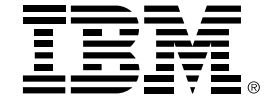


# IBM System z Technology Summit



DB2 9 & DB2 10 for z/OS Optimizer  
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# Agenda

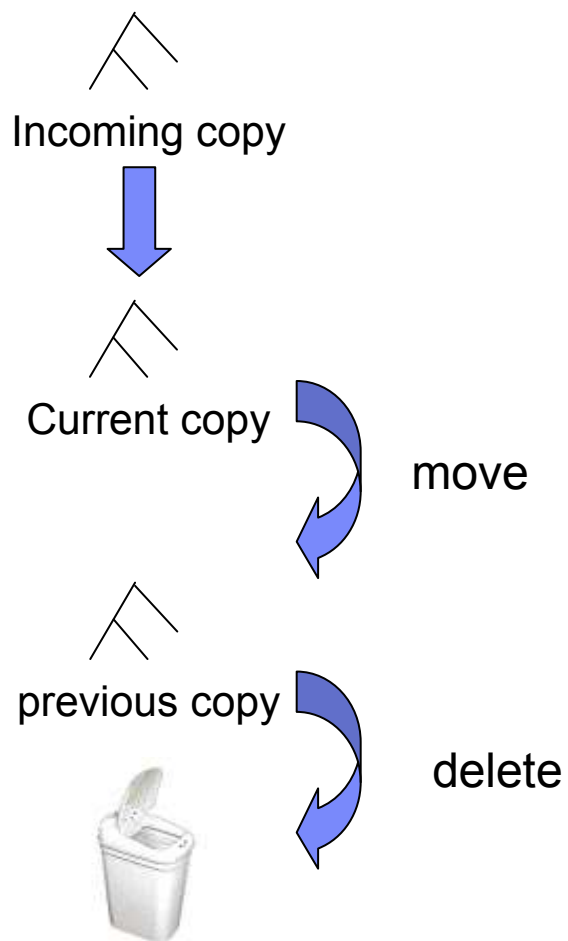
- **Bind/Prepare**
  - Plan management
  - Hints/Bind options
  - Explain
  - Dynamic Statement Caching
  - REOPT
- **Optimizer costing**
- **Runtime query performance**
- **Indexing**
- **Complex queries**

# 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)

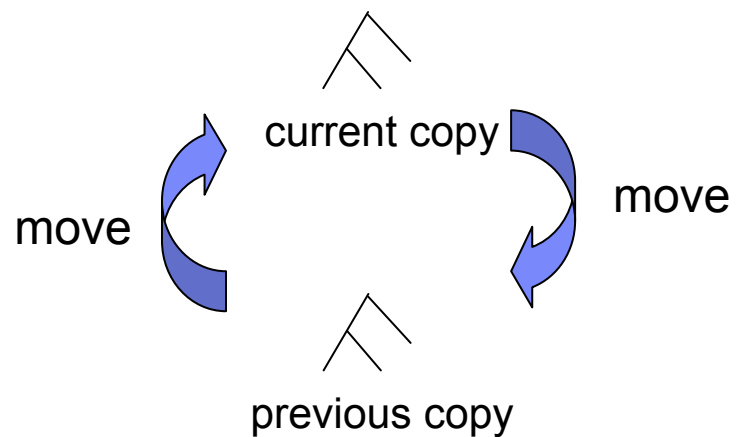
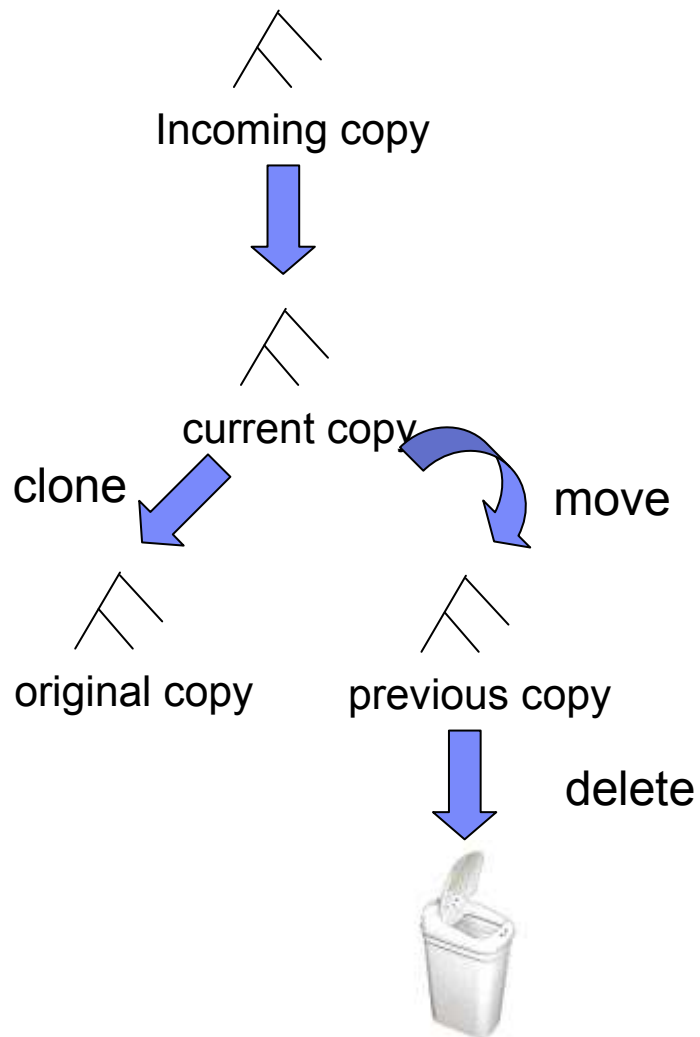


