Get the best out of Oracle Partitioning

A practical guide and reference

Before we start ..

Oracle wants to hear from you!

- There's still lots of ideas and things to do
- Input steers the direction

Let us know about

- Interesting use cases and implementations
- Enhancement requests
- Complaints

Contact us at:

- dw-pm_us@oracle.com
- hermann.baer@oracle.com
- @sdjh2000 (twitter/X)

Oracle Partitioning

Partitioning Overview

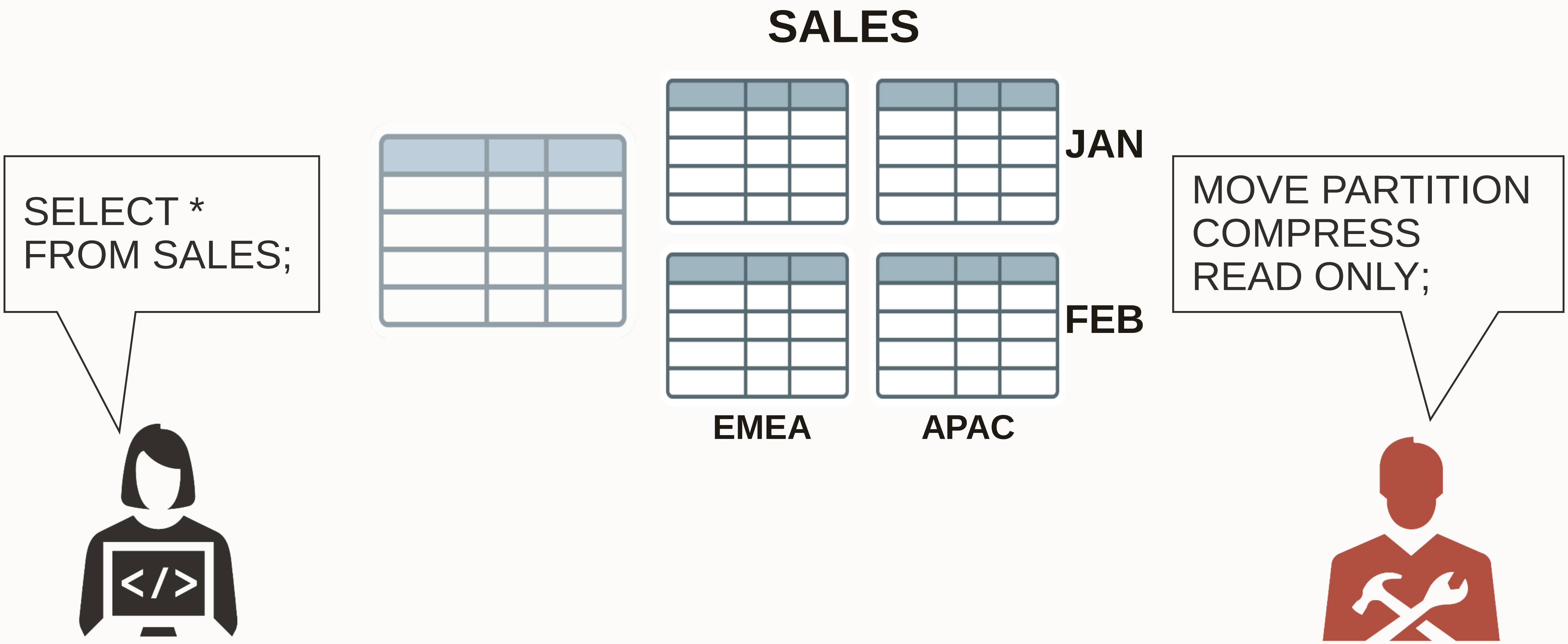
What is Oracle Partitioning?

- Powerful functionality to logically divide objects into smaller pieces
- Key requirement for large databases needing high performance and high availability
- Driven by business requirements

Why use Oracle Partitioning?

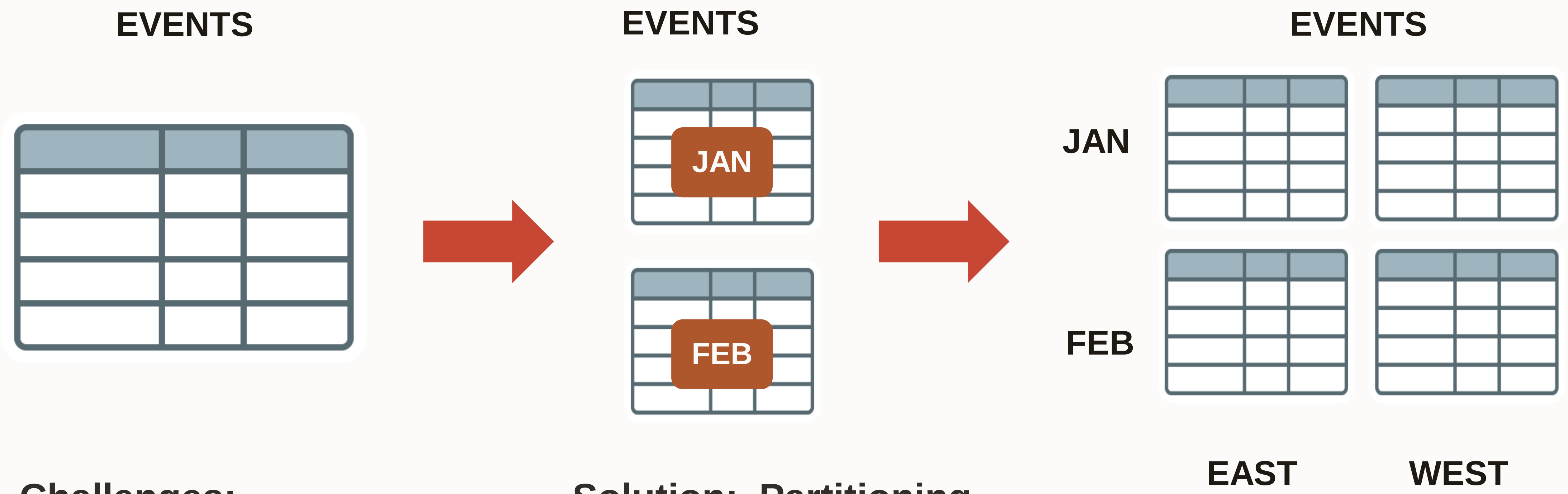
- Performance – lowers data access times
- Availability – improves access to critical information
- Costs – leverages multiple storage tiers
- Easy Implementation – requires no changes to applications and queries
- Mature Feature – supports a wide array of partitioning methods
- Well Proven – used by thousands of Oracle customers

The two Personalities of Partitioning



How does Partitioning work?

Enables large databases and indexes to be split into smaller, more manageable pieces



Challenges:
Large tables are difficult to manage

Solution: Partitioning

- Divide and conquer
- Easier data management
- Improve performance

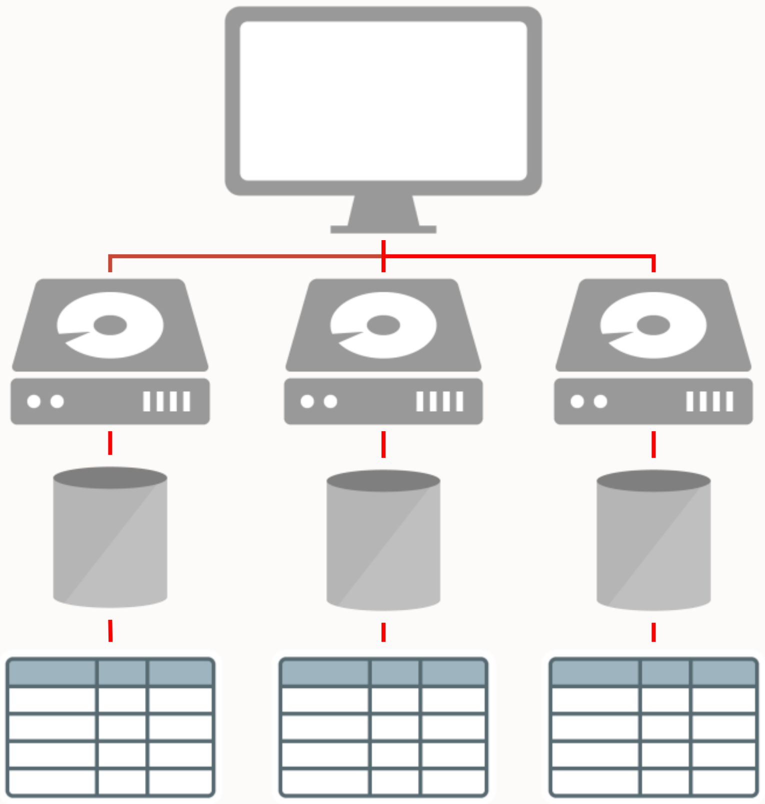
Partitioning Concepts

def **Par•ti•tion**

To divide (something) into parts

"Merriam Webster Dictionary"

Physical Partitioning
Shared Nothing Architecture



Fundamental system setup requirement

- Node owns piece of DB
- Enables parallelism

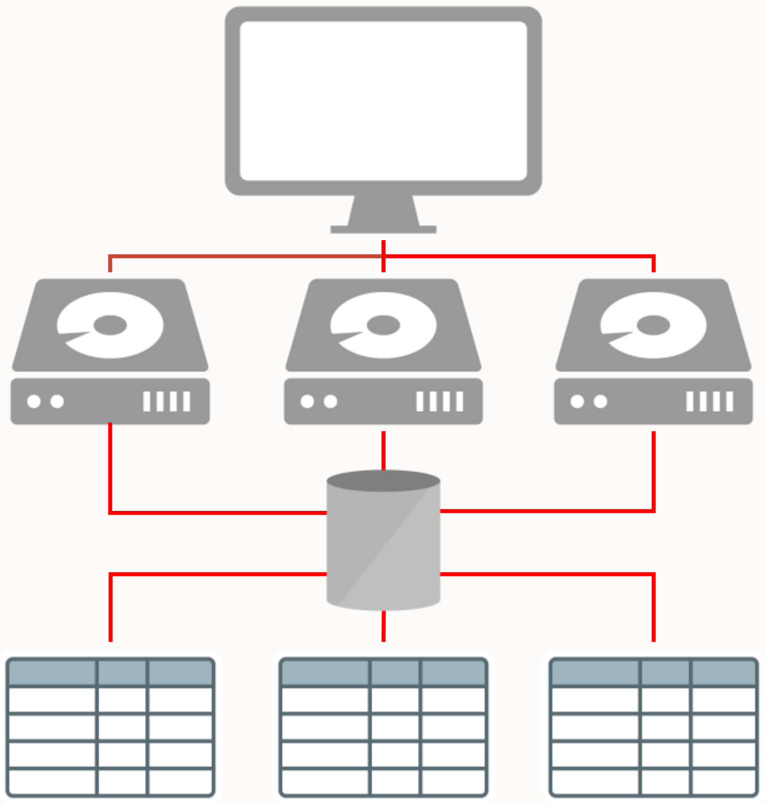
Number of partitions is equivalent to minimum required parallelism

- Always needs HASH or random distribution

Equally sized partitions per node required for proper load balancing

Logical Partitioning

Shared Everything Architecture - Oracle



Does not underlie any constraints

- SMP, MPP, Cluster, Grid does not matter

Purely based on the business requirement

- Availability, Manageability, Performance

Beneficial for every environment

- Provides the most comprehensive functionality

Partitioning Benefits

Increased Performance

Only work on the data that is relevant

Partitioning enables data management operations such as…

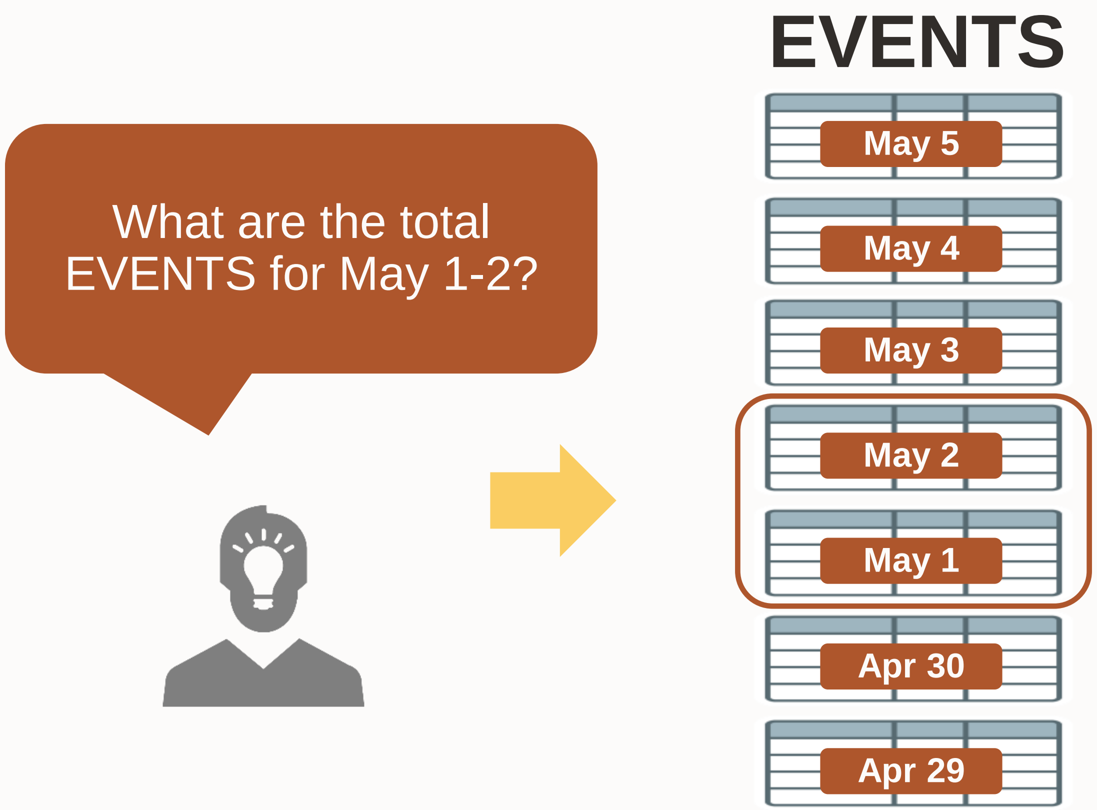
- Data loads, joins and pruning,
- Index creation and rebuilding,
- Optimizer statistics management,
- Backup and recovery

… at partition level instead of on the entire table

Result: Order of magnitude gains on performance

Increased Performance - Example

Partition Pruning

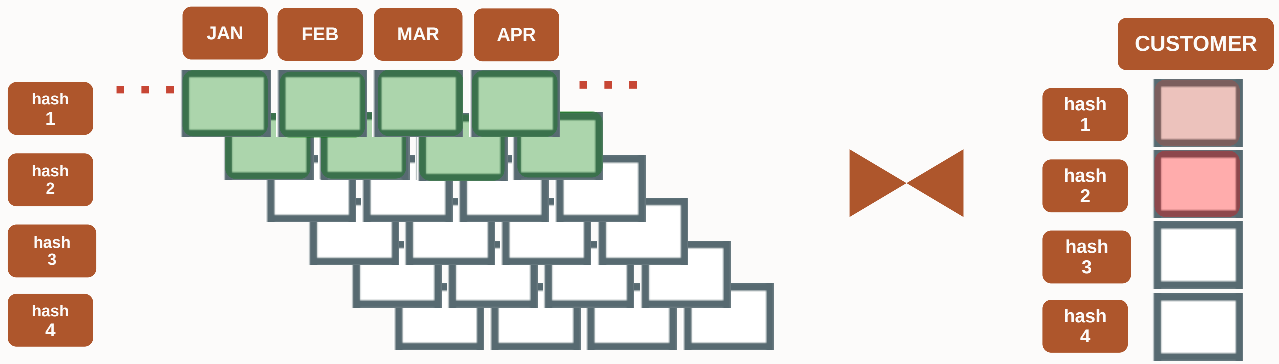


Partition elimination

- Dramatically reduces amount of data retrieved from storage
- Performs operations only on relevant partitions
- Transparently improves query performance and optimizes resource utilization

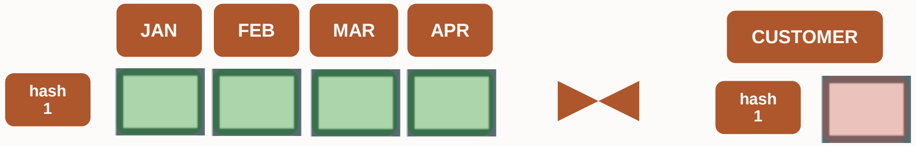
Increased Performance - Example

Partition-wise joins



A large join is divided into multiple smaller joins, executed in parallel

- # of partitions to join must be a multiple of DOP
- Both tables must be partitioned the same way on the join column



Decreased Costs

Store data in the most appropriate manner

Partitioning finds the balance between…

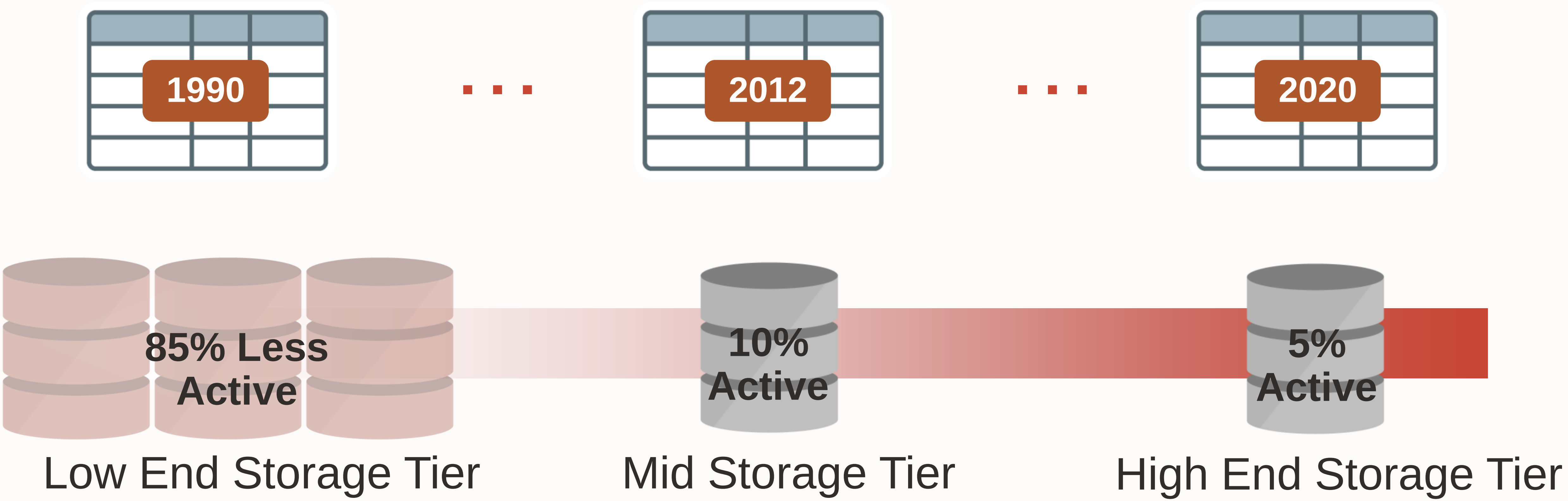
- Data importance
- Storage performance
- Storage reliability
- Storage form

… allowing you to leverage multiple storage tiers

Result: Reduce storage costs by 2x or more

Decreased Costs - Example

Partition for Tiered Storage



Increased Availability

Individual partition manageability

Partitioning reduces…

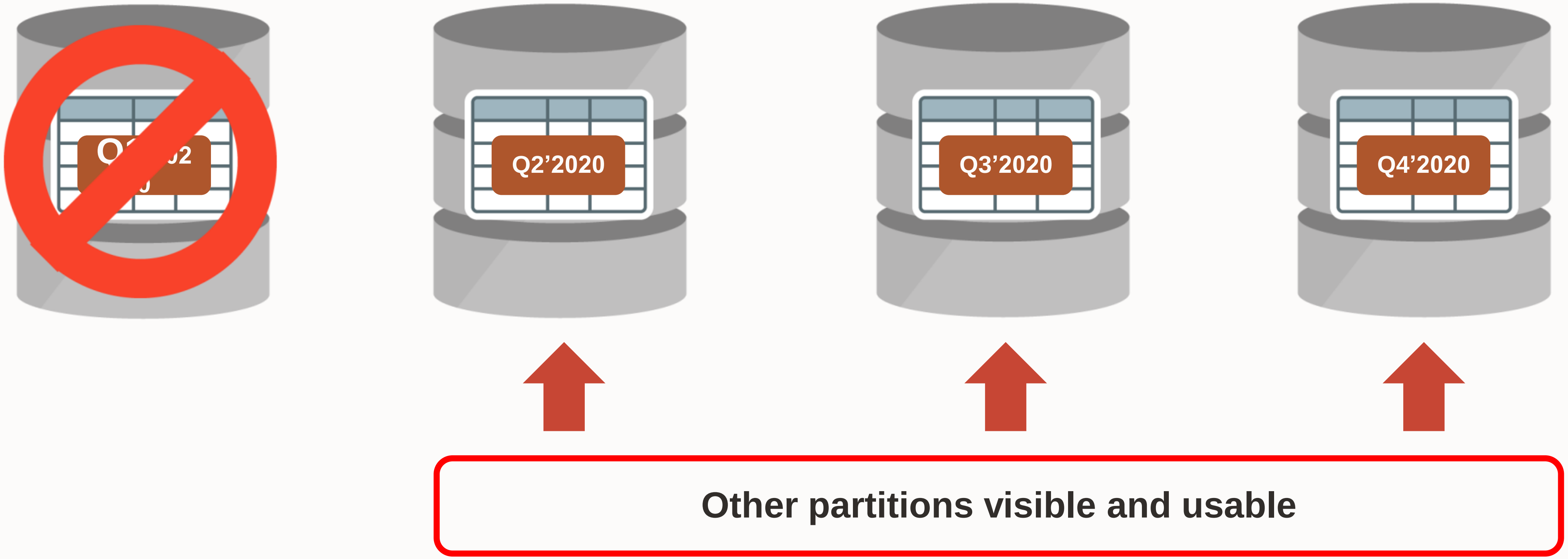
- Maintenance windows
- Impact of scheduled downtime and failures,
- Recovery times

… if critical tables and indexes are partitioned

Result: Improves access to critical information

Increased Availability - Example

Partition for Manageability/Availability



Easy Implementation

Transparent to applications

Partitioning requires NO changes to applications and queries

- Adjustments might be necessary to fully exploit the benefits of Partitioning

Mature, Well Proven Functionality

Over a decade of development

Used by tens of thousands of Oracle customers

Supports a wide array of partitioning methods

Oracle Partitioning today

	Core functionality	Performance	Manageability
Oracle 8.0	Range partitioning Local and global Range indexing	Static partition pruning	Basic maintenance: ADD, DROP, EXCHANGE
Oracle 8i	Hash partitioning Range-Hash partitioning	Partition-wise joins Dynamic partition pruning	Expanded maintenance: MERGE
Oracle 9i	List partitioning		Global index maintenance
Oracle 9i R2	Range-List partitioning	Fast partition SPLIT	
Oracle 10g	Global Hash indexing		Local Index maintenance
Oracle 10g R2	1M partitions per table	Multi-dimensional pruning	Fast DROP TABLE
Oracle 11g	Virtual column based partitioning More composite choices Reference partitioning		Interval partitioning Partition Advisor Incremental stats mgmt
Oracle 11g R2	Hash-* partitioning Expanded Reference partitioning	"AND" pruning	Multi-branch execution (aka table or-expansion)
Oracle 12c R1	Interval-Reference partitioning	Partition Maintenance on multiple partitions Asynchronous global index maintenance	Online partition MOVE, Cascading TRUNCATE, Partial indexing
Oracle 12c R2	Auto-list partitioning Multi-column list [sub]partitioning	Online partition maintenance operations Online table conversion to partitioned table Reduced cursor invalidations for DDL's	Filtered partition maintenance operations Read only partitions Create table for exchange
Oracle 18c	Partitioned external tables	Completion of online partition maintenance Enhanced online table conversions	Validation of data content
Oracle 19c	Hybrid partitioned tables		Object storage access*
Oracle 23c	Interval and auto list for hybrid partitioned tables Logical partition change tracking for materialized views	ALTER TABLE MOVE for all partitions of a table (21c) ALTER TABLE MODIFY to nonparallel	Enhanced Partition metadata Table and partition level read access tracking

* Manual installation of DBMS_CLOUD on non-autonomous, see MOS 2748362.1

Partitioning Methods

What can be partitioned?

Tables

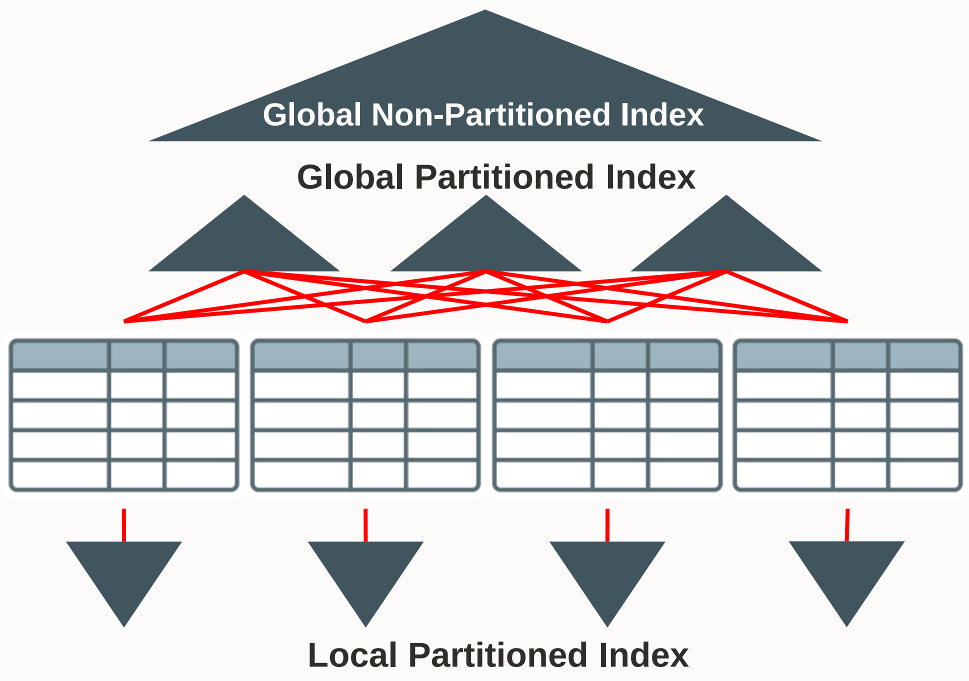
- Heap tables
- Index-organized tables

Indexes

- Global Indexes
- Local Indexes

Materialized Views

Hash Clusters



Partitioning Methods

Single-level partitioning

- Range
- List
- Hash

Composite-level partitioning

  - [Range | List | Hash | Interval] – [Range | List | Hash]

Partitioning extensions

- Interval
- Reference
- Interval Reference
- Virtual Column Based
- Auto

Range Partitioning

Introduced in Oracle 8.0

Range Partitioning

Data is organized in ranges

- Lower boundary derived by upper boundary of preceding partition
- Split and merge as necessary
- No gaps

Ideal for chronological data

List Partitioning

Introduced in Oracle 9i (9.0)

List Partitioning

Data is organized in lists of values

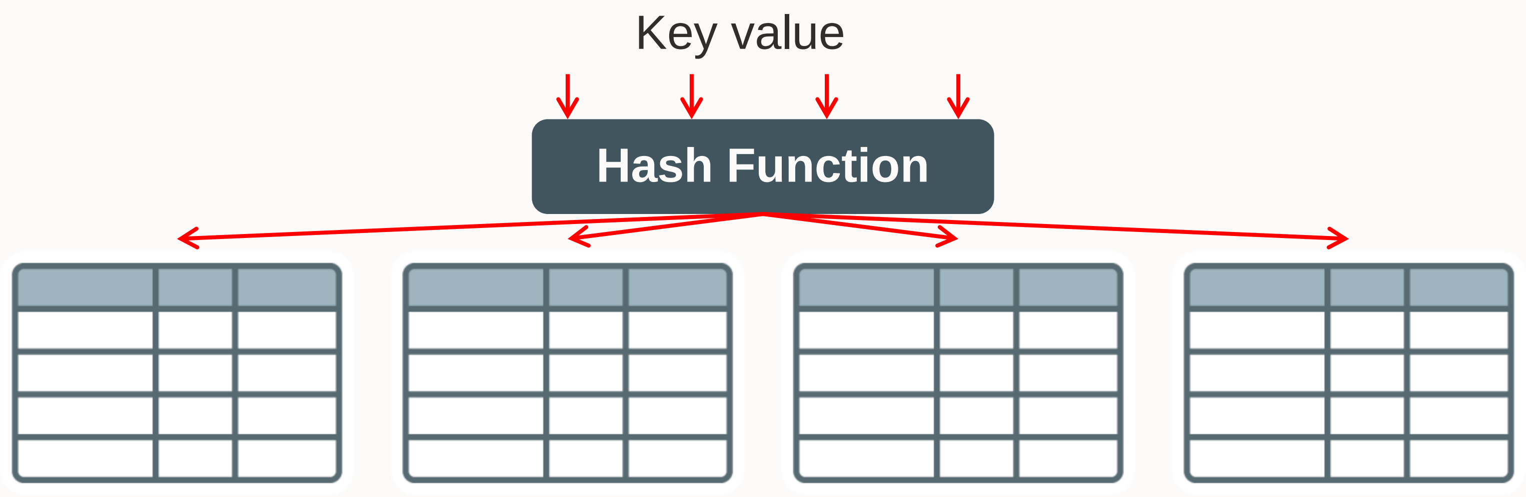
- One or more unordered distinct values per list
- Functionality of DEFAULT partition (Catch-it-all for all unspecified values)
- Check contents of DEFAULT partition – create new partitions as per need

Ideal for segmentation of distinct values, e.g. region

Hash Partitioning

Introduced in Oracle 8i (8.1)

Hash Partitioning



Data is placed based on hash value of partition key

- Number of hash buckets equals number of partitions

Ideal for equal data distribution

- Number of partitions should be a power of 2 for equal data distribution

Composite Partitioning

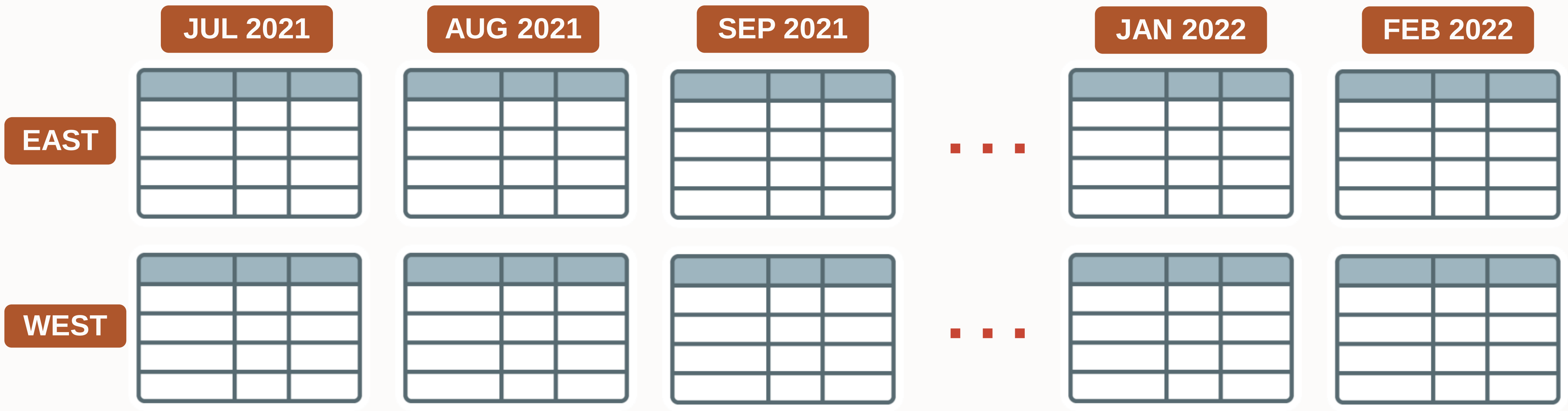
Range-Hash introduced in Oracle 8i

Range-List introduced in Oracle 9i Release 2

[Interval | Range | List | Hash]-[Range | List | Hash] introduced in Oracle 11g Release 1|2

***Hash-Hash in 11.2**

Composite Partitioning



Data is organized along two dimensions

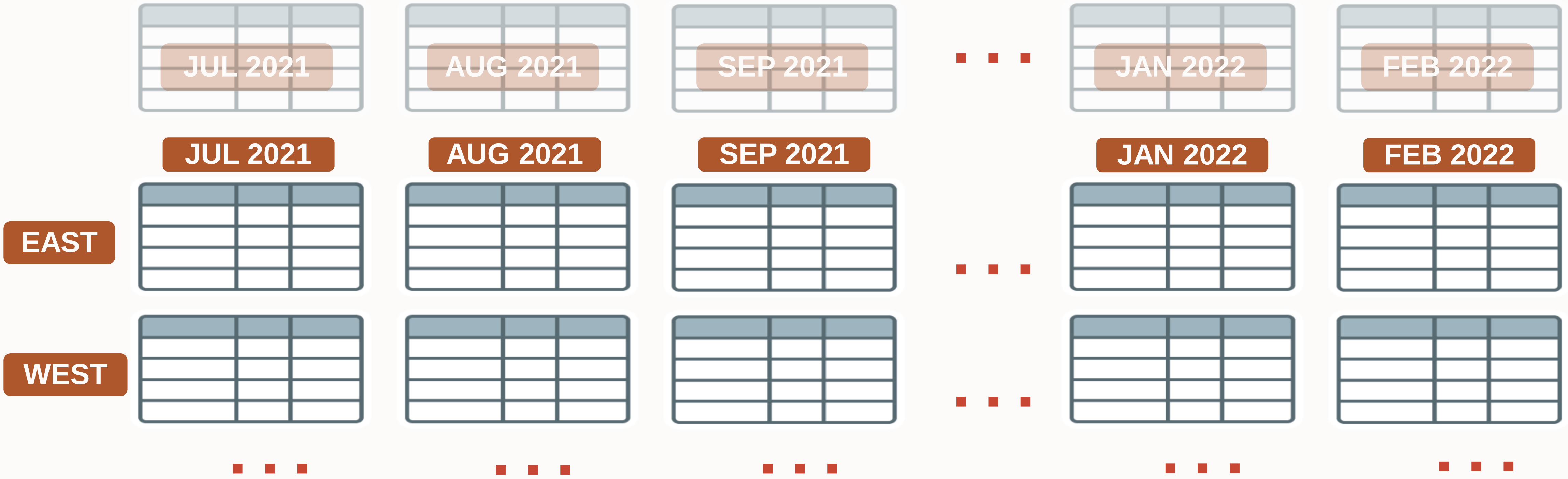
- Record placement is deterministically identified by dimensions
  - Example RANGE-LIST

Composite Partitioning

Concept

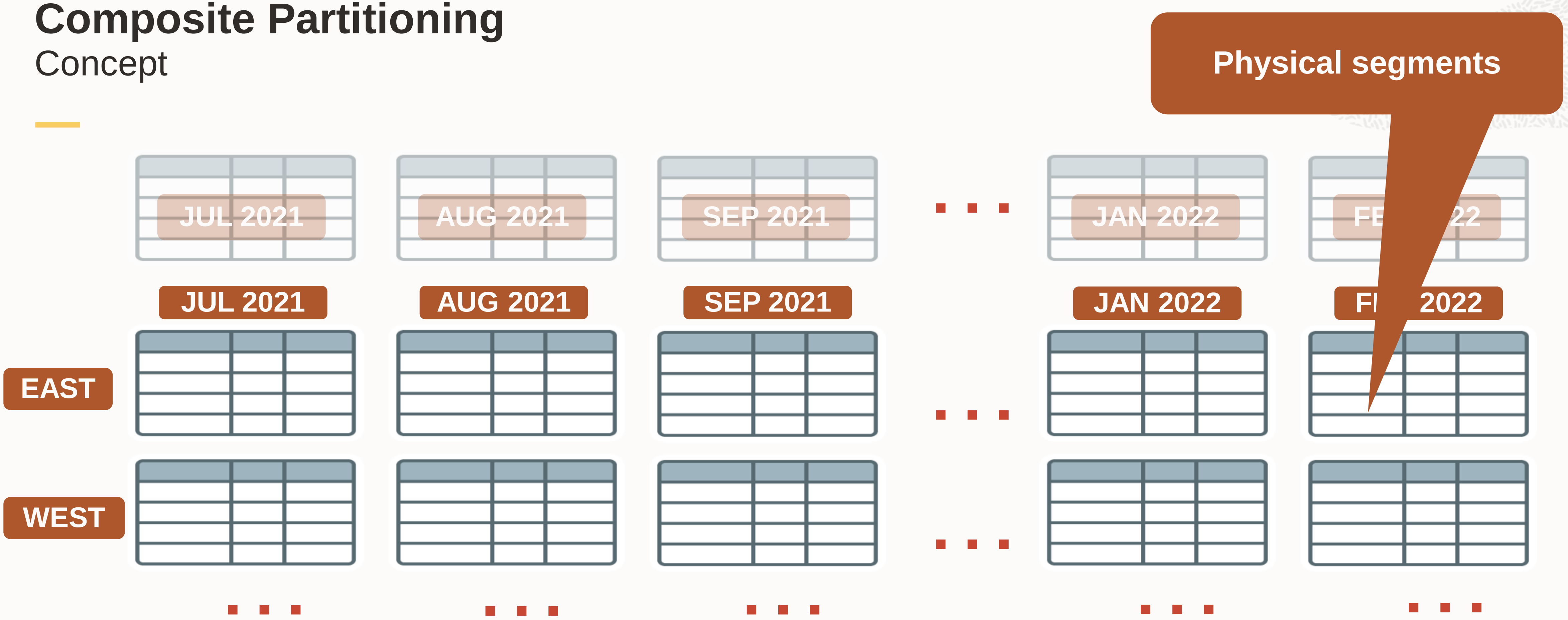

```
CREATE TABLE EVENTS ..PARTITION BY RANGE (time_id)
```


Composite Partitioning
Concept




```
CREATE TABLE EVENTS ..PARTITION BY RANGE (time_id)
                     SUPARTITION BY LIST (region)
```

Composite Partitioning
Concept

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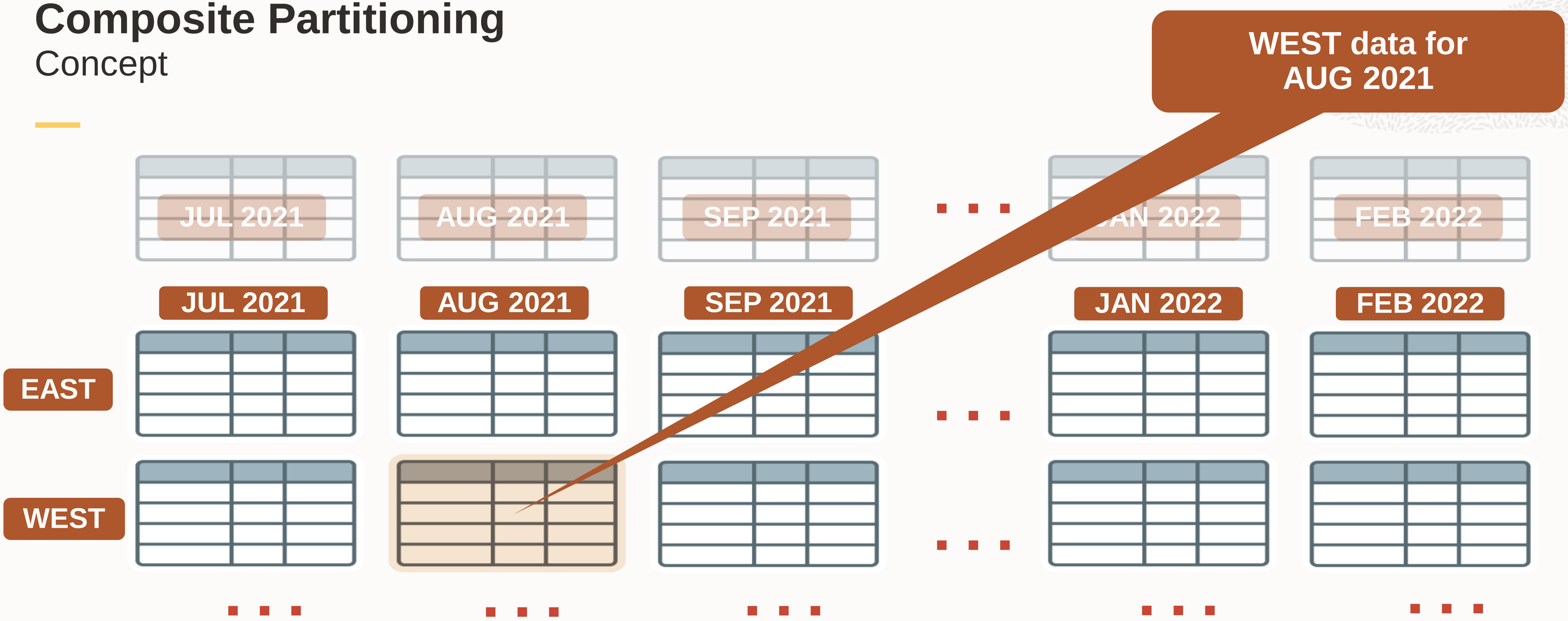


