IBM System z Technology Summit

DB2 9 & DB2 10 for z/OS Optimizer

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Agenda

- **Optimizer costing**
- **Runtime query performance**
- **Indexing**
- **Complex queries**

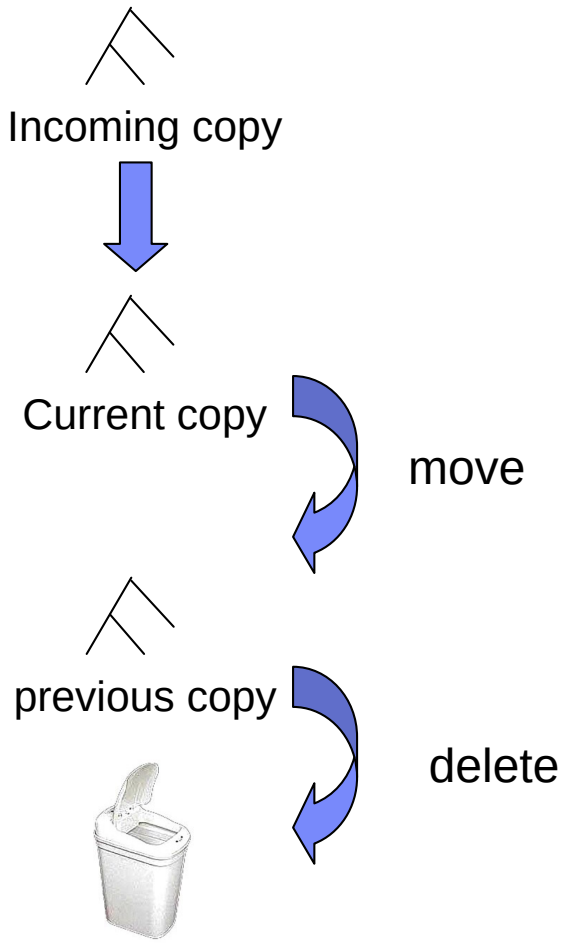
Plan Management Overview

- **Ability to backup your static SQL packages (DB2 9)**

- **At REBIND**
  - Save old copies of packages in Catalog/Directory
  - Switch back to previous or original version
- **Two flavors**
  - BASIC
    - 2 copies: Current and Previous
  - EXTENDED
    - 3 copies: Current, Previous, Original
  - Default controlled by a ZPARM
  - Also supported as REBIND options

Plan Management - BASIC support

REBIND … PLANMGMT(BASIC)



REBIND … SWITCH(PREVIOUS)

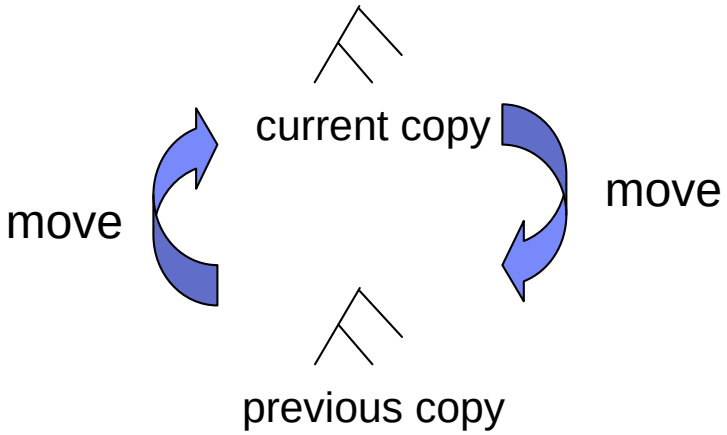
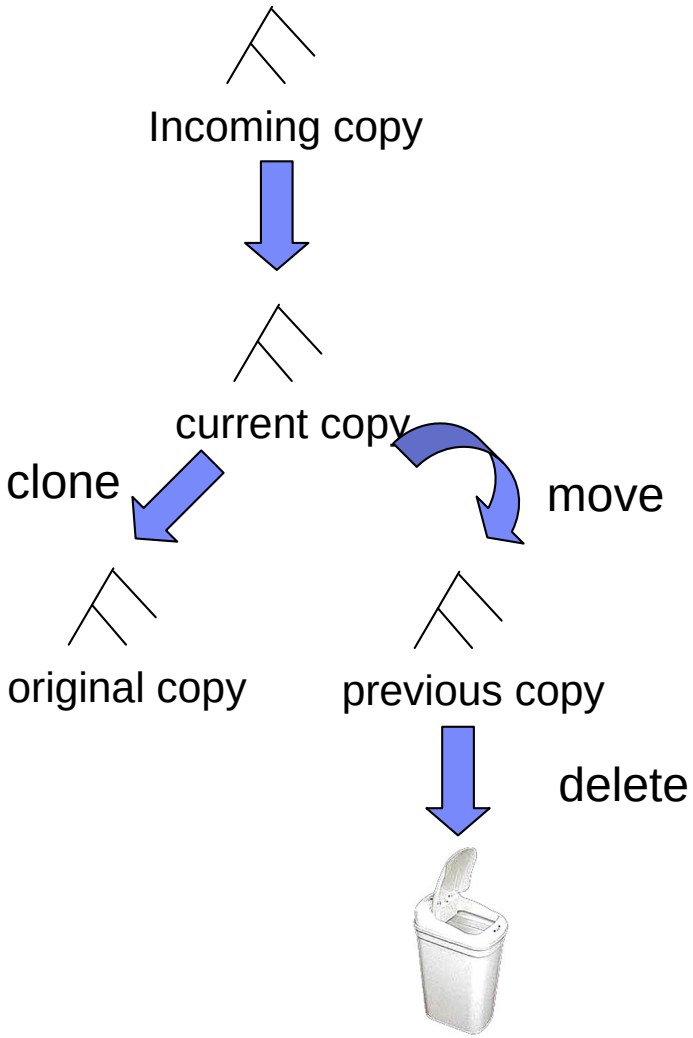


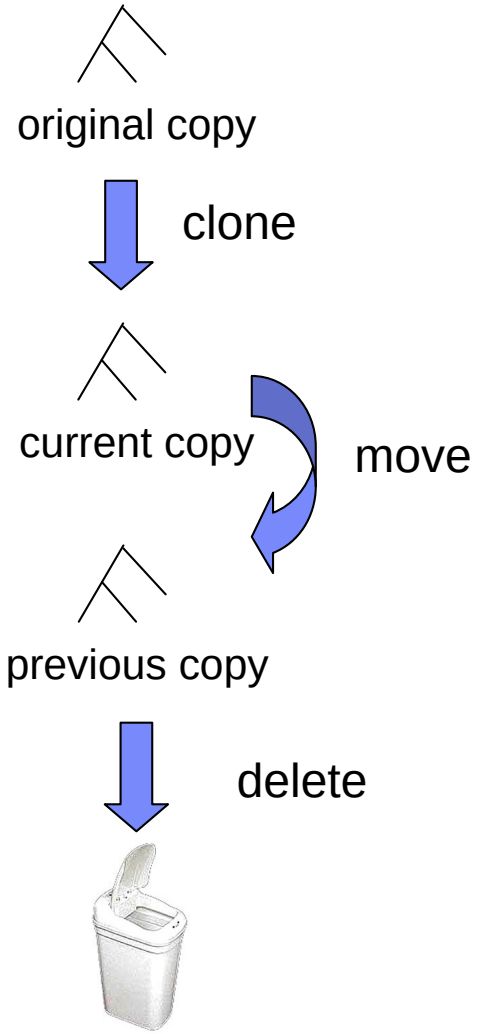
Chart is to be read from bottom to top

Plan Management - EXTENDED support

REBIND … PLANMGMT(EXTENDED)



REBIND … SWITCH(ORIGINAL)



DB2 10 Updates to Plan Management

- **SYSIBM.SYSPACKCOPY**
  - New catalog table
  - Hold SYSPACKAGE-style metadata for any previous or original package copies
  - No longer need to SWITCH to see information on inactive copies
    - Complaint from DB2 9

