJ7-224	1/2 Horsepower Engine	--	4	
XJ7-225	Large Grass Catcher	10.25	0	
XJ7-445	Carburetor	12.75	0	
XJ7-232	Spark Plug	.67	0	
XJ7-432	Crank Shaft	5.75	0	
XJ7-676	Piston	--	4	
XJ7-545	Chassis	--	0	

BILL RELATIONAL				
PARENT	COMPONENT	SEQ	QUANTITY	LEVEL
ABC-110	XJ7-545	0	1	0
ABC 110	XJ7 223	1	4	0
ABC-110	XJ7-224	2	1	0
ABC-110	XJ7-225	3	1	0
XJ7-224	XJ7-445	0	1	1
XJ7-224	XJ7-232	1	1	1
XJ7-224	XJ7-432	2	1	1
XJ7-224	XJ7-676	3	1	1

Figure 2. Tables for the relational model database

The pointer-based network model approach is illustrated by the logical schema diagram in [Figure 3](#). The item and bill records are connected by two sets, called bill-of-materials (BOM) and where-used. [Figure 4](#) shows an instance diagram for the lawnmower, where each rectangle represents an instance of a physical database record. Note that a parent item owns several bill records (BOM set), each of which is owned by one component item (where-used set). The components can be parents also, each owning more bills, etc. Thus you can see that the simple structure from [Figure 3](#) can represent a very complex problem.

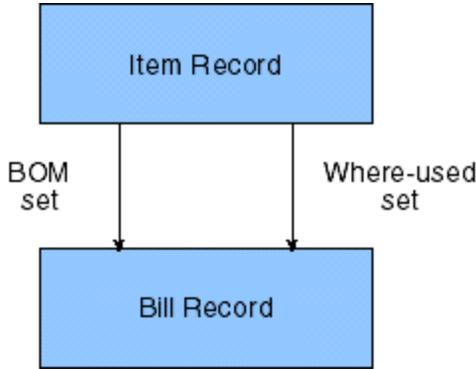


Figure 3: Schema Diagram for Network Database Model

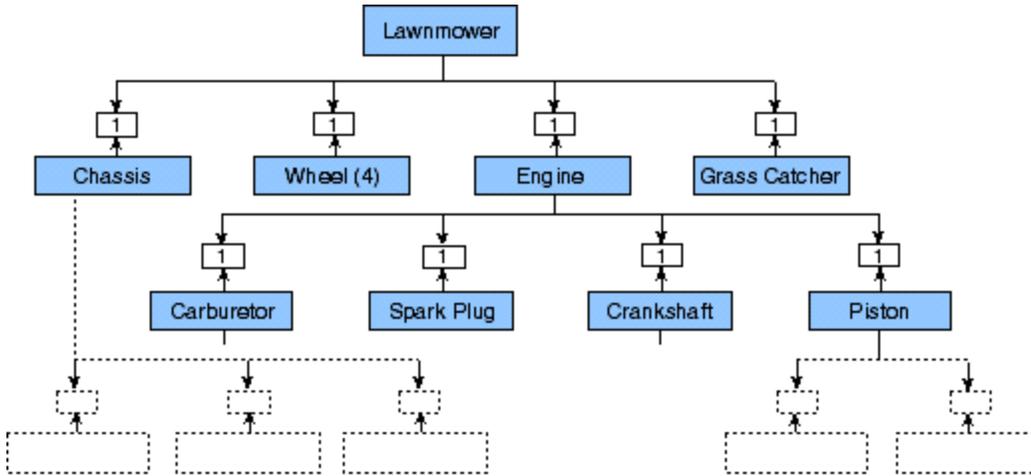


Figure 4: Instance Diagram for Network Database Model (Partial Illustration)

Benchmark Assumptions

The data dictionaries illustrated in [Appendix 1](#) and [Appendix 2](#) show the similarities and differences between the relational and network bill-of-material data structures using RDM's database definition language. The essential fields are `id_code`, `cost` and `quantity`. Description and cost are there to pad the records and make the example slightly more realistic. `Sequence` and `component_count` are required by the relational benchmark only, as are the parent and component IDs in the `bill` record.

The number of levels, the number of components per level, and the part ID of the finished product are specified on the command line when the benchmark program is run. Item records are generated with random 15-character alpha IDs. For time comparison purposes, the number of components was held constant at 5, and the number of levels was held constant at 6. A build involves a roll-up of approximately 9330 records.

