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Do these DB2 10 for z/OS Optimizer Enhancments apply to me?

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Agenda

- Introduction
- IN-list and complex ORs
- Predicate simplification
- Stage 2 predicate pushdown
- View/Table expression merge
- Misc optimizations
- Summary

DB2 10 and Query Performance

- Major **focus of DB2 10 was "out-of-the-box" performance improvements**
  - Query performance has a large impact on application/system performance (and thus, TCO)
  - Bigger focus on performance than prior releases of DB2
- 3-pronged approach for DB2 10 query performance
  - Plan management and query stabilization
  - Runtime optimizations (regardless of access path choice)
  - New optimizer choices

DB2 10 Optimizer changes overview

- Plan management and Query Stabilization
  - Concentrate statements with literals
  - Plan management – APREUSE/APCOMPARE
  - EXPLAIN enhancements
  - Statement level hints and options
- Runtime optimizations
  - Predicate evaluation enhancements
  - RID overflow to work file
- New access path choices
  - Multi-IN list matches
  - Range-list access
- Misc
  - RUNSTATS performance and usability
  - Even distribution for parallelism and removal of limitations

See session 12740 "DB2 for z/OS Migration – Query Performance Considerations"

Focus of this presentation

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- Introduction
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Performance enhancement for complex OR & long IN-lists

- Improvement to early-out of (non-matching) ORs and IN-lists
  - For example: `WHERE C1 IN (1,2,3,...,100)`
    - DB2 9 stops predicate comparison once a match was found, but cycles through the predicate tree to find the end.
    - DB2 10 stops predicate comparison and jumps to end
- Predicate application (code path) is also reduced in DB2 10
- Runtime optimization - no REBIND needed
- Not visible in PLAN_TABLE

IN-list Table
Table Type 'I' and Access Type 'IN'

- The IN-list predicate will be represented as an in-memory table if:
  - List prefetch is chosen, OR
  - More than one IN-list is chosen as matching
- The EXPLAIN output associated with the in-memory table will have:
  - New Table Type: TBTYPE – 'I'
  - New Access Type: ACTYPE – 'IN'

```
SELECT … FROM T1 WHERE T1.C1 IN (?, ?, ?);
```

QBNO	PLANNO	METHOD	TNAME	ACTYPE	MC	ACNAME	QBTYPE	TBTYPE	PREFETCH
1	1	0	DSNIN001(01)	***IN***	0		SELECT	***I***	
1	2	1	T1	I	1	T1_IX_C1	SELECT	T	***L***

Multi IN-List Example

- Ability to match on more than one IN-list
  - DB2 9 could only match on the 1st IN-list
  - DB2 10 can match on all three columns in this example

```
SELECT … FROM T1
WHERE C1 IN (?, ?)
  AND C2 IN (?, ?)
  AND C3 = ?
```

```
index I1 on T1 (C1,C2,C3)
column  cardinality

C1                   2
C2                  20
C3          10,000,000
```

```
Pln                                          I SORT COMP  T
Nr Nr   M Table          AC  MC Index        O UJOG UJOG  T
-- --- -- ------------   --  -- ------       - ---- ----  -
 1   1  0 DSNIN002(01)   IN   0 I1           N NNNN NNNN  I
 1   1  1 DSNIN003(01)   IN   0 I1           N NNNN NNNN  I
 1   1  1 T1             I    3 I1           N NNNN NNNN  T
```

IN-list Predicate Transitive Closure (PTC)

```
SELECT …
FROM T1, T2
WHERE T1.C1 = T2.C1
  AND T1.C1 IN (?, ?, ?)
  AND T2.C1 IN (?, ?, ?)   ← Optimizer can generate
                              this predicate via PTC
```

- Without IN-list PTC (DB2 9)
  - Optimizer will be unlikely to consider T2 as the first table accessed
- With IN-list PTC (DB2 10)
  - Optimizer can choose to access T2 or T1 first
- PTC already supported for =, BETWEEN, <, <=, >, >=

Reducing Matchcols for IN-lists

```
SELECT …
FROM T1
WHERE C1 = ?
  AND C2 IN (?, ?, ?, ?, ?) ← Optimizer may
                               choose not to match
```

- If the equals (=) predicates provide strong filtering
  - Optimizer may choose not to match on the IN-list
    - Instead apply as index screening
    - To avoid overhead of additional index probing
- Example above
  - MATCHCOLS reduced from 2 to 1
  - ACCESSTYPE changed from “N” to “I”
- Optimizer already trims IN-lists if equals predicates are unique

Range-list access
Targets two types of OR queries

- Cursor scrolling (pagination) SQL
  - Retrieve next n rows
  - Common in COBOL/CICS and any screen scrolling application
  - Not to be confused with “scrollable cursors”
    - Hence term pagination to avoid confusion (???)
- Complex OR predicates against the same columns
  - Common in SAP

- In both cases:
  - The OR (disjunct) predicate refers to a single table only.
  - Each OR predicate can be mapped to the same index.
  - Each disjunct has at least one matching predicate.

