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(54) PERSISTING DATABASE QUERY PLANS THAT INCLUDE DYNAMIC CONDITIONS

(71) Applicant: **SAP SE**, Walldorf (DE)

(72) Inventors: **Boyang Zhang**, Xi'an (CN); **Yinghua Ouyang**, Xi'an (CN); **Zhen Tian**, Xi'an (CN)

(73) Assignee: **SAP SE**, Walldorf (DE)

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G06F 16/2453	(2019.01)
G06F 16/2455	(2019.01)

(52) **U.S. Cl.**
CPC .. ***G06F 16/24542*** (2019.01); ***G06F 16/24526*** (2019.01); ***G06F 16/24539*** (2019.01); ***G06F 16/24552*** (2019.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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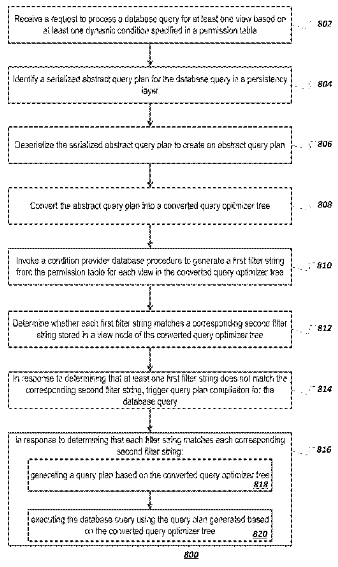
Primary Examiner — Son T Hoang
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) ABSTRACT

The present disclosure involves systems, software, and computer implemented methods for managing database query plans with dynamic conditions. One example method includes receiving a request to process a query based on at least one dynamic condition. A serialized abstract query plan is identified, deserialized, and converted into a query optimizer tree. A condition provider procedure is invoked to generate a first filter string for each view in the query optimizer tree. Comparisons are made to determine matches between first filter strings and corresponding second filter string stored in the query optimizer tree. In response to determining that a first filter string does not match the corresponding second filter string, query plan compilation is triggered. In response to determining that each filter string matches each corresponding second filter string, a query plan is generated based on the converted query optimizer tree and the query is executed using the query plan.

20 Claims, 9 Drawing Sheets


Receive a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table
802
Identify a serialized abstract query plan for the database query in a persistency layer
804
Deserialize the serialized abstract query plan to create an abstract query plan
806
Convert the abstract query plan into a converted query optimizer tree
808
Invoke a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree
810
Determine whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree
812
In response to determining that at least one first filter string does not match the corresponding second filter string, trigger query plan compilation for the database query
814
In response to determining that each filter string matches each corresponding second filter string:
816
generating a query plan based on the converted query optimizer tree
818
executing the database query using the query plan generated based on the converted query optimizer tree
820
800

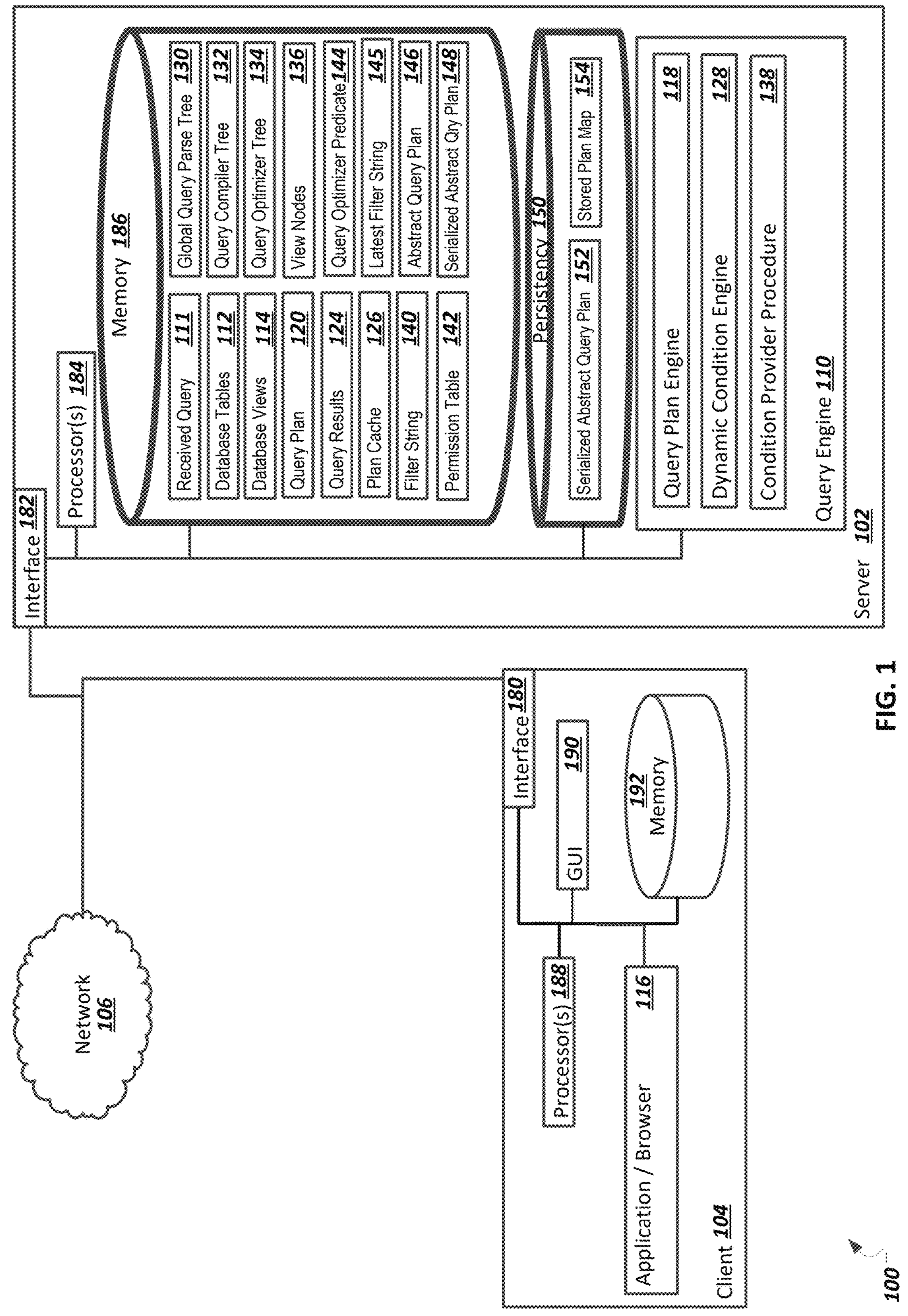

Interface 182
Processor(s) 184
Memory 186
Received Query 111
Database Tables 112
Database Views 114
Query Plan 120
Query Results 124
Plan Cache 126
Filter String 140
Permission Table 142
Global Query Parse Tree 130
Query Compiler Tree 132
Query Optimizer Tree 134
View Nodes 136
Query Optimizer Predicate 144
Latest Filter String 145
Abstract Query Plan 146
Serialized Abstract Qry Plan 148
Persistency 150
Serialized Abstract Query Plan 152
Stored Plan Map 154
Query Plan Engine 118
Dynamic Condition Engine 128
Condition Provider Procedure 138
Query Engine 110
Server 102
Network 106
Interface 180
GUI 190
192 Memory
Processor(s) 188
Application / Browser 116
Client 104
100