In this benchmark, we assume that cost is associated only with the lowest level component records and that a particular component is used only once in the bill of materials, although both data structures will support a component's multiple use. The where-used index is included in the relational example to replicate the network example's ability to produce a listing of parents owning a specified component.

The Relational Benchmark Program

The two principal functions in the relational benchmark C program are **rbuild_bill()** and **rget_cost()**, each of which is recursive (self-calling) to allow easy multi-level processing. The **rbuild_bill()** function is straight-forward. With a single call, **rbuild_bill()** builds one level of the bill (component item and bill records) and calls itself to build the lower levels.

Note that each item record contains a count of its components and each bill record contains a sequence number.

The **rget_cost()** function returns the rolled-up cost for those parts of the bill below the designated item. **rget_cost()** reads the component count from the item record and cycles through the "attached" bill records, finding the component items. Many index keyfind and keynext operations are performed.

Component_count is an important bill record field because the program uses it to detect the bottom of the tree, saving the time otherwise required to do an unsuccessful keyfind for non-existent lower levels.

The Network Benchmark Program

In the network model C program for the benchmark, the two principal (recursive) functions are **build_bill()** and **get_cost()**. A single call to **build_bill()** builds one level of the bill (component item and bill records) and calls itself to build the lower levels. Note that the bill record does not need parent and component item IDs because it is linked directly to those item records through the sets that determine the component sequence. The parent item record does not need a component count field because that information is built into the set structure also. As with the relational benchmark, the **get_cost()** function reads the component count from the item record and cycles through the "attached" bill records, to find the component items. It returns the rolled-up cost.

RDM Benchmark Results

Our engineering department compiled and ran the programs described above to compare the performance of RDM when different features were used. We stress that these results are valuable as a relative comparison of RDM features. Your absolute results will vary depending on computing platform, processor speed vs. disk speed, etc. However, the relative performance gain produced by using one RDM data model instead of another - network model vs. relational model - should carry over into all computing environments.

Three important sets of numbers result from the benchmarks:

1. Disk space consumed by a database
2. Time to build the database (Creation time)
3. Time to roll up the cost (Retrieval time)

Database Size

The size of a relational database is greater due to the requirement to store redundant foreign keys to implement the relationships. (These relationships are maintained through pointers in the network model implementation.) In addition, the relational implementation adds a sequence field to one record to maintain the equivalent of network

model set FIFO (first-in-first-out) ordering, and a field to store the component count for run-time optimization (to know the bottom of the bill-of-materials hierarchy has been reached and that another key lookup is unnecessary). In the network model, member counts are maintained automatically by the database. Table 1 shows the total database sizes, which are the sums of the file sizes in each database after 44 runs. The Bytes per Item includes both an **item** and **bill** record, plus the storage overhead. Storage overhead for the network model includes set linkage, while overhead for the relational model includes indexing.

Database Model	Total Database Size	Bytes per Item
Network Model	86,071,296	210
Relational Model	120,422,400	293

Table 1: Database Size Comparison

Creation Time (Database Population)

Figure 5 shows the performance of RDM in building the database (writing to the database) using the two implementations. The time required to write to the database (represented by clock ticks, as returned by the `times()` function) is graphed against the total number of finished items in the database, with each item consisting of about 18,660 records each (9,330 item records, 9,330 bill records). For example, with the relational model, it would take approximately 366 ticks to add the ninth lawnmower to the database. The network model shows 258 ticks, a 42 percent improvement, and this advantage is more pronounced as the size of the database increases.

The network model is faster for database population because the time required to establish the relationships between the **item** and **bill** records is constant regardless of the size of the database. This is in contrast to the relational model where the time to update the B-tree indexes increases in some proportion to the number of values stored in the B-tree.

