Exciting Optimizer and SQL Performance Enhancements in DB2 9 for z/OS and Beyond

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Agenda

- Plan Stability
- Indexing Enhancements
- General Query Performance Enhancements
- Histogram Statistics
- Generalized sparse index and in-memory data cache
- REOPT AUTO
- V10 Query Performance Enhancements

Plan Stability

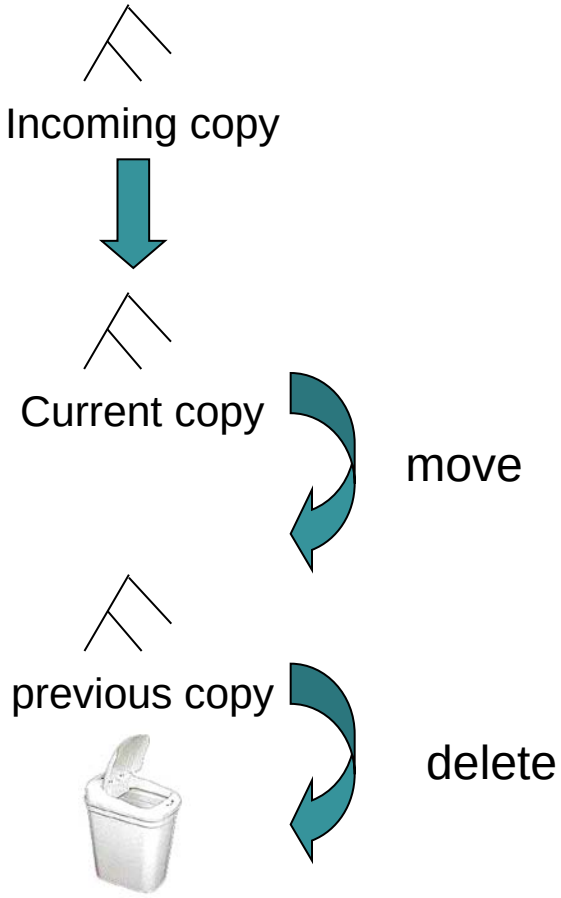
Plan Stability Overview

- Ability to backup your static SQL packages

- 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 Stability - BASIC support

REBIND … PLANMGMT(BASIC)



REBIND … SWITCH(PREVIOUS)

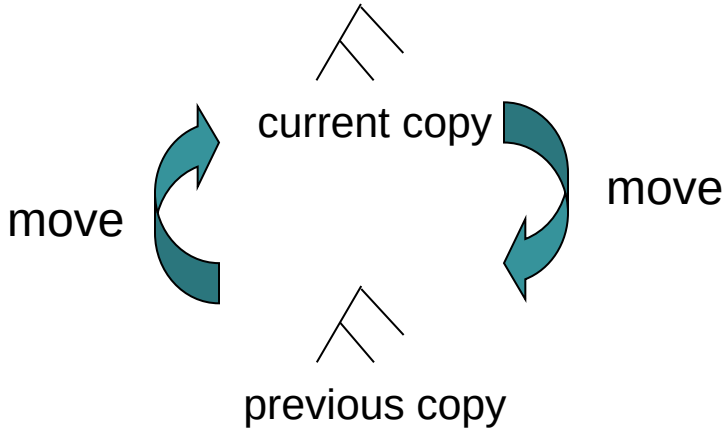
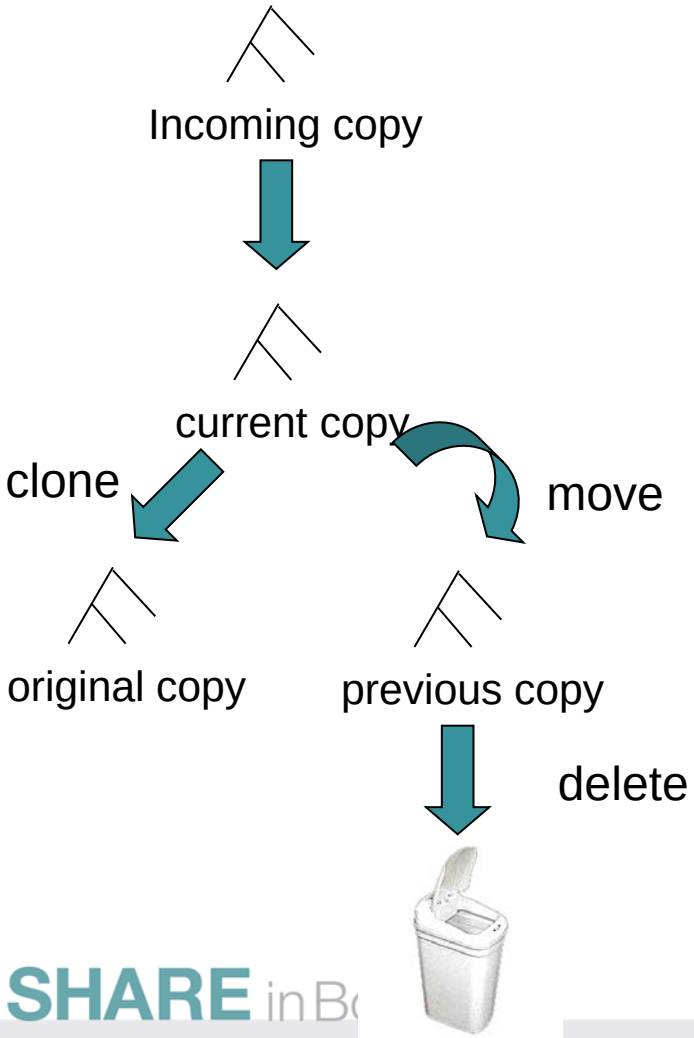