- **APRETAINDUP option of REBIND**
  - Default YES
    - Retain duplicate for BASIC or EXTENDED
  - Optional NO
    - Do not retain duplicate access path as PREVIOUS or ORIGINAL
      - PREVIOUS/ORIGINAL must be from DB2 9 or later

What-if? BIND

- **BIND package to see what new**
- **Bind package EXPLAIN(ONLY) and/or SQLERROR(CHECK)**
  - Existing package copies are not overwritten
    - Performs explain or syntax/semantic error checks on SQL
  - Requires BIND, BINDAGENT, or EXPLAIN privilege.
  - Supported for BIND only
    - Not REBIND
    - Targeted to application changes
      - Eg. Development environment is DB2 LUW, production DB2 for z/OS

Retrieving Access Path with EXPLAIN(NO)

- **EXPLAIN PACKAGE**
  - Extract existing PLAN_TABLE information for packages
    - NOT a new explain
    - The package/copy must be created on DB2 9 or later
  - Useful if you didn't BIND with EXPLAIN(YES)
    - Or PLAN_TABLE entries are lost

```
>>-EXPLAIN----PACKAGE----------->

>>-----COLLECTION--collection-name--PACKAGE--package-name--------->

>----+-------------------------+----+------------------+-------->
     |                         |    |                  |
     +---VERSION-version-name--+    +---COPY--copy-id--+
```

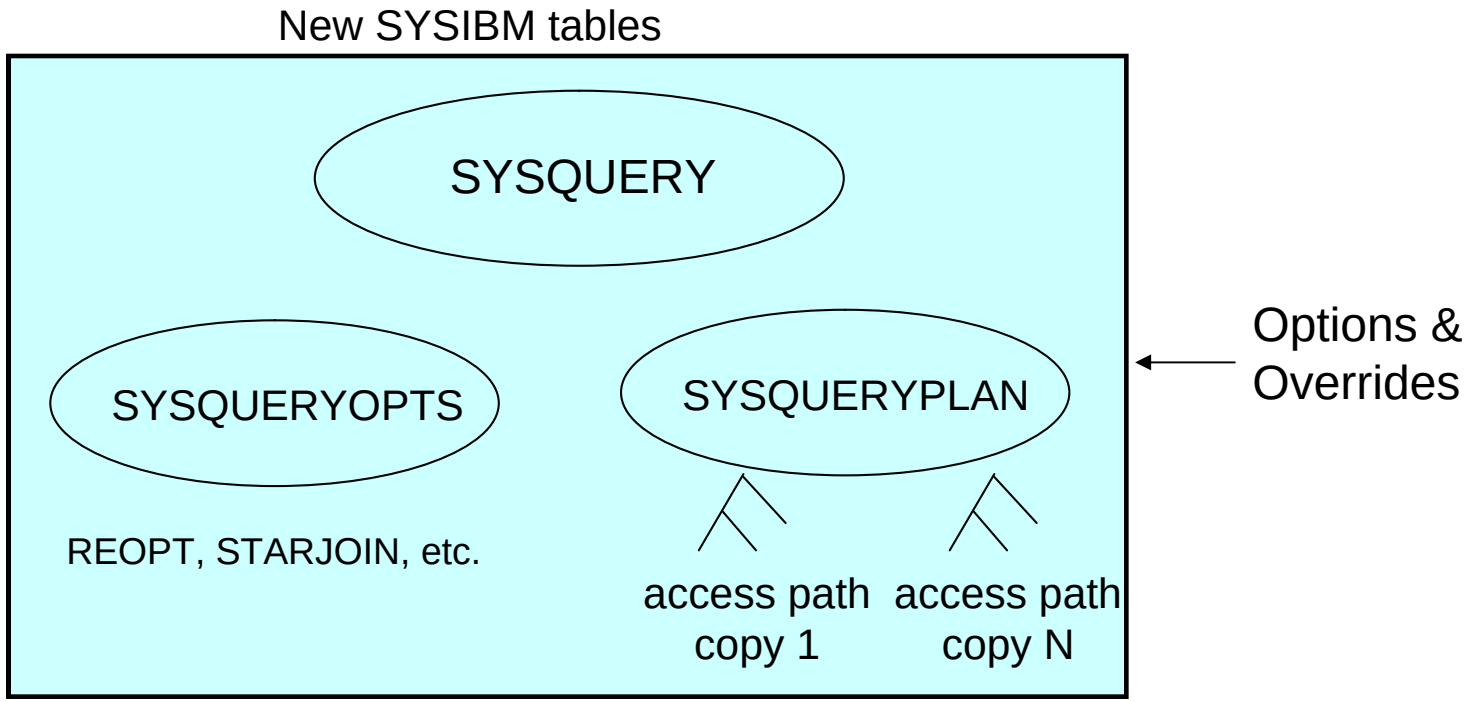
    - COPY-ID can be 'CURRENT', 'PREVIOUS', 'ORIGINAL'

Access Path Stability with statement level hints

- **Current limitations in hint matching**
  - QUERYNO is used to link queries to their hints – a bit fragile
  - For dynamic SQL, require a change to apps – can be impractical
- **New mechanisms:**
  - Associate query text with its corresponding hint … more robust
  - Hints enforced for the entire DB2 subsystem
    - irrespective of static vs. dynamic, etc.
  - Hints integrated into the access path repository

- **PLAN_TABLE isn't going away**
- **Only the "hint lookup" mechanism is being improved.**

Access Path Repository – Hints/Statement level



Statement level hints (cont.)

- **Steps to use new hints mechanism**
  - Populate a user table DSN_USERQUERY_TABLE with query text
  - Populate PLAN_TABLE with the corresponding hints
  - Run new command BIND QUERY
    - To integrate the hint into the repository.
  - FREE QUERY can be used to remove the hint.

Statement-level BIND options

- **Statement-level granularity may be required rather than:**
  - Subsystem level ZPARMs (STARJOIN, SJTABLES, MAX_PAR_DEGREE)
  - Package level BIND options (REOPT, DEF_CURR_DEGREE)
- **For example**
  - Only one statement in the package needs REOPT(ALWAYS)

- **New mechanism for statement-level bind options:**
  - Similar to mechanism used for hints
  - DSN_USERQUERY_TABLE can also hold per-statement options

Literal Replacement

- **Dynamic SQL with literals can now be re-used in the cache**
  - Literals replaced with &
    - Similar to parameter markers but not the same
- **To enable either you:-**
  - Put CONCENTRATE STATEMENTS WITH LITERALS in the PREPARE ATTRIBUTES clause
  - Or set LITERALREPLACEMENT in the ODBC initialization file
  - Or set the keyword enableLiteralReplacement='YES' in the JCC Driver
- **Lookup Sequence**
  - Original SQL with literals is looked up in the cache
  - If not found, literals are replaced and new SQL is looked up in the cache
    - Additional match on literal usability
    - Can only match with SQL stored with same attribute, not parameter marker
  - If not found, new SQL is prepared and stored in the cache

Literal Replacement …

- **Example:**

```
WHERE ACCOUNT_NUMBER = 123456
```

  – This would be replaced by

```
WHERE ACCOUNT_NUMBER = &
```

- **Performance Expectation**
  - Using parameter marker still provides best performance
  - Biggest performance gain for repeated SQL with different literals
  - NOTE: Access path is not optimized for literals
    - True for parameter markers/host variables today
    - Need to use REOPT for that purpose

Agenda

- **Bind/Prepare**

- **Runtime query performance**
- **Indexing**
- **Complex queries**

Histogram Statistics

- RUNSTATS **will produce equal-depth histogram**
  - Each quantile (range) will have approx same number of rows
    - Not same number of values
  - Another term is range frequency

- **Example**
  - 1, 3, 3, 4, 4, 6, 7, 8, 9, 10, 12, 15 (sequenced)
  - Lets cut that into 3 quantiles.
    - 1, 3, 3, 4 ,4 6,7,8,9 10,12,15

