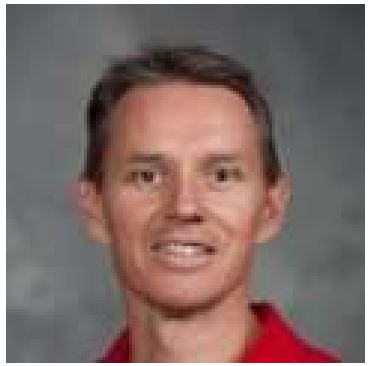
# DB2 for z/OS: Partitioning and Indexing – Query Performance Considerations



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GUIDE Share France
Une Association Indépendante d'Utilisateurs IBM

Réunion du Guide DB2 pour z/OS France
Mardi 18 novembre 2014
Tour Europlaza, Paris-La Défense

# Agenda

- **Introduction**
- **Matching index access**
- **Index screening**
- **Partitioning**
- **Conclusion**



# Introduction



# Indexing and I/O

- Main goal of an index is to improve performance for access to the data
  - By filtering rows in the index
- Number of data I/Os is dependent on
  - Number of rows retrieved
    - To reduce the number of I/Os, request less rows!!!
  - Filtering provided by
    - Matching predicates
    - Screening predicates
    - Partition pruning (page range screening)



# Indexing and I/O (cont.)

- Number of data I/Os is dependent on (cont.)
  - Organization of data
    - How clustering matches data access
  - Random vs Sequential access
    - List prefetch makes random I/Os sequential
      - But List prefetch cannot change location of rows
    - Dynamic/Sequential prefetch can read more pages than necessary
    - FARINDREF will increase random I/Os
      - Variable length (or compressed) rows updated that do not fit in their current page will be relocated.



# Indexing and I/O – Table Joins

- For joins, number of I/Os is dependent on
  - Filtering occurring early in the join sequence
  - Random vs Sequential access
    - Sort of the composite permits sequential access to inner index and possibly table too
    - Hybrid join can improve random I/O to inner table
      - Nested loop join will perform list prefetch on inner once per outer row
      - Hybrid join consolidates RIDs on inner to perform 1 consolidated list prefetch request.
    - Merge scan join performs the join using sequential match/merge



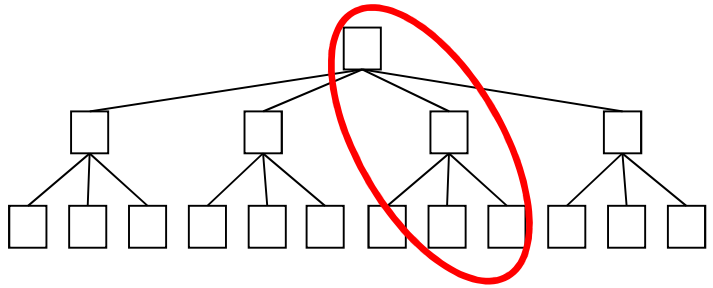
# Matching index access



# Index matching

- Index matching restricts access to a subset of the index
  - Reducing index I/O
    - If 5% of the index rows qualify, then approx 5% of the index pages are read
  - Generally results in reduction in data I/O

```
SELECT *
FROM PHONE_BOOK
WHERE LASTNAME = 'PURCELL'
```

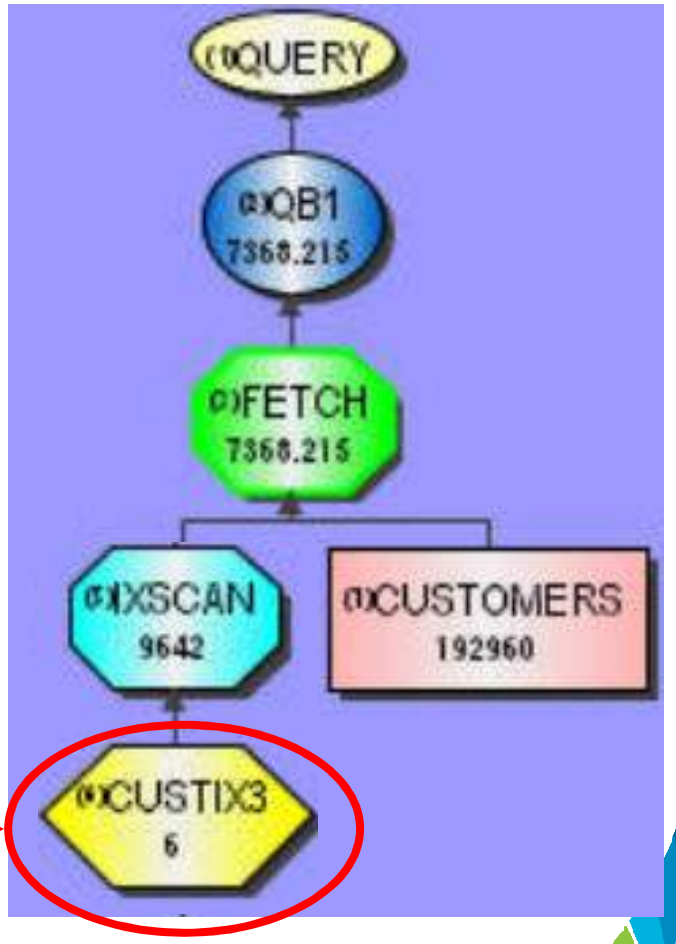


# Index matching to reduce I/O

- Example had Matchcols = 3 given 3 predicates
  - Optimal index choice

```
SELECT *
FROM CUSTOMERS
WHERE COUNTRY = 'USA'
  AND GENDER = 'F'
  AND STATUS = 'N'
OPTIMIZE FOR 1 ROW
```

```
INDEX CUSTIX3 (COUNTRY ASC
              ,STATUS ASC
              ,GENDER ASC)
```



# How many rows qualify?

- Count shows 1,121 rows qualifying
  - Given that there are 192,960 rows in the table
    - That's 0.6% of the table….excellent filtering!!!

```
SELECT COUNT(*) = 1,121
FROM CUSTOMERS
WHERE COUNTRY = 'USA'
  AND GENDER = 'F'
  AND STATUS = 'N'
```



# How many data pages are accessed?

- 0.6% of the table qualifies……..but……
  - It is 0.6% of the rows
  - How many data I/Os are required to retrieve these rows?

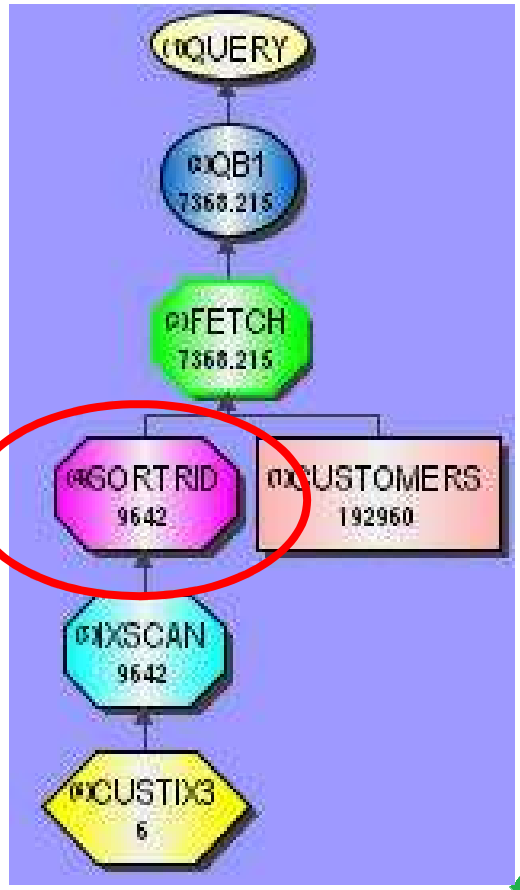
```
BP1     BPOOL ACTIVITY      TOTAL
--------------------------  --------
GETPAGES                      1121
```

1,121 data getpages to retrieve 1,121 rows

# How to reduce the number of I/Os?

- By removing the OPTIMIZE clause
  - List prefetch can be used
  - May reduce the number of I/Os
    - Since duplicate pages are accessed only once

```
SELECT *
FROM CUSTOMERS
WHERE COUNTRY = 'USA'
  AND GENDER = 'F'
  AND STATUS = 'N'
```



# Is list prefetch enough?

- 0.6% of the table qualifies……..but……
  - It is 0.6% of the rows
  - How many data pages do these rows occur on?