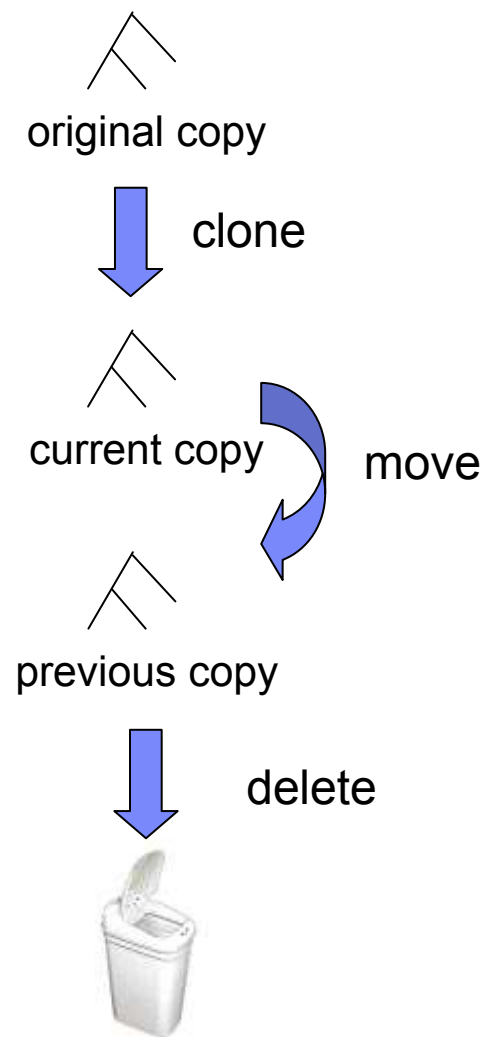
Chart is to be read from bottom to top

# Plan Management - EXTENDED support

REBIND ... PLANMGMT(EXTENDED)



REBIND ... SWITCH(ORIGINAL)



# Plan Management Notes

- **REBIND PACKAGE ...**
  - PLANMGMT (BASIC)  
2 copies: Current and Previous
  - PLANMGMT (EXTENDED)  
3 copies: Current, Previous, Original
  
- **REBIND PACKAGE ...**
  - SWITCH(PREVIOUS)  
Switch between current & previous
  - SWITCH(ORIGINAL)  
Switch between current & original
  
- **Most bind options can be changed at REBIND**
  - *But a few must be the same ...*
  
- 3 important updates:
  1. APAR PK80375 – SPT01 Compression (DB2 V8 & 9)
  2. APAR PM09354 – Support DBPROTOCOL change
  3. Article – Search for “Escaping the REBIND blues in DB2 9 for z/OS”
  
- **FREE PACKAGE ...**
  - PLANMGMTSCOPE(ALL) – Free package completely
  - PLANMGMTSCOPE(INACTIVE) – Free old copies
  
- **Catalog support**
  - SYSPACKAGE reflects active copy
  - SYSPACKDEP reflects dependencies of all copies
  - Other catalogs (SYSPKSYSTEM, ...) reflect metadata for all copies
  
- **Invalidation and Auto Bind**
  - Each copy invalidated separately

# 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.**

## 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
  - Package level BIND options
- **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

# Dynamic SQL REOPT - AUTO

- **For dynamic SQL with parameter markers**
  - DB2 will automatically reoptimize the SQL when
    - **Filtering of one or more of the predicates changes dramatically**
      - Such that table join sequence or index selection may change
    - Some statistics cached to improve performance of runtime check
  - Newly generated access path will replace the global statement cache copy.
  
- **First optimization is the same as REOPT(ONCE)**
  - Followed by analysis of the values supplied at each execution of the statement



# Agenda

- **Bind/Prepare**
- **Optimizer costing**
  - RUNSTATS
  - Cost model enhancements
  - Subquery costing
- **Runtime query performance**
- **Indexing**
- **Complex queries**

# Clusterratio Enhancement

- **New Clusterratio formula in DB2 9**

- Including new DATAREPEATFACTOR statistic

- Differentiates density and sequential



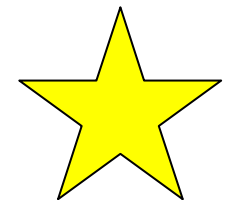
Dense (and sequential)



Sequential (not dense)

- **Controlled by zparm STATCLUS**

- ENHANCED is default
- STANDARD disables, and is NOT recommended



- **Recommend RUNSTATS before mass REBIND in first version AFTER V8**

# Clusterratio Impacts

- **Clusterratio may be**
  - Higher for indexes
    - With many duplicates (lower colcardf)
      - In recognition of sequential RIDs
    - On smaller tables
      - Less clusterratio degradation from random inserts
    - Indexes that are reverse sequential
  - Lower for random indexes
    - No benefit from dynamic prefetch
- **Clusterratio(CR)/DataRepeatfactor (DRF) patterns**

	High DRF	Low DRF
High CR	Sequential but not dense	Density matching clustering or small table
Low CR	Random index	Unlikely