Seq No	Low Value	High Value	Cardinality	Frequency
1	**1**	**4**	**3**	**5/12**
2	**6**	**9**	**4**	**4/12**
3	**10**	**15**	**3**	**3/12**

Histogram Statistics Notes

- **RUNSTATS**
  - Maximum 100 quantiles for a column
  - Same value columns WILL be in the same quantile
  - Quantiles will be similar size but:
    - Will try to avoid big gaps inside quantiles
    - Highvalue and lowvalue may have separate quantiles
    - Null WILL have a separate quantile
- **Supports column groups as well as single columns**
- **Think “frequencies” for high cardinality columns**

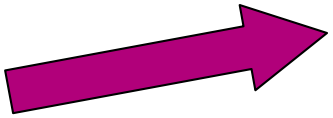
Histogram Statistics Example

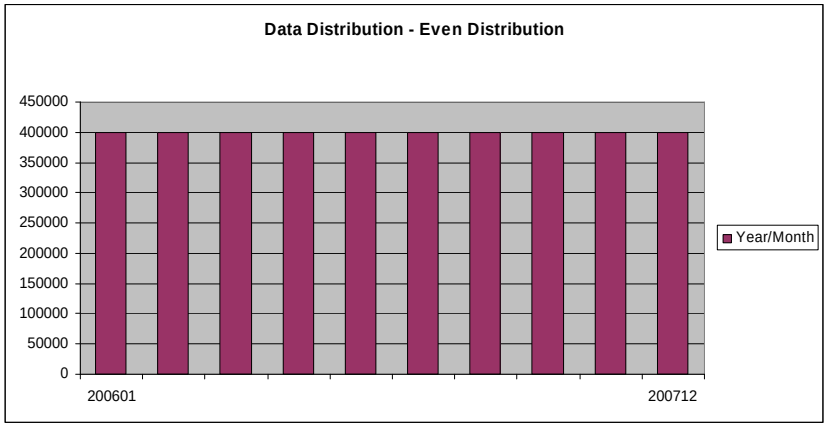
- **SAP uses INTEGER (or VARCHAR) for YEAR-MONTH**

WHERE YEARMONTH BETWEEN 200601 AND 200612

- Assuming data for 2006 & 2007
  - FF = (high-value – low-value) / (high2key – low2key)
  - FF = (200612 – 200601) / (200711 – 200602)
  - **10% of rows estimated to return**

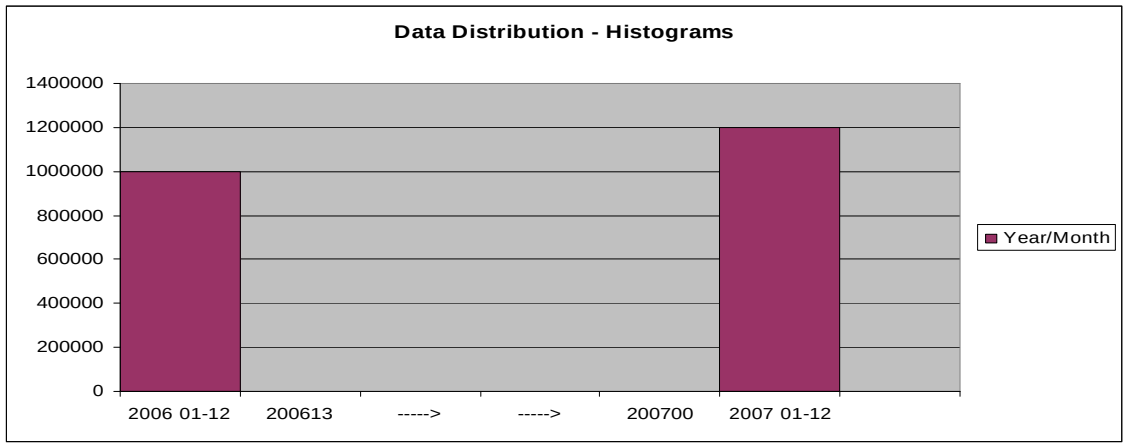
Data assumed as evenly distributed between low and high range





Histogram Statistics Example

- Example (cont.)
  - Data only exists in ranges 200601-12 & 200701-12
    - Collect via histograms
      - 45% of rows estimated to return



No data between
200613 & 200700

WHERE YEARMONTH BETWEEN 200601 AND 200612

Autonomic Statistics Solution Overview

- **Autonomic Statistics is implemented though a set of Stored Procedures**
  - *Stored procedures are provided to enable administration tools and packaged applications to automate statistics collection.*
    - ADMIN_UTL_MONITOR
    - ADMIN_UTL_EXECUTE
    - ADMIN_UTL_MODIFY
  - Working together, these SP's
    - Determine what stats to collect
    - Determine when stats need to be collected
    - Schedule and Perform the stats collection
    - Records activity for later review
  - *See Chapter 11 "Designing DB2 statistics for performance" in the DB2 10 for z/OS Performance Monitoring and Tuning Guide for details on how to configure autonomic monitoring directly within DB2.*

RUNSTATS Simplification/Performance Overview

- **RUNSTATS options to SET/UPDATE/USE a stats profile**
  - Integrate specialized statistics into generic RUNSTATS job
    - RUNSTATS … TABLE tbl COLUMN(C1)… **SET PROFILE**
      - Alternatively use **SET PROFILE FROM EXISTING STATS**
    - RUNSTATS … TABLE tbl COLUMN(C5)… **UPDATE PROFILE**
    - RUNSTATS … TABLE tbl **USE PROFILE**

- **New option for page-level sampling**
  - But what percentage of sampling to use?
    - RUNSTATS … TABLE tbl **TABLESAMPLE SYSTEM AUTO**

Optimizer Validation with Realtime Stats

- **Index Probing & RTS lookup**
  - Estimate # of rids within a given start/stop index key range at bind/prepare
- **Exploited when these two conditions are met.**
  - Query has matching index-access local predicate
  - Predicate contain literals, or REOPT(ALWAYS|ONCE|AUTO)
- **And 1 of the following is also true**
  - Predicate is estimated to qualify no rows
  - Stats indicate the table contains no rows
  - Table is defined as VOLATILE or qualifies for NPGTHRSH
- **New EXPLAIN table to externalize runtime estimates**
  - User managed DSN_COLDIST_TABLE

DB2 10 - Minimizing Optimizer Challenges

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

- **DB2 10 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

Extending VOLATILE TABLE usage

- **VOLATILE TABLE support added in DB2 V8**
  - Targeted to SAP Cluster Tables
    - Use Index access whenever possible
    - **Avoids list prefetch**
      - Can be a problem for OR predicates or UPDATEs at risk of loop

- **DB2 10 provides VOLATILE to general cases**
  - Tables matching SAP cluster tables will maintain original limitations
    - Table with 1 unique index
  - Tables with > 1 index will follow NPGTHRSH rules
    - Use Index access whenever possible
    - **No limitation on list prefetch**
    - Less chance of getting r-scan when list-prefetch plan is only alternative

Global Optimization - Problem Scenario 1

- **V8, Large Non-correlated subquery is materialized***

```
SELECT * FROM SMALL_TABLE A
WHERE A.C1 IN
        (SELECT B.C1 FROM BIG_TABLE B)
```

  - "BIG_TABLE" is scanned and put into workfile
  - "SMALL_TABLE" is joined with the workfile

- **V9 may rewrite non-correlated subquery to correlated**
  - Much more efficient if scan / materialisation of BIG_TABLE was avoided
  - Allows matching index access on BIG_TABLE

```
SELECT * FROM SMALL_TABLE A
WHERE EXISTS
  (SELECT 1 FROM BIG_TABLE B WHERE B.C1 = A.C1)
```

Global Optimization - Problem Scenario 2

- **V8, Large outer table scanned rather than using matching index access***

```
SELECT * FROM BIG_TABLE A
WHERE EXISTS
  (SELECT 1 FROM SMALL_TABLE B WHERE A.C1 = B.C1)
```

  - "BIG_TABLE" is scanned to obtain A.C1 value
  - "SMALL_TABLE" gets matching index access

- **V9 may rewrite correlated subquery to non-correlated**

```
SELECT * FROM BIG_TABLE A
WHERE A.C1 IN
  (SELECT B.C1 FROM SMALL_TABLE B)
```

  - "SMALL_TABLE" scanned and put in workfile
  - Allows more efficient matching index access on BIG_TABLE

Global Optimization

- **Global opt internally represent subqueries as virtual tables**
  - Allows subquery to be considered in different join sequences
  - May or may not represent a physical workfile
    - Additional row added to PLAN_TABLE for non-correlated subq
      - PM30425 adds this new row for correlated
  - Apply only to subqueries that cannot be transformed to joins
    - SELECT only (not INSERT/SELECT, UPDATE, DELETE)

Correlated or non-correlated?.....I shouldn't have to care!