Simple scrolling
Index matching and ORDER BY

- Scroll forward to obtain the next 20 rows
  - WHERE clause may appear as:

```
WHERE (LASTNAME='JONES' AND FIRSTNAME>'WENDY')
   OR (LASTNAME>'JONES')
ORDER BY LASTNAME, FIRSTNAME;
```

  - Assumes index is available on (LASTNAME, FIRSTNAME)
  - DB 10 supports
    - Single matching index access with sort avoided
  - DB2 9 requires
    - Multi-index access, list prefetch and sort

Simple scrolling – Pre-DB2 10 Solution

- To avoid multi-index access in online transactions for scrolling SQL
  - Customers added redundant predicate to support single matching index
  - And – potentially OPTIMIZE FOR n ROWS

```
WHERE ((LASTNAME='JONES' AND FIRSTNAME>'WENDY')
   OR (LASTNAME>'JONES'))
AND LASTNAME >= 'JONES'
ORDER BY LASTNAME, FIRSTNAME
OPTIMIZE FOR 1 ROW;
```

  - DB2 10 supports
    - MATCHCOLS=2 on 1st OR, and MC=1 on 2nd OR
  - DB2 9 supports
    - MATCHCOLS=1 on predicate in **red**

- NOTE: APAR PM56355 to encourage range-list access with OFnR and extra predicate

Complex OR predicates against same index

- Given WHERE clause
  - And index on one or both columns

```
WHERE (LASTNAME='JONES' AND FIRSTNAME='WENDY')
   OR (LASTNAME='SMITH' AND FIRSTNAME='JOHN');
```

- DB2 9 requires
  - Multi-index access with list prefetch
- DB2 10 supports
  - Matching single (range-list) index access – no list prefetch
  - Or, Multi-index access with list prefetch

Range-list – PLAN_TABLE representation

- Order of PLAN_TABLE entries is by coding sequence
  - Determination of execution sequence deferred to runtime
    - When all host variables/parameter markers are resolved
  - For this example, coding sequence does not match execution sequence

```
WHERE (LASTNAME>'JONES')
   OR (LASTNAME='JONES' AND FIRSTNAME>'WENDY')
ORDER BY LASTNAME, FIRSTNAME;
```

QBlockno	Planno	Accessname	Access_Type	Matchcols	Mixopseq
1	1	IX1	NR	1	1
1	1	IX1	NR	2	2

New access type (NR = IN-List Range)

Coding sequence

Range-list – not always chosen

- Range-list (ACCESSTYPE='NR') is a new optimizer choice
  - Does not mean "ALWAYS" chosen
    - This is a cost-based choice
- Range-list is a good choice when
  - Single matching index access is needed to avoid:
    - RID processing
    - Sort (if order is needed)
  - Ideal for online (CICS/COBOL or web) screen scrolling
- Biggest challenge for optimizer
  - Programs that FETCH first n rows, but do NOT have OPTIMIZE or FETCH FIRST clause

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Remove “Always False” Predicates

- Remove “Always False” literal predicates
  - Literal “IN” or “=“ only (no host vars or REOPT)
    - Original “OR” is stage 2
      - Disables index access and many query transformations

```
WHERE ('A' = 'B' OR COL1 IN ('B', 'C'))
```

  - Becomes….

```
WHERE COL1 IN ('B', 'C')
```

  - Documented tricks are NOT pruned (OR 0=1)
    - Available in V8/9 via zparm PREDPRUNE

Other variations of “Always False/True”

- Removal of “Always False” literal predicates
  - Does NOT apply for “Always False” within “AND”

```
WHERE ((COL1= 'C' AND 'A' = 'B') OR COL1 ='B')
```