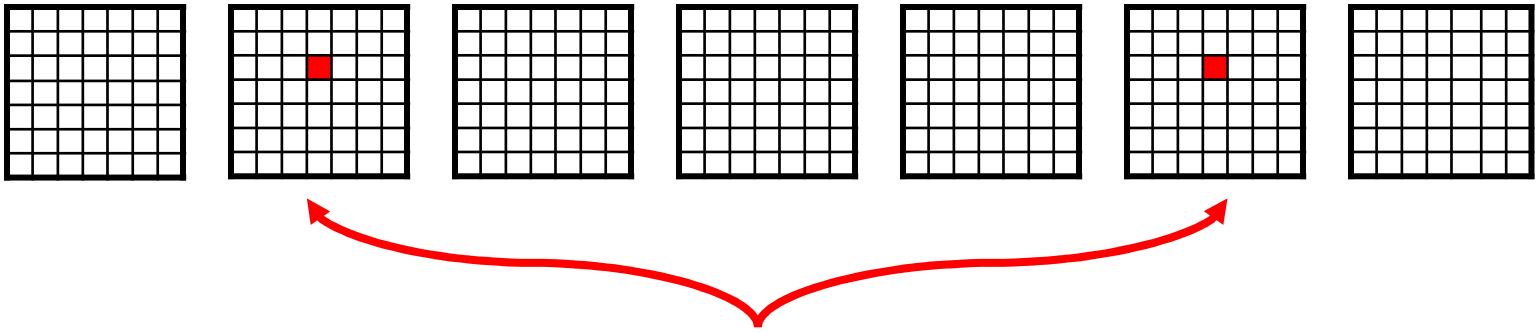
```
BP1     BPOOL ACTIVITY      TOTAL
---------------------   ---------
GETPAGES                      969
```

969 data getpages to retrieve 1,121 rows



# Current clustering effect

- Table is currently clustered by the unique key
  - ACCTNO
- When retrieving a large number of rows unrelated to ACCTNO, qualified rows are found on many pages
  - 969 getpages from 4020 pages total



On average, 1.2 rows found on every 4th page

# Data clustering vs scattering

- 1,121 rows qualified, and 48 rows per page
- Number of data pages accessed via index:
  - Min # pages (clustered) = 1121/48 = 24
  - Max # pages = 1121
    - Pages may or may not be consecutive
    - Actual max getpages is 1121 * 2 = 2242
      - If updated row is relocated because it does not fit on original page (NEARINDREF/FARINDREF)
  - # of getpages
    - = # of qualified pages if list prefetch used (+ # of INDREF rows)
    - <= # of qualified rows (* 2) for random I/O



# After re-clustering

- After clustering by the data access:
  - STATUS, GENDER, ACCTNO
- Number of getpages  25
  - Compared with original 969

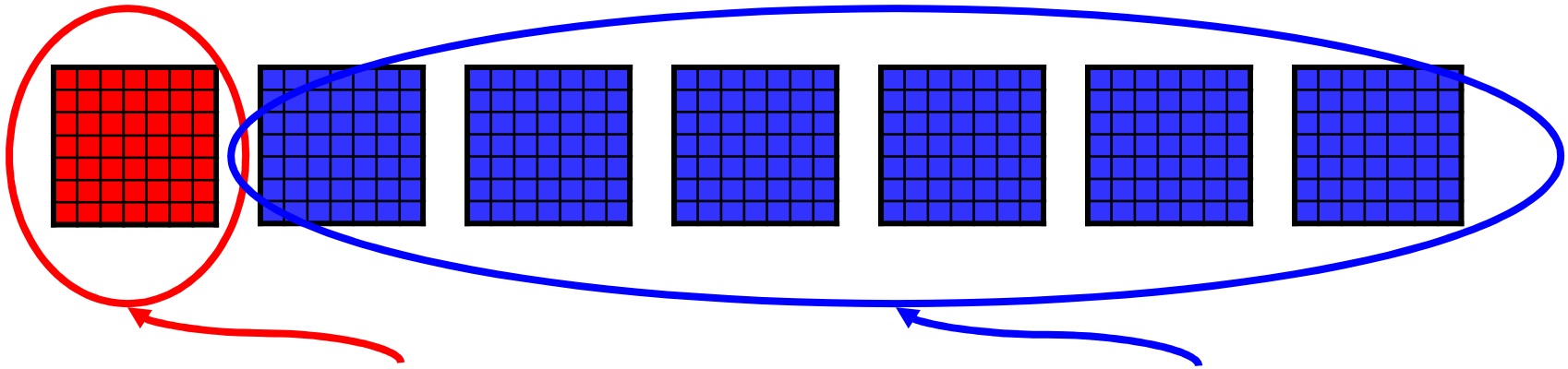
```
BP1     BPOOL ACTIVITY      TOTAL
---------------------   --------
GETPAGES                      25
```

- Note: ACCTNO was added to clustering index so that original clustering is maintained within STATUS/GENDER



# New clustering effect - STATUS

- Clustered by STATUS, GENDER, ACCTNO
  - Status = 95% Y, 5% N
    - The clustering effect is (example not to scale):

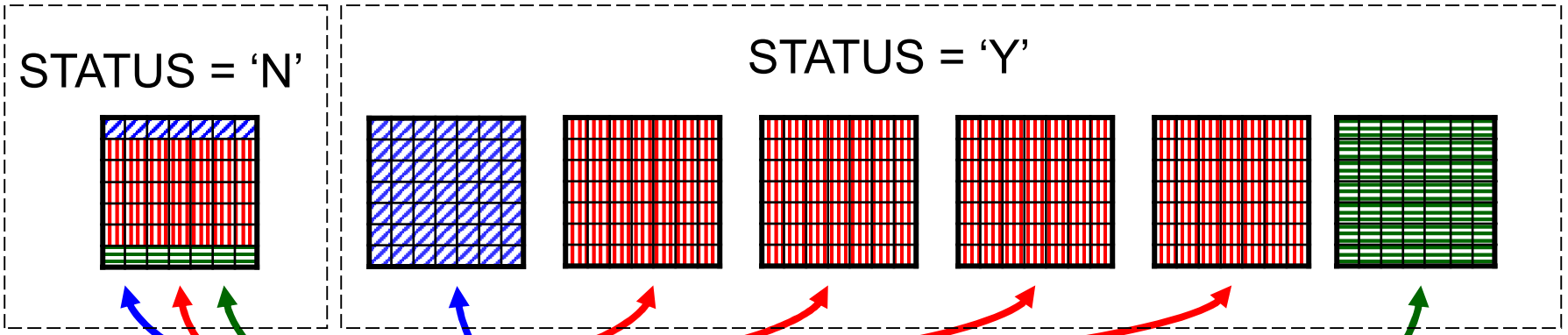


WHERE STATUS = 'N'
accesses only these pages

WHERE STATUS = 'Y'
accesses only these pages

# New clustering effect - GENDER

- Clustered by STATUS, GENDER, ACCTNO
  - Gender = 70% M, 17.5% NULL, 12.5% F
    - GENDER is clustered within each STATUS value
    - The clustering effect is (example not to scale):




GENDER = 'M'
appear on these pages

GENDER = 'F'
appear on these pages

GENDER IS NULL
appear on these pages

# Clustering vs Clusterratio

- Clustering is the density of the data
- Clusterratio implies the sequential nature of the data
  - For the clustering index, clusterratio and clustering are equivalent
  - For the non-clustering index, high clusterratio could mean
    - the data is clustered (dense)
    - OR, the data is sequential but not dense
- DB2 9 RUNSTATS collects data to distinguish these for optimizer
  - Zparm STATCLUS=ENHANCED (default) – Strongly recommended