Agenda

- **Bind/Prepare**
- **Optimizer costing**

- **Indexing**
- **Complex queries**

GROUP BY Sort Avoidance

- **Improved sort avoidance for GROUP BY**
  - Reorder GROUP BY columns to match available index

```
SELECT … FROM T1
GROUP BY C2, C1      ←GROUP BY in C2, C1 sequence
Index 1 (C1, C2)     ←Index in C1, C2 sequence
```

  - Remove 'constants' from GROUP BY ordering requirement

```
SELECT … FROM T1
WHERE C2 = 5         ←C2 Constant
GROUP BY C2, C1
```

    - ordering requirement reduced to just C1

GROUP BY Sort Avoidance Implications

- **Implications of improved sort avoidance for GROUP BY**
  - May improve query performance!!!
  - Data may be returned in a different order
    - Always been true in any DB2 release
      - Also true in other DBMSs
    - Relational theory states that order is NOT guaranteed without ORDER BY

Sort Performance Enhancements

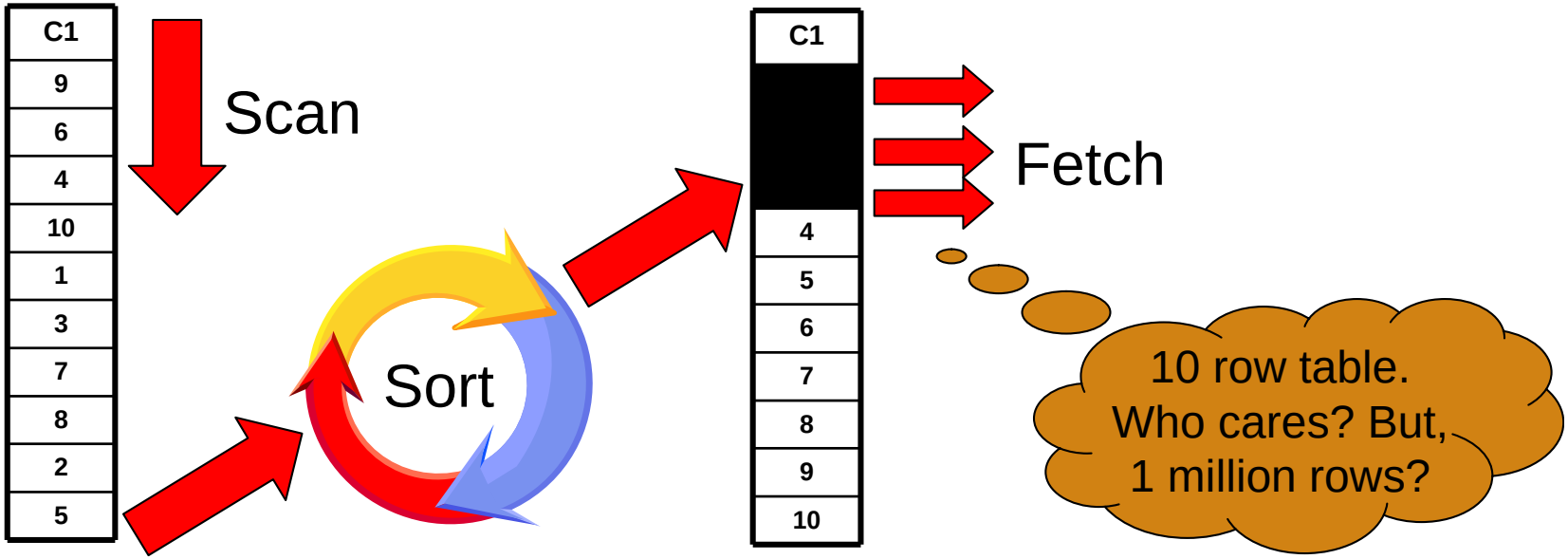
- **FETCH FIRST n ROWS ONLY (FFnR) and Sort**
  - DB2 9 added in-memory replacement for FFnR to avoid sort
    - Provided (n * (sort key + data)) < 32K
  - DB2 10 extends this to 128K

- **Avoid workfile usage for small sorts**
  - DB2 9 avoided allocating WF for final sort only
    - If <= 255 rows and result < 32K (sort key + data)
  - DB2 10 extends this to intermediate sorts also
    - Except for parallelism or SET function

Improving sort with FETCH FIRST

- **DB2 V8 example**
  - Sort is not avoided via index
    - Must sort all qualified rows

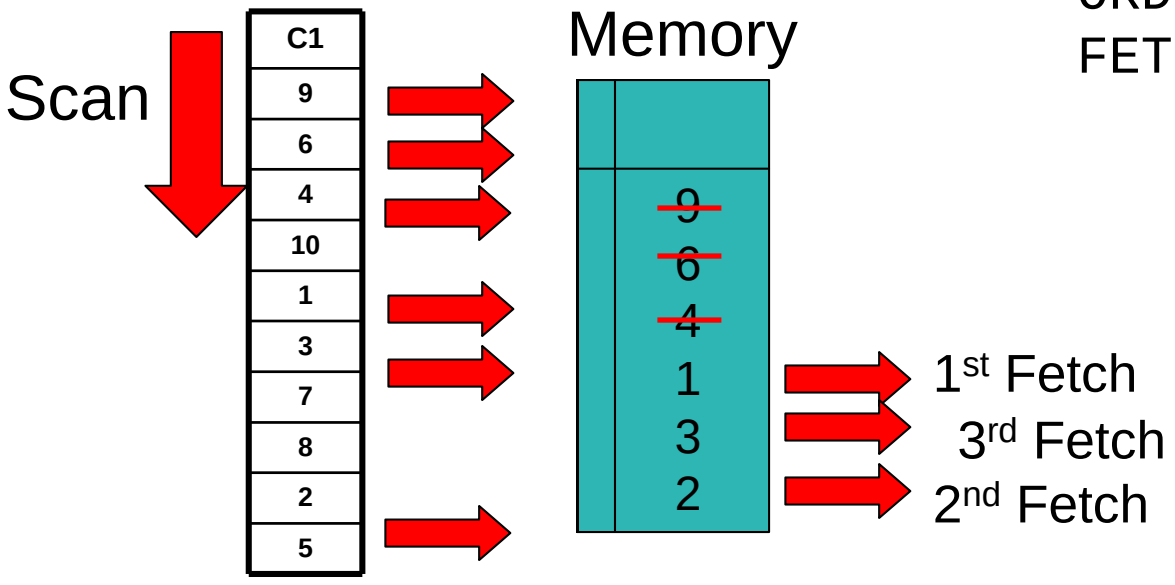
```
SELECT C1
FROM   T
ORDER BY C1
FETCH FIRST 3 ROWS ONLY
```



Improving sort with FETCH FIRST

- **DB2 9 example**
  - New algorithm for in-memory swap avoids (traditional) sort
    - Pointers maintain order

```
SELECT C1
FROM  T
ORDER BY C1
FETCH FIRST 3 ROWS ONLY
```



Suggestion: Add FETCH FIRST when subset is required.

