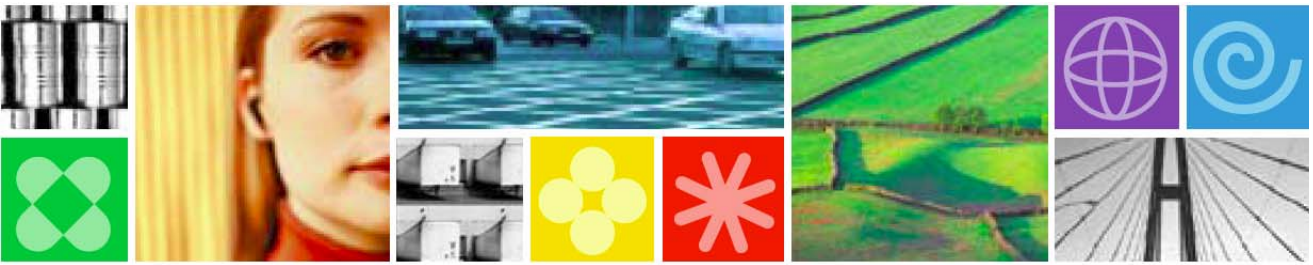
What's new for SQL Optimization in IBM DB2 9 for z/OS



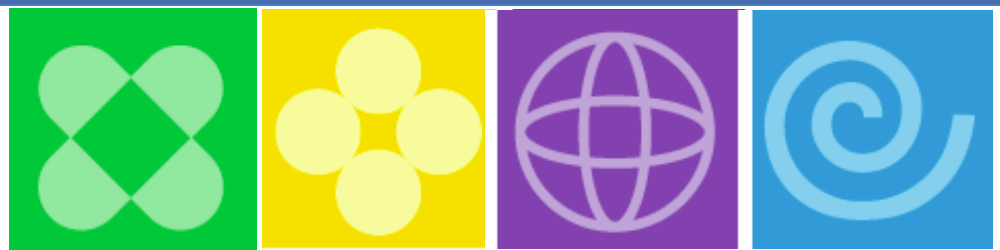
Disclaimer

THE INFORMATION CONTAINED IN THIS PRESENTATION IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. WHILE EFFORTS WERE MADE TO VERIFY THE COMPLETENESS AND ACCURACY OF THE INFORMATION CONTAINED IN THIS PRESENTATION, IT IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED. IN ADDITION, THIS INFORMATION IS BASED ON IBM'S CURRENT PRODUCT PLANS AND STRATEGY, WHICH ARE SUBJECT TO CHANGE BY IBM WITHOUT NOTICE. IBM SHALL NOT BE RESPONSIBLE FOR ANY DAMAGES ARISING OUT OF THE USE OF, OR OTHERWISE RELATED TO, THIS PRESENTATION OR ANY OTHER DOCUMENTATION. NOTHING CONTAINED IN THIS PRESENTATION IS INTENDED TO, NOR SHALL HAVE THE EFFECT OF, CREATING ANY WARRANTIES OR REPRESENTATIONS FROM IBM (OR ITS SUPPLIERS OR LICENSORS), OR ALTERING THE TERMS AND CONDITIONS OF ANY AGREEMENT OR LICENSE GOVERNING THE USE OF IBM PRODUCTS AND/OR SOFTWARE.

Agenda

- Service Updates
- Plan Stability
- General Query Performance Enhancements
- Indexing Enhancements
- Histogram Statistics
- Global Query Optimization
- Generalized sparse index and in-memory data cache
- Dynamic Index ANDing
- REOPT AUTO

Service updates



Prune “Always False” Predicates

- APAR PK49265 (ZPARM PREDPRUNE)
  - Literal “IN” or “=“ only (no host vars or REOPT)

```
WHERE ('A' = 'B' OR T1.COL1 IN ('B', 'C'))
```

  - Becomes….

```
WHERE T1.COL1 IN ('B', 'C')
```

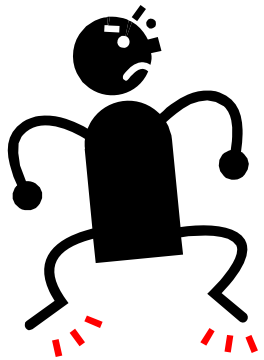
  - Original “OR” is stage 2
    - Disables index access and many query transformations
  - Documented tricks are NOT pruned (OR 0=1)

Index-only Preference

- Ever created an index to support index-only?
  - Only to have optimizer choose index + data?

```
SELECT C2
FROM T1
WHERE C1 = ?

Index 1 (C1)          ←Index + data
Index 2 (C1, C2)      ←Index-only
```



  - APAR PK51734
    - ZPARM OPTIXOPREF
      - Optimizer will prioritize index-only over index + data given same index prefix

Full index matching preference

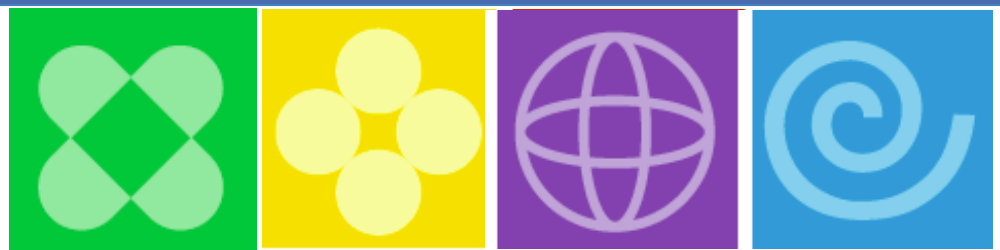
- Optimizer already preferences 1 row index
  - Full equals match on a unique index
- APAR PK59731
  - When FETCH FIRST 1 ROW ONLY is specified
    - Will choose index with matching on all predicates

```
WHERE C1 = ?
  AND C2 = ?
  AND C3 > ?
FETCH FIRST 1 ROW ONLY

Index 1 (C1, C2, C3)
```

←Preference this over other indexes

Plan Stability



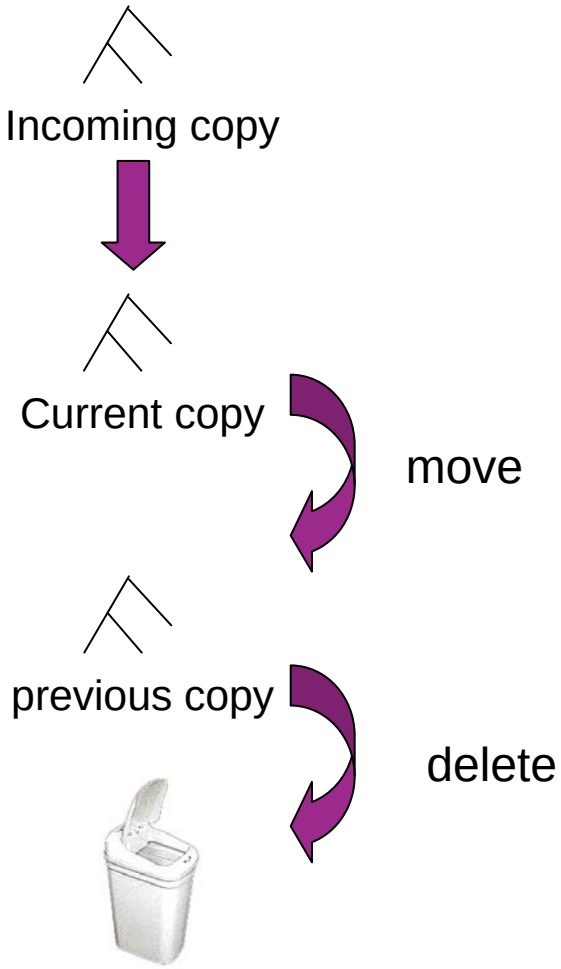
Plan Stability Overview

- 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)