# Index Screening

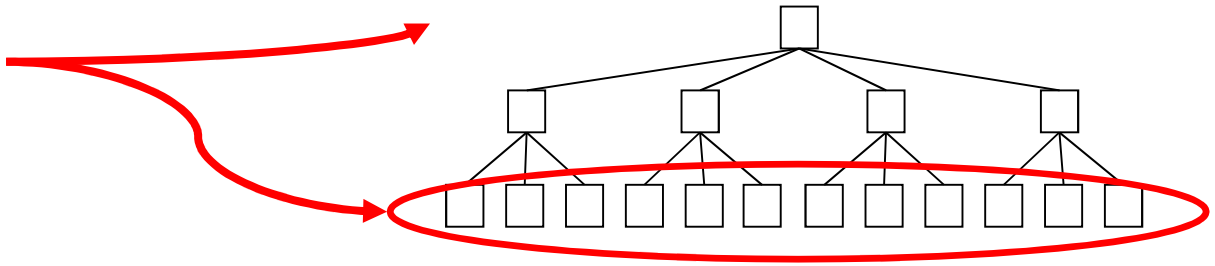


# Index screening

- Index screening does not reduce the number of index rows/pages read
  - Can reduce the number of data rows accessed
  - May or may not result in reduction of data I/O

```
SELECT *
FROM PHONEBOOK
WHERE FIRSTNAME = 'TERRY'
```

No predicate on LASTNAME, so whole index must be read



# Index screening to reduce I/O

- Before reclustering from prior example
  - 1 screening predicate on GENDER
    - Tablespace scan chosen

```
SELECT *
FROM CUSTOMERS
WHERE GENDER = 'F'
```

```
INDEX CUSTIX3 (COUNTRY ASC
              ,STATUS ASC
              ,GENDER ASC)
```

Tablespace scan chosen instead of Non-matching index scan

# How many rows qualify?

- Count shows 24,393 rows qualifying
  - Given that there are 192,960 rows in the table
    - That's 12.64% of the table….OK filtering!!!

```
SELECT COUNT(*) = 24,393
FROM CUSTOMERS
WHERE GENDER = 'F'
```



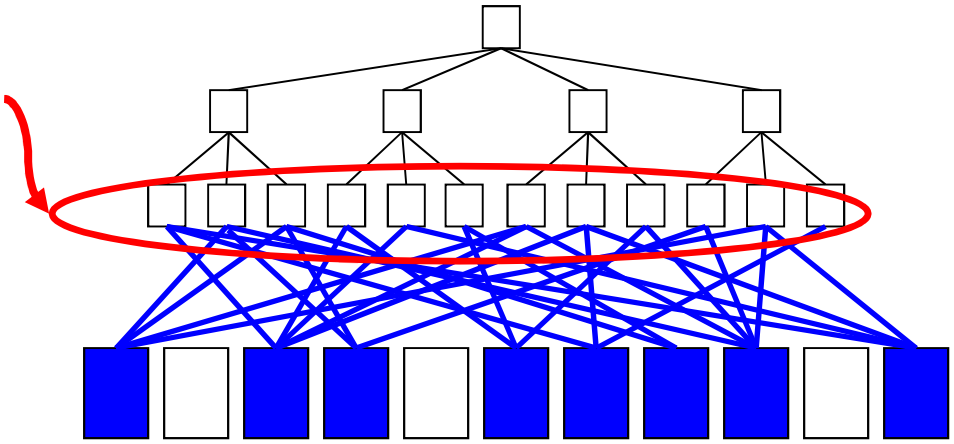
# How many pages do the rows appear on?

- Used OPTHINT to force non-matching index scan

```
BP1     BPOOL ACTIVITY      TOTAL
--------------------------  --------
GETPAGES                    18683
```

  - 18683 getpages to retrieve 24,393 rows
    - Many pages repeatedly accessed
      - Table has 4020 pages

Non-matching index scan



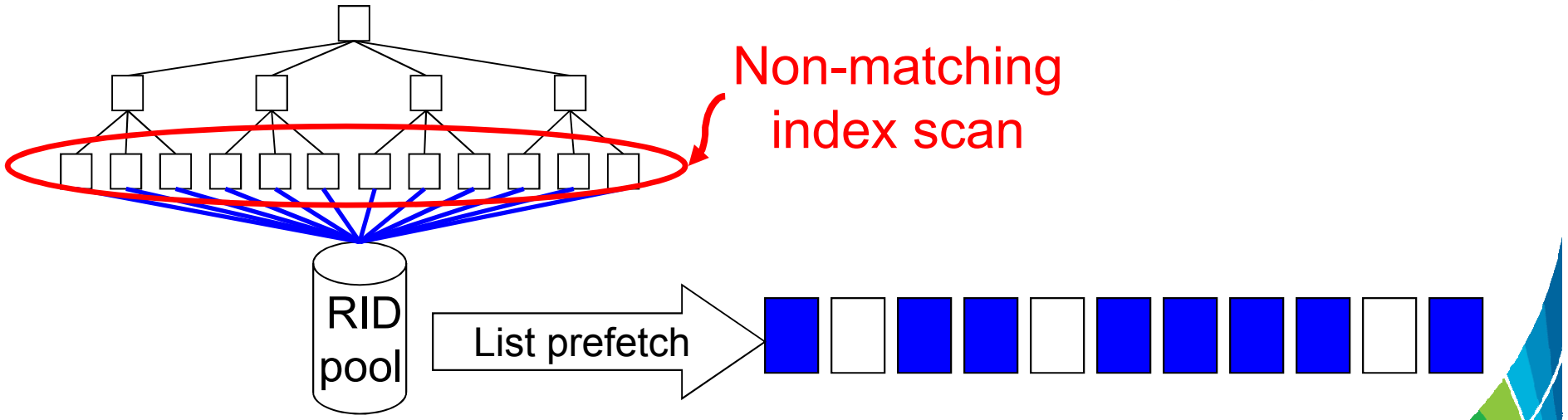


# How many pages do the rows appear on?

- Use OPTHINT to force list prefetch

```
BP1     BPOOL ACTIVITY      TOTAL
---------------------   --------
GETPAGES                    3807
```

  - 3807 getpages to retrieve 24,393 rows
    - GENDER = 'F' appear on most data pages (94.7%)



# After re-clustering

- After clustering by the data access:
  - STATUS, GENDER, ACCTNO
- Number of getpages  509
  - Compared with previous 3807 (with list prefetch)

```
BP1     BPOOL ACTIVITY      TOTAL
---------------------   --------
GETPAGES                      509
```

  - GENDER rows are now clustered within STATUS
    - Rather than scattered throughout all pages



# Matching vs Screening

- The number of qualified rows from the index is dependant on filtering
  - Regardless whether from matching or screening
  - Number of data pages accessed depends on
    - Placement of data (clustering)
    - Ordering of access from index to data
      - High clusterratio implies sequential order
      - List prefetch can “sequentialize” I/O
- Matching can result in a subset of the index accessed
  - Screening does not limit the subset of the index



# Partitioning and indexing (PI, DPSI, and NPI)



# Clustering vs partitioning

- Clustering is a logical grouping
  - Inserts attempt to maintain clustering sequence
- Partitioning is a physical grouping
  - Inserts guarantee that rows can only be inserted into the partition dictated by the partition limit keys
  - Partitioning pruning can be exploited without indexing
  - Can support efficient insert-at-end processing within partitions
  - Freespace search is limited to a partition
- Combine partitioning and clustering (and also UNION ALL in View) for multi-dimensional clustering



