MongoDB ESR Rule(Equality, Sort, Range)

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Introduction

The **ESR Rule** in MongoDB stands for **Equality, Sort, Range**, a set of principles to design and utilize indexes efficiently for query optimization. Following this rule ensures that indexes are used effectively to minimize query execution time and improve performance.

- **Equality:** Prioritize fields with exact matches first to reduce the dataset quickly.
- **Sort:** Include fields used for sorting next to avoid in-memory sorting.
- **Range:** Add fields with range filters last, as they are less restrictive.

Why was ESR introduced?

MongoDB indexes are designed to process queries efficiently, but not all queries utilize indexes effectively.

Challenge: Queries with multiple conditions (equality, sorting, and range) often failed to fully utilize compound indexes, leading to slower performance.

Solution: The ESR rule provides a structured approach to query design that matches how MongoDB's query planner and index structures operate, ensuring maximum performance.

Why is the order ESR followed

The order **ESR (Equality, Sort, Range)** is used in MongoDB because it aligns with how its query planner evaluates and optimizes queries for maximum efficiency. Here's why the order matters:

1. **Equality (E)**
    - Equality conditions (e.g., `field = value`) are the most restrictive and quickly reduce the dataset to relevant matches.
    - By narrowing down the dataset early, it minimizes the work required for sorting or evaluating ranges.

2. **Sort (S)**
    - After equality filtering, sorting can be done more efficiently on the reduced dataset.
    - If the sort order matches the index order, MongoDB can sort without additional processing, avoiding slow in-memory sorting.
3. **Range (R)**
    - Range conditions (e.g., `field > value`, `field < value`) are less restrictive and often result in larger datasets.
    - Placing range queries last ensures that they are applied only after equality filtering and sorting, making the query faster and more efficient.