FIG. 1

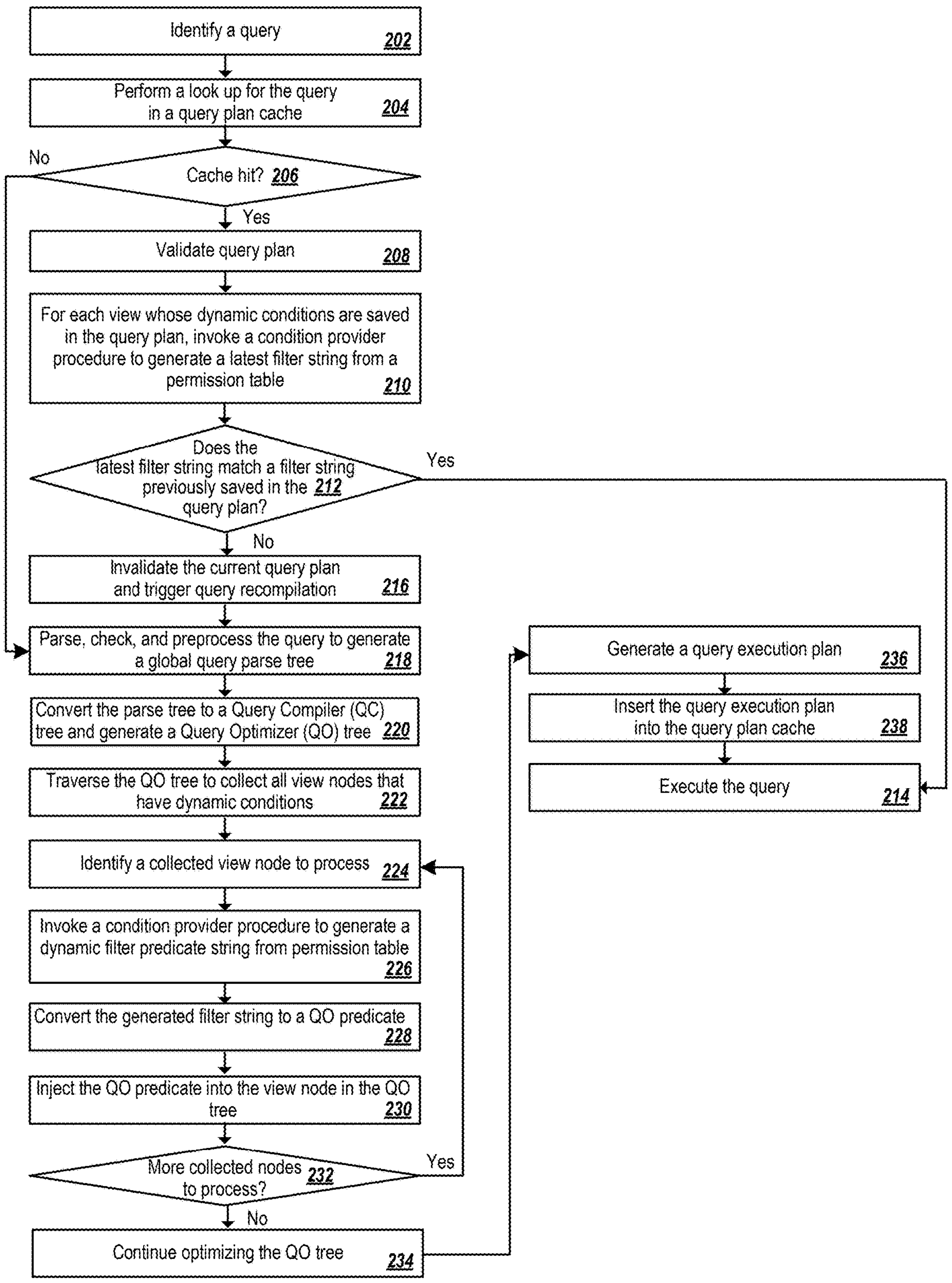

Identify a query 202
Perform a look up for the query in a query plan cache 204
Cache hit? 206
No
Yes
Validate query plan 208
For each view whose dynamic conditions are saved in the query plan, invoke a condition provider procedure to generate a latest filter string from a permission table 210
Does the latest filter string match a filter string previously saved in the query plan? 212
Yes
No
Invalidate the current query plan and trigger query recompilation 216
Parse, check, and preprocess the query to generate a global query parse tree 218
Convert the parse tree to a Query Compiler (QC) tree and generate a Query Optimizer (QO) tree 220
Traverse the QO tree to collect all view nodes that have dynamic conditions 222
Identify a collected view node to process 224
Invoke a condition provider procedure to generate a dynamic filter predicate string from permission table 226
Convert the generated filter string to a QO predicate 228
Inject the QO predicate into the view node in the QO tree 230
More collected nodes to process? 232
Yes
No
Continue optimizing the QO tree 234
Generate a query execution plan 236
Insert the query execution plan into the query plan cache 238
Execute the query 214

FIG. 2 200

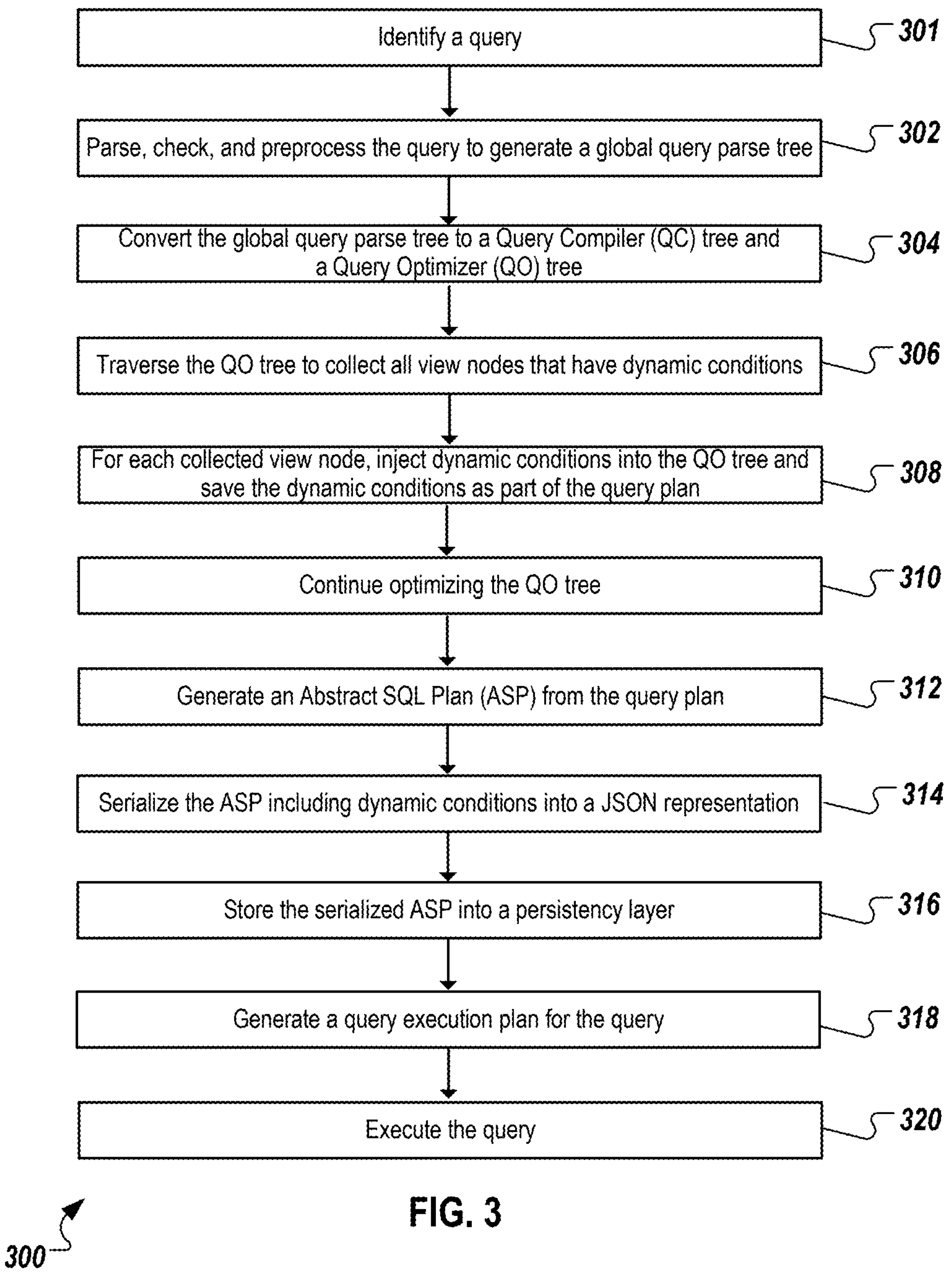

Identify a query
301
Parse, check, and preprocess the query to generate a global query parse tree
302
Convert the global query parse tree to a Query Compiler (QC) tree and a Query Optimizer (QO) tree
304
Traverse the QO tree to collect all view nodes that have dynamic conditions
306
For each collected view node, inject dynamic conditions into the QO tree and save the dynamic conditions as part of the query plan
308
Continue optimizing the QO tree
310
Generate an Abstract SQL Plan (ASP) from the query plan
312
Serialize the ASP including dynamic conditions into a JSON representation
314
Store the serialized ASP into a persistency layer
316
Generate a query execution plan for the query
318
Execute the query
320
300