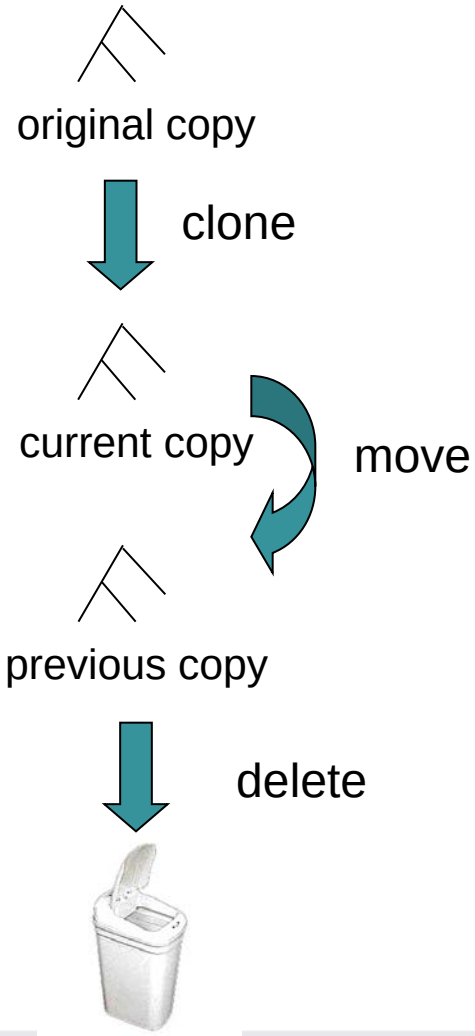
Chart is to be read from bottom to top

Plan Stability - EXTENDED support

REBIND … PLANMGMT(EXTENDED)



REBIND … SWITCH(ORIGINAL)



Access Plan Stability 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 …*

- 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

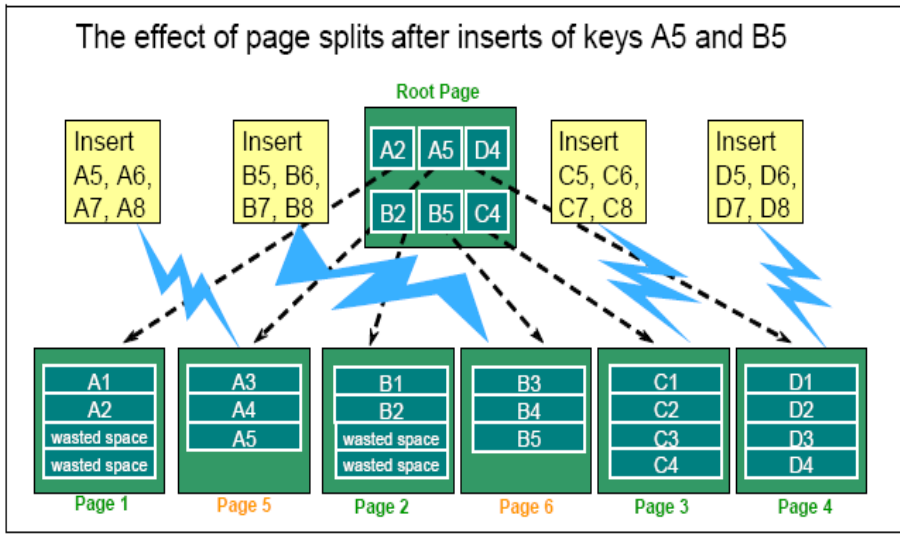
Indexing Enhancements

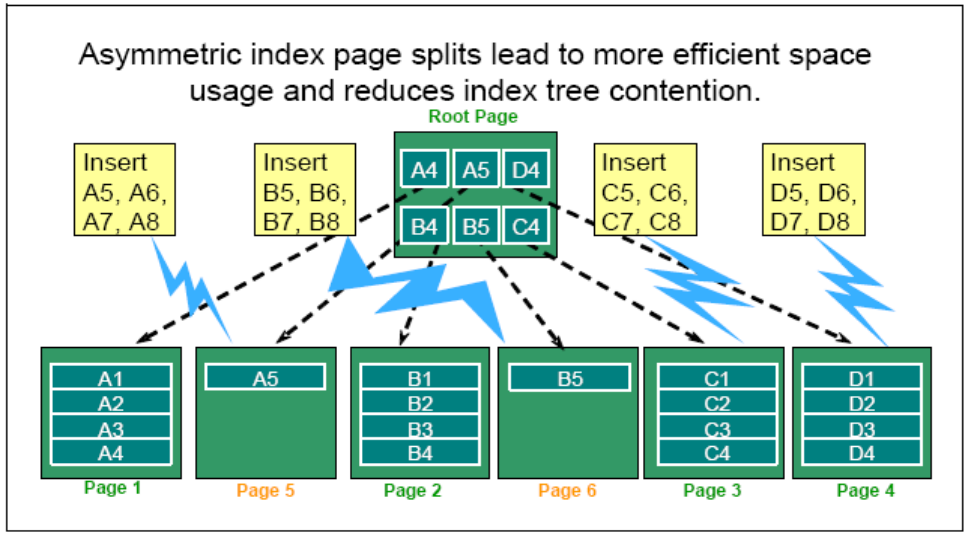
Insert/Update/Delete Performance

- DB2 9 addresses several traditional problem areas for high bandwidth INSERT/UPDATE/DELETE workloads.
  - Log Latch Contention (LC 19) and LRSN Spin (NFM & DS)
  - IX Leaf Page Split Overhead
  - Free Space Search Overhead
  - IX and DATA hot spots
- Table Space APPEND Option (can ALTER on and off)
- Not Logged Tablespaces
- Asymmetric Leaf Page Split
- Randomized Index Key
- Larger Index Page Sizes
- Increased Index Look-aside

- Up to 2x increased logging rate
- 10x reduction in LC19 waits
- Adjust LOGBUFF accordingly

Asymmetric Index Page Split (NFM)



