Information Management

IBM

Data Management

Optimizing Applications Using Extended Explain Tables

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Agenda

- Primary cause of access path problems
- DSN_PREDICAT_TABLE structure
- Populating DSN_PREDICAT_TABLE
- Tuning opportunities

Primary Cause of Access Path Problems

- **Inaccurate selectivity estimates** due to ...
  - Lack of statistics
  - Difficult to estimate predicates
  - Host variables / parameter markers with …
    - Range predicates
    - Skewed columns

Access Path Instability

- Is the access path for your SQL obvious?
  - Is the optimizer able to apply the filtering early?
  - Are there indexes that support an efficient path?
  - Do statistics allow distinction between the choices?

- If no……
  - You're more likely to have performance regressions
    - From minor changes in statistics
    - At release or maintenance upgrade times

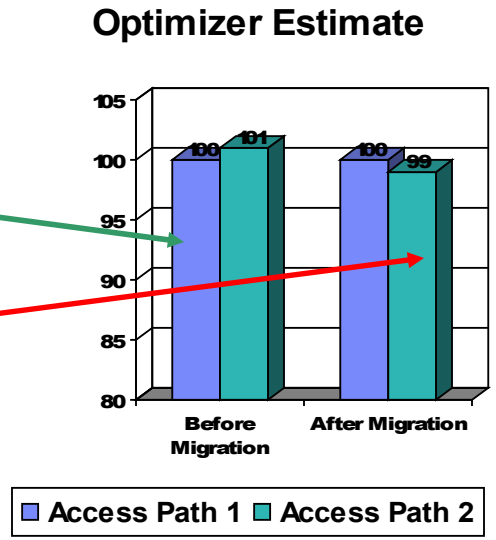
Why can performance fluctuate?

- When access path costs do not reflect reality
  - Eg. Actual performance of 2 access paths
    - Access path 1 = 100 msec
    - Access path 2 = 1 min

Best performing

600 X slower

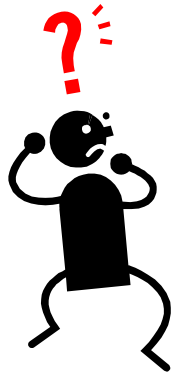
  - Before
    - Access path 1 wins
      - → Estimate 100msec vs 101msec
  - After migration/maint etc.
    - Access path 2 wins
      - → Estimate 100msec vs 99msec



The problem?

- After Rebind
  - Access path 2 cost improved from 101 to 99 msec
    - But reality is 1 min (approx 600X greater)

- Should the focus be on:
  - What caused the cost to change from 101 to 99?
  - OR, why the cost isn't closer to 1 min?



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  - Lack of statistics
  - Difficult to estimate predicates
  - Host variables / parameter markers with …
    - Range predicates
    - Skewed columns

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Example DSN_PREDICAT_TABLE content

- Query

```
SELECT SUM(L_EXTENDEDPRICE*L_DISCOUNT) AS REVENUE
  FROM LINEITEM
 WHERE L_SHIPDATE >= DATE('1994-01-01')
   AND L_SHIPDATE <  DATE('1994-01-01') + 1 YEAR
   AND L_DISCOUNT BETWEEN 0.06-0.01 AND 0.06+0.01
   AND L_QUANTITY < 24
```

- DSN_PREDICAT_TABLE Contents

	PREDNO	TYPE	LEFT_HAND_SIDE	LHS_TABNO	LHS_QBNO	RIGHT_HAND_SIDE	RHS_TABNO	RHS_QBNO
1_	1	AND		0	0		0	0
2_	2	RANGE	L_SHIPDATE	1	1	VALUE	0	0
3_	3	RANGE	L_SHIPDATE	1	1	VALUE	0	0
4_	4	BETWEEN	L_DISCOUNT	1	1	NONCOLEXP	0	0
5_	5	RANGE	L_QUANTITY	1	1	VALUE	0	0

	FILTER_FACTOR	TEXT
1_	1.000000000000000E+00	(((TPCD30G.LINEITEM.L_SHIPDATE>='1994-01-01' AND TPCD30G.LINEITEM.L_SHIPDATE<'19
2_	7.211780548095703E-01	TPCD30G.LINEITEM.L_SHIPDATE>='1994-01-01'
3_	4.305213093757629E-01	TPCD30G.LINEITEM.L_SHIPDATE<'1995-01-01'
4_	9.999996423721313E-02	TPCD30G.LINEITEM.L_DISCOUNT BETWEEN CAST((0.06-0.01) AS FLOAT(0,8)) AND CAST((
5_	4.799535274505615E-01	TPCD30G.LINEITEM.L_QUANTITY<24