Before ESR

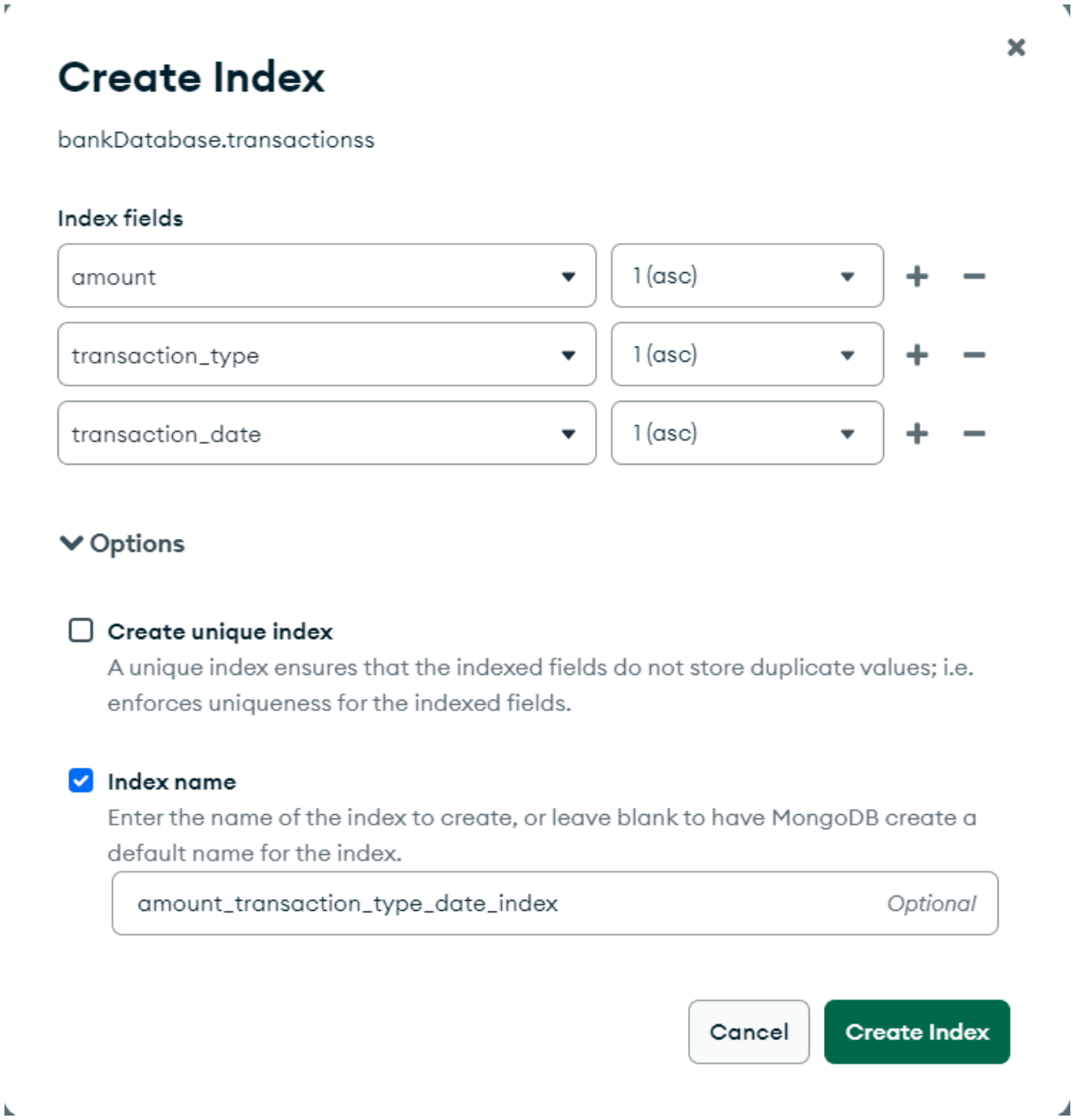
Scenario

Find transactions where:

1. The `amount` is greater than or equal to `$3000` (**Range**).
2. The `transaction_type` is `"Deposit"` (**Equality**).
3. The results are sorted by `transaction_date` in ascending order (**Sort**).

Step-by-Step Guide

1. **Create an Index**
    - Navigate to the `Indexes` tab in MongoDB Compass for your collection (`transactions`).
    - Click `Create Index`.
    - Add the following fields:
        - `amount` as **Ascending (1)**.
        - `transaction_type` as **Ascending (1)**.
        - `transaction_date` as **Ascending (1)**.
    - Name your index (e.g., `amount_transaction_type_date_index`).
    - Click `Create Index`.



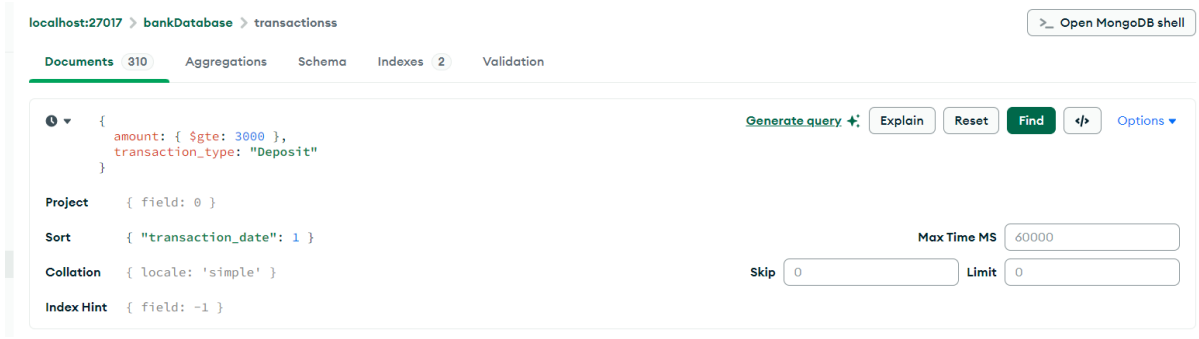
2. **Run the Query**
   - Go to the `Documents` tab.
   - Click on `Type a query` and enter the following query:

```
{ amount: { $gte: 3000 }, transaction_type: "Deposit" }
```