FIG. 3

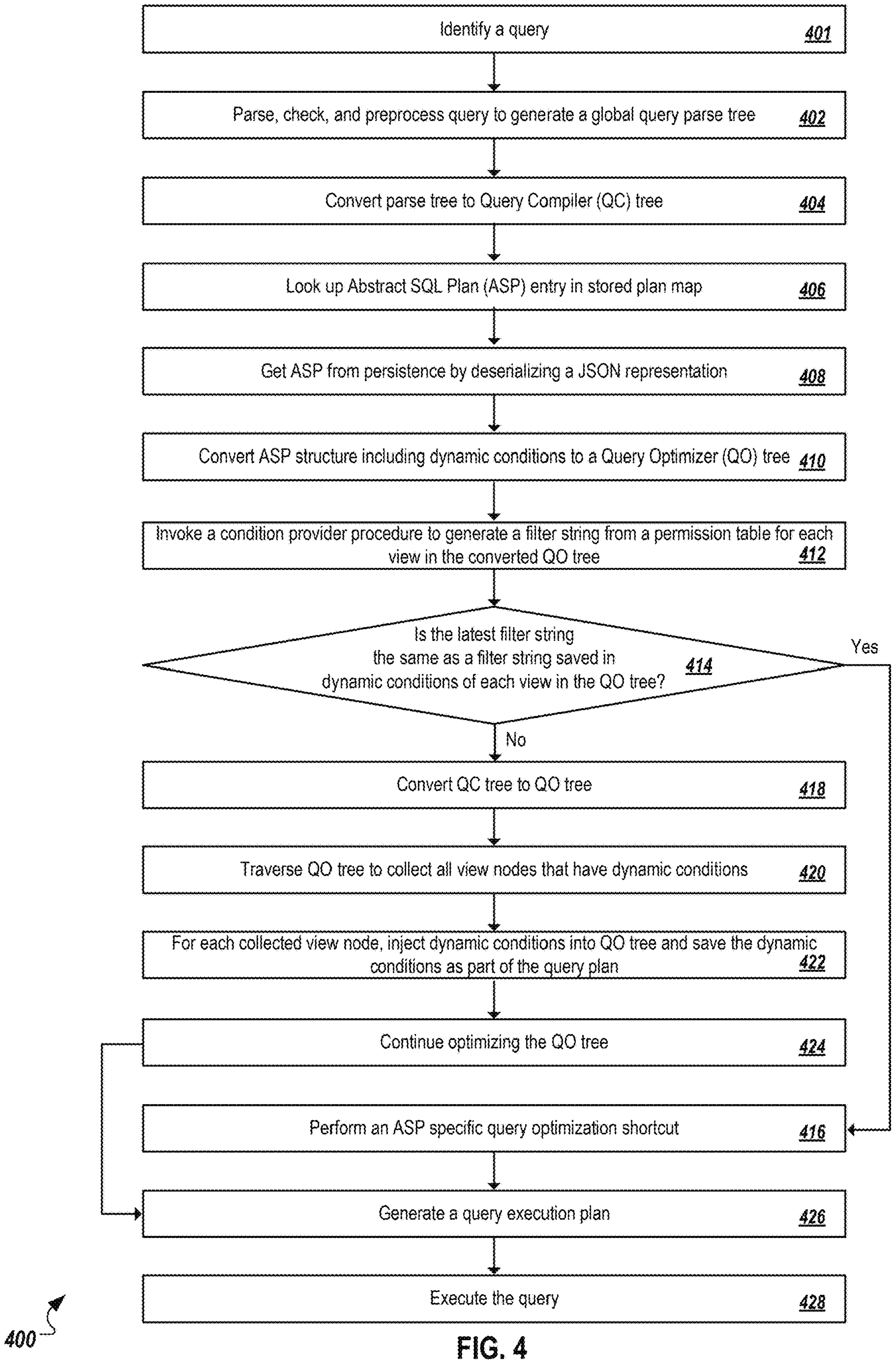

Identify a query 401
Parse, check, and preprocess query to generate a global query parse tree 402
Convert parse tree to Query Compiler (QC) tree 404
Look up Abstract SQL Plan (ASP) entry in stored plan map 406
Get ASP from persistence by deserializing a JSON representation 408
Convert ASP structure including dynamic conditions to a Query Optimizer (QO) tree 410
Invoke a condition provider procedure to generate a filter string from a permission table for each view in the converted QO tree 412
Is the latest filter string the same as a filter string saved in dynamic conditions of each view in the QO tree? 414
Yes
No
Convert QC tree to QO tree 418
Traverse QO tree to collect all view nodes that have dynamic conditions 420
For each collected view node, inject dynamic conditions into QO tree and save the dynamic conditions as part of the query plan 422
Continue optimizing the QO tree 424
Perform an ASP specific query optimization shortcut 416
Generate a query execution plan 426
Execute the query 428
400

FIG. 4

502

```
–create a SQL view protected by row level security
create column table "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE" ("year_key" nvarchar(10),  "year_sid" nvarchar(10), "customer_sid" nvarchar(10), "sales" int);
insert into "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE" values ('2006', '2006', 'CUSTOMER_A', 1000);
insert into "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE" values ('2006', '2006', 'CUSTOMER_B', 3000);
insert into "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE" values ('2007', '2007', 'CUSTOMER_A', 1000);
insert into "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE" values ('2007', '2007', 'CUSTOMER_B', 2000);
CREATE VIEW "TEST_SCHEMA"."DYNAMICSQLSF_FOR_SQL_VIEW" AS (SELECT * FROM "TEST_SCHEMA"."CETEST_SC_ONEFACTTABLE")
 WITH STRUCTURED FILTER CHECK;
CREATE SCHEMA DYNAMIC_SQL_SF_SCHEMA;
```

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FIG. 5A

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```
–create permission table
CREATE COLUMN TABLE "DYNAMIC_SQL_SF_SCHEMA"."TABLE_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW" ("filter_string" varchar(5000), "userName"
varchar(256));
INSERT INTO "DYNAMIC_SQL_SF_SCHEMA"."TABLE_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW" VALUES('"year_key" = "2006"', 'SYSTEM');
CREATE PROCEDURE "DYNAMIC_SQL_SF_SCHEMA"."PROC_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW" (OUT VAL VARCHAR(5000))
            LANGUAGE SQLSCRIPT SQL SECURITY DEFINER READS SQL DATA AS
            BEGIN
              DECLARE v_Val VARCHAR(5000);
              DECLARE CURSOR c_GetOneOperand FOR
                SELECT "filter_string" FROM "DYNAMIC_SQL_SF_SCHEMA"."TABLE_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW" WHERE "userName" =
                    SESSION_USER;
              OPEN c_GetOneOperand;
              FETCH c_GetOneOperand INTO v_Val;
              IF c_GetOneOperand::NOTFOUND THEN
                VAL  = NULL;
              ELSE
                VAL  = v_Val;
              END IF;
              CLOSE c_GetOneOperand;
            END;
```

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FIG. 5B

```
--create row level security to bind protected database object and condition provider procedure
CREATE STRUCTURED FILTER "TEST_SCHEMA"."SQLSF_FOR_SQL_VIEW" FOR SELECT ON "TEST_SCHEMA"."DYNAMICSQLSF_FOR_SQL_VIEW"
CONDITION PROVIDER "DYNAMIC_SQL_SF_SCHEMA"."PROC_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW";
```

560

FIG. 5C

```
--filter predicate "year_key" = '2006' from permission table will be retrieved and applied to query execution
SELECT "year_key",  "year_sid", "sales" FROM "TEST_SCHEMA"."DYNAMICSQLSF_FOR_SQL_VIEW" GROUP BY "year_key", "year_sid", "sales";
```

580

FIG. 5D

```
--the preparation count would not increase if dynamic condition or other related objects are changed
SELECT preparation_count, execution_count, * FROM sys.m_sql_plan_cache_ WHERE to_nvarchar(statement_string) LIKE
'SELECT%DYNAMICSQLSF_FOR_SQL_VIEW%' and to_nvarchar(statement_string) not LIKE 'SELECT%m_sql_plan_cache_%';
```

600

FIG. 6A