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Composite Partitioning

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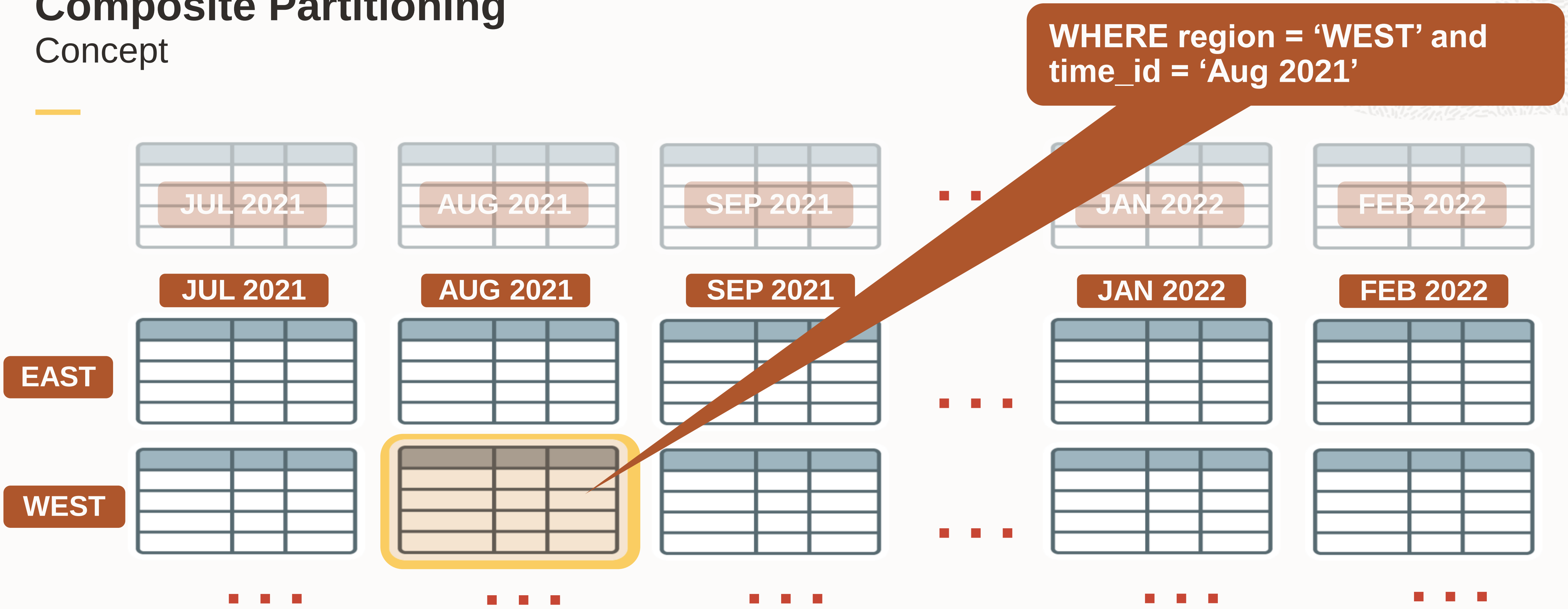
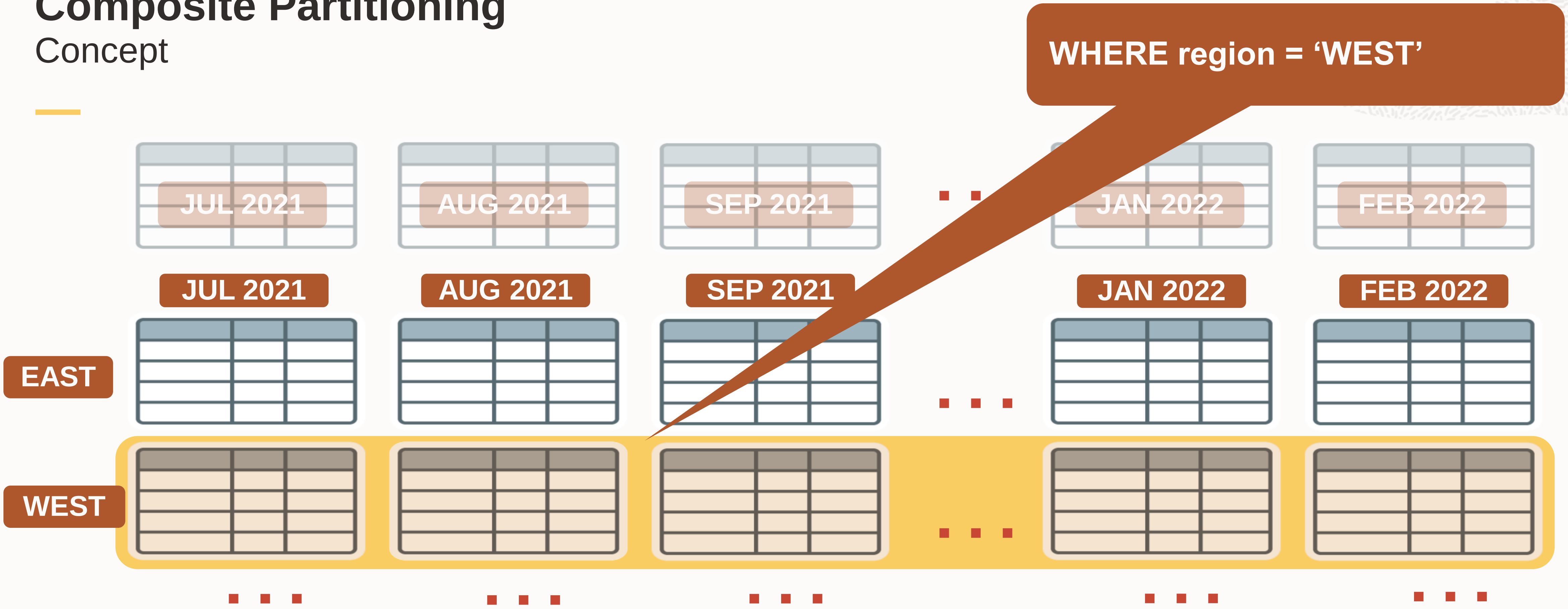


Partition pruning is independent of composite order

- Pruning along one or both dimensions
- Same pruning for RANGE-LIST and LIST_RANGE

Composite Partitioning
Concept



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Composite Partitioning
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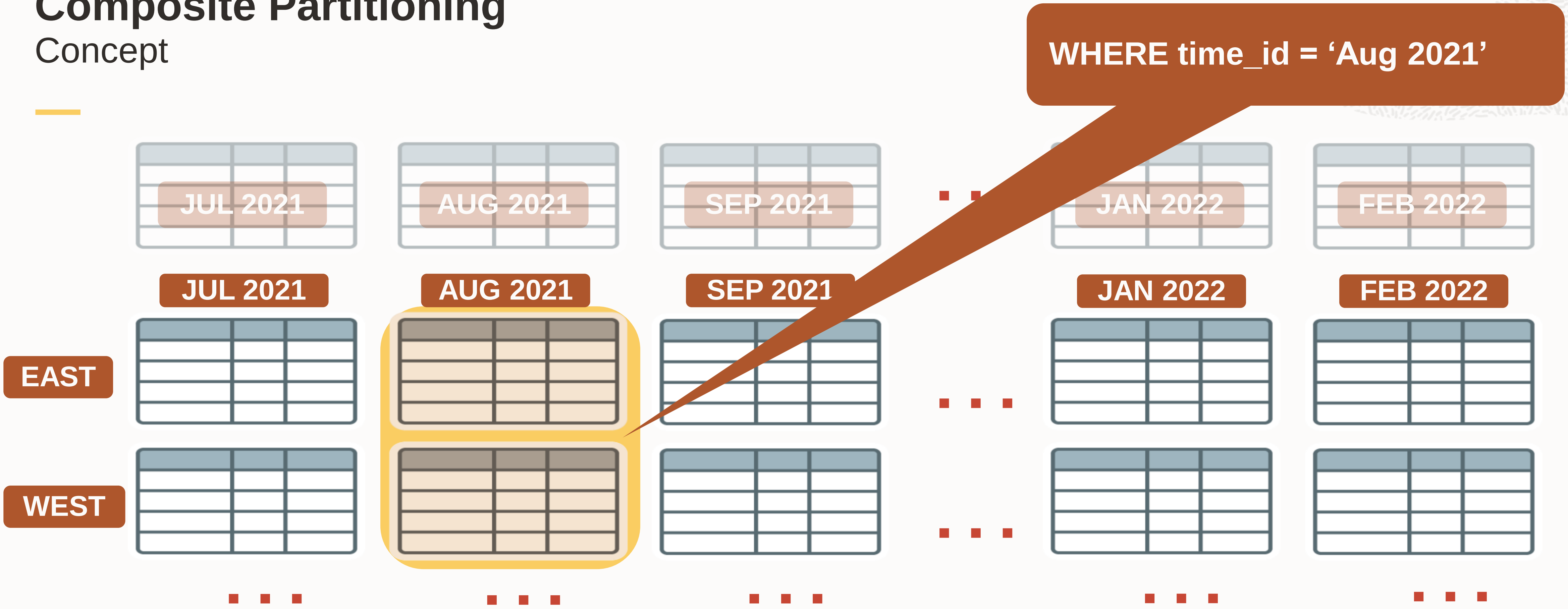

Partition pruning is independent of composite order

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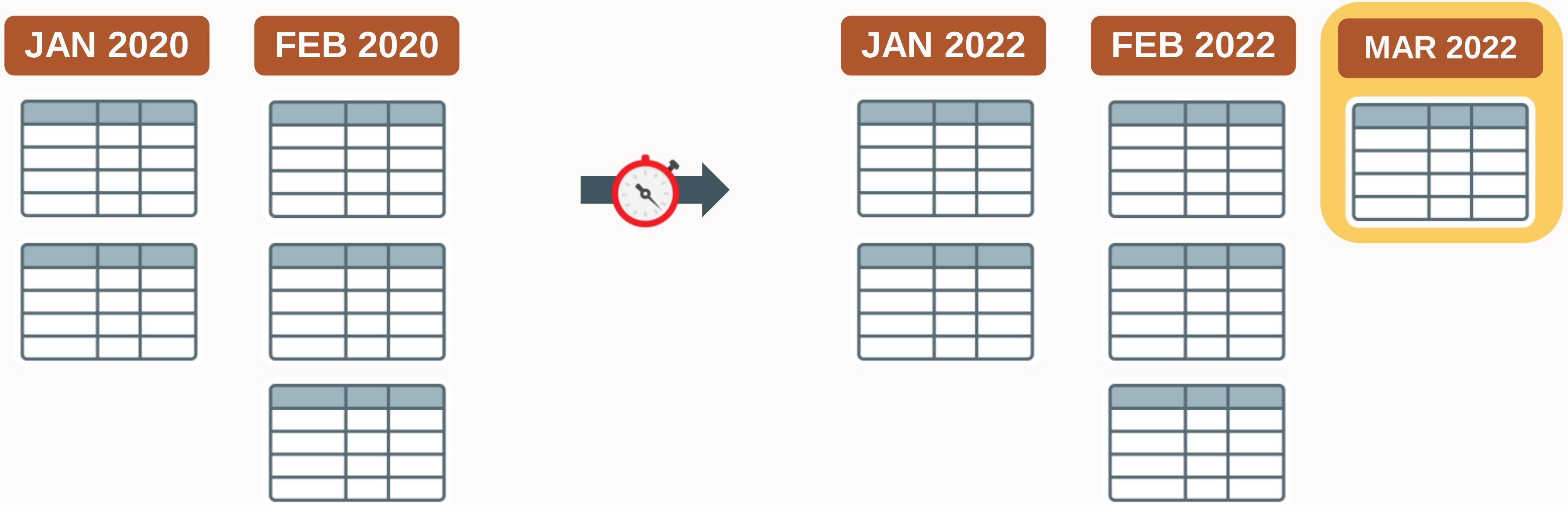
Composite Interval Partitioning
Add Partition



Without subpartition template, only **one** subpartition will be created

- Range: MAXVALUE
- List: DEFAULT
- Hash: one hash bucket

Composite Interval Partitioning
Subpartition template

Subpartition template defines shape of future subpartitions

- Can be added and/or modified at any point in time
- No impact on existing [sub]partitions

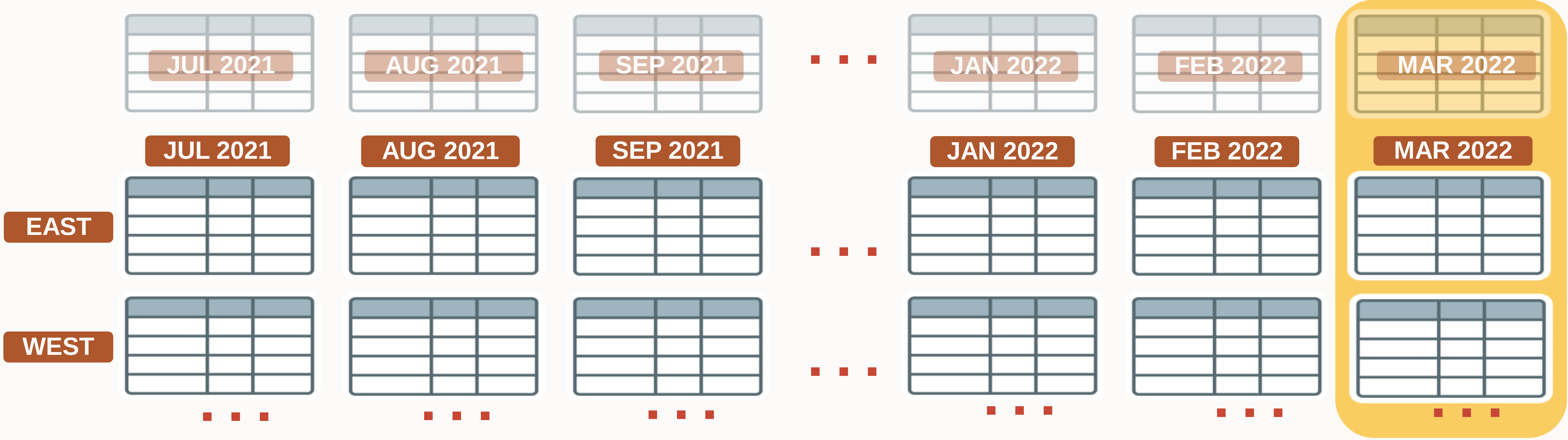
Controls physical attributes for subpartitions as well

- Just like the default settings for a partitioned table does for partitions

Difference Interval and Range Partitioning

- Naming template only for Range
- System-generated names for Interval

Composite Partitioning
Add Partition

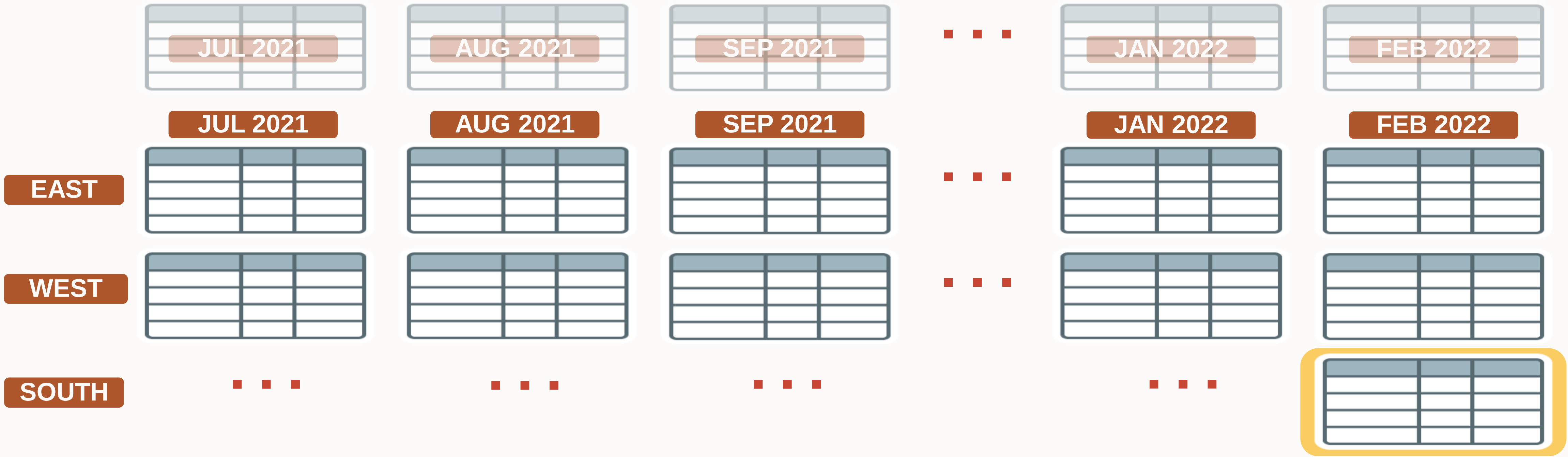


ADD PARTITION always on top-level dimension

- Identical for all newly added subpartitions
  - RANGE-LIST: new time_id range
  - LIST-RANGE: new list of region values

Composite Partitioning

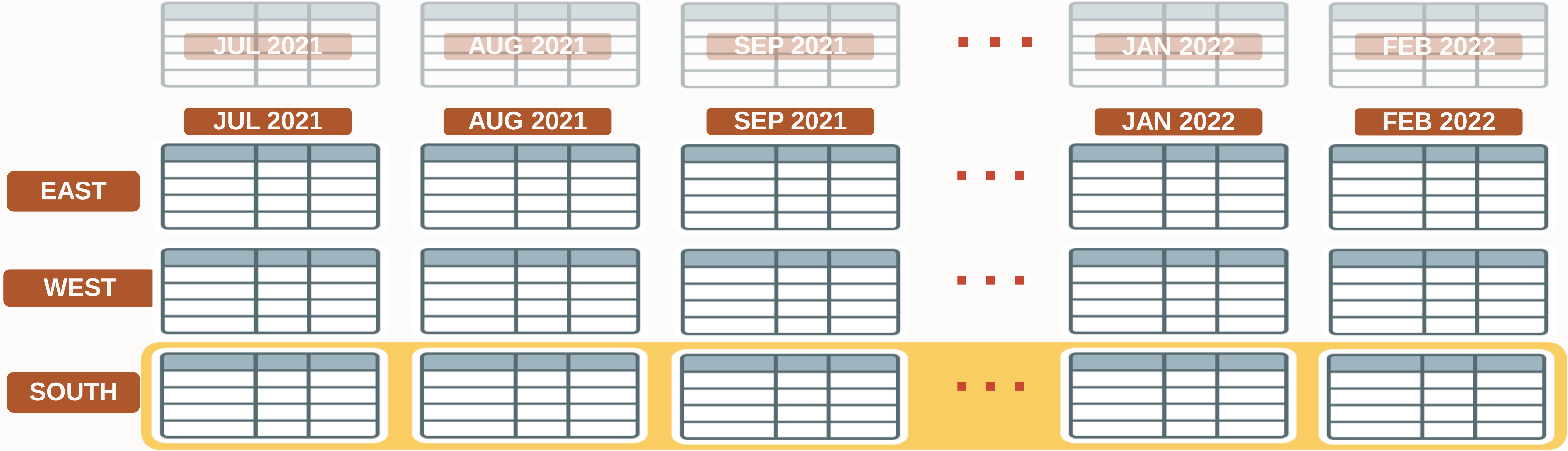
Add Subpartition



ADD SUBPARTITION only for one partition

- Asymmetric, only possible on subpartition level
- Impact on partition-wise joins

Composite Partitioning
Add Subpartition

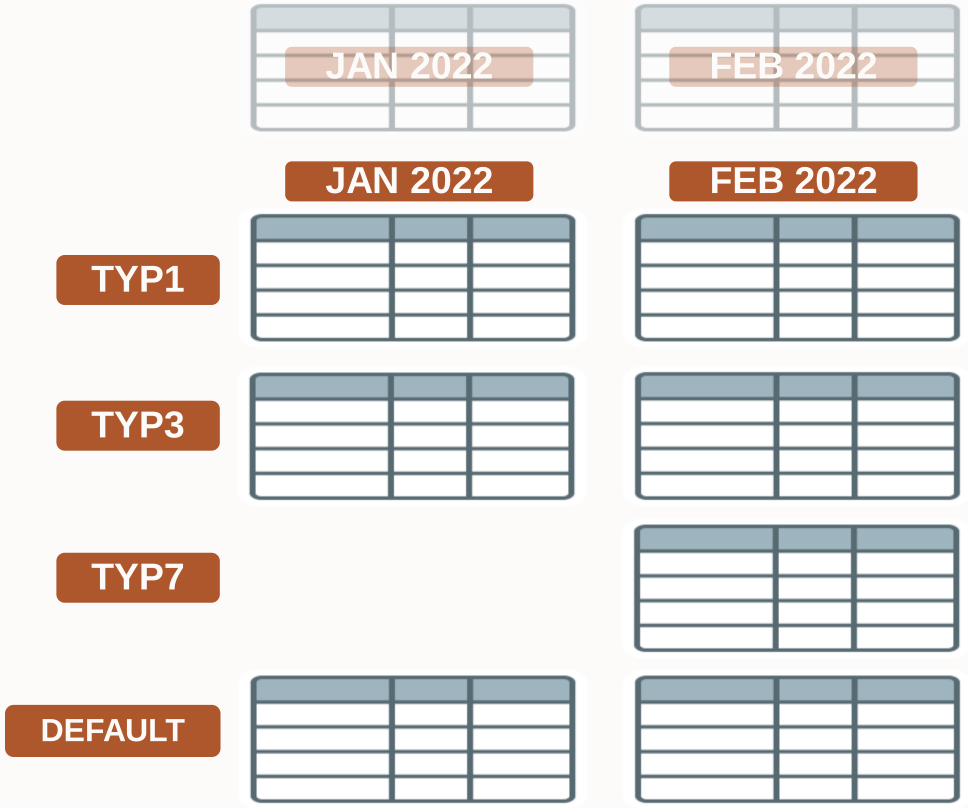


ADD SUBPARTITION for all partitions

- N operations necessary (for each existing partition)
- Adjust subpartition template for future partitions

Composite Partitioning

Asymmetric subpartitions



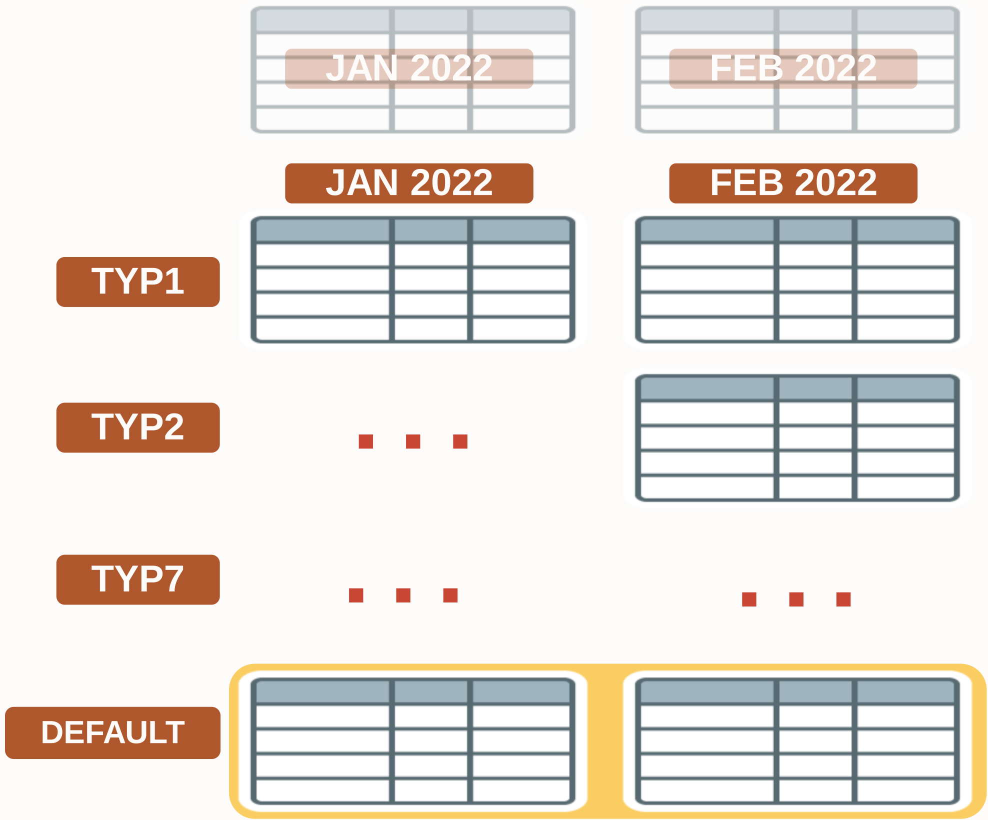
Number of subpartitions varies for individual partitions

- Most common for LIST subpartition strategies

```
CREATE TABLE EVENTS..
PARTITION BY RANGE (time_id)
SUPARTITION BY LIST (model)
```


Composite Partitioning

Asymmetric subpartitions



Number of subpartitions varies for individual partitions

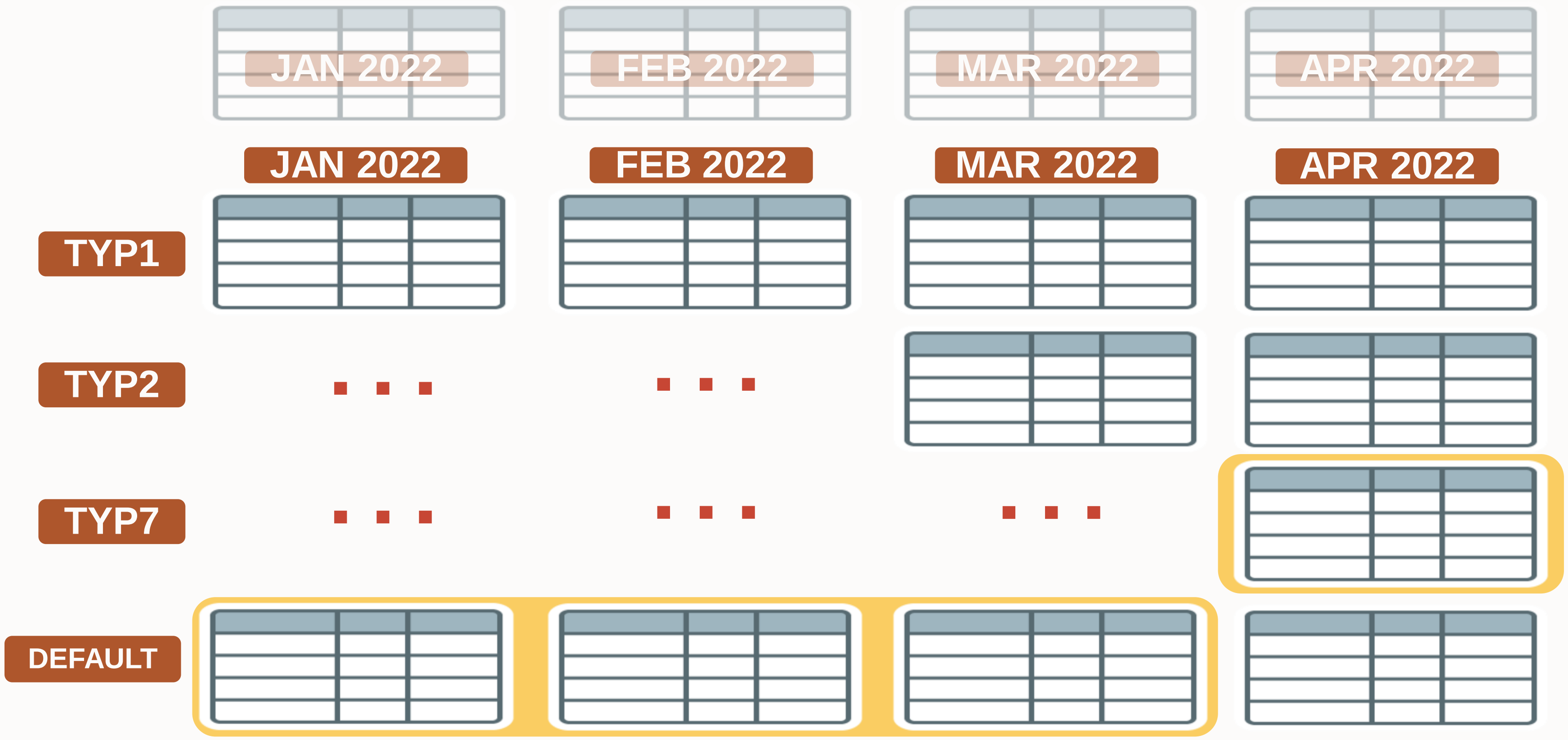
- Most common for LIST subpartition strategies

Zero impact on partition pruning capabilities

```
SELECT .. FROM events
WHERE model = 'TYP7';
```


Composite Partitioning

Asymmetric subpartitions




```
SELECT .. FROM events
WHERE model = 'TYP7';
```

Composite Partitioning

Always use appropriate composite strategy

Top-level dimension mainly chosen for Manageability

- E.g. add and drop time ranges

Sub-level dimension chosen for performance or manageability

- E.g. load_id, customer_id

Asymmetry has advantages but should be thought through

- E.g. different time granularity for different regions
- Remember the impact of asymmetric composite partitioning

Partitioning and Indexing

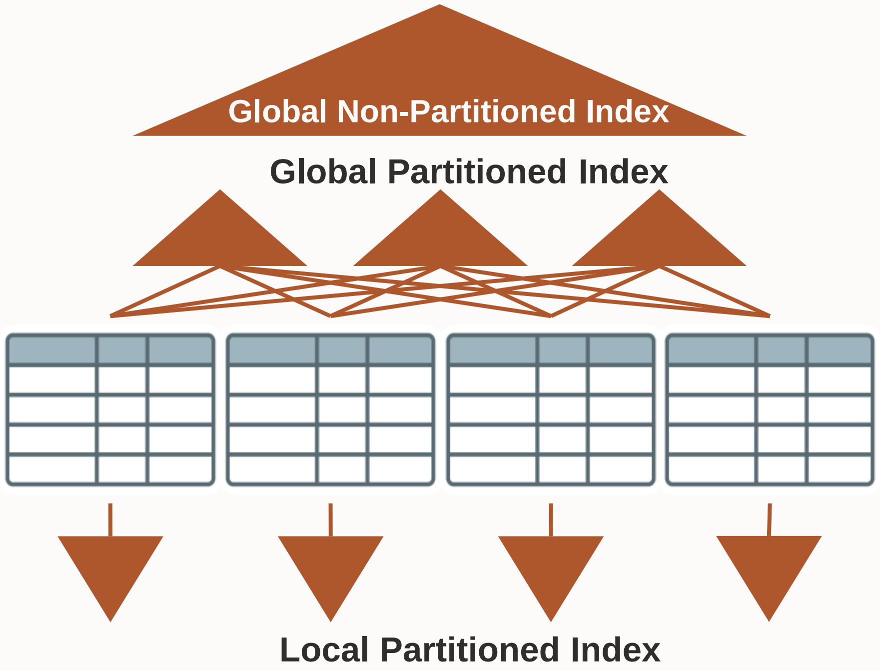
Indexing of Partitioned Tables

GLOBAL index points to rows in any partition

- Index can be partitioned or not

LOCAL index is partitioned same as table

- Index partitioning key can be different from index key



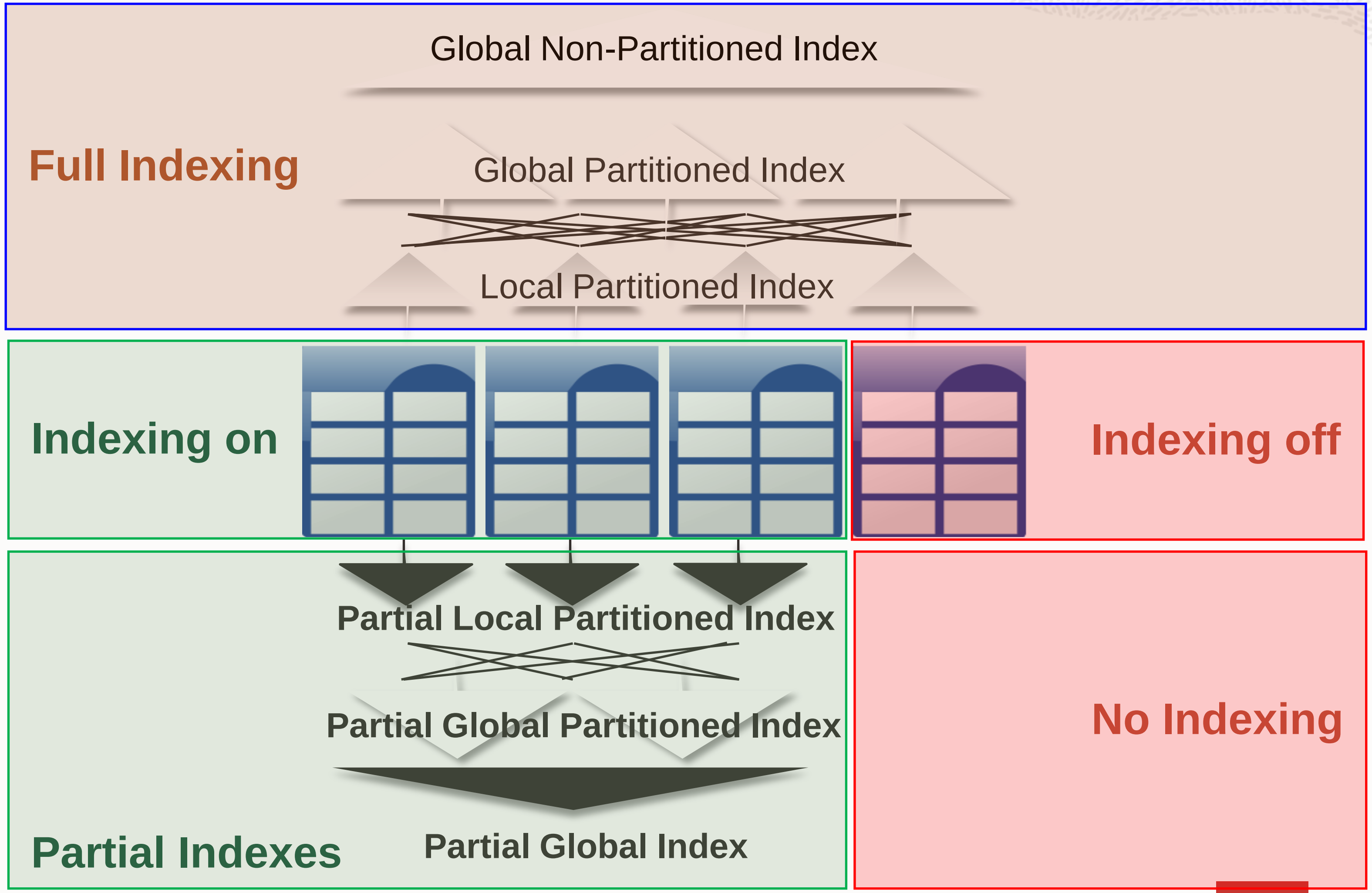
Indexing of Partitioned Tables

Partial indexes span only some partitions

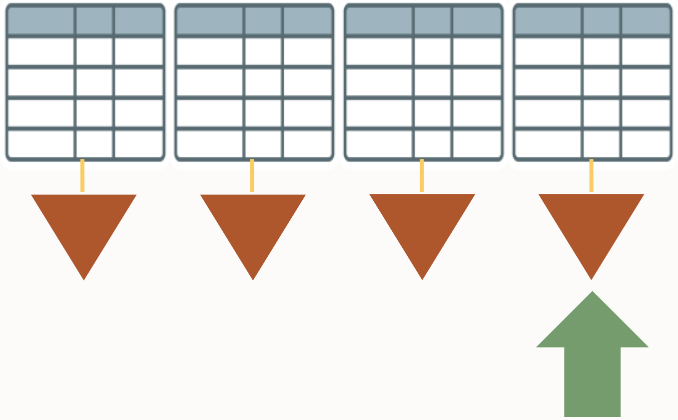
Applicable to local and global indexes

Complementary to full indexing

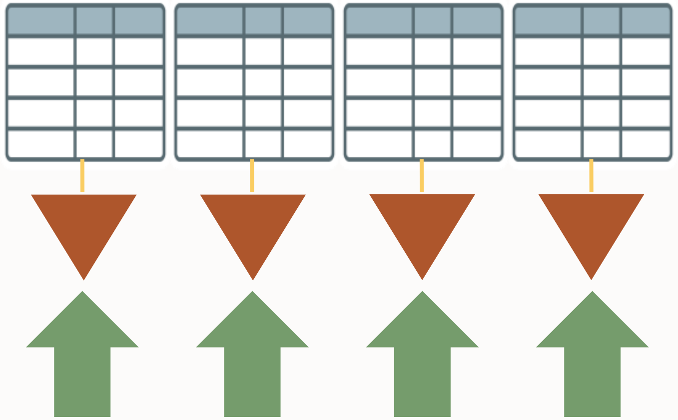
Full support of online index maintenance



Data Access – Local Index and Global Partitioned Index



Partitioned index access with single partition pruning



Partitioned index access without any partition pruning

Data Access – Local Index and Global Partitioned Index

Number of index probes identical to number of accessed partitions

- No partition pruning leads to a probe into all index partitions

Not optimally suited for OLTP environments

- No guarantee to always have partition pruning
- Exception: global hash partitioned indexes for DML contention alleviation
  - Most commonly small number of partitions

Pruning on global partitioned indexes based on the index prefix

- Index prefix identical to leading keys of index

Local Index

Index is partitioned along same boundaries as table (data) partition

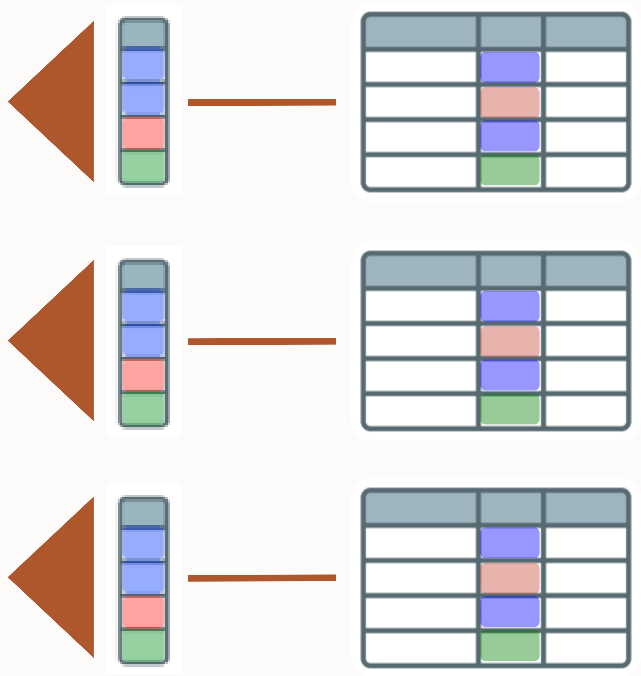
- B-tree or bitmap

Pros

- Easy to manage
- Parallel index scans

Cons

- Less efficient for retrieving small amounts of data (without partition pruning in place)



Global Non-Partitioned Index

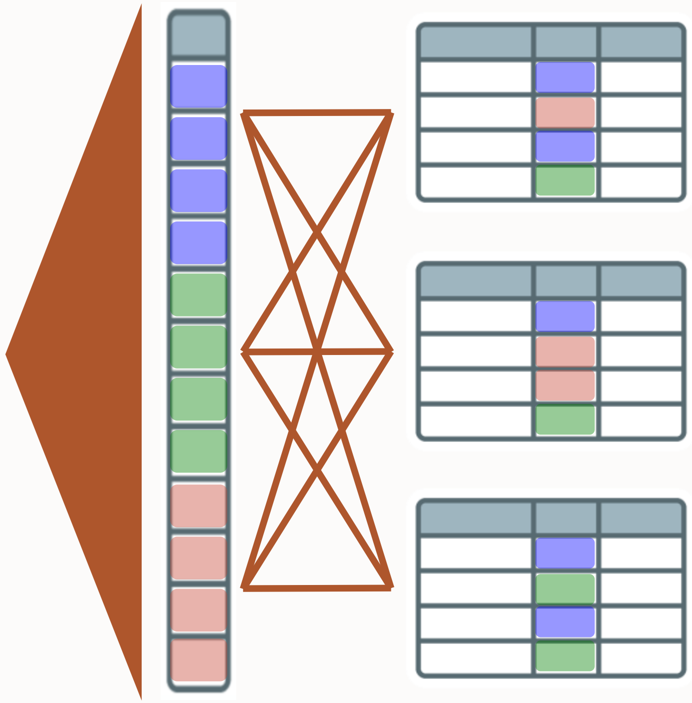
One index b-tree structure that spans all partitions

Pros

- Efficient access to any individual record

Cons

- Partition maintenance always involves index maintenance



Global Partitioned Index

Index is partitioned independently of data

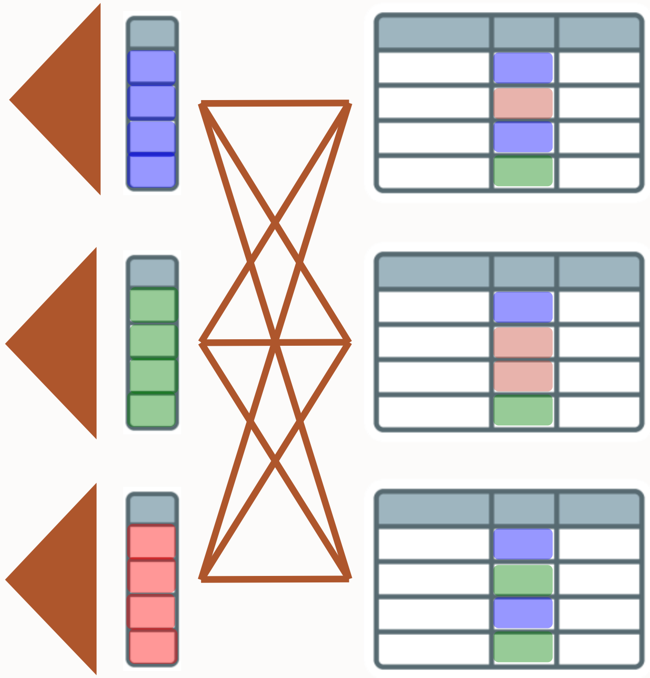
- Each index structure may reference any and all partitions.

Pros

- Availability and manageability

Cons

- Partition maintenance always involves index maintenance



Index Maintenance and Partition Maintenance

Online index maintenance available for **both** global and local indexes

- Global index maintenance since Oracle 9i, local index maintenance since Oracle 10g

Fast index maintenance for **both** local and global indexes for DROP and TRUNCATE

- Asynchronous global index maintenance added in Oracle 12c Release 1

Index maintenance necessary for **both** local and global indexes for all other partition maintenance operations

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Index maintenance necessary for **both** local and global indexes for all other partition maintenance operations

Decision for partition maintenance with index maintenance should be always performance versus availability

- **Rebuild of index always faster when more than 5%-10% of data are touched**

Consider partial indexing for both old and new data

- **Not all data has to be indexed to begin with**

Indexing for unique constraints and primary keys

Unique Constraints/Primary Keys

Unique constraints are enforced with unique indexes

- Primary key constraint adds NOT NULL to column
- Table can have only one primary key (“unique identifier”)

Partitioned tables offer two types of indexes

- Local indexes
- Global index, both partitioned and non-partitioned

Which one to pick?

- Do I even have a choice?