     - Click on `options`

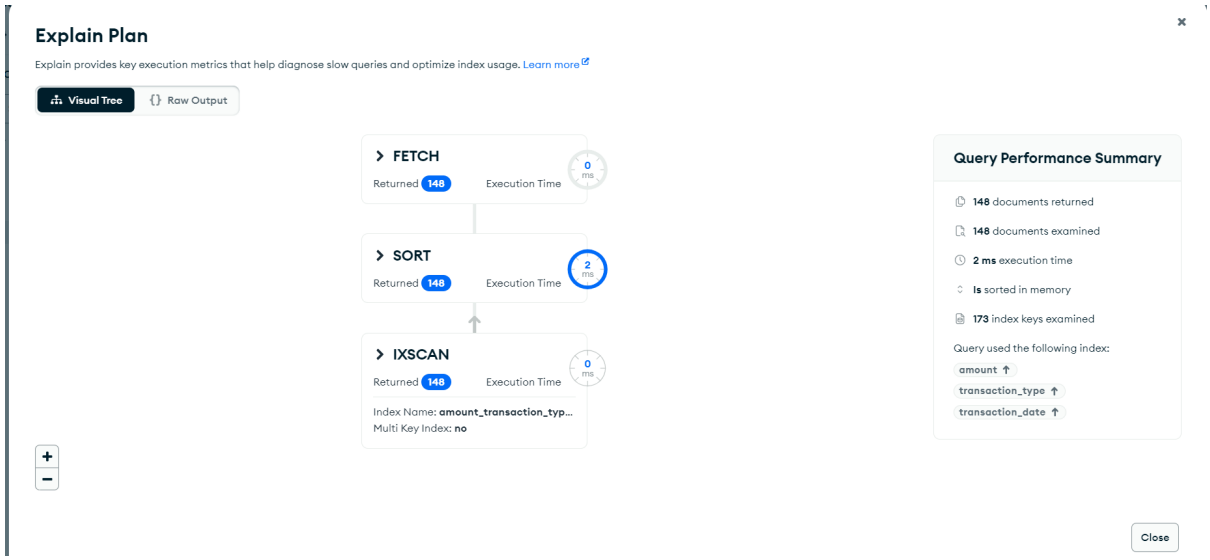
```
sort
 { transaction_date: 1 }
```

   - Click `Find`.



3. **Explain Plan**

   - Click on `Explain Plan` to analyze the query.
   - You will notice MongoDB scans the `amount` field first, filters `transaction_type`, and performs in-memory sorting on `transaction_date`.
   - **Drawbacks**: Increased execution time and resource usage.



Issues

- **Inefficient Index Scan**: MongoDB starts with the `amount` field, which is less restrictive than `transaction_type`. This results in a larger dataset being processed before filtering.
- **In-Memory Sorting**: Sorting on `transaction_date` is performed in memory, increasing resource usage.
- **Poor Performance**: With large datasets, this approach can lead to slower queries and higher memory consumption.