```
--change the dynamic filter predicate string by updating the permission table
UPDATE "DYNAMIC_SQL_SF_SCHEMA"."TABLE_FOR_DYNAMIC_SQL_SF_SQLSF_FOR_SQL_VIEW" SET "filter_string" = '"year_key" = "2007"'
  WHERE "userName" = 'SYSTEM';
```

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FIG. 6B

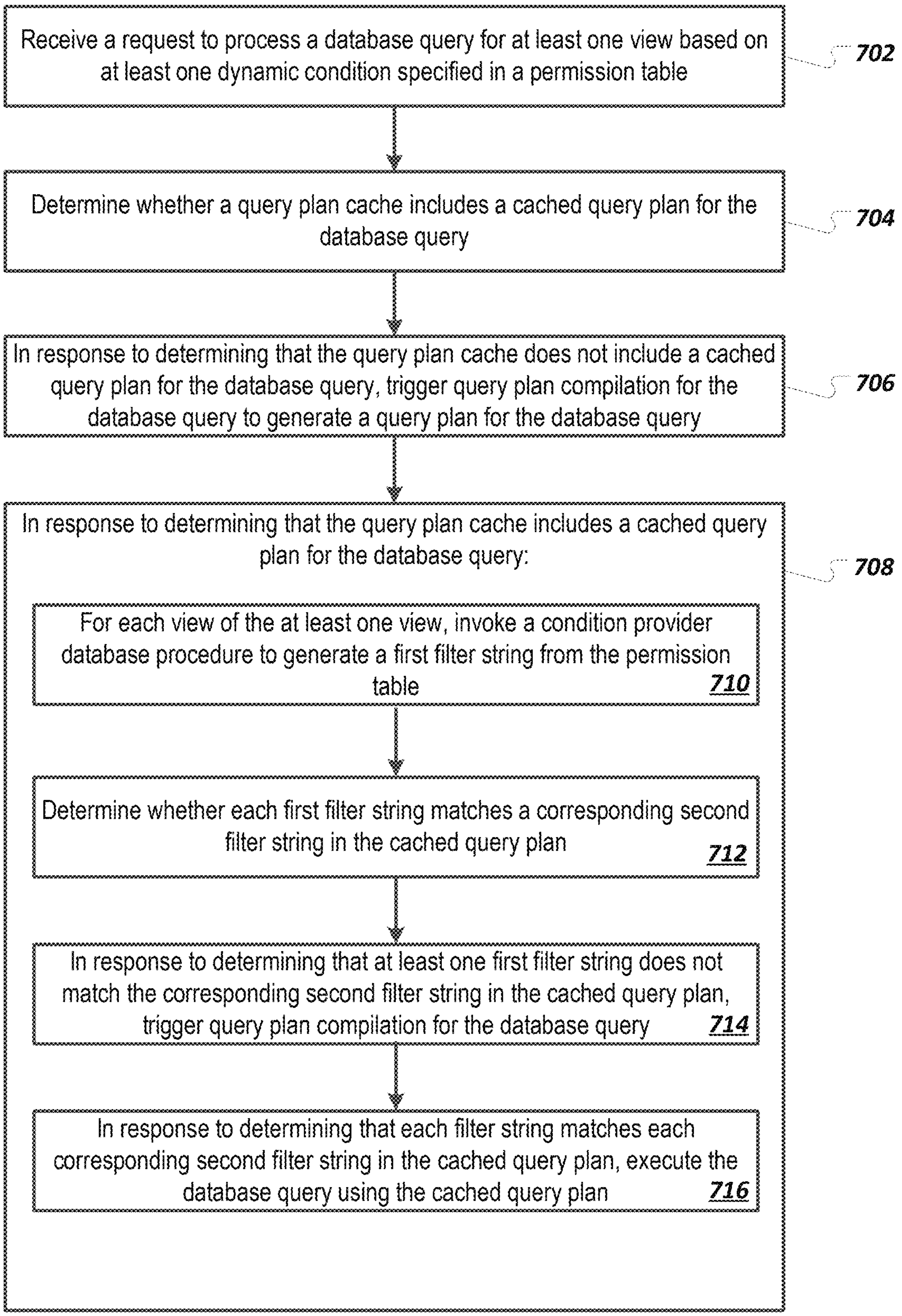
Receive a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table
702
Determine whether a query plan cache includes a cached query plan for the database query
704
In response to determining that the query plan cache does not include a cached query plan for the database query, trigger query plan compilation for the database query to generate a query plan for the database query
706
In response to determining that the query plan cache includes a cached query plan for the database query:
708
For each view of the at least one view, invoke a condition provider database procedure to generate a first filter string from the permission table
710
Determine whether each first filter string matches a corresponding second filter string in the cached query plan
712
In response to determining that at least one first filter string does not match the corresponding second filter string in the cached query plan, trigger query plan compilation for the database query
714
In response to determining that each filter string matches each corresponding second filter string in the cached query plan, execute the database query using the cached query plan
716

FIG. 7 700

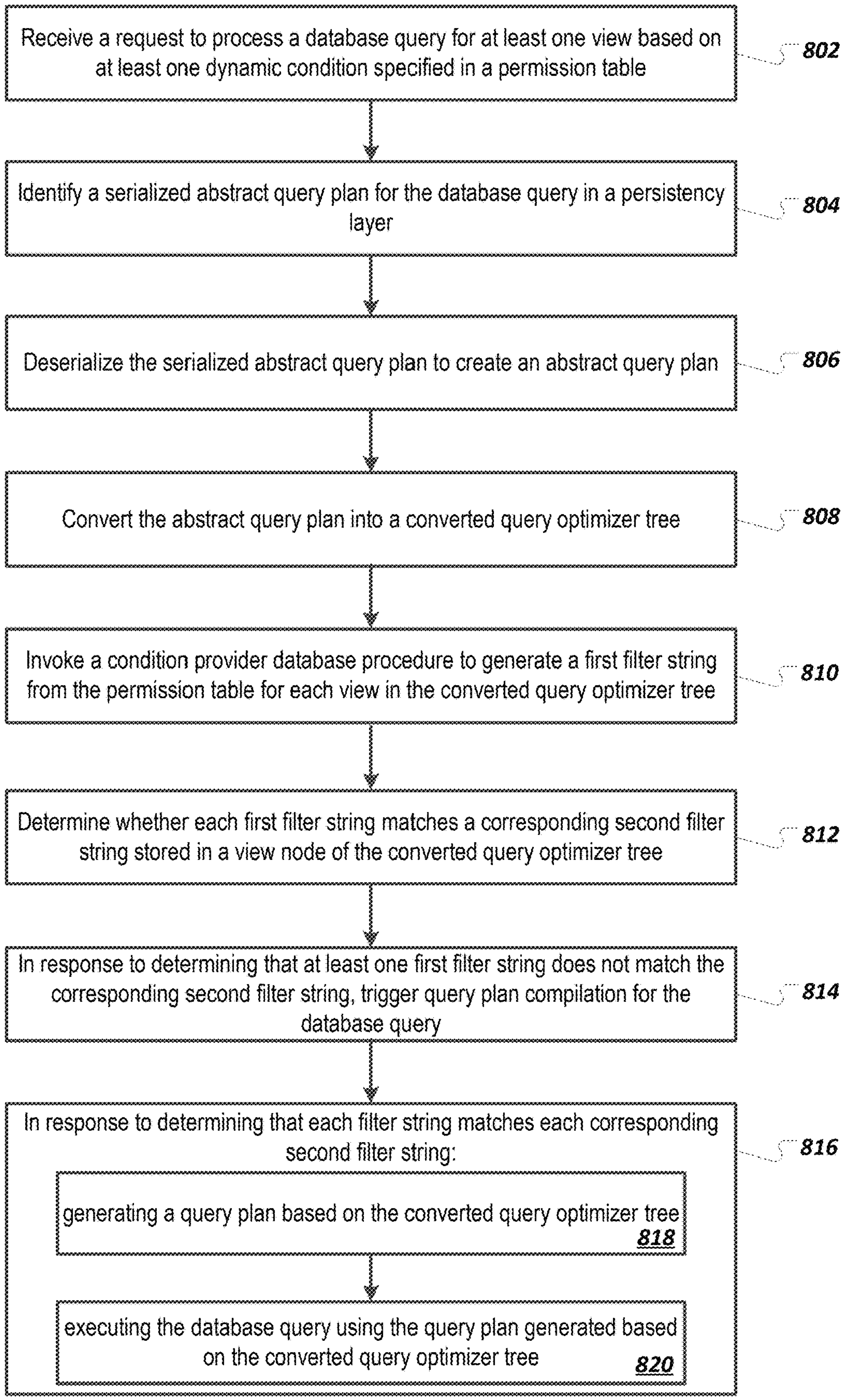
Receive a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table
802
Identify a serialized abstract query plan for the database query in a persistency layer
804
Deserialize the serialized abstract query plan to create an abstract query plan
806
Convert the abstract query plan into a converted query optimizer tree
808
Invoke a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree
810
Determine whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree
812
In response to determining that at least one first filter string does not match the corresponding second filter string, trigger query plan compilation for the database query
814
In response to determining that each filter string matches each corresponding second filter string:
816
generating a query plan based on the converted query optimizer tree
818
executing the database query using the query plan generated based on the converted query optimizer tree
820

FIG. 8 800

PERSISTING DATABASE QUERY PLANS THAT INCLUDE DYNAMIC CONDITIONS

TECHNICAL FIELD

The present disclosure relates to computer-implemented methods, software, and systems for managing database query plans for queries that include dynamic conditions.

BACKGROUND

A database query plan includes a sequence of steps for executing a query. Different query plans can be created for a same query. The different query plans can be evaluated and a query plan that is predicted to achieve a best performance can be selected for execution of the query.

SUMMARY

The present disclosure involves systems, software, and computer implemented methods for managing query plans for queries that include dynamic conditions. An example method includes: receiving a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table; identifying a serialized abstract query plan for the database query in a persistency layer, wherein the serialized abstract query plan is a persisted and serialized query plan for the database query; deserializing the serialized abstract query plan to create an abstract query plan; converting the abstract query plan into a converted query optimizer tree; invoking a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree; determining whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree; in response to determining that at least one first filter string does not match the corresponding second filter string, triggering query plan compilation for the database query; and in response to determining that each filter string matches each corresponding second filter string: generating a query plan based on the converted query optimizer tree; and executing the database query using the query plan generated based on the converted query optimizer tree.

Implementations may include one or more of the following features.

The serialized abstract query plan can be identified after a database system restart. The serialized abstract query plan can be identified after a query plan for the database query has been evicted from a query plan cache. The abstract query plan can be generated from a first query plan produced during query plan compilation. The abstract query plan generated from the first query plan produced during query plan compilation can be serialized to produce the serialized abstract query plan. The serialized abstract query plan can be saved in the persistency layer. The serialized abstract query plan can be a JavaScript Object Notation representation of the abstract query plan. Query plan compilation can include: parsing the database query to generate a global query parse tree; converting the global query parse tree to a query compiler tree; and converting the query compiler tree to a query optimizer tree. Query plan compilation can include traversing the query optimizer tree to collect all view nodes that have a dynamic condition. Query plan compilation can include saving, in the query plan, dynamic condition information for collected view nodes. The condition provider database procedure can generate different first filter strings for different users.

While generally described as computer-implemented software embodied on tangible media that processes and transforms the respective data, some or all of the aspects may be computer-implemented methods or further included in respective systems or other devices for performing this described functionality. The details of these and other aspects and embodiments of the present disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating an example system for managing query plans for queries that include dynamic conditions.

FIG. **2** is a flowchart of an example method for adding caching support for query plans for queries that include dynamic conditions.

FIG. **3** is a flowchart of an example method for a capture phase of adding persistency support for query plans for queries that include dynamic conditions.

FIG. **4** is a flowchart of an example method for a replay phase of adding persistency support for query plans for queries that include dynamic conditions.

FIG. **5**A illustrates example database statements for creating a view protected by row level security.

FIG. **5**B illustrates example database statements for creating a permission table.

FIG. **5**C illustrates an example database statement for creating row level security by binding a protected database object and condition provider procedure.

FIG. **5**D illustrates an example query for which a filter predicate is applied during query execution.

FIG. **6**A illustrates an example query that can be executed to determine whether dynamic conditions have changed for a query as compared to dynamic conditions of a query retrieved from a query plan cache.

FIG. **6**B illustrates an example database statement that can be executed to update a permission table.

FIG. **7** is a flowchart of an example method for adding caching support for query plans for queries that include dynamic conditions.

FIG. **8** is a flowchart of an example method for adding persistency support for query plans for queries that include dynamic conditions.

DETAILED DESCRIPTION

Dynamic plan conditions can be used for row level access control on database objects in a database system. For example, while sales data for all regions may be included within one analytic view, a database can be configured so that regional sales managers only see the data for their region. Dynamic plan conditions can generate different filter strings for different users to access different portions of data in the same view.

However, some database systems may have limitations with regards to dynamic plan conditions. For instance, a database system as initially designed may not support caching of query plans that include dynamic conditions. As a result, a query plan with dynamic conditions cannot leverage the plan cache to avoid unnecessary query compilation, since the query would need to be compiled for each query execution rather than using precompiled information in the plan cache. Compiling the query for each execution can have a substantial negative effect on query performance as compared to queries that use the plan cache.

As another example, a database system that supports abstract query plans (e.g., abstract SQL (Structured Query Language) plans), might not, as initially designed, support abstract query plans that include dynamic plan conditions. An abstract query plan is a persisted and serialized query optimization plan that can be used to ensure stability of query performance plans so that query performance plans can be used to reduce query compilation even after a system restart. When a database system does not support abstract query plans with dynamic plan conditions, a query involving dynamic conditions cannot leverage an abstract query plan to reduce query compilation times, and therefore query performance can be negatively affected.

Different solutions can be used to solve the problems described above that can occur due to database limitations with respect to dynamic plan conditions. For example, a persistency solution can be used to add support to a database system for persisted query plans that involve dynamic conditions. As another example, a caching solution can be used to add support to a database system for caching query plans with dynamic conditions.

As an overview, the persistency solution for adding support for persisted query plans that include dynamic conditions can include activities in an abstract query plan capture phase and an abstract query plan replay phase. In the abstract query plan capture phase, dynamic conditions can be collected and saved as part of a query plan for each view upon filter injection during query compilation. An abstract query plan can be generated from the query plan before a query execution plan generation phase. The abstract query plan that includes dynamic conditions can be serialized (e.g., into a JSON (JavaScript Object Notation) representation) and the serialized abstract query plan can be stored in a persistency layer.

In the abstract query plan replay phase, an abstract query plan can be retrieved from the persistency layer and deserialized. Abstract query plan structure(s) in the deserialized data that include dynamic conditions can be converted to a query optimizer (QO) tree structure. A condition provider procedure can be invoked to generate a filter string from a permission table for each view in the converted QO tree. A comparison can be performed to determine whether a latest filter string of a query is the same as a filter string saved in dynamic conditions of the QO tree. If such a comparison returns a match, the system can determine that an abstract query plan replay succeeded and that an abstract query plan specific compilation shortcut can be used for the query, thus improving performance as compared to recompiling a query plan. If the comparison does not result in a match, the system can determine that the abstract query plan replay did not succeed and that a fallback procedure of query compilation for the query can be performed.