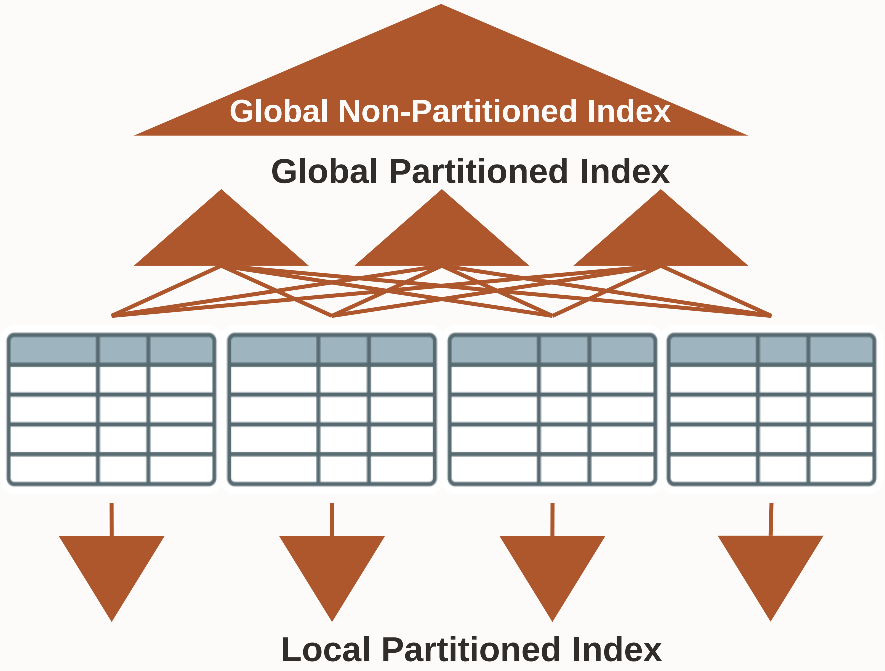
Index Partitioning

GLOBAL index points to rows in all partitions

- Index can be partitioned or not
- Partition maintenance affects entire index

LOCAL index points to rows in one partition

- Index is partitioned same as table
- Index partitioning key can be different from index key
- Index partitions can be maintained separately



Unique Constraints/Primary Keys

Applicability of Local Indexes

Local indexes are equi-partitioned with the table

- Follow autonomy concept of a table partition
  - “I only care about myself”

Requirement for local indexes to enforce uniqueness

- Partition key column(s) to be a subset of the unique key

Unique Constraints/Primary Keys, cont.

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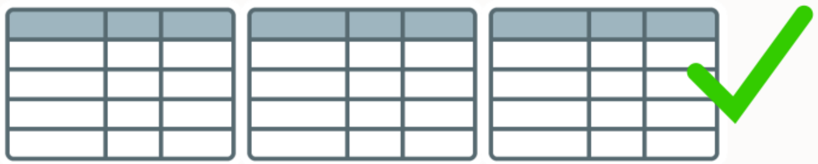
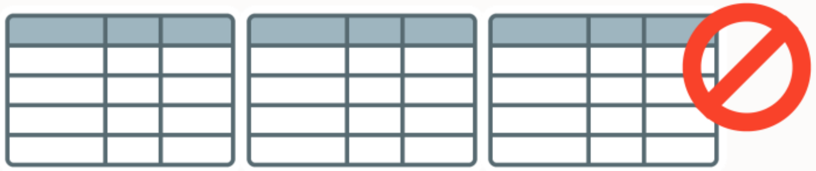


PARTITION BY (col1), PK(col1)



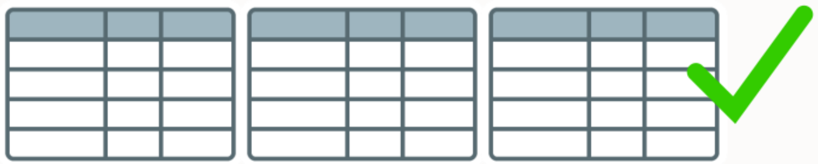
PARTITION BY (col1), PK(col2)

Unique Constraints/Primary Keys, cont.
Applicability of Global Indexes

Global indexes do not have any relation to the partitions of a table

- By definition, a global index contains data from all partitions
- True for both partitioned and non-partitioned global indexes

Global index can always be used to enforce uniqueness



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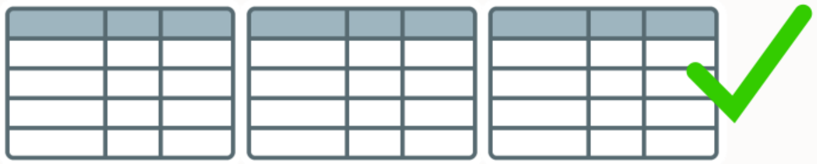


PARTITION BY (col1), PK(col2)

Partial Indexing

Introduced in Oracle 12c Release 1 (12.1)

Enhanced Indexing with Oracle Partitioning

Indexing prior to Oracle Database 12c

Local indexes

Non-partitioned or partitioned global indexes

Usable or unusable index segments

- Non-persistent status of index, no relation to table

Enhanced Indexing with Oracle Partitioning

Indexing with Oracle Database 12c

Local indexes

Non-partitioned or partitioned global indexes

Usable or unusable index segments

- Non-persistent status of index, no relation to table

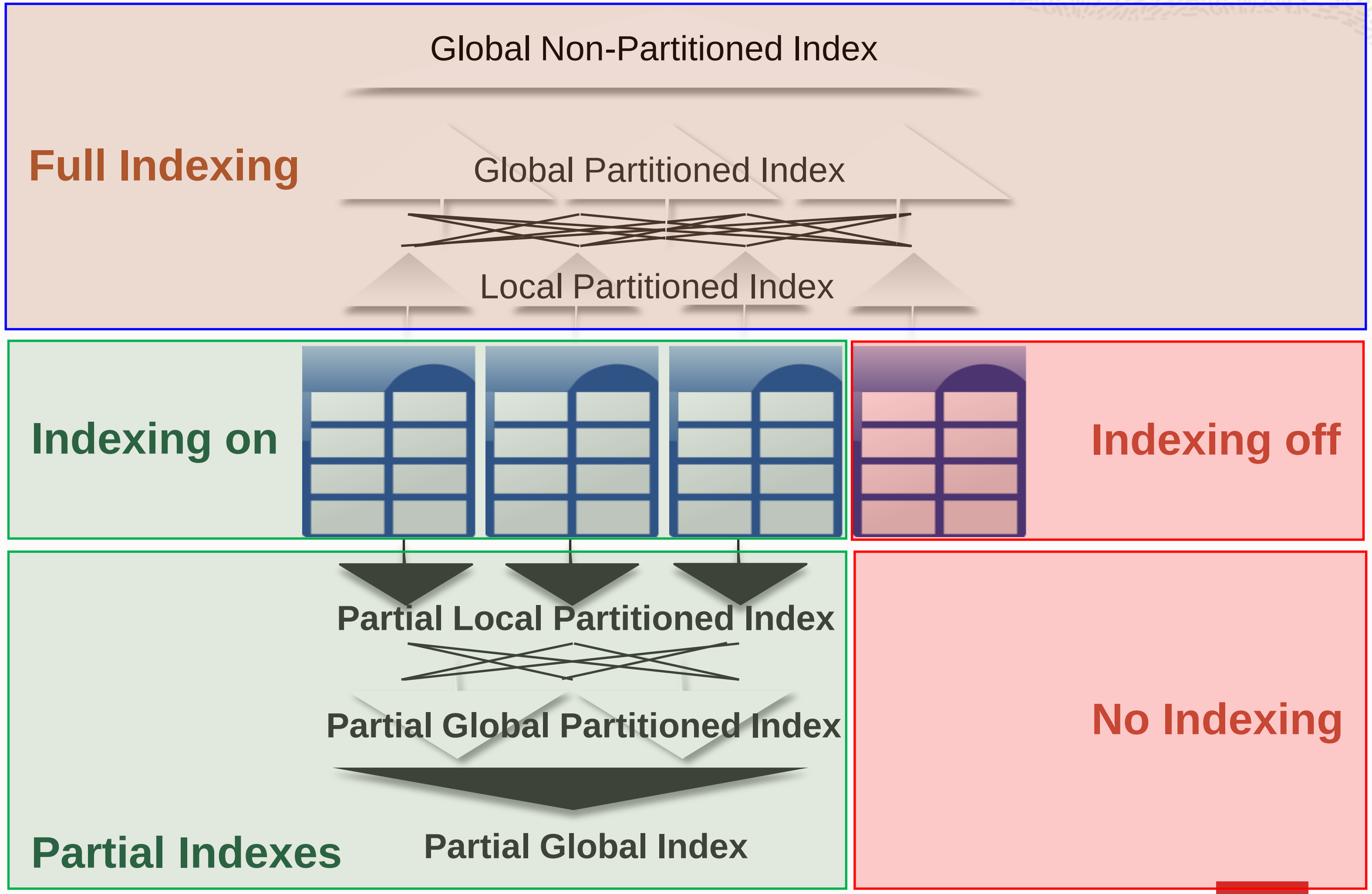
Partial local and global indexes

- Partial indexing introduces table and [sub]partition level metadata
- Leverages usable/unusable state for local partitioned indexes
- Policy for partial indexing can be overwritten

Enhanced Indexing of Partitioned Tables

Partial Local and Global Indexes

- Partial indexes span only some partitions
- Applicable to local and global indexes
- Complementary to full indexing
- Full support of online index maintenance



Enhanced Indexing with Oracle Partitioning

Partial Local and Global Indexes

Before

```
SQL> create table pt (col1, col2, col3, col4)
  2  indexing off
  3  partition by range (col1)
  4  interval (1000)
  5  (partition p100 values less than (101) indexing on,
  6   partition p200 values less than (201) indexing on,
  7   partition p300 values less than (301) indexing on);

Table created.

SQL> REM partitions and its indexing status
SQL> select partition_name, high_value, indexing
  2  from user_tab_partitions where table_name='PT';

PARTITION_NAME                 HIGH_VALUE                     INDEXING
------------------------------ ------------------------------ --------
P100                           101                            ON
P200                           201                            ON
P300                           301                            ON
SYS_P1256                      1301                           OFF
```

After

```
SQL> REM local indexes
SQL> create index i_l_partpt on pt(col1) local indexing partial;
SQL> create index i_l_pt on pt(col4) local;

SQL> REM global indexes
SQL> create index i_g_partpt on pt(col2) indexing partial;
SQL> create index i_g_pt on pt(col3);


SQL> REM index status
SQL> select index_name, partition_name, status, null
  2  from user_ind_partitions where index_name in ('I_L_PARTPT','I_L_PT')
  3  union all
  4  select index_name, indexing, status, orphaned_entries
  5  from user_indexes where index_name in ('I_G_PARTPT','I_G_PT');

INDEX_NAME                     PARTITION_NAME                 STATUS     ORPHAN
------------------------------ ------------------------------ ---------- ------
I_L_PARTPT                     P100                           USABLE
I_L_PARTPT                     P200                           USABLE
I_L_PARTPT                     P300                           USABLE
I_L_PARTPT                     SYS_P1257                      UNUSABLE
I_L_PT                         P200                           USABLE
I_L_PT                         P300                           USABLE
I_L_PT                         SYS_P1258                      USABLE
I_L_PT                         P100                           USABLE
I_G_PT                         FULL                           VALID      NO
I_G_PARTPT                     PARTIAL                        VALID      NO

10 rows selected.
```

Enhanced Indexing with Oracle Partitioning

Partial Local and Global Indexes

Partial global index excluding partition 4

```
SQL> explain plan for select count(*) from pt where col2 = 3;

Explained.

SQL> select * from table(dbms_xplan.display);

-------------------------------------------------------------------------------------------------------------------------------
| Id  | Operation                                     | Name         | Rows  | Bytes | Cost (%CPU)| Time     | Pstart| Pstop |
-------------------------------------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                              |              |     1 |    22 |    54  (12)| 00:00:01 |       |       |
|   1 |  SORT AGGREGATE                               |              |     1 |    22 |            |          |       |       |
|   2 |   VIEW                                        | VW_TE_2      |     2 |       |    54  (12)| 00:00:01 |       |       |
|   3 |    UNION-ALL                                  |              |       |       |            |          |       |       |
|*  4 |     TABLE ACCESS BY GLOBAL INDEX ROWID BATCHED| PT           |     1 |    26 |     2   (0)| 00:00:01 | ROWID | ROWID |
|*  5 |      INDEX RANGE SCAN                         | I_G_PARTPT   |     1 |       |     1   (0)| 00:00:01 |       |       |
|   6 |     PARTITION RANGE SINGLE                    |              |     1 |    26 |    52  (12)| 00:00:01 |     4 |     4 |
|*  7 |      TABLE ACCESS FULL                        | PT           |     1 |    26 |    52  (12)| 00:00:01 |     4 |     4 |
-------------------------------------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   4 - filter("PT"."COL1"<301)
   5 - access("COL2"=3)
   7 - filter("COL2"=3)
```

Unusable versus Partial Indexes

Unusable Indexes

Unusable index partitions are commonly used in environments with fast load requirements

- “Save” the time for index maintenance at data insertion
- Unusable index segments do not consume any space (11.2)

Unusable indexes are ignored by the optimizer

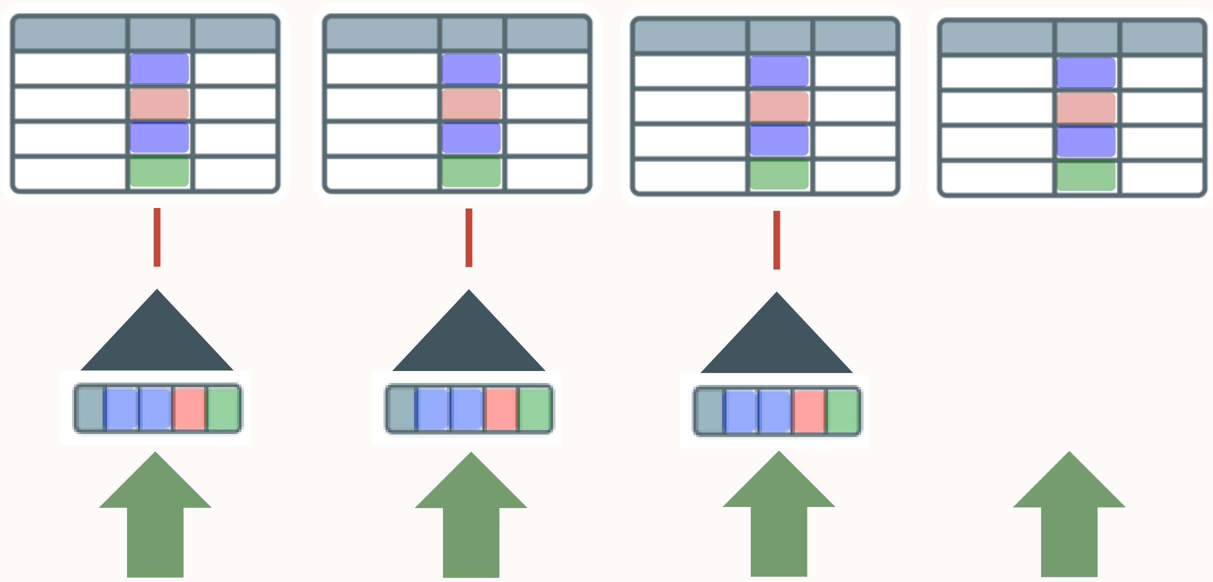
Partitioned indexes can be used by the optimizer even if some partitions are unusable

```
SKIP_UNUSABLE_INDEXES = [TRUE | FALSE ]
```

- Prior to 11.2, static pruning and only access of usable index partitions mandatory
- With 11.2, intelligent rewrite of queries using UNION ALL

Table-OR-Expansion

Multiple SQL branches are generated and executed



Intelligent UNION ALL expansion in the presence of partially unusable indexes

- Transparent internal rewrite
- Usable index partitions will be used
- Full partition access for unusable index partitions

Table-OR-Expansion

Sample Plan - Multiple SQL branches are generated and executed

```
 select count(*) from toto where name ='FOO' and rn between 1300 and
1400

Plan hash value: 2830852558

-----------------------------------------------------------------------------------------------------
| Id  | Operation                              | Name     | Rows  | Bytes | Cost (%CPU)| Time      | Pstart| Pstop |
-----------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT                       |          |       |       |   27M(100)|           |       |       |
|   1 |  SORT AGGREGATE                        |          |     1 |    21 |            |           |       |       |
|   2 |   VIEW                                 | VW_TE_2  |     2 |       |   27M   (3)| 92:15:22  |       |       |
|   3 |    UNION-ALL                           |          |       |       |            |           |       |       |
|   4 |     PARTITION RANGE SINGLE             |          |     1 |    20 |    2   (0)| 00:00:01  |    14 |    14 |
|   5 |      TABLE ACCESS BY LOCAL INDEX ROWID| TOTO     |     1 |    20 |    2   (0)| 00:00:01  |    14 |    14 |
|*  6 |       INDEX RANGE SCAN                 | I_TOTO   |     1 |       |    1   (0)| 00:00:01  |    14 |    14 |
|   7 |     PARTITION RANGE SINGLE             |          |     1 |    22 |   27M   (3)| 92:15:22  |    15 |    15 |
|*  8 |      TABLE ACCESS FULL                 | TOTO     |     1 |    22 |   27M   (3)| 92:15:22  |    15 |    15 |
-----------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   6 - access("NAME"='FOO')
   8 - filter(("NAME"='FOO' AND "TOTO"."RN"=1400))


27 rows selected.
```

Partitioning Extensions

Interval Partitioning

Introduced in Oracle 11g Release 1 (11.1)

Interval Partitioning

Extension to Range Partitioning

Full automation for equi-sized range partitions

Partitions are created as metadata information only

- Start Partition is made persistent

Segments are allocated as soon as new data arrives

- No need to create new partitions
- Local indexes are created and maintained as well

No need for any partition management

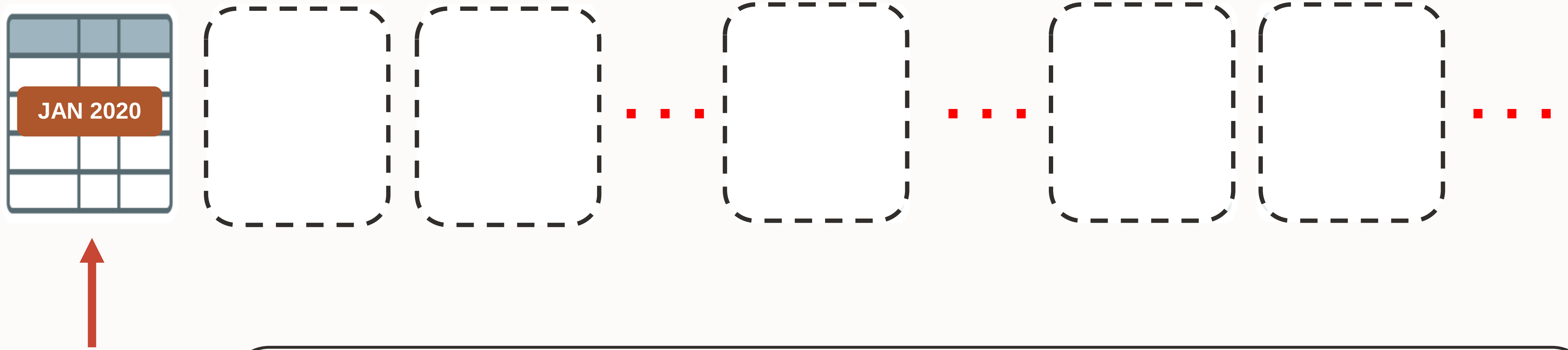
Interval Partitioning

Partitions are created automatically as data arrives

- Extension to RANGE partitioning

Interval Partitioning

As easy as One, Two, Three…

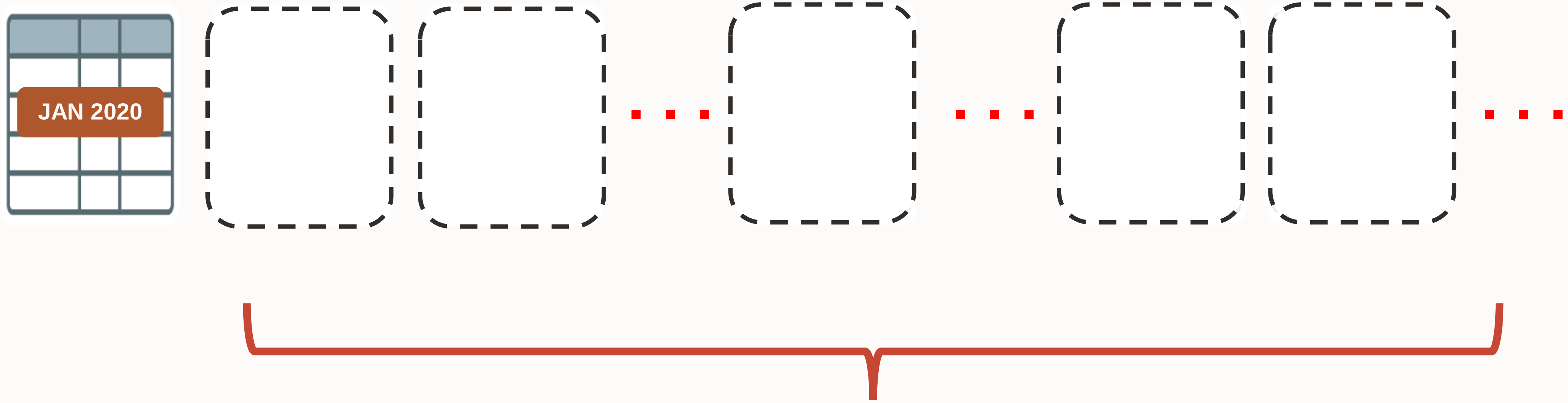


First partition is created

```
CREATE TABLE EVENTS (order_date DATE, ...)
PARTITON BY RANGE (order_date)
INTERVAL(NUMTOYMINTERVAL(1,'month')
(PARTITION p_first VALUES LESS THAN ('01-FEB-2020');
```

Interval Partitioning

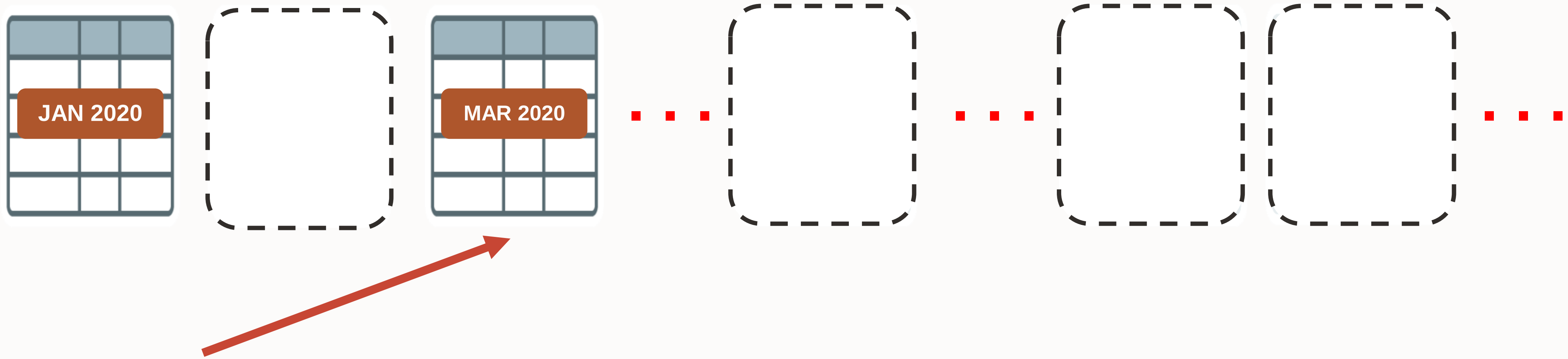
As easy as One, Two, Three…



Other partitions only exist in table metadata

Interval Partitioning

As easy as One, Two, Three…

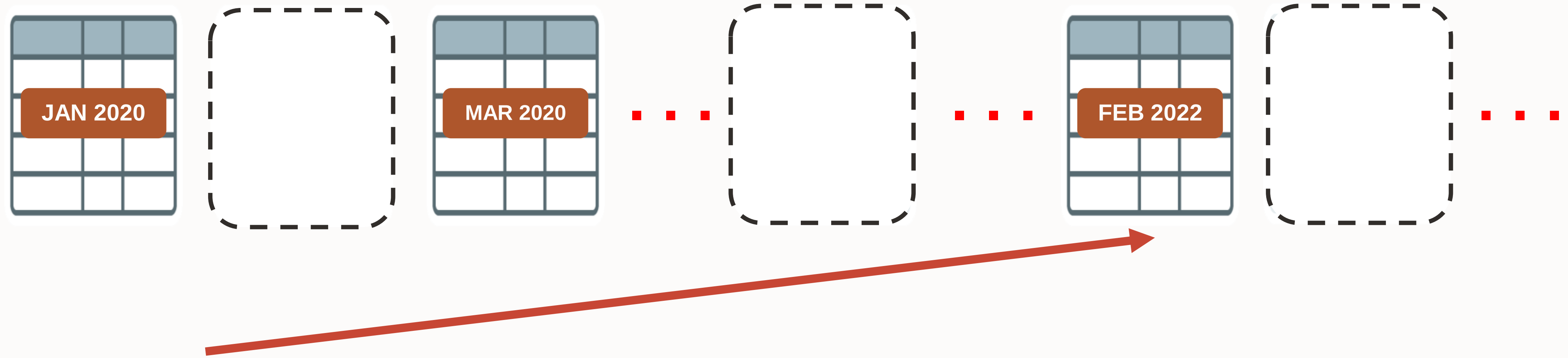


New partition is automatically instantiated

```
INSERT INTO EVENTS (order_date DATE, ...)
VALUES ('15-MAR-2020',...);
```

Interval Partitioning

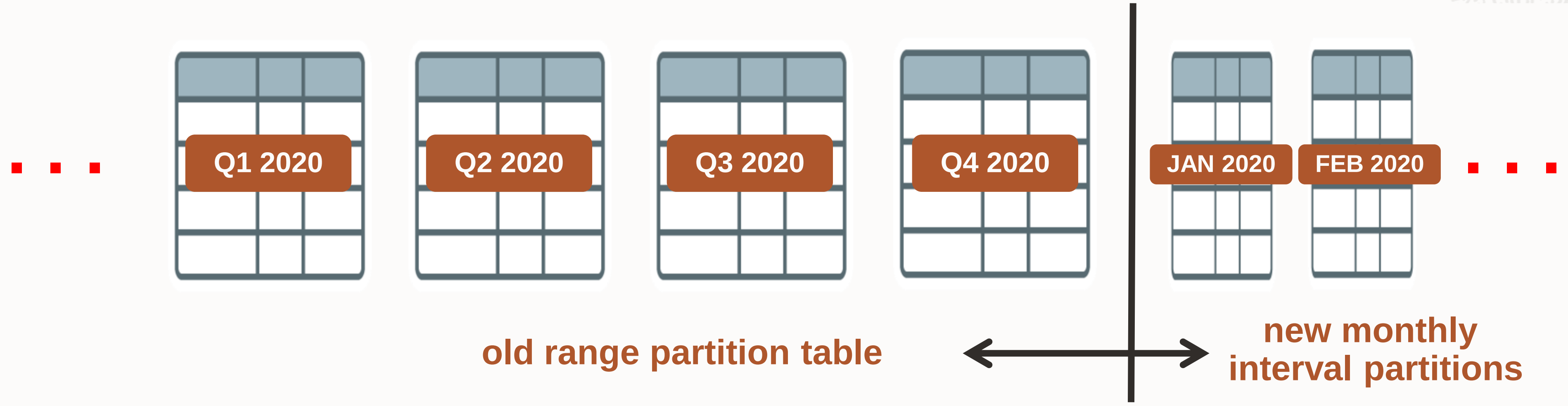
As easy as One, Two, Three…



Whenever data for a new partition arrives

```
INSERT INTO EVENTS ( order_date DATE, ...)
VALUES ('04-FEB-2022',...);
```

Interval Partitioning

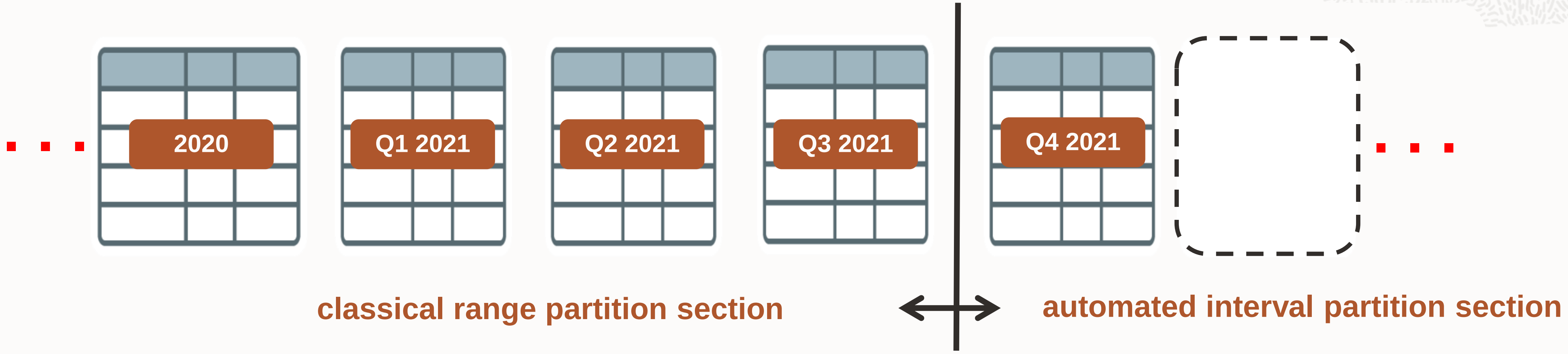


Range partitioned tables can be extended into interval partitioned tables

- Simple metadata command
- Investment protection

```
ALTER TABLE EVENTS
SET INTERVAL(NUMTOYMINTERVAL(1,'month');
```

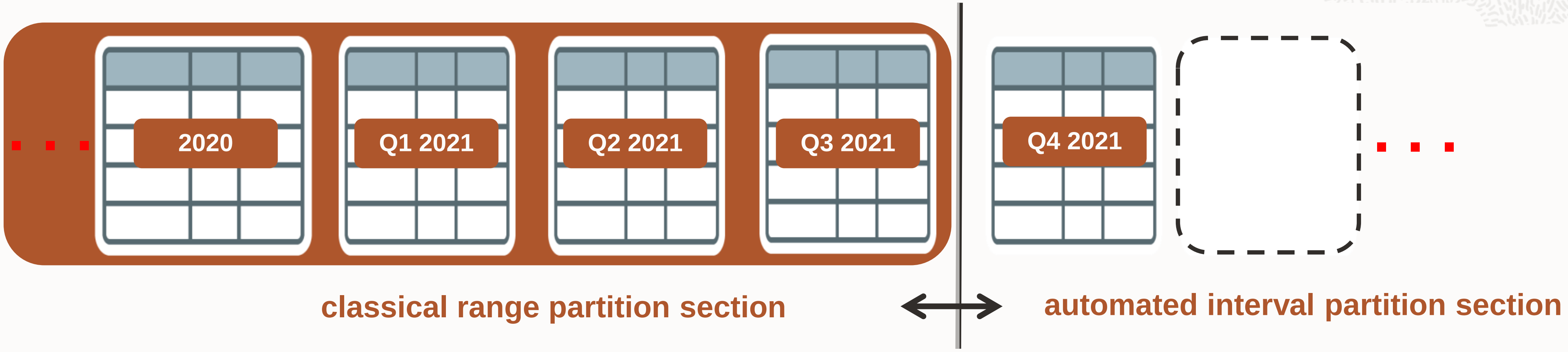
Interval Partitioning



Interval partitioned table has classical range and automated interval section

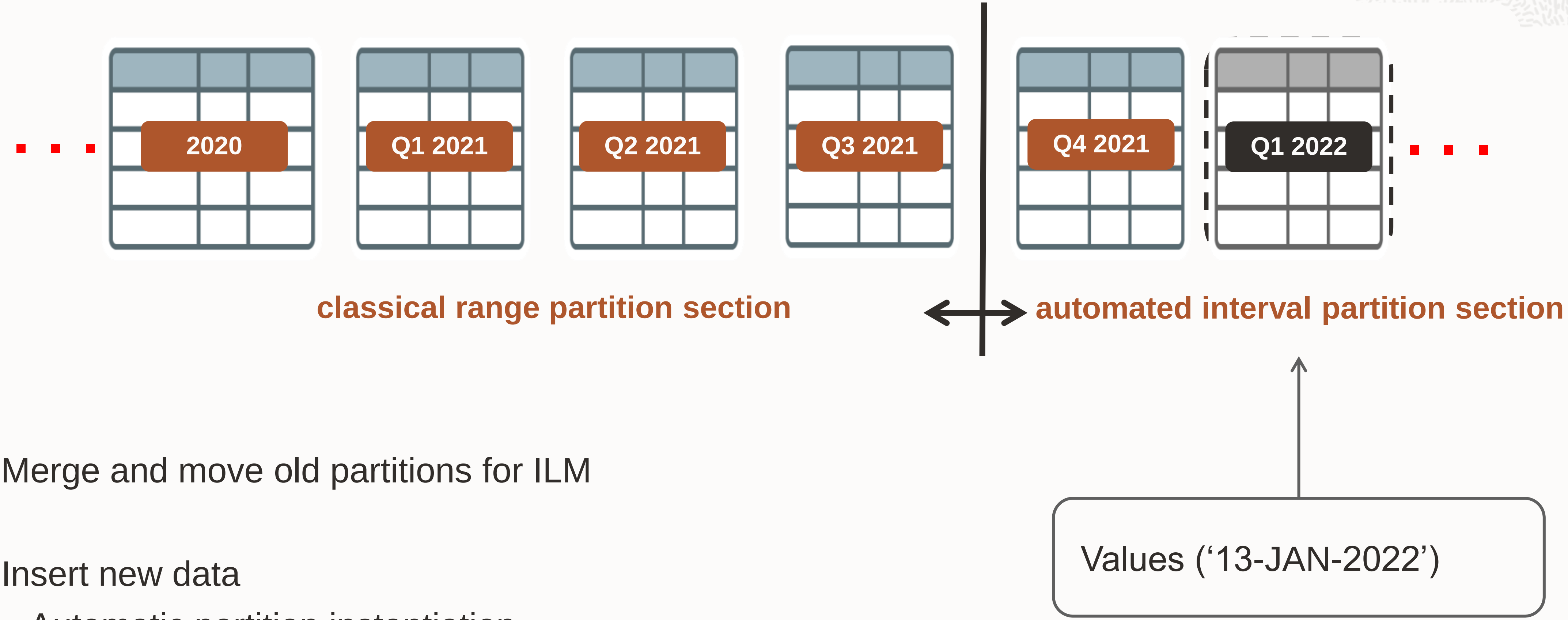
- Automated new partition management plus full partition maintenance capabilities: “Best of both worlds”

Interval Partitioning



1. Merge and move old partitions for ILM

Interval Partitioning



1. Merge and move old partitions for ILM

2. Insert new data
   1. Automatic partition instantiation

Deferred Segment Creation vs Interval Partitioning

Interval Partitioning

- Maximum number of one million partitions are pre-defined
  - Explicitly defined plus interval-based partitions
- No segments are allocated for partitions without data
  - New record insertion triggers segment creation
- Ideal for “ever-growing” tables

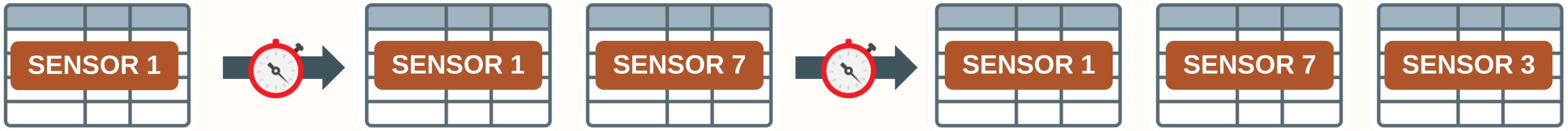
“Standard” Partitioning with deferred segment creation

- Only explicitly defined partitions are existent
  - New partitions added via DDL
- No segments are allocated for partitions without data
  - New record insertion triggers segment creation when data matches pre-defined partitions
- Ideal for sparsely populated pre-defined tables

Auto-List Partitioning

Introduced in Oracle Database 12.2

Auto-List Partitioning



Partitions are created automatically as data arrives

- Extension to LIST partitioning
- Every distinct partition key value will be stored in separate partition

Details of Auto-List strategy

Automatically creates new list partitions that contain one value per partition

- Only available as top-level partitioning strategy in 12.2.0.1

No notion of default partition

System generated partition names for auto-created partitions

- Use FOR VALUES clause for deterministic [sub]partition identification

Can evolve list partitioning into auto-list partitioning

- Only requirement is having no DEFAULT partition
- Protection of your investment into a schema

Auto-List Partitioned Table

Syntax example

```
CREATE TABLE EVENTS( sensor_type  VARCHAR2(50),
                     channel       VARCHAR2(50), …)
PARTITION BY LIST (sensor_type) AUTOMATIC
( partition p1 values ('GYRO'));
```


Auto-List is not equivalent to List + DEFAULT

Different use case scenarios

List with DEFAULT partitioning

- Targeted towards multiple large distinct list values plus “not classified”

Auto-list partitioning

- Expects ‘critical mass of records’ per partition key value
- Could be used as pre-cursor state for using List + DEFAULT

Auto-List is not equivalent to List + DEFAULT

Different use case scenarios

List with DEFAULT partitioning

- Targeted towards multiple large distinct list values plus “not classified”

Auto-list partitioning

- Expects ‘critical mass of records’ per value
- Could be used as pre-cursor state for using List + DEFAULT

.. Plus they are functionally conflicting and cannot be used together

- Either you get a new partition for a new partition key value
- .. Or “dump” it in the catch-it-all bucket

Virtual Column Based Partitioning

Introduced in Oracle 11g Release 1 (11.1)

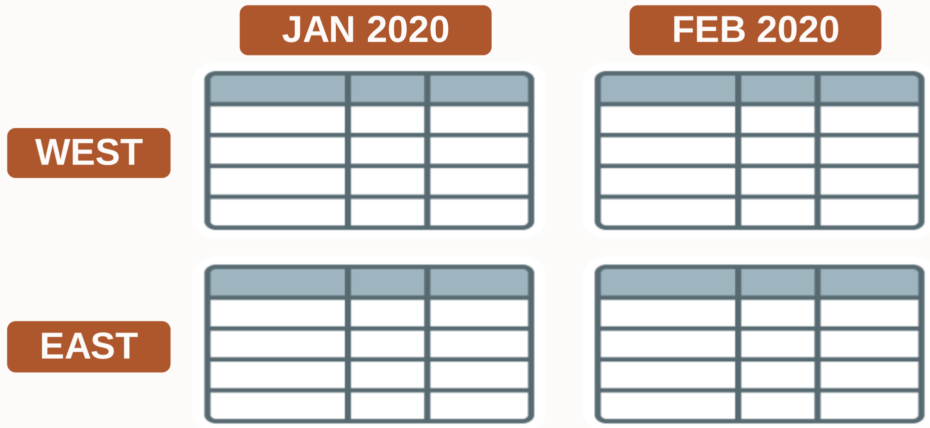
Virtual Column Based Partitioning

```
EVENTS

EVENT_ID   EVENT_DATE  SENSOR_ID   ... REGION AS (SUBSTR(EVENT_ID,6,2))
---------- ----------- ----------- --- -------------------------------
9834-GY-14 12-JAN-2020       65920        GY
8300-TH-97 14-FEB-2020       39654        TH
3886-TH-02 16-JAN-2020        4529        GY
2566-GY-94 19-JAN-2020       15327        TH
3699-GY-63 02-FEB-2020       18733        TH
```

REGION requires no storage

Partition by ORDER_DATE, REGION



Virtual Columns
Example

Base table with all attributes ...

```
CREATE TABLE accounts
(acc_no      number(10)    not null,
 acc_name    varchar2(50) not null, …
```

12500	Adams	
12507	Blake	
12666	King	
12875	Smith	

Virtual Columns
Example

Base table with all attributes ...

- ... is extended with the virtual (derived) column

```
CREATE TABLE accounts
(acc_no     number(10)   not null,
 acc_name   varchar2(50) not null, ...
 acc_branch number(2)    generated always as
   (to_number(substr(to_char(acc_no),1,2)))
```

12500	Adams	12
12507	Blake	12
12666	King	12
12875	Smith	12

Virtual Columns

Example

Base table with all attributes ...

- ... is extended with the virtual (derived) column
- ... and the virtual column is used as partitioning key

```
CREATE TABLE accounts
(acc_no      number(10)    not null,
 acc_name    varchar2(50) not null, ...
 acc_branch number(2)     generated always as
   (to_number(substr(to_char(acc_no),1,2)))
partition by list (acc_branch) …
```

12500	Adams	12
12507	Blake	12
12666	King	12
12875	Smith	12

...