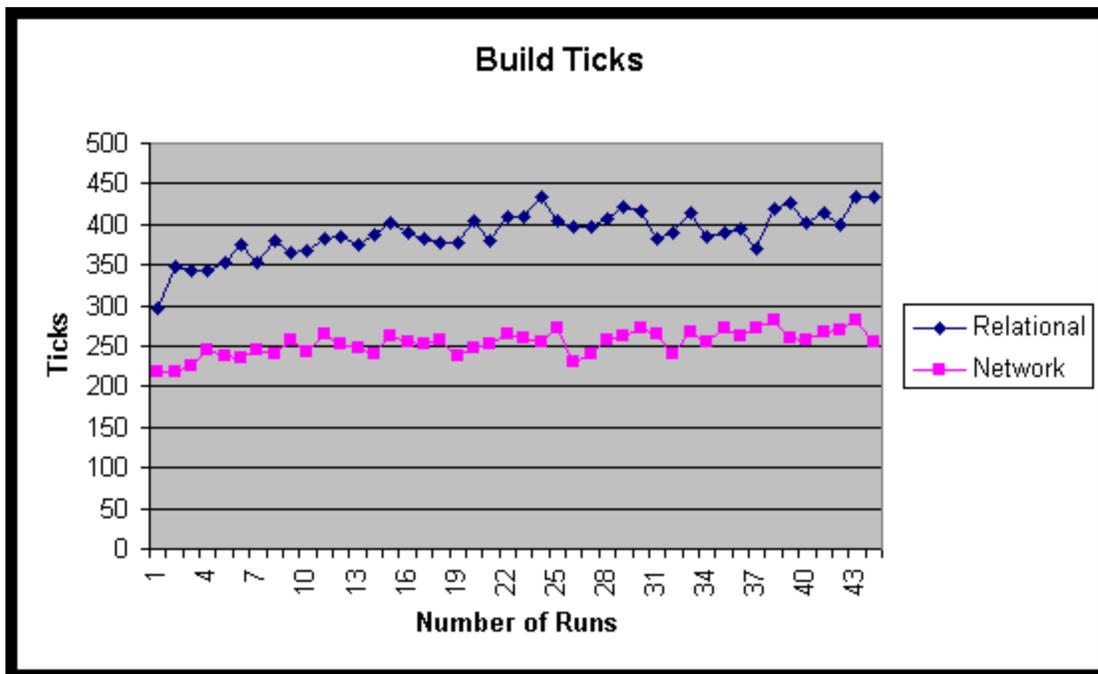


Figure 5: Database Population Performance

It becomes apparent from [Figure 5](#) that performance slows in relational model database population due to the overhead of maintaining B-tree indexes. This becomes even more apparent as the size of the database grows and the cost of updating the B-tree becomes proportionately greater.

Database Retrieval (Querying)

[Figure 6](#) shows RDM's performance in performing a cost roll-up on the bill-of-materials database, that is, determining the cost of the nth item stored in the database, by summing its component parts' costs. Again, performance is most impressive using the network model.