## 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**

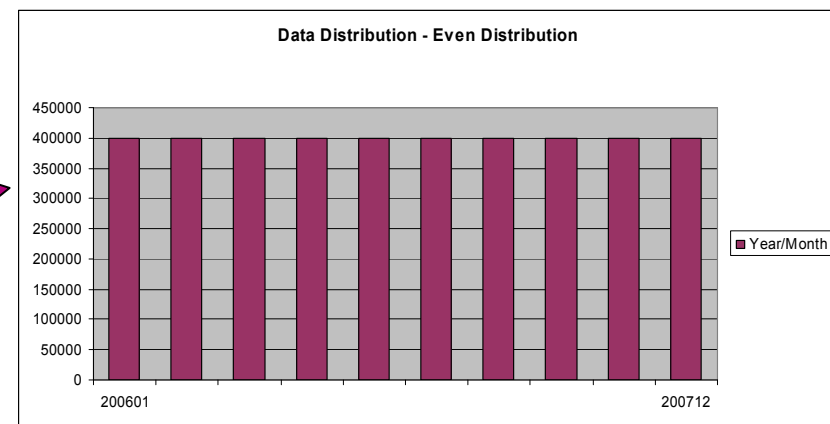
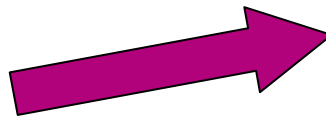
# Histogram Statistics Example

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

WHERE YEARMONTH BETWEEN 200601 AND 200612

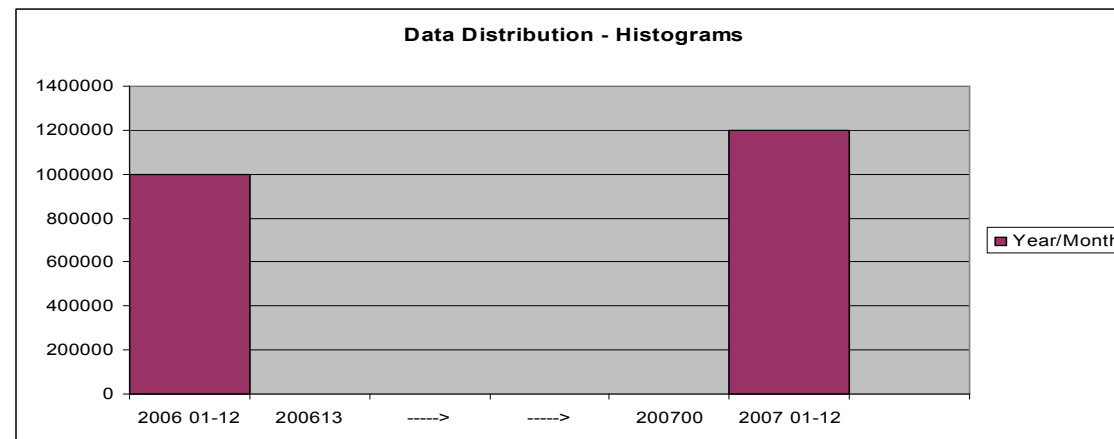
- Assuming data for 2006 & 2007
  - $FF = (\text{high-value} - \text{low-value}) / (\text{high2key} - \text{low2key})$
  - $FF = (200612 - 200601) / (200711 - 200602)$
  - **10% of rows estimated to return**

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 through 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 NPGTHRS

- **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
    - Avoids list prefetch
      - Can be a problem for OR predicates or UPDATES at risk of loop
  
- **DB2 10 extends 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
    - Index access without limitation on list prefetch

## 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**
- **Runtime query performance**
  - Sort/sort avoidance
  - Sparse index
  - Predicate application
- **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  $(n * (\text{sort key} + \text{data})) < 32\text{K}$
- DB2 10 extends this to 128K

## ▪ **Avoid workfile usage for small sorts**



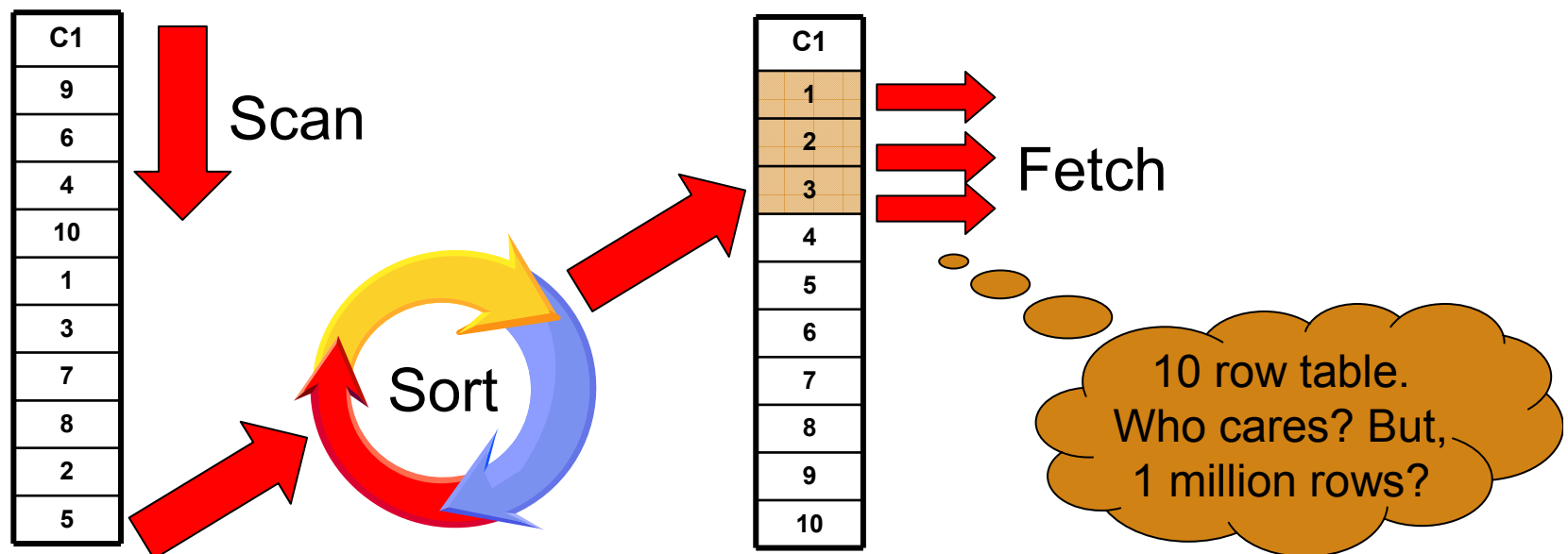
- DB2 9 avoided allocating WF for final sort only
  - If  $\leq 255$  rows and result  $< 32\text{K}$  (sort key + data)
- DB2 10 extends this to intermediate sorts also
  - Except for parallelism or SET function