DSN_PREDICAT_TABLE

- Contains information about each predicate
  - One row for each atomic predicate
  - One row for each AND/OR tree
- View into optimizer's selectivity estimates
  - Can be used to determine how likely it is that optimizer's estimates are incorrect

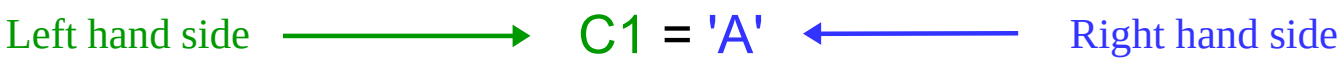
DSN_PREDICAT_TABLE Columns

- The predicate table correlates to the plan table
  - QUERYNO
  - QBLOCKNO
  - APPLNAME
  - PROGNAME
  - COLLID*
  - VERSION*
  - SECTNOI*
  - EXPLAIN_TIME (PLAN_TABLE.BIND_TIME)
- Unique identifier of a predicate within a query
  - PREDNO

*Added in DB2 10

DSN_PREDICAT_TABLE Columns

- Predicate Structure
  - Optimizer tracks the left hand side (LHS) and the right hand side (RHS) of a predicate



  - Optimizer may decide to swap sides from what was originally coded in the query

Column Name	Meaning
LHS_QBNO	Query block of LHS
LHS_TABNO	Table number of LHS
RHS_QBNO	Query block of RHS
RHS_TABNO	Table number of RHS

  - QBNO fields match PLAN_TABLE.QBLOCKNO
  - TABNO fields match PLAN_TABLE.TABNO

DSN_PREDICAT_TABLE Columns

- Predicate Structure

Column Name	Meaning
LEFT_HAND_SIDE	Column name or description of LHS
RIGHT_HAND_SIDE	Column name or description of RHS

  - Descriptions of LHS/RHS when not a column
    - VALUE
      - Literal value
    - COLEXP
      - Column expression
    - NONCOLEXP
      - Non-column expression
    - CORSUB
      - Correlated subquery
    - NONCORSUB
      - Non-correlated subquery

DSN_PREDICAT_TABLE Columns

- Predicate Attributes

Column Name	Meaning
TYPE	Predicate type – One of... • AND • OR • EQUAL • RANGE • BETWEEN • IN • LIKE • NOT LIKE • EXISTS • NOTEXIST • SUBQUERY • HAVING • OTHERS
CLAUSE	SQL clause where the predicate appears – One of... • WHERE • ON • HAVING • SELECT

DSN_PREDICAT_TABLE Columns

- Predicate Attributes

Column Name	Meaning
FILTER_FACTOR	Estimated selectivity
BOOLEAN_TERM	Whether a false value indicates the entire WHERE clause is false
SEARCHARG	Y – Indicates the predicate can be processed by DM (stage 1) N – Indicates the predicate must be handled by RDS (stage 2)
AFTER_JOIN	A – After join predicate D – During join predicate Blank - N/A
ADDED_PRED	Y – Predicate generated by predicate transitive closure
TEXT	Text of the predicate
MARKER	Y – Predicate has a host variable or parameter marker
PARENT_PNO	Parent predicate PREDNO
NEGATION	Y – The predicate is negated via NOT
LITERALS	The literal values used (separated by colons)

Example DSN_PREDICAT_TABLE content

- Query

```
SELECT SUM(L_EXTENDEDPRICE*L_DISCOUNT) AS REVENUE
  FROM LINEITEM
 WHERE L_SHIPDATE >= DATE('1994-01-01')
   AND L_SHIPDATE <  DATE('1994-01-01') + 1 YEAR
   AND L_DISCOUNT BETWEEN 0.06-0.01 AND 0.06+0.01
   AND L_QUANTITY < 24
```

- DSN_PREDICAT_TABLE Contents

	PREDNO	TYPE	LEFT_HAND_SIDE	LHS_TABNO	LHS_QBNO	RIGHT_HAND_SIDE	RHS_TABNO	RHS_QBNO
1_	1	AND		0	0		0	0
2_	2	RANGE	L_SHIPDATE	1	1	VALUE	0	0
3_	3	RANGE	L_SHIPDATE	1	1	VALUE	0	0
4_	4	BETWEEN	L_DISCOUNT	1	1	NONCOLEXP	0	0
5_	5	RANGE	L_QUANTITY	1	1	VALUE	0	0

	FILTER_FACTOR	TEXT
1_	1.000000000000000E+00	(((TPCD30G.LINEITEM.L_SHIPDATE>='1994-01-01' AND TPCD30G.LINEITEM.L_SHIPDATE<'19
2_	7.211780548095703E-01	TPCD30G.LINEITEM.L_SHIPDATE>='1994-01-01'
3_	4.305213093757629E-01	TPCD30G.LINEITEM.L_SHIPDATE<'1995-01-01'
4_	9.999996423721313E-02	TPCD30G.LINEITEM.L_DISCOUNT BETWEEN CAST((0.06-0.01) AS FLOAT(0,8)) AND CAST((
5_	4.799535274505615E-01	TPCD30G.LINEITEM.L_QUANTITY<24

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- Populating DSN_PREDICAT_TABLE
- Tuning opportunities

Populating DSN_PREDICAT_TABLE

- All extended explain tables are populated during EXPLAIN
  - Table definitions must match the documented DDL
  - For most extended explain tables, no warnings or errors are generated. Problems result in no data.