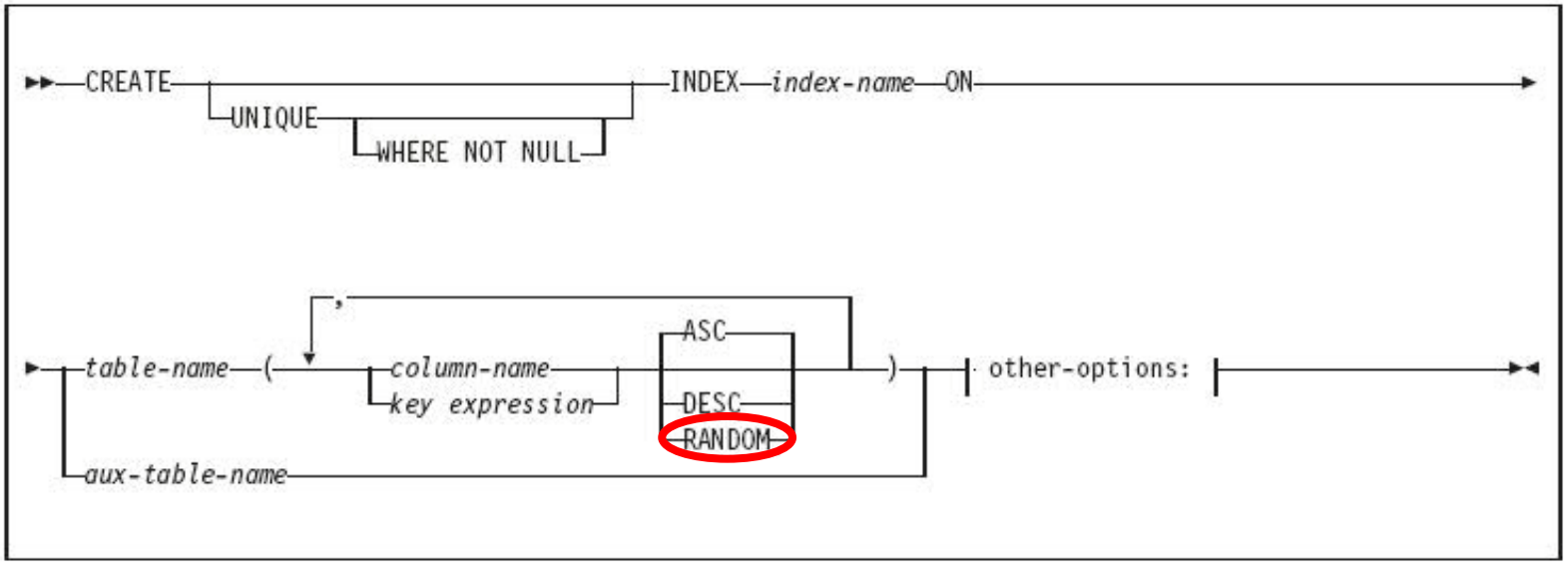


- Index split roughly 50/50 (prior to DB2 9)
- Sequential inserts → ~50% free space

- Up to 50% reduction in IX page splits
- Up to 20% reduction in DB2 CPU
- Up to 30% reduction in DB2 ET

- New algorithm dynamically accommodates a varying pattern of inserts
- Up to 90/10 split
- Effective across multiple inserting threads (due to tracking at the page level).
- Improve space utilization and reduce contention.

Randomized Index Key (NFM)



- Lock contention relief
- LC 6 relief

Vs.

- Additional getpages
- Additional read/write I/Os
- Increased lock requests

- Cannot support order
- Can provide dramatic improvement or degradation!
- Recommend making randomized indexes bufferpool resident
- Can be any one or more columns of an IX key

Index Compression (NFM)

- Always stored as 4k page on disk
- Best with high BP hit ratio

Difference between data and index compression

	Data	Index
Level of compression	Row	Page (1)
CPU overhead (who is charged for comp/decomp)	In Acctg	In Acctg and/or DBM1 SRB
Comp in DASD	Yes	Yes
Comp in BP and Log	Yes	No
Comp Dictionary	Yes	No (2)
'Typical' Comp Ratio CR	10 - 90%	25 - 75% (3)

Use DSN1COMP utility to predict index compression ratio.

Larger Index page Sizes (NFM)

- 8K, 16K, or 32K page
  - Up to 8 times less index split (16x with asym. IX splits)
- Good for heavy inserts to reduce index splits
  - Especially recommended if high LC6 contention in data sharing
    - 2 forced log writes per split in data sharing
  - Or high LC254 contention in non data sharing shown in IFCID57

- Lower NLEAF & NLEVELS (more keys per page)
- Exploitation of larger page sizes (> 8K) more likely without index compression
- Better IX look-a-side and getpage avoidance
- Can result in increased (or decreased) I/O overhead

- Up to 50% CPU & 40% ET reduction in DS
- Up to 20% CPU & 30% ET reduction in non DS

Index *Look-aside* (CM)

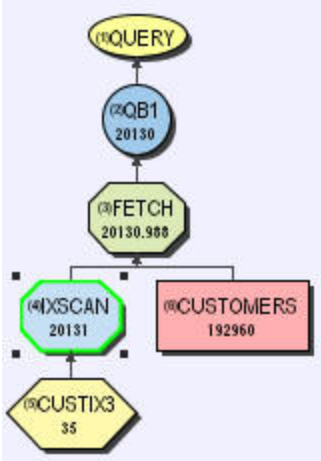
- In V8
  - Insert – clustering index only
  - Delete – no index lookaside
- In V9,
  - Insert & Delete – now possible for additional indexes where CLUSTERRATIO >= 80%
  - IX Update = Delete + Insert
- Potential for big reduction in index getpages and thus CPU time
  - Benchmark Example - Heavy insert
    - Large table, 3 indexes, all in ascending index key sequence,
    - 0+6+6=12 index Getpages per average insert in V8
    - 0+1+1=2 in V9
- Big winner for seq. insert, update or delete patterns