Improvements to predicate application

- **Major enhancements to OR and IN predicates**
  - Improved performance for AND/OR combinations and long IN-lists
    - General performance improvement to stage 1 predicate processing
  - IN-list matching
    - Matching on multiple IN-lists
    - Transitive closure support for IN-list predicates
    - List prefetch support
    - Trim IN-lists from matching when preceding equals are highly filtering
  - SQL pagination
    - Single index matching for complex OR conditions

- **Many stage 2 expressions to be executed at stage 1**
  - Stage 2 expressions eligible for index screening
    - Not applicable for list prefetch
  - Externalized in DSN_FILTER_TABLE column PUSHDOWN

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***

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 is the first table accessed
- **With IN-list PTC (DB2 10)**
  - Optimizer can choose to access T2 or T1 first.

SQL Pagination

- **Targets 2 types of 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”
  - 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
  - Assumes index is available on (LASTNAME, FIRSTNAME)
  - WHERE clause may appear as:

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

  - DB2 10 supports
    - Single matching index access with sort avoided 
  - DB2 9 requires
    - Multi-index access, list prefetch and sort
    - OR, extra predicate (AND LASTNAME >= ‘JONES’) for matching single index access and sort avoidance

Complex OR predicates against same index

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

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

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

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 workfile**
  - 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

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

Agenda

- **Bind/Prepare**
- **Optimizer costing**
- **Runtime query performance**

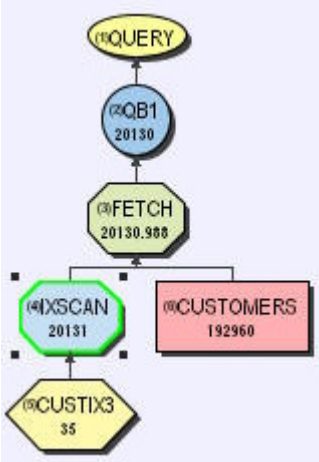
- **Complex queries**

Index on Expression

- **DB2 9 supports “index on expression”**
  - Can turn a stage 2 predicate into indexable

```
SELECT *
FROM CUSTOMERS
WHERE YEAR(BIRTHDATE) = 1971

CREATE INDEX ADMF001.CUSTIX3
    ON ADMF001.CUSTOMERS
(YEAR(BIRTHDATE) ASC)
```



Previous FF = 1/25
Now, RUNSTATS collects frequencies. Improved FF accuracy

Name	Value
Input RIDs	192960
Index Leaf Pages	241
Matching Predicates	Filter Factor
ADMF001.CUSTOMERS.= CAST(1971 AS INTEGER)	0.1043
Scanned Leaf Pages	26
Output RIDs	20131
Total Filter Factor	0.1043
Matching Columns	1

Data Caching and Sparse Index

- **Data Caching**
  - Built at runtime
    - Is a runtime enhancement to sparse index
  - Extended to non-star join in DB2 9

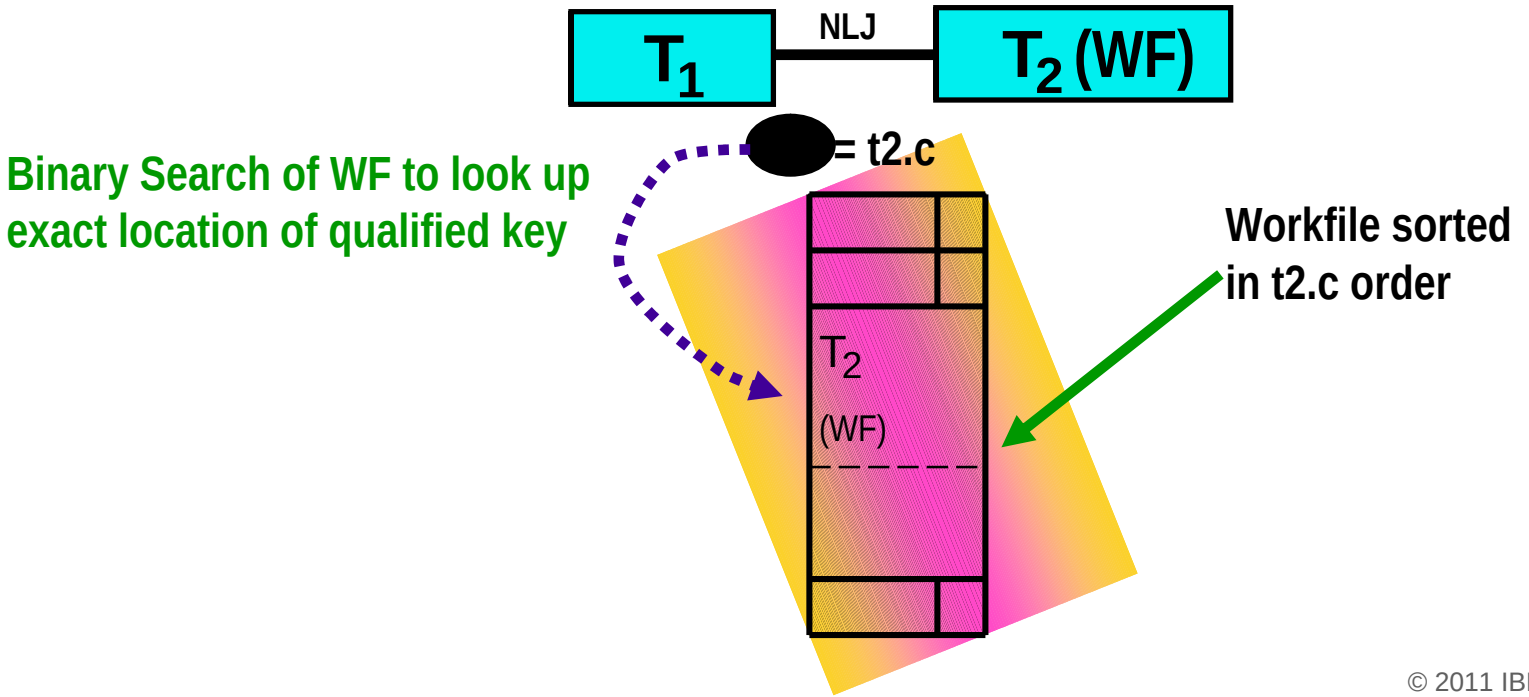
- **New ZPARM MXDTCACH**
  - Maximum extent in MB, for data caching per thread
  - If memory is insufficient
    - Fall-back to sparse index at runtime

- **Considered when lacking an index on join column(s):**
  - Temporary tables
  - Subqueries converted to joins
  - …..any table

How does Data Caching WF work?

- Data Cache contains the full result of materialized result
  - Sparse index will be a subset of WF entries

- Example, WF may have 10,000 entries
  - Cache is “binary searched” to find target location of search key



Index Include Columns

- **Index INCLUDE columns**
  - Create an Index as UNIQUE, and add additional columns
  - Ability to consolidate redundant indexes

```
INDEX1 UNIQUE (C1)
INDEX2 (C1,C2)
```