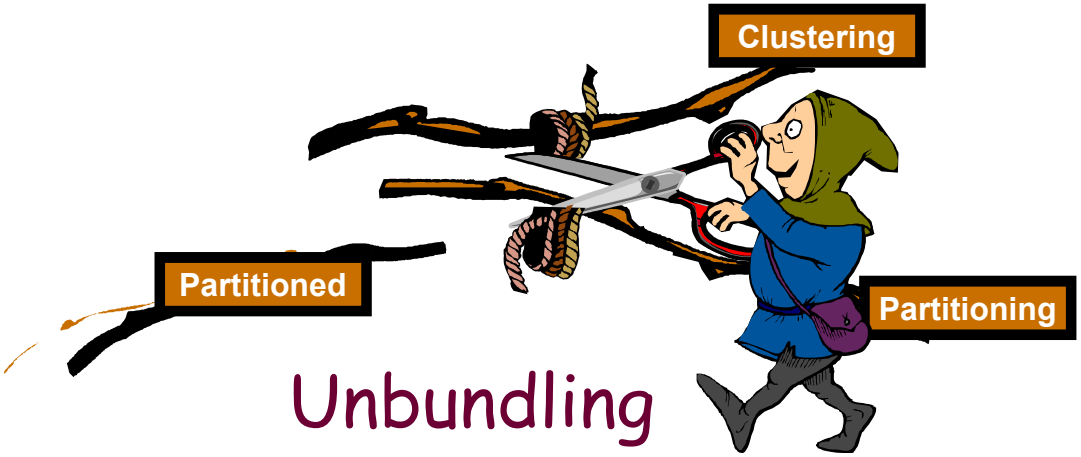
# Table controlled partitioning

- Introduced in DB2 V8
- Unbundling Partitioned Table Attributes
  - Partition without an index
    - Table controlled partitioning
  - Data Partitioned Secondary Index
  - Cluster on any index
- Prior to V8, only index-controlled partitioning supported
  - Many tables may remain as index-controlled

# Table-controlled partitioning

- Partitioning clause moved to CREATE TABLE

```
CREATE  TABLE  CUSTOMER  (
          ACCOUNT_NUM INTEGER,
          CUST_LAST_NM CHAR(30),
          . . .
          LAST_ACTIVITY_DT DATE,
          STATE_CD CHAR(2))
       PARTITION BY ( ACCOUNT_NUM ASC )
       ( PARTITION  1   ENDING AT (199),
         PARTITION  2   ENDING AT (299),
         PARTITION  3   ENDING AT (399),
         PARTITION  4   ENDING AT (499)  ) ;
```



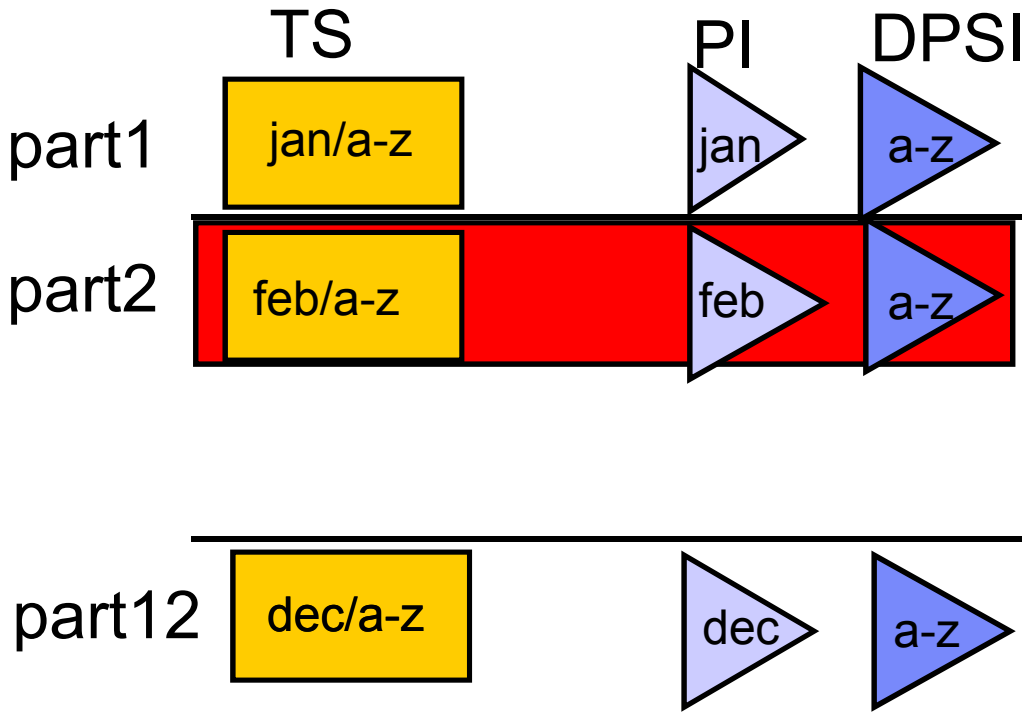

No indexes are required for partitioning!!

TB

| | | | |
|---|---|---|---|
| 101 | 201 | 301 | 401 |
| 102 | 202 | 302 | 402 |
| 103 | 203 | 303 | 403 |
| 104 | 204 | 304 | 404 |
| 105 | 205 | 305 | 405 |
| 106 | 206 | 306 | 406 |

Partitioned table

# Example: Table-based partitioning




- Partition data by month (PI is optional!)
- Clustering by id or name (DPSI clustering)
- No NPI's to deal with, true partition independence

# Version 8+ classification of indexes

- An index may / may not be correlated with the partitioning columns of the table
  - **Partitioning index (PI)**
  - Secondary index
- An index may / may not be physically partitioned
  - Partitioned
  - Non-partitioned
- Clustering index:
  - Any index may be the clustering index
  - The clustering index can be non-unique



# Partitioning indexes

- A partitioning index
  - Has the same leftmost columns as the columns which partition the table
  - These columns have the same collating sequence (ASC / DESC)

```
CREATE TABLE CUSTOMER (
        ACCOUNT_NUM                     INTEGER,
        LAST ACTIVITY_DT        CHAR(3),
        CCODE                                   CHAR(2),
        . . .                                                   )
        PARTITION BY (ACCOUNT_NUM               ASC)
        ...
CREATE . . . INDEX  part_ix_1  ON CUSTOMER (
        ACCOUNT_NUM                     ASC)
```

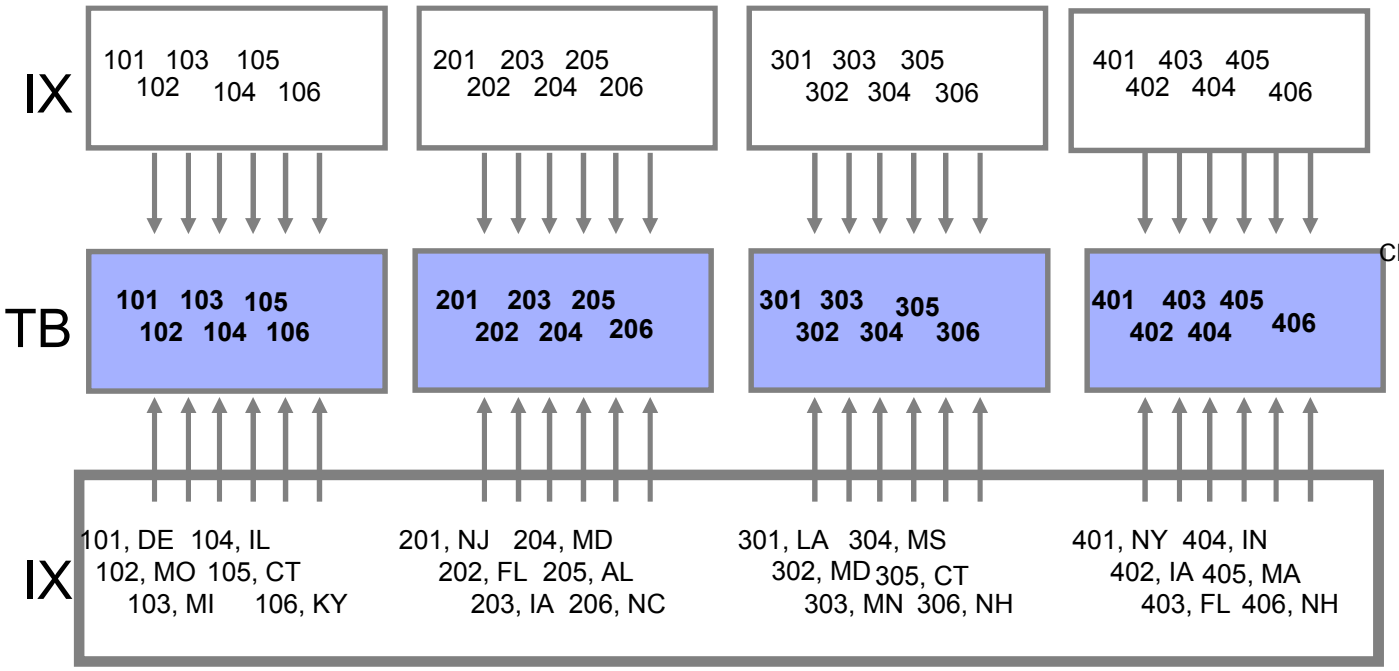
**Partitioning does not equal partitioned!!! But, all partitioning indexes should be partitioned.**

# Partitioning indexes -2

A partitioning index has the same leftmost columns, in the same collating sequence, as the columns which partition the table

- NOTE: IX_1 is partitioned, IX_2 is not (why would you not partition?)