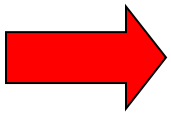
- “Always True” predicates are NOT pruned
  - These will be executed by DB2 for each row processed

```
WHERE 1=1
```

Remove Unnecessary Tables

- Remove unnecessary LEFT OUTER JOIN tables
  - If no columns are SELECTed from the RIGHT table, then
    - The right table is unnecessary if no duplicates because:
      - Unique index on join key of right table
      - Or, SELECT DISTINCT

```
SELECT DISTINCT T1.C3
FROM T1 LEFT OUTER JOIN T2
ON T1.C2 = T2.C2
WHERE T1.C1 = ?
```



```
SELECT DISTINCT T1.C3
FROM T1
WHERE T1.C1 = ?
```

  - NOTE: “Removed” tables will NOT appear in explain (PLAN_TABLE)

» Available in V8/9 via zparm PREDPRUNE

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Stage 2 predicate “pushed down” to IM/DM

- Most Stage 2 (residual) predicates can execute as index screening (indexable) or stage 1 (sargable)
  - CPU time improvement
  - Reduced data getpages if stage 2 predicate becomes index screening
  - Applies to
    - Arithmetic/datetime expressions, scalar built-in functions, CAST (essentially all expressions without subqueries or CASE)
  - Does not apply to
    - Cannot be OR’d with an IN predicate
    - List prefetch
  - Eligible for DM (stage 1) pushdown but NOT IM pushdown
    - Join predicates
    - OR’d predicates that span different predicate stages
- Externalized in DSN_FILTER_TABLE column PUSHDOWN

Stage 2 predicate “pushed down” to IM/DM

- Timing
  - Index matching
  - Index screening
  - Stage 2 pushed down to IM — No data access
  - Stage 1 — Data access
  - Stage 2 pushed down to DM
  - Stage 2
- Push down decision is made after the access path selection
  - Does not influence access path selection decisions (not cost-based)
  - RDS is still invoked to evaluate

Stage 2 predicate “pushed down” examples (1)

Given an index on CITY, ZIPCODE

```
EXPLAIN ALL SET QUERYNO = 1 FOR
 SELECT CUSTNO FROM CUSTOMERS
 WHERE CITY = ?
   AND MOD(ZIPCODE,5)=0;
```

DSN_FILTER_TABLE output

```
   +-----------------------------------------------+
   |  QUERYNO  |  PREDNO  |   STAGE    | PUSHDOWN |
   +-----------------------------------------------+
 1_|         1 |        2 | MATCHING   |          |
 2_|         1 |        3 | STAGE2     | I        | ← Eligible for IM
   +-----------------------------------------------+
```

Where is PREDNO=1? From DSN_PREDICAT_TABLE

```
   ------------------------------------------------------------------------------------
   | PREDNO | TYPE |  TEXT
   ------------------------------------------------------------------------------------
 1_|      1 | AND  | (SYSADM.CUSTOMERS.CITY=? AND MOD(SYSADM.CUSTOMERS.ZIPCODE,5)=0)
```

Stage 2 predicate “pushed down” examples (2)

```
EXPLAIN ALL SET QUERYNO = 2 FOR
 SELECT CUSTNO FROM CUSTOMERS
 WHERE CITY = ?
   AND( CASE WHEN ZIPCODE = 99999 THEN 1 ELSE ZIPCODE END) = 99999;

EXPLAIN ALL SET QUERYNO = 3 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND (MOD(ZIPCODE,5)=0 OR ZIPCODE IN (99998, 99999));
```

	QUERYNO	PREDNO	STAGE	PUSHDOWN	
3_	2	2	MATCHING		
4_	2	3	STAGE2		← Not Eligible (CASE expr)
5_	3	2	MATCHING		
6_	3	3	STAGE2		← Not Eligible (IN-list)

Stage 2 predicate “pushed down” – Predicate Tricks (3)

```
EXPLAIN ALL SET QUERYNO = 4 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND (ZIPCODE = 99999 OR 0=1);    ← documented trick

EXPLAIN ALL SET QUERYNO = 5 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND (ZIPCODE = 99999 OR 1=2);    ← Incorrect use of documented trick
```

	QUERYNO	PREDNO	STAGE	PUSHDOWN	
7_	4	2	MATCHING		
8_	**4**	**3**	**STAGE2**	**I**	**← Eligible for IM**
9_	5	2	MATCHING		
10_	**5**	**3**	**MATCHING**		**← ??????**