# 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
```

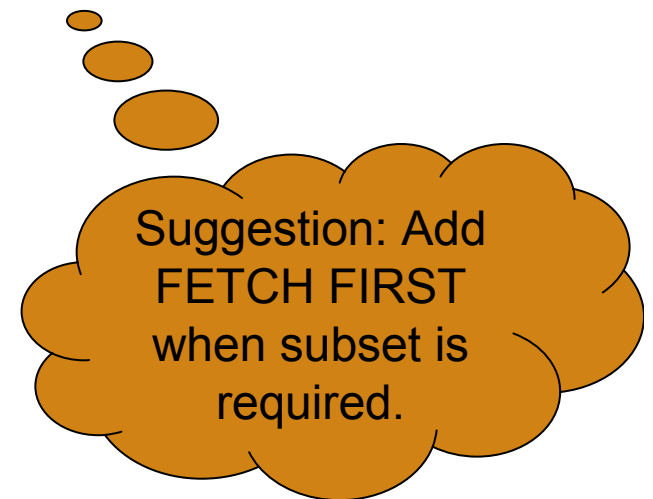
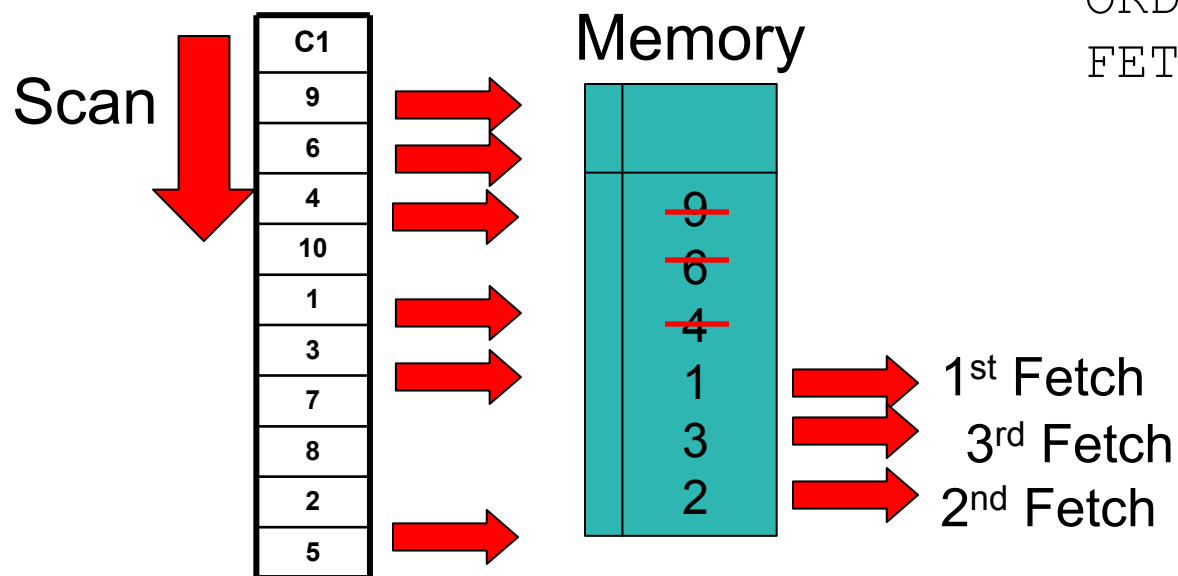


# Improving sort with FETCH FIRST

## ▪ 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
```



## 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



## 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: TBTYP – 'I'
  - New Access Type: ACTYP – 'IN'

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

QBNO	PLANNO	METHOD	TNAME	ACTYPE	MC	ACNAME	QBTYPE	TBTYP	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='JONES' AND FIRSTNAME='WENDY')  
      OR (LASTNAME='SMITH' AND FIRSTNAME='JOHN');
```

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

## 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**

- **Indexing**
  - Index on expression
  - Tracking index use
  - Sparse index
  - Include columns

- **Complex queries**

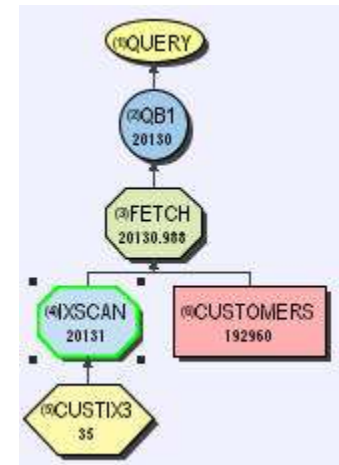
# Index on Expression

- **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

## Index Enhancement - Tracking Usage

- **Additional indexes require overhead for**
  - Utilities
    - REORG, RUNSTATS, LOAD etc
  - Data maintenance
    - INSERT, UPDATE, DELETE
  - Disk storage
  - Optimization time
    - Increases optimizer's choices
  
- **But identifying unused indexes is a difficult task**
  - Especially in a dynamic SQL environment

# Tracking Index Usage

- **RTS records the index last used date.**
  - SYSINDEXSPACESTATS.LASTUSED
    - Updated once in a 24 hour period
      - RTS service task updates at 1st externalization interval (set by STATSINT) after 12PM.
    - if the index is used by DB2, update occurs.
    - If the index was not used, no update.
  
- **"Used", as defined by DB2 as:**
  - As an access path for query or fetch.
  - For searched UPDATE / DELETE SQL statement.
  - As a primary index for referential integrity.
  - To support foreign key access



## Tracking Index Usage Implications

- **What can you do with this information?**
  - LAST\_USED only shows when the index was last used
    - Cannot predict future use
  
  - Assume you decide to DROP an index due to lack of usage
    - Is the index UNIQUE?
      - Is there another index that can guarantee that UNIQUENESS?
    - Related statistics will be dropped
      - Same issue as “What If?” Optimization
      - For index on C1, C2, C3
        - > RUNSTATS options to collect statistics