Partitioning index part_IX_1 (ACCOUNT_NUM ASC)



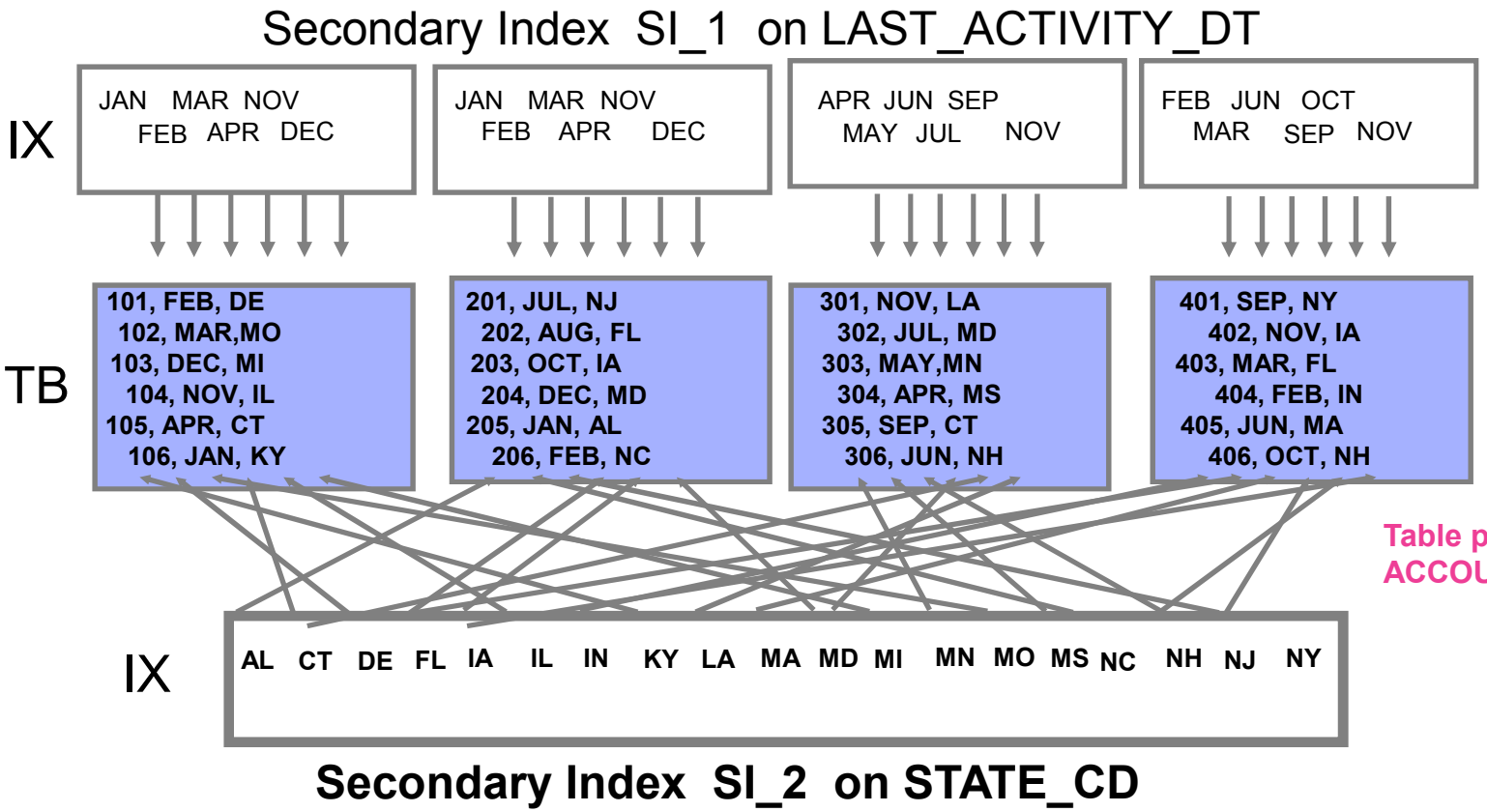

```
CREATE TABLE CUSTOMER (
    ACCOUNT_NUM
            INTEGER,
    CUST_LAST_NM
            CHAR(30),
    . . .
            )
    PARTITION BY (
        ACCOUNT_NUM      ASC)

    . . .
```

Partitioning index part_IX_2 (ACCOUNT_NUM ASC, STATE_CD) [not partitioned]

# Secondary indexes (Partitioned & Non-Partitioned)

A secondary index is any index which is **not** a partitioning index

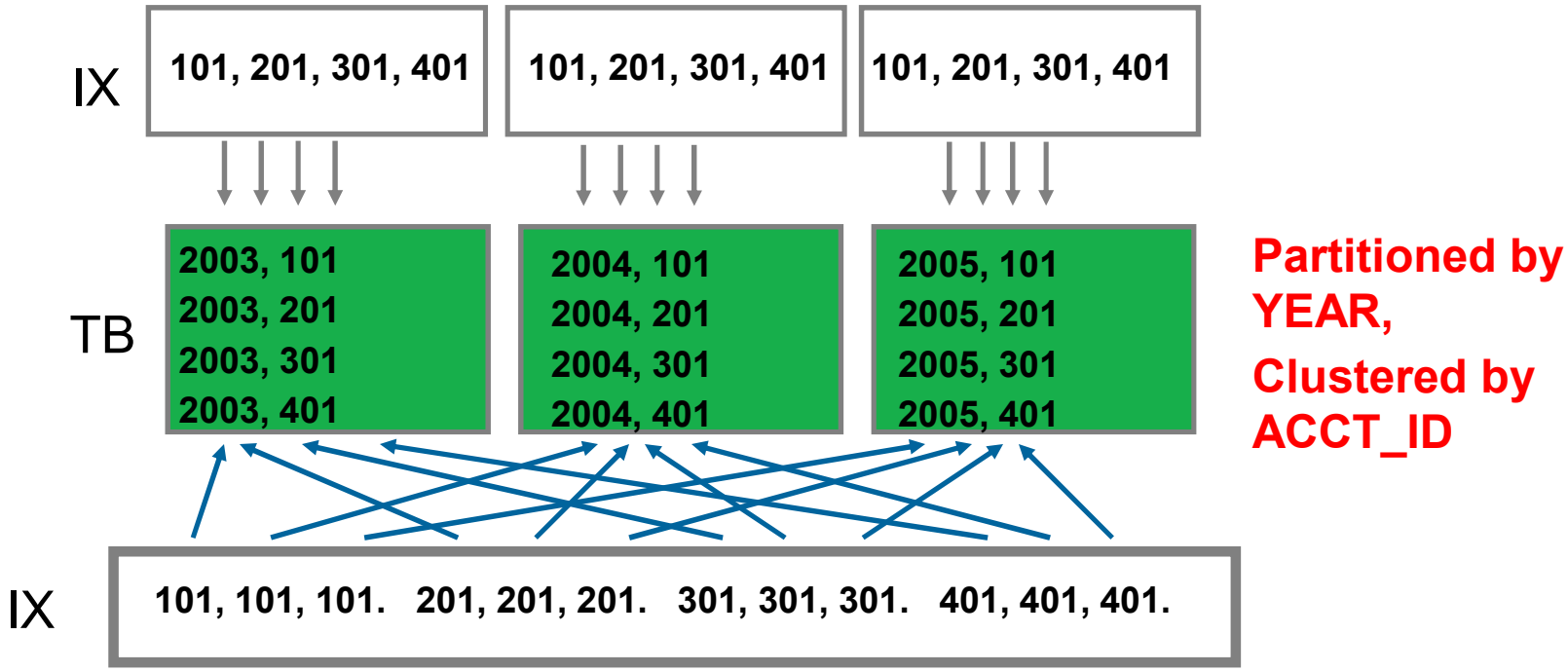
- Can be partitioned – SI_1 known as Data Partitioned Secondary Index (DPSI)
- Or not partitioned – SI_2 – Non-partitioned Secondary Index (NPSI or NPI)