- If no data is populated, most likely the DDL is incorrect.

Populating DSN_PREDICAT_TABLE

- Populate explain tables for an application
- Mine the data for application level actions
- Avoid tuning solely at the SQL level

Populating DSN_PREDICAT_TABLE

- Static SQL
  - Bind with EXPLAIN(YES) populates extended explain tables
  - Application use cases
    - REBIND a collection
    - REBIND with EXPLAIN(ONLY) (v10 only)
    - BIND into a new collection
      → Avoid impacting current access path choices

Populating DSN_PREDICAT_TABLE

- Dynamic SQL
  - Explain query populates extended explain tables
  - Application use case
    - Dynamic statement cache
      - → Needs an application or tool to populate explain tables
        - EXPLAIN STMTCACHE ALL
        - for each row in DSN_STATEMENT_CACHE_TABLE
          EXPLAIN <sql>
      - → Extended explain information is not saved in the cache so “EXPLAIN STMTCACHE STMTID xxx” will not populate extended explain tables

Agenda

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Tuning Opportunities

- Query rewrites
- Missing statistics 
- Identify potential indexes
- Queries at risk

Tuning Opportunities

- Query rewrites
  - SUBSTR(C1,1,1)='A'
    - Rewrite to C1 LIKE 'A%'
  - T1.C1 BETWEEN T2.C2 AND T2.C3
    - Rewrite to T1.C1 => T2.C2 AND T1.C1 <= T2.C3
  - DATE(TIMESTAMPCOL) = '2011-07-31'
    - Rewrite to
      TIMESTAMPCOL BETWEEN '2011-07-31-00.00.00.000000'
      AND '2011-07-31-23.59.59.999999'

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Convert SUBSTR to LIKE
  - Stage 2 to stage 1 indexable

```
SELECT P.QUERYNO
      ,P.APPLNAME
      ,SUBSTR(P.PROGNAME,1,18) PROGNAME
      ,SUBSTR(P.TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE P
WHERE P.LHS_TABNO = 0
  AND P.RHS_TABNO = 0
  AND P.LEFT_HAND_SIDE = 'COLEXP'
  AND P.RIGHT_HAND_SIDE = 'VALUE'
  AND P.TYPE = 'EQUAL'
  AND P.TEXT LIKE 'SUBSTR%'
  AND CASE
    WHEN POSSTR(P.TEXT,',')=0 THEN 0
    WHEN STRIP(SUBSTR(P.TEXT,POSSTR(P.TEXT,',')+1,1))='1' THEN 1
    ELSE 0
  END = 1
```

'Column expression = value' predicate

Equal predicate

SUBSTR starting at first character

*Note that this assumes the first comma is related to the SUBSTR function. Complex expressions may not be identified.

  - Rewrite SUBSTR(C1,1,1)='A' to C1 LIKE 'A%'
  - Simple application change that will improve performance even if no index is available/chosen
    - Stage 1 vs stage 2

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Convert BETWEEN on columns to 2 range predicates
  - Partially stage 2 to stage 1 indexable

```
SELECT P.QUERYNO
      ,P.APPLNAME
      ,SUBSTR(P.PROGNAME,1,18) PROGNAME
      ,SUBSTR(P.TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE P
WHERE P.TYPE = 'BETWEEN'
  AND P.RIGHT_HAND_SIDE = 'COLEXP'
```

Between predicate

RHS has a column

  - Rewrite C1 BETWEEN C2 AND C3 to C1 => C2 AND C1 <= C3
  - Simple application change that will improve performance even if no index is available/chosen
    - Stage 1 vs stage 2

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Convert predicates with DATE(TIMESTAMPCOL) to range predicates
  - Stage 2 to stage 1 indexable

```
SELECT P.QUERYNO
      ,P.APPLNAME
      ,SUBSTR(P.PROGNAME,1,18) PROGNAME
      ,SUBSTR(P.TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE P
WHERE P.LEFT_HAND_SIDE = 'COLEXP'
  AND P.TEXT LIKE 'DATE%'
```

Column expression on the LHS

DATE function

  - Rewrite DATE(TIMESTAMPCOL) = '2011-01-01' to TIMESTAMPCOL BETWEEN '2011-01-01-00.00.00.000000' AND '2011-01-01-23.59.59.999999'
  - Similar rewrites can be done for range predicates
  - Simple application change that will improve performance even if no index is available/chosen
    - Stage 1 vs stage 2

Tuning Opportunities

- Query rewrites
  - Queries with non-column expressions
    - 'Y' = ?
    - Push these into the application
  - Queries with trick predicates
    - Are these trick predicates still needed?
    - Are they solving a problem that only exists in an old version of DB2?
  - Queries with no stage 1 local predicates
  - Queries with cartesian joins

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Identify queries with non-column expressions
  - 'Y' = ?