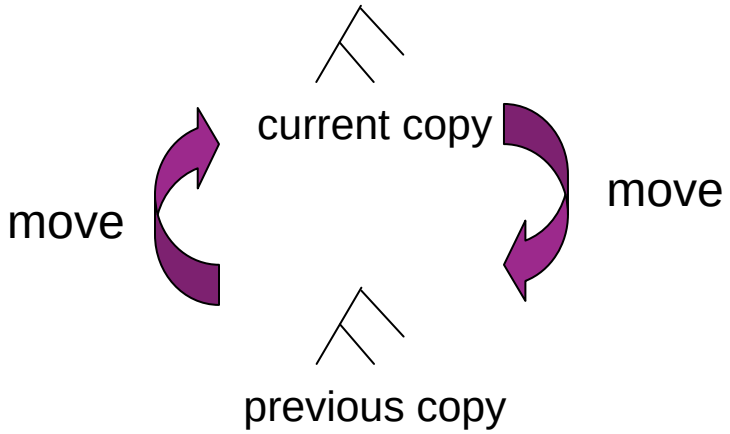
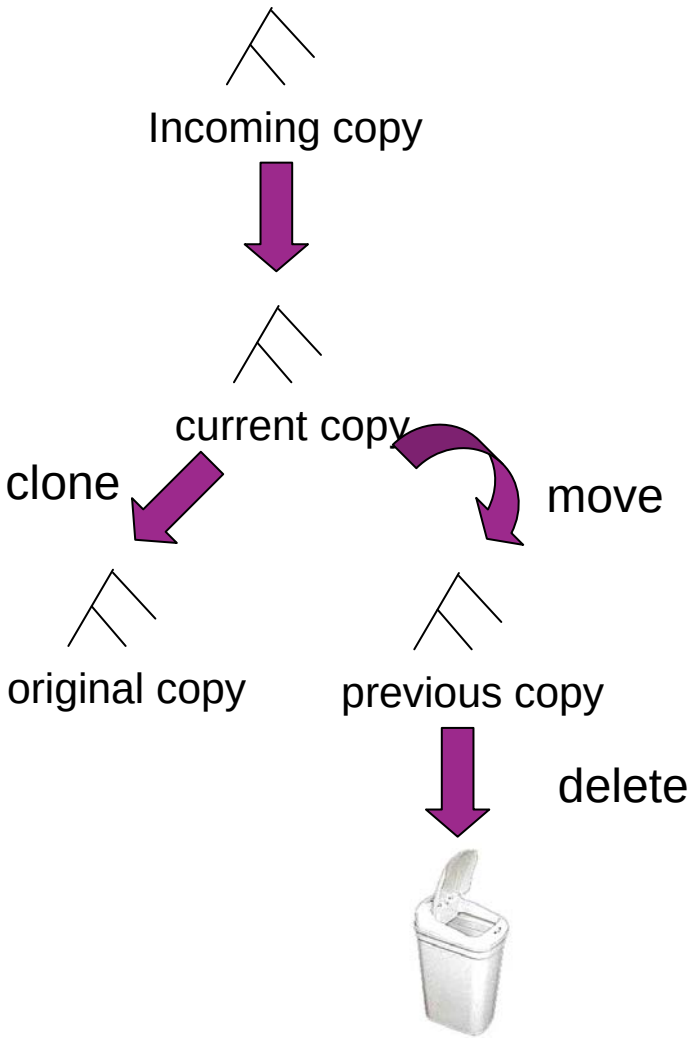


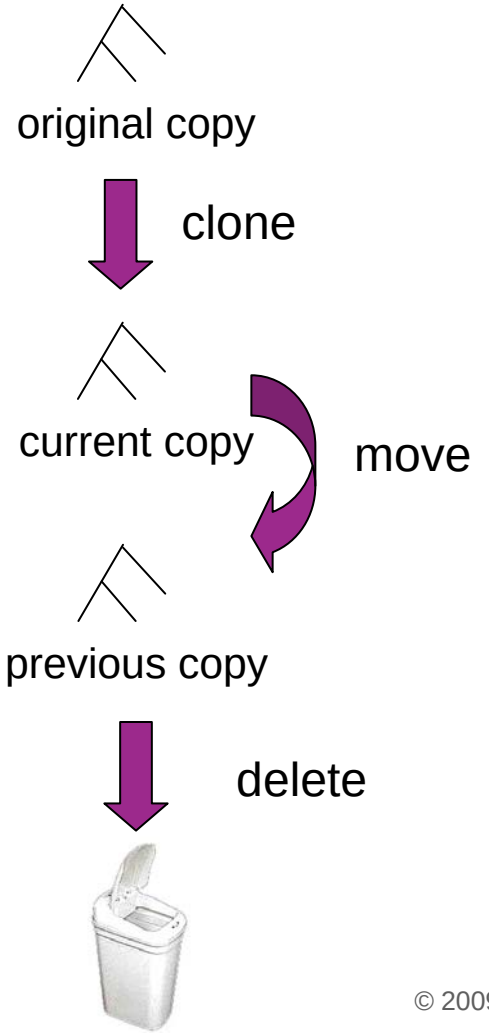
Chart is to be read from bottom to top

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

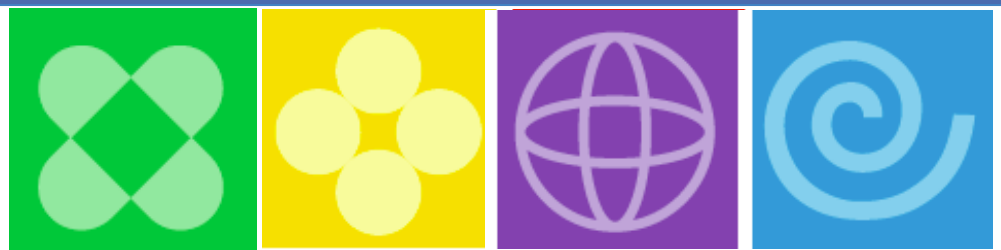
- Catalog support
  - SYSPACKAGE reflects active copy
  - SYSPACKDEP reflects dependencies of all copies
  - Other catalogs (SYSPKSYSTEM, …) reflect metadata for all copies

- Invalidation and Auto Bind
  - Each copy invalidated separately

2 important updates:

1. APAR PK80375 – SPT01 Compression
2. Article – IDUG Solutions Journal (www.idug.org)

Indexing Enhancements



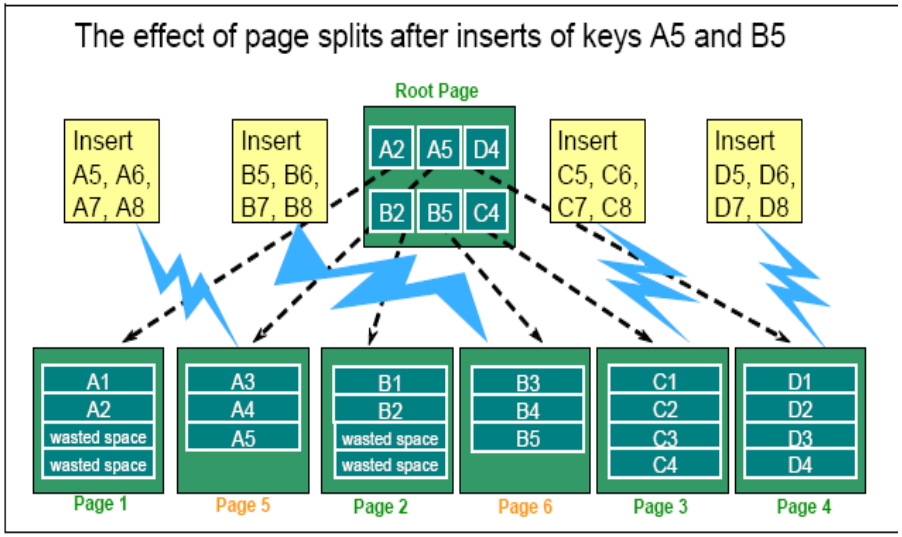
Insert/Update/Delete Performance

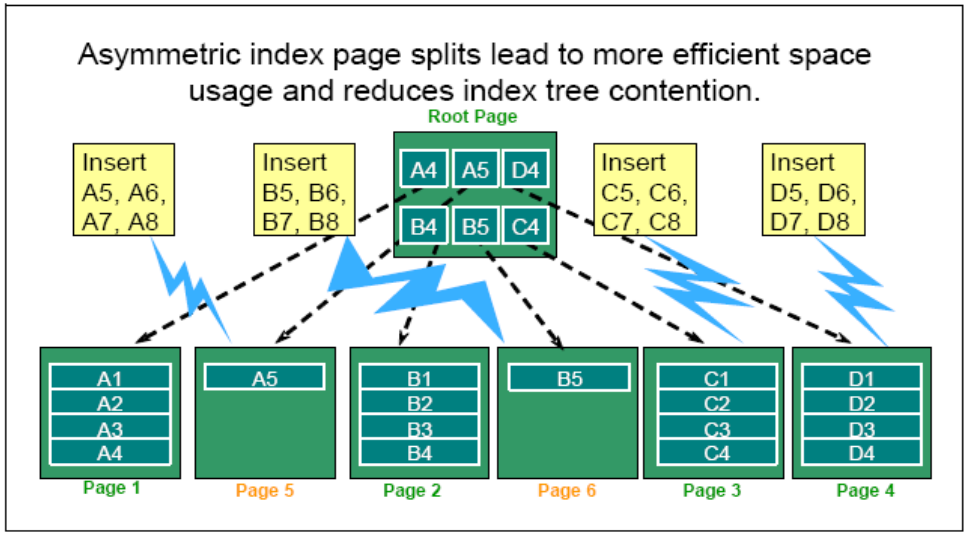
- DB2 9 addresses several traditional problem areas for high bandwidth INSERT/UPDATE/DELETE workloads.
  - Log Latch Contention (LC 19) and LRSN Spin (NFM & DS)
  - IX Leaf Page Split Overhead
  - Free Space Search Overhead
  - IX and DATA hot spots

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

- Table Space APPEND Option (can ALTER on and off)
- Not Logged Table spaces
- Asymmetric Leaf Page Split
- Larger Index Page Sizes
- Increased Index Look-aside

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.

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)