# Partitioning/Clustering Considerations

- Index Clusterratio may differ depending on DPSI or NPI
  - Even if this is the CLUSTERing index

**DPSI on ACCT_ID – Clustering perfectly aligned with partitions**



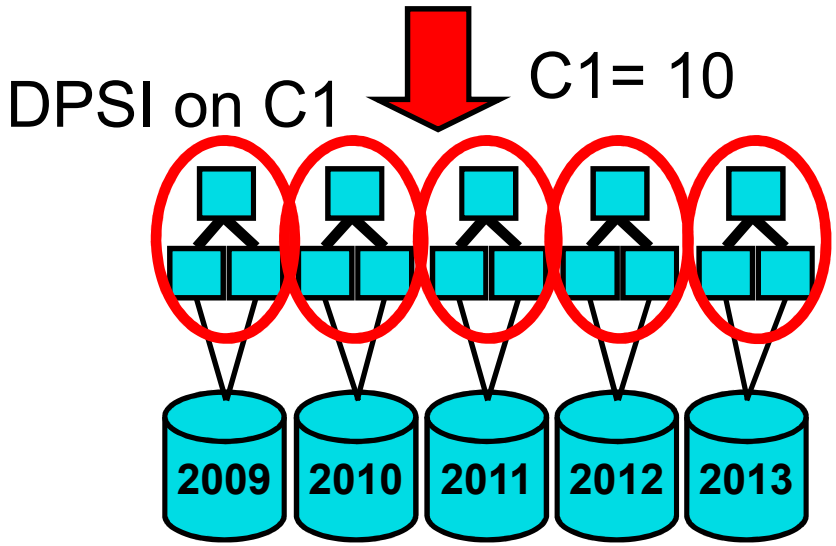

**Partitioned by YEAR,**

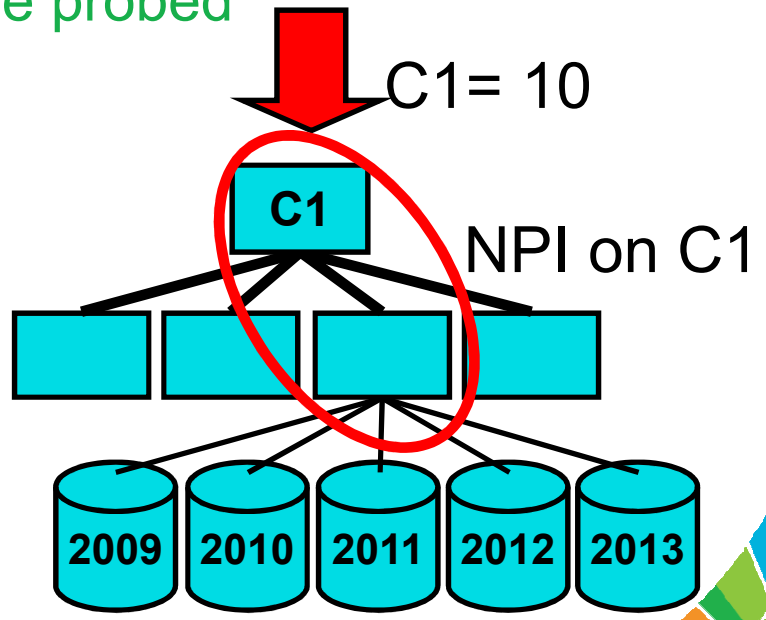
**Clustered by ACCT_ID**

**NPI on ACCT_ID – Clustering not aligned, keys cross partitions**

# Index Access - DPSI vs NPI

- Access to a secondary index without specifying a range de-limiting predicate results in:
  - For DPSI
    - All b-tree structures (up to 4096) must be probed
  - For NPI
    - Only one b-tree structure must be probed

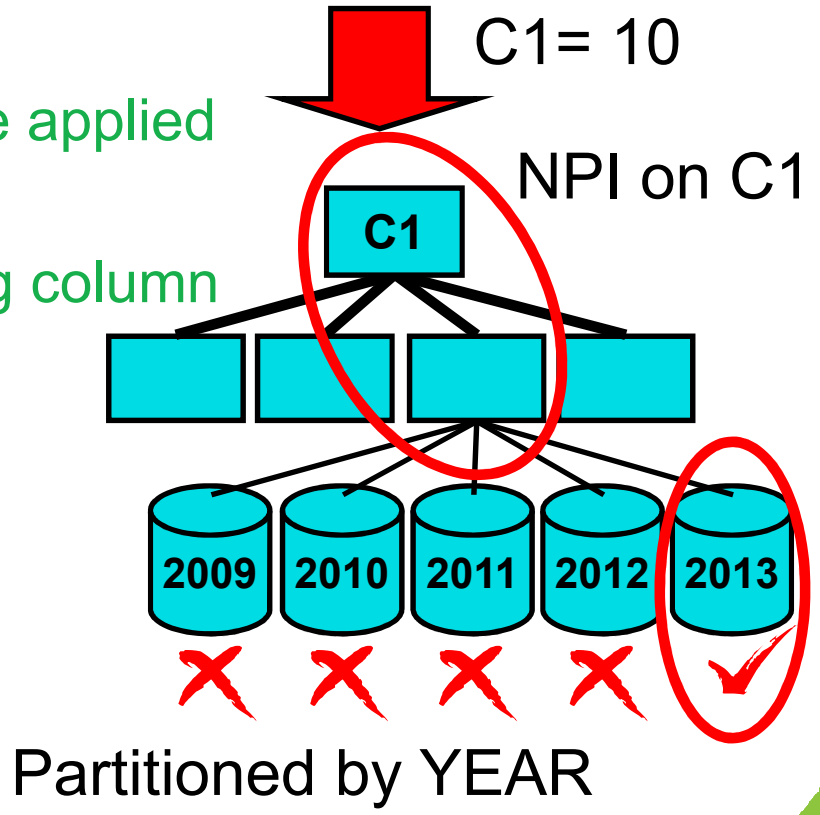


# Page Range Screening - NPI

- Page Range Screening can be applied
  - before data access on an NPI to limit the partitions accessed
    - if a predicate exists that can be applied
  - Similar to index screening
    - Without requiring the screening column to be indexed