```
COLGROUP (C1)  FREQVAL  COUNT  10  
COLGROUP (C1, C2, C3)
```

# 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

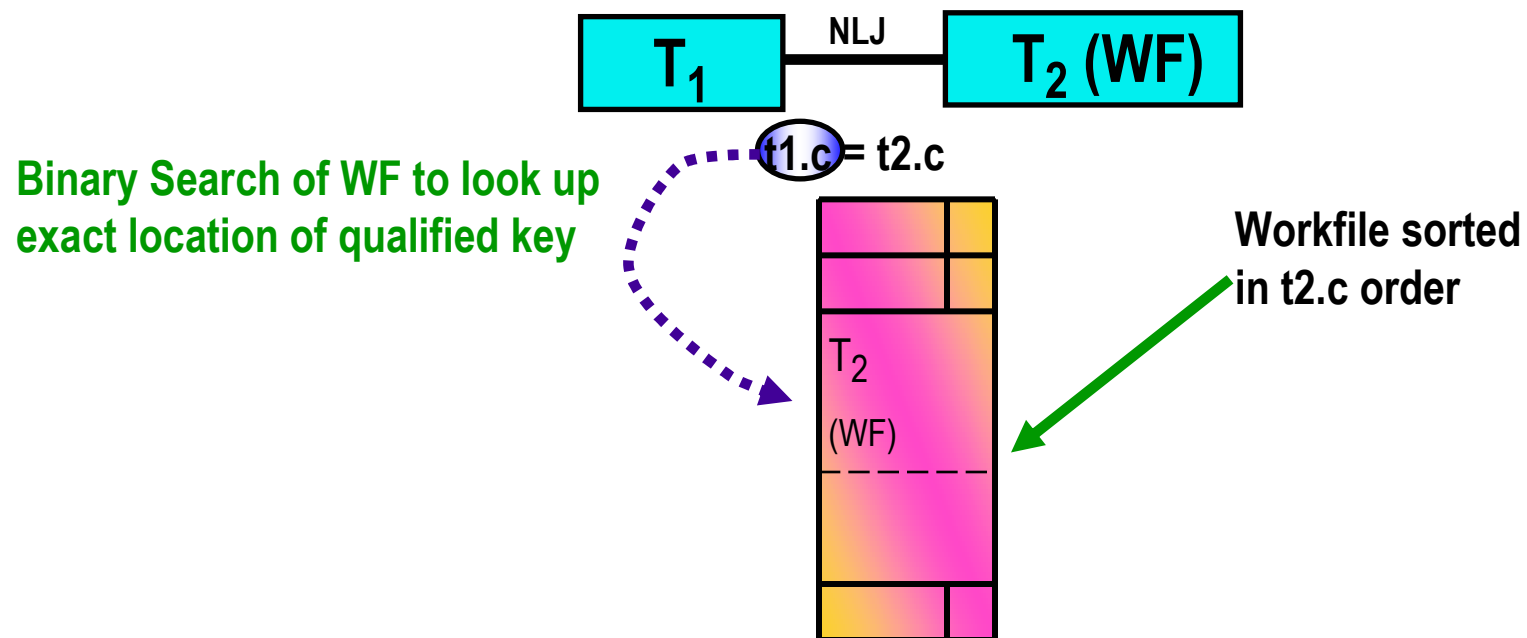
- Maximum extent in MB, for data caching per thread
- If memory is insufficient
  - Fall-back to sparse index at runtime

## ▪ 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)
```