32320	Jones	32
32407	Clark	32
32758	Hurd	32
32980	Kelly	32

Virtual Columns
Partition Pruning

Conceptual model considers virtual columns as **visible** and **used** attributes

Partition pruning currently only works with predicates on the virtual column (partition key) itself

- No transitive predicates

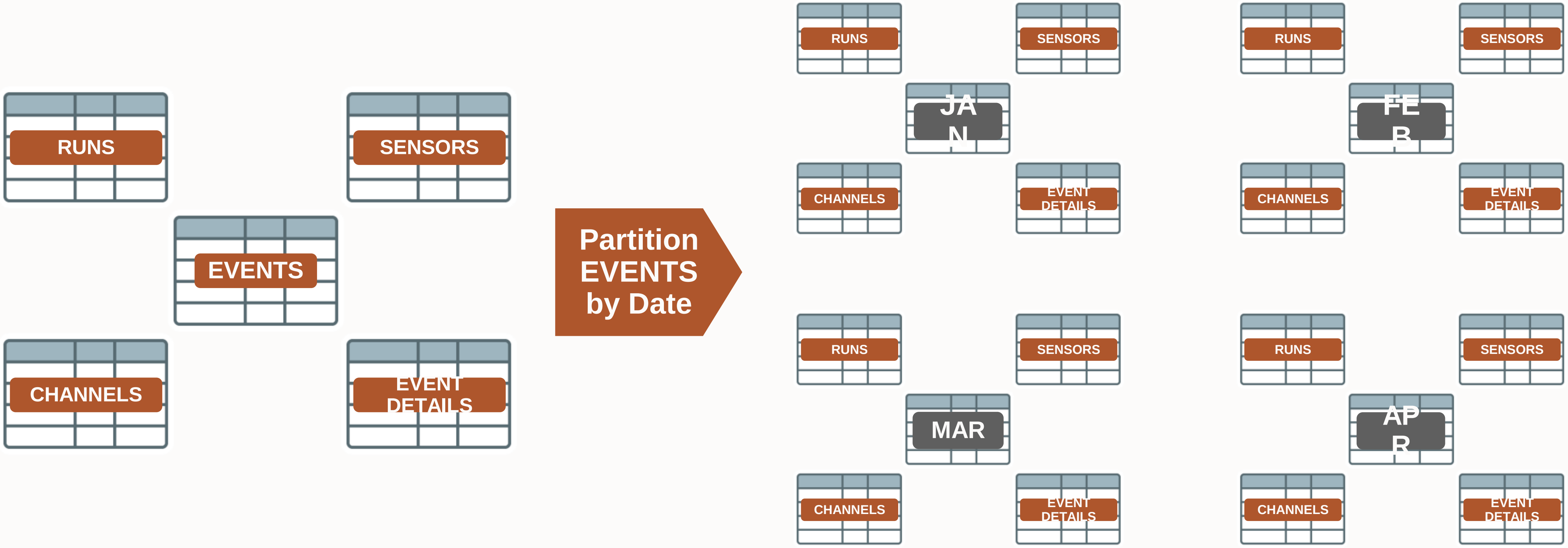
Enhancement planned for future release (not imminent)

Reference Partitioning

Introduced in Oracle 11g Release 1 (11.1)

Reference Partitioning

Inherit partitioning strategy



Reference Partitioning

Business Problem

Related tables benefit from same partitioning strategy

- Sample 3NF order entry data model

Redundant storage of same information solves problem

- Data and maintenance overhead

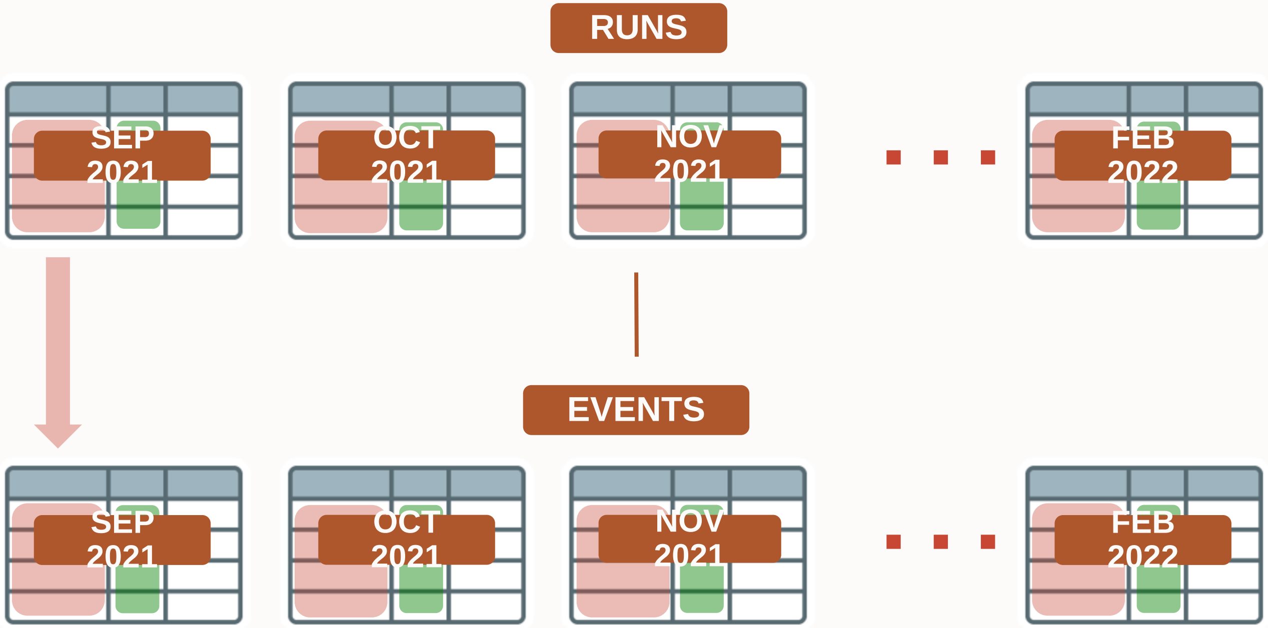
Solution

Oracle Database 11g introduces Reference Partitioning

- Child table inherits the partitioning strategy of parent table through PK-FK
- Intuitive modelling

Enhanced Performance and Manageability

Primary Key – Foreign Key without Reference Partitioning

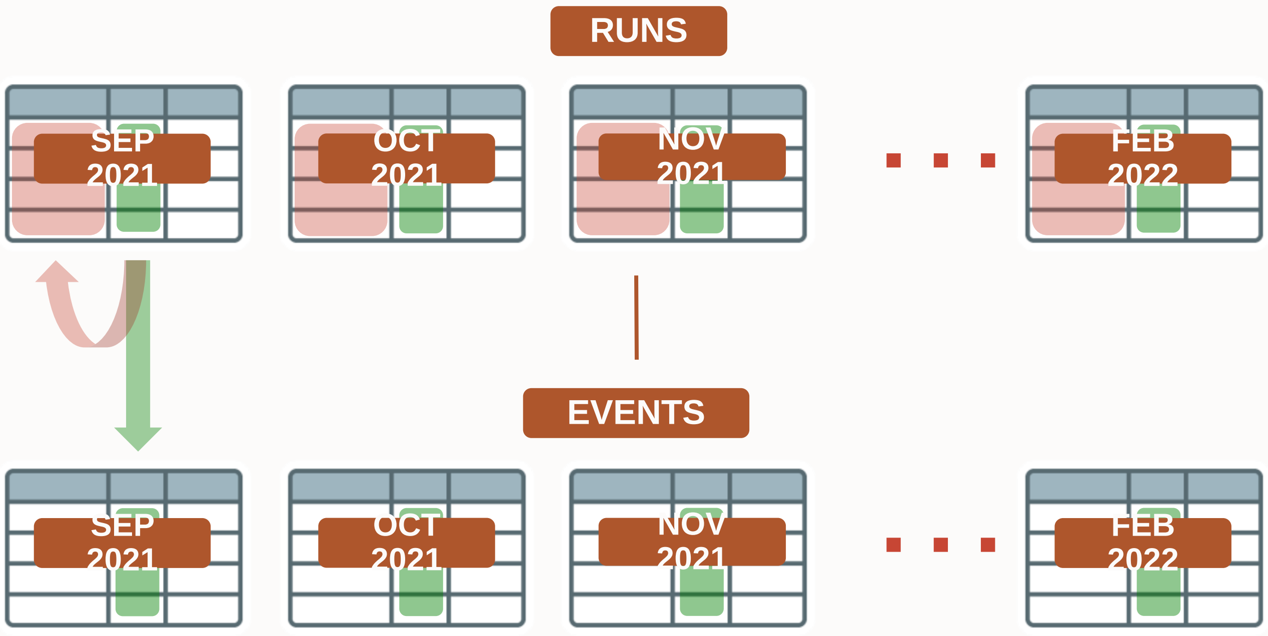



```
RANGE(run_date)
Primary key run_id
```

- Redundant storage
- Redundant maintenance

```
RANGE(run_date)
Foreign key run_id
```


Primary Key – Foreign Key with Reference Partitioning




```
RANGE(run_date)
Primary key run_id
```

- Partitioning key inherited through PK-FK relationship

```
RANGE(run_date)
Foreign key run_id
```


Reference Partitioning
Use Cases

Traditional relational model

- Primary key inherits down to all levels of children and becomes part of an (elongated) primary key definition

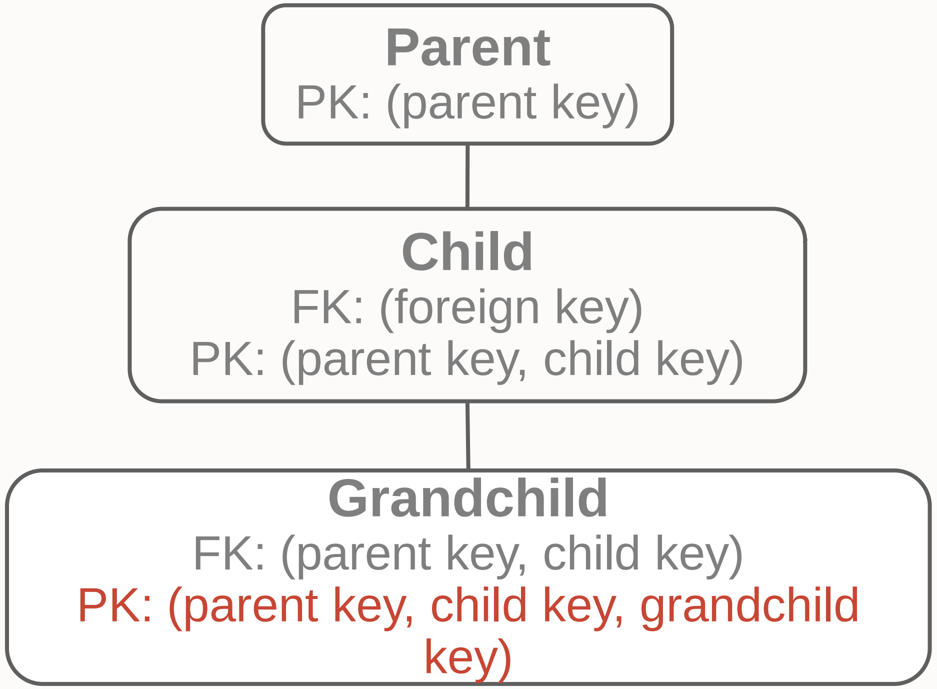
Object oriented-like model

- Several levels of primary-foreign key relationship
- Primary key on each level is primary key + “object ID”

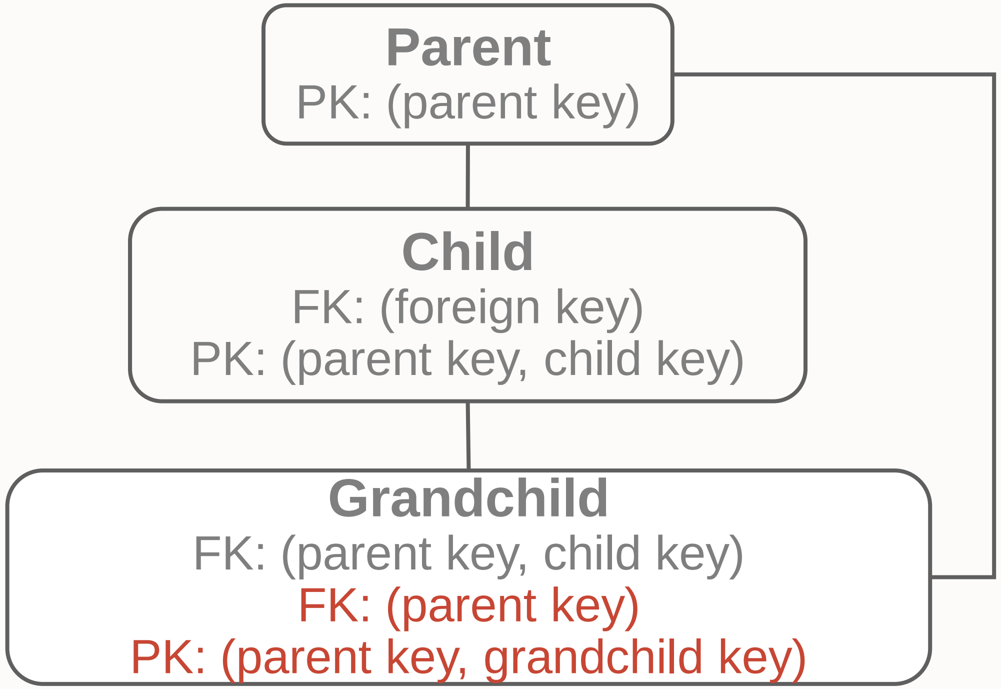
Reference Partitioning well suited to address both modeling techniques

Reference Partitioning

Relational Model



“Object-like” model



Reference Partitioning

Example

```
create table project (project_id number not null,
                      project_number varchar2(30),
                      project_name varchar2(30), …
                      constraint proj_pk primary key (project_id))
partition by list (project_id)
(partition p1 values (1),
 partition p2 values (2),
 partition pd values (DEFAULT));
```

```
create table project_customer (project_cust_id number not null,
                               project_id number not null,
                               cust_name varchar2(30),
                               constraint pk_proj_cust primary key
                                 (project_id, project_cust_id),
                               constraint proj_cust_proj_fk foreign key
                                 (project_id) references project(project_id))
partition by reference (proj_cust_proj_fk);
```


Reference Partitioning

Example, cont.

```
create table proj_cust_address (project_cust_addr_id number not null,
                                project_cust_id number not null,
                                project_id number not null,
                                cust_address varchar2(30),
                                constraint pk_proj_cust_addr primary key
                                   (project_id, project_cust_addr_id),
                                constraint proj_c_addr_proj_cust_fk foreign key
                                   (project_id, project_cust_id)
                                    references project_customer
                                              (project_id, project_cust_id))
partition by reference (proj_c_addr_proj_cust_fk);
```


Reference Partitioning
Some metadata

Table information

```
SQL> SELECT table_name, partitioning_type, ref_ptn_constraint_name
     FROM   user_part_tables
     WHERE  table_name IN ('PROJECT','PROJECT_CUSTOMER','PROJ_CUST_ADDRESS');

TABLE_NAME                PARTITION   REF_PTN_CONSTRAINT_NAME
----------------------- ---------   ------------------------------
PROJECT                   LIST
PROJECT_CUSTOMER          REFERENCE   PROJ_CUST_PROJ_FK
PROJ_CUST_ADDRESS         REFERENCE   PROJ_C_ADDR_PROJ_FK
```

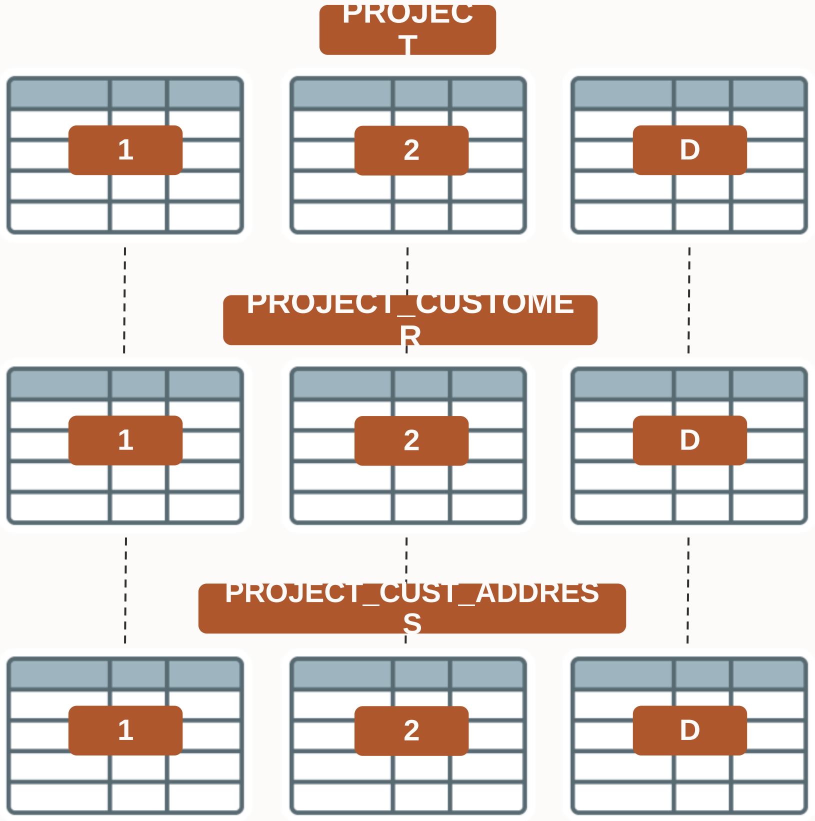
Partition information

```
SQL> SELECT table_name, partition_name, high_value
     FROM   user_tab_partitions
     WHERE  table_name in ('PROJECT','PROJECT_CUSTOMER')
     ORDER BY table_name, partition_position;

TABLE_NAME                PARTITION_NAME      HIGH_VALUE
----------------------- ------------------- ---------------------------
PROJECT                   P1                  1
PROJECT                   P2                  2
PROJECT                   PD                  DEFAULT
PROJECT_CUSTOMER          P1
PROJECT_CUSTOMER          P2
PROJECT_CUSTOMER          PD
```

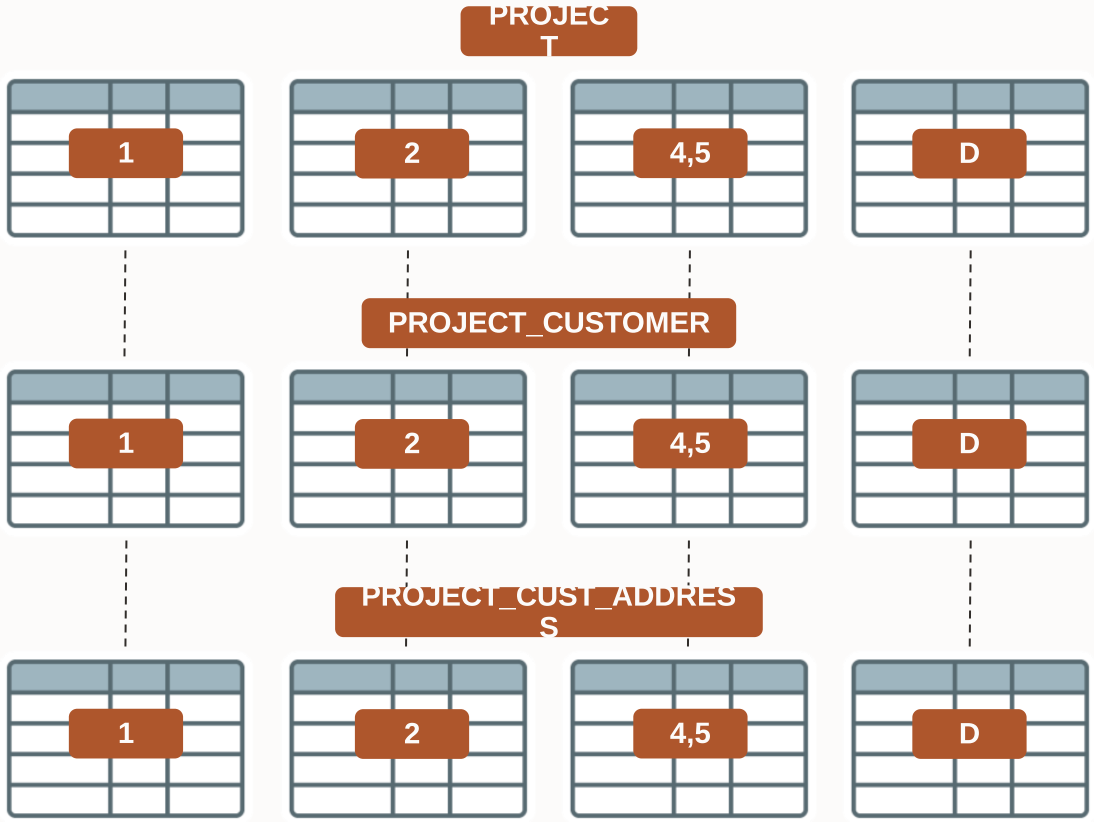

Reference Partitioning

Partition Maintenance




```
ALTER TABLE project
SPLIT PARTITION pd VALUES (4,5)
INTO
(PARTITION pd, PARTITION p45);
```

Reference Partitioning
Partition Maintenance




```
ALTER TABLE project
SPLIT PARTITION pd VALUES (4,5) INTO
(PARTITION pd, PARTITION p45);
```

PROJECT partition PD will be split

- “Default” and (4,5)

PROJECT_CUSTOMER will split its dependent partition

- Co-location with equivalent parent record of PROJECT
- Parent record in (4,5) means child record in (4.5)

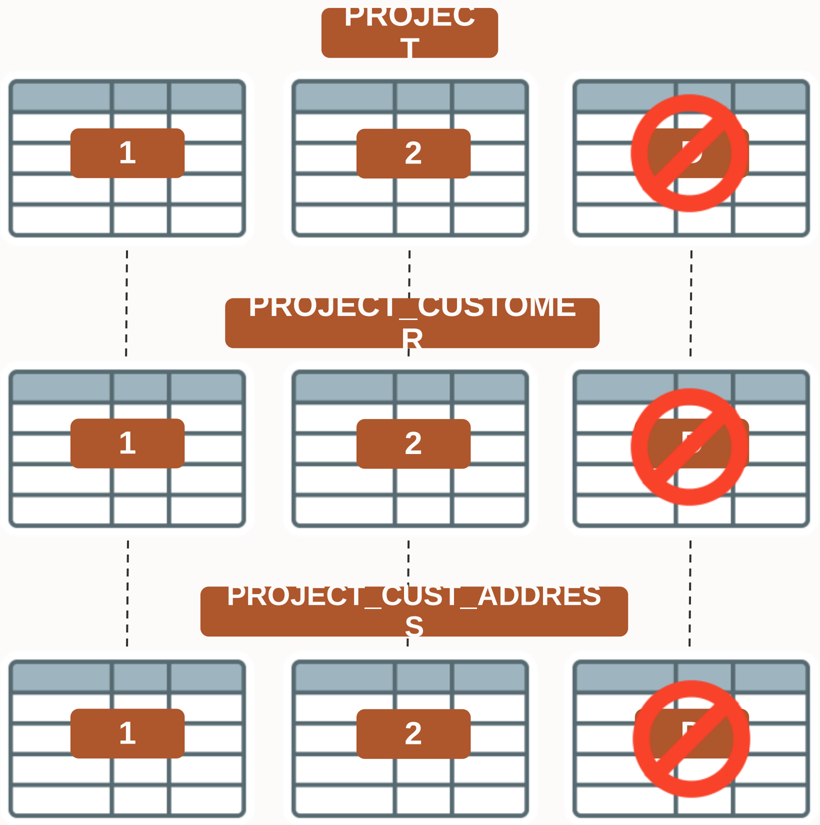
PROJECT_CUST_ADDRESS will split its dependent partition

- Co-location with equivalent parent record of PROJECT_CUSTOMER

One-level lookup required for both placements

Reference Partitioning

Partition Maintenance




```
ALTER TABLE project_cust_address
DROP PARTITION pd;
```

PROJECT partition PD will be dropped

- PK-FK is guaranteed not to be violated

PROJECT_CUSTOMER will drop its dependent partition

PROJECT_CUST_ADDRESS will drop its dependent partition

Unlike “normal” partitioned tables, PK-FK relationship stays enabled

- You cannot arbitrarily drop or truncate a partition with the PK of a PK-FK relationship

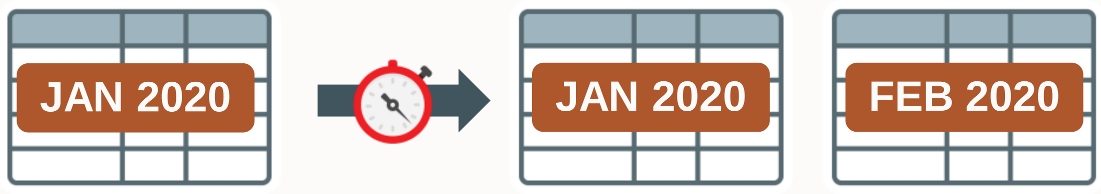
Same is true for TRUNCATE

- Bottom-up operation

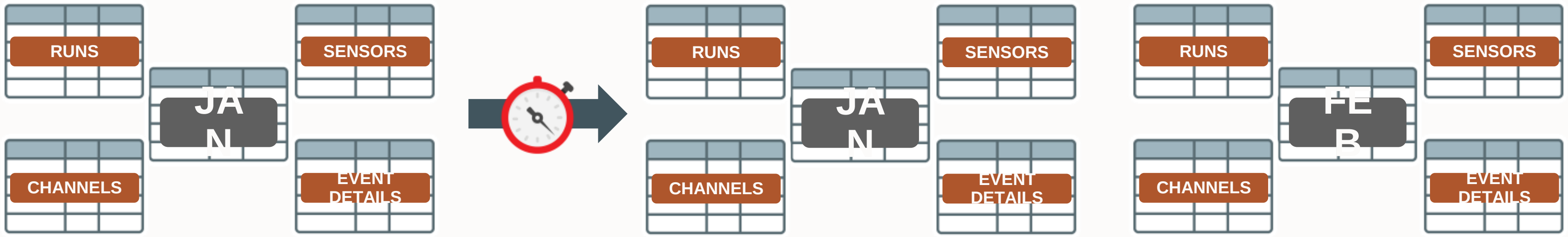
Interval Reference Partitioning

Introduced in Oracle 12c Release 1 (12.1)

Interval-Reference Partitioning




```
INSERT INTO events
VALUES ('14-FEB-2020', ... );
```



New partitions are automatically created when new data arrives

All child tables will be automatically maintained

Combination of two successful partitioning strategies for better business modeling

Interval-Reference Partitioning

```
SQL> REM create some interval-referenced tables ..
SQL> create table intRef_p (pkcol number not null, col2 varchar2(200),
  2                          constraint pk_intref primary key (pkcol))
  3  partition by range (pkcol) interval (10)
  4  (partition p1 values less than (10));

Table created.

SQL>
SQL> create table intRef_c1 (pkcol number not null, col2 varchar2(200), fkcol number not null,
  2                           constraint pk_c1 primary key (pkcol),
  3                           constraint fk_c1 foreign key (fkcol) references intRef_p(pkcol) ON DELETE CASCADE)
  4  partition by reference (fk_c1);

Table created.

SQL>
SQL> create table intRef_c2 (pkcol number primary key not null, col2 varchar2(200), fkcol number not null,
  2                           constraint fk_c2 foreign key (fkcol) references intRef_p(pkcol) ON DELETE CASCADE)
  3  partition by reference (fk_c2);

Table created.
```


Interval-Reference Partitioning

New partitions only created when data arrives

- No automatic partition instantiation for complete reference tree
- Optimized for sparsely populated reference partitioned tables

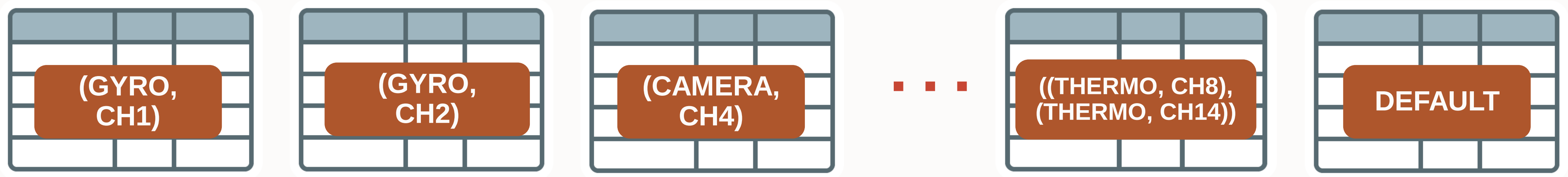
Partition names inherited from already existent partitions

- Name inheritance from direct relative
- Parent partition p100 will result in child partition p100
- Parent partition p100 and child partition c100 will result in grandchild partition c100

Multi-Column List Partitioning

Introduced in Oracle Database 12.2

Multi-Column List Partitioning



Data is organized in lists of multiple values (multiple columns)

- Individual partitions can contain sets of multiple values
- Functionality of DEFAULT partition (catch-it-all for unspecified values)

Ideal for segmentation of distinct value tuples,
e.g. (sensor_type, channel, …)

Details of Multi-Column List strategy

Allow specification of more than one column as partitioning key

- Up to 16 partition key columns
- Each set of partitioning keys must be unique

Notation of one DEFAULT partition

Functional support

- Supported as both partition and sub-partition strategy
- Support for heap tables
- Support for external tables
- Supported with Reference Partitioning and Auto-List

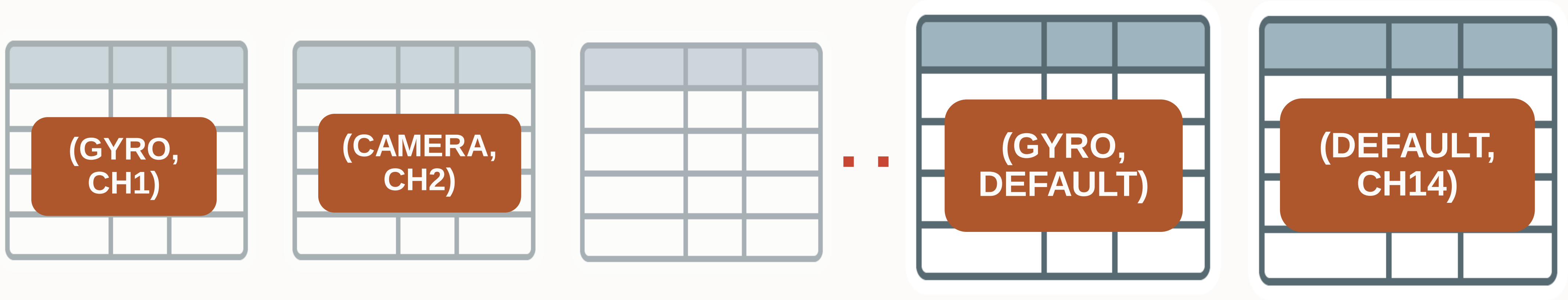
Multi-Column List partitioned table

Syntax example

```
CREATE TABLE EVENTS( sensor_type  VARCHAR2(50),
                     channel      VARCHAR2(50), …)
PARTITION BY LIST (sensor_type, channel)
( partition p1 values ('GYRO','CH1'),
  partition p2 values ('GYRO','CH2'),
  partition p3 values ('CAMERA','CH4'),
…
  partition p44 values (('THERMO','CH8'),
                        ('THERMO','CH14')),
  partition p45 values (DEFAULT)
);
```


Multi-Column List Partitioning

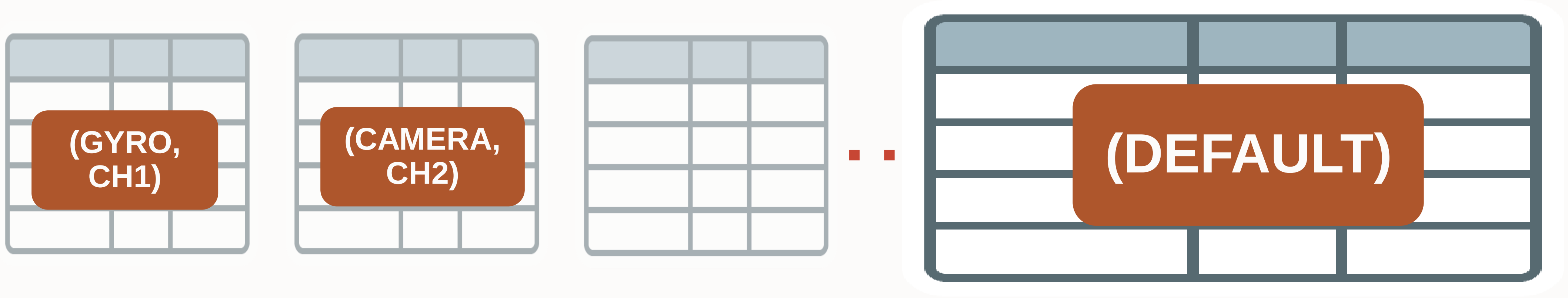
What if there was a DEFAULT per column?



Where do we store (GYRO, CH14) ????

Multi-Column List Partitioning

What if there was a DEFAULT per column?



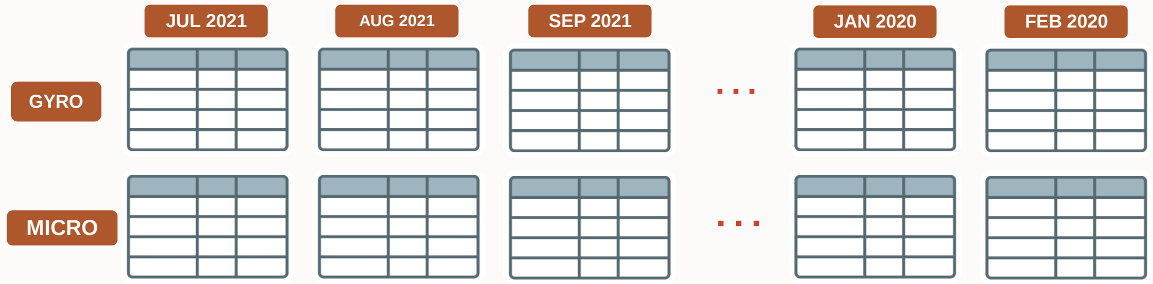
Where do we store (GYRO, CH12) ????

- In the one-and-only DEFAULT partition

Multi-column list partitioning prior to 12.2

List – List partitioning

- Almost equivalent
- Only two columns as key (two levels)
- Conceptual symmetrical



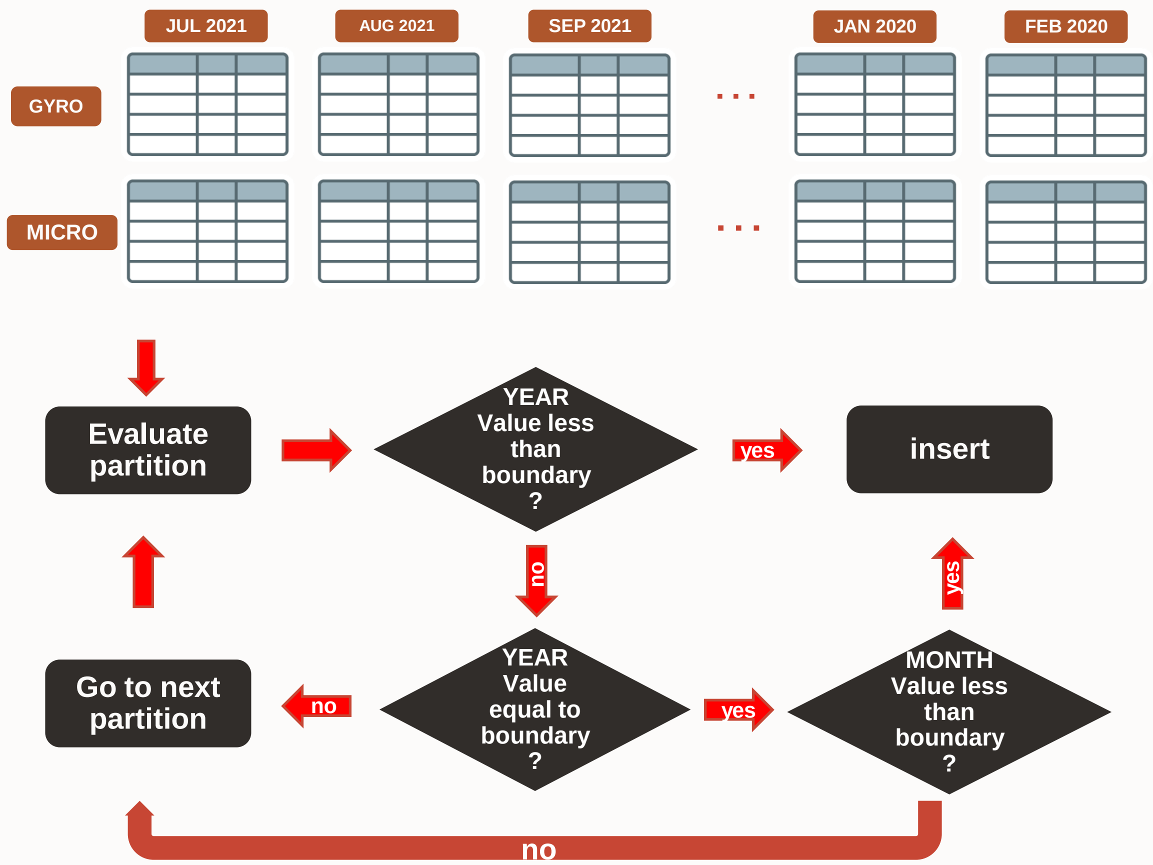
Multi-column list partitioning prior to 12.2

List – List partitioning

- Almost equivalent
- Only two columns as key (two levels)
- Conceptual symmetrical

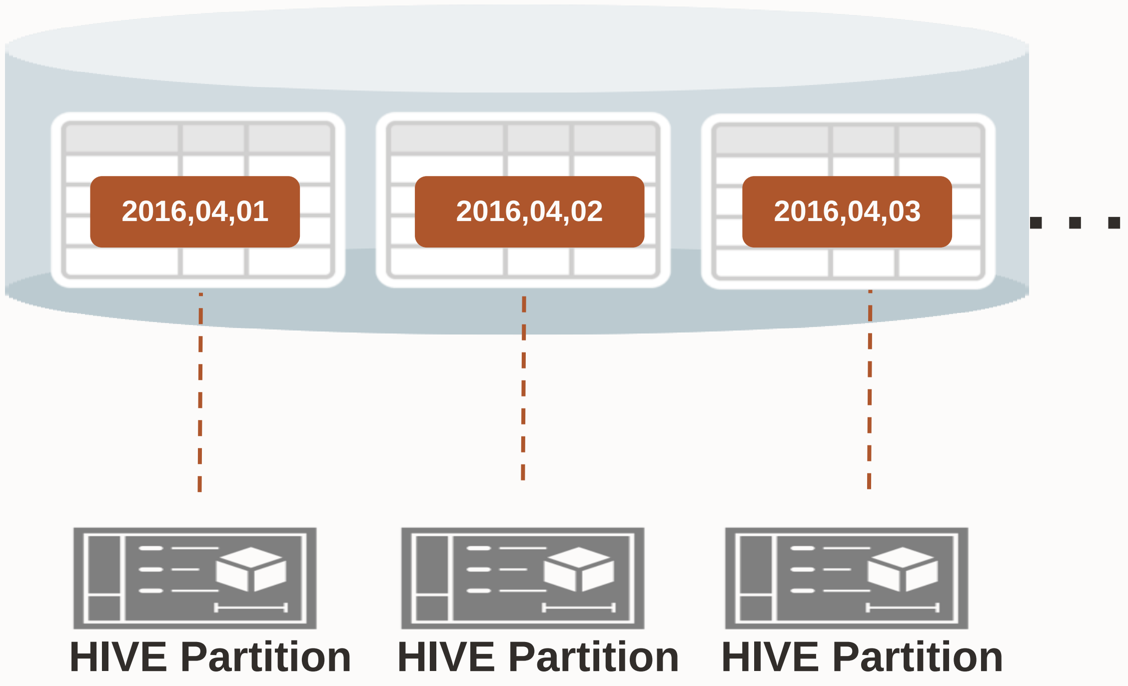
Multi-column range partitioning

- NOT equivalent
- Hierarchical evaluation of predicates only in case of disambiguity



Partitioning and External Data

Partitioned External Tables



All data outside the database

- Files in file system
- Partitioned Hive & HDFS tables

Exposes the power of Oracle partitioning to external data

- Partition pruning
- Partition maintenance

Enables order-of-magnitudes faster query performance and enhanced data maintenance

Partitioned External Tables

Initial creation

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
ORGANIZATION EXTERNAL
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..)
) REJECT LIMIT unlimited
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  DEFAULT DIRECTORY old_data_dir LOCATION (‘q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’)
  LOCATION (‘q2_2015.csv’),
  partition q3_2015 values less than (‘2015-04-01’)
  LOCATION (‘q3_2015.csv’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```

Partitioned External Tables
Initial creation

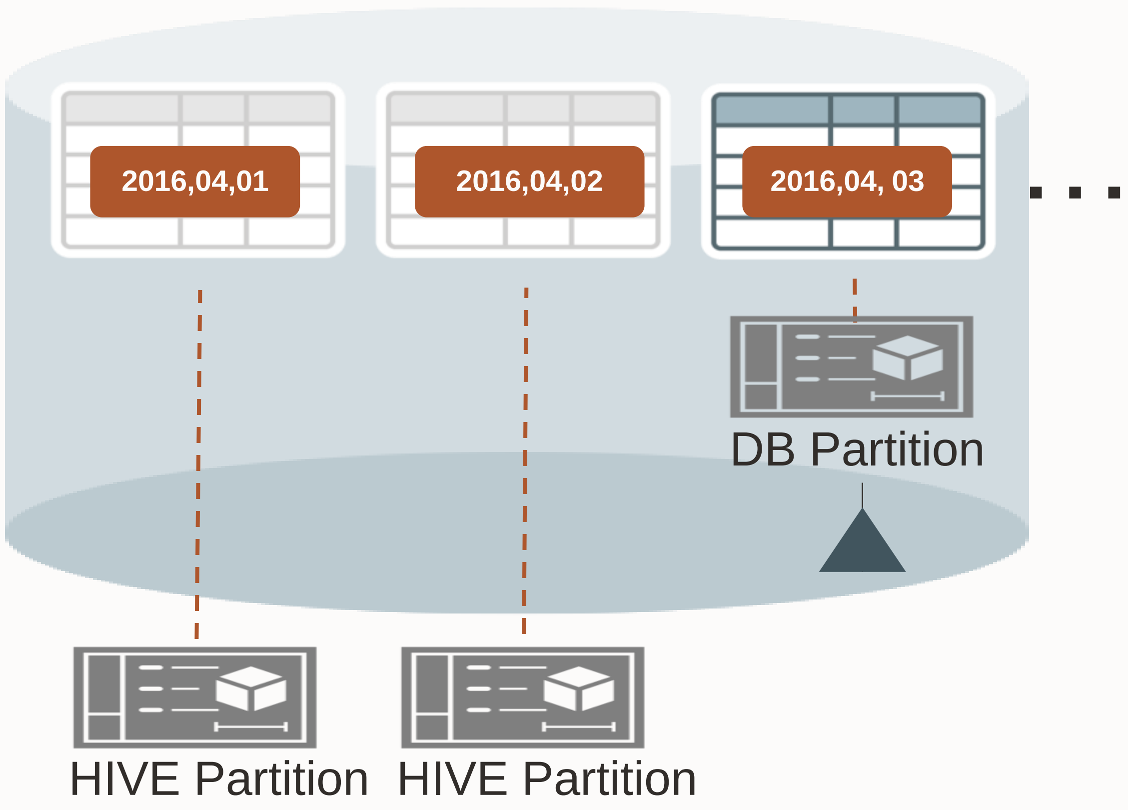
```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
ORGANIZATION EXTERNAL
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..)
) REJECT LIMIT unlimited
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  DEFAULT DIRECTORY old_data_dir LOCATION (‘q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’)
  LOCATION (‘q2_2015.csv’),
  partition q3_2015 values less than (‘2015-04-01’)
  LOCATION (‘q3_2015.csv’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```


Partitioned External Tables

Initial creation

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
ORGANIZATION EXTERNAL
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..)
) REJECT LIMIT unlimited
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  DEFAULT DIRECTORY old_data_dir LOCATION (‘q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’)
  LOCATION (‘q2_2015.csv’),
  partition q3_2015 values less than (‘2015-04-01’)
  LOCATION (‘q3_2015.csv’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```


Hybrid Partitioned Tables



Single table contains both internal (RDBMS) and external partitions

- Full functional support, such as partial indexing, partial read only, constraints, materialized views, etc.

Optimized hybrid processing

- Full leverage of both RDBMS and external processing capabilities

Partition maintenance for information lifecycle management

- Currently limited support
- Enhancements in progress

Hybrid Partitioned Tables

Initial creation

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
EXTERNAL PARTITION ATTRIBUTES
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..) REJECT LIMIT unlimited
)
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  EXTERNAL LOCATION (‘order_q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’),
  partition q3_2015 values less than (‘2015-04-01’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```


Hybrid Partitioned Tables

Initial creation

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
EXTERNAL PARTITION ATTRIBUTES
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..) REJECT LIMIT unlimited
)
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  EXTERNAL LOCATION (‘order_q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’),
  partition q3_2015 values less than (‘2015-04-01’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```

Hybrid Partitioned Tables

Initial creation

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
EXTERNAL PARTITION ATTRIBUTES
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (..) REJECT LIMIT unlimited
)
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than (‘2014-10-01’)
  EXTERNAL LOCATION (‘order_q1_2015.csv’),
  partition q2_2015 values less than (‘2015-01-01’),
  partition q3_2015 values less than (‘2015-04-01’),
  partition q4_2015 values less than (‘2015-07-01’)
);
```