Consolidate to

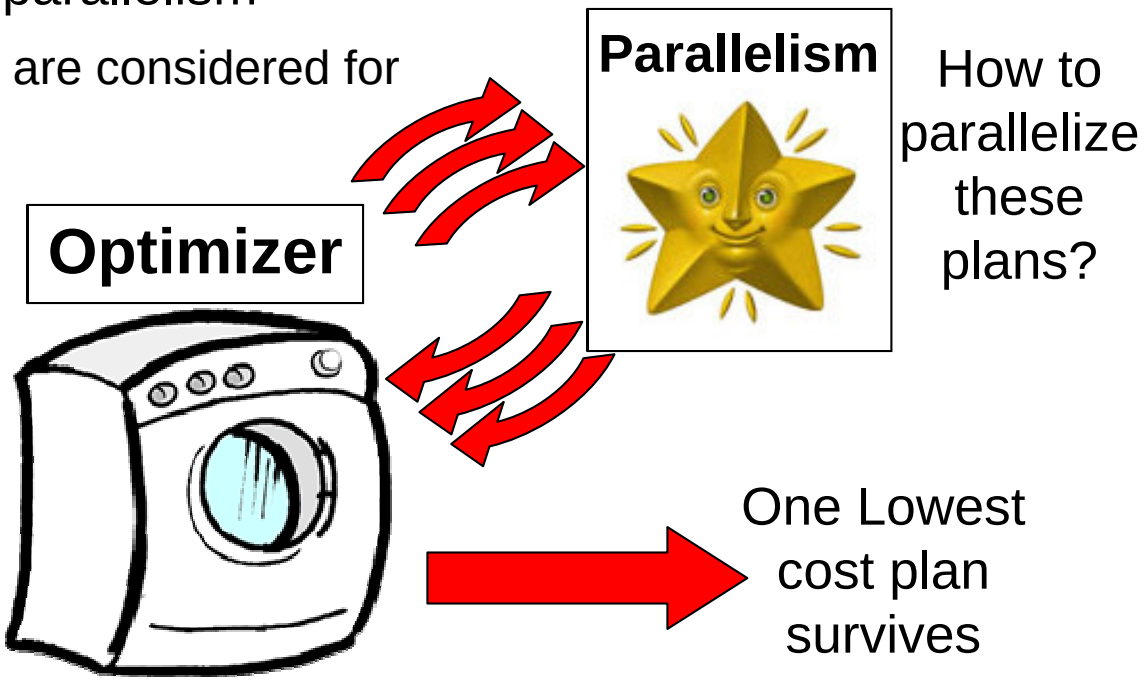
```
INDEX1 UNIQUE (C1) INCLUDE (C2)
```

Agenda

- **Bind/Prepare**
- **Optimizer costing**
- **Runtime query performance**
- **Indexing**

Parallelism Enhancements

- **In V8**
  - Lowest cost is BEFORE parallelism
- **In DB2 9**
  - Lowest cost is AFTER parallelism
    - Only a subset of plans are considered for parallelism

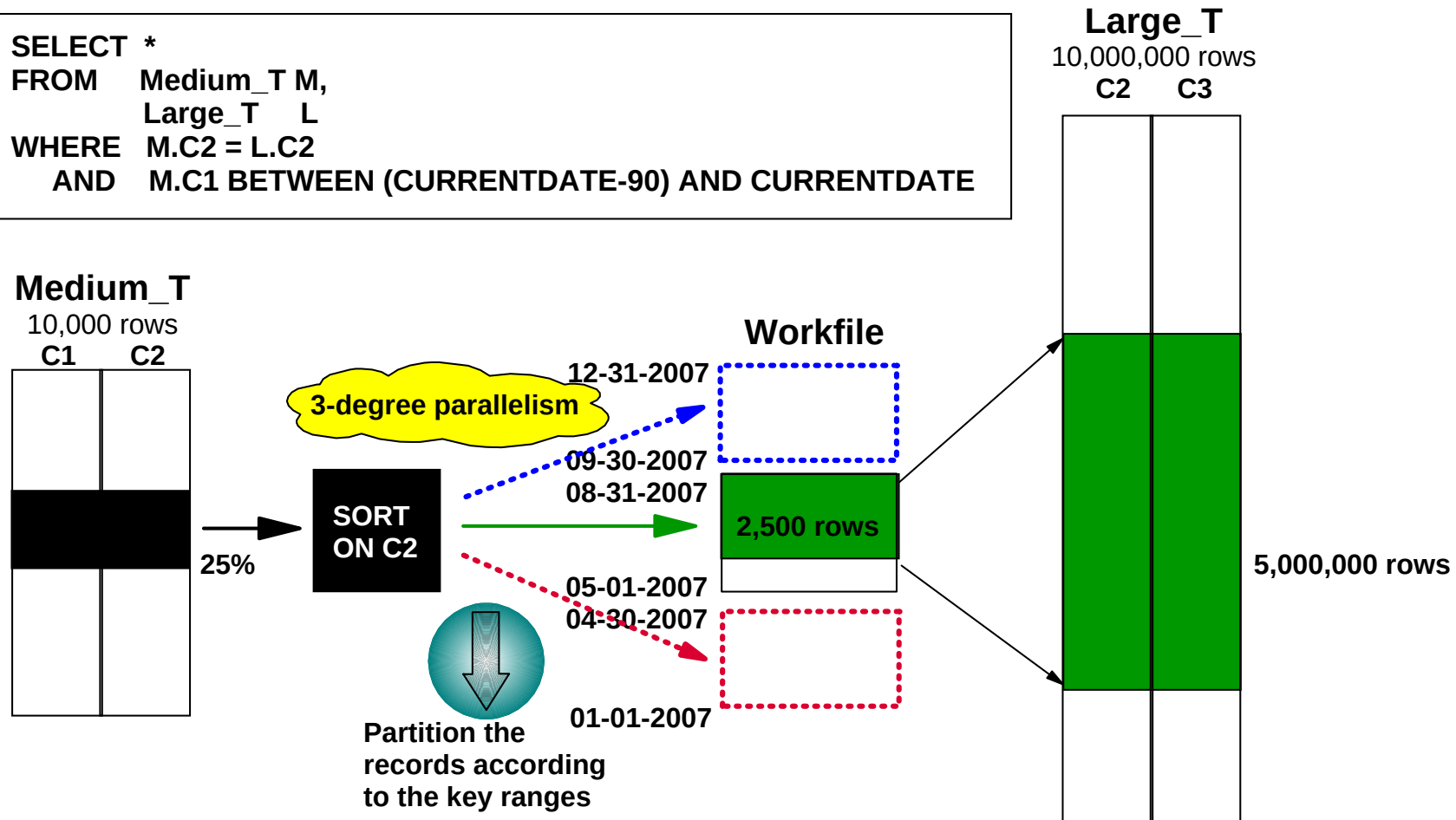


Parallelism Enhancements - Effectiveness

- **Previous Releases of DB2 may use Key Range Partitioning**
  - Key Ranges Decided at Bind Time
  - Based on Statistics (low2key, high2key, column cardinality)
    - Assumes uniform data distribution
    - Histograms can help
      - But rarely collected
  - If Statistics are outdated or data is not uniformly distributed what happens to performance?

Key range partition - Today

```
SELECT  *
FROM    Medium_T M,
        Large_T   L
WHERE   M.C2 = L.C2
  AND   M.C1 BETWEEN (CURRENTDATE-90) AND CURRENTDATE
```