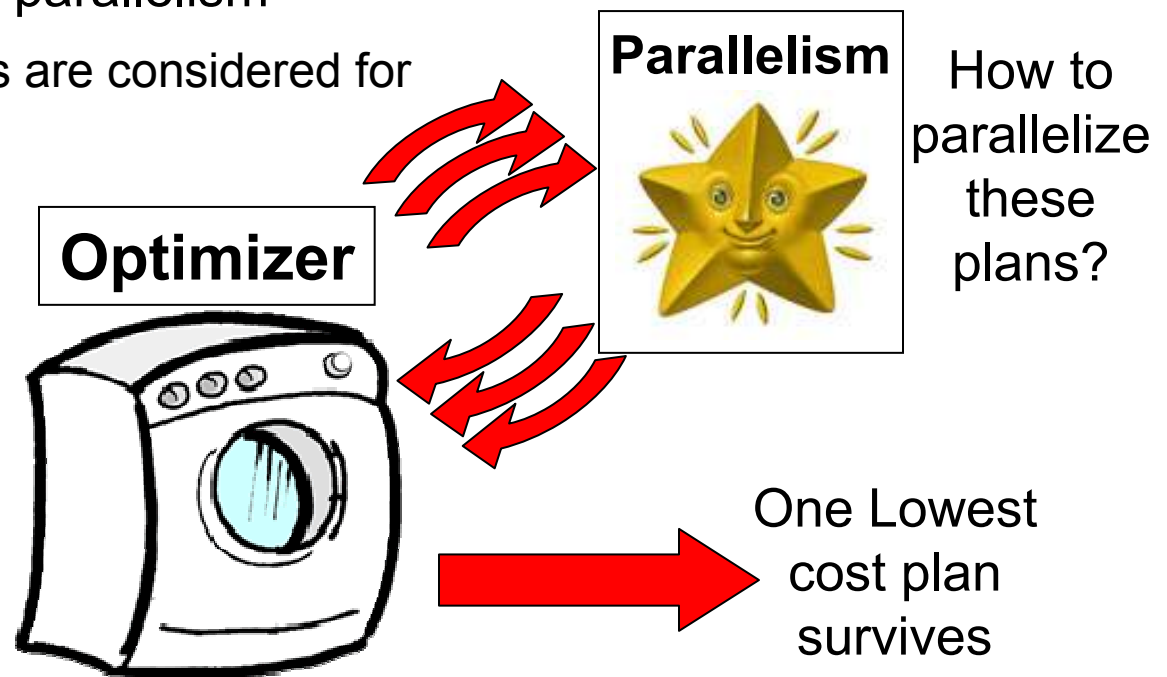
```
Consolidate to  
INDEX1 UNIQUE (C1) INCLUDE (C2)
```

# Agenda

- **Bind/Prepare**
- **Optimizer costing**
- **Runtime query performance**
- **Indexing**
- **Complex queries**
  - Parallelism
  - BI/DW

# 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



## Additional DB2 9 Parallelism Enhancements

- **Degree can cut on non-leading table**
  - Benefit for leading workfile, 1-row table etc.
  
- **Histogram statistics exploited for more even distribution**
  
- **New zparm `PARA_EFF`**
  - Controls optimizer cost reduction applied for parallelism benefit
    - Default 50 (%)
    - Lower PARAMDEG can tolerate higher `PARA_EFF`
    - Higher PARAMDEG may mean lower `PARA_EFF`

# Removal Of Parallelism Restrictions #1

- Support parallelism for multi-row fetch
  - **In previous releases**
    - parallelism is disabled for the last parallel group in the top level query block
      - if there is no more table to join after the parallel group
      - and there is no GROUP BY clause or ORDER BY clause
  - Example:- `SELECT * FROM CUSTOMER`
    - There is no parallel group in the query and there are no table joins
    - There is no GROUP BY clause
    - There is no ORDER BY clause
    - So NO PARALLELISM will be used
  
- **This restriction is only removed if the CURSOR is DECLARED as READ ONLY**
  - Ambiguous Cursors will not have the restriction removed



## Removal Of Parallelism Restrictions #2

- **Allow parallelism if a parallel group contains a work file**
  - DB2 generates temporary a work file when view or table expression is materialized
  - This type of work file can not be shared among child task in previous releases of DB2, hence parallelism is disabled
  - **DB2 10 will make the work file shareable**
    - only applies to CP mode parallelism and no full outer join case

# 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
    
```

**Medium\_T**  
10,000 rows  
C1 C2

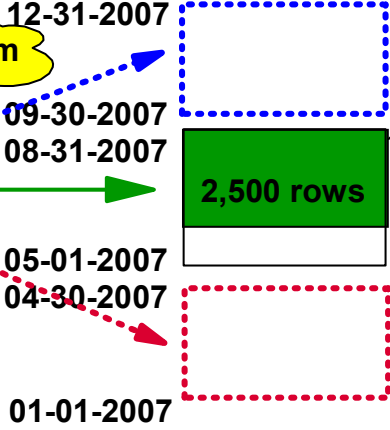

25%

3-degree parallelism

**SORT  
ON C2**



Partition the records according to the key ranges



**Large\_T**  
10,000,000 rows  
C2 C3


5,000,000 rows

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

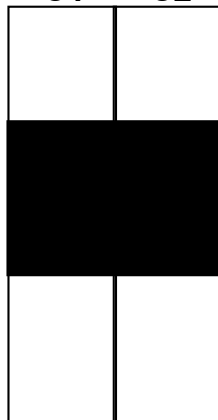
- **DB2 10 can use** Dynamic record range partitioning
  - Materialize the intermediate result in a sequence of join processes
  - Results divided into ranges with equal number of records
  - Division doesn't have to be on the key boundary
    - Unless required for group by or distinct function
  - Record range partitioning is dynamic
    - no longer based on the key ranges decided at bind time
  - Now based on number of composite records and number of workload elements
    - 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
    
```

**Medium\_T**  
10,000 rows  
C1 C2



25%

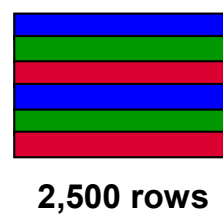
3-degree parallelism  
10 ranges

**SORT  
ON C2**



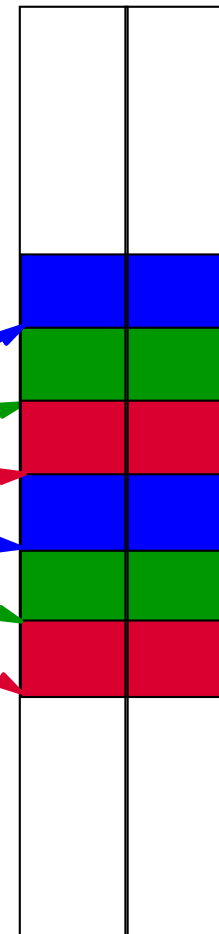
Partition the records -  
each range has same  
number of records