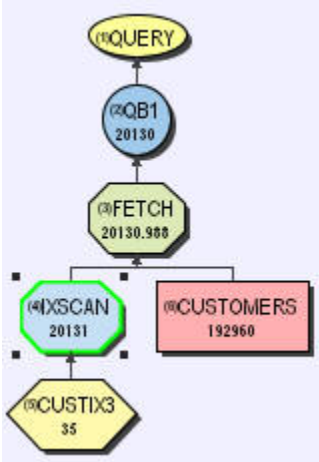
- In V8
  - Insert – clustering index only
  - Delete – no index lookaside
- In V9,
  - Insert & Delete – now possible for additional indexes where CLUSTERRATIO >= 80%
  - IX Update = Delete + Insert
- Potential for big reduction in index getpages and thus CPU time
  - Benchmark Example - Heavy insert
    - 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)
```



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

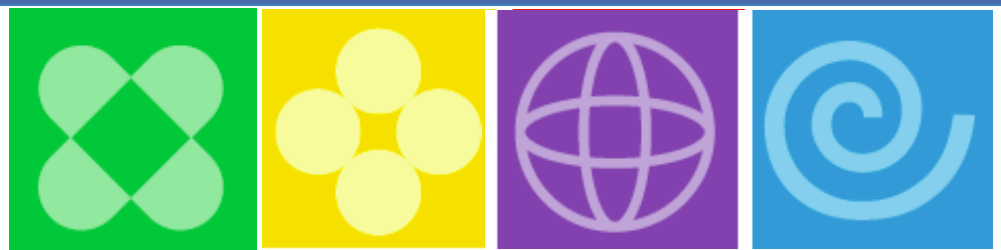
- Additional indexes require overhead for
  - Utilities
    - REORG, RUNSTATS, LOAD etc
  - Data maintenance
    - INSERT, UPDATE, DELETE
  - Disk storage
  - Optimization time
    - Increases optimizer's choices
- But identifying unused indexes is a difficult task
  - Especially in a dynamic SQL environment

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

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

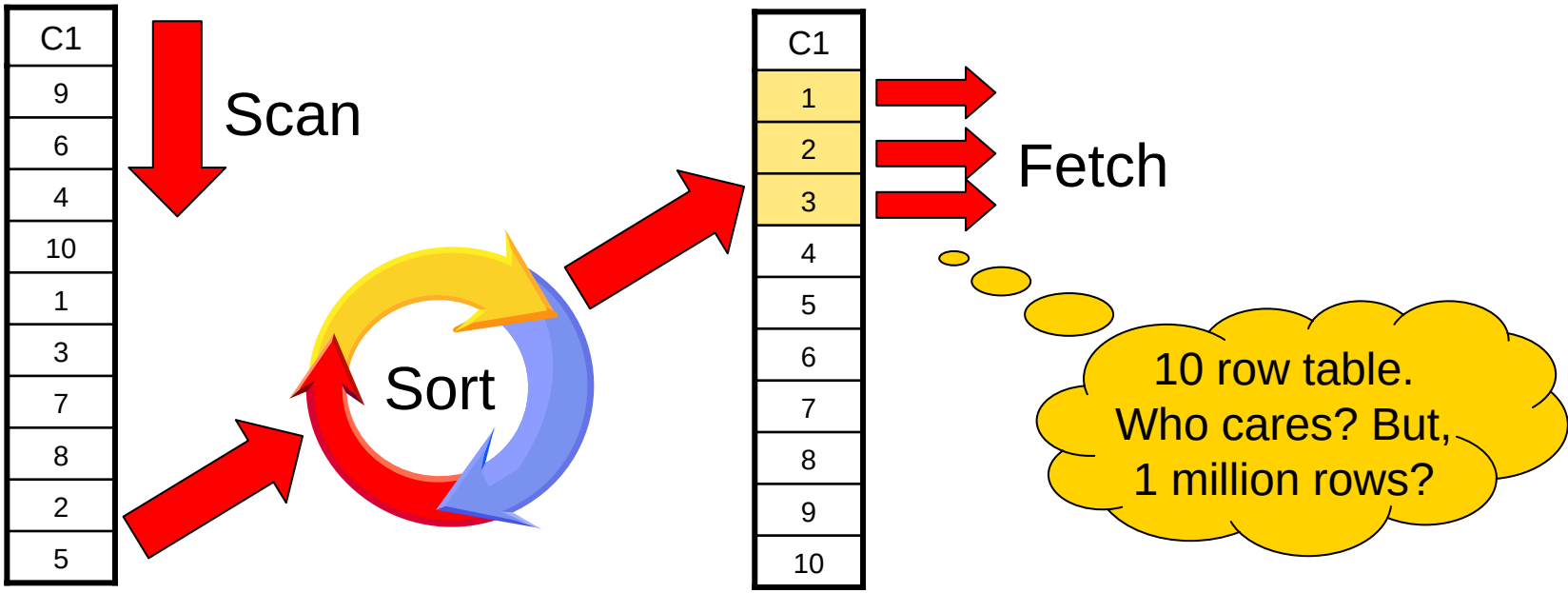
Sort Improvements

- 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

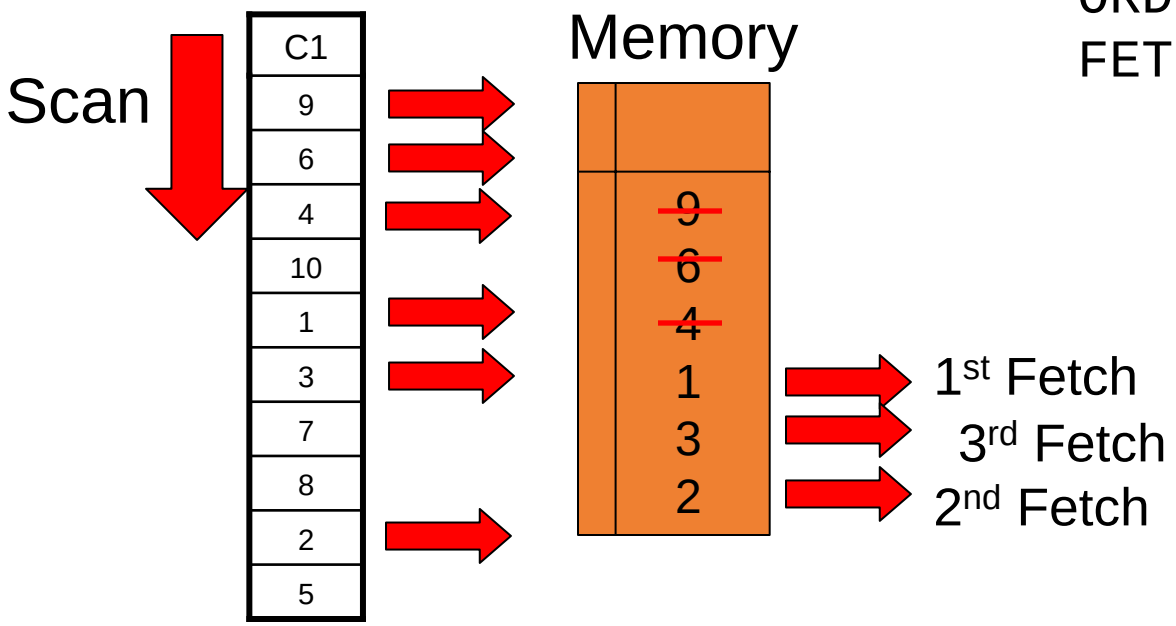
```
SELECT C1
FROM  T
ORDER BY C1
FETCH FIRST 3 ROWS ONLY
```



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

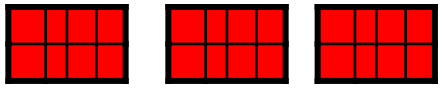
Sequential Prefetch	Dynamic Prefetch
Chosen at bind/prepare time	Detected at runtime
Requires hit to a triggering page	Tracks sequential access pattern
Only prefetch in one direction	Prefetch forward or backward
Used for tablespace scan & LOBs	Used for index & index+data access

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

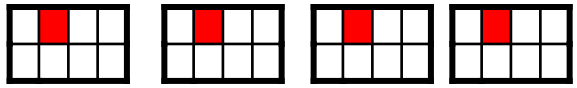