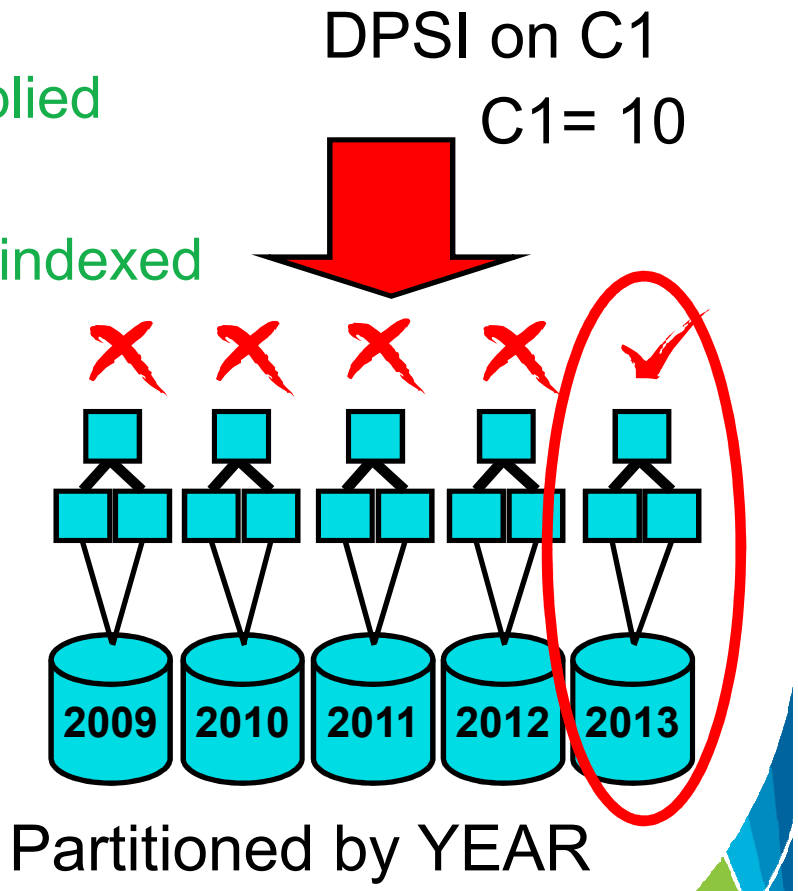
```
SELECT cols
FROM T1
WHERE C1 = 10
AND YEAR = 2013
```



# Page Range Screening - DPSI

- Page Range Screening can be applied
  - When index access occurs
    - if a predicate exists that can be applied
  - Similar to index matching
    - Without requiring the column to be indexed
  - Effect is 2 matching columns
    - 1 from index, 1 from partition
  - Can also function independently

```
WHERE C1 = 10
AND YEAR = 2013
```

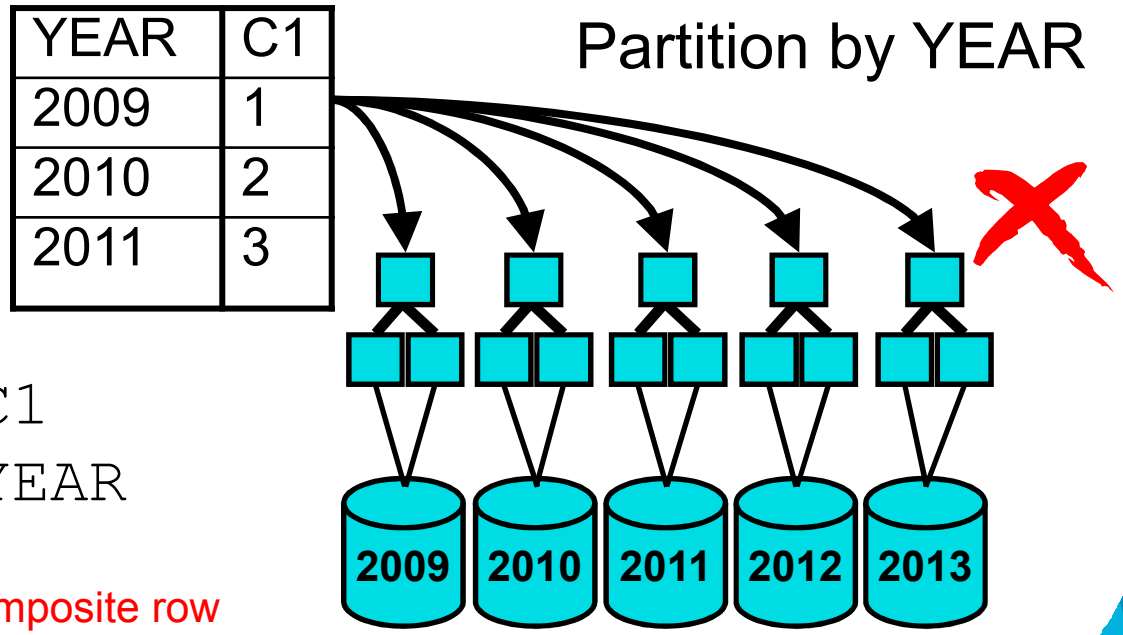


# Pre-V11 DPSI Join Probing (Join on partitioning Col)

- Current challenge
  - 1st composite row probes all parts
  - 2nd composite row probes all parts
  - Etc

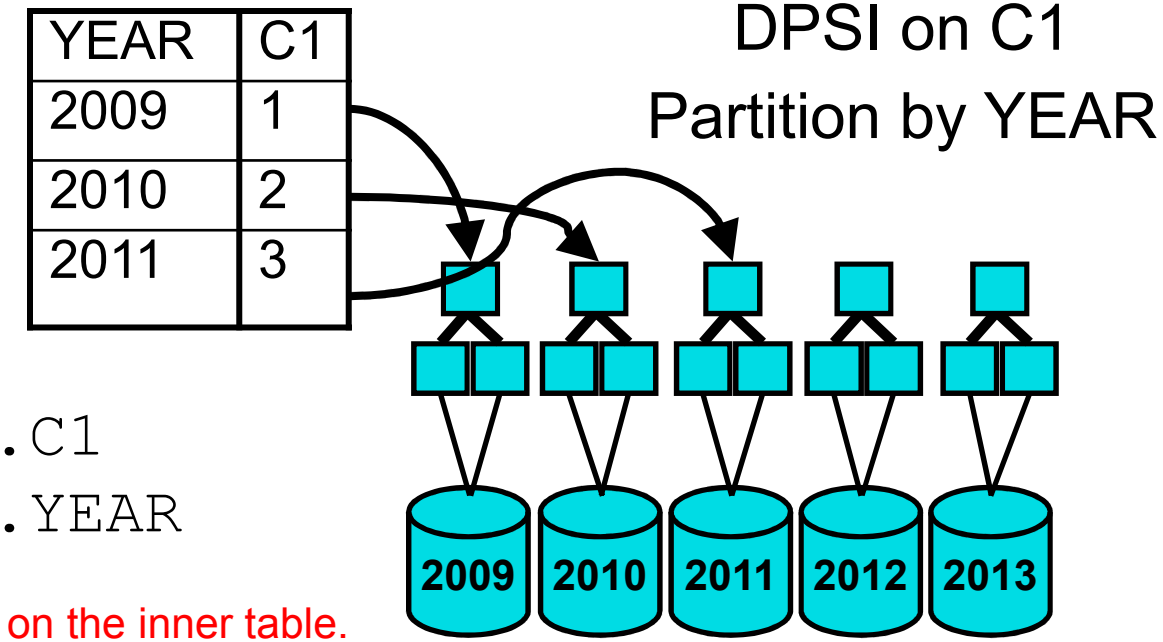
```
SELECT *
FROM T1, T2
WHERE T1.C1 = T2.C1
AND T1.YEAR = T2.YEAR
```

All parts are accessed for each composite row



# V11 DPSI Join Probing (Join on Partitioning Col)

- Join recognizes page range screening
  - 1st composite row probes 1 part.
  - 2nd composite row probes 1 part.
  - And so on.