**** OR 1=2 has been pruned, leaving indexable predicate. OR 0=1 is NOT pruned.**

Stage 2 predicate “pushed down” – Predicate Tricks (4)

```
EXPLAIN ALL SET QUERYNO = 6 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND ZIPCODE = 99999+0;        ← Documented trick to disable index matching

EXPLAIN ALL SET QUERYNO = 7 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND ZIPCODE+0 = 99999;        ← Incorrect use of documented trick (stage 2 pred)
```

	QUERYNO	PREDNO	STAGE	PUSHDOWN	
11_	6	2	MATCHING		
12_	**6**	**3**	**STAGE1**		← applied as screening
13_	7	2	MATCHING		
14_	**7**	**3**	**STAGE2**	**I**	← Eligible for IM

Stage 2 predicates “pushed down” examples (5)

Given and index on CITY, ZIPCODE

```
EXPLAIN ALL SET QUERYNO = 8 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND (ZIPCODE+0 = 99999 OR ZIPCODE = 99998); ← All OR'd predicates are in index

EXPLAIN ALL SET QUERYNO = 9 FOR
 SELECT CUSTNO
 FROM CUSTOMERS
 WHERE CITY = ?
 AND (ZIPCODE+0 = 99999 OR CUSTNO = 1);      ← All OR'd predicates NOT in index
```

	QUERYNO	PREDNO	STAGE	PUSHDOWN	
15_	8	2	MATCHING		
16_	**8**	**3**	**STAGE2**	**I**	← **Eligible for IM**
17_	9	2	MATCHING		
18_	**9**	**3**	**STAGE2**	**D**	← **Eligible for DM (stage 1)**

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Merge expression on preserved side of Outer Join

- DB2 can merge view/table expression on preserved side of outer join
  - CASE, VALUE, COALESCE, NULLIF, IFNULL
    - Exception if merged predicate is stage 2

```
SELECT A.C1, B.C1, A.C2, B.C2
FROM T1, (SELECT COALESCE(C1,0) as C1, C2
          FROM   T2) A      <--table expression 'A' will be Merged
     LEFT OUTER JOIN
         (SELECT COALESCE(C1,0) as C1, C2
          FROM   T3) B      <-- B will be Materialized
     ON A.C2 = B.C2
WHERE T1.C2 = A.C2;
```

Merge single table view/ table expression with subquery

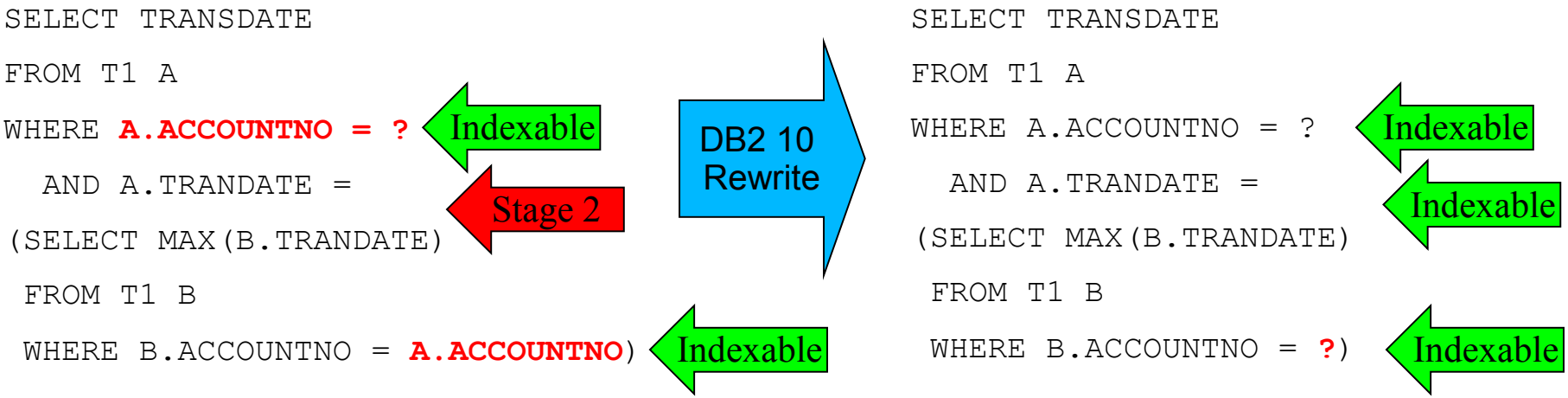
```
SELECT *
FROM T1 LEFT OUTER JOIN
      (SELECT * FROM T2
       WHERE T2.C1 = (SELECT MAX(T3.C1) FROM T3 ) ) TE <--subquery
ON T1.C1 = TE.C1;
```

```
SELECT *
FROM T1 LEFT OUTER JOIN T2                  <-- table expression is merged
ON T2.C1 = (SELECT MAX(T3.C1) FROM T3)   <-- subquery ON-predicate
AND T1.C1 = TT.C1;
```