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,SUBSTR(TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE
WHERE LEFT_HAND_SIDE IN ('VALUE','NONCOLEXP')
  AND RIGHT_HAND_SIDE IN ('VALUE','NONCOLEXP')
  AND LHS_TABNO = 0
  AND RHS_TABNO = 0
  AND LHS_QBNO = 0
  AND RHS_QBNO = 0
  AND CLAUSE <> 'HAVING'
  AND LITERALS = 'HV'
```

No columns referenced in the predicate

Predicate contains host variable or parameter marker

  - Push non-column expressions into the application

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Identify queries with trick predicates
  - 0>1
  - T1.C1 = T1.C1

0>1 part

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,SUBSTR(TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE
WHERE LEFT_HAND_SIDE IN ('VALUE','NONCOLEXP')
  AND RIGHT_HAND_SIDE IN ('VALUE','NONCOLEXP')
  AND LHS_TABNO = 0
  AND RHS_TABNO = 0
  AND LHS_QBNO = 0
  AND RHS_QBNO = 0
  AND CLAUSE <> 'HAVING'
  AND LITERALS <> 'HV'
UNION ALL
```

No columns referenced in the predicate

No host variable / parameter markers

T1.C1 = T1.C1 part

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,SUBSTR(TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE
WHERE LHS_QBNO <> 0
  AND LHS_TABNO <> 0
  AND LHS_QBNO = RHS_QBNO
  AND LHS_TABNO = RHS_TABNO
  AND LEFT_HAND_SIDE = RIGHT_HAND_SIDE
```

Column exists on LHS

LHS and RHS match

- Are these trick predicates still needed?
- Were they added to address a limitation in a previous release of DB2?

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Query blocks with no stage 1 local predicates

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18)
FROM (
  SELECT QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
        ,SUM(CASE WHEN SEARCHARG='Y' THEN 1
             ELSE 0 END) STAGE1_CNT
  FROM DSN_PREDICAT_TABLE
  GROUP BY QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
) A
WHERE A.STAGE1_CNT = 0
```

No stage 1 predicates

  - This condition is legitimate, but should likely be rare
    - Are there opportunities to rewrite these queries so that stage 1 predicates exist?
      → Opportunity could be application specific
  - Mining query could be modified to join to SYSTABLES and limit to only query blocks containing a large table

Mining DSN_PREDICAT_TABLE – Query Rewrites

- Query blocks containing cartesian joins

QBs w/ >1 tbl →

All tables w/join predicates →

```
WITH MULT_TBL (QUERYNO, QBLOCKNO, APPLNAME
               ,PROGNAME, EXPLAIN_TIME) AS (
  SELECT QUERYNO, QBLOCKNO, APPLNAME
        ,PROGNAME, BIND_TIME
  FROM (
    SELECT DISTINCT QUERYNO, QBLOCKNO, APPLNAME
      ,QBLOCKNO, APPLNAME, PROGNAME, BIND_TIME, TABNO
    FROM PLAN_TABLE
    WHERE TABNO <> 0
  ) A
  GROUP BY QUERYNO, QBLOCKNO, APPLNAME
          ,PROGNAME, BIND_TIME
  HAVING COUNT(*)>1
),PREDS (QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
        ,EXPLAIN_TIME, TABNO) AS (
   SELECT QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
         ,EXPLAIN_TIME, RHS_TABNO
   FROM DSN_PREDICAT_TABLE
   WHERE LHS_TABNO <> 0
   UNION
   SELECT QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
         ,EXPLAIN_TIME, LHS_TABNO
   FROM DSN_PREDICAT_TABLE
   WHERE RHS_TABNO <> 0
)
```

```
SELECT M.QUERYNO, M.QBLOCKNO, M.APPLNAME
      ,SUBSTR(M.PROGNAME,1,18) PROGNAME
      ,M.EXPLAIN_TIME
FROM MULT_TBL M
INNER JOIN PLAN_TABLE PL
  ON PL.QUERYNO = M.QUERYNO
 AND PL.QBLOCKNO = M.QBLOCKNO
 AND PL.APPLNAME = M.APPLNAME
 AND PL.PROGNAME = M.PROGNAME
 AND PL.BIND_TIME = M.EXPLAIN_TIME
LEFT OUTER JOIN PREDS P
  ON P.QUERYNO = M.QUERYNO
 AND P.QBLOCKNO = M.QBLOCKNO
 AND P.APPLNAME = M.APPLNAME
 AND P.PROGNAME = M.PROGNAME
 AND P.EXPLAIN_TIME = M.EXPLAIN_TIME
 AND P.TABNO = PL.TABNO
WHERE PL.TABNO <> 0
  AND P.QUERYNO IS NULL
```