- ET reductions between 5-50% measured at SVL
- 10-75% reduction in synchronous I/O’s

Clusterratio Enhancement

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

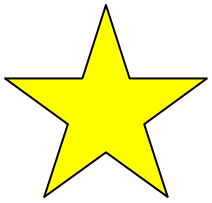


Dense (and sequential)



Sequential (not dense)

- Controlled by zparm STATCLUS
  - ENHANCED is default
  - STANDARD disables, and is NOT recommended



- Recommend RUNSTATS before mass REBIND in DB2 9

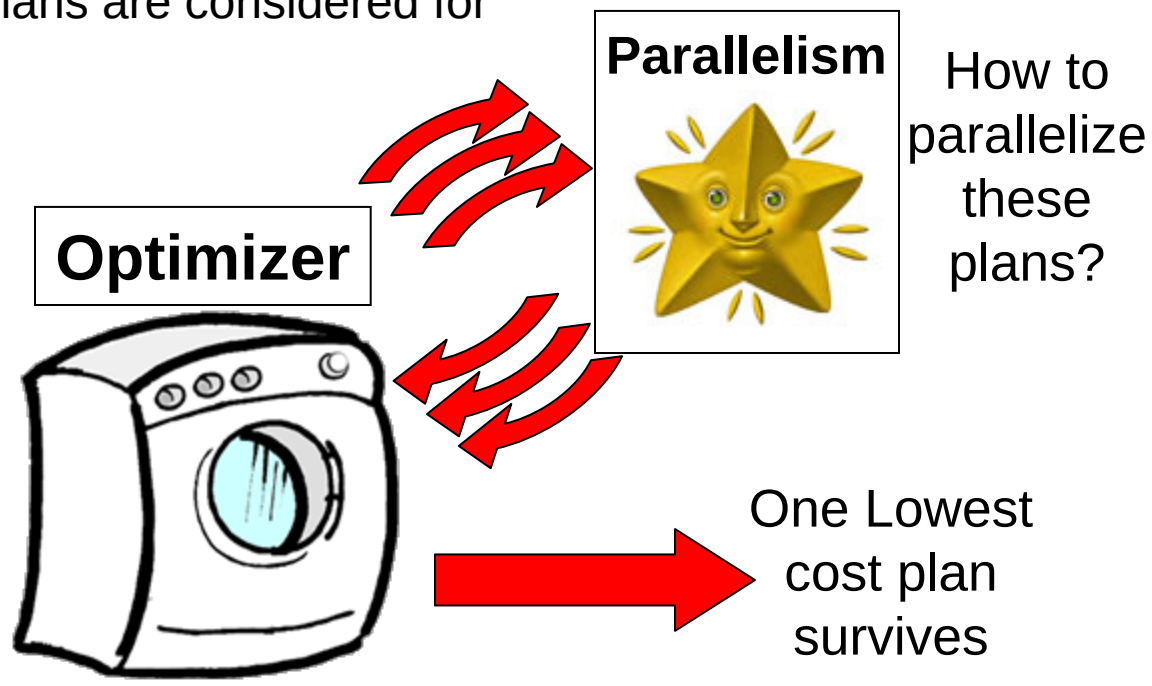
Clusterratio Impacts

- 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

Parallelism Enhancements

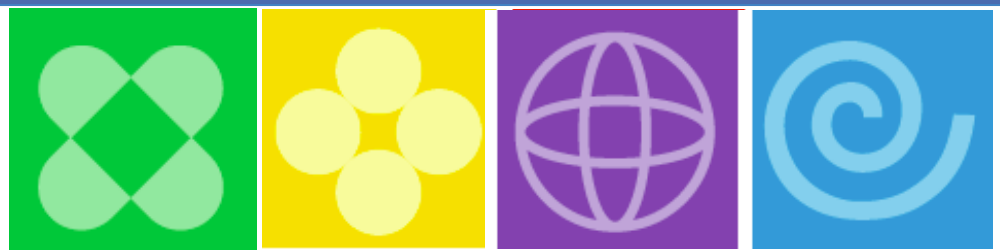
- In V8
  - Lowest cost is BEFORE parallelism
- In DB2 9
  - Lowest cost is AFTER parallelism
    - Only a subset of plans are considered for parallelism



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

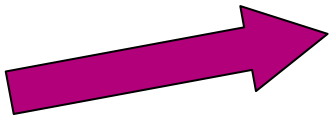
Histogram Statistics Example

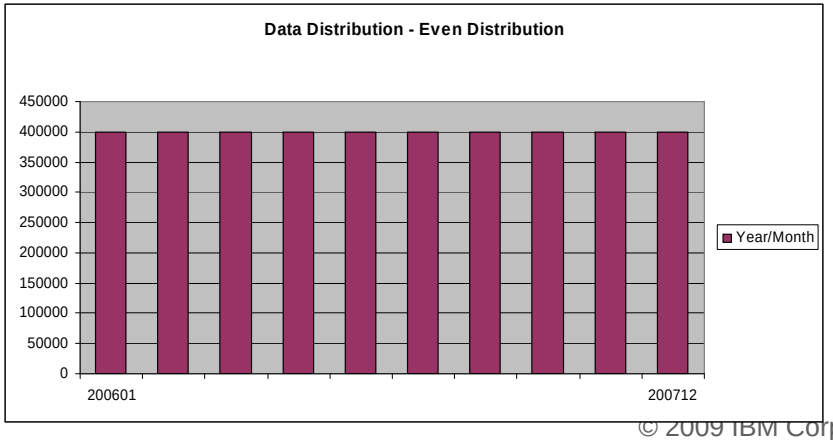
- SAP uses INTEGER (or VARCHAR) for YEAR-MONTH

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**

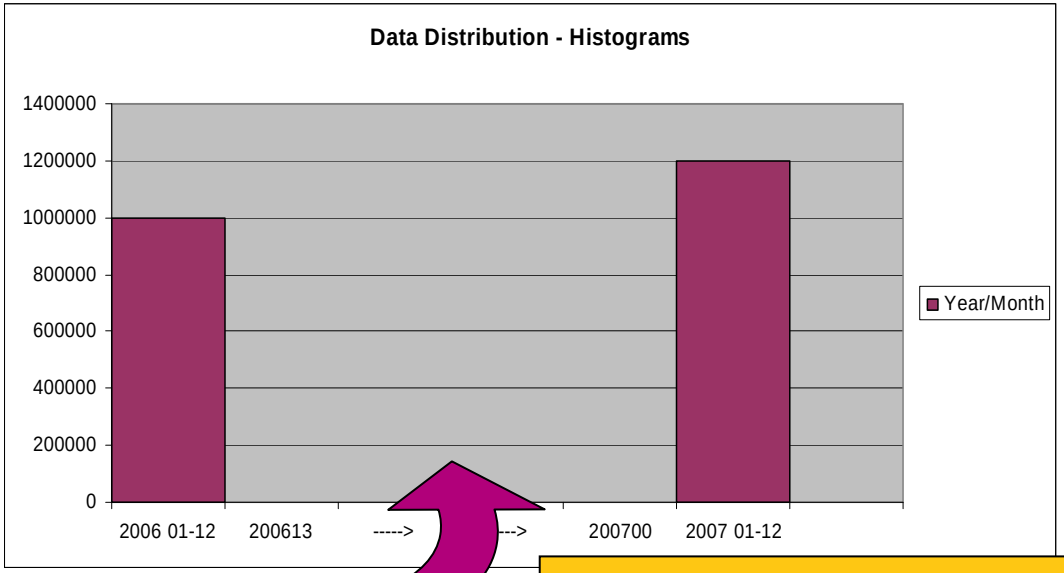
Data assumed as evenly distributed between low and high range





Histogram Statistics Example

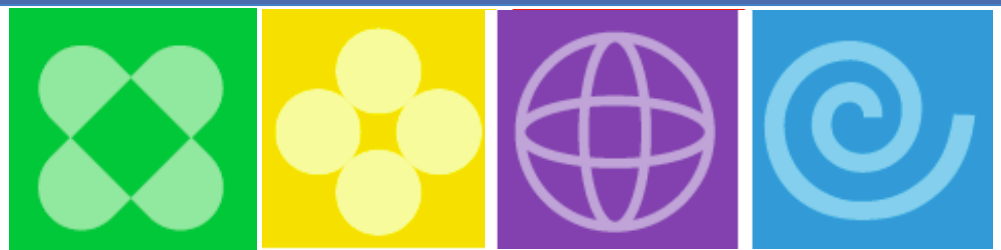
- Example (cont.)
  - Data only exists in ranges 200601-12 & 200701-12
    - Collect via histograms
      - 45% of rows estimated to return



No data between 200613 & 200700

WHERE YEARMONTH BETWEEN 200601 AND 200612

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

* Assumes subquery is not transformed to join

- 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)
```