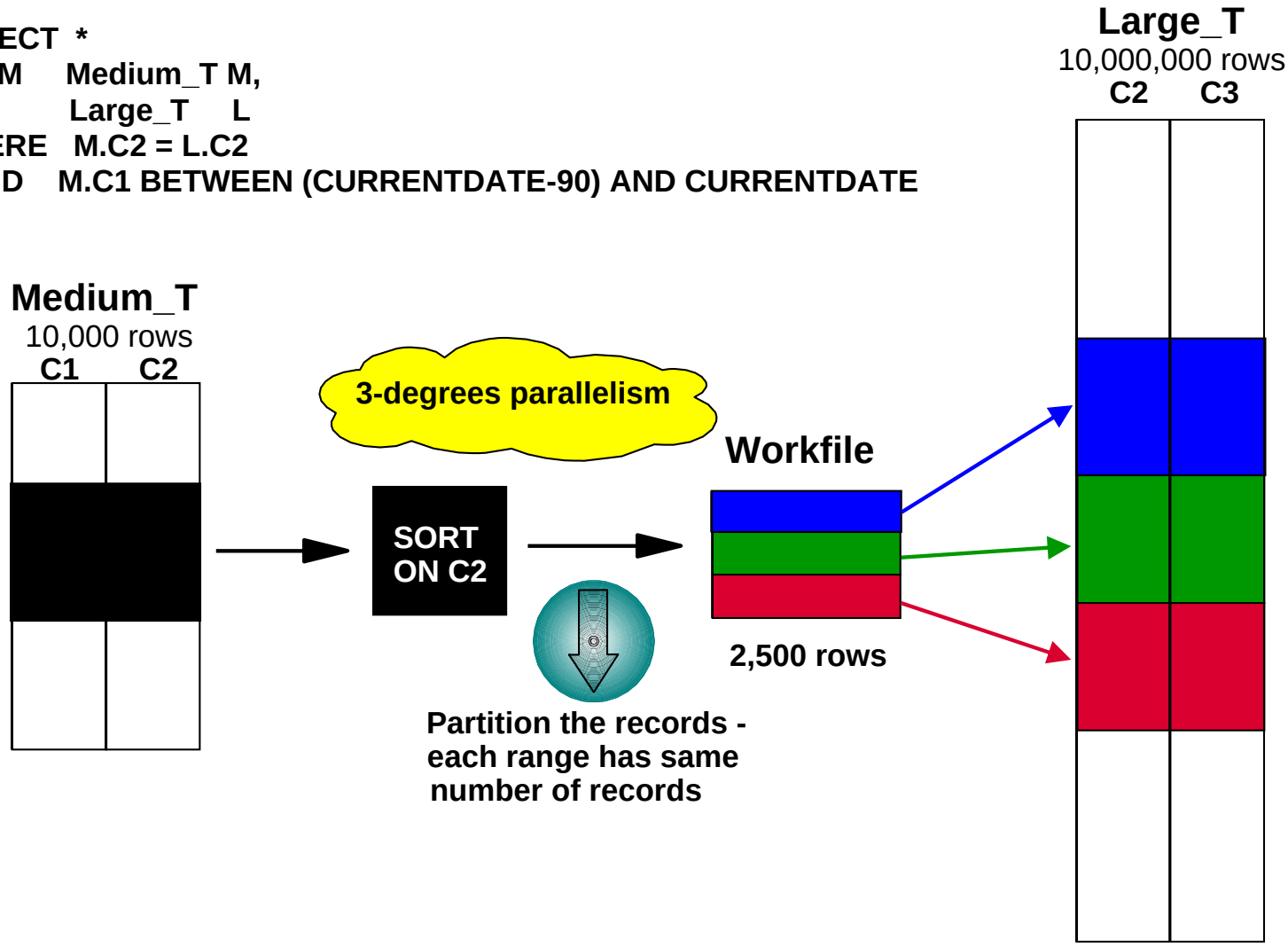
M.C1 is date column, assume currentdate is 8-31-2007, after the between predicate is applied, only rows with date between 06-03-2007 and 8-31-2007 survived, but optimizer chops up the key ranges within the whole year after the records are sorted :-(

Parallelism Effectiveness – Record range

- **DB2 10 can use** Dynamic record range partitioning
  - Materialize the intermediate result in a sequence of join processes
  - Results divided into ranges with equal number of records
  - Division doesn't have to be on the key boundary
    - Unless required for group by or distinct function
  - Record range partitioning is dynamic
    - no longer based on the key ranges decided at bind time
  - Now based on number of composite records and parallel degree
    - Data skew, out of date statistics etc. will not have any effect on performance

Dynamic record range partition

```
SELECT  *
FROM    Medium_T M,
        Large_T  L
WHERE   M.C2 = L.C2
  AND   M.C1 BETWEEN (CURRENTDATE-90) AND CURRENTDATE
```



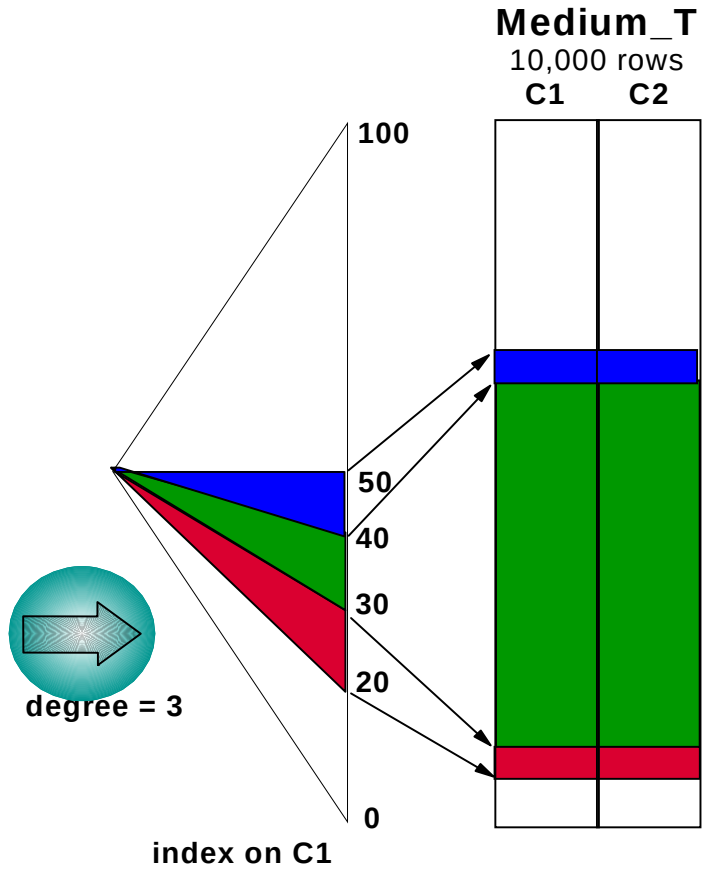
Parallelism Effectiveness - Straw Model

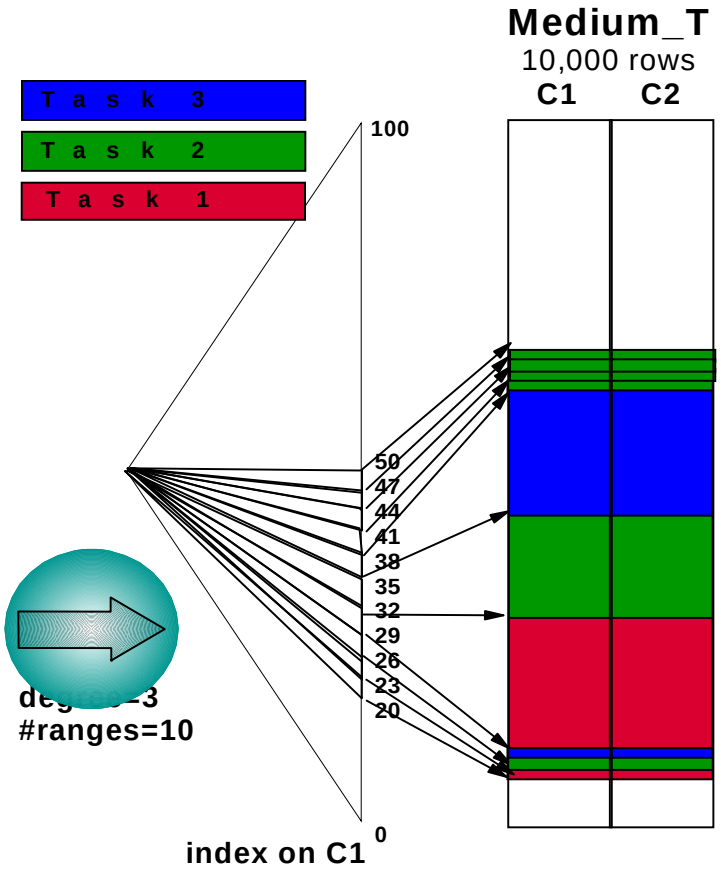
- **Previous releases of DB2 divide the number of keys or pages by the number representing the parallel degree**
  - One task is allocated per degree of parallelism
  - The range is processed and the task ends
  - Tasks may take different times to process

- **DB2 10 can use the Straw Model workload distribution method**
  - More key or page ranges will be allocated than the number of parallel degrees
  - The same number of tasks as before are allocated (same as degree)
  - Once a task finishes it's smaller range it will process another range
  - Even if data is skewed this new process should make processing faster