Evolving to Hybrid Partitioned Tables

```
ALTER TABLE orders
ADD EXTERNAL PARTITION ATTRIBUTES
(   TYPE oracle_loader
    DEFAULT DIRECTORY data_dir
    ACCESS PARAMETERS
         (records delimited by newline
          badfile 'cdxt_%a_%p.bad'
          logfile 'cdxt_%a_%p.log'
          fields terminated by ','
          missing field values are null
         )
    REJECT LIMIT unlimited
);
```

Hybrid Partitioned Tables

Lifecycle Management Support

Initial support of lifecycle management between external and internal storage through EXCHANGE

- No MOVE or other advanced functionality (SPLIT, MERGE)
- Data movement done by customer/application

Currently no support for lifecycle management between external and internal storage

- Functionality will be included in Oracle Database 19c, Release 19.7
  - Exchange internal partition with external table (bug 28876926)
  - Exchange external partition with internal table (bug 30172925)

Access Data in Object Stores

Data in any object store can be accessed

- Oracle Object Store, AWS S3 or Azure

Explicit authentication or pre-authenticated URIs

(Admittedly not a specific Partitioning feature, but cool nevertheless)

File System Access versus Object Storage

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
ORGANIZATION EXTERNAL
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (
                           )
) REJECT LIMIT unlimited
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than ('2014-10-01')
  LOCATION ('q1_2015.csv'),
  partition q2_2015 values less than ('2015-01-01')
  LOCATION ('q2_2015.csv'),
  partition q3_2015 values less than ('2015-04-01')
  LOCATION ('q3_2015.csv'),
  partition q4_2015 values less than ('2015-07-01')
);
```

File System Access versus Object Storage

```
CREATE TABLE orders ( order_id number,
                      order_date DATE,   … )
ORGANIZATION EXTERNAL
(  TYPE oracle_loader DEFAULT DIRECTORY data_dir
   ACCESS PARAMETERS (
   CREDENTIAL 'OSS_ACCESS' )
) REJECT LIMIT unlimited
PARTITION BY RANGE(order_date)
( partition q1_2015 values less than ('2014-10-01')
  LOCATION ('https://swiftobjectstorage.us-ashburn-1 ...'),
  partition q2_2015 values less than ('2015-01-01')
  LOCATION ('...'),
  partition q3_2015 values less than ('2015-04-01')
  LOCATION ('...'),
  partition q4_2015 values less than ('2015-07-01')
);
```


Data Placement Validation

Internal partitioning enforces proper data placement

- Even here there is one exception

External partitioning relies on proper data in the files mapping to partitions

Data Placement Validation

Internal partitioning enforces proper data placement

- Even here there is one exception

External partitioning relies on proper data in the files mapping to partitions

New function added with partitioned external tables to validate data placement

- ORA_PARTITION_VALIDATION(rowid)
- Returns 1 for correct data placement, 0 otherwise

Data Placement Validation

```
SQL> SELECT hpto.*,
             ORA_PARTITION_VALIDATION(rowid) AS correct_partition
     FROM hpto;

 DEPTNO    DNAME                    LOC                         CORRECT_PARTITION
---------- ---------------------    --------------------------- -----------------
        12 dept_12                  xp1_15                      1
        16 dept_16                  dept_loc_16                 1
        17 dept_17                  dept_loc_17                 1
        29 dept_29                  xp2_30                      1
        31 dept_31                  dept_loc_31                 1
        32 dept_32                  dept_loc_32                 1
      9999 dept_50                  xp_wrong                    0
```


Partitioning for Performance

Partitioning for Performance

Partitioning is transparently leveraged to improve performance

Partition pruning

- Using partitioning metadata to access only partitions of interest

Partition-wise joins

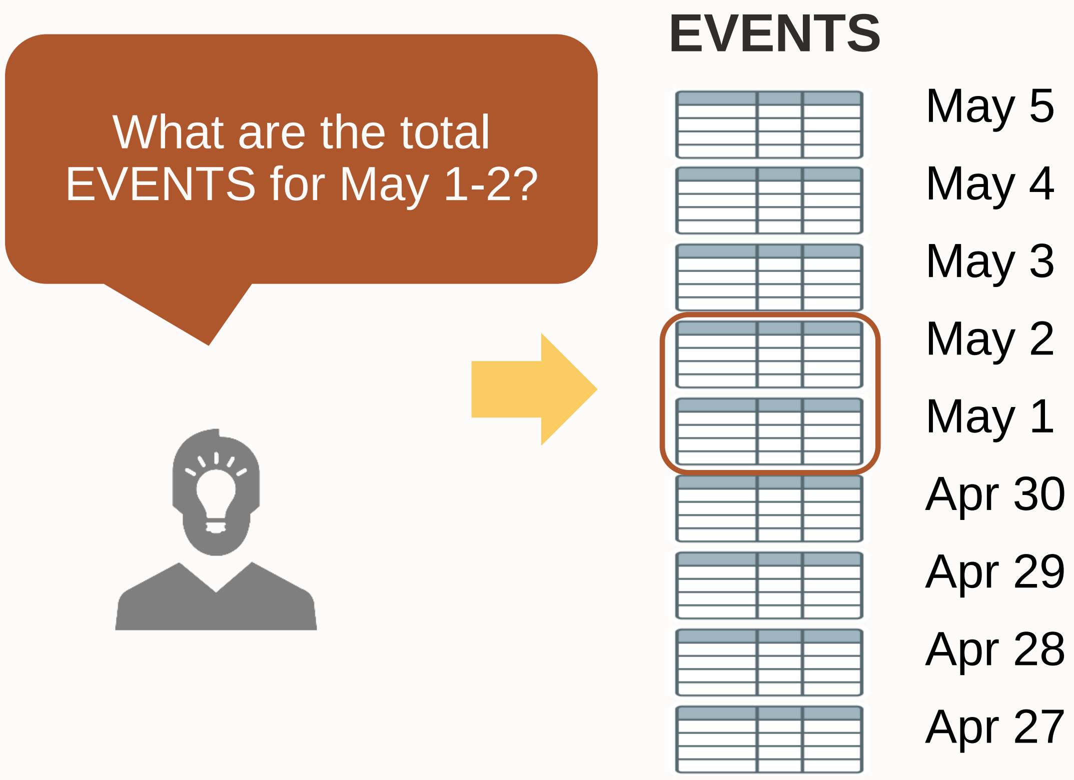
- Join equi-partitioned tables with minimal resource consumption
- Process co-location capabilities for RAC environments

Partition-Exchange loading

- “Load” new data through metadata operation

Partitioning for Performance

Partition Pruning



Partition elimination

- Dramatically reduces amount of data retrieved from storage
- Performs operations only on relevant partitions
- Transparently improves query performance and optimizes resource utilization

Partition Pruning

Works for simple and complex SQL statements

Transparent to any application

Two flavors of pruning

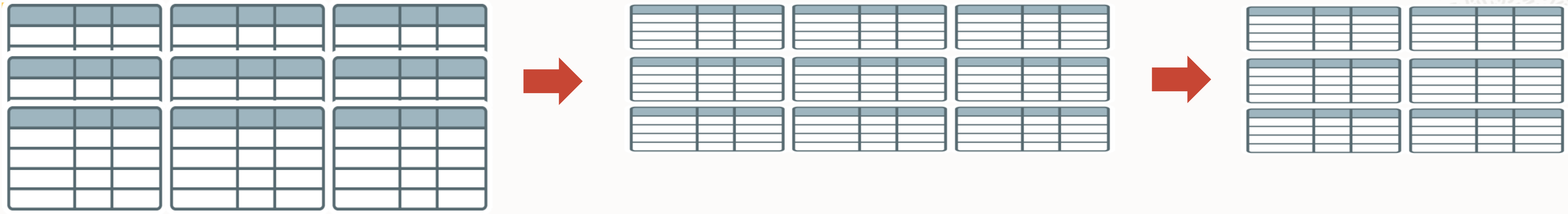
- Static pruning at compile time
- Dynamic pruning at runtime

Complementary to Exadata Storage Server

- Partitioning prunes logically through partition elimination
- Exadata prunes physically through storage indexes
  - Further data reduction through filtering and projection

Performance Features Multiply the Benefits

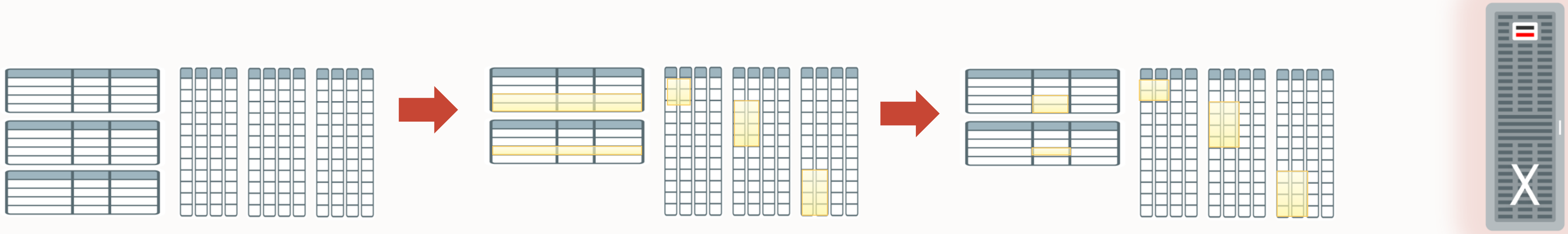
Example



100 TB of User Data

10 TB of User Data
With 10x Compression

2TB of User Data
With Partition Pruning



2 TB of User Data
1TB on disk, 1TB in-memory

100 GB of User Data
With Storage Indexes and Zone Maps

30 GB of User Data
With Smart Scan

Sub second Scan
No Indexes

Static Partition Pruning

```
SELECT avg( luminosity ) FROM EVENTS
WHERE times_id
BETWEEN '01-MAR-2021' and '31-MAY-2021';
```

2021-JAN | 2021-FEB | 2021-MAR | 2021-APR | 2021-MAY | 2021-JUN

Relevant Partitions are known at compile time

- Look for actual values in PSTART/PSTOP columns in the plan

Optimizer has most accurate information for the SQL statement

Static Pruning

Sample Plan

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND s.time_id between TO_DATE('01-JAN-2021', 'DD-MON-YYYY')
              and     TO_DATE('01-JAN-2020', 'DD-MON-YYYY')

Plan hash value: 2025449199

---------------------------------------------------------------------------------------------------
| Id | Operation                   | Name   | Rows   | Bytes  | Cost  (%CPU)| Time       | Pstart| Pstop |
---------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT            |        |        |        |     3  (100)|            |       |       |
|  1 |  SORT AGGREGATE             |        |      1 |     12 |             |            |       |       |
|  2 |   PARTITION RANGE ITERATOR  |        |  313   |  3756  |     3     (0)| 00:00:01  |     9 |    13 |
|* 3 |    TABLE ACCESS FULL        | EVENTS|  313   |  3756  |     3     (0)| 00:00:01  |     9 |    13 |
---------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter("S"."TIME_ID"<=TO_DATE(' 2020-01-01 00:00:00', 'syyyy-mm-dd hh24:mi:ss'))

22 rows selected.
```


Static Pruning

Sample Plan

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND s.time_id between TO_DATE('01-JAN-2021', 'DD-MON-YYYY')
   and TO_DATE('01-JAN-2020', 'DD-MON-YYYY')

Plan hash value: 2025449199

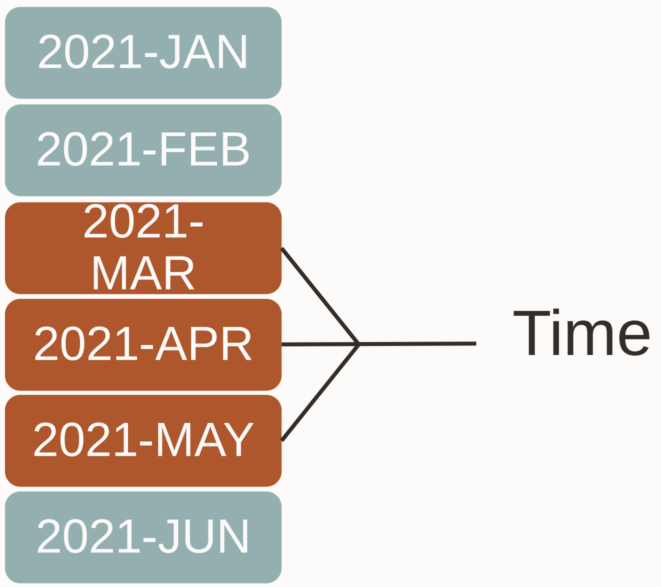
----------------------------------------------------------------------------------------------------
| Id | Operation                    | Name    | Rows   | Bytes | Cost (%CPU)| Time       | Pstart| Pstop |
----------------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT            |         |        |       |    3  (100)|            |       |       |
|   1 |  SORT AGGREGATE             |         |      1 |    12 |            |            |       |       |
|   2 |   PARTITION RANGE ITERATOR  |         |   313  |  3756 |    3    (0)| 00:00:01   |     9 |    13 |
|*  3 |    TABLE ACCESS FULL        | EVENTS|   313  |  3756 |    3    (0)| 00:00:01   |     9 |    13 |
----------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter("S"."TIME_ID"<=TO_DATE(' 2020-01-01 00:00:00', 'syyyy-mm-dd hh24:mi:ss'))

22 rows selected.
```


Dynamic Partition Pruning




```
SELECT avg( luminosity )
FROM EVENTS s, times t
WHERE t.time_id = s.time_id
AND   t.calendar_month_desc IN
        ('MAR-2021', 'APR-2021', 'MAY-2021');
```

Advanced Pruning mechanism for complex queries

Relevant partitions determined at runtime

- Look for the word 'KEY' in PSTART/PSTOP columns in the Plan

Dynamic Partition Pruning

Sample Plan – Nested Loop

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND t.calendar_month_desc in (‘MAR-2021’, ‘APR-2021’, ‘MAY-2021’)

Plan hash value: 1350851517

----------------------------------------------------------------------------------------------------
| Id | Operation                   | Name   | Rows   | Bytes | Cost (%CPU)| Time       | Pstart| Pstop |
----------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT            |        |        |       |   13  (100)|            |       |       |
|  1 |  SORT AGGREGATE             |        |     1  |    28 |            |            |       |       |
|  2 |   NESTED LOOP               |        |     2  |    56 |   13    (0)| 00:00:01   |       |       |
|* 3 |    TABLE ACCESS FULL        | TIMES  |     2  |    32 |   13    (8)| 00:00:01   |       |       |
|  4 |    PARTITION RANGE ITERATOR|        |     2  |    24 |    0    (0)|            |   KEY |   KEY |
|* 5 |     TABLE ACCESS FULL       | EVENTS|     2  |    24 |    0    (0)|            |   KEY |   KEY |
----------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter((“T”.”CALENDAR_MONTH_DESC”=‘MAR-2021’ OR “T”.”CALENDAR_MONTH_DESC”=‘APR-2021’
              OR “T”.”CALENDAR_MONTH_DESC”=‘MAY-2021’))
   5 - filter(“T”.”TIME_ID”=“S”.”TIME_ID”)

26 rows selected.
```


Dynamic Partition Pruning

Sample Plan – Nested Loop

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND t.calendar_month_desc in ('MAR-2021', 'APR-2021', 'MAY-2021')

Plan hash value: 1350851517

----------------------------------------------------------------------------------------------------
| Id | Operation                  | Name   | Rows   | Bytes | Cost (%CPU)| Time       | Pstart| Pstop |
----------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT           |        |        |       |   13  (100)|            |       |       |
|  1 |  SORT AGGREGATE            |        |     1  |    28 |            |            |       |       |
|  2 |   NESTED LOOP              |        |     2  |    56 |   13    (0)| 00:00:01   |       |       |
|* 3 |    TABLE ACCESS FULL       | TIMES  |     2  |    32 |   13    (8)| 00:00:01   |       |       |
|  4 |    PARTITION RANGE ITERATOR|        |     2  |    24 |    0    (0)|            |   KEY |   KEY |
|* 5 |     TABLE ACCESS FULL      | EVENTS |     2  |    24 |    0    (0)|            |   KEY |   KEY |
----------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter(("T"."CALENDAR_MONTH_DESC"='MAR-2021' OR "T"."CALENDAR_MONTH_DESC"='APR-2021'
              OR "T"."CALENDAR_MONTH_DESC"='MAY-2021'))
   5 - filter("T"."TIME_ID"="S"."TIME_ID")

26 rows selected.
```


Dynamic Partition Pruning

Sample Plan - Subquery pruning

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND t.calendar_month_desc in ('MAR-2021', 'APR-2021', 'MAY-2021')

Plan hash value: 2475767165

---------------------------------------------------------------------------------------------------
| Id | Operation                   | Name   | Rows   | Bytes  | Cost (%CPU)| Time      | Pstart| Pstop |
---------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT            |        |        |        | 2000K(100)|           |       |       |
|  1 |  SORT AGGREGATE             |        |     1  |    28  |           |           |       |       |
|* 2 |   HASH JOIN                 |        |   24M|   646M| 2000K(100)| 06:40:01  |       |       |
|* 3 |    TABLE ACCESS FULL        | TIMES  |     2  |    32  |    43   (8)| 00:00:01  |       |       |
|  4 |    PARTITION RANGE SUBQUERY|        |   10G|   111G| 1166K(100)| 03:53:21  |KEY(SQ)|KEY(SQ)|
|  5 |     TABLE ACCESS FULL       | EVENTS|   10G|   111G| 1166K(100)| 03:53:21  |KEY(SQ)|KEY(SQ)|
---------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("S"."TIME_ID"="T"."TIME_ID")
   3 - filter(("T"."CALENDAR_MONTH_DESC"='MAR-2021' OR "T"."CALENDAR_MONTH_DESC"='APR-2021'
              OR "T"."CALENDAR_MONTH_DESC"='MAY-2021'))

26 rows selected.
```

Dynamic Partition Pruning

Sample Plan - Bloom filter pruning

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND t.calendar_month_desc in ('MAR-2021', 'APR-2021', 'MAY-2021')

Plan hash value: 365741303

----------------------------------------------------------------------------------------------------------
| Id | Operation                    | Name     | Rows   | Bytes | Cost  (%CPU)| Time       | Pstart| Pstop |
----------------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT             |          |        |       |   19  (100)|            |       |       |
|  1 |  SORT AGGREGATE              |          |      1 |    28 |            |            |       |       |
|* 2 |   HASH JOIN                  |          |      2 |    56 |   19  (100)| 00:00:01 |       |       |
|  3 |    PART JOIN FILTER CREATE   | :BF0000 |      2 |    32 |   13    (8)| 00:00:01 |       |       |
|* 4 |     TABLE ACCESS FULL        | TIMES    |      2 |    32 |   13    (8)| 00:00:01 |       |       |
|  5 |    PARTITION RANGE JOIN-FILTER|         |    960 | 11520 |    5    (0)| 00:00:01 |:BF0000|:BF0000|
|  6 |     TABLE ACCESS FULL        | EVENTS   |    960 | 11520 |    5    (0)| 00:00:01 |:BF0000|:BF0000|
----------------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("S"."TIME_ID"="T"."TIME_ID")
   4 - filter(("T"."CALENDAR_MONTH_DESC"='MAR-2021' OR "T"."CALENDAR_MONTH_DESC"='APR-2021'
              OR "T"."CALENDAR_MONTH_DESC"='MAY-2021'))

27 rows selected.
```

"AND" Pruning

```
FROM events s, times t …
WHERE s.time_id = t.time_id ..
AND t.fiscal_year in (2021,2020)
AND s.time_id
  between TO_DATE('01-JAN-2021','DD-MON-YYYY')
  and TO_DATE('01-JAN-2022','DD-MON-YYYY')
```

Dynamic pruning

Static pruning

All predicates on partition key will used for pruning

- Dynamic and static predicates will now be used combined

Example:

- Star transformation with pruning predicate on both the FACT table and a dimension

“AND” Pruning

Sample Plan

```
Plan hash value: 552669211

-------------------------------------------------------------------------------------------------------
| Id | Operation                    | Name     | Rows  | Bytes | Cost (%CPU)| Time      | Pstart| Pstop |
-------------------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT             |          |     1 |    24 |   17   (12)| 00:00:01 |       |       |
|  1 |  SORT AGGREGATE              |          |     1 |    24 |            |          |       |       |
|* 2 |   HASH JOIN                  |          |   204 |  4896 |   17   (12)| 00:00:01 |       |       |
|  3 |    PART JOIN FILTER CREATE   | :BF0000  |   185 |  2220 |   13    (8)| 00:00:01 |       |       |
|* 4 |     TABLE ACCESS FULL        | TIMES    |   185 |  2220 |   13    (8)| 00:00:01 |       |       |
|  5 |    PARTITION RANGE AND       |          |   313 |  3756 |    3    (0)| 00:00:01 |KEY(AP)|KEY(AP)|
|* 6 |     TABLE ACCESS FULL        | EVENTS   |   313 |  3756 |    3    (0)| 00:00:01 |KEY(AP)|KEY(AP)|
-------------------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("S"."TIME_ID"="T"."TIME_ID")
   4 - filter("T"."TIME_ID"<=TO_DATE(' 2020-01-01 00:00:00', 'syyyy-mm-dd hh24:mi:ss') AND
              ("T"."FISCAL_YEAR"=2021 OR "T"."FISCAL_YEAR"=2020) AND "T"."TIME_ID">=TO_DATE(' 2021-01-01
              00:00:00', 'syyyy-mm-dd hh24:mi:ss'))
   6 - filter("S"."TIME_ID"<=TO_DATE(' 2020-01-01 00:00:00', 'syyyy-mm-dd hh24:mi:ss'))

22 rows selected.
```

Ensuring Partition Pruning

Don’t use functions on partition key filter predicates

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND TO_CHAR(s.time_id, ‘YYYYMMDD’) between ‘20210101’ and ‘20220101’

Plan hash value: 672559287

-------------------------------------------------------------------------------------------
| Id | Operation              | Name   | Rows   | Bytes  | Cost (%CPU)| Time      | Pstart| Pstop |
-------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT       |        |        |        |    6  (100)|           |       |       |
|  1 |  SORT AGGREGATE        |        |     1  |    12  |            |           |       |       |
|  2 |   PARTITION RANGE ALL|        |     2  |    24  |    6   (17)| 00:00:01  |     1 |    16 |
|* 3 |    TABLE ACCESS FULL | EVENTS|     2  |    24  |    6   (17)| 00:00:01  |     1 |    16 |
-------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter((TO_CHAR(INTERNAL_FUNCTION(“S”.”TIME_ID”),’YYYYMMDD’)>=‘20210101’ AND
              TO_CHAR(INTERNAL_FUNCTION(“S”.”TIME_ID”),‘YYYYMMDD’)<=‘20220101’))

23 rows selected.
```

Ensuring Partition Pruning

Don’t use functions on partition key filter predicates

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND TO_CHAR(s.time_id, ‘YYYYMMDD’) between ‘20210101’ and ‘20220101’
```

```
| Pstart| Pstop |
|       |       |
|     1 |    16 |
|     1 |    16 |

101’ AND
01’))
```

```
SELECT avg( luminosity )
FROM atlas.EVENTS s, altas.times t
WHERE s.time_id = t.time_id
AND s.time_id between TO_DATE(‘20210101’,’YYYYMMDD’) and TO_DATE(‘20220101’,’YYYYMMDD’)

Plan hash value: 2025449199

-------------------------------------------------------------------------------------------
| Id | Operation                  | Name   | Rows  | Bytes | Cost (%CPU)| Time     | Pstart| Pstop |
-------------------------------------------------------------------------------------------
|  0 | SELECT STATEMENT           |        |       |       |    3  (100)|          |       |       |
|  1 |  SORT AGGREGATE            |        |     1 |    12 |            |          |       |       |
|  2 |   PARTITION RANGE ITERATOR |        |   313 |  3756 |    3    (0)| 00:00:01 |     9 |    13 |
|* 3 |    TABLE ACCESS FULL       | EVENTS |   313 |  3756 |    3    (0)| 00:00:01 |     9 |    13 |
-------------------------------------------------------------------------------------------

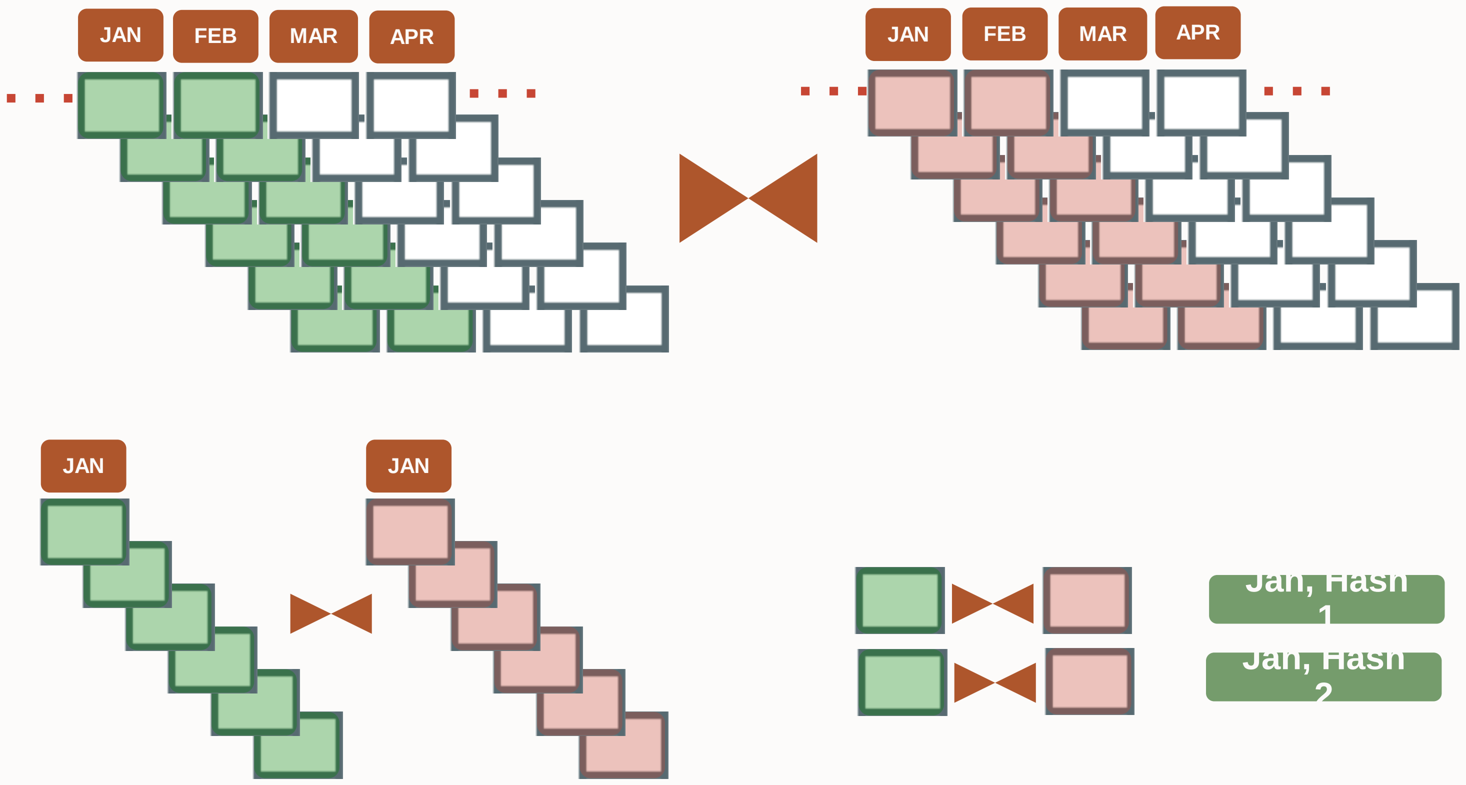
Predicate Information (identified by operation id):
---------------------------------------------------

   3 - filter(“S”.”TIME_ID”<=TO_DATE(‘ 2020-01-01 00:00:00’, ‘syyyy-mm-dd hh24:mi:ss’))

22 rows selected.
```


Partition-wise Joins

Partition pruning and PWJ's "at work"

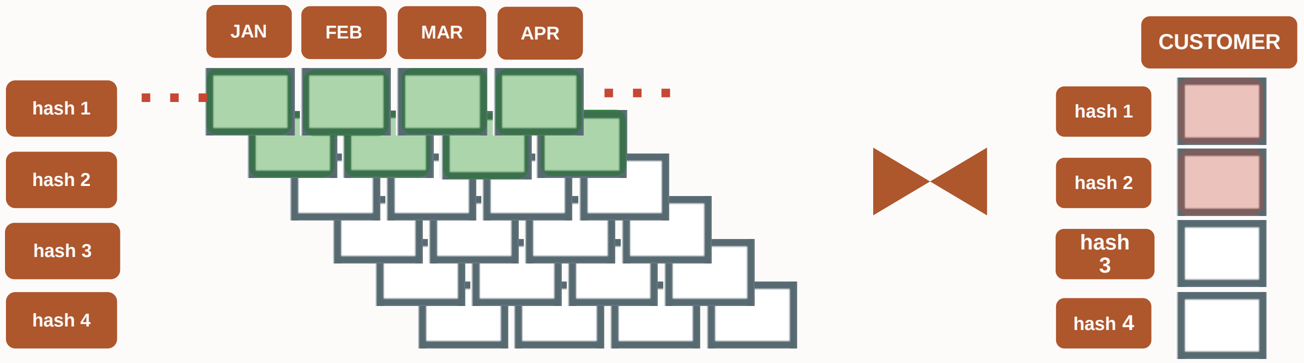


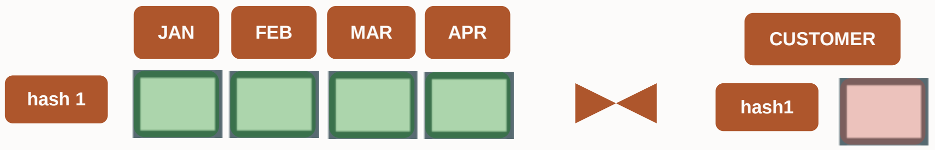
Large join is divided into multiple smaller joins, executed in parallel

- # of partitions to join must be a multiple of DOP
- Both tables must be partitioned the same way on the join column

Partition-wise Joins

Partition pruning and PWJ's "at work"





Large join is divided into multiple smaller joins, executed in parallel

- # of partitions to join must be a multiple of DOP
- Both tables must be partitioned the same way on the join column

Partition Purging and Loading

Remove and add data as metadata only operations

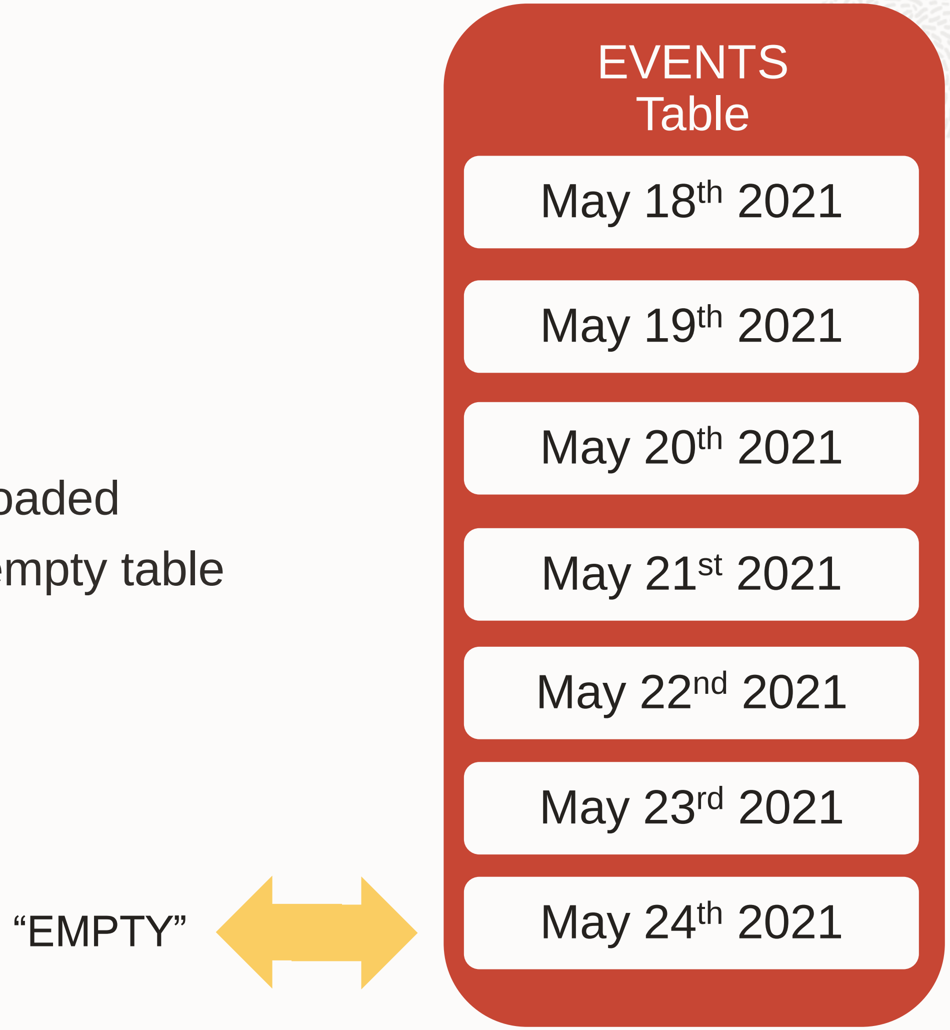
- Exchange the metadata of partitions

Exchange standalone table w/ arbitrary single partition

- Data load: standalone table contains new data to being loaded
- Data purge: partition containing data is exchanged with empty table

Drop partition alternative for purge

- Data is gone forever



Partitioning Maintenance

Partition Maintenance

Fundamental Concepts for Success

While performance seems to be the most visible one, don't forget about the rest, e.g.

- Partitioning must address all business-relevant areas of Performance, Manageability, and Availability

Partition autonomy is crucial

- Fundamental requirement for any partition maintenance operations
- Acknowledge partitions as metadata in the data dictionary

Partition Maintenance

Fundamental Concepts for Success

Provide full partition autonomy

- Use local indexes whenever possible
- Enable partition all table-level operations for partitions, e.g. TRUNCATE, MOVE, COMPRESS

Make partitions visible and usable for database administration

- Partition naming for ease of use

Maintenance operations must be partition-aware

- Also true for indexes

Maintenance operations must not interfere with online usage of a partitioned table

Aspects of Data Management

Addressable with Partition Maintenance Operations

Fast population of data

- EXCHANGE
- Per-partition direct path load

Fast removal of data

- DROP, TRUNCATE, EXCHANGE

Fast reorganization of data

- MOVE, SPLIT, MERGE

Partition Maintenance

Table Partition Maintenance Operations

```
ALTER TABLE ADD PARTITION(S)
ALTER TABLE DROP PARTITION(S)
ALTER TABLE EXCHANGE PARTITION
ALTER TABLE MODIFY PARTITION
   [PARALLEL][ONLINE]
ALTER TABLE MOVE PARTITION [PARALLEL][ONLINE]
ALTER TABLE RENAME PARTITION
ALTER TABLE SPLIT PARTITION [PARALLEL][ONLINE]
ALTER TABLE MERGE PARTITION(S) [PARALLEL]
   [ONLINE]
ALTER TABLE COALESCE PARTITION [PARALLEL]
ALTER TABLE ANALYZE PARTITION
ALTER TABLE TRUNCATE PARTITION(S)
Export/Import [by partition]
Transportable tablespace [by partition]
```

Index Maintenance Operations

```
ALTER INDEX MODIFY PARTITION
ALTER INDEX DROP PARTITION(S)
ALTER INDEX REBUILD PARTITION
ALTER INDEX RENAME PARTITION
ALTER INDEX RENAME
ALTER INDEX SPLIT PARTITION
ALTER INDEX ANALYZE PARTITION
```

All partitions remain available all the time

No DML lock for ONLINE operations

DML lock on impacted partitions in OFFLINE mode

Partition Maintenance on Multiple Partitions

Introduced in Oracle 12c Release 1 (12.1)

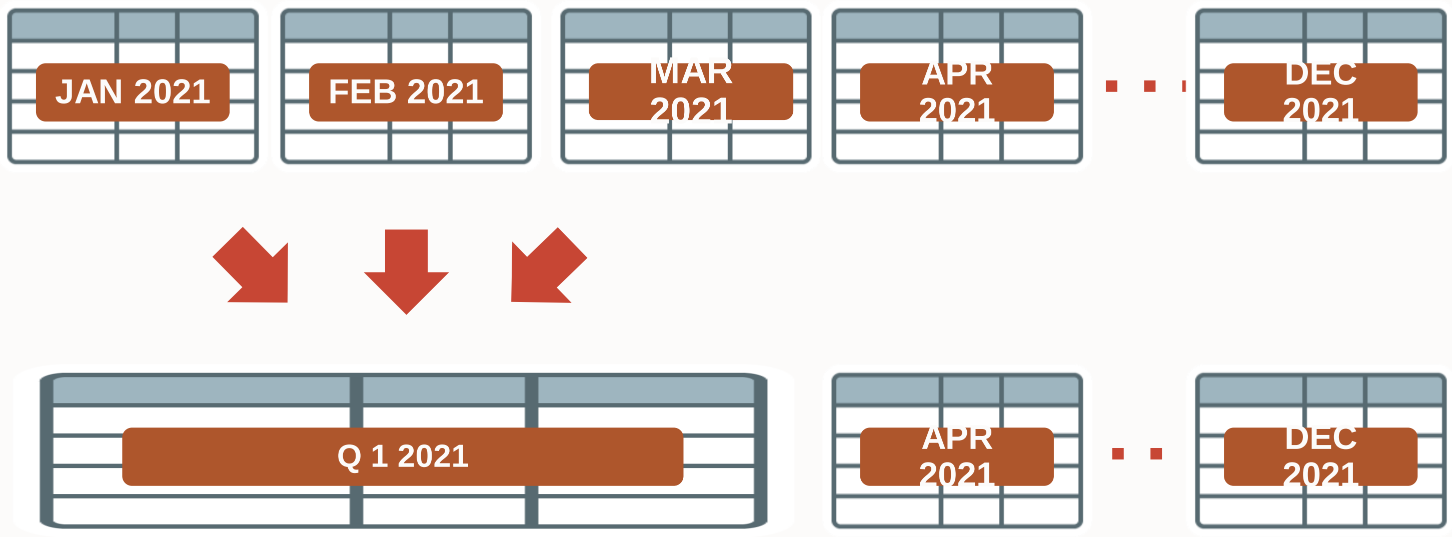
Enhanced Partition Maintenance Operations

Operate on multiple partitions

Partition Maintenance on multiple partitions in a single operation

Full parallelism

Transparent maintenance of local and global indexes




```
ALTER TABLE  events
MERGE PARTITIONS Jan2021, Feb2021, Mar2021
INTO PARTITION Q1_2021 COMPRESS FOR ARCHIVE HIGH;
```


Enhanced Partition Maintenance Operations

Operate on multiple partitions

Specify multiple partitions in order

```
SQL > alter table pt merge partitions part05, part15, part25
      into partition p30;

Table altered.
```

Specify a range of partitions

```
SQL > alter table pt merge partitions part10 to part30
       into partition part30;
Table altered.
```

```
SQL > alter table pt split partition p30 into
2  (partition p10 values less than (10),
3   partition p20 values less than (20),
4   partition p30);

Table altered.
```

Works for all PMOPS

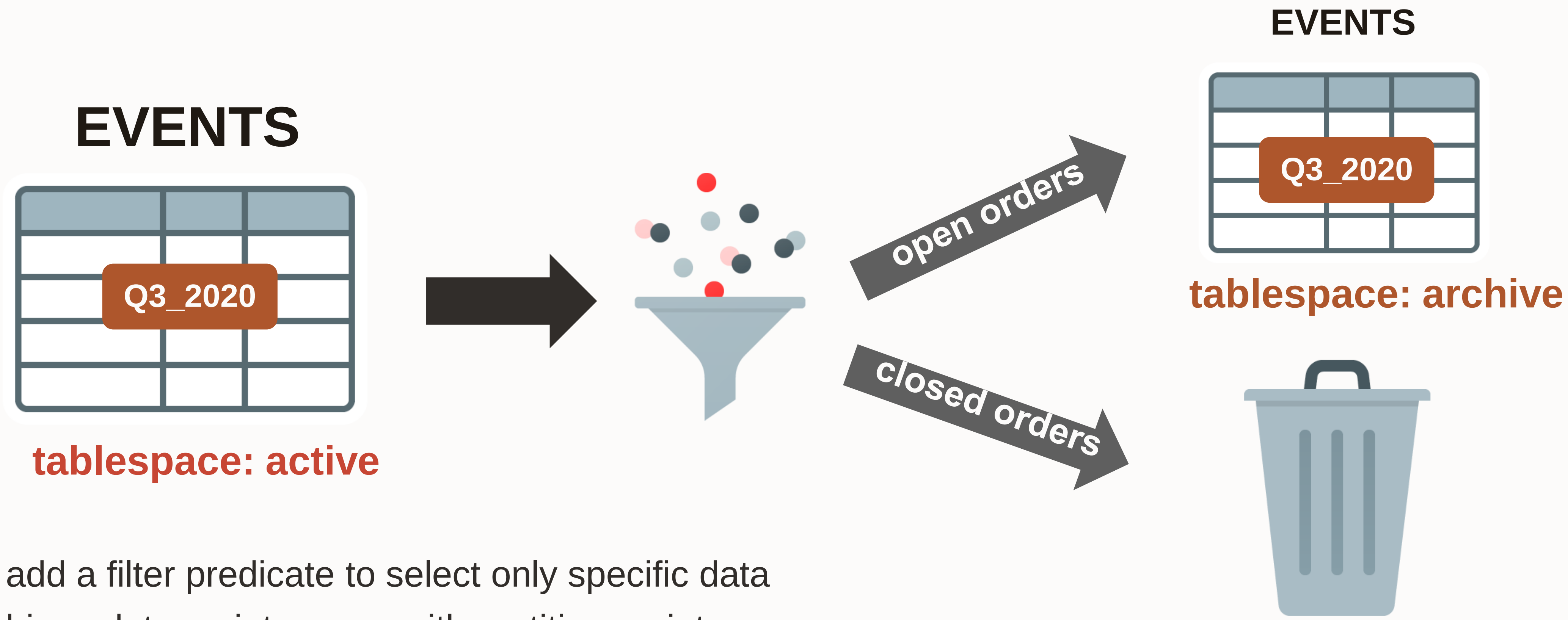
Supports optimizations like fast split

Filtered Partition Maintenance Operations

Introduced in Oracle Database 12.2

Filtered Partition Maintenance Operations

Move Partition Example



Can add a filter predicate to select only specific data

Combines data maintenance with partition maintenance

Details of Filtered Partition Maintenance Operations

Can specify a **single table filter predicate** to MOVE, SPLIT and MERGE operations

- Specification must be consistent across all partition maintenance
- Specification needs to clearly specify the data of interest

Specification will be added to the recursively generated CTAS command for the creation of the various new partition or sub-partitions segments

Filter predicates work for both offline and new online PMOP’s

Filtered Partition Maintenance Operations

Move Partition Syntax Example