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)
```



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

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

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

General Query Performance Enhancements

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

- Continued….
  - Allow swapping of ordering columns using transitive closure

```
SELECT … FROM T1, T2
WHERE T1.C1 = T2.C1
GROUP BY T1.C1, T2.C3
```

←Contains T1 & T2

    - ordering requirement changed to T2.C1, T2.C3

  - Improvement for 'partially ordered' cases with unique index

```
SELECT C1, C2+C3, C4 FROM T1
GROUP BY 1, 2, 3
```

    - if we have unique index on C4, C1
      - *Sort can be avoided*

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

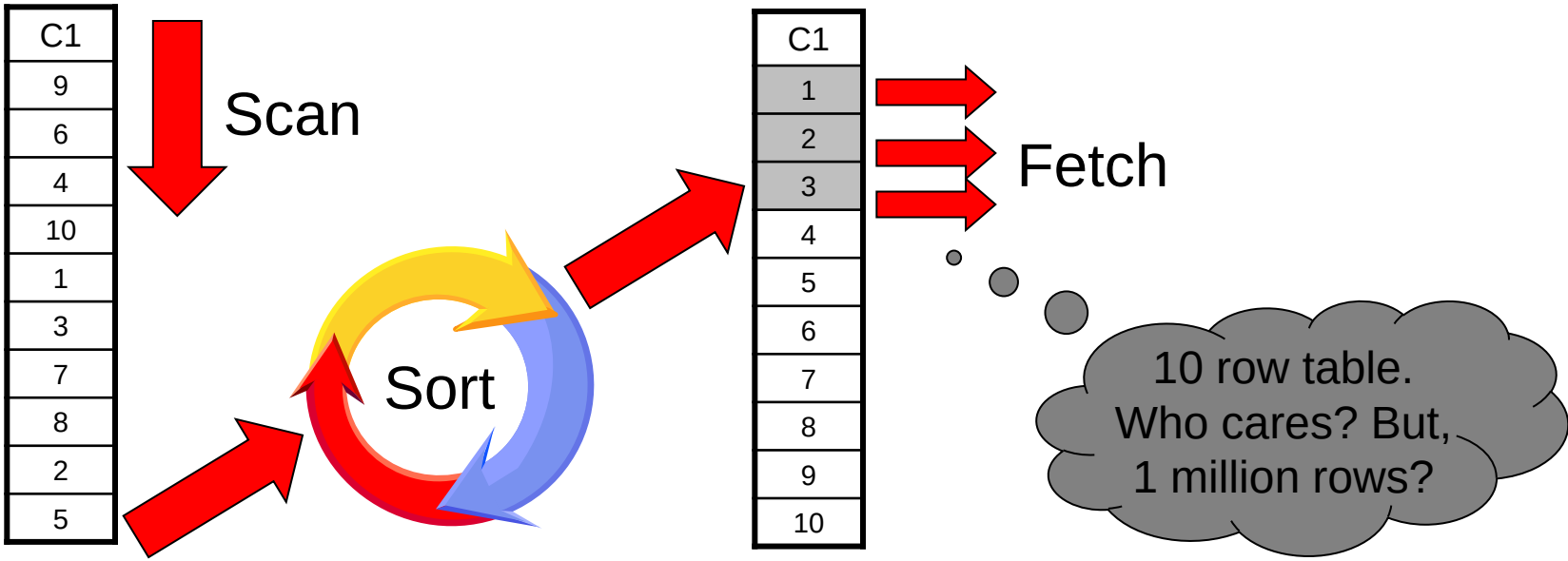
Sort Improvements

- Reduced workfile usage for very small sorts
  - Final sort step requiring 1 page will NOT allocate workfile
- More efficient sort with FETCH FIRST clause
  - V8 and prior,
    - Sort would continue to completion
    - Then return only the requested ‘n’ rows
  - From V9,
    - If the requested ‘n’ rows will fit into a 32K page,
      - *As the data is scanned,*
        - *Only the top ‘n’ rows are kept in memory*
        - *Order of the rows is tracked*
        - *No requirement for final sort*

FETCH FIRST V8 Example

- Sort is not avoided via index
  - Must sort all qualified rows

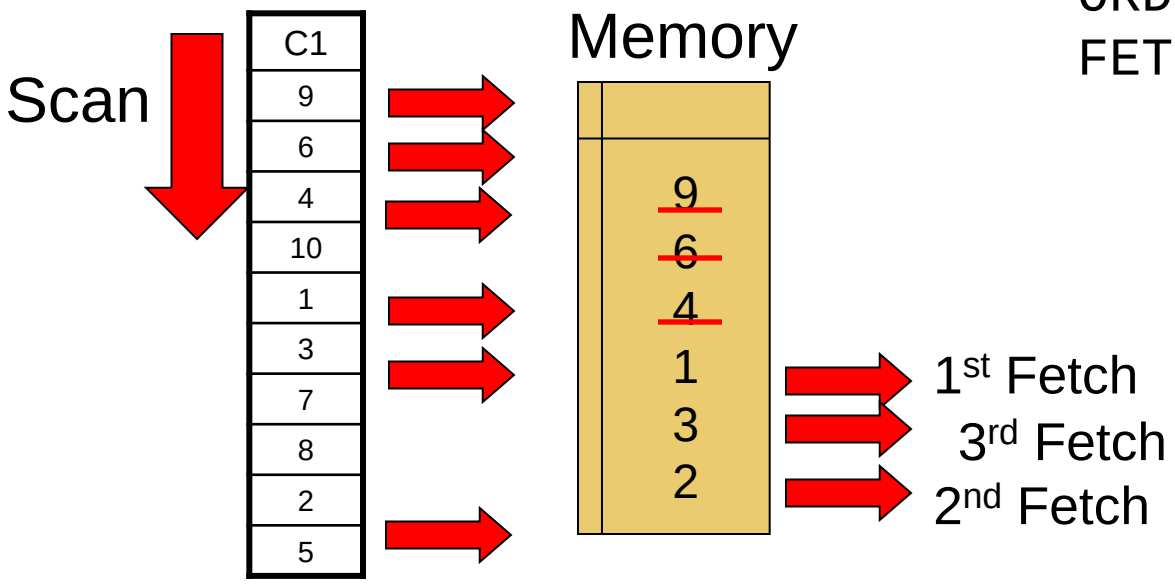
```
SELECT C1
FROM  T
ORDER BY C1
FETCH FIRST 3 ROWS ONLY
```



FETCH FIRST DB2 9 Example

- Sort is not avoided via index
  - But in-memory swap avoids sort
    - Pointers maintain order

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



Suggestion: Add FETCH FIRST when subset is required.

Dynamic Prefetch Enhancements

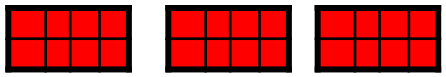
Sequential Prefetch	Dynamic Prefetch
Chosen at bind/prepare time	Detected at runtime
Requires hit to a triggering page	Tracks sequential access pattern
Only prefetch in one direction	Prefetch forward or backward
Used for tablespace scan & LOBs	Used for index & index+data access

- Seq. Pref. cannot fall back to Dyn. Pref. at run time