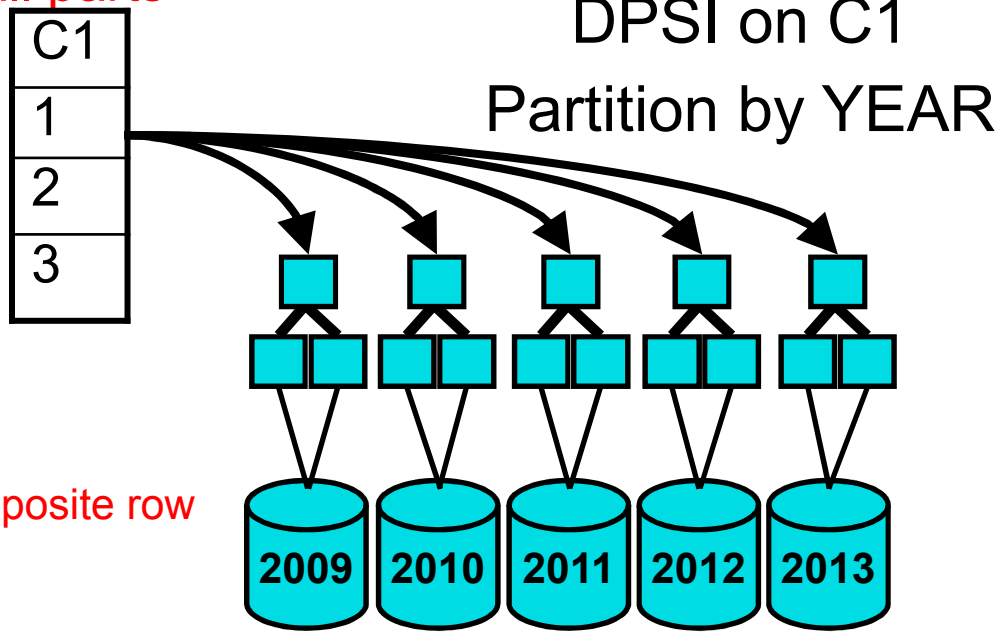

```
SELECT *
FROM T1, T2
WHERE T1.C1 = T2.C1
AND T1.YEAR = T2.YEAR
```

Only qualified parts are probed on the inner table.

# Pre V11 DPSI Probing Challenge for Joins

- NOTE: No page range join predicate
- Current challenge for join to a DPSI
  - 1st composite row probes all parts
  - 2nd composite row probes all parts
  - Etc

```
SELECT *
FROM T1, T2
WHERE T1.C1 = T2.C1
```



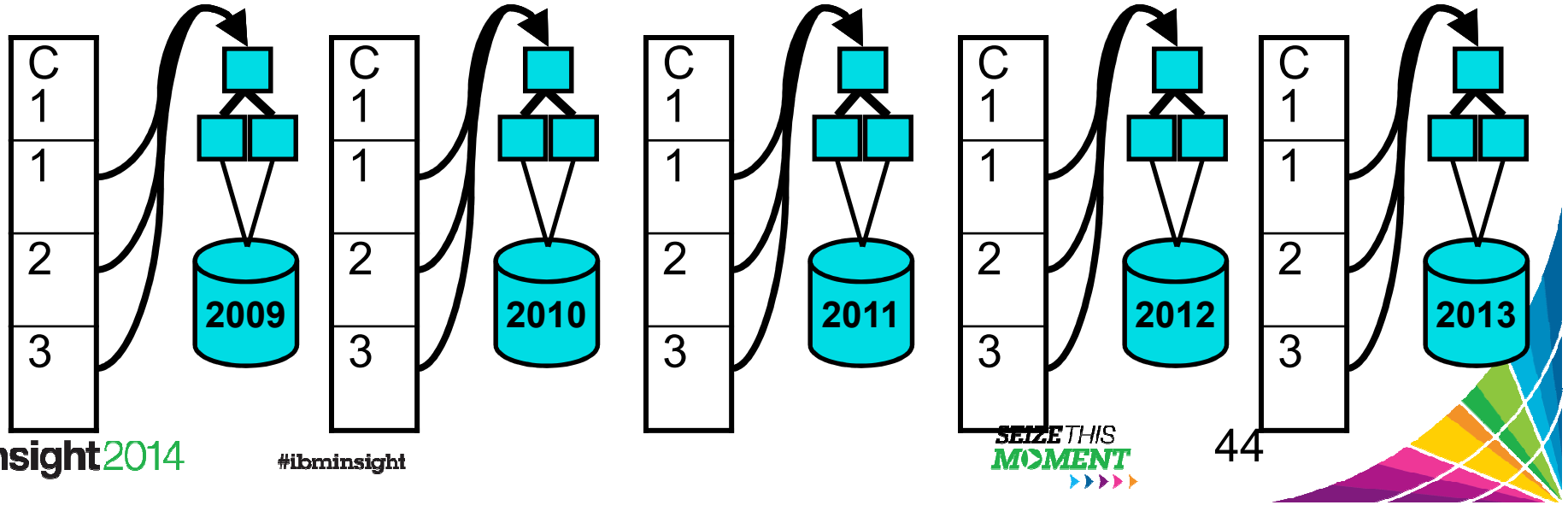

All parts are accessed for each composite row in a round robin fashion

# DPSI Probing – DB2 11 Join Solution

- DB2 11 solution – DPSI part-level Nested Loop Join
  - Repeat composite table for each child task
    - Each child task is a 2 table join
    - Allows each join to T2 to access index sequentially (and data if high CR)

```
SELECT *
FROM T1, T2
WHERE T1.C1 = T2.C1
```

T2
DPSI on C1



# DPSIs that could be PIs

- Partitioning indexes (PIs) do not have the same query performance challenges as DPSIs
- Remember we said any “partitioned” index that has the same leftmost columns as the partitioning key is a PI (Partitioning Index)???

```
PARTITION BY ("C1" ASC,
              "C2" ASC,
              "C3" ASC,
              "C4" ASC,
              "C5" ASC)
(PARTITION 1
ENDING AT ('19999999')
,PARTITION 2
ENDING AT ('29999999')
.....
,PARTITION 16
ENDING AT (MAXVALUE)
```

```
CREATE  UNIQUE  INDEX "PROD"."IX1"
  ON  "PROD"."T1"  (
   ("C1" ASC,
    "C2" ASC,
    "C3" ASC,
    "C4" ASC,
    "C5" ASC)
 CLUSTER PARTITIONED
```

DPSI or PI?

```
CREATE  INDEX "PROD"."IX2"
  ON  "PROD"."T1"  (
   "C1" ASC,
   "C6" ASC)
 NOT CLUSTER PARTITIONED
```

DPSI or PI?

# DPSIs that could be PIs

- Index keys must align with “PARTITION BY” columns to be a PI.
- What if I specify less columns in the limit key?
  - Doesn’t matter.
- Why would you have more “PARTITION BY columns?
  - Pre-V8, index-controlled partitioning meant uniqueness, clustering and partitioning were all linked
    - Hence the reason for these multi-column indexes
      - Because you needed to create the index for all columns, and not just the partitioning columns.



# DPSIs that could be PIs

- Switch from index controlled to table controlled ignored the fact that only the “limit key” columns were relevant
- ZPARM **IX_TB_PART_CONV_EXCLUDE**
  - Delivered 11/2011 in V9/10 via APAR PM45829 (default NO)
  - APAR PM90893 10/2013 changed default to YES
- What does this zparm do?
  - When switching from index controlled to table controlled partitioning
    - Only “limit key” columns will be used as partitioning columns



# DPSIs that could be PIs

- Recap of original example
  - With **IX_TB_PART_CONV_EXCLUDE=YES**
    - Both indexes would be PIs

```
PARTITION BY ("C1" ASC)
(PARTITION 1
ENDING AT ('19999999')
,PARTITION 2
ENDING AT ('29999999')
.....
,PARTITION 16
ENDING AT (MAXVALUE)
```

```
CREATE  UNIQUE  INDEX "PROD"."IX1"
  ON  "PROD"."T1"  (
   ("C1" ASC,
    "C2" ASC,
    "C3" ASC,
    "C4" ASC,
    "C5" ASC)
 CLUSTER PARTITIONED

CREATE  INDEX "PROD"."IX2"
  ON  "PROD"."T1"  (
   "C1" ASC,
   "C6" ASC)
 NOT CLUSTER PARTITIONED
```



# Conclusion



# I/O Conclusion

- When an index provides 10% filtering
  - Is that 10% of the data pages?
  - Or, 10% of the rows on 100% of the data pages?
- Filtering pages is just as important as filtering rows
  - Indexing filters the rows
  - Clustering/partitioning filters the pages
- Cluster/partition by data access, not by the primary key
  - And remember there is clustering of the index, and clustering of the data



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# DB2 11 for z/OS: Partitioning and Indexing – Query Performance Considerations

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