STRAW Model

```
SELECT  *
FROM    Medium_T M
WHERE   M.C1 BETWEEN 20 AND 50
```



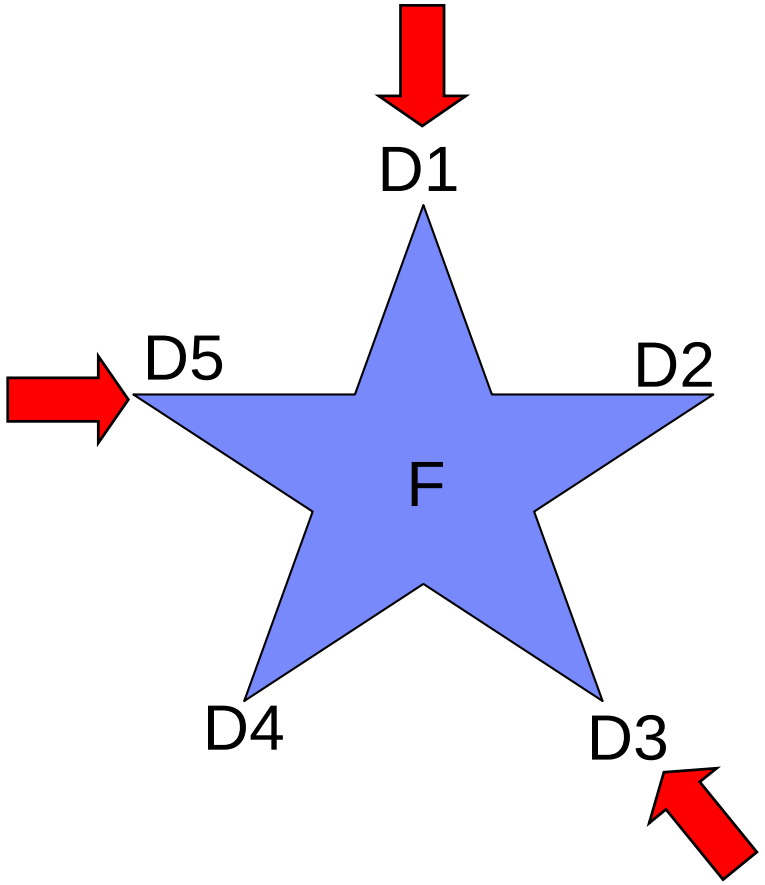


Divided in key ranges before DB2 10

Divided in key ranges with Straw Model

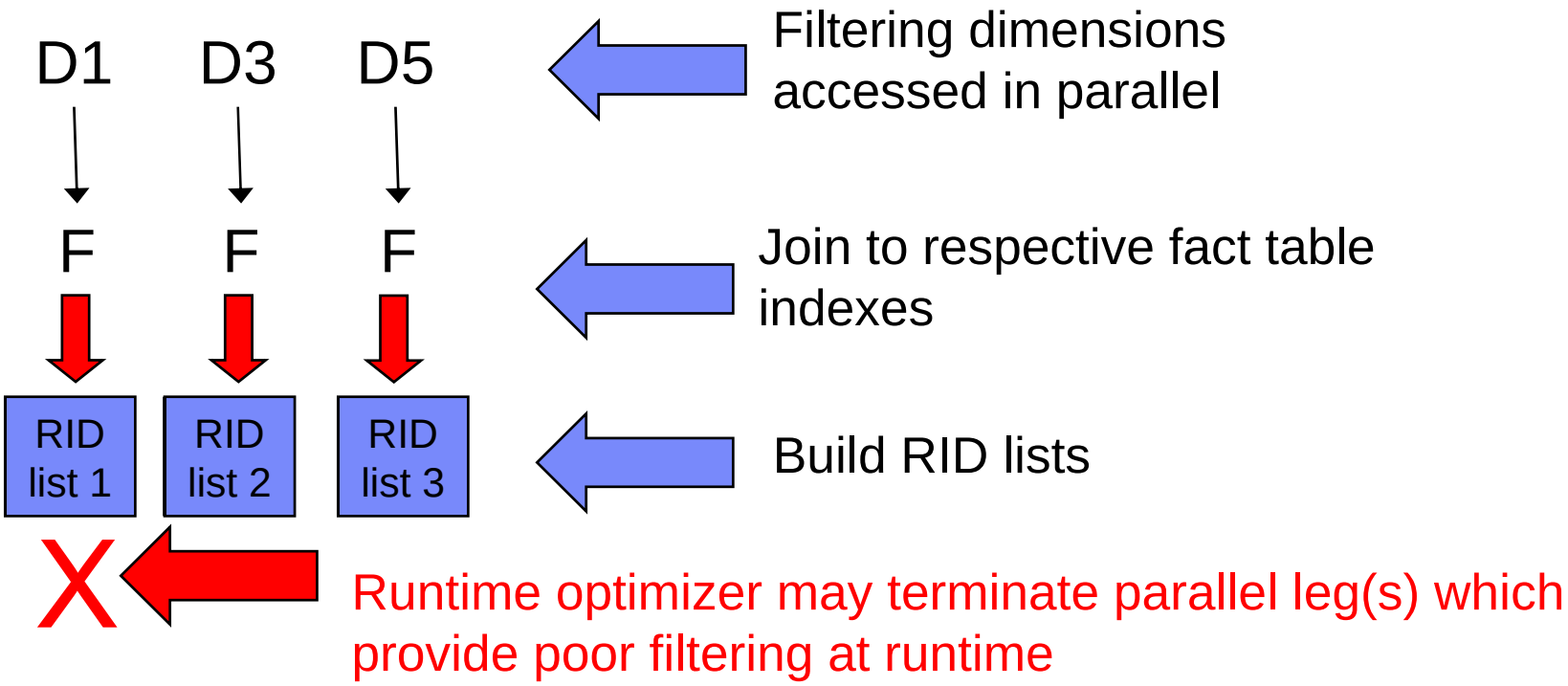
Dynamic Index ANDing Challenge

- **Filtering may come from multiple dimensions**
  - Creating multi-column indexes to support the best combinations is difficult



Index ANDing – Pre-Fact

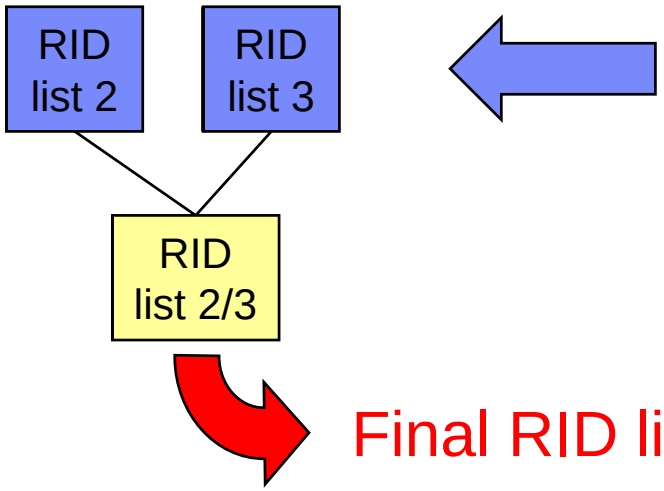
- **Pre-fact table access**
  - –Filtering may not be (truly) known until runtime



Index ANDing – Fact and Post-Fact

- **Fact table access**
  - –Intersect filtering RID lists
  - –Access fact table
    - From RID list
- **Post fact table**
  - –Join back to dimension tables

Using parallelism



Remaining RID lists are "ANDed" (intersected)

Final RID list used for parallel fact table access

Dynamic Index Anding Highlights

- **Pre-fact table filtering**
  - Filtering dimensions accessed concurrently
- **Runtime optimization**
  - Terminate poorly filtering legs at runtime
- **More aggressive parallelism**
- **Fallback to workfile for RID pool failure**
  - Instead of r-scan

APAR PK76100 – zparm to enable EN_PJSJ