- View/Table expression with subquery on NULL-supplied side
  - Merge into ON clause
- On preserved side
  - Merge into WHERE clause

Correlated to Non-correlated Rewrite

- DB2 10 can rewrite correlated to non-correlated
  - If correlation predicates are covered by local predicates in outer
    - Can result in additional index matching predicate
  - Only targets simple example shown



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Minimizing Optimizer Challenges – Safe Optimization

- Potential causes of sub-optimal plans
  - Insufficient statistics
  - Unknown literal values used for host variables or parameter markers

- Optimizer will evaluate the risk for each predicate

  - For example: WHERE BIRTHDATE < ?
    - Could qualify 0-100% of data depending on literal value used
  - As part of access path selection
    - Compare access paths with close cost and choose lowest risk plan

Minimizing impact of RID failure

- RID overflow can occur for
  - Concurrent queries each consuming shared RID pool
  - Single query requesting > 25% of table or hitting RID pool limit

- DB2 9 will fallback to tablespace scan*

- DB2 10 will continue by writing new RIDs to work file 
  - Work file usage may increase
    - Mitigate by increasing RID pool size (default increased in DB2 10).
    - MAXTEMPS_RID zparm for maximum WF usage for each RID list
  - Not supported for queries with column functions (MAX, MIN etc)
  - Runtime optimization (no REBIND needed)

* Hybrid join can incrementally process. Dynamic Index ANDing will use WF for failover.