- Plan table may still show ‘S’ for IX + Data access

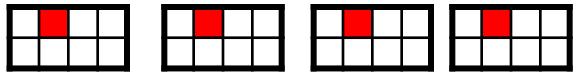
- ET reductions between 5-50% measured at SVL
- 10-75% reduction in synchronous I/O’s

Clusterratio Enhancement

- New Clusterratio formula in DB2 9
  - Including new DATAREPEATFACTOR statistic
    - Differentiates density and sequential

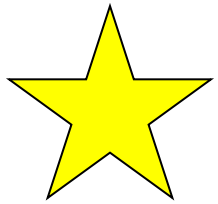


Dense (and sequential)



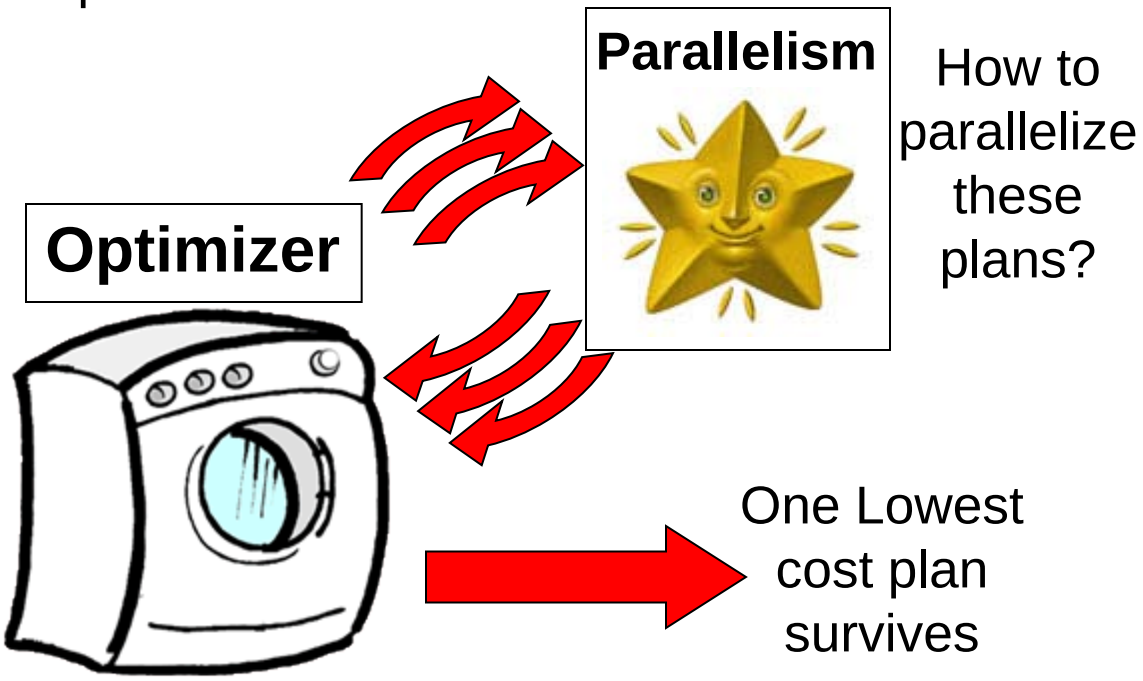
Sequential (not dense)

- Controlled by zparm STATCLUS
  - ENHANCED is default
  - STANDARD disables, and is NOT recommended
- Recommend RUNSTATS before mass REBIND in DB2 9



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 Parallelism Enhancements

- In V8
  - Degree cut on leading table (exception star join)
- In DB2 9
  - Degree can cut on non-leading table
    - Benefit for leading workfile, 1-row table etc.
  - Histogram statistics exploited for more even distribution
    - For index access with NPI
  - CPU bound query degree <= # of CPUs * 4
    - <= # of CPUs in V8

Histogram Statistics

RUNSTATS 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

RUNSTATS 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

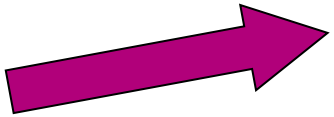
Histogram Statistics Example

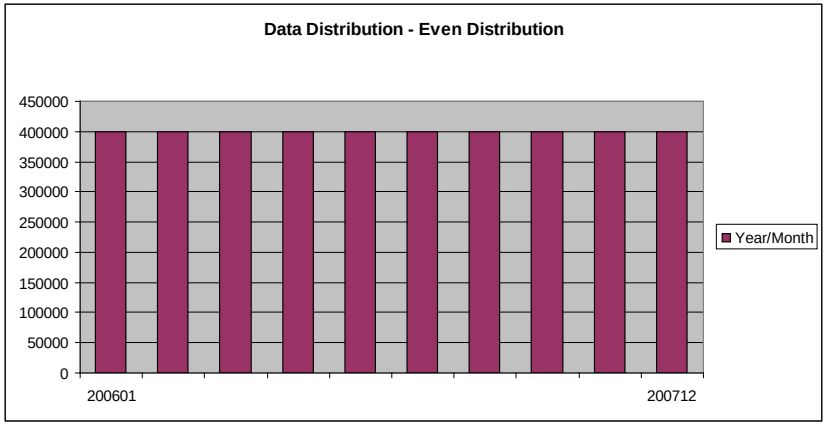
- SAP uses INTEGER (or VARCHAR) for YEAR-MONTH

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***

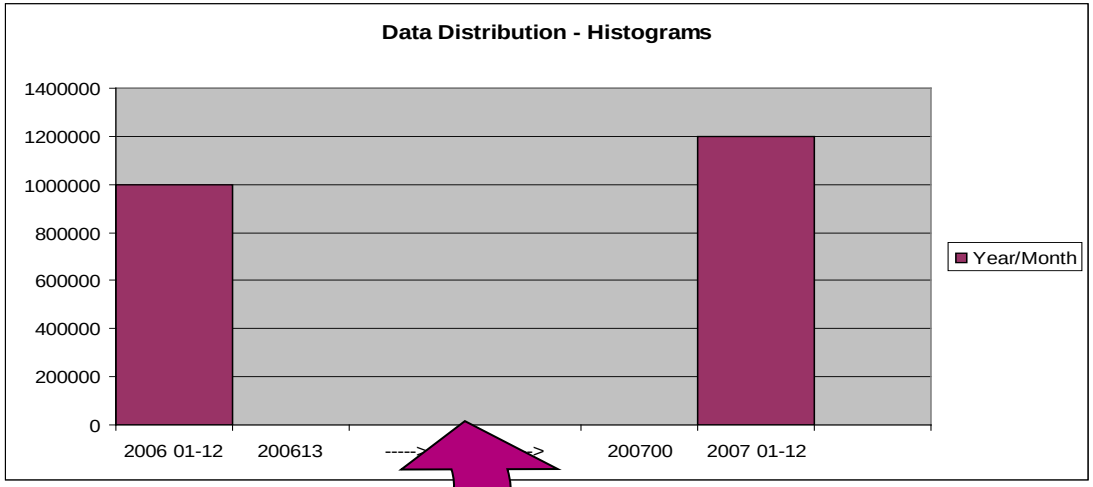
Data assumed as evenly distributed between low and high range





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

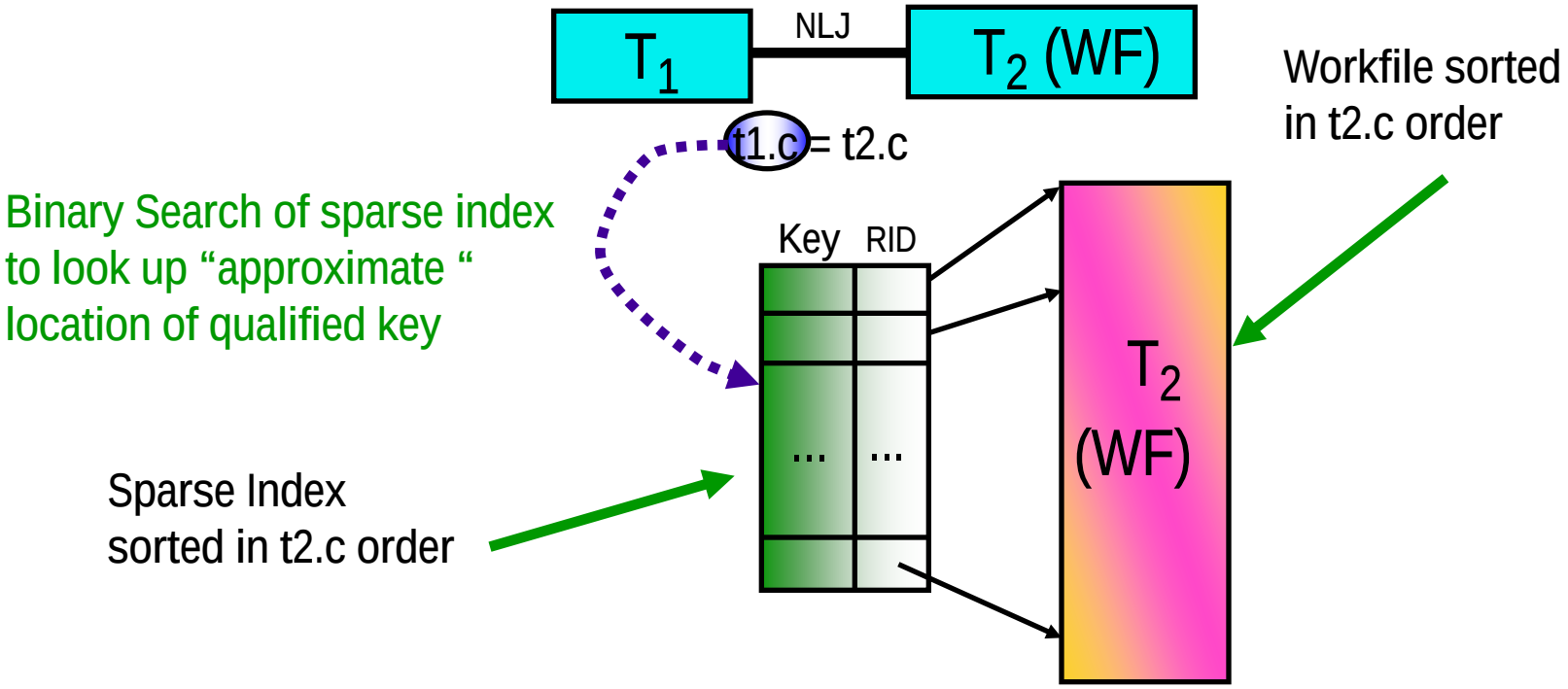
Generalized Sparse Index and In-memory Data Caching

Pre-V9 Sparse Index & in-memory data cache

- V4 introduced sparse index
  - for non-correlated subquery workfiles
- V7 extended sparse index
  - for the materialized work files within star join
- V8 replaced sparse index
  - with in-memory data caching for star join
    - Runtime fallback to sparse index when memory is insufficient

How does Sparse Index work?

- Sparse index may be a subset of workfile (WF)
  - Example, WF may have 10,000 entries
    - Sparse index may have enough space (240K) for 1,000 entries
    - Sparse index is “binary searched” to find target location of search key