**Workfile**



2,500 rows

**Large\_T**  
10,000,000 rows  
C2 C3



5,000,000 rows

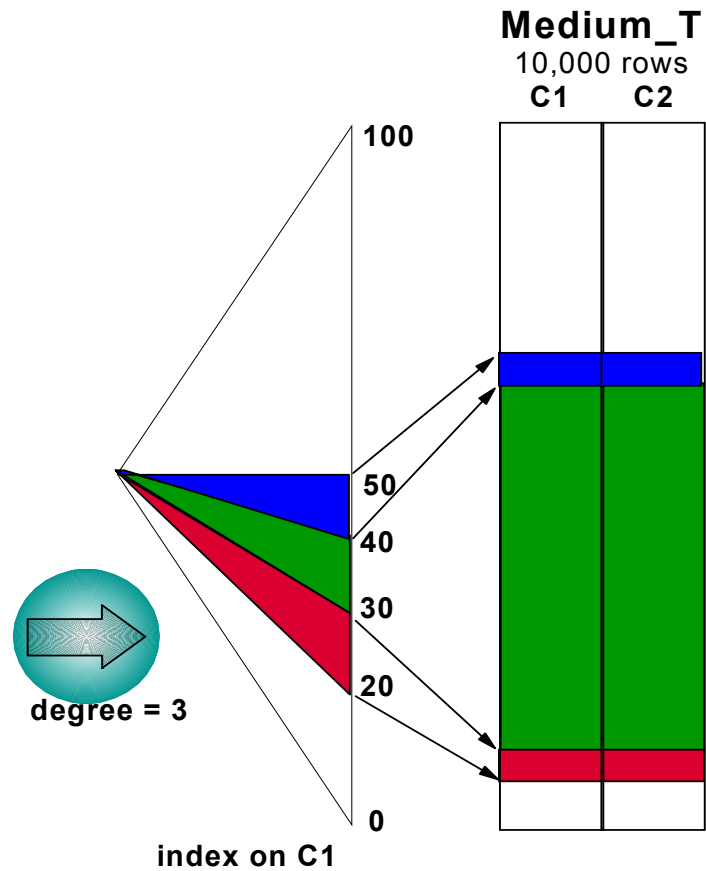
**Task 3**  
**Task 2**  
**Task 1**

## Parallelism Effectiveness - Straw Model

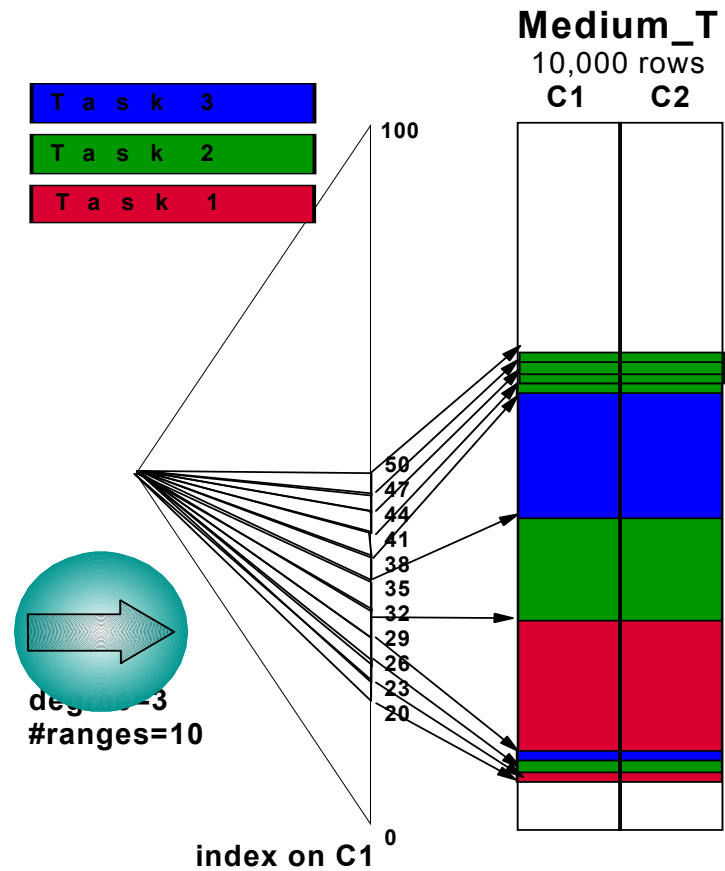
- **Previous releases of DB2 divide the number of keys or pages by the number representing the parallel degree**
  - One task is allocated per degree of parallelism
  - The range is processed and the task ends
  - Tasks may take different times to process
  