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

* Assumes subquery is not transformed to join

- 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

Virtual Tables

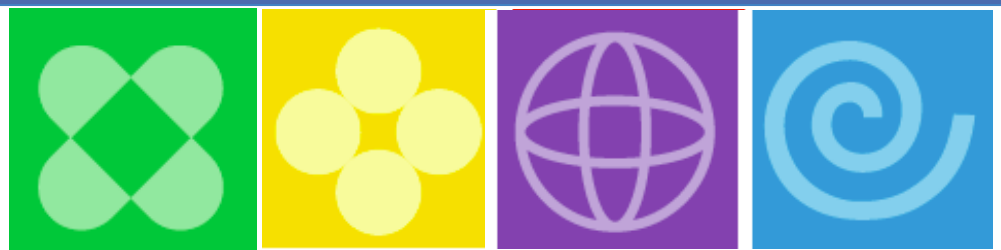
- A new way to internally represent subqueries
  - Represented as a Virtual table
    - Allows subquery to be considered in different join sequences
    - May or may not represent a workfile
    - Apply only to subqueries that cannot be transformed to joins

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

EXPLAIN Output

- Additional row for materialized “Virtual Table”
  - Table type is "W" for "Workfile".
    - Name includes an indicator of the subquery QB number
      - Example ➔ “DSNWFQB(02)”
  - Non-materialized Virtual tables will not be shown in EXPLAIN output.
- Additional column PARENT_PLANNO
  - Used with PARENT_QBLOCKNO to connect child QB to parent
  - V8 only contains PARENT_QBNO
    - Not possible to distinguish which plan step the child tasks belong to.