    - At most 10 WF entries are scanned

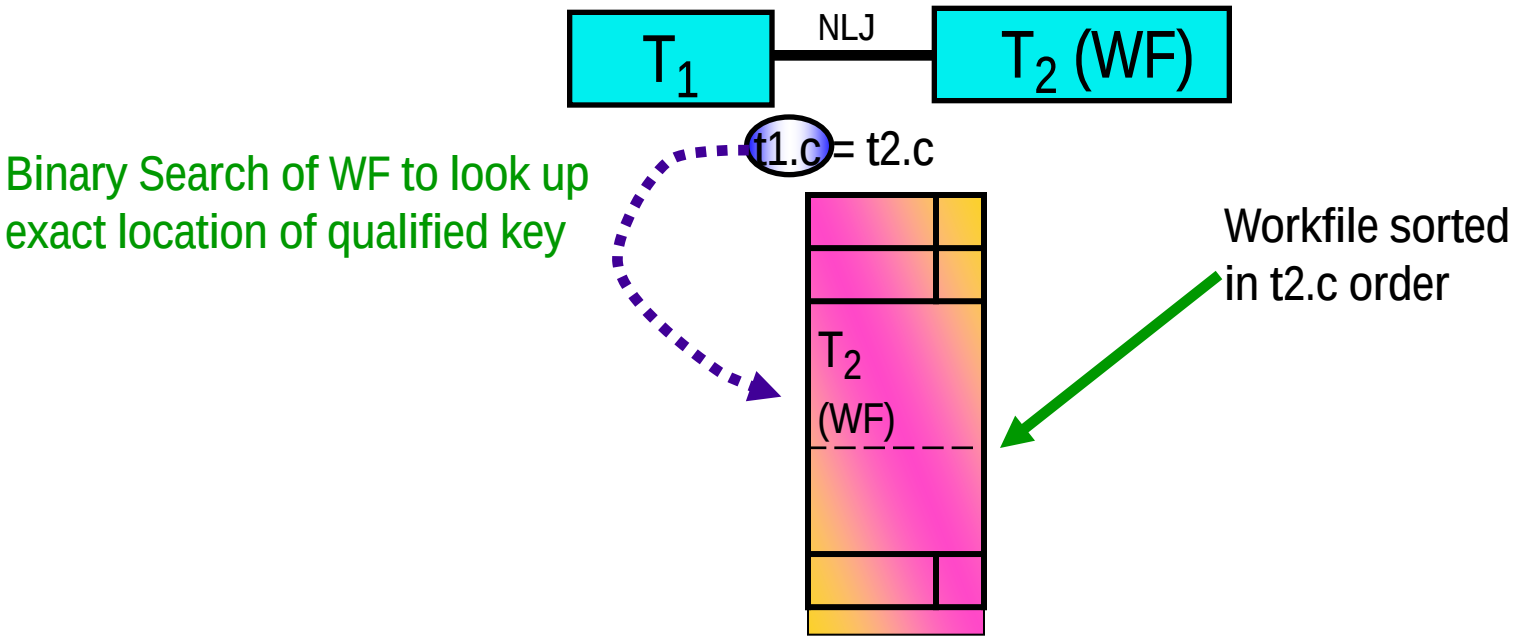


Data Caching vs Sparse Index

- Data Caching
  - Also known as In-Memory WF
  - Is a runtime enhancement to sparse index
- Sparse Index/In-Memory WF
  - 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

How does In-Memory WF work?

- Whereas sparse index may be a subset of WF
  - IMWF contains the full result (not sparse)
  - Example, WF may have 10,000 entries
    - IMWF is “binary searched” to find target location of search key



Benefit of Data Caching

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

- V9 also supports multi-column sparse index

REOPT Auto Based On Parameter Marker Change

REOPT enhancement for dynamic SQL

- V8 REOPT options
  - Dynamic SQL
    - REOPT(NONE, ONCE, ALWAYS)
  - Static SQL
    - REOPT(NONE, ALWAYS)
- V9 Addition for Dynamic SQL
  - Bind option REOPT(AUTO)

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

V10 Query Performance Enhancements Overview

DB2 10 Query Enhancements

- CPU time reductions for queries, batch, & transactions
- SQL enhancements: Moving Sum, Moving Average, temporal, timestamp, implicit cast, SQL PL, …
- pureXML improvements
- Access improvements: Index include columns, hash, index list prefetch, workfile spanned records, …
- Optimization techniques
  - Remove parallelism restrictions and more even parallel distribution. Increased zIIP usage.
  - In-memory techniques for faster query performance
  - Access path stability and control
- Analysis: instrumentation, Data Studio & Optim Query Tuner
- Advanced query acceleration techniques
  - IBM Smart Analytics Optimizer

Safe Query Optimization

- V10 - Consider the uncertainty of predicate filtering when selecting an index
  - Uncertain predicate filtering from non-uniform data, host variables or parameter markers
  - DB2 might choose an index that has slightly higher cost estimate if that index has a higher cost certainty

- V10 - List prefetch enhancement
  - RID list processing continues in work file when DB2 exhausts the RID pool resources (avoid R scan)

Range List Index Scan - problem to be solved

Table PHONEBOOK

last name	first name	phone	street	city	…