- **DB2 10 can use the Straw Model workload 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 its 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
```



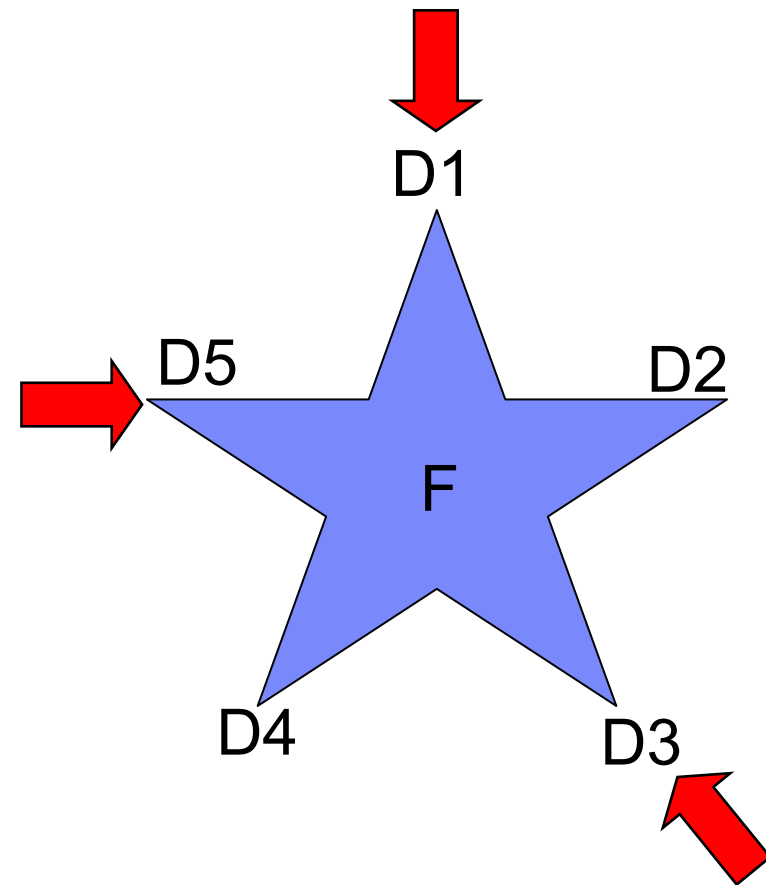
Divided in key ranges before DB2 10



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

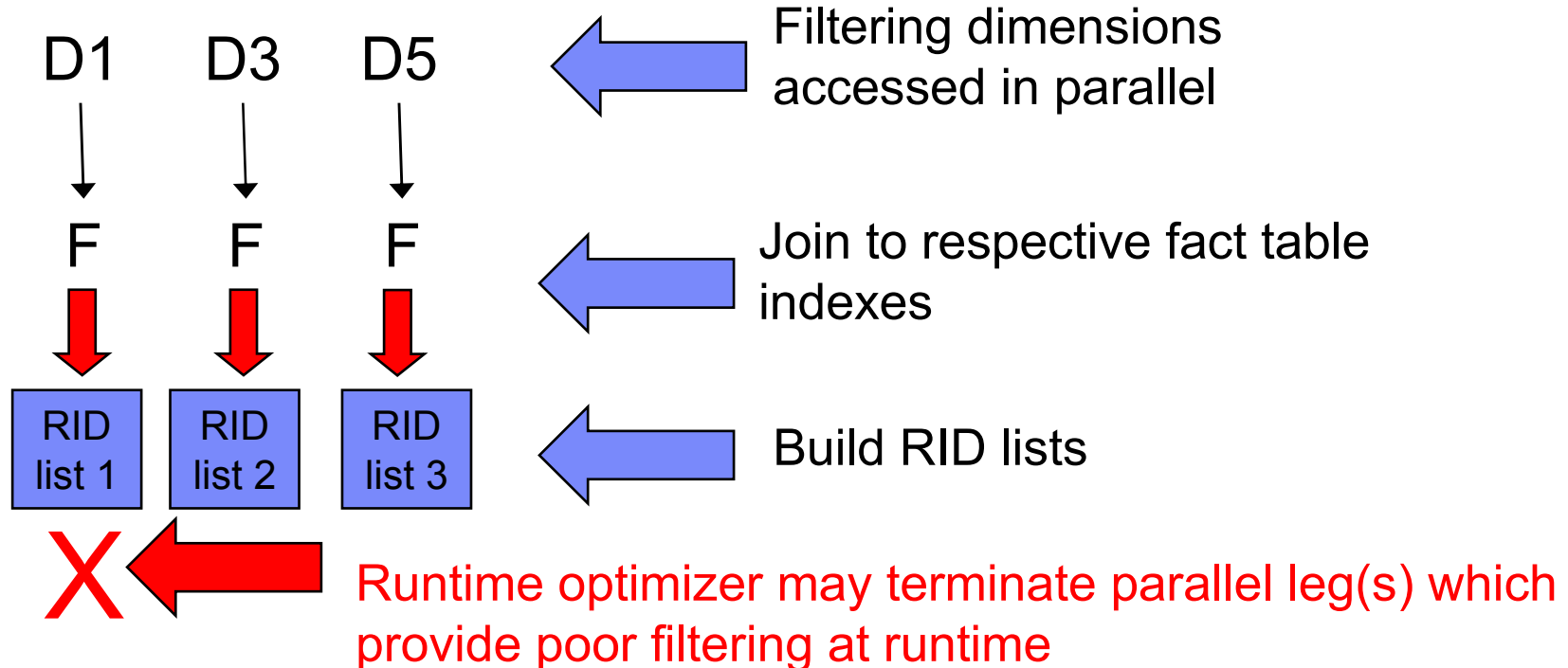




## Index ANDing – Pre-Fact

- **Pre-fact table access**

- Filtering may not be (truly) known until runtime



## Index ANDing – Fact and Post-Fact

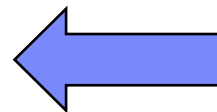
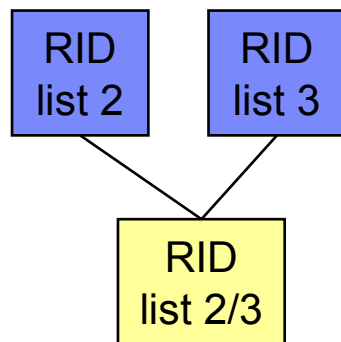
- **Fact table access**

- 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**