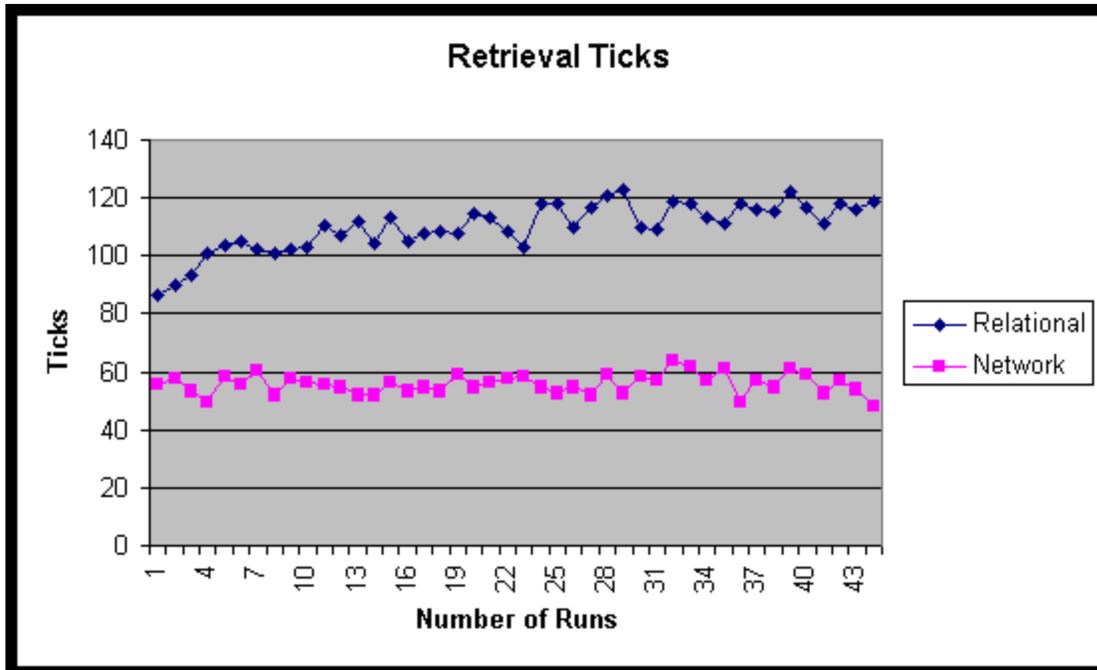


Figure 6: Database Navigation Performance

Analysis

Why is the network model program so much faster? It's faster because it avoids index processing. In a six-level benchmark, for example, about 18,000 keyfind and 7,800 keynext operations are required to roll up the cost. The network model program requires only one keyfind. The network-model set connections afford direct connections between items and bills. The relational benchmark time-per-record increases with file size because the depth of the index nodes increases, while the network performance plot remains flat.

Conclusions

RDM performance becomes truly outstanding when a developer implements certain unique features. As the graphs above clearly indicate, disk storage space can be saved by designing a database under the network model (a 40 percent reduction in storage requirements over the relational database in the example above).

Programming simplicity can be observed in the sample code. Navigational position information is more naturally represented by set currency. The relational code must reestablish index positions when moving between levels

C++ Interface Users Guide

in the hierarchy. Although this benchmark code did not take advantage of the "where-used" relationship (allowing the same sub-tree of parts to be placed under more than one item), the DDL illustrates how naturally the relationship can be represented.

Appendix A1, network model

```
/* BOM.DDL bill-of-materials network model benchmark schema */

database bom {
  data file "bom.d01" contains item;
  data file "bom.d02" contains bill;
  key file "bom.k01" contains id_code;

  record item {
    unique key char id_code[16];
    char description[58];
    double cost;
  }
  record bill {
    double quantity;
    long level;
  }

  set bom {
    order last;
    owner item;
    member bill;
  }
  set where_used {
    order last;
    owner item;
    member bill;
  }
}
```

Appendix B1, relational model

```
/* RBOM.DDL bill-of-materials relational model benchmark schema */

database rbom {
  data file "rbom.d01" contains ritem;
  data file "rbom.d02" contains rbill;
  key file "rbom.k01" contains rid_code;
  key file "rbom.k02" contains rbom, rwhere_used;

  record ritem {
    unique key char rid_code[16];
    char rdescription[58];
  }
}
```

```
    double rcost;
    long rcomponent_count;
}
record rbill {
    char rparent[16];
    char rcomponent[16];
    long rsequence;
    double rquantity;
    long rlevel;

    compound key rbom {
        rparent;
        rsequence;
    }
    compound key rwhere_used {
        rcomponent;
        rsequence;
    }
}
}
```

Generating Documentation for the C++ API

The RDMc C++ API supports the Doxygen documentation system for C++. The Doxygen executables can be downloaded and installed from [Doxygen web site](#).

CPPBOM Example

To create documentation for the `cppbom` example application the following steps must be taken. It is assumed you have Doxygen installed and properly configured.

- Build the `cppbom` example application (see example documentation for further information)
- In a RDMc development command shell environment navigate to the `GettingStarted/example/cppbom` directory
- Run **doxygen** to generate the documentation for the API generated for the `cppbom` example database
 - The documentation will be placed in a directory called "html"
 - Inside the folder will be the `index.html` root for the generated documentation

An example of the generated output can be found at the following link: [cppbom example](#)

RDMc C++ API

To create documentation for the C++ API here are the steps that need to be taken. It is assumed you have Doxygen installed and properly configured for your development environment.

- Generate the C++ API using the `-cpp` option for `ddlp`
- Copy the example `Doxyfile` from the `GettingStarted\Examples\cppbom` directory to the directory where the new C++ files generated by `ddlp` are located
- Edit the `Doxyfile` INPUT value, replace `cppbom_api.h` and `cppbom_api.cpp` with the API source and header file for your database (the files generated by `ddlp`)
- You need to keep the `DbTypes.h`, `Cursor.h`, and `Db.h` header files in order to generate documentation for the base classes. These classes contain many generic methods that are used by the derived classes in your specific API
- The `RDM_HOME` environmental variable is used to locate the RDMc base class header files, you will need to make sure that environmental variable is set before running **doxygen**.
- Run **doxygen** in the directory containing the `Doxyfile` file to generate the documentation
 - The documentation will be generated in a directory called "html".
 - Inside the folder will be the `index.html` root for the generated documentation