```
SELECT *
   FROM PHONEBOOK
WHERE (LASTNAME='SMITH' AND
FIRSTNAME>='JOHN') OR
(LASTNAME>'SMITH')
ORDER BY LASTNAME, FIRSTNAME
FETCH FIRST 10 ROWS;
```

Index IX1 on (lastname, firstname)

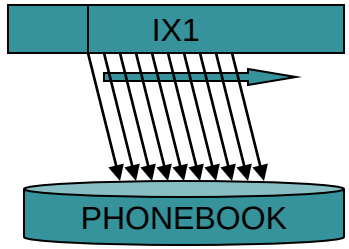
Current possible access path

1. Table space scan
2. Non-matching index access
3. Multi-index access (index ORing)

Both need to retrieve all the qualified rows, sort them for ORDER BY , then return 10 first ordered result

Ideal access path

Direct index access and avoid ORDER BY sort
Terminate the process after getting first 10 rows



Range List Index Scan

- V 10 – DB2 introduces new access method, range list access, to process OR predicates
  - Range list access is only considered when
    - OR predicate is on leading table
    - OR predicate is stage 1 predicate
    - Each disjunct has at least one matching column
- New access type ‘NR’ in PLAN_TABLE

Range List Index Scan Benefits

- An index access with matching predicates. It can narrow down the search scope comparing to tablespace scan or non-matching index scan.
- It is a single index access instead of multiple indexes access (index ORing). Index is exploited once.
- It allows index key ordering to be maintained which is significantly important to data-dependent pagination application. If the index satisfies order by ordering, sort can be avoided.
- Process can be terminated early if only part of result set is required (e.g. with FETCH FIRST n ROWS ONLY clause).

IN-list Predicate Enhancements

- Index matching on multiple IN-list predicates.
- Predicate transitive closure for IN-list predicates.
- List prefetch.
- New access type – ACTYPE - 'IN' and new table type TBTYPE – 'I'
  - If more than one matching IN-list predicates
  - Each IN-list predicate is an in-memory table

View/Table Expression Merge Enhancement

- More Merge scenarios (instead of physical materialization) for View/Table Expressions
  - Especially in outer join.
    - More join sequence can be considered.
    - Can apply predicates early
- In general a more aggressive Merge strategy for View/Table Expressions is preferable.

Stage 2 Predicate Pushdown to Stage 1

- Example:

```
CREATE TABLE T1(C1,C2,C3)
CREATE INDEX IX1 ON T1(C1,C2)

SELECT *
FROM T1 WHERE T1.C1 >0
AND T1.C2+1=5 AND T1.C3+2=4 ;
```

Matching predicate

IM pushdown

DM pushdown

Query Parallelism Enhancements

- What are the enhancements to reduce query elapsed time?
  - Dynamic record range partitioning
  - Straw model
  - Removal of some parallelism restrictions
  - SMJ with sparse index on inner table work file
- When the enhancements are not eligible?
  - Sysplex parallelism
  - Full outer join queryblock
  - IO parallelism

Dynamic Record Range Partitioning

- Why record range partitioning?
  - Key range partitioning is determined at bind time
  - Key range may not be cut evenly due to data skew, data correlation and out of date statistics
    - *Query elapsed time not optimal due to unbalanced amount of work in parallel child tasks*

- What is dynamic record range partitioning?
  - Dynamically materialize the intermediate result in joins
    - *Result may fit in in-memory work file*
  - Based on the number of records in the composite table
  - Divide the result into ranges with equal number of records
  - Up to x times reduction in elapsed time with x parallel degree

- If used, dsn_pgroup_table field RANGEKIND = ‘R’

Parallelism Straw Model

- Difference vs. non-straw model
  - Number of ranges (elements) > number of degree
  - Number of parallel tasks = number of degree
    - True for both straw and non straw model
  - Each parallel task continues on the next available range after it finishes the current one
  - Parallel tasks stop after all the ranges are processed

- When it is used?
  - Parallel group cost is not too small
  - Leading table is index access and the colcard is not too small
  - Leading table is R-scan and the number of pages is not too small

- If used, dsn_pgroup_table field STRAW_MODEL = 'Y'

Remove Restrictions for Parallelism

- Parallelism no longer disabled when parallel group contains work file from
  - Materialized view
  - Materialized table expression
- Parallelism no longer disabled in the last parallel group of the top query block when multi-row fetch is used
  - This restriction is removed under the condition that the cursor is **read only**
- Parallelism no longer disabled when queryblock contains OLAP functions
  - OLAP functions are still processed at parent side

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Key Details About DB2 10: Getting Ready

Prerequisites: migrate from DB2 9 for z/OS or DB2 for z/OS V8

- z/OS V1.10 SMS-managed DB2-managed DB2 catalog
- System z10, z9, z890, z990, and above (no z800, z900)
- DB2 Connect 9 FP1, 9.7 FP3 for many 10 functions, FP2 beta
- IMS 10 & 11 (not 9) CICS compilers (See announcement)
- Info APARs for migration II14477 (9), II14474 (8)
- SPE PK56922 PK69411 PK61766 PK85956 PM04680 PK87280 PK87281 PM08102 PM08105
- Premigration check DSNTIJPA PM04968

Items deprecated in earlier versions eliminated: more for V8 mig.

- Private protocol → DRDA (DSNTP2DP, PK92339, PK64045)
- Old plans and packages V5 or before → REBIND
- Plans containing DBRMs → packages PK62876 PK79925 (V8)
- ACQUIRE(ALLOCATE) → ACQUIRE(USE)
- Old plan table formats → DB2 V8 or 9, Unicode, 59 cols PK85068
- BookManager use for DB2 publications → Info Center, pdf

Exciting Optimizer & SQL Performance Enhancements in DB2 9 for z/OS and Beyond

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