For the caching solution of adding support to a database system for caching query plans with dynamic conditions, dynamic conditions can be collected and normalized as unified filter strings for each view upon filter injection during query compilation. The collected dynamic conditions can be saved as part of respective cached query plans. When executing a generated query plan for a received query, a condition provider procedure can be invoked to generate a filter string from a permission table for each view. A comparison can be performed to determine whether a latest filter string of the query is the same as a filter string saved in a cached query plan. If the comparison returns a match, the cached query plan can be used, thus saving query plan recompilation. If the comparison does not return a match, the current query plan can be invalidated which can trigger query recompilation. The second solution thus provides a method to cache query plans for queries that include dynamic conditions so that the plan cache can be leveraged for such queries, which can avoid unnecessary query compilation and substantially improve query performance.

FIG. **1** is a block diagram illustrating an example system **100** for managing query plans for queries that include dynamic conditions. Specifically, the illustrated system **100** includes or is communicably coupled with a server **102**, a client device **104**, and a network **106**. Although shown separately, in some implementations, functionality of two or more systems or servers may be provided by a single system or server. In some implementations, the functionality of one illustrated system, server, or component may be provided by multiple systems, servers, or components, respectively.

A server **102** (e.g., a database server) includes a query engine **110**. The query engine **110** can process a received query **111** against database artifacts such as database tables **112**, database views **114**, etc. The query engine **110** can process queries based on requests received from an application/browser **116**, from internal server processes, or other types of requests. A query plan engine **118** of the query engine **110** can generate a query plan **120** based on the received query **111**. The query engine **110** can execute the query plan **120** to generate query results **124**. The query results **124** can be provided to a requestor who provided the received query **111**. The query plan **120** can be placed into a plan cache **126** so that the query plan **120** may be reused for processing other queries that are the same (or have a same form) as the received query **111**.

As described above, a database system, before implementation of the solutions described herein, might not support storing, in the plan cache **126**, queries that have dynamic conditions. A dynamic condition engine **128** (which can be part of the query plan engine **118** or can be a separate component) can provide support for caching query plans for queries that have dynamic conditions. When a first instance of a particular received query **111** that includes a dynamic condition is received, the plan cache **126** will not have an entry for the query. The dynamic condition engine **128** can perform a set of steps to add caching support for the query. Although these steps are described below as being performed by the dynamic condition engine **128**, some steps may be more generally performed by the query engine **110**.

As an example, the dynamic condition engine **128** can process the received query **111** by parsing, checking, and pre-processing the received query **111** which can result in generation of a global query parse tree **130**. The dynamic condition engine **128** can convert the global query parse tree **130** to a query compiler tree **132** and a query optimizer tree **134**. The dynamic condition engine **128** can traverse the query optimizer tree **134** and generate or identify a collection of view nodes **136** that have dynamic conditions.

The dynamic condition engine **128** can perform a set of steps for each view node in the collection of view nodes **136**. For example, the dynamic condition engine **128** can invoke a condition provider procedure **138** to generate a dynamic filter predicate string **140** from a permission table **142**. The permission table **142** is shown as separate from the database tables **112** for illustration purposes but may be included in the database tables **112**. The dynamic condition engine **128** can convert the dynamic filter predicate string **140** to a query optimizer predicate **144**. The dynamic condition engine **128** can inject the query optimizer predicate **144** into a corresponding view node in the query optimizer tree **134**. The dynamic condition engine **128** can normalize dynamic conditions as a unified filter string. The dynamic condition engine **128** (or more generally the query engine **110**) can perform other optimizations of the query optimizer tree **134**. The dynamic condition engine **128** (or more generally the query engine **110**) can generate the query plan **120** (e.g., based at least on the query optimizer tree **134**). The dynamic condition engine **128** can insert the query plan **120** into the plan cache **126**. The query engine **110** can execute the first instance of the received query **111** based on the query plan **120**.

For subsequent instances of the received query **111**, the dynamic condition engine **128** can perform a lookup for the query in the plan cache **126** and determine that a cache hit occurs, which can result in the dynamic condition engine **128** determining whether to use a cached query plan for the query. For instance, the dynamic condition engine **128** can validate a query plan **120** identified in the plan cache **126**. For instance, for each view for which dynamic conditions are saved in the query plan **120**, the dynamic condition engine **128** can invoke the condition provider procedure **138** to generate a latest filter string **145** from the permission table **142**. The dynamic condition engine **128** can determine whether the latest filter string **145** matches the filter string **140** previously saved in the query plan **120**. If the latest filter string **145** matches the filter string **140** previously saved in the query plan **120**, the query engine **110** can execute the query using the query plan **120** identified in the plan cache **126**. Accordingly, processing resources can be saved by using the cached query plan. If the latest filter string **145** does not match the filter string **140** previously saved in the query plan **120**, the query plan **120** can be invalidated and query recompilation can be triggered (and a new query plan **120** can be generated and used for the query).

When processing the received query **111** (e.g., for the first time), the dynamic condition engine **128** can also perform steps regarding adding persistency support for abstract query plans. The dynamic condition engine **128** may perform the persistency support steps separately from the caching support steps, or may perform some of the persistency support steps in conjunction with the caching support steps.

As mentioned above, the persistency support steps include steps for a capture phase and a reply phase. In the capture phase, the dynamic condition engine **128** can process the received query **111** by parsing, checking, and pre-processing the received query **111** to generate the global query parse tree **130** and convert the global query parse tree **130** to the query compiler tree **132** and the query optimizer tree **134**. The dynamic condition engine **128** can traverse the query optimizer tree **134** to generate the collection of view nodes **136** that have dynamic conditions. The dynamic condition engine **128** can, for each view node, inject dynamic conditions into the query optimizer tree **134** and save the dynamic conditions as part of the query plan **120**.

The dynamic condition engine **128** can generate an abstract query plan **146** from the query plan **120**. The dynamic condition engine **128** can serialize the abstract query plan **146**, such as by converting the abstract query plan **146** into a JSON (JavaScript Object Notation) format or another serialized format, to create a serialized abstract query plan **148**. The dynamic condition engine **128** can store the serialized abstract query plan **148** in a persistency layer **150**, as a stored serialized abstract query plan **152**. Additionally, the dynamic condition engine **128** can add an entry in a stored plan map **154** that maps the stored serialized abstract query plan **152** to the received query **111**.

The dynamic condition engine **128** (or more generally the query engine **110**) can generate the query plan **120** (e.g., based at least on the query optimizer tree **134**). The query engine **110** can execute the received query **111** based on the query plan **120**. As mentioned, the capture phase of the persistency solution can be performed at least partially in conjunction with the caching solution, so that the first instance of the received query **111** is executed after the query plan **120** is cached and after the serialized abstract query plan **148** is stored in the persistency layer **150**.

The server **102** can leverage the stored serialized abstract query plan **152**, such as after a system restart (which can result in clearing of memory **186** of the server **102**) and/or after a query plan **120** is evicted from the plan cache **126**. The query plan **120** may be evicted from the plan cache **126** due to capacity limitation of the plan cache **126**, for example.

For example, when another instance of the received query **111** is received, the dynamic condition engine **128** can process the received query **111** by parsing, checking, and pre-processing the received query **111** to generate the global query parse tree **130** and convert the global query parse tree **130** to the query compiler tree **132**. The dynamic condition engine **128** can look up the received query **111** in the stored plan map **154** to copy the stored serialized abstract query plan **152** into the serialized abstract query plan **148**. The dynamic condition engine **128** can deserialize the serialized abstract query plan **148** to obtain the abstract query plan **146**. The dynamic condition engine **128** can convert the abstract query plan **146**, including dynamic conditions, to the query optimizer tree **134**.

The dynamic condition engine **128** can invoke the condition provider procedure **138** to generate a latest filter string **145** from the permission table **142** for each view in the query optimizer tree **134**. The dynamic condition engine **128** can determine, for each view, whether the latest filter string **145** for the view matches a filter string saved in dynamic conditions of the view in the query optimizer tree **134**. If each comparison for views of the received query **111** results in a match, the dynamic condition engine **128** can determine to perform a shortcut by using the query optimizer tree **134** converted from the abstract query plan **146**. For example, the dynamic condition engine **128** can generate the query plan **120** based on the converted query optimizer tree **134** and execute the received query **111** using the query plan **120**.