No join predicates

- Identify queries with unexpected cartesian joins
- Mining query will miss join predicates on a column expression (i.e. T1.C1 = T2.C1 + 3)

Tuning Opportunities

- Missing statistics
  - Columns with no statistics
  - No frequency statistics on columns that are likely skewed
    - INACTIVE_IND = 'N'
    - ACTIVITY_CODE = 'A'
  - No histogram statistics for range predicates
    - EFF_DT > '2011-07-31'

Mining DSN_PREDICAT_TABLE – Missing Statistics

- Columns with no statistics

```
SELECT DISTINCT
       SUBSTR(C.TBCREATOR,1,18) TBCREATOR
      ,SUBSTR(C.TBNAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) NAME
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
WHERE P.LHS_TABNO <> 0
  AND C.COLCARDF < 0
UNION
```

```
SELECT DISTINCT
       SUBSTR(C.TBCREATOR,1,18) TBCREATOR
      ,SUBSTR(C.TBNAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) NAME
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.RHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.RIGHT_HAND_SIDE
WHERE P.RHS_TABNO <> 0
  AND C.COLCARDF < 0
ORDER BY 1,2,3
```

Identify columns on the LHS

Find columns with no statistics

Identify columns on the RHS

Union results from LHS and RHS of predicate

Mining DSN_PREDICAT_TABLE – Missing Statistics

- Missing frequency statistics

```
SELECT DISTINCT
       SUBSTR(C.TBCREATOR,1,18) TBCREATOR
      ,SUBSTR(C.TBNAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) NAME
      ,C.COLCARDF
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
```

```
WHERE P.LHS_TABNO <> 0
  AND P.RIGHT_HAND_SIDE = 'VALUE'
  AND C.COLCARDF < 100
  AND C.COLCARDF <> -1
  AND (P.MARKER = 'N'
    OR C.NULLS = 'Y')
  AND NOT EXISTS (
    SELECT 1
    FROM SYSIBM.SYSCOLDIST CD
    WHERE CD.TBOWNER = C.TBCREATOR
      AND CD.TBNAME = C.TBNAME
      AND CD.NAME = C.NAME
      AND CD.TYPE = 'F'
      AND CD.NUMCOLUMNS = 1
  )
ORDER BY 1,2,3
```

'COL op value' predicate

Low cardinality column

Need a nullable column
Or predicate w/o hv

No frequency statistics
collected yet

- Why low cardinality columns?
  - More opportunity for data skew
  - Experience shows many low cardinality columns are skewed
- Why nullable column or predicate without host variable?
  - Predicates with a host variable can only use a null frequency statistic
  - But what about REOPT?

Mining DSN_PREDICAT_TABLE – Missing Statistics

- Missing histogram statistics for range predicates

```
SELECT DISTINCT
       SUBSTR(C.TBCREATOR,1,18) TBCREATOR
      ,SUBSTR(C.TBNAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) NAME
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
```

```
WHERE P.LHS_TABNO <> 0
  AND P.RIGHT_HAND_SIDE = 'VALUE'
  AND P.TYPE IN ('RANGE',
      'BETWEEN','LIKE','NOT LIKE')
    AND (P.MARKER = 'N'
    OR C.NULLS = 'Y')
  AND NOT EXISTS (
    SELECT 1
    FROM SYSIBM.SYSCOLDIST CD
    WHERE CD.TBOWNER = C.TBCREATOR
      AND CD.TBNAME = C.TBNAME
      AND CD.NAME = C.NAME
      AND CD.TYPE = 'H'
      AND CD.NUMCOLUMNS = 1
  )
ORDER BY 1,2,3
```

'COL op value' predicate

Range, between or like predicate

Need a nullable column

Or predicate w/o hv

No histogram statistics collected yet

  - Again, what about REOPT?