Generalized Sparse Index and In-memory Data Caching

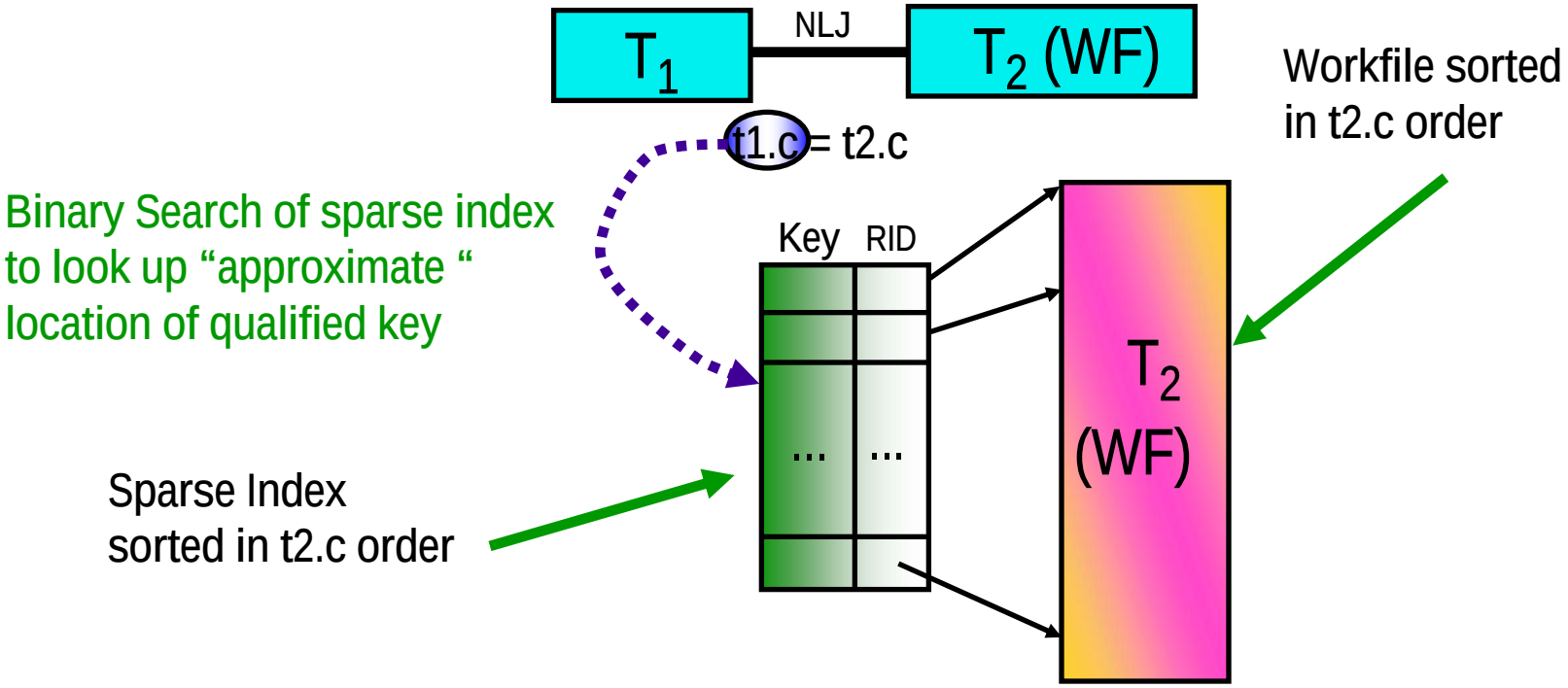


Pre-V9 Sparse Index & in-memory data cache

- 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

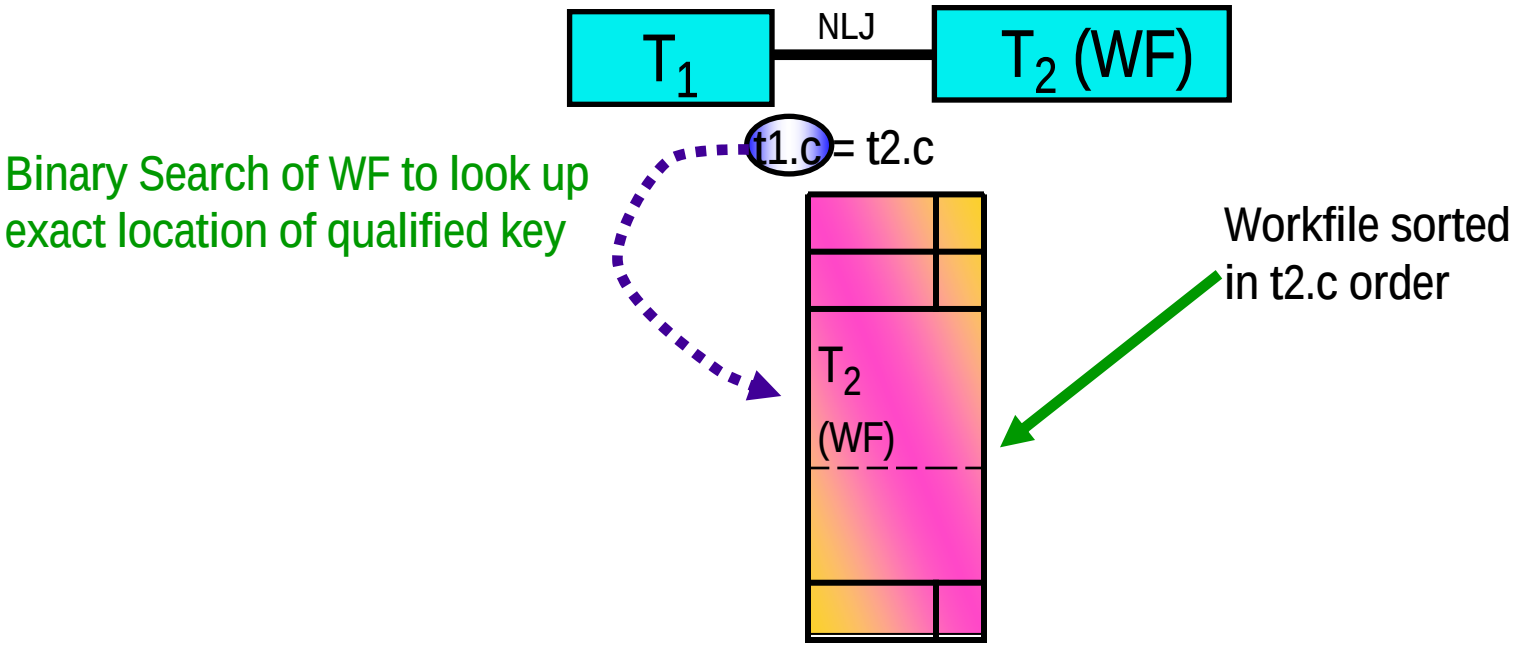


Data Caching vs Sparse Index

- 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

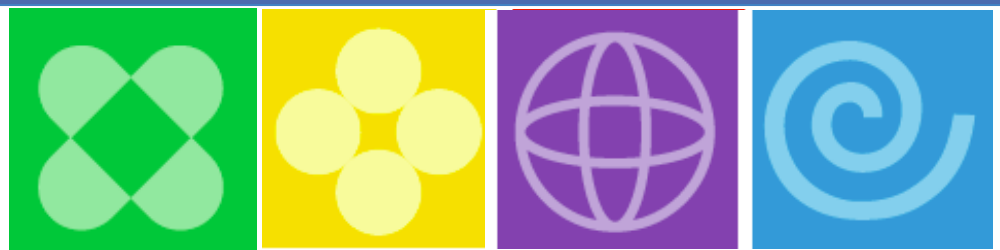


Benefit of Data Caching

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

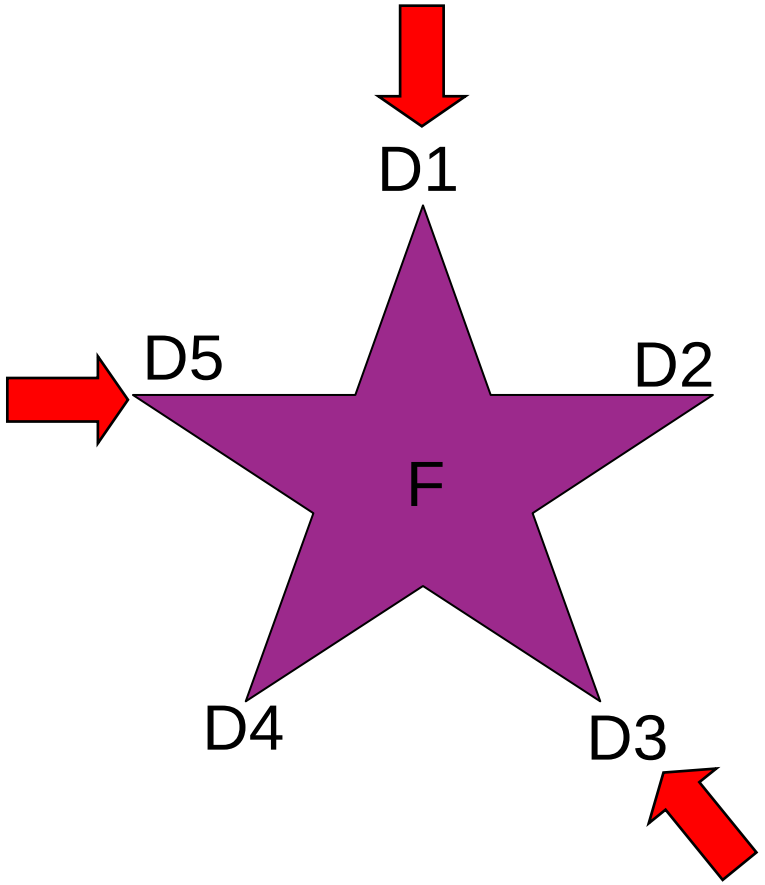
- V9 also supports multi-column sparse index

Dynamic Index ANDing



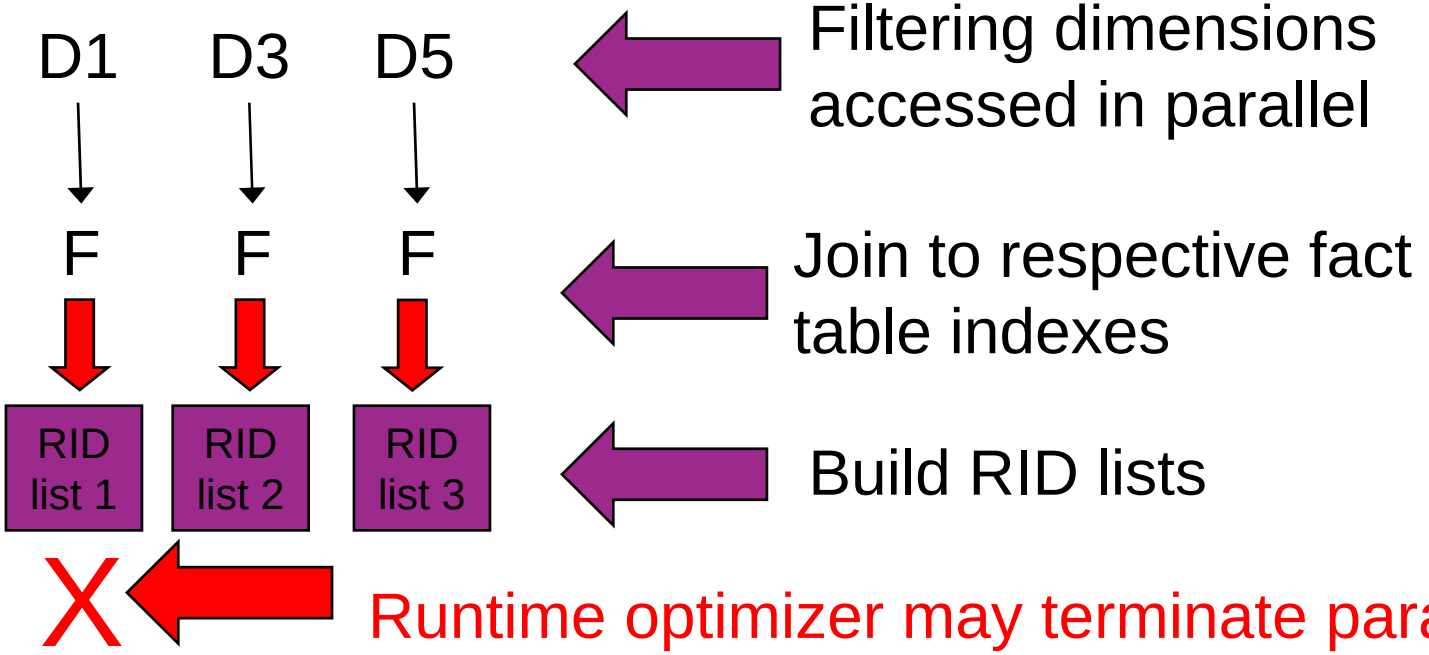
Dynamic Index ANDing Challenge

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



Index ANDing – Pre-Fact

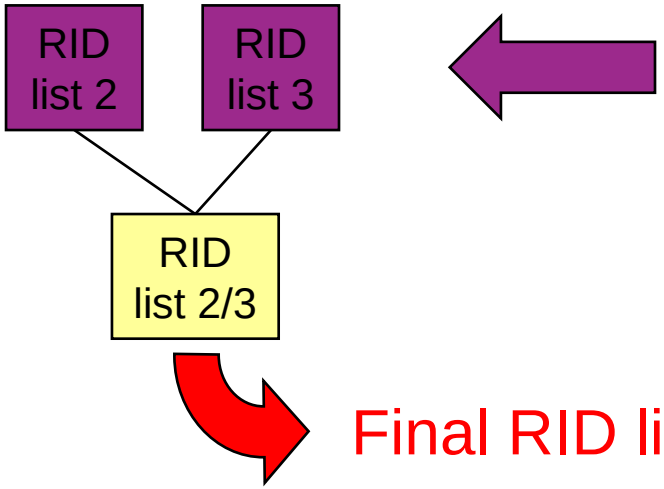
- Pre-fact table access
  - Filtering may not be (truly) known until runtime