As another example, if the dynamic condition engine **128** determines, for at least one view, that the latest filter string **145** for the view does not match a filter string saved in dynamic conditions of the view in the query optimizer tree **134**, that the abstract query plan shortcut cannot be performed and that a fallback to standard query compilation should be performed. For example, the dynamic condition engine **128** can generate a new version of the query optimizer tree **134** from the current version of the query compiler tree **132**. The dynamic condition engine **128** can traverse the query optimizer tree **134** and generate or identify a collection of view nodes **136** that have dynamic conditions.

The dynamic condition engine **128** can inject dynamic conditions into a corresponding view node in the query optimizer tree **134**. The dynamic condition engine **128** (or more generally the query engine **110**) can perform other optimizations of the query optimizer tree **134**, as part of query compilation. The dynamic condition engine **128** (or more generally the query engine **110**) can generate the query plan **120** (e.g., based at least on the query optimizer tree **134**). The query engine **110** can execute the first instance of the received query **111** based on the query plan **120**. The dynamic condition engine **128** can also insert the query plan **120** into the plan cache **126**, as described above.

As used in the present disclosure, the term "computer" is intended to encompass any suitable processing device. For example, although FIG. **1** illustrates a single server **102**, and a single client device **104**, the system **100** can be implemented using a single, stand-alone computing device, two or more servers **102**, or two or more client devices **104**. Indeed, the server **102** and the client device **104** may be any computer or processing device such as, for example, a blade server, general-purpose personal computer (PC), Mac®, workstation, UNIX-based workstation, or any other suitable device. In other words, the present disclosure contemplates computers other than general purpose computers, as well as computers without conventional operating systems. Further, the server **102** and the client device **104** may be adapted to execute any operating system, including Linux, UNIX, Windows, Mac OS®, Java™, Android™, iOS or any other suitable operating system. According to one implementation, the server **102** may also include or be communicably coupled with an e-mail server, a Web server, a caching server, a streaming data server, and/or other suitable server.

Interfaces **180** and **182** are used by the client device **104** and the server **102**, respectively, for communicating with other systems in a distributed environment—including within the system **100**—connected to the network **106**. Generally, the interfaces **180** and **182** each comprise logic encoded in software and/or hardware in a suitable combination and operable to communicate with the network **106**. More specifically, the interfaces **180** and **182** may each comprise software supporting one or more communication protocols associated with communications such that the network **106** or interface's hardware is operable to communicate physical signals within and outside of the illustrated system **100**.

The server **102** includes one or more processors **184**. Each processor **184** may be a central processing unit (CPU), a blade, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or another suitable component. Generally, each processor **184** executes instructions and manipulates data to perform the operations of the server **102**. Specifically, each processor **184** executes the functionality required to receive and respond to requests from the client device **104**, for example.

Regardless of the particular implementation, "software" may include computer-readable instructions, firmware, wired and/or programmed hardware, or any combination thereof on a tangible medium (transitory or non-transitory, as appropriate) operable when executed to perform at least the processes and operations described herein. Indeed, each software component may be fully or partially written or described in any appropriate computer language including C, C++, Java™, JavaScript®, Visual Basic, assembler, Perl®, any suitable version of 4GL, as well as others. While portions of the software illustrated in FIG. **1** are shown as individual modules that implement the various features and functionality through various objects, methods, or other processes, the software may instead include a number of sub-modules, third-party services, components, libraries, and such, as appropriate. Conversely, the features and functionality of various components can be combined into single components as appropriate.

The server **102** includes memory **186**. In some implementations, the server **102** includes multiple memories. The memory **186** may include any type of memory or database module and may take the form of volatile and/or non-volatile memory including, without limitation, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), removable media, or any other suitable local or remote memory component. The memory **186** may store various objects or data, including caches, classes, frameworks, applications, backup data, business objects, jobs, web pages, web page templates, database tables, database queries, repositories storing business and/or dynamic information, and any other appropriate information including any parameters, variables, algorithms, instructions, rules, constraints, or references thereto associated with the purposes of the server **102**.

The client device **104** may generally be any computing device operable to connect to or communicate with the server **102** via the network **106** using a wireline or wireless connection. In general, the client device **104** comprises an electronic computer device operable to receive, transmit, process, and store any appropriate data associated with the system **100** of FIG. **1**. The client device **104** can include one or more client applications, including the application/browser **116**. A client application is any type of application that allows the client device **104** to request and view content on the client device **104**. In some implementations, a client application can use parameters, metadata, and other information received at launch to access a particular set of data from the server **102**. In some instances, a client application may be an agent or client-side version of the one or more enterprise applications running on an enterprise server (not shown).

The client device **104** further includes one or more processors **188**. Each processor **188** included in the client device **104** may be a central processing unit (CPU), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or another suitable component. Generally, each processor **188** included in the client device **104** executes instructions and manipulates data to perform the operations of the client device **104**. Specifically, each processor **188** included in the client device **104** executes the functionality required to send requests to the server **102** and to receive and process responses from the server **102**.

The client device **104** is generally intended to encompass any client computing device such as a laptop/notebook computer, wireless data port, smart phone, personal data assistant (PDA), tablet computing device, one or more processors within these devices, or any other suitable processing device. For example, the client device **104** may comprise a computer that includes an input device, such as a keypad, touch screen, or other device that can accept user information, and an output device that conveys information associated with the operation of the server **102**, or the client device **104** itself, including digital data, visual information, or a GUI **190**.

The GUI **190** of the client device **104** interfaces with at least a portion of the system **100** for any suitable purpose, including generating a visual representation of the application/browser **116**. In particular, the GUI **190** may be used to view and navigate various Web pages, or other user interfaces. Generally, the GUI **190** provides the user with an efficient and user-friendly presentation of business data provided by or communicated within the system. The GUI **190** may comprise a plurality of customizable frames or views having interactive fields, pull-down lists, and buttons operated by the user. The GUI **190** contemplates any suitable graphical user interface, such as a combination of a generic web browser, intelligent engine, and command line interface (CLI) that processes information and efficiently presents the results to the user visually.

Memory **192** included in the client device **104** may include any memory or database module and may take the form of volatile or non-volatile memory including, without limitation, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), removable media, or any other suitable local or remote memory component. The memory **192** may store various objects or data, including user selections, caches, classes, frameworks, applications, backup data, business objects, jobs, web pages, web page templates, database tables, repositories storing business and/or dynamic information, and any other appropriate information including any parameters, variables, algorithms, instructions, rules, constraints, or references thereto associated with the purposes of the client device **104**.

There may be any number of client devices **104** associated with, or external to, the system **100**. For example, while the illustrated system **100** includes one client device **104**, alternative implementations of the system **100** may include multiple client devices **104** communicably coupled to the server **102** and/or the network **106**, or any other number suitable to the purposes of the system **100**. Additionally, there may also be one or more additional client devices **104** external to the illustrated portion of system **100** that are capable of interacting with the system **100** via the network **106**. Further, the term "client", "client device" and "user" may be used interchangeably as appropriate without departing from the scope of this disclosure. Moreover, while the client device **104** is described in terms of being used by a single user, this disclosure contemplates that many users may use one computer, or that one user may use multiple computers.

FIG. **2** is a flowchart of an example method **200** for adding caching support for query plans for queries that include dynamic conditions.

At **202**, a query is identified.

At **204**, a lookup is performed to attempt to locate a cached query plan for the query in a plan cache.

At **206**, a determination is made as to whether a cache hit has occurred (e.g., whether the attempt to locate a cached query plan for the query in the plan cache was successful).

At **208**, if a cache hit has occurred, the query plan retrieved from the cache is validated.

At **210**, for each view whose dynamic conditions are saved in the query plan, a condition provider procedure is invoked to generate a latest filter string from a permission table.