```
ALTER TABLE orders MOVE PARTITION q3_2020
TABLESPACE archive
INCLUDING ROWS WHERE order_state = 'open';
```


Filtered Partition Maintenance Operations

Move Partition Syntax Example

```
ALTER TABLE orders MOVE PARTITION q3_2020
TABLESPACE archive online
INCLUDING ROWS WHERE order_state = 'open';
```

.. and what happens with online?

Filtered Partition Maintenance Operation

DML Behavior for online operations

Filter condition is NOT applied to ongoing concurrent DML

```
INCLUDING ROWS WHERE order_state = ‘open’
```


Filtered Partition Maintenance Operation

DML Behavior for online operations

Filter condition is NOT applied to ongoing concurrent DML

```
INCLUDING ROWS WHERE order_state = 'open'
```

Inserts will always go through

```
INSERT VALUES(order_state ='closed')
```


Filtered Partition Maintenance Operation

DML Behavior for online operations

Filter condition is NOT applied to ongoing concurrent DML

```
INCLUDING ROWS WHERE order_state = 'open'
```

Inserts will always go through

```
INSERT VALUES(order_state ='closed')
```

Deletes on included data will always go through

```
DELETE WHERE order_state = 'open'
```

Deletes on deleted data are void

```
DELETE WHERE order_state = 'closed'
```


Filtered Partition Maintenance Operation

DML Behavior for online operations

Filter condition is NOT applied to ongoing concurrent DML

```
INCLUDING ROWS WHERE order_state = 'open'
```

Inserts will always go through

```
INSERT VALUES(order_state ='closed')
```

Deletes on included data will always go through

```
DELETE WHERE order_state = 'open'
```

Deletes on deleted data are void

```
DELETE WHERE order_state = 'closed'
```

Updates on included data always goes through

```
UPDATE set order_status = 'closed'
WHERE order_state = 'open'
```

Updates on excluded data are void

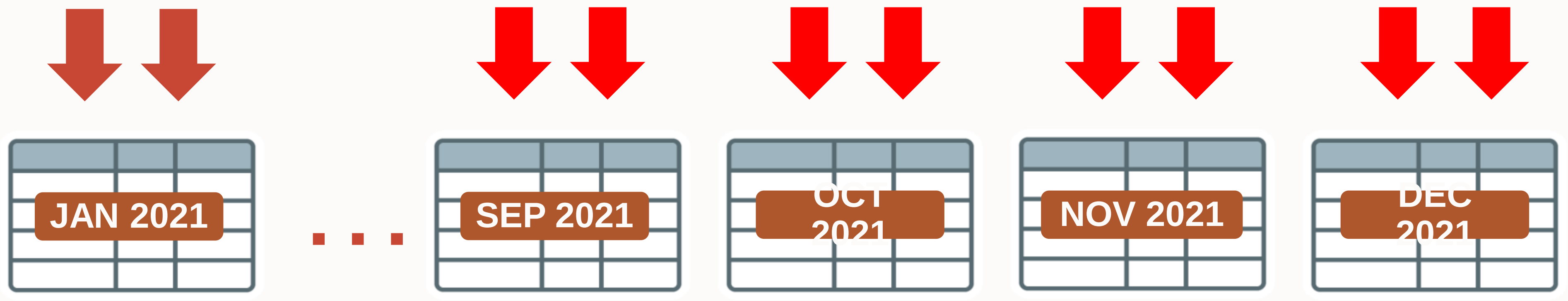
```
UPDATE set order_status = 'open'
WHERE order_state = 'closed'
```


Online Move Partition

Introduced in Oracle 12c Release 1 (12.1)

Enhanced Partition Maintenance Operations

Online Partition Move



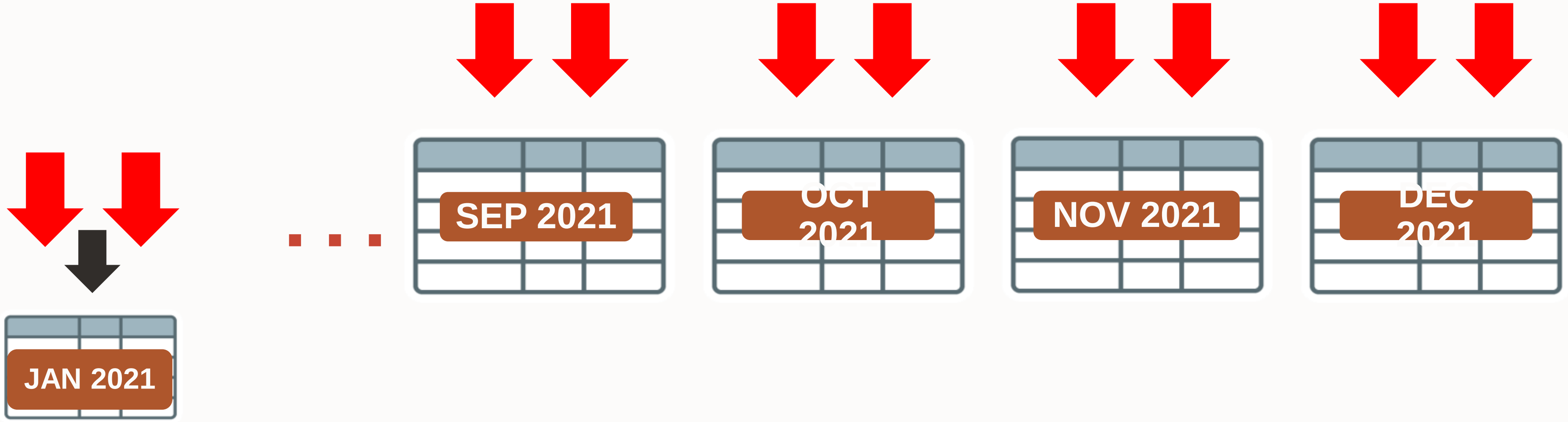
Transparent MOVE PARTITION ONLINE operation

Concurrent DML and Query

Index maintenance for local and global indexes

Enhanced Partition Maintenance Operations

Online Partition Move



Transparent MOVE PARTITION ONLINE operation

Concurrent DML and Query

Index maintenance for local and global indexes

Enhanced Partition Maintenance Operations

Online Partition Move – Best Practices

Minimize concurrent DML operations if possible

- Require additional disk space and resources for journaling
- Journal will be applied recursively after initial bulk move
- The larger the journal, the longer the runtime

Concurrent DML has impact on compression efficiency

- Best compression ratio with initial bulk move

Asynchronous Global Index Maintenance

Introduced in Oracle 12c Release 1 (12.1)

Asynchronous global index maintenance

Usable global indexes after DROP and TRUNCATE PARTITION without the need of index maintenance

- Affected partitions are known internally and filtered out at data access time

DROP and TRUNCATE become fast, metadata-only operations

- Significant speedup and reduced initial resource consumption

Delayed Global index maintenance

- Deferred maintenance through ALTER INDEX REBUILD|COALESCE
- Automatic cleanup using a scheduled job

Asynchronous global index maintenance

Before

```
SQL> select count(*) from pt partition for (9999);

  COUNT(*)
----------
  25341440

Elapsed: 00:00:01.00
SQL> select index_name, status, orphaned_entries from user_indexes;

INDEX_NAME                     STATUS   ORPHANED_ENTRIES
------------------------------ -------- --------------------
I1_PT                          VALID    NO

Elapsed: 00:00:01.04
SQL>
SQL> alter table pt drop partition for (9999) update indexes;

Table altered.

Elapsed: 00:02:04.52
SQL>
SQL> select index_name, status, orphaned_entries from user_indexes;

INDEX_NAME                     STATUS   ORPHANED_ENTRIES
------------------------------ -------- --------------------
I1_PT                          VALID    NO

Elapsed: 00:00:00.10
```

After

```
SQL> select count(*) from pt partition for (9999);

  COUNT(*)
----------
  25341440

Elapsed: 00:00:00.98
SQL> select index_name, status, orphaned_entries from user_indexes;

INDEX_NAME                     STATUS   ORPHANED_ENTRIES
------------------------------ -------- --------------------
I1_PT                          VALID    NO

Elapsed: 00:00:00.33
SQL>
SQL> alter table pt drop partition for (9999) update indexes;

Table altered.

Elapsed: 00:00:00.04
SQL>
SQL> select index_name, status, orphaned_entries from user_indexes;

INDEX_NAME                     STATUS   ORPHANED_ENTRIES
------------------------------ -------- --------------------
I1_PT                          VALID    YES

Elapsed: 00:00:00.05
```

Asynchronous Global Index Maintenance

Initial implementation of maintenance package

- Always use INDEX COALESCE CLEANUP
- Rely on parallelism of index

Enhancements added to latest release

- Choice of INDEX COALESCE CLEANUP or “classical” index cleanup
- Choice of parallelism for maintenance operation

Classical cleanup recommended for more frequent index cleanup

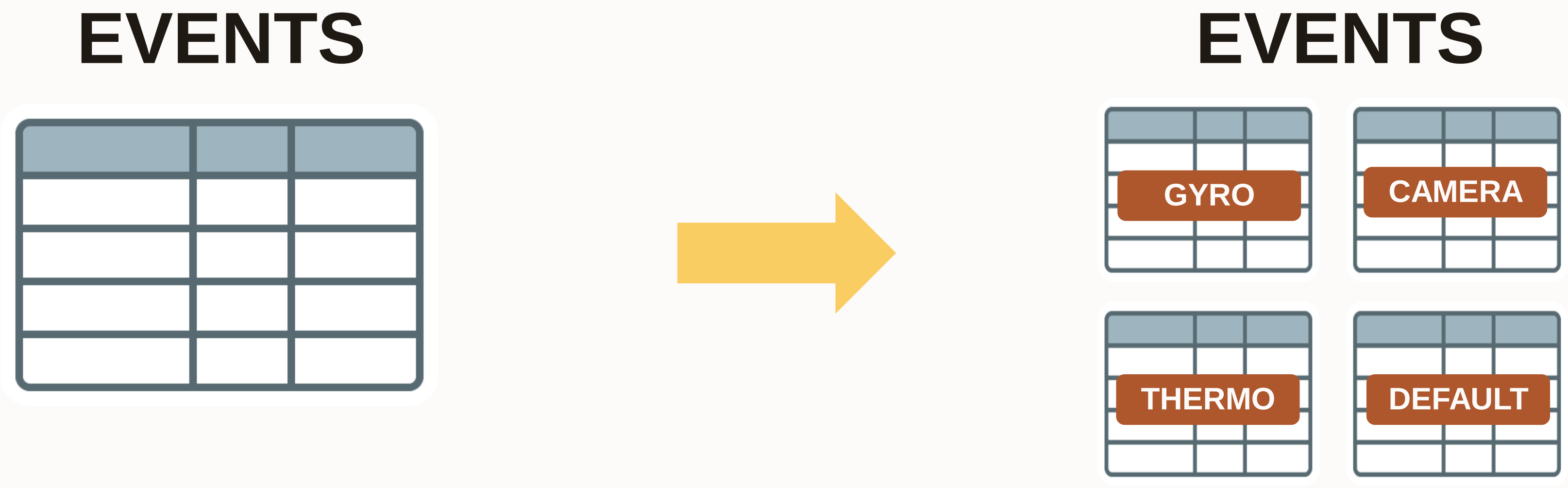
- Seems to be the more common customer use case, thus the new default

Functionality available for 12.1 through bug 24515918

Online Table Conversion to Partitioned Table

Introduced in Oracle Database 12.2/18.1 (partition-to-partition)

Online Table Conversion



Completely non-blocking (online) DDL

Online Table Conversion

Syntax Example

```
CREATE TABLE EVENTS ( sensor_grp  VARCHAR2 (50),
                      channel     VARCHAR2 (50), … );

ALTER TABLE EVENTS MODIFY
PARTITION BY LIST ( sensor_grp )
  (partition p1 values ('GYRO_GRP'),
   partition p2 values ('CAMERA_GRP'),
   partition p3 values ('THERMO_GRP'),
   partition p4 values (DEFAULT))
UPDATE INDEXES ONLINE;
```

Online Table Conversion
Indexing

Indexes are converted and kept online throughout the conversion process

Full flexibility for indexes, following today’s rules

Default indexing rules to provide minimal to no access change behavior

- Global partitioned indexes will retain the original partitioning shape.
- Non-prefixed indexes will become global non-partitioned indexes.
- Prefixed indexes will be converted to local partitioned indexes.
- Bitmap indexes will become local partitioned indexes

Online table conversion of partitioned tables

Not everybody thinks big and starts small …

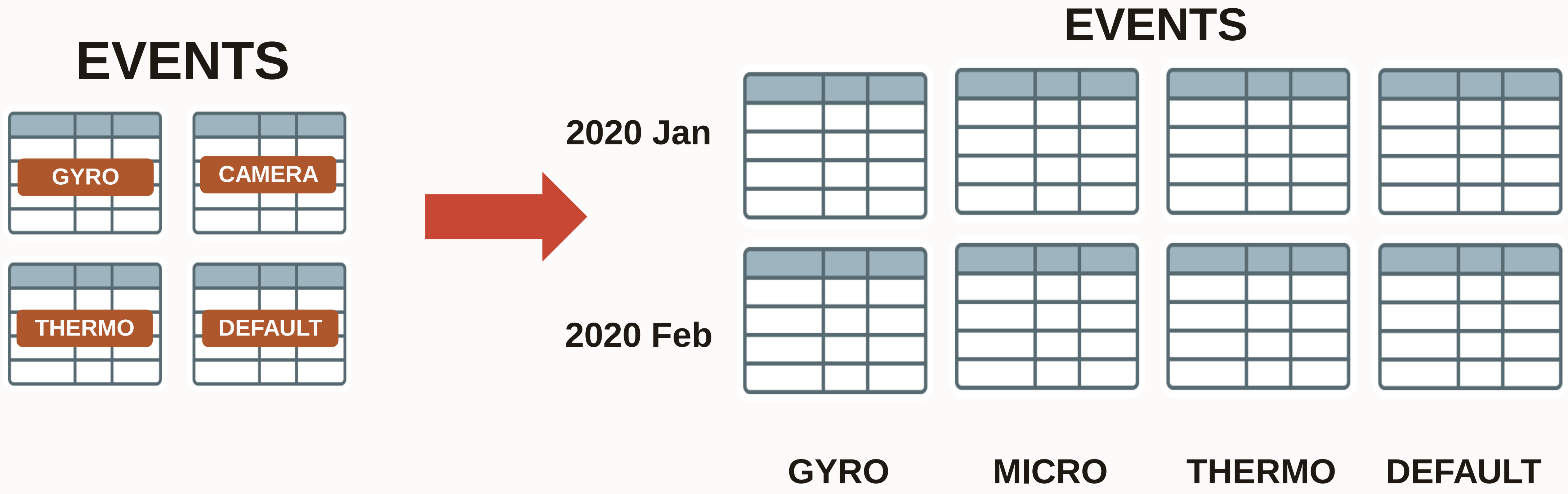
- … so tables can start off small as non-partitioned ones
- … and they grow and grow
- … and they are used in a different way than expected
- … and their maintenance becomes a problem
- … and performance can get impacted

How to convert such tables without downtime?

Now I have partitioning …

- … but I chose the “wrong” type/granularity (for whatever reason)

Online table conversion of partitioned tables



Completely non-blocking (online) DDL for table and indexes

Online table conversion of partitioned tables

Indexes are converted and kept online throughout the conversion

Default indexing rules to provide minimal to no access change behavior

- Almost identical than rules for conversion of non-partitioned table
- Differences:
  - Local indexes stay local if any of the partition keys of the two dimensions is included
  - Global prefixed partitioned indexes will be converted to local partitioned indexes

Full flexibility for indexes, following today's rules

- Override whatever you want to see being changed

Online table conversion of partitioned tables

```
CREATE TABLE EVENTS ( run_id      NUMBER,
                      sensor_type VARCHAR2 (50), … )
PARTITION BY LIST ( … )

ALTER TABLE EVENTS MODIFY
PARTITION BY RANGE    ( run_id      )
SUBPARTITION BY LIST ( sensor_type )…
UPDATE INDEXES
  (i1_run_id GLOBAL,
   i2_sensor LOCAL,
   i3 GLOBAL PARTITION BY RANGE ( … )
      (PARTITION p0100 VALUES LESS THAN   (100000),
       PARTITION p1500 VALUES LESS THAN  (1500000),
       PARTITION pmax  VALUES LESS THAN (MAXVALUE)))
ONLINE;
```


Create Table for Exchange

Introduced in Oracle Database 12.2

Create Table for Exchange

Simple DDL command

Ensures both the semantic and internal table shape are identical so partition exchange command will always succeed

Operates like a special CREATE TABLE AS SELECT operation

Always creates an empty table

Create Table for Exchange

Syntax Example

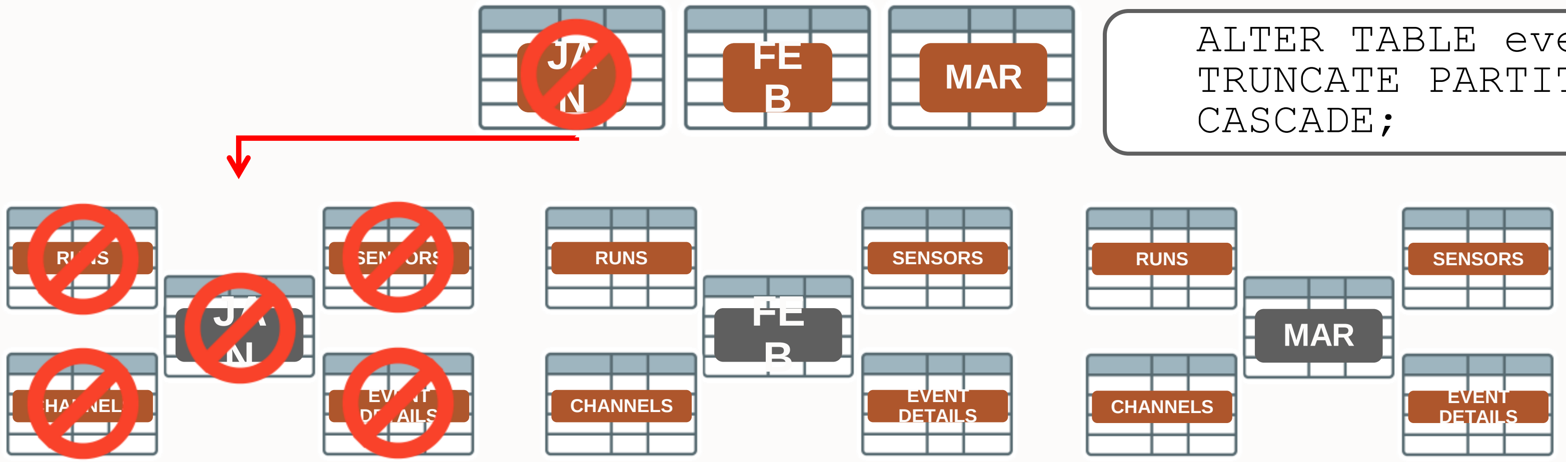
```
CREATE TABLE events_cp TABLESPACE ts_boson
FOR EXCHANGE WITH events;
```


Cascading Truncate and Exchange for Reference Partitioning

Introduced in Oracle 12c Release 1 (12.1)

Advanced Partitioning Maintenance

Cascading TRUNCATE and EXCHANGE PARTITION



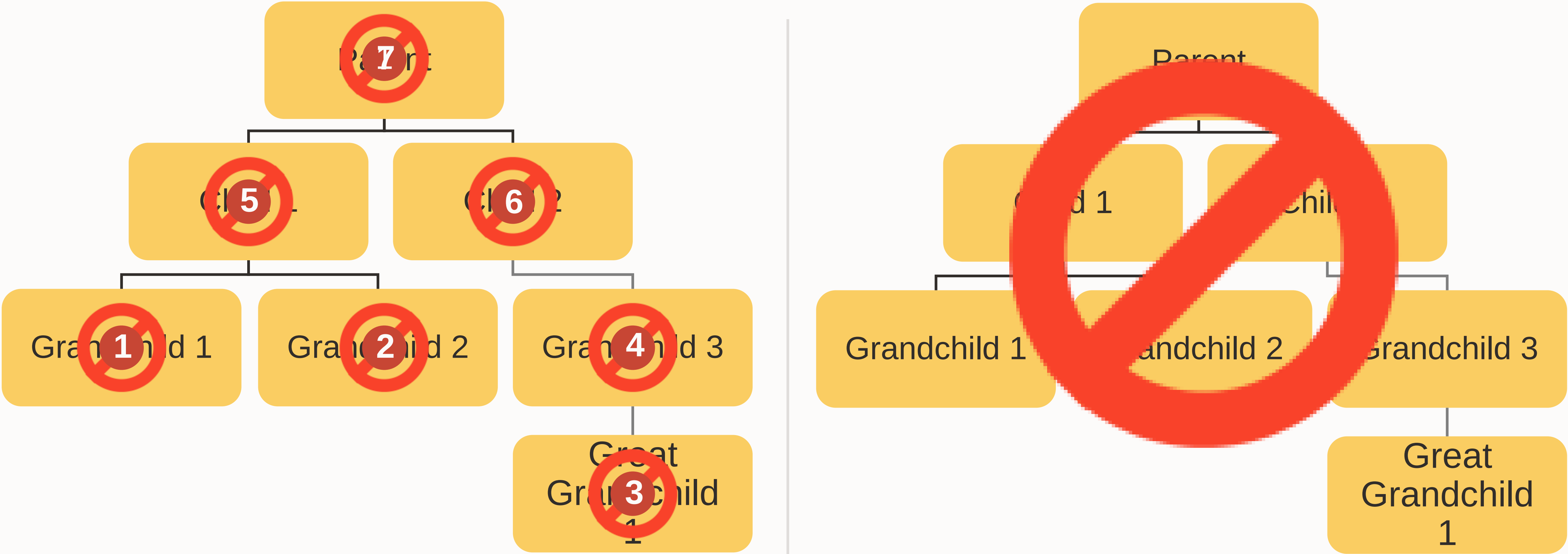

```
ALTER TABLE events
TRUNCATE PARTITION Jan2020
CASCADE;
```

Cascading TRUNCATE and EXCHANGE for improved business continuity

Single atomic transaction preserves data integrity

Simplified and less error prone code development

Cascading TRUNCATE PARTITION



Proper bottom-up processing required

Seven individual truncate operations

One truncate operation

Cascading TRUNCATE PARTITION

```
SQL> create table intRef_p (pkcol number not null, col2 varchar2(200),
  2                         constraint pk_intref primary key (pkcol))
  3  partition by range (pkcol) interval (10)
  4  (partition p1 values less than (10));

Table created.

SQL>
SQL> create table intRef_c1 (pkcol number not null, col2 varchar2(200), fkcol number not null,
  2                          constraint pk_c1 primary key (pkcol),
  3                          constraint fk_c1 foreign key (fkcol) references intRef_p(pkcol) ON DELETE CASCADE)
  4  partition by reference (fk_c1);

Table created.
```


Cascading TRUNCATE PARTITION

```
SQL> create table intRef_p (pkcol nu
  2                         constrai
  3  partition by range (pkcol) inte
  4  (partition p1 values less than

Table created.

SQL>
SQL> create table intRef_c1 (pkcol n
  2                           constra
  3                           constra
  4  partition by reference (fk_c1);

Table created.
```

```
SQL> select * from intRef_p;

     PKCOL COL2
---------- ------------------------------
       333 data for truncate - p
       999 data for truncate - p

SQL> select * from intRef_c1;

     PKCOL COL2                                FKCOL
---------- ------------------------------ ----------
      1333 data for truncate - c1                333
      1999 data for truncate - c1                999

SQL> alter table intRef_p truncate partition for (999) cascade update indexes;

Table truncated.

SQL> select * from intRef_p;

     PKCOL COL2
---------- ------------------------------
       333 data for truncate - p

SQL> select * from intRef_c1;

     PKCOL COL2                                FKCOL
---------- ------------------------------ ----------
      1333 data for truncate - c1                333
```


Cascading TRUNCATE PARTITION

CASCADE applies for whole reference tree

- Single atomic transaction, all or nothing
- Bushy, deep, does not matter
- Can be specified on any level of a reference-partitioned table
- ON DELETE CASCADE for all foreign keys required

Cascading TRUNCATE available for non-partitioned tables as well

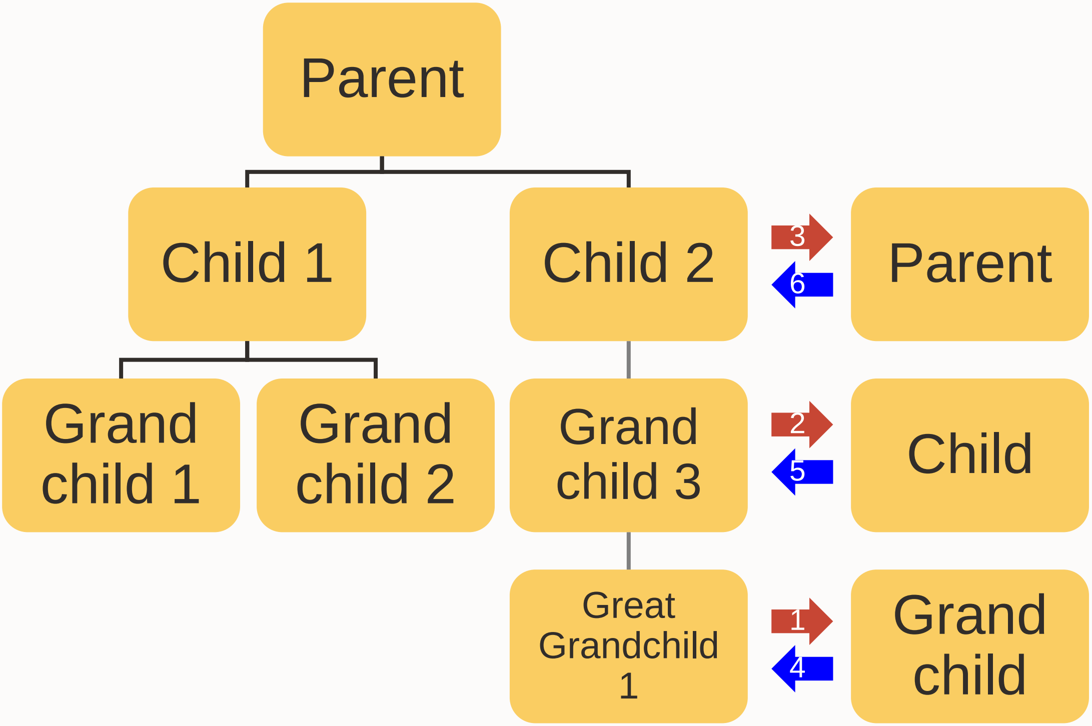
- Dependency tree for non-partitioned tables can be interrupted with disabled foreign key constraints

Reference-partitioned hierarchy must match for target and table to-be-exchanged

For bushy trees with multiple children on the same level, each child on a given level must reference to a different key in the parent table

- Required to unambiguously pair tables in the hierarchy tree

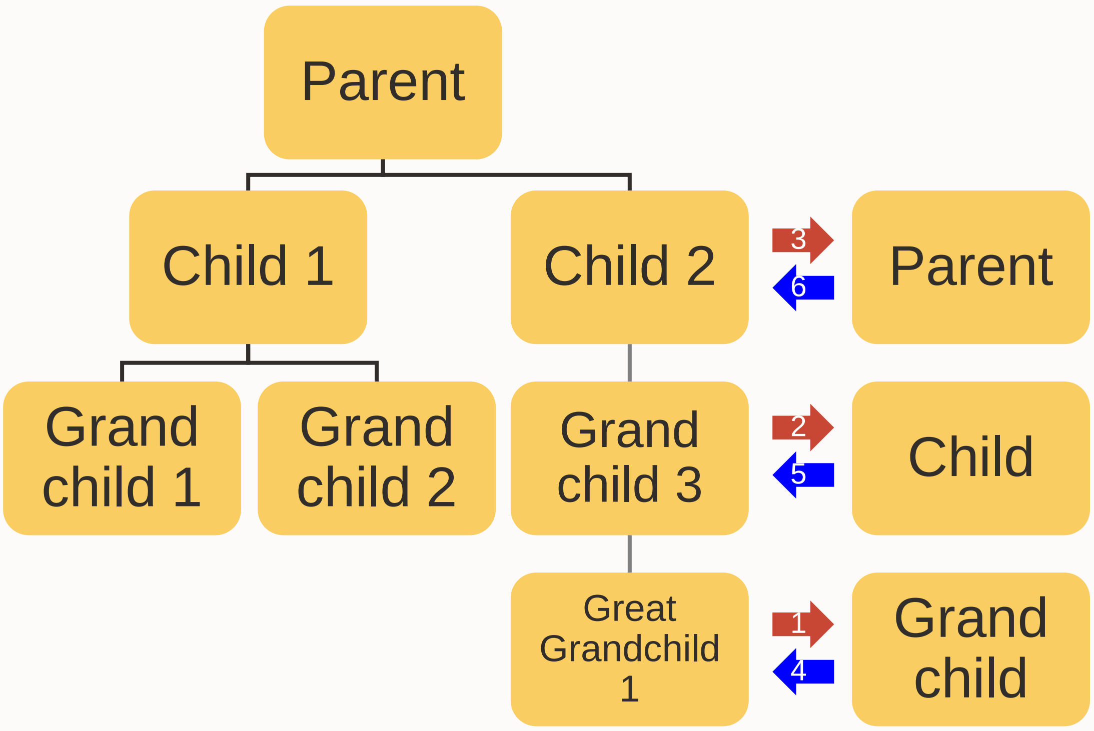
Cascading EXCHANGE PARTITION



Exchange (clear) out of target bottom-up

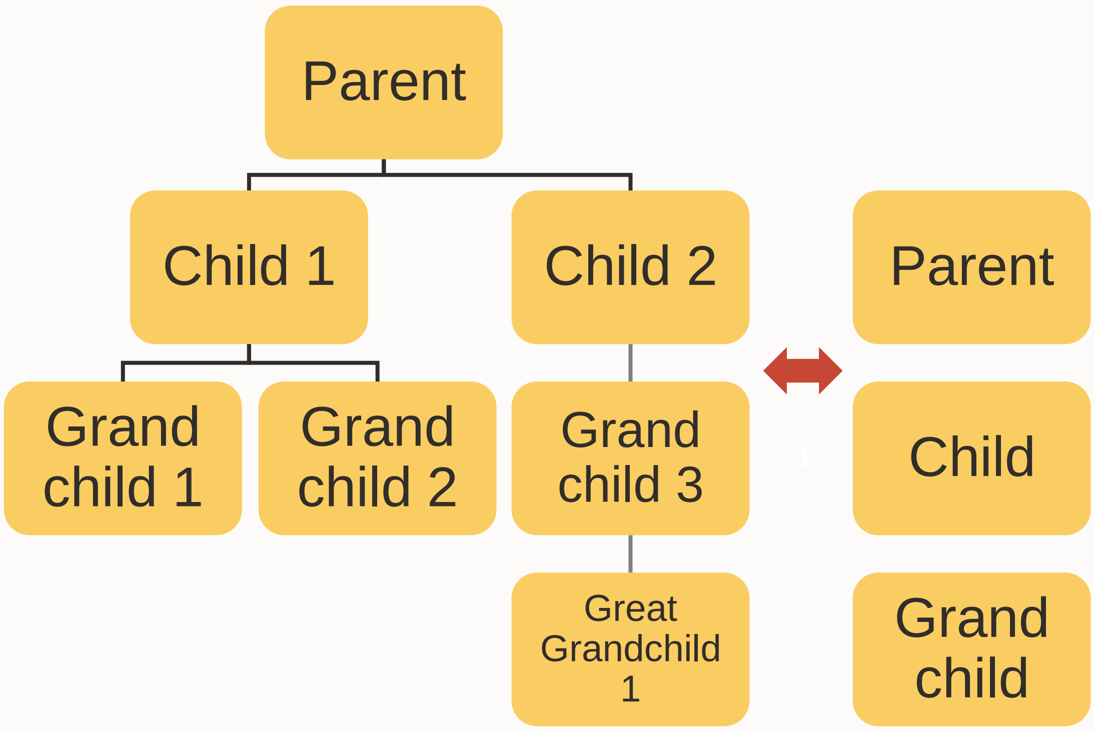
Exchange (populate) into target top-down

Cascading EXCHANGE PARTITION



Exchange (clear) out of target bottom-up

Exchange (populate) into target top-down



Exchange complete hierarchy tree

One exchange operation

Cascading EXCHANGE PARTITION

```
SQL> create table intRef_p (pkcol number not null, col2 varchar2(200),
  2                        constraint pk_intref primary key (pkcol))
  3  partition by range (pkcol) interval (10)
  4  (partition p1 values less than (10));

SQL> create table intRef_c1 (pkcol number not null, col2 varchar2(200), fkcol number not null,
  2                         constraint pk_c1 primary key (pkcol),
  3                         constraint fk_c1 foreign key (fkcol) references intRef_p(pkcol) ON DELETE CASCADE)
  4  partition by reference (fk_c1);

SQL> create table intRef_gc1 (col1 number not null, col2 varchar2(200), fkcol number not null,
  2                          constraint fk_gc1 foreign key (fkcol) references intRef_c1(pkcol) ON DELETE CASCADE)
  3  partition by reference (fk_gc1);
```


Cascading EXCHANGE PARTITION

```
SQL> REM create some PK-FK equivalent table construct for exchange
SQL> create table XintRef_p (pkcol number not null, col2 varchar2(200),
  2                         constraint xpk_intref primary key (pkcol));

SQL> create table XintRef_c1 (pkcol number not null, col2 varchar2(200), fkcol number not null,
  2                          constraint xpk_c1 primary key (pkcol),
  3                          constraint xfk_c1 foreign key (fkcol) references XintRef_p(pkcol) ON DELETE CASCADE);

SQL> create table XintRef_gc1 (col1 number not null, col2 varchar2(200), fkcol number not null,
  2                           constraint xfk_gc1 foreign key (fkcol) references XintRef_c1(pkcol) ON DELETE CASCADE);
```


Cascading EXCHANGE PARTITION

```
SQL> select * from intRef_p;

     PKCOL COL2
---------- -----------------------------------
       333  p333 - data BEFORE exchange - p
       999  p999 - data BEFORE exchange - p

SQL> select * from intRef_c1;

     PKCOL COL2                                     FKCOL
---------- ----------------------------------- ----------
      1333  p333 - data BEFORE exchange - c1          333
      1999  p999 - data BEFORE exchange - c1          999

SQL> select * from intRef_gc1;

      COL1 COL2                                     FKCOL
---------- ----------------------------------- ----------
      1333  p333 - data BEFORE exchange - gc1        1333
      1999  p999 - data BEFORE exchange - gc1        1999
```

```
SQL> select * from XintRef_p;

     PKCOL COL2
---------- -----------------------------------
       333  p333 - data AFTER exchange - p

SQL> select * from XintRef_c1;

     PKCOL COL2                                     FKCOL
---------- ----------------------------------- ----------
      1333  p333 - data AFTER exchange - c1           333

SQL> select * from XintRef_gc1;

      COL1 COL2                                     FKCOL
---------- ----------------------------------- ----------
      1333  p333 - data AFTER exchange - gc1         1333
```


Cascading EXCHANGE PARTITION

```
SQL> alter table intRef_p exchange partition for (333) with table XintRef_p cascade update indexes;

Table altered.
```


Cascading EXCHANGE PARTITION

```
SQL> select * from intRef_p;

     PKCOL COL2
---------- ------------------------------------
       333 p333 - data AFTER exchange - p
       999 p999 - data BEFORE exchange - p

SQL> select * from intRef_c1;

     PKCOL COL2                                      FKCOL
---------- ------------------------------------ ----------
      1333 p333 - data AFTER exchange - c1             333
      1999 p999 - data BEFORE exchange - c1            999

SQL> select * from intRef_gc1;

      COL1 COL2                                      FKCOL
---------- ------------------------------------ ----------
      1333 p333 - data AFTER exchange - gc1           1333
      1999 p999 - data BEFORE exchange - gc1          1999
```

```
SQL> select * from XintRef_p;

     PKCOL COL2
---------- ------------------------------------
       333 p333 - data BEFORE exchange - p

SQL> select * from XintRef_c1;

     PKCOL COL2                                      FKCOL
---------- ------------------------------------ ----------
      1333 p333 - data BEFORE exchange - c1            333

SQL> select * from XintRef_gc1;