After ESR

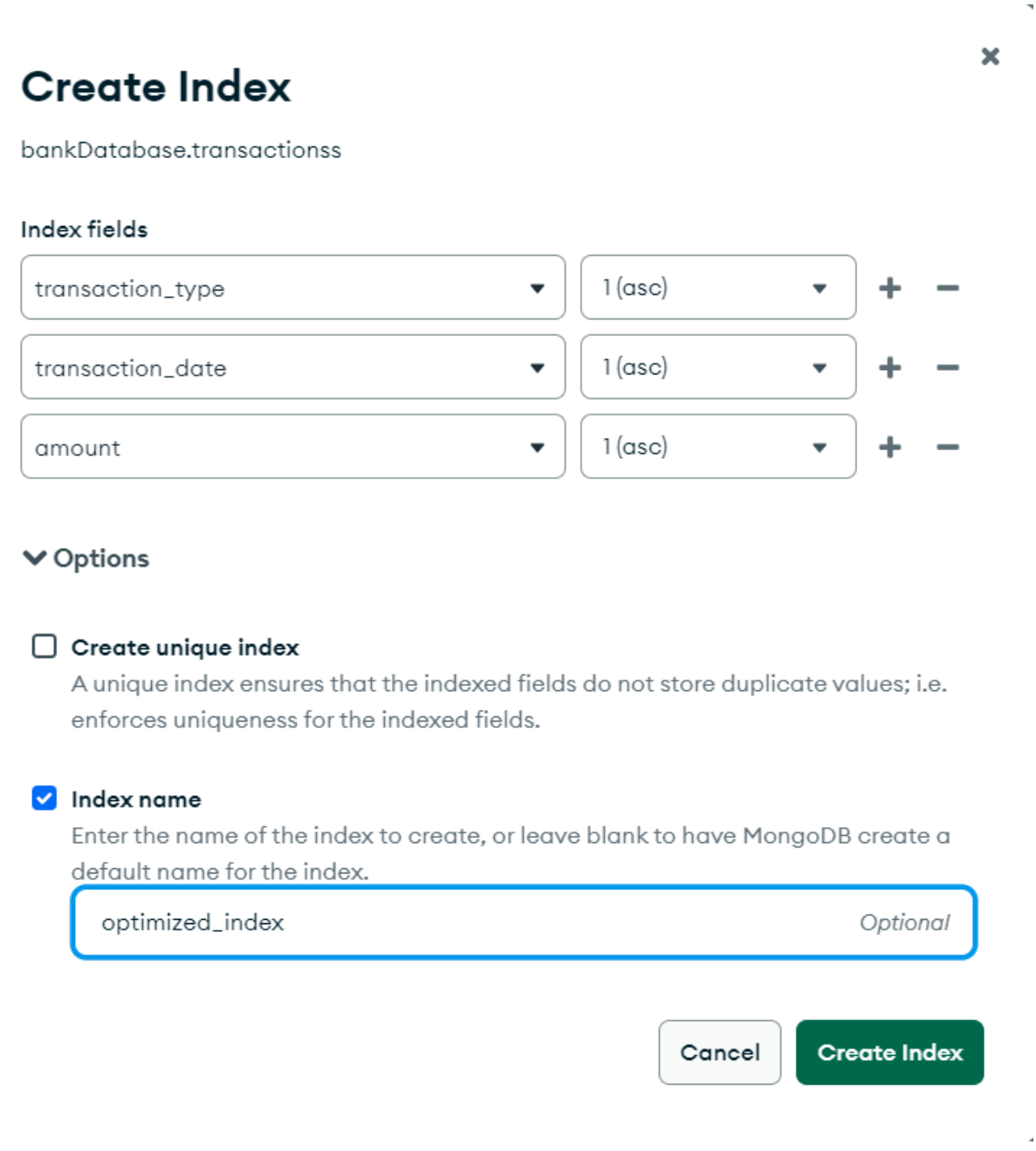
Optimized Query (After ESR)

To optimize, follow the ESR order:

1. **Equality**: `transaction_type = "Deposit"` should come first.
2. **Sort**: `transaction_date` should come next.
3. **Range**: `amount >= 3000` should be evaluated last.

Step-by-Step Guide

1. **Create an Optimized Index**
   - Go to the `Indexes` tab and click `Create Index`.
   - Add the following fields:
     - `transaction_type` as **Ascending (1)**.
     - `transaction_date` as **Ascending (1)**.
     - `amount` as **Ascending (1)**.
   - Name your index (e.g., `optimized_index`).
   - Click `Create Index`.

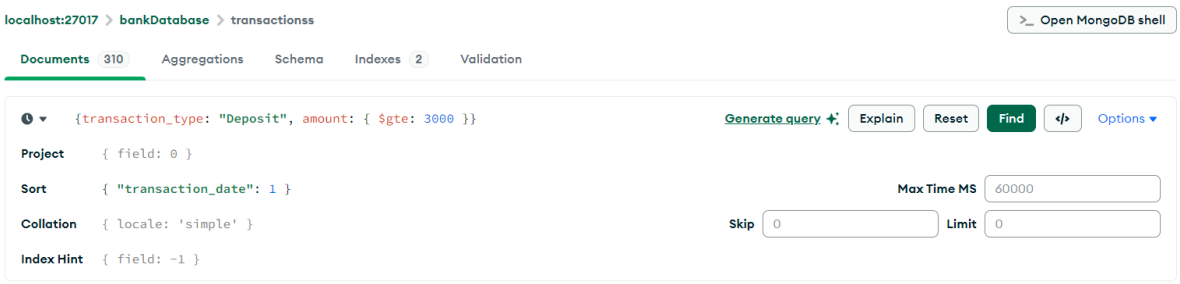


2. **Run the Optimized Query**
   - Go to the `Documents` tab.
   - Enter the same query:

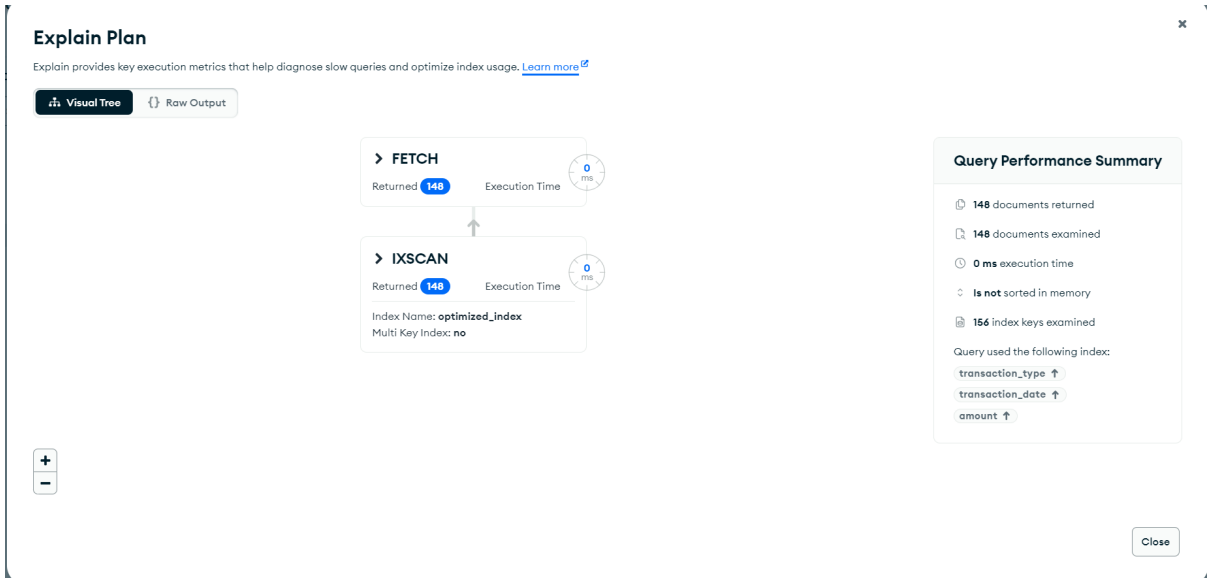
```
{ transaction_type: "Deposit", amount: { $gte: 3000 } }
```

- Click on `options`

```
sort
 { transaction_date: 1 }
```

- Click **`Find`**.
- 

3. **Explain Plan**

- Click on **`Explain Plan`** again.
- MongoDB will use the optimized index:
  - First, it filters by `transaction_type = "Deposit"`.
  - Then, it sorts by `transaction_date`.
  - Finally, it filters `amount >= 3000`.
- **Benefits**: Faster query execution with no in-memory sorting or filtering.
- 

Benefits

- **Efficient Index Usage**: The query fully utilizes the index.
- **No In-Memory Sorting**: Sorting is handled by the index.
  - **Note:** If MongoDB does in-memory sorting, all documents stored on disk are read into RAM, then a sorting algorithm is performed. In-memory sorting is inefficient, time-consuming &

sorting a large number of documents in memory is quite expensive. Moreover, MongoDB aborts the operation if memory usage is more than 32MB.

- **Improved Performance**: Faster query execution, even on large datasets.

Comparison

Aspect	Before ESR	After ESR
Index	`{ amount: 1, transaction_type: 1, transaction_date: 1 }`	`{ transaction_type: 1, transaction_date: 1, amount: 1 }`
Execution	Scans `amount` first, sorts in memory	Filters `transaction_type` first, sorts using index
Sorting	In-memory sorting	Index-based sorting
Performance	Slow, high resource usage	Fast, efficient