Mining DSN_PREDICAT_TABLE – Missing Statistics

- Will these queries identify all missing statistics?
  - No, but they will identify common problems.
  - What else could be missing?
    - Correlation statistics (multi-column cardinality)
      - → Recommendation is to collect KEYCARD statistics on all indexes (default in DB2 10)
    - Histogram statistics for use outside range FF estimation
      - → Parallelism cutting
      - → Join FF estimation
    - Index statistics
      - → Easy to check – query SYSINDEXES
    - Multi-column frequency statistics

REOPT

- So, what about REOPT?
  - Optimizer cannot use frequency/histogram statistics (except NULL) with a host variable
  - This does not mean FF estimation with the host variable is accurate
    - Especially for range predicates with host variables
  - Determine if optimizer's estimated FF varies enough from the actual FF at runtime to require REOPT for a good, stable access path
    - If so, missing frequency/histogram statistics can be identified by...
      - → Removing the P.MARKER / C.NULLS predicates from earlier queries or...
      - → Adding a join to check if SYSPACKSTMT.STATUS = 'G'

REOPT

- So, what about REOPT?
  - Consider REOPT options and associated overhead
    - REOPT(ALWAYS)
      - → Likely not acceptable for transactional SQL
      - → Potentially a good choice for longer running SQL
    - REOPT(ONCE)
      - → Reduce the prepare impact
      - → First set of values could be unusual resulting in a sub-optimal cached path for future executions

Tuning Opportunities

- Identify potential indexes
  - Are there columns not indexed that...
    - Have high cardinality
    - Occur often in equal predicates
  - Are there predicates with a low filter factor on a column that is not indexed?

Mining DSN_PREDICAT_TABLE – Identify potential indexes

- Are there columns not indexed that...
  - Have high cardinality
  - Occur often in local equal predicates

```
SELECT SUBSTR(T.CREATOR,1,18) TBCREATOR
      ,SUBSTR(T.NAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) COLNAME
      ,C.COLCARDF / T.CARDF RATIO
      ,COUNT(*) AS CNT
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
INNER JOIN SYSIBM.SYSTABLES T
   ON T.CREATOR = PL.CREATOR
  AND T.NAME = PL.TNAME
WHERE P.LHS_TABNO <> 0
  AND P.RHS_TABNO = 0
  AND P.TYPE = 'EQUAL'
  AND P.SEARCHARG = 'Y'
  AND P.NEGATION = 'N'
  AND C.COLCARDF / T.CARDF > 0.2
  AND T.CARDF > 100
  AND NOT EXISTS (
     SELECT 1
     FROM SYSIBM.SYSINDEXES IX
     INNER JOIN SYSIBM.SYSKEYS K
        ON K.IXCREATOR = IX.CREATOR
       AND K.IXNAME = IX.NAME
     WHERE IX.TBCREATOR = PL.CREATOR
       AND IX.TBNAME = PL.TNAME
       AND K.COLNAME = P.LEFT_HAND_SIDE
  )
GROUP BY T.CREATOR, T.NAME, C.NAME
        ,T.CARDF, C.COLCARDF
HAVING COUNT(*) > 2
ORDER BY CNT DESC
```

Local indexable equal predicate

High column cardinality compared to table cardinality

No index exists on this column

Occurs “often”

- What about join predicates?
  - Same logic, just need to check LHS and RHS and remove RIGHT_HAND_SIDE = 'VALUE' predicate

Mining DSN_PREDICAT_TABLE – Identify potential indexes

- What about cases where an index exists, but cannot be matching?
  - Modify the NOT EXISTS predicate

```
AND NOT EXISTS (
   SELECT 1
   FROM SYSIBM.SYSINDEXES IX
   INNER JOIN SYSIBM.SYSKEYS K
      ON K.IXCREATOR = IX.CREATOR
     AND K.IXNAME = IX.NAME
   INNER JOIN TABLE(
      SELECT COUNT(*) AS CNT
            ,SUM(CASE WHEN A.CNT = A.NUM_IN THEN 1
                      ELSE 0 END) AS NUM_IN
      FROM (
         SELECT COUNT(*) AS CNT
               ,SUM(CASE WHEN P2.TYPE='IN' THEN 1
                         ELSE 0 END) AS NUM_IN
         FROM DSN_PREDICAT_TABLE P2
             ,SYSIBM.SYSKEYS K2
         WHERE K2.IXCREATOR = K.IXCREATOR
           AND K2.IXNAME = K.IXNAME
           AND P2.QUERYNO = P.QUERYNO
           AND P2.QBLOCKNO = P.QBLOCKNO
           AND P2.APPLNAME = P.APPLNAME
           AND P2.PROGNAME = P.PROGNAME
           AND P2.EXPLAIN_TIME = P.EXPLAIN_TIME
           AND K2.COLSEQ < K.COLSEQ
           AND ((P2.LHS_TABNO=PL.TABNO AND
                 K2.COLNAME=P2.LEFT_HAND_SIDE)
             OR (P2.RHS_TABNO=PL.TABNO AND
                 K2.COLNAME=P2.RIGHT_HAND_SIDE)
           )
           AND P2.TYPE IN ('EQUAL','IN')
           AND P2.SEARCHARG = 'Y'
           AND P2.NEGATION = 'N'
         GROUP BY K2.COLNO
      ) A
   ) PREV_KEYS
     ON K.COLSEQ = PREV_KEYS.CNT - 1
   WHERE IX.TBCREATOR = PL.CREATOR
     AND IX.TBNAME = PL.TNAME
     AND K.COLNAME = P.LEFT_HAND_SIDE
     AND PREV_KEYS.NUM_IN <= 1
```