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

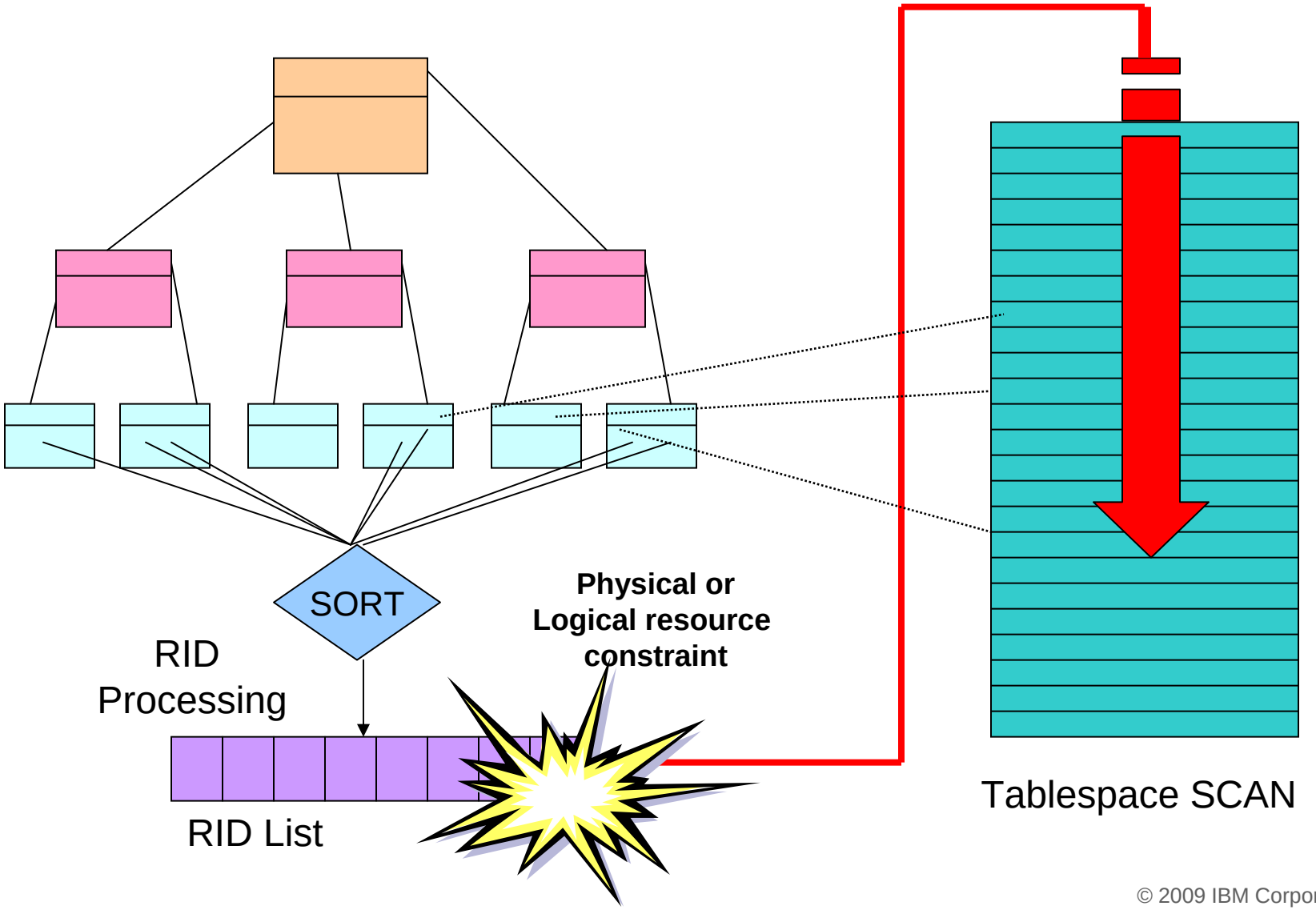
Using parallelism



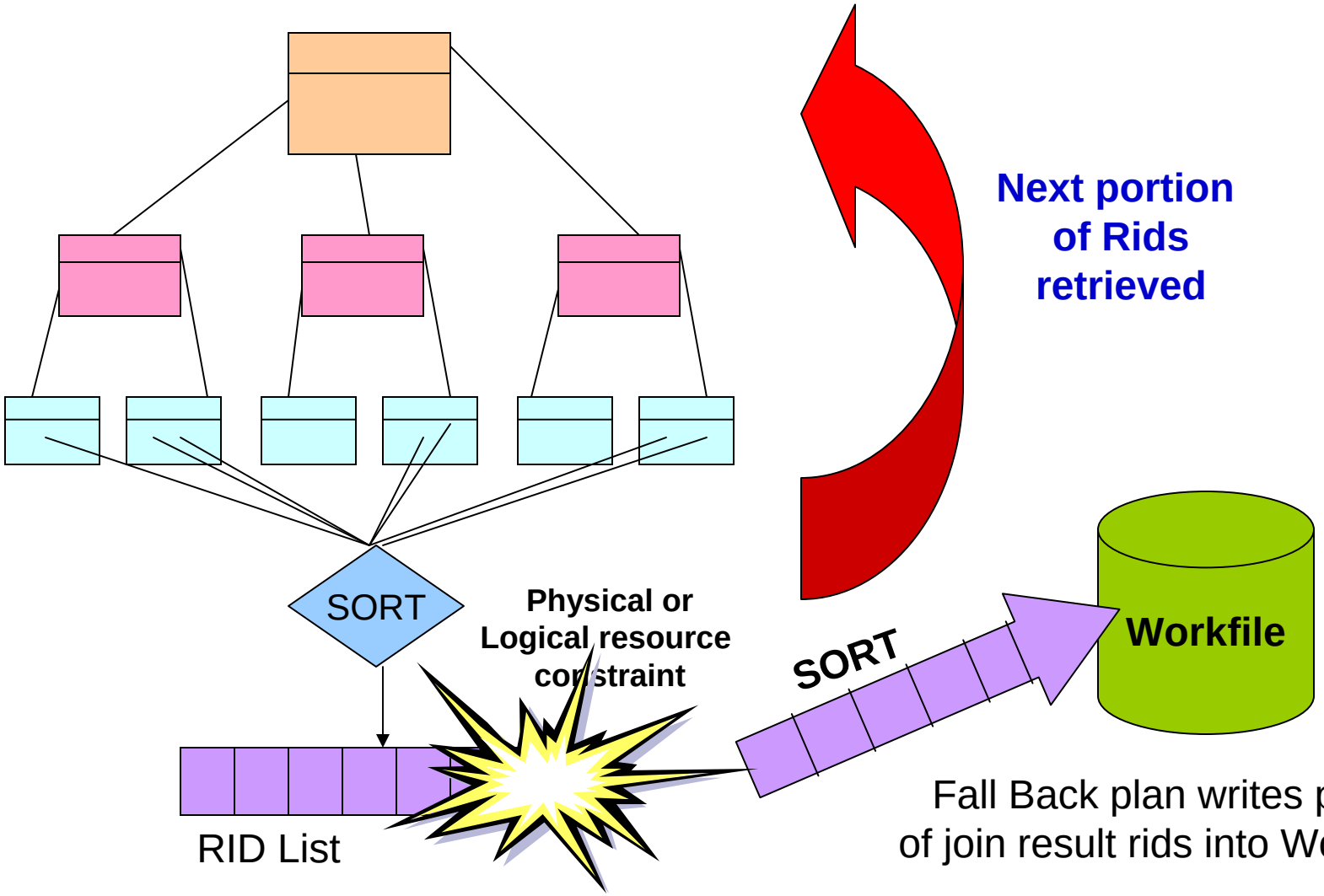
Remaining RID lists are "ANDed" (intersected)

Final RID list used for parallel fact table access

V8 RID Pool failure = TS Scan



V9 RID Pool Fallback Plan

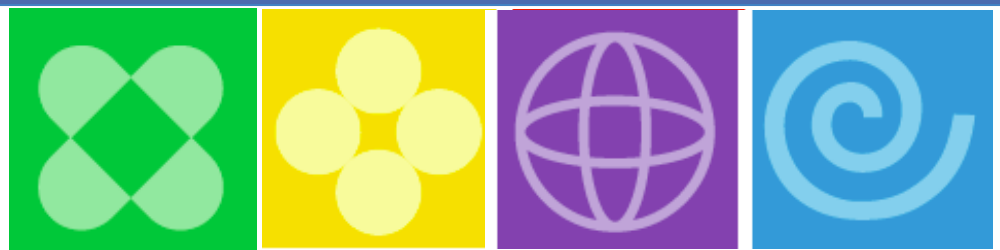


Dynamic Index Anding Highlights

- 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

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

What's new for SQL Optimization in IBM DB2 9 for z/OS