At **212**, a determination is made, for each view whose dynamic conditions are saved in the query plan, whether the latest filter string from the permission table matches a filter string previously saved in the query plan.

At **214**, if, for each view, the latest filter string matches a filter string stored in the query plan, the query is executed using the query plan.

At **216**, if at least one latest filter string does not match a filter string previously saved in the query plan, the query plan is invalidated and query recompilation is triggered.

At **218**, the query is parsed, checked, and preprocessed to generate a global query parse tree.

At **220**, the global query parse tree is converted to a query compiler (QC) tree and a query optimizer (QO) tree.

At **222**, the query optimizer tree is traversed to collect all view nodes that have dynamic conditions.

At **224**, a given collected view node to process is identified.

At **226**, a condition provider procedure is invoked to generate a dynamic filter predicate string from the permission table.

At **228**, the dynamic filter predicate string is converted to a QO predicate.

At **230**, the QO predicate is injected into the view node in the QO tree.

At **232**, a determination is made as to whether there are any more collected view nodes to process. If there is at least one more collected view node to process, a next collected view node to process is identified (e.g., at step **224**).

At **234**, when there are no more collected view nodes to process, further optimizations of the QO tree may be performed.

At **236**, a query execution plan is generated for the query (e.g., based on the QO tree).

At **238**, the query execution plan is inserted into the query plan cache (e.g., for use by subsequent executions of the query). The query can then be executed (e.g., at step **214**) based on the query execution plan.

FIG. **3** is a flowchart of an example method **300** for a capture phase of adding persistency support for query plans for queries that include dynamic conditions.

At **301**, a query is identified.

At **302**, the query is parsed, checked, and preprocessed to generate a global query parse tree.

At **304**, the global query parse tree is converted to a query compiler (QC) tree and a query optimizer (QO) tree.

At **306**, the query optimizer tree is traversed to collect all view nodes that have dynamic conditions.

At **308**, for each collected view node, dynamic conditions are injected into the query optimizer tree and saved as part of a query plan.

At **310**, further optimizations of the query optimizer tree are performed.

At **312**, an abstract SQL plan (e.g., ASP, or abstract query plan) is generated from the query plan.

At **314** the ASP including dynamic conditions is serialized (e.g., into a JSON representation).

At **316**, the serialized ASP is stored in a persistency layer.

At **318**, a query execution plan is generated for the query (e.g., based on the QO tree).

At **320**, the query is executed based on the query execution plan.

FIG. **4** is a flowchart of an example method **400** for a replay phase of adding persistency support for query plans for queries that include dynamic conditions.

At **401**, a query is identified.

At **402**, the query is parsed, checked, and preprocessed to generate a global query parse tree.

At **404**, the global query parse tree is converted to a query compiler (QC) tree.

At **406**, a look up in a stored plan map is performed to locate an ASP entry for the query.

At **408**, an ASP structure is obtained from the stored plan map by deserializing a JSON representation in the located ASP entry.

At **410**, the ASP structure, including dynamic conditions in the ASP structure, is converted into a Query Optimizer (QO) tree.

At **412**, a condition provider procedure is invoked to generate a filter string from a permission table for each view in the converted QO tree.

At **414**, for each view in the converted QO tree, a determination is made as to whether a latest filter string is the same filter string as a filter string saved in dynamic conditions in the QO tree.

At **416**, if the result of the comparison in step **414** is yes, an ASP specific query optimization shortcut is performed by using the obtained ASP during query optimization.

At **418**, if the result of the comparison in step **414** is no, the QC tree is converted into a query optimizer (QO) tree.

At **420**, the query optimizer tree is traversed to collect all view nodes that have dynamic conditions.

At **422**, for each collected view node, dynamic conditions are injected into the query optimizer tree and saved as part of a query plan.

At **424**, further optimizations of the query optimizer tree are performed.

At **426** (e.g., either arriving at step **426** after step **424** or after step **416**), a query execution plan is generated.

At **428**, the query is executed based on the query execution plan.

FIG. **5**A illustrates example database statements **500** for creating a view protected by row level security. A statement **502** can be executed to create a table. Statements **504** can be executed to populate the table with values. A statement **506** can be executed to create, based on the table, a view that is protected by row level security (e.g., using a structured filter check). A statement **508** can be executed to create a schema for the view and table.

FIG. **5**B illustrates example database statements **530** for creating a permission table and condition provider procedure. A statement **532** can be executed to create the permission table. A statement **534** can be executed to insert values into the permission table. A statement **536** can be executed to create the condition provider procedure that can be used to generate filter strings from the permission table.

FIG. **5**C illustrates example an database statement **560** for creating row level security by binding a protected database object and condition provider procedure. The database statement **560** can be executed to bind the view created using the database statements **500** described above with respect to FIG. **5**A with the condition provider procedure created using the database statements **530** described above with respect to FIG. **5**B.

FIG. **5**D illustrates an example query **580** for which a filter predicate is applied during query execution. When the query **580** is executed, for example, a filter predicate of ""year_key"='2006'" can be retrieved from the permission table (e.g., based on the configurations achieved from execution of the example database statements **500**, **530**, and **560**) and applied to the execution of the example query **580**. The query **580** is an example of a query for which query plan caching support and/or abstract query plan persistency can be performed, for example, as described herein.

FIG. **6**A illustrates an example query **600** that can be executed to determine whether dynamic conditions have changed for a query as compared to dynamic conditions of a query retrieved from a query plan cache. The example query **600** can correspond to step **212** of FIG. **2**, for example.

FIG. **6**B illustrates an example database statement **650** that can be executed to update a permission table. The example database statement **650** can be executed, for example, when dynamic conditions have changed for a query as compared to dynamic conditions of a query retrieved from a query plan cache. In response to dynamic condition changes, the cached query plan can be invalidated, a query compiler can recompile the query which can include execution of the database statement **650** for changing a dynamic filter predicate string by updating the permission table.

FIG. **7** is a flowchart of an example method for adding caching support for query plans for queries that include dynamic conditions. It will be understood that method **700** and related methods may be performed, for example, by any suitable system, environment, software, and hardware, or a combination of systems, environments, software, and hardware, as appropriate. For example, one or more of a client, a server, or other computing device can be used to execute method **700** and related methods and obtain any data from the memory of a client, the server, or the other computing device. In some implementations, the method **700** and related methods are executed by one or more components of the system **100** described above with respect to FIG. **1**. For example, the method **700** and related methods can be executed by the dynamic condition engine **127** of FIG. **1**.

At **702**, a request is received to process a database query for at least one view based on at least one dynamic condition specified in a permission table.

At **704**, a determination is made as to whether a query plan cache includes a cached query plan for the database query.

At **706**, in response to determining that the query plan cache does not include a cached query plan for the database query, query plan compilation is triggered for the database query to generate a query plan for the database query. The database query can be executed using the generated query plan after query plan compilation. The query plan can be inserted into the query plan cache after query plan compilation.

Query plan compilation for a query based on dynamic conditions can include parsing the database query to generate a global query parse tree, converting the global query parse tree to a query compiler tree, and converting the query compiler tree to a query optimizer tree. Query plan compilation can also include traversing the query optimizer tree to collect all view nodes that have a dynamic condition and saving, in the query plan, dynamic condition information for collected view nodes. Saving dynamic condition information for a first collected view node can include invoking the condition provider database procedure to generate a dynamic filter predicate string from the permission table, converting the dynamic filter predicate string to a query optimizer predicate, injecting the query optimizer predicate in the first collected view node in the query optimizer tree, normalizing a dynamic condition of the first collected view node as a unified filter string, and saving the unified filter string for the dynamic condition of the first collected view node in the query plan.

At **708**, in response to determining that the query plan cache includes a cached query plan for the database query, various operations are performed, as described below for steps **710**, **712**, **714**, and **716**.

At **710**, for each view of the at least one view, a condition provider database procedure is invoked to generate a first filter string from the permission table. The condition provider database procedure can generate different first filter string for different users.

At **712**, a determination is made as to whether each first filter string matches a corresponding second filter string in the cached query plan.

At **714**, in response to determining that at least one first filter string does not match the corresponding second filter string in the cached query plan, query plan compilation is triggered for the database query.

At **716**, in response to determining that each filter string matches each corresponding second filter string in the cached query plan, the database query is executed using the cached query plan.