      COL1 COL2                                      FKCOL
---------- ------------------------------------ ----------
      1333 p333 - data BEFORE exchange - gc1          1333
```

Partitioning – Random Tidbits

Difference Between Range and Interval

Interval Partitioning

Full automation for equi-sized range partitions

Partitions are created as metadata information only

- Start Partition is made persistent

Segments are allocated as soon as new data arrives

- No need to create new partitions
- Local indexes are created and maintained as well

Interval Partitioning is almost a transparent extension to range partitioning

- .. But interval implementation introduces some subtle differences

Interval versus Range Partitioning

Partition bounds

- Interval partitions have lower and upper bound
  - No infinite upper bound (MAXVALUES)
- Range partitions only have upper bounds
  - Lower bound derived by previous partition
  - Upper bound infinite (MAXVALUES)

Partition naming

- Interval partitions cannot be named in advance
  - Use the PARTITION FOR (<value>) clause
- Range partitions must be named

Interval versus Range Partitioning, cont.

Partition merge

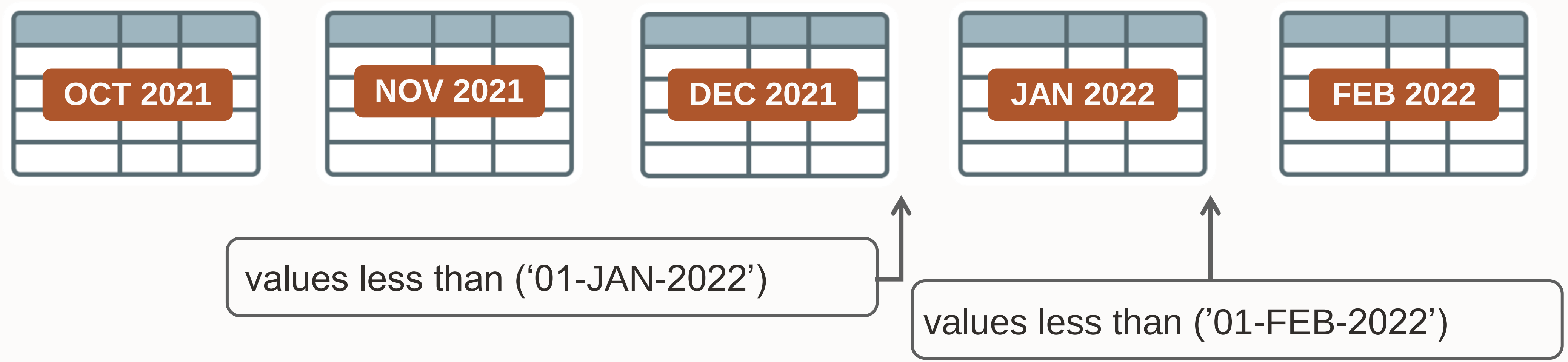
- Multiple non-existent interval partitions are silently merged
- Only two adjacent range partitions can be merged at any point in time

Number of partitions

- Interval partitioned tables have always one million partitions
  - Non-existent partitions “exist” through INTERVAL clause
  - No MAXVALUE clause for interval partitioning
    - Maximum value defined through number of partitions and INTERVAL clause
- Range partitioning can have up to one million partitions
  - MAXVALUE clause defines most upper partition

Interval versus Range Partitioning

Partition Bounds for Range Partitioning

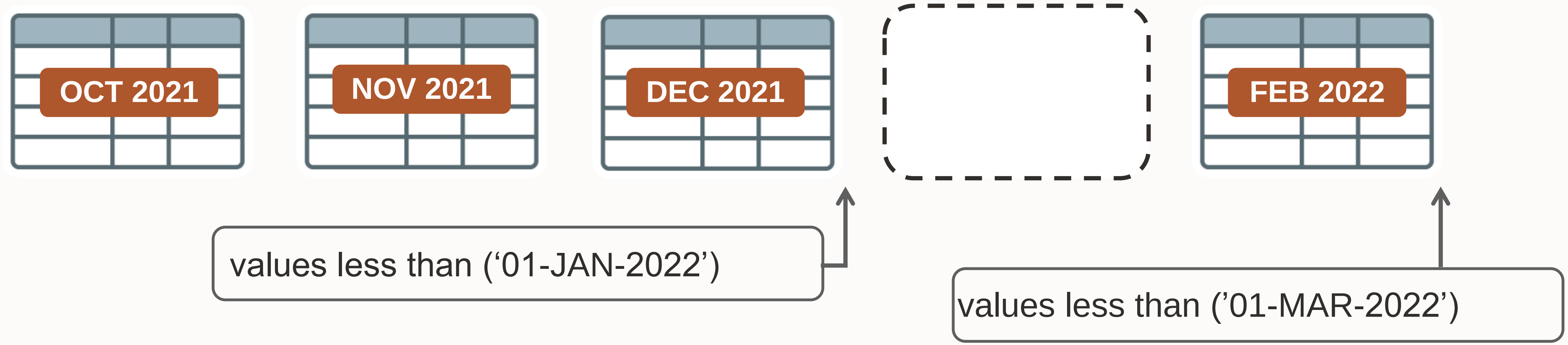


Partitions only have upper bounds

- Lower bound derived through upper bound of previous partition

Interval versus Range Partitioning

Partition Bounds for Range Partitioning

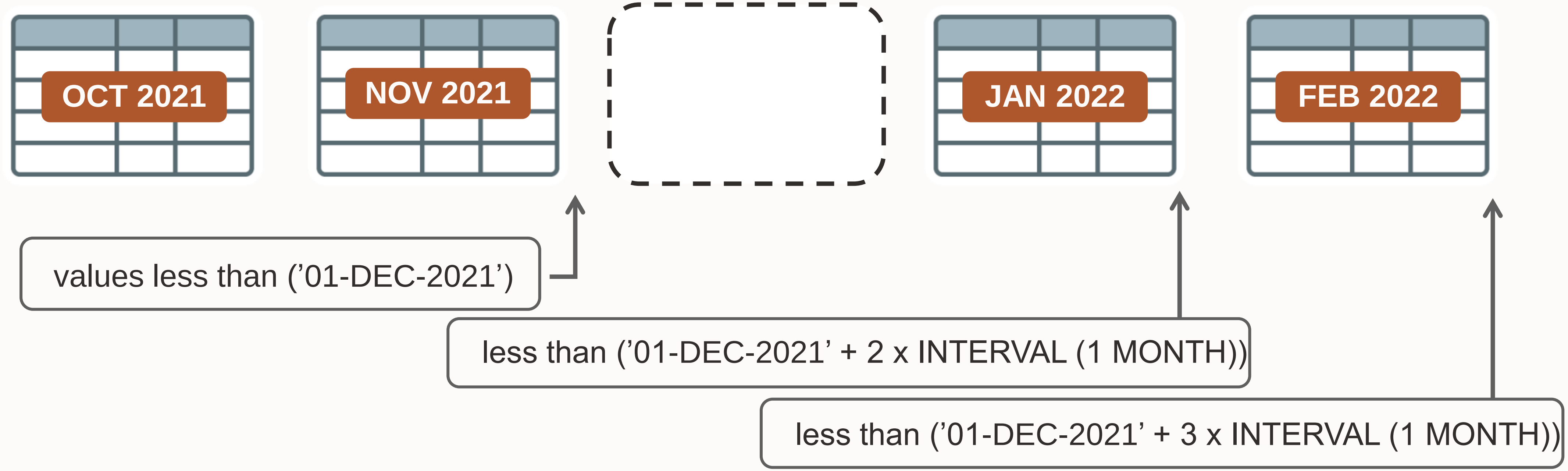


Drop of previous partition moves lower boundary

- “Feb 2022” now spawns 01-JAN-2022 to 28-FEB-2022

Interval versus Range Partitioning

Partition Bounds for Interval Partitioning

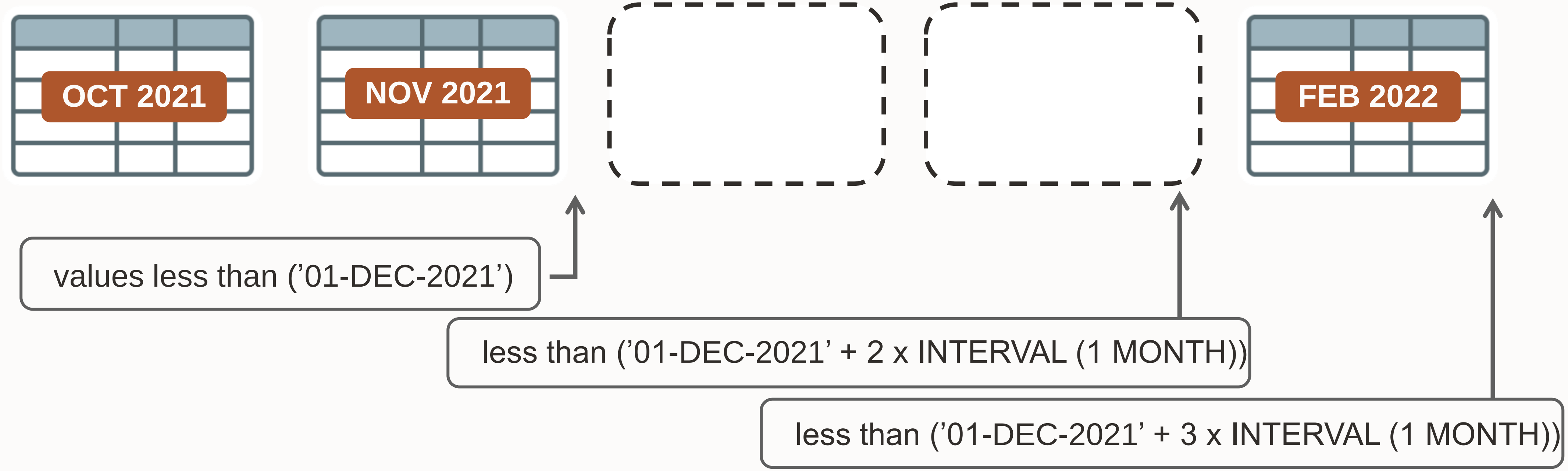


Partitions have upper and lower bounds

- Derived by INTERVAL function and last range partition

Interval versus Range Partitioning

Partition Bounds for Interval Partitioning



Drop does not impact partition boundaries

- "Feb 2022" still spawns 01-FEB-2022 to 28-FEB-2022

Interval versus Range Partitioning
Partition Naming

Range partitions **can** be named

- System generated name if not specified

```
SQL> alter table t add partition values less than(20);
Table altered.
SQL> alter table t add partition P30 values less than(30);
Table altered.
```

Interval partitions **cannot** be named

- Always system generated name

```
SQL> alter table t add partition values less than(20);
                 *
ERROR at line 1: ORA-14760: ADD PARTITION is not permitted
on Interval partitioned objects
```

Use new deterministic PARTITION FOR () extension

```
SQL> alter table t1 rename partition for (9) to p_10;
Table altered.
```

Interval versus Range Partitioning

Partition Merge – Range Partitioning

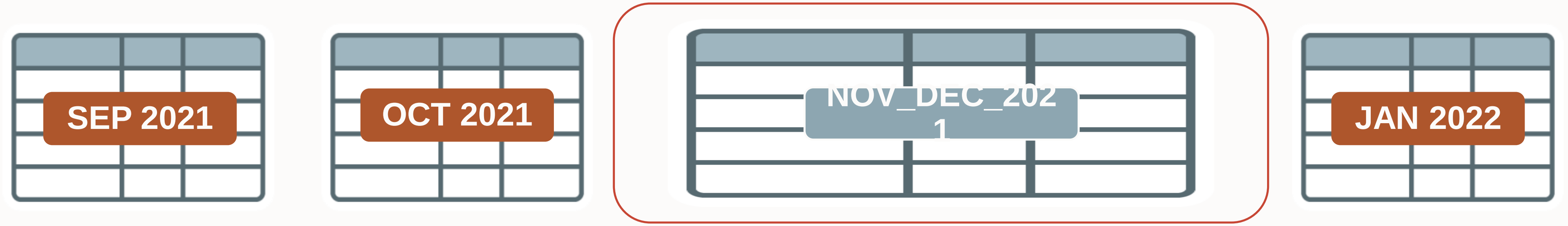

```
MERGE PARTITIONS NOV_2021, DEC_2021 INTO PARTITION NOV_DEC_2021
```

Merge two adjacent partitions for range partitioning

- Upper bound of higher partition is new upper bound
- Lower bound derived through upper bound of previous partition

Interval versus Range Partitioning

Partition Merge – Range Partitioning



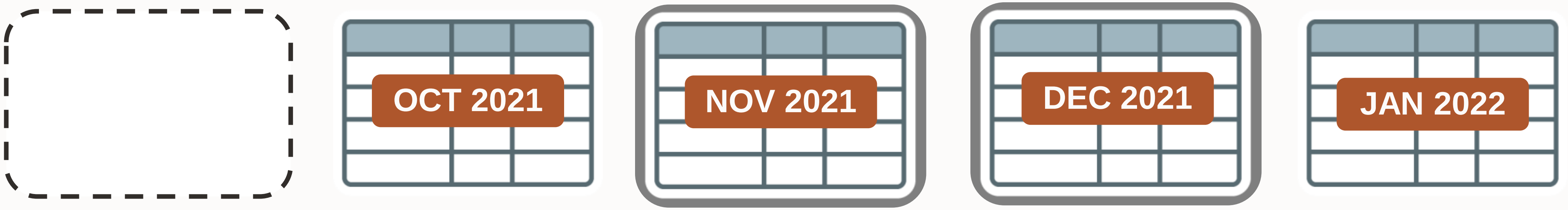

```
MERGE PARTITIONS NOV_2021, DEC_2021 INTO PARTITION NOV_DEC_2021
```

New segment for merged partition is created

- Rest of the table is unaffected

Interval versus Range Partitioning

Partition Merge – Interval Partitioning




```
MERGE PARTITIONS NOV_2021, DEC_2021 INTO PARTITION NOV_DEC_2021
```

Merge two adjacent partitions for interval partitioning

- Upper bound of higher partition is new upper bound
- Lower bound derived through lower bound of first partition

Interval Versus Range Partitioning

Partition Merge – Interval Partitioning


```
MERGE PARTITIONS NOV_2021, DEC_2021 INTO PARTITION NOV_DEC_2021
```

New segment for merged partition is created

- Holes before highest non-interval partition will be silently "merged" as well
  - Interval only valid beyond the highest non-interval partition

Multi-Column Range Partitioning

Introduced in Oracle 8i (8.1)

Multi-column Range Partitioning

Concept

Partitioning key is composed of several columns and subsequent columns define a higher granularity than the preceding one

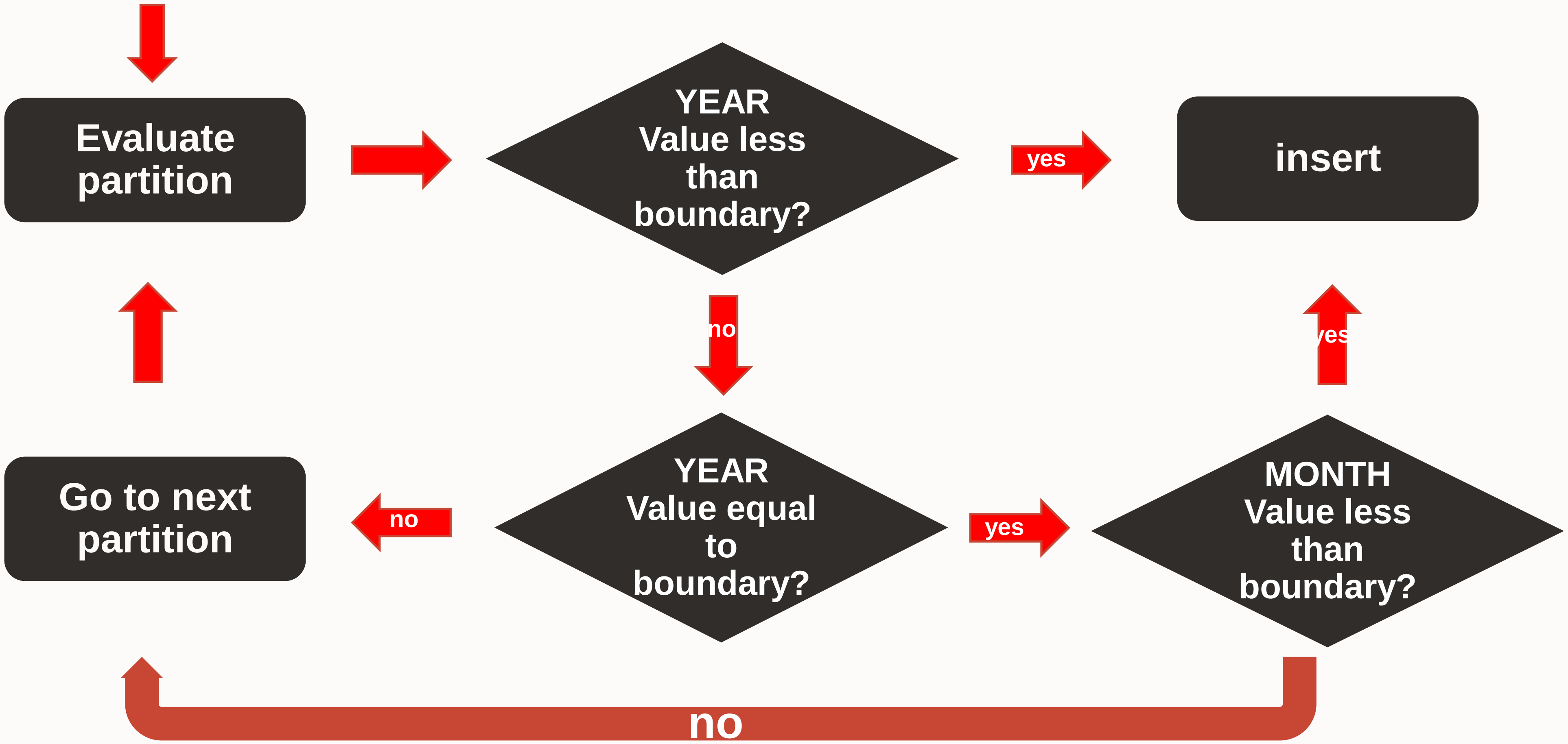
- E.g. (YEAR, MONTH, DAY)
- It is NOT an n-dimensional partitioning

Major watch-out is difference of how partition boundaries are evaluated

- For simple RANGE, the boundaries are less than (exclusive)
- Multi-column RANGE boundaries are less than or equal
  - The nth column is investigated only when all previous (n-1) values of the multicolumn key exactly match the (n-1) bounds of a partition

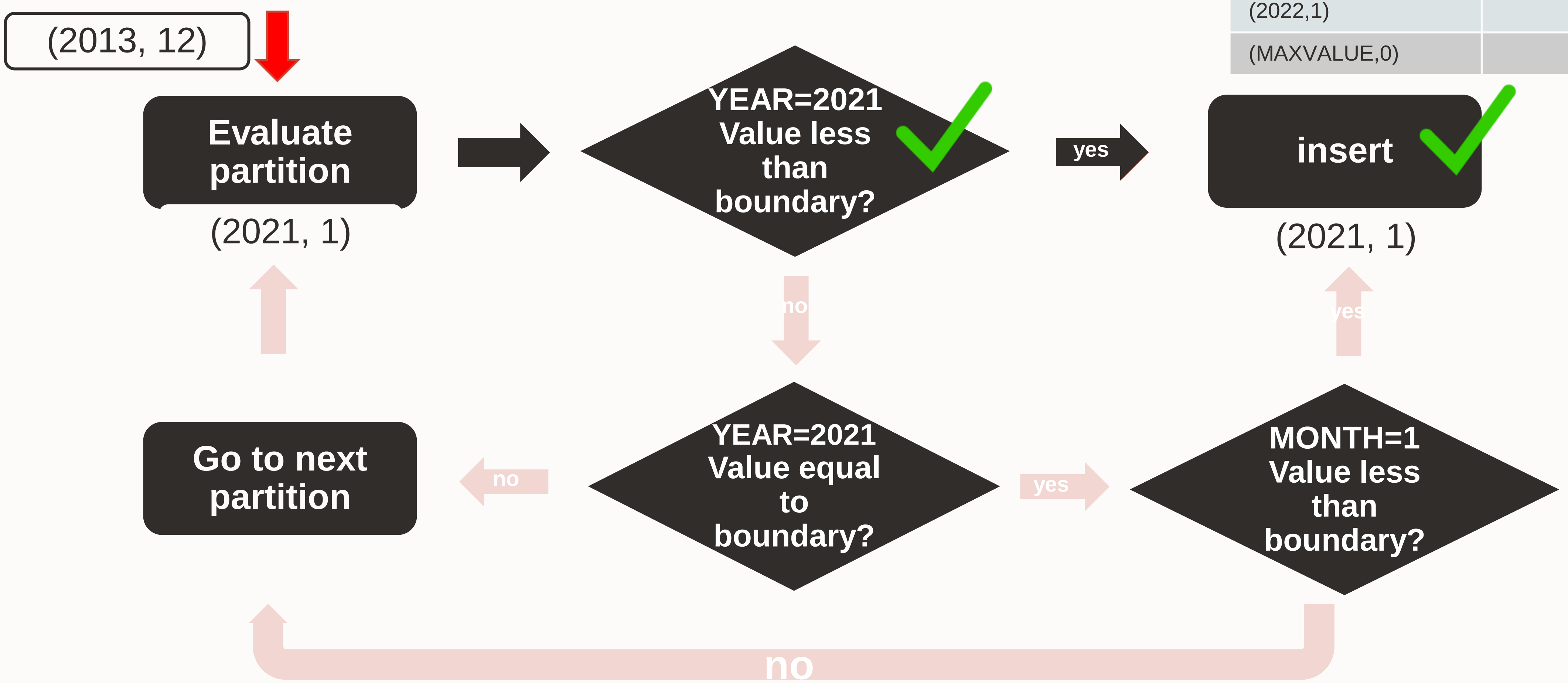
Multi-Column Range Partition

Sample Decision Tree (YEAR, MONTH)



Multi-Column Range Partition
Example

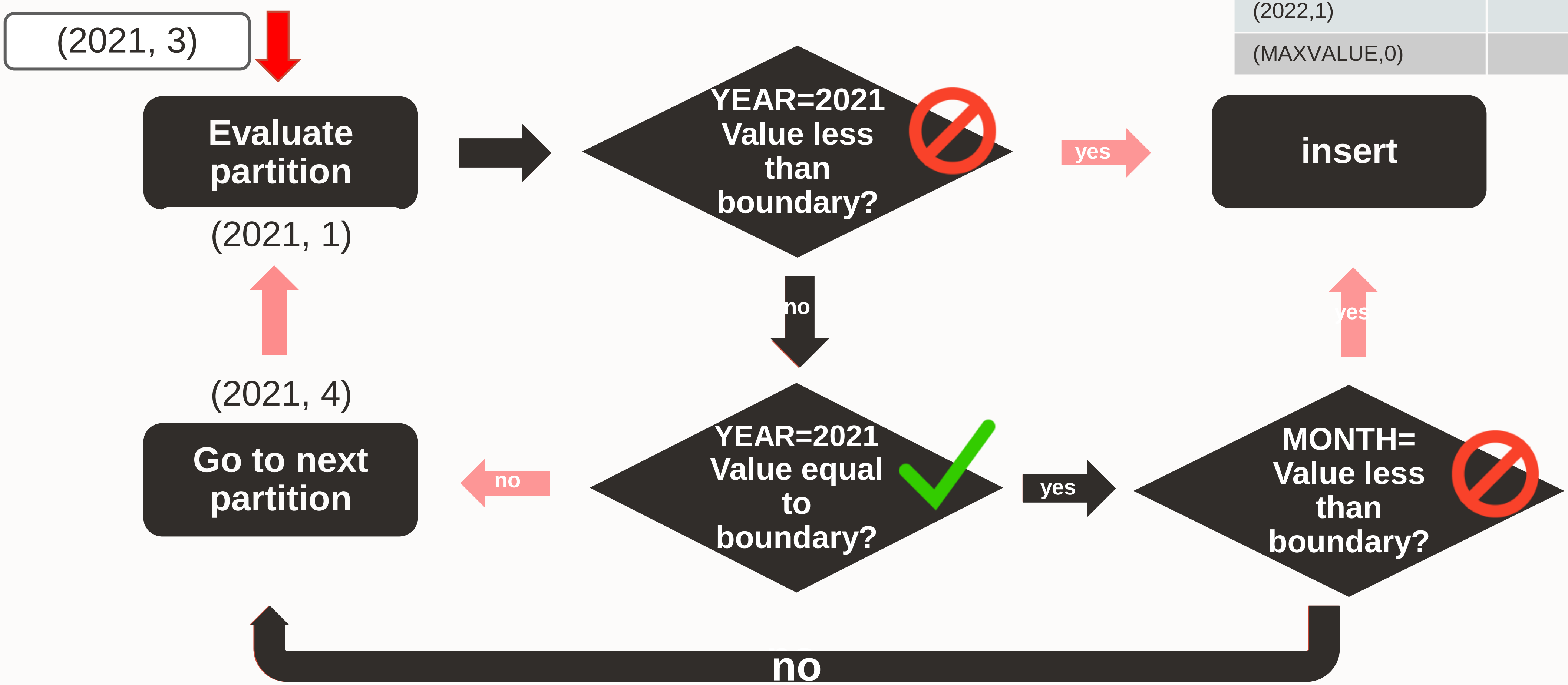
(YEAR,MONTH) Boundaries	Values
(2021,1)	(2013, 12)
(2021,4)	
(2021,7)	
(2021,10)	
(2022,1)	
(MAXVALUE,0)	



Multi-Column Range Partition

Example Cont'd

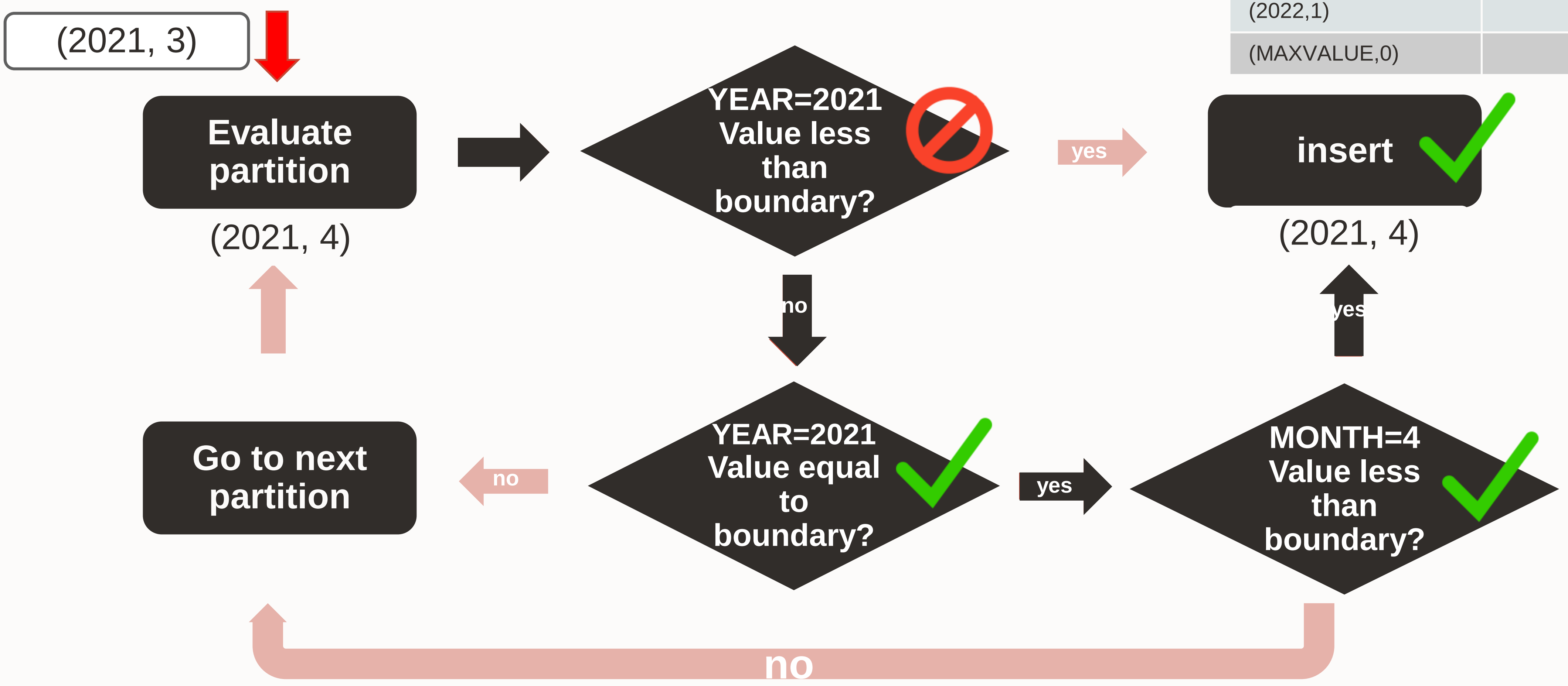
(YEAR,MONTH) Boundaries	Values
(2021,1)	(2013, 12)
(2021,4)	
(2021,7)	
(2021,10)	
(2022,1)	
(MAXVALUE,0)	



Multi-Column Range Partition

Example Cont'd

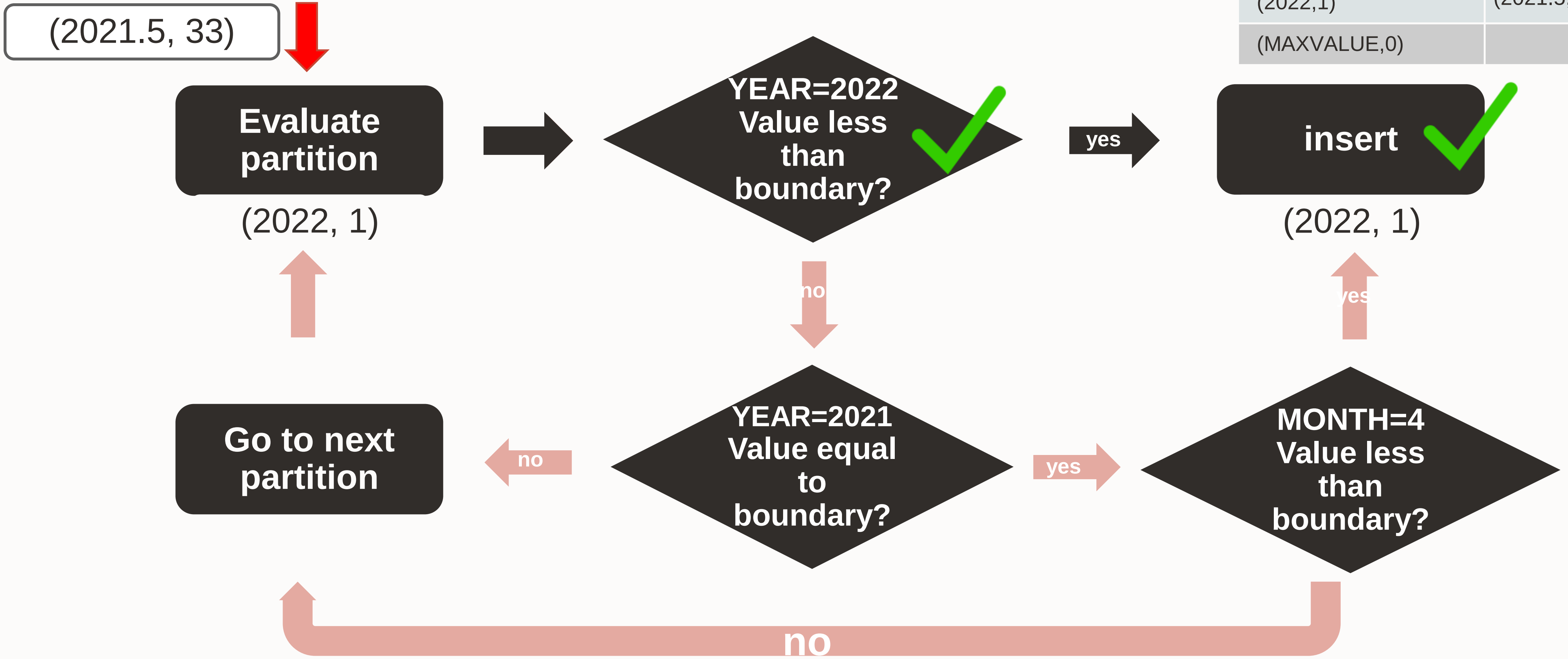
(YEAR,MONTH) Boundaries	Values
(2021,1)	(2013, 12)
(2021,4)	(2021, 3)
(2021,7)	
(2021,10)	
(2022,1)	
(MAXVALUE,0)	



Multi-Column Range Partition

Example Cont'd

(YEAR,MONTH) Boundaries	Values
(2021,1)	(2013, 12)
(2021,4)	(2021, 3)
(2021,7)	
(2021,10)	
(2022,1)	(2021.5, 33)
(MAXVALUE,0)	



Multi-Column Range Partitioning

Things to bear in mind

✓ Powerful partitioning mechanism to add a third (or more) dimensions

- Smaller data partitions

Pruning works also for trailing column predicates without filtering the leading column(s)

△ Boundaries are not enforced by the partition definition

- Ranges are consecutive

Logical ADD partition can mean SPLIT partition in the middle of the table

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
CREATE TABLE events (event_id number, site_id CHAR(2),start_date date)
PARTITION BY RANGE (site_id, start_date)
SUBPARTITION BY HASH (event_id) SUBPARTITIONS 16
(PARTITION l1_2020 VALUES LESS THAN ('L1',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION l1_2021 VALUES LESS THAN ('L1',to_date('01-JAN-2022','dd-mon-yyyy')),
 PARTITION l2_2020 VALUES LESS THAN ('L2',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION l3_2020 VALUES LESS THAN ('L3',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION x3_2021 VALUES LESS THAN ('X1',to_date('01-JAN-2022','dd-mon-yyyy')),
 PARTITION x4_2020 VALUES LESS THAN ('X4',to_date('01-JAN-2021','dd-mon-yyyy'))
);
```

Character SITE_ID has to be defined in an ordered fashion

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
CREATE TABLE events (event_id number, site_id CHAR(2),start_date date)
PARTITION BY RANGE (site_id, start_date)
SUBPARTITION BY HASH (event_id) SUBPARTITIONS 16
(PARTITION l1_2020 VALUES LESS THAN ('L1',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION l1_2021 VALUES LESS THAN ('L1',to_date('01-JAN-2022','dd-mon-yyyy')),
 PARTITION l2_2020 VALUES LESS THAN ('L2',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION l2_2021 VALUES LESS THAN ('L2',to_date('01-JAN-2022','dd-mon-yyyy')),
 PARTITION x1_2020 VALUES LESS THAN ('X1',to_date('01-JAN-2021','dd-mon-yyyy')),
 PARTITION x1_2021 VALUES LESS THAN ('X1',to_date('01-JAN-2022','dd-mon-yyyy'))
);
```

Non-defined SITE_ID will follow the LESS THAN probe and always end in the lowest partition of a defined SITE_ID

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
CREATE TABLE events(prod_id number, site_id CHAR(2),start_date date)
PARTITION BY RANGE (site_id, start_date)
SUBPARTITION BY HASH (prod_id) SUBPARTITIONS 16
(PARTITION l1_2020 VALUES LESS THAN ('L1',to_date('01-JAN-2014','dd-mon-yyyy')),
 PARTITION l1_2021 VALUES LESS THAN ('L1',to_date('01-JAN-2020','dd-mon-yyyy')),
 PARTITION l2_2020 VALUES LESS THAN ('L2',to_date('01-JAN-2014','dd-mon-yyyy')),
 PARTITION x1_2021 VALUES LESS THAN ('X1',to_date('01-JAN-2020','dd-mon-yyyy')),
 PARTITION x4_2020 VALUES LESS THAN ('X4',to_date('01-JAN-2014','dd-mon-yyyy')),
 PARTITION x4_2021 VALUES LESS THAN ('X4',to_date('01-JAN-2020','dd-mon-yyyy'))
);
```

?

Future dates will always go in the lowest partition of the next higher SITE_ID or being rejected

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
create table events(prod_id number, site_id CHAR(2),start_date date)
partition by range (site_id, start_date)
subpartition by hash (prod_id) subpartitions 16
(partition below_L1   values less than ('L1',to_date('01-JAN-1492','dd-mon-yyyy')),
partition l1_2013     values less than ('L1',to_date('01-JAN-2014','dd-mon-yyyy')),
partition l1_2021     values less than ('L1',to_date('01-JAN-2020','dd-mon-yyyy')),
partition l1_max      values less than ('L1',MAXVALUE),
partition below_x1    values less than ('X1',to_date('01-JAN-1492','dd-mon-yyyy')),
 …
partition x4_max      values less than ('X4',MAXVALUE),
partition pmax        values less than (MAXVALUE,MAXVALUE));
```

Introduce a dummy 'BELOW_...' partition to catch "lower" nondefined SITE_ID

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
create table events(prod_id number, site_id CHAR(2),start_date date)
partition by range (site_id, start_date)
subpartition by hash (prod_id) subpartitions 16
(partition below_l1  values less than (‘L1',to_date('01-JAN-1492','dd-mon-yyyy')),
 partition l1_2020   values less than (‘L1',to_date('01-JAN-2021','dd-mon-yyyy')),
 partition l1_2021   values less than (‘L1',to_date('01-JAN-2022','dd-mon-yyyy')),
 partition l1_max    values less than (‘L1',MAXVALUE),
 partition below_x1  values less than (‘X1',to_date('01-JAN-1492','dd-mon-yyyy')),
  …
 partition x4_max    values less than (‘X4',MAXVALUE),
 partition pmax      values less than (MAXVALUE,MAXVALUE));
```

Introduce a MAXVALUE ‘X_FUTURE’ partition to catch future dates

Multi-Column Range Partition

A slightly different real-world scenario

Multi-column range used to introduce a third (non-numerical) dimension

```
create table events(prod_id number, site_id CHAR(2),start_date date)
partition by range (site_id, start_date)
subpartition by hash (prod_id) subpartitions 16
(partition below_l1  values less than ('L1',to_date('01-JAN-1492','dd-mon-yyyy')),
 partition l1_2020   values less than ('L1',to_date('01-JAN-2021','dd-mon-yyyy')),
 partition l1_2021   values less than ('L1',to_date('01-JAN-2022','dd-mon-yyyy')),
 partition l1_max    values less than ('L1',MAXVALUE),
 partition below_x1  values less than ('X1',to_date('01-JAN-1492','dd-mon-yyyy')),
  …
 partition x4_max    values less than ('X4',MAXVALUE),
 partition pmax      values less than (MAXVALUE,MAXVALUE));
```

If necessary, catch the open-ended SITE_ID (leading key column)

Differences partitioned and nonpartitioned Objects

Physical and logical attributes

Physical and Logical Attributes

Logical attributes

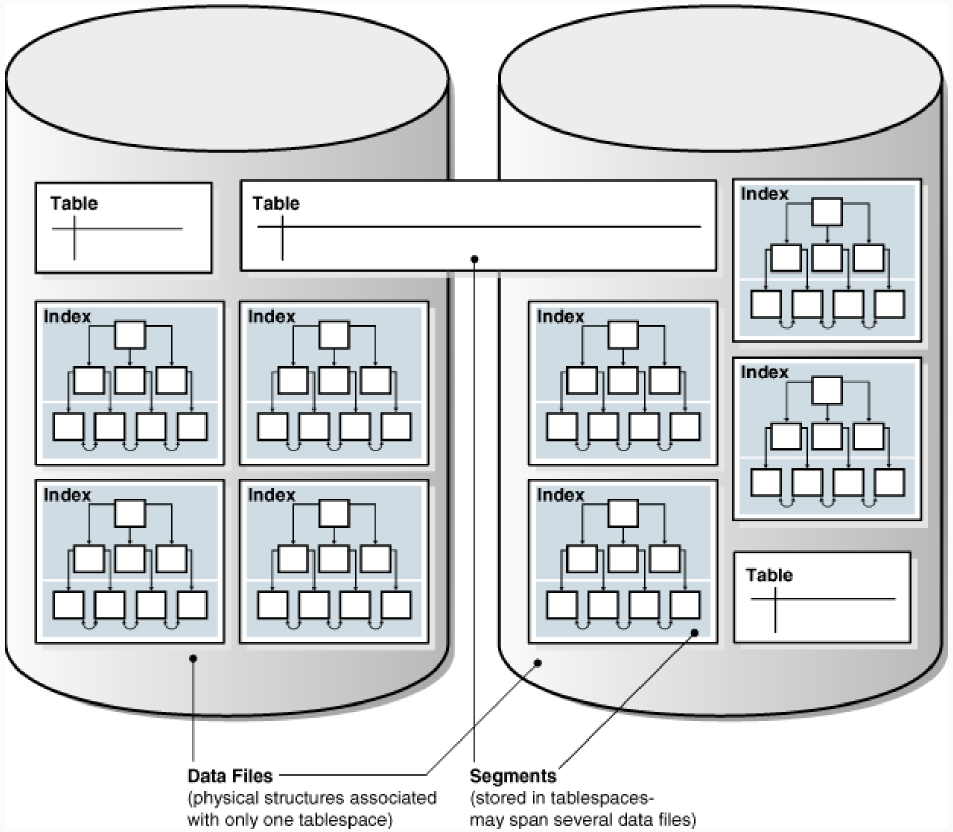
- Partitioning setup
- Indexing and index maintenance
- Read only (in conjunction with tablespace separation)

Physical attributes

- Data placement
- Segment properties in general

Nonpartitioned Tables

Physical and Logical Attributes



Logical table properties

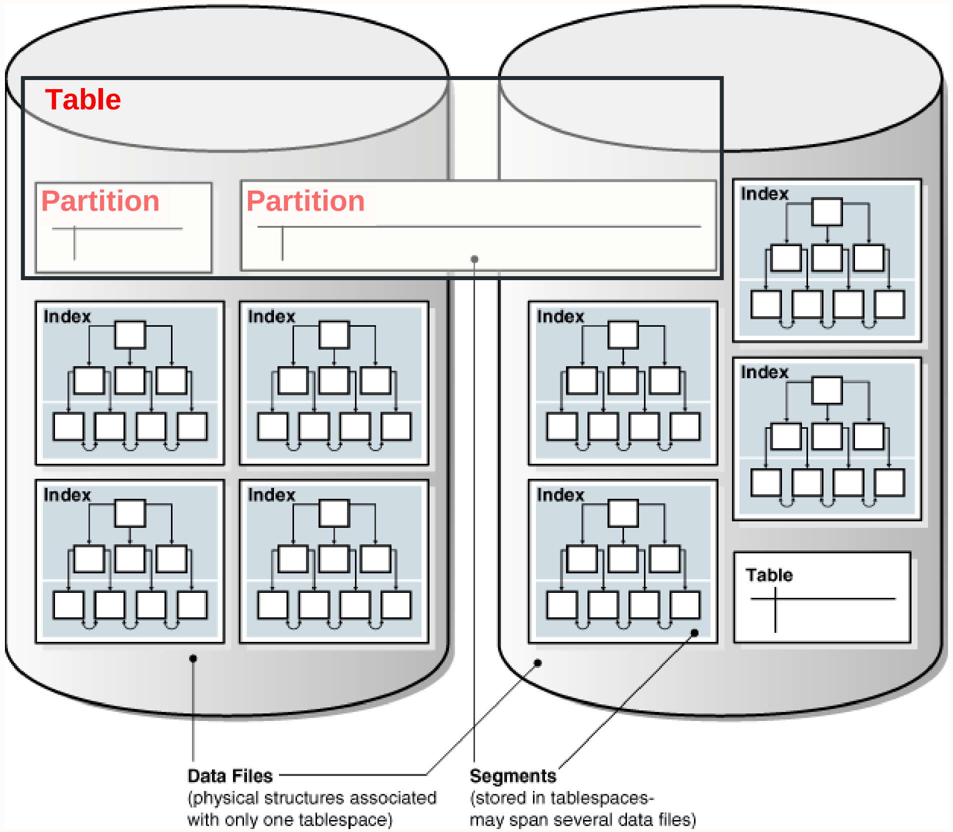
- Columns and data types
- Constraints
- Indexes, …

Physical table properties

- Table equivalent to segment
- Tablespace
- Compression, [Logging | nologging], …
- In-memory
- Properties managed and changed on segment level

Nonpartitioned Tables

Physical and Logical Attributes



Logical **table** properties

- Columns and data types
- Constraints
- **Partial** Indexes, …
- **Physical property directives**

Physical **[sub]partition** properties

- **[Sub]partition** equivalent to segment
- Tablespace
- Compression, [Logging | nologging], …
- In-memory
- Properties managed and changed on segment level

Partitioned Tables
Physical and Logical Attributes

Table is metadata-only and directive for future partitions

- No physical segments on table level
- Physical attributes become directive for new partitions, if specified

Single-level partitioned table

- Partitions are equivalent to segments
- Physical attributes are managed and changed on partition level

Composite-level partitioned tables

- Partitions are metadata only and directive for future subpartitions
- Subpartitions are equivalent to segments

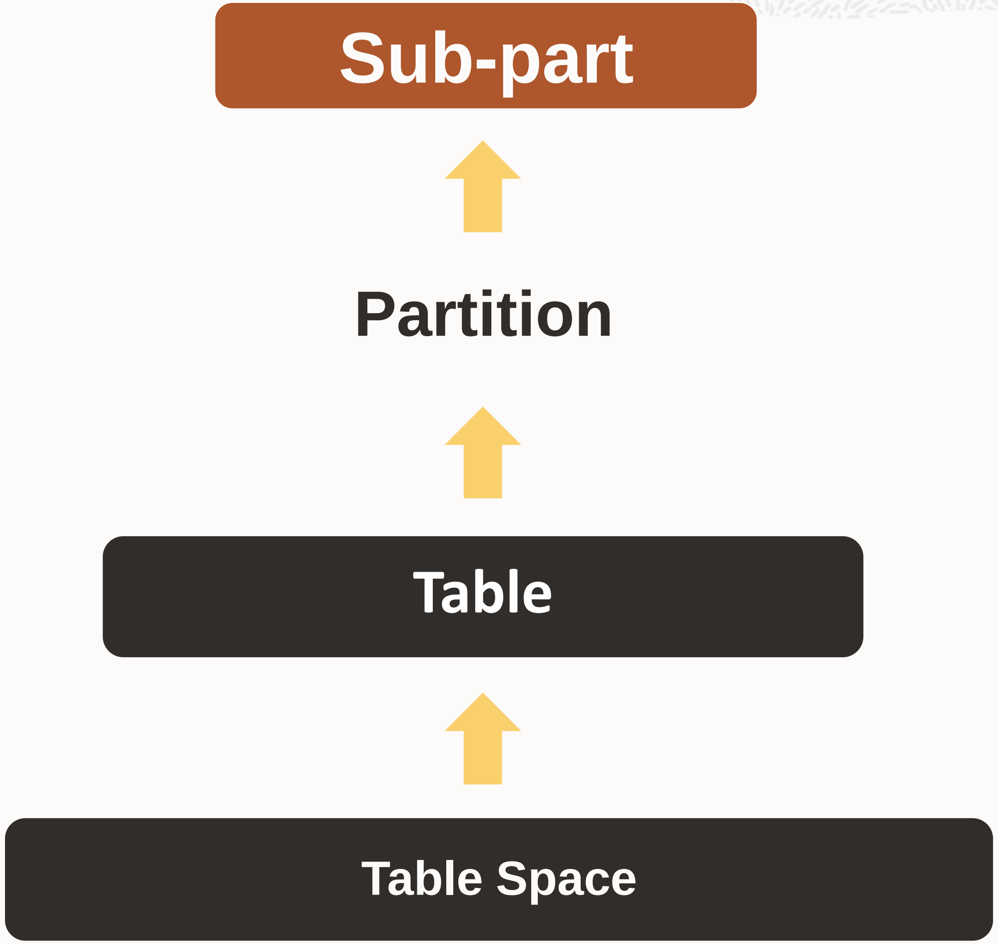
Data Placement with Partitioned Tables

Each partition or sub-partition is a separate object

Specify storage attributes at each individual level

- As placement policy for lower levels
- For each individual [sub]partition

If storage attributes are not specified standard hierarchical inheritance kicks in