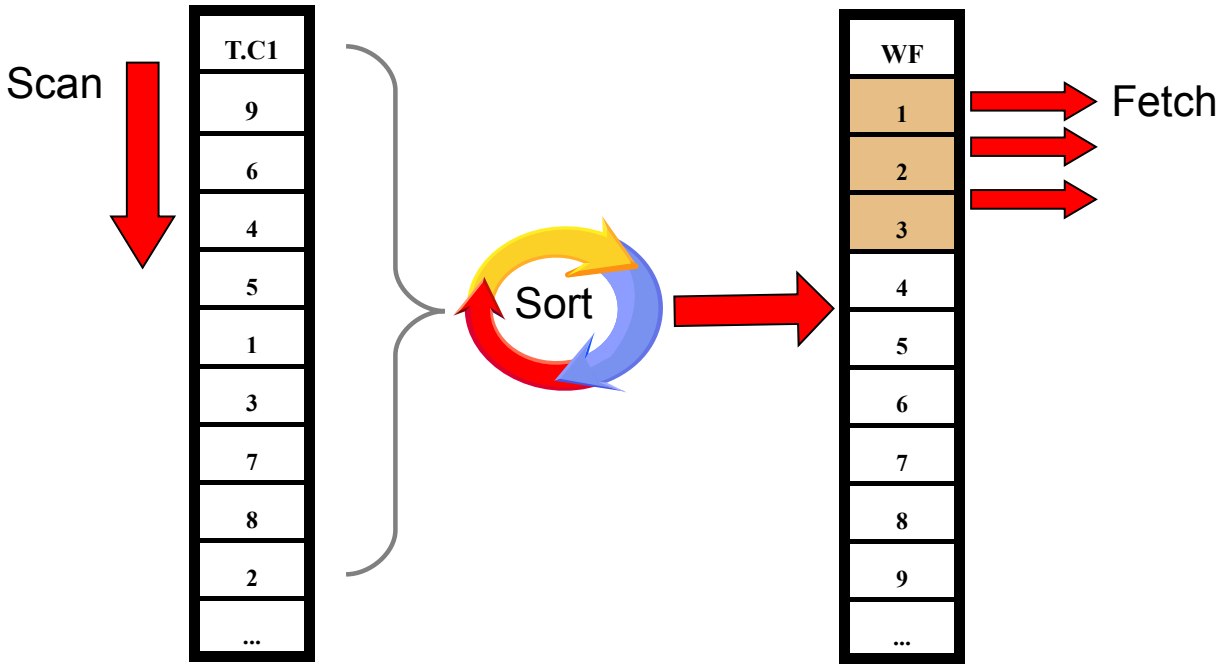
Sort performance enhancements

- Tournament tree sort is avoided for FETCH FIRST n ROWS ONLY
  - DB2 9 - only ORDER BY and (n * (sort key + data)) < 32K
  - DB2 10 - extended to GROUP BY (without HAVING), and to
    (n * (sort key + data)) < 128K
    if over 128K, each WF for each run contains only n rows
  - Instead of sorting, uses in-memory replacement technique
    - Demonstrated on next slides

Sort performance enhancements 2

- Sort is not avoided for FETCH FIRST n ROWS ONLY prior to DB2 10:

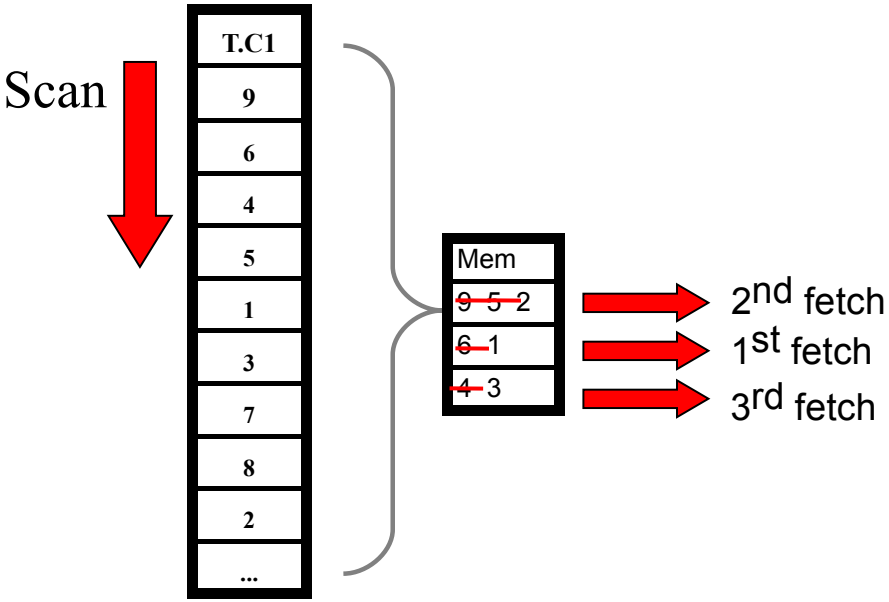
```
SELECT SUM(C1)
FROM   T1
GROUP BY C2
FETCH FIRST 3 ROWS ONLY;
```



Sort performance enhancements 3

- Sort avoidance for FETCH FIRST n ROWS ONLY in DB2 9 and later:

```
SELECT SUM(C1)
FROM   T1
GROUP BY C2
FETCH FIRST 3 ROWS ONLY;
```



Other Sort performance enhancements

- In-memory work file for small sorts
  - extended to intermediate sorts (DB2 9 was top query sort only)
    - Up to 255 rows
  - block fetch for reading the in-memory Sort work file
    - top query sort only
    - (#rows in work file * (sort key + data)) < 1M
    - Significant CPU time reduction (due to avoiding RDS/DM trips)
- RID sort and RID intersection are done in-place, RID union is done with extra 2 RID blocks only
  - Minimizes RID pool storage usage (50% savings for sort/union)

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    - Bigger focus on query performance than prior releases of DB2
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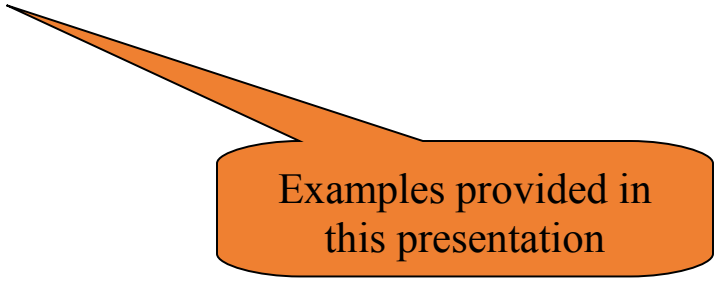
    - Runtime optimizations (regardless of access path choice)
    - New optimizer choices



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