FIG. **8** is a flowchart of an example method for adding persistency support for query plans for queries that include dynamic conditions. It will be understood that method **800** and related methods may be performed, for example, by any suitable system, environment, software, and hardware, or a combination of systems, environments, software, and hardware, as appropriate. For example, one or more of a client, a server, or other computing device can be used to execute method **800** and related methods and obtain any data from the memory of a client, the server, or the other computing device. In some implementations, the method **800** and related methods are executed by one or more components of the system **100** described above with respect to FIG. **1**. For example, the method **800** and related methods can be executed by the dynamic condition engine **128** of FIG. **1**.

At **802**, a request is received to process a database query for at least one view based on at least one dynamic condition specified in a permission table.

At **804**, a serialized abstract query plan for the database query is identified in a persistency layer. The serialized abstract query plan is a persisted and serialized query plan for the database query. The serialized abstract query plan can be identified after a database system restart or after a query plan for the database query has been evicted from a query plan cache. The abstract query plan may have been generated from a first query plan produced during query plan compilation. The serialized abstract query plan can be a JavaScript Object Notation or other type of representation of the abstract query plan.

At **806**, the serialized abstract query plan is deserialized to create an abstract query plan.

At **808**, the abstract query plan is converted into a converted query optimizer tree.

At **810**, a condition provider database procedure is invoked to generate a first filter string from the permission table for each view in the converted query optimizer tree. The condition provider database procedure can generate different first filter strings for different users.

At **812**, a determination is made as to whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree.

At **814**, in response to determining that at least one first filter string does not match the corresponding second filter string, query plan compilation is triggered for the database query. Query plan compilation for a query based on dynamic conditions can include: parsing the database query to generate a global query parse tree; converting the global query parse tree to a query compiler tree; and converting the query compiler tree to a query optimizer tree. Query plan compilation can also include traversing the query optimizer tree to collect all view nodes that have a dynamic condition and saving in the query plan, dynamic condition information for collected view nodes.

At **816**, in response to determining that each filter string matches each corresponding second filter string, steps **818** and **820** are executed.

At **818**, a query plan based is generated based on the converted query optimizer tree.

At **820**, the database query is executed using the query plan generated based on the converted query optimizer tree.

The preceding figures and accompanying description illustrate example processes and computer-implementable techniques. But system **100** (or its software or other components) contemplates using, implementing, or executing any suitable technique for performing these and other tasks. It will be understood that these processes are for illustration purposes only and that the described or similar techniques

may be performed at any appropriate time, including concurrently, individually, or in combination. In addition, many of the operations in these processes may take place simultaneously, concurrently, and/or in different orders than as shown. Moreover, system **100** may use processes with additional operations, fewer operations, and/or different operations, so long as the methods remain appropriate.

In other words, although this disclosure has been described in terms of certain embodiments and generally associated methods, alterations and permutations of these embodiments and methods will be apparent to those skilled in the art. Accordingly, the above description of example embodiments does not define or constrain this disclosure. Other changes, substitutions, and alterations are also possible without departing from the spirit and scope of this disclosure.

What is claimed is:

1. A computer-implemented method comprising:

receiving a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table;

identifying a serialized abstract query plan for the database query in a persistency layer, wherein the serialized abstract query plan is a persisted and serialized query plan for the database query;

deserializing the serialized abstract query plan to create an abstract query plan;

converting the abstract query plan into a converted query optimizer tree;

invoking a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree;

determining whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree;

in response to determining that at least one first filter string does not match the corresponding second filter string, triggering query plan compilation for the database query; and

in response to determining that each filter string matches each corresponding second filter string:

generating a query plan based on the converted query optimizer tree; and

executing the database query using the query plan generated based on the converted query optimizer tree.

2. The computer-implemented method of claim **1**, wherein the serialized abstract query plan is identified after a database system restart.

3. The computer-implemented method of claim **1**, wherein the serialized abstract query plan is identified after a query plan for the database query has been evicted from a query plan cache.

4. The computer-implemented method of claim **1**, wherein the abstract query plan is generated from a first query plan produced during query plan compilation.

5. The computer-implemented method of claim **4**, wherein the abstract query plan generated from the first query plan produced during query plan compilation is serialized to produce the serialized abstract query plan.

6. The computer-implemented method of claim **1**, further comprising saving the serialized abstract query plan in the persistency layer.

7. The computer-implemented method of claim **6**, wherein the serialized abstract query plan comprises a JavaScript Object Notation representation of the abstract query plan.

8. The computer-implemented method of claim **1**, wherein query plan compilation comprises:

parsing the database query to generate a global query parse tree;

converting the global query parse tree to a query compiler tree; and

converting the query compiler tree to a query optimizer tree.

9. The computer-implemented method of claim **8**, wherein query plan compilation comprises traversing the query optimizer tree to collect all view nodes that have a dynamic condition.

10. The computer-implemented method of claim **9**, wherein query plan compilation comprises saving, in the query plan, dynamic condition information for collected view nodes.

11. The computer-implemented method of claim **1**, wherein the condition provider database procedure generates different first filter strings for different users.

12. A system comprising:

one or more computers; and

a computer-readable medium coupled to the one or more computers having instructions stored thereon which, when executed by the one or more computers, cause the one or more computers to perform operations comprising:

receiving a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table;

identifying a serialized abstract query plan for the database query in a persistency layer, wherein the serialized abstract query plan is a persisted and serialized query plan for the database query;

deserializing the serialized abstract query plan to create an abstract query plan;

converting the abstract query plan into a converted query optimizer tree;

invoking a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree;

determining whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree;

in response to determining that at least one first filter string does not match the corresponding second filter string, triggering query plan compilation for the database query; and

in response to determining that each filter string matches each corresponding second filter string:

generating a query plan based on the converted query optimizer tree; and

executing the database query using the query plan generated based on the converted query optimizer tree.

13. The system of claim **12**, wherein the serialized abstract query plan is identified after a database system restart.

14. The system of claim **12**, wherein the serialized abstract query plan is identified after a query plan for the database query has been evicted from a query plan cache.

15. The system of claim **12**, wherein the abstract query plan is generated from a first query plan produced during query plan compilation.

16. The system of claim **15**, wherein the abstract query plan generated from the first query plan produced during query plan compilation is serialized to produce the serialized abstract query plan.

17. A computer program product encoded on a non-transitory storage medium, the product comprising non-transitory, computer readable instructions for causing one or more processors to perform operations comprising:

receiving a request to process a database query for at least one view based on at least one dynamic condition specified in a permission table;

identifying a serialized abstract query plan for the database query in a persistency layer, wherein the serialized abstract query plan is a persisted and serialized query plan for the database query;

deserializing the serialized abstract query plan to create an abstract query plan;

converting the abstract query plan into a converted query optimizer tree;

invoking a condition provider database procedure to generate a first filter string from the permission table for each view in the converted query optimizer tree;

determining whether each first filter string matches a corresponding second filter string stored in a view node of the converted query optimizer tree;

in response to determining that at least one first filter string does not match the corresponding second filter string, triggering query plan compilation for the database query; and

in response to determining that each filter string matches each corresponding second filter string:

generating a query plan based on the converted query optimizer tree; and

executing the database query using the query plan generated based on the converted query optimizer tree.

18. The computer program product of claim **17**, wherein the serialized abstract query plan is identified after a database system restart.

19. The computer program product of claim **17**, wherein the serialized abstract query plan is identified after a query plan for the database query has been evicted from a query plan cache.

20. The computer program product of claim **17**, wherein the abstract query plan is generated from a first query plan produced during query plan compilation.

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