Look for indexable predicates for previous keys that don't stop matching

All previous keys can match

No more than 1 IN predicate exists

Mining DSN_PREDICAT_TABLE – Identify potential indexes

- Are there columns not indexed that have a good filter factor

```
SELECT SUBSTR(T.CREATOR,1,18) TBCREATOR
      ,SUBSTR(T.NAME,1,18) TBNAME
      ,SUBSTR(C.NAME,1,18) COLNAME
      ,P.FILTER_FACTOR * T.CARDF QUAL_ROWS
      ,COUNT(*) AS CNT
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
INNER JOIN SYSIBM.SYSTABLES T
   ON T.CREATOR = PL.CREATOR
  AND T.NAME = PL.TNAME
WHERE P.LHS_TABNO <> 0
  AND P.RHS_TABNO = 0
  AND P.SEARCHARG = 'Y'
  AND P.NEGATION = 'N'
  AND P.FILTER_FACTOR * T.CARDF < 1000
  AND T.CARDF > 100
  AND NOT EXISTS (
     ...
  )
GROUP BY T.CREATOR, T.NAME, C.NAME
        ,T.CARDF, C.COLCARDF
HAVING COUNT(*) > 2
ORDER BY CNT DESC
```

Local indexable predicate

Less than 1000 rows expected to qualify

No matching index support

Occurs “often”

  - What if the filter factor is wrong?
    - Similar problem to comparing costs – estimates are only as good as inputs
      - → Are statistics up to date on this column?
      - → Is the filter factor a default?

Tuning Opportunities

- Queries at risk
  - Default filter factors
    - Range predicates with host variable / parameter marker
    - Column to column range predicates
    - Indexable range predicates with host variables / parameter markers
  - Data skew
    - Indexable predicates with host variables / parameter markers on skewed columns
  - Multiple risky index choices
    - More than one index choice on a range predicate with host variable / parameter marker
    - Some other combination of above

Mining DSN_PREDICAT_TABLE – Queries at risk

- Identify queries containing predicates with default filter factors
  - Range predicates with host variables / parameter markers

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,SUBSTR(LEFT_HAND_SIDE,1,18) COLNAME
      ,SUBSTR(TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE
WHERE LHS_TABNO <> 0
  AND TYPE IN ('RANGE','BETWEEN','LIKE')
  AND RHS_TABNO = 0
  AND MARKER = 'Y'
```

Local range predicate

Contains host variable / parameter marker

  - Limited usefulness across an entire workload since this is a common pattern
  - Among problem queries, could be a good indicator for REOPT consideration

  - This doesn't mean optimizer cannot pick a good path for these queries
  - This does mean that optimizer is depending on a default guess
    - More likely to see access path problems

Mining DSN_PREDICAT_TABLE – Queries at risk

- Identify queries containing column to column range predicates
  - C1 < C2

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,SUBSTR(TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE
WHERE LHS_TABNO <> 0
  AND RHS_TABNO <> 0
  AND TYPE IN ('RANGE','BETWEEN','LIKE')
```

Columns on both sides

Local range predicate

  - Histogram statistics on both sides can help
  - Design to avoid risky choices
    - Is there a clear choice access path?
    - Is there an index on this range predicate that might look attractive, but is not?

Mining DSN_PREDICAT_TABLE – Queries at risk

- Indexable local range predicates on indexed columns with default filter factors

```
SELECT DISTINCT
       P.QUERYNO
      ,P.QBLOCKNO
      ,P.APPLNAME
      ,SUBSTR(P.PROGNAME,1,18) PROGNAME
      ,SUBSTR(T.NAME,1,18) TBNAME
      ,SUBSTR(P.LEFT_HAND_SIDE,1,18) COLNAME
      ,SUBSTR(P.TEXT,1,100) TEXT
FROM DSN_PREDICAT_TABLE P
INNER JOIN PLAN_TABLE PL
   ON PL.QUERYNO = P.QUERYNO
  AND PL.QBLOCKNO = P.QBLOCKNO
  AND PL.APPLNAME = P.APPLNAME
  AND PL.PROGNAME = P.PROGNAME
  AND PL.BIND_TIME = P.EXPLAIN_TIME
  AND PL.TABNO = P.LHS_TABNO
INNER JOIN SYSIBM.SYSCOLUMNS C
   ON C.TBCREATOR = PL.CREATOR
  AND C.TBNAME = PL.TNAME
  AND C.NAME = P.LEFT_HAND_SIDE
INNER JOIN SYSIBM.SYSTABLES T
   ON T.CREATOR = PL.CREATOR
  AND T.NAME = PL.TNAME
INNER JOIN SYSIBM.SYSINDEXES IX
   ON T.CREATOR = IX.TBCREATOR
  AND T.NAME = IX.TBNAME
INNER JOIN SYSIBM.SYSKEYS K
   ON K.IXCREATOR = IX.CREATOR
  AND K.IXNAME = IX.NAME
  AND K.COLNAME = P.LEFT_HAND_SIDE
WHERE P.LHS_TABNO <> 0
  AND P.RHS_TABNO = 0
  AND P.SEARCHARG = 'Y'
  AND P.NEGATION  = 'N'
  AND P.MARKER = 'Y'
  AND P.TYPE IN ('RANGE','BETWEEN','LIKE')
```

Column is indexed

Indexable range predicate with a marker

  - More useful than local range predicates with markers
    - Cases where join order / join sequence are impacted by the incorrect filter factor are missed
  - There could be other, significantly better indexes such that this risky choice doesn't compete
  - Candidates for REOPT

Mining DSN_PREDICAT_TABLE – Queries at risk

- Indexable local range predicates with default filter factors on more than one index

```
SELECT QUERYNO
      ,QBLOCKNO
      ,APPLNAME
      ,SUBSTR(PROGNAME,1,18) PROGNAME
      ,COUNT(*)
FROM (
  SELECT DISTINCT
         P.QUERYNO
        ,P.QBLOCKNO
        ,P.APPLNAME
        ,P.PROGNAME
        ,IX.CREATOR
        ,IX.NAME
  FROM DSN_PREDICAT_TABLE P
  INNER JOIN PLAN_TABLE PL
     ON PL.QUERYNO = P.QUERYNO
    AND PL.QBLOCKNO = P.QBLOCKNO
    AND PL.APPLNAME = P.APPLNAME
    AND PL.PROGNAME = P.PROGNAME
    AND PL.BIND_TIME = P.EXPLAIN_TIME
    AND PL.TABNO = P.LHS_TABNO
  INNER JOIN SYSIBM.SYSCOLUMNS C
     ON C.TBCREATOR = PL.CREATOR
    AND C.TBNAME = PL.TNAME
    AND C.NAME = P.LEFT_HAND_SIDE
  INNER JOIN SYSIBM.SYSTABLES T
     ON T.CREATOR = PL.CREATOR
    AND T.NAME = PL.TNAME
  INNER JOIN SYSIBM.SYSINDEXES IX
     ON T.CREATOR = IX.TBCREATOR
    AND T.NAME = IX.TBNAME
  INNER JOIN SYSIBM.SYSKEYS K
     ON K.IXCREATOR = IX.CREATOR
    AND K.IXNAME = IX.NAME
    AND K.COLNAME = P.LEFT_HAND_SIDE
  WHERE P.LHS_TABNO <> 0
    AND P.RHS_TABNO = 0
    AND P.SEARCHARG = 'Y'
    AND P.NEGATION  = 'N'
    AND P.MARKER = 'Y'
    AND P.TYPE IN ('RANGE','BETWEEN','LIKE')
) A
GROUP BY QUERYNO, QBLOCKNO, APPLNAME, PROGNAME
HAVING COUNT(*)>1
```

Same conditions as before

More than one index

  - Similar considerations to previous example
    - More likely to cause query instability since there are multiple index choices competing for which optimizer doesn't have accurate filtering
  - Mining query could report cases in which multiple indexes filter on the same columns → Less risky
  - All are candidates for REOPT

Tuning Opportunities

- Queries at risk
  - Default filter factors
    - Range predicates with host variable / parameter marker
    - Column to column range predicates
    - Indexable range predicates with host variables / parameter markers
  - Data skew
    - Indexable predicates with host variables / parameter markers on skewed columns
  - Multiple risky index choices
    - More than one index choice on a range predicate with host variable / parameter marker
    - Some other combination of above

Conclusion – What did we discuss?

- Primary cause of access path problems
  - Inaccurate selectivity estimation
- Populating DSN_PREDICAT_TABLE
- Using DSN_PREDICAT_TABLE to identify query tuning opportunities
  - Missing statistics
  - Query rewrites
  - New index candidates
  - At risk queries

Optimize applications using extended explain tables

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