Data Placement with Partitioned Tables

Special Case Interval Partitioning

Interval Partitioning" pre-creates" all partitions

- All 1 million [sub]partitions exist logically

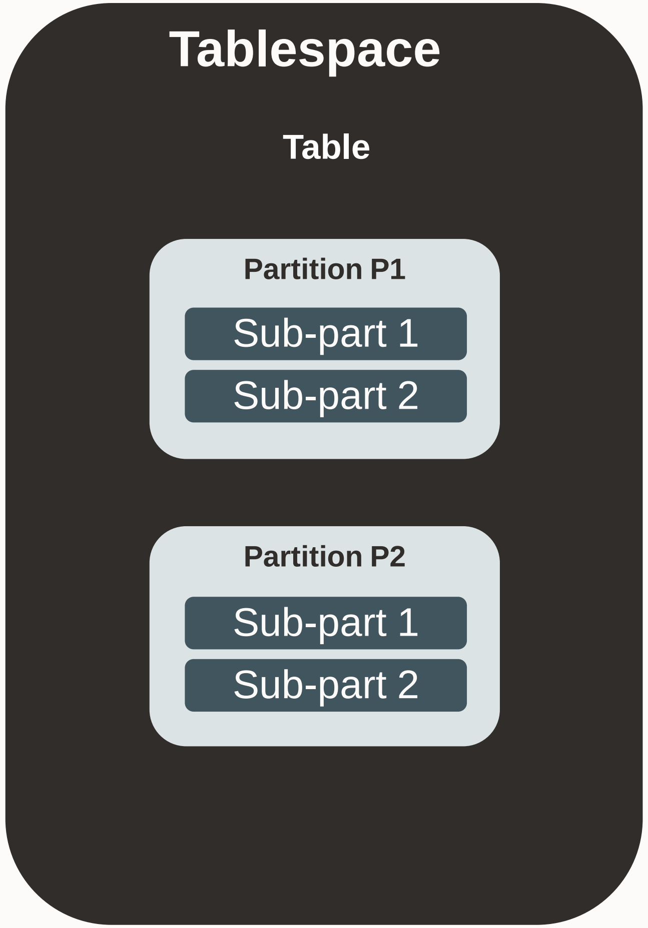
Physical storage is (almost) determined as well

Partition placement

- Inherited from table level
- STORE IN () clause for round-robin partition placement

Subpartition placement

- Usage of subpartition template
- STORE IN clause currently is currently a no-op



Data Placement with Partitioned Tables

Subpartition template

Allows predefinition of subpartitions for future partitions

Stored as metadata in the data dictionary

- Not only syntactic (macro) sugar

```
CREATE TABLE stripe_regional_EVENTS
      (deptno number, item_no varchar2(20),
       txn_date date, txn_amount number, state varchar2(2))
PARTITION BY RANGE (txn_date)
SUBPARTITION BY LIST (state)
SUBPARTITION TEMPLATE
    (SUBPARTITION northwest VALUES ('OR', 'WA') TABLESPACE tbs_1
     SUBPARTITION southwest VALUES ('AZ, 'UT', 'NM') TABLESPACE tbs_2
     SUBPARTITION northeast VALUES ('NY', 'VM', 'NJ') TABLESPACE tbs_3
     SUBPARTITION southeast VALUES ('FL', 'GA') TABLESPACE tbs_4
     SUBPARTITION midwest VALUES (SD', 'WI') TABLESPACE tbs_5
     SUBPARTITION south VALUES ('AL', 'AK') TABLESPACE tbs_6
     SUBPARTITION south VALUES (DEFAULT) TABLESPACE tbs_7
    )
(PARTITION q1_2021 VALUES LESS THAN ( TO_DATE('01-APR-2021', 'DD-MON-YYYY')),
(PARTITION q2_2021 VALUES LESS THAN ( TO_DATE('01-JUL-2021', 'DD-MON-YYYY')),
(PARTITION q3_2021 VALUES LESS THAN ( TO_DATE('01-OCT-2021', 'DD-MON-YYYY')),
(PARTITION q4_2021 VALUES LESS THAN ( TO_DATE('01-JAN-2020', 'DD-MON-YYYY')),
);
```

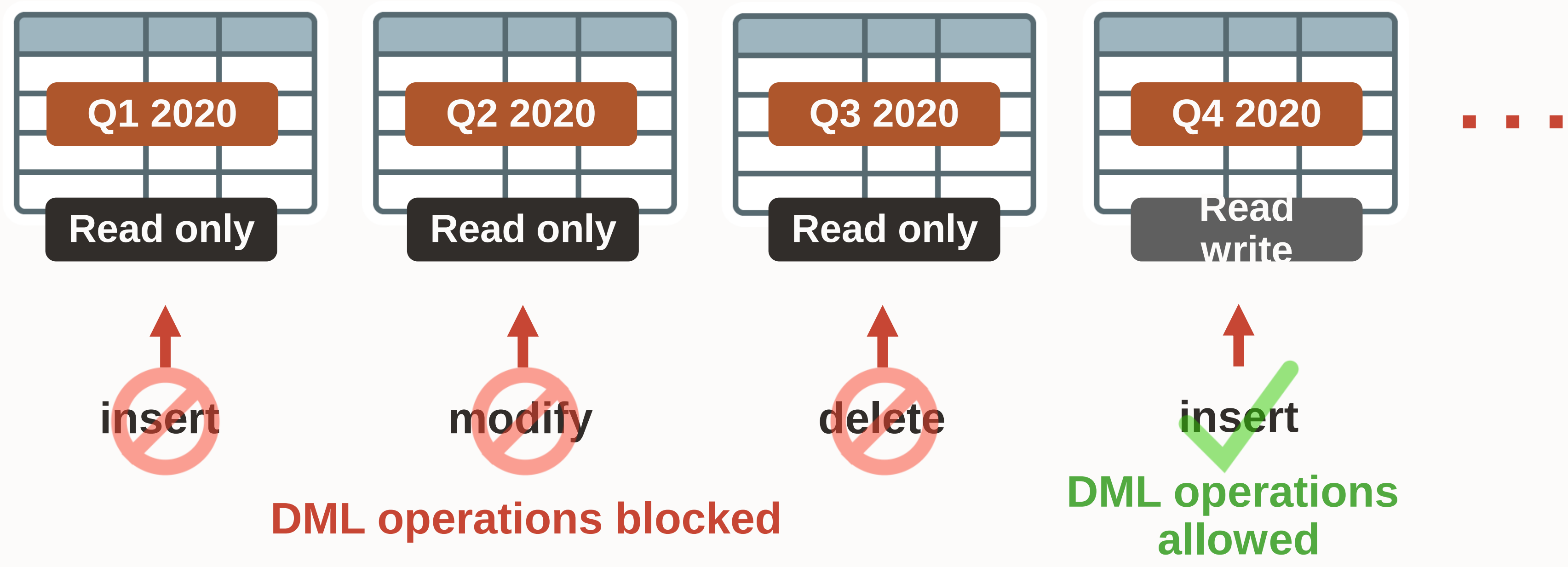
Subpartition definition for all future partitions

Subpartition applied to every partition

Read Only Partitions

Introduced in Oracle Database 12.2

Read Only Partitions



Partitions and sub-partitions can be set to read only or read write

Any attempt to alter data in a read only partition will result in an error

Ideal for protecting data from unintentional DML by any user or trigger

Details of Read Only Partitions

Read only attribute guarantees data immutability

- “SELECT <column_list> FROM <table>” will always return the same data set after a table or [sub]partition is set to read only

If not specified, each partition and subpartition will inherit read only property from top level parent

- Modifying lower level read only property will override higher level property
- Alter tablespace has highest priority and cannot be overwritten

Data immutability does not prevent all structural DDL for a table

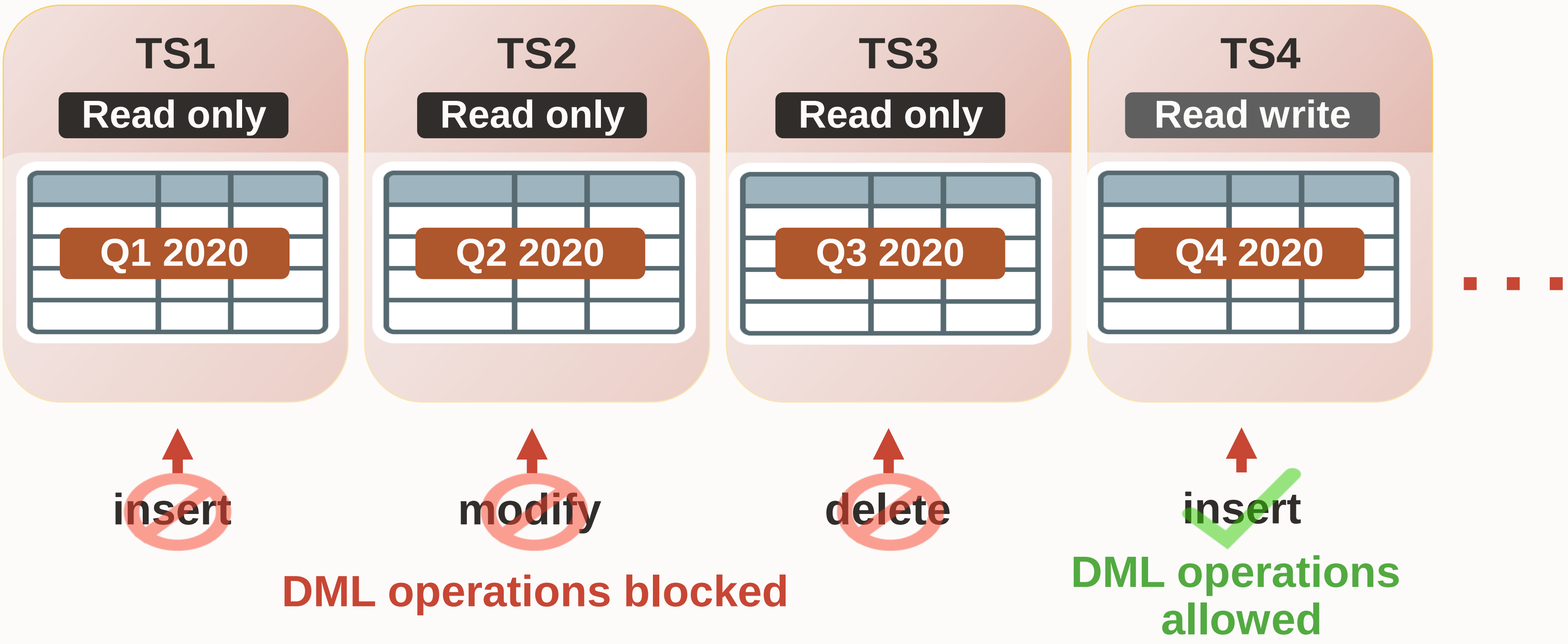
- ADD and MODIFY COLUMN are allowed and do not violate data immutability of existing data
- Others like DROP/RENAME/SET UNUSED COLUMN are forbidden
- DROP [read only] PARTITION forbidden, too - - violates data immutability of the table

Read Only Partitions

```
CREATE TABLE events ( event_id number,
                      evnt_date DATE,   … ) read only

PARTITION BY RANGE(event_date)
( partition q1_2020 values less than (‘2020-04-01’),
  partition q2_2020 values less than (‘2020-07-01’),
  partition q3_2020 values less than (‘2020-10-01’),
  partition q4_2020 values less than (‘2021-01-01’) read write
);
```

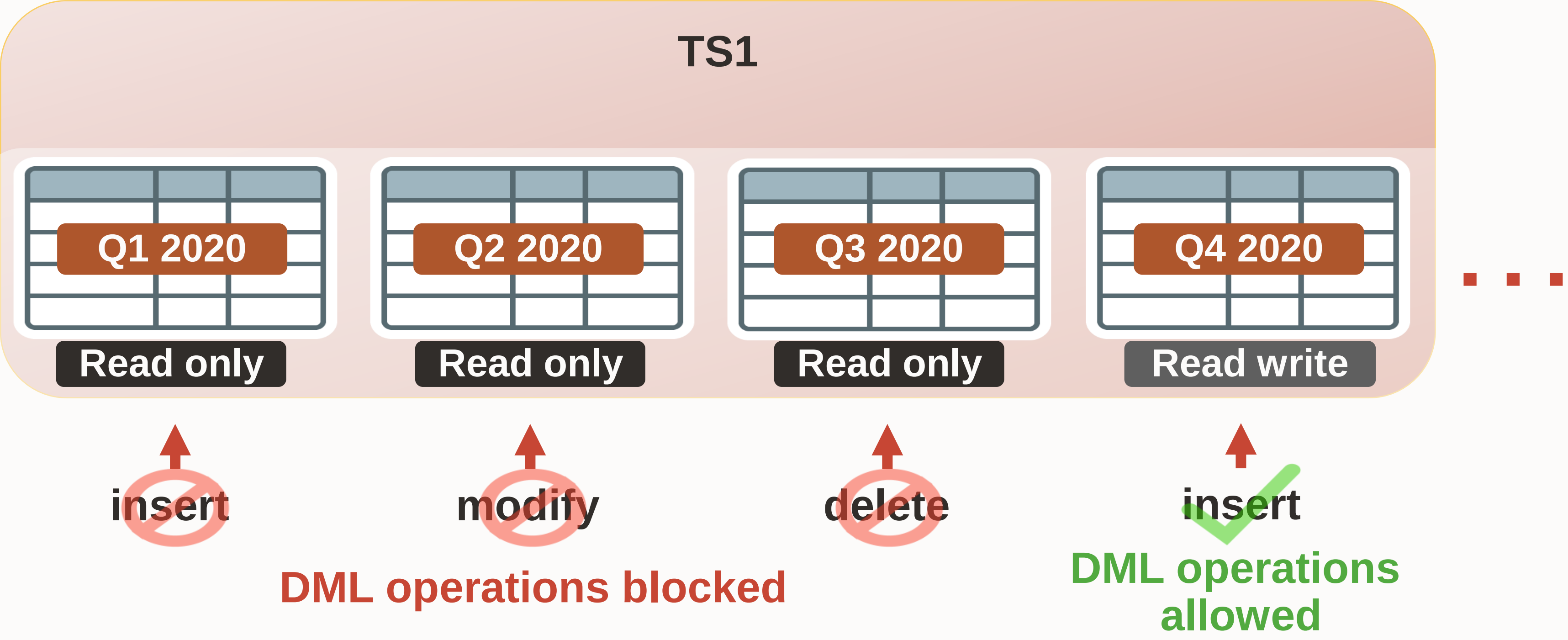

Read Only Tablespaces and Partitions



Partitions and sub-partitions can be placed in read only tablespaces

Any attempt to alter data in a read only tablespace will result in an error

Read Only Partitions



Partitions and sub-partitions can be set to read only or read write

Any attempt to alter data in a read only partition will result in an error

Read Only Object vs. Read Only Tablespace

Read Only Tablespaces **protect physical storage** from updates

- DDL operations that are not touching the storage are allowed
  - E.g. ALTER TABLE SET UNUSED, DROP TABLE
- No guaranteed data immutability

Read Only Objects **protect data** from updates

- 'Data immutability'
- Does not prevent changes on storage
  - E.g. ALTER TABLE MOVE COMPRESS, ALTER TABLE MERGE PARTITIONS

Read Only Partitions

Read only attribute guarantees data immutability

- “SELECT <column_list> FROM <table>” will always return the same data set after a table or [sub]partition is set to read only

Data immutability does not prevent all structural DDL for a table

- ADD and MODIFY COLUMN are allowed and do not violate data immutability of existing data
- Others like DROP/RENAME/SET UNUSED COLUMN are forbidden
- DROP [read only] PARTITION forbidden, too - - violates data immutability of the table

Reduced Cursor Invalidations for DDL's

Introduced in Oracle Database 12.2

Reduced Cursor Invalidations for DDL’s

Reduces the number of hard parses caused by DDL’s

- If hard parses are unavoidable, workload is spread over time
- New optional clause “[DEFERRED | IMMEDIATE] INVALIDATION” for several DDL’s
- If DEFERRED, Oracle will avoid invalidating dependent cursors when possible
- If IMMEDIATE, Oracle will immediately invalidate dependent cursors
- If neither, CURSOR_INVALIDATION parameter controls default behavior

Supported DDL’s:

- Create, drop, alter index
- Alter table column operations
- Alter table segment operations
- Truncate table

Reduced Cursor Invalidations for DDL's

Syntax Example

```
DROP INDEX meas_campaign DEFERRED INVALIDATION;
```

Statistics Management for Partitioning

Statistics Gathering

You must gather Optimizer statistics

- Using dynamic sampling is not an adequate solution
- Statistics on global and partition level recommended
  - Subpartition level optional

Run all queries against empty tables to populate column usage

- This helps identify which columns automatically get histograms created on them

Optimizer statistics should be gathered after the data has been loaded but before any indexes are created

- Oracle will automatically gather statistics for indexes as they are being created

Statistics Gathering

By default DBMS_STATS gathers the following stats for each table

- global (table level), partition level, sub-partition level

Optimizer uses global stats if query touches two or more partitions

Optimizer uses partition stats if queries do partition elimination and only one partition is necessary to answer the query

- If queries touch two or more partitions the optimizer will use a combination of global and partition level statistics

Optimizer uses sub-partition level statistics only if your queries do partition elimination and one sub-partition is necessary to answer query

Efficient Statistics Management

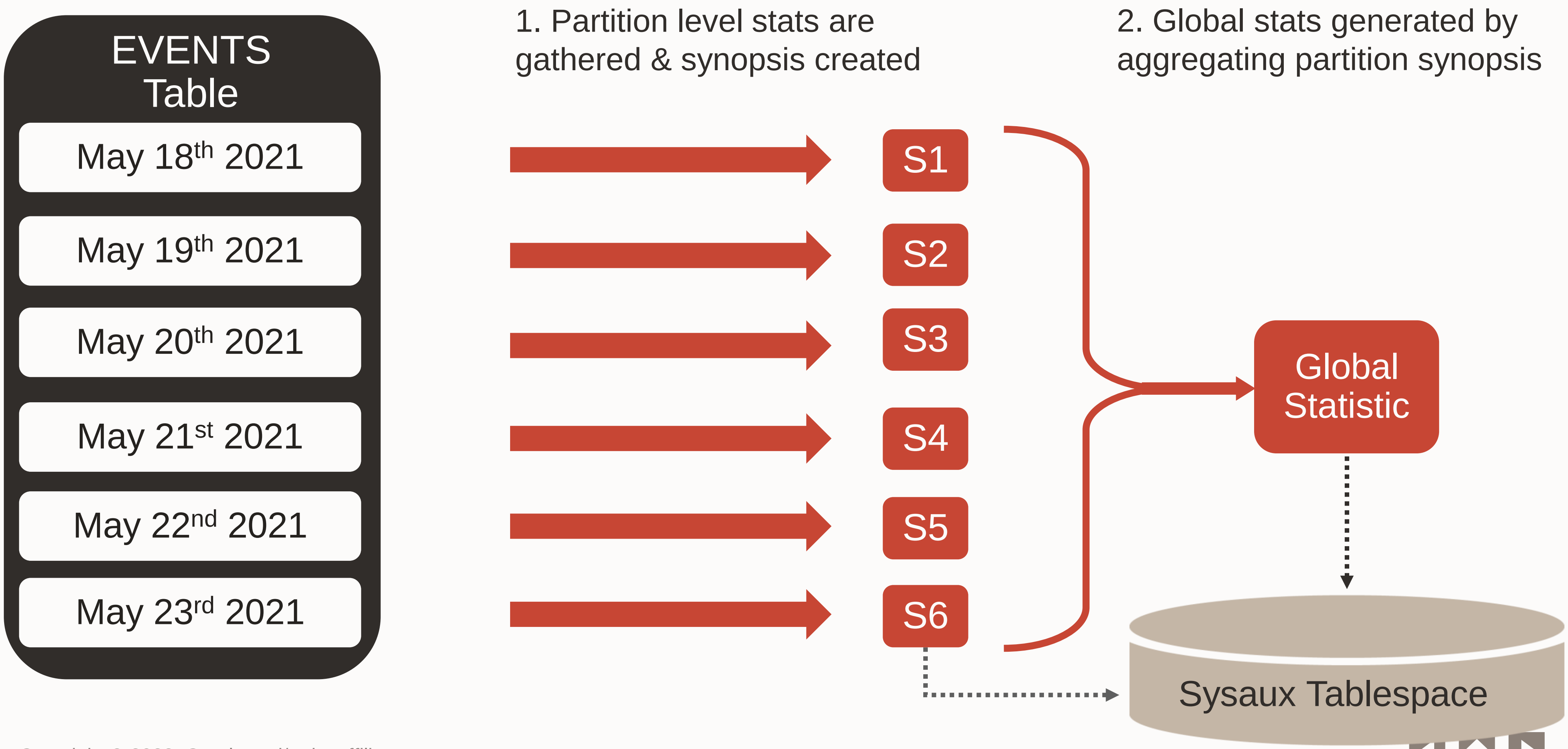
Use AUTO_SAMPLE_SIZE

- The only setting that enables new efficient statistics collection
- Hash based algorithm, scanning the whole table
  - Speed of sampling, accuracy of compute

Enable incremental global statistics collection

- Avoids scan of all partitions after changing single partitions
  - Prior to 11.1, scan of all partitions necessary for global stats
- Managed on per table level
  - Static setting
- Create synopsis for non-partitioned table to being exchanged (Oracle Database 12c)

Incremental Global Statistics

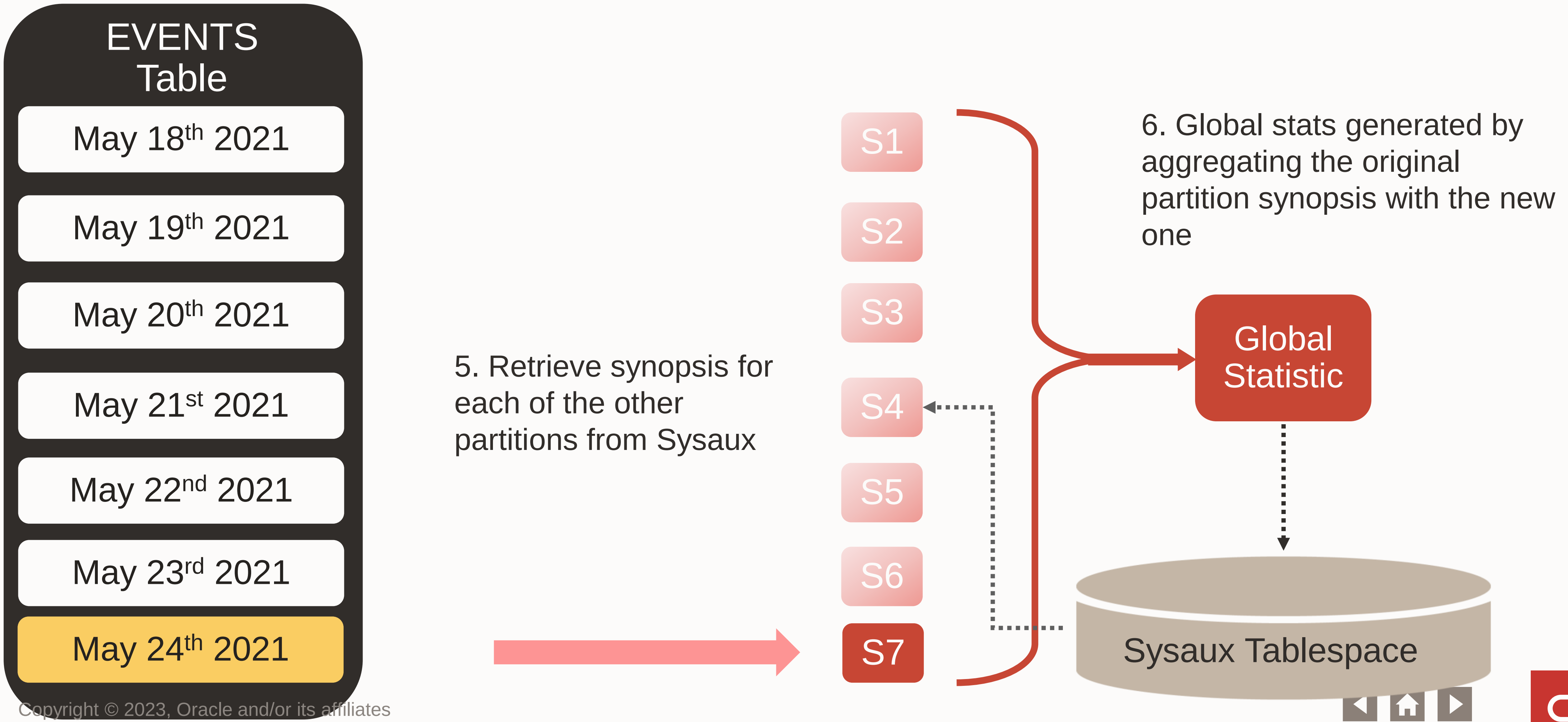


Incremental Global Statistics, Cont

3. A new partition is added to the table and data is loaded

4. Gather partition statistics for new partition

Incremental Global Statistics, Cont



Step necessary to gather accurate statistics

Turn on incremental feature for the table

```
EXEC DBMS_STATS.SET_TABLE_PREFS('ATLAS','EVENTS','INCREMENTAL','TRUE');
```

After load gather table statistics using GATHER_TABLE_STATS

- No need to specify parameters

```
EXEC DBMS_STATS.GATHER_TABLE_STATS('ATLAS','EVENTS');
```

The command will collect statistics for partitions and update the global statistics based on the partition level statistics and synopsis

Possible to set incremental to true for all tables

- Only works for already existing tables

```
EXEC DBMS_STATS.SET_GLOBAL_PREFS('INCREMENTAL','TRUE');
```


Best Practices and How-To's

Think about your partitioning strategy

Choosing your Partitioning Strategy

Think about

- your data
- your usage

What do you expect from Partitioning?

- Query performance benefits
- Load (or purge) performance benefits
- Data management benefits

Choosing your Partitioning Strategy

Logical shape of the data

How is data inserted into your system?

How is data maintained in your system?

How is data accessed in your system?

Choosing your Partitioning Strategy

Logical shape of the data

How is data inserted into your system?

- Time, location, tenant, business user, …
- Ranges, unrelated list of values, “just lots of them”, …

How is data maintained in your system?

How is data accessed in your system?

Choosing your Partitioning Strategy

Logical shape of the data

How is data inserted into your system?

- Time, location, tenant, business user, …
- Ranges, unrelated list of values, “just lots of them”, …

How is data maintained in your system?

- Moving window of active data, legal requirements, data “forever”, ...
- Don’t know yet

How is data accessed in your system?

Choosing your Partitioning Strategy

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- Time, location, tenant, business user, …
- Ranges, unrelated list of values, “just lots of them”, …

How is data maintained in your system?

- Moving window of active data, legal requirements, data “forever”, ...
- Don’t know yet

How is data accessed in your system?

- Always full, with common FILTER predicates, always index access, …
- Don’t know yet

Choosing your Partitioning Strategy

Performance improvements

Query speedup

- Partition elimination
- Partition-wise joins

DML speedup

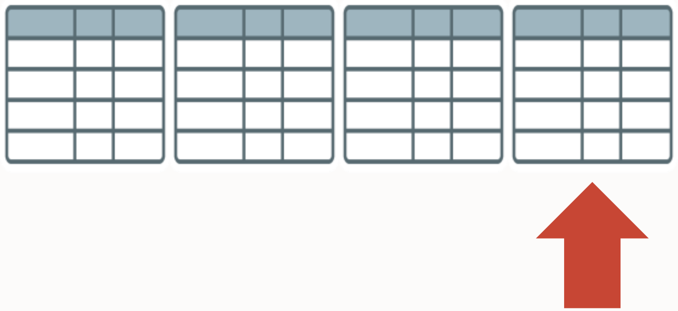
- Alleviation of contention points

Data maintenance

- DDL instead of DML

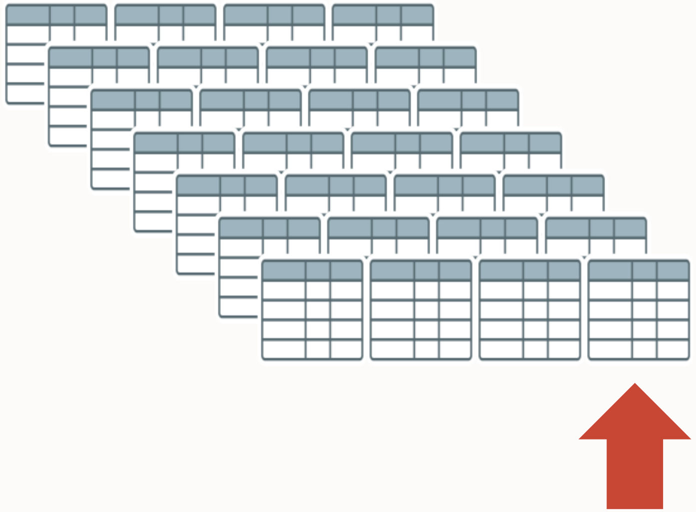
Choosing your Partitioning Strategy

Data Access – Full Table Access



I/O savings are linear to the number of pruned partitions

- One of 10: ten times less IO
- One of 100: hundred times less IO



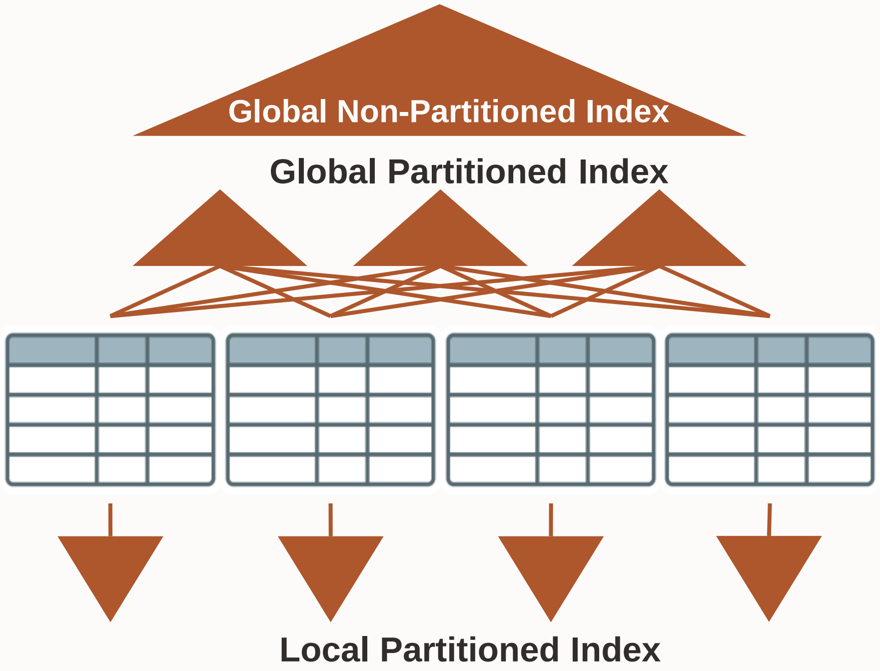
Runtime improvements depend on

- Relative contribution of IO versus CPU work
- Potential impact on subsequent operations

Choosing your Partitioning Strategy
Indexing of partitioned tables

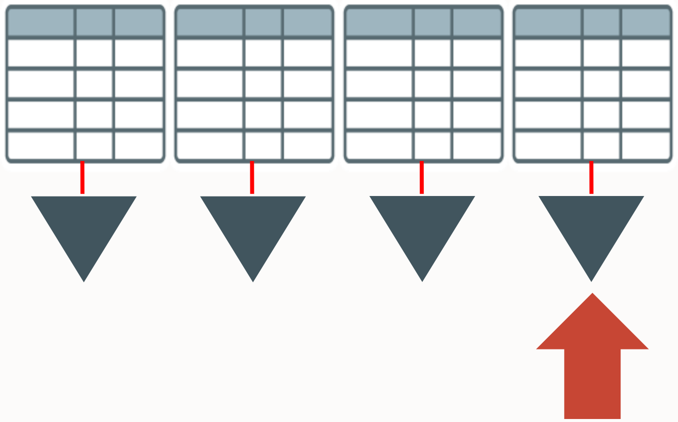
GLOBAL index points to rows in any partition
- Index can be partitioned or not

LOCAL index is partitioned same as table
- Index partitioning key can be different from index key

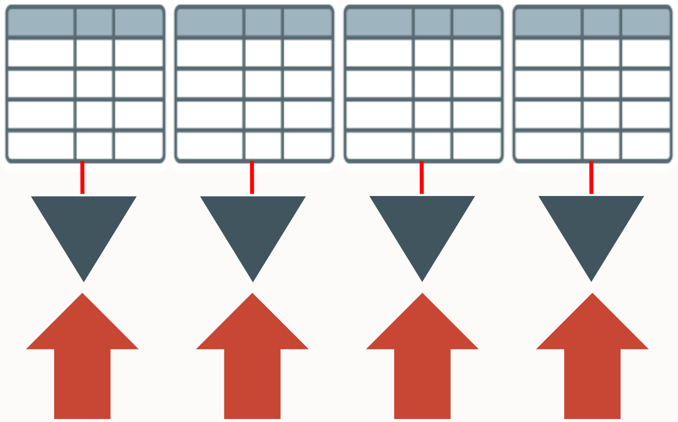


Choosing your Partitioning Strategy

Data Access – local index and global partitioned index



Partitioned index access with single partition pruning



Partitioned index access without any partition pruning

Local and Global Partitioned Indexes

Data Access

Number of index probes identical to number of accessed partitions

- No partition pruning leads to a probe into all index partitions

Not optimally suited for OLTP environments

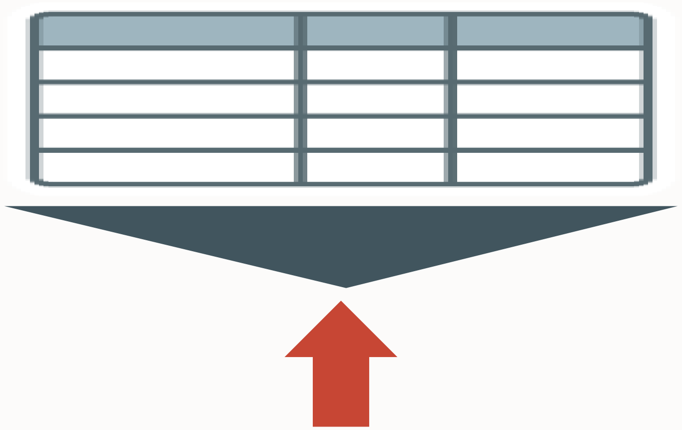
- No guarantee to always have partition pruning
- Exception: global hash partitioned indexes for DML contention alleviation
  - Most commonly small number of partitions

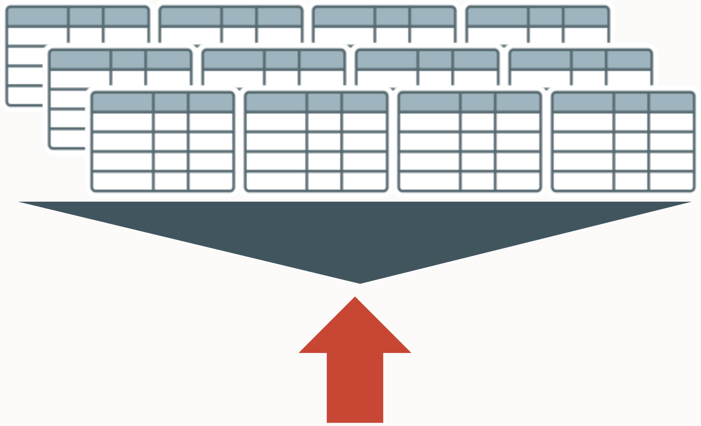
Pruning on global partitioned indexes based on the index prefix

- Index prefix identical to leading keys of index

Choosing your Partitioning Strategy

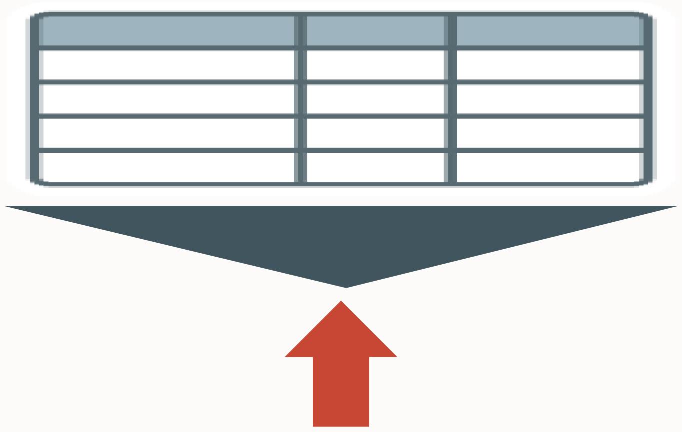
Global Nonpartitioned Index

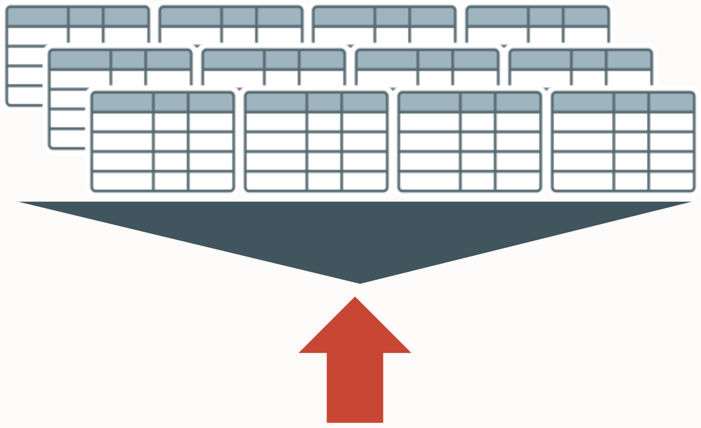




Can you see the difference?

Choosing your Partitioning Strategy
Global Nonpartitioned Index





Can you see the difference?

There is more or less none*

* Some differences for index size, due to large rowid

Global Indexes
Data Access

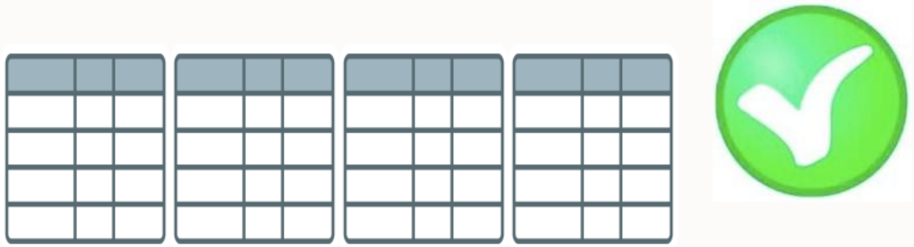
No pruning for non-partitioned indexes

- You always probe into a single index segment

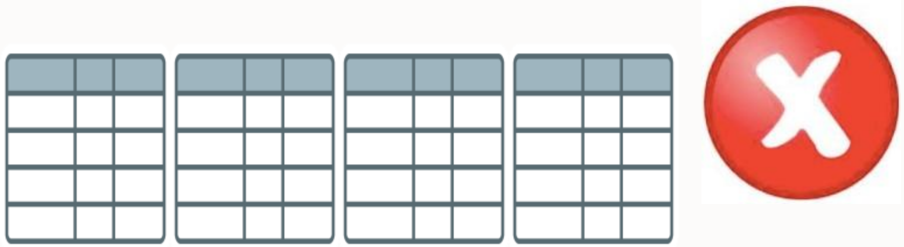
Global partitioned index prefix identical to leading keys of index

- Pruning on index prefix, not partition key column(s)

Most common in OLTP environments



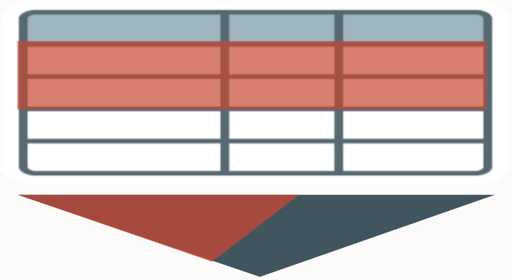
`PARTITION BY (col1), idx(col1)`



`PARTITION BY (col1), idx(col2)`

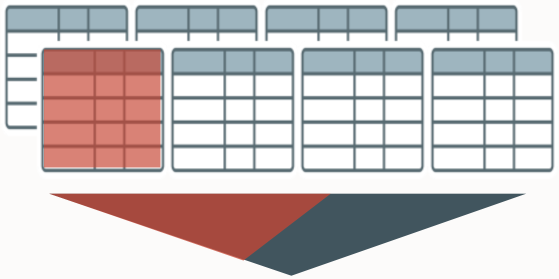
Choosing your Partitioning Strategy

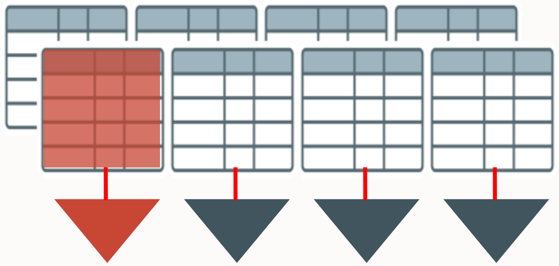
Data Maintenance



```
DELETE FROM ...
      WHERE ...
```

- Records get deleted
  - Index maintenance
  - Undo and redo





```
ALTER TABLE ... DROP PARTITION ...
```

- Partition gets dropped
  - Fast global index maintenance (12c)
  - Minimal undo

- Partition gets dropped
  - Local index gets dropped
  - Minimal undo

Local Indexes
Data Maintenance

Incremental index creation possible

- Initial unusable creation, rebuild of individual partitions

Fast index maintenance for all partition maintenance operations that only touch one partition

- Exchange, drop, truncate

Partition maintenance that touches more than one partition require index maintenance

- Merge, split creates new data segments
- New index segments are created as well

Global Indexes

Data Maintenance

Incremental index creation is hard, if not impossible

"Fast" index maintenance for drop and truncate beginning with Oracle Database 12c

- Fast actually means delayed index maintenance

Partition maintenance except drop and truncate requires index maintenance

- Conventional index maintenance equivalent to the DML operations that would represent the PMOP

How many partitions?

It depends ..

Data Volume and Number of Partitions

Imagine a 100TB table …

- With one million partitions, each partition is 100MB in size

Imagine a 10TB table …

- With one million partitions, each partition is 10MB in size

Imagine a 1TB table …

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Imagine a 1TB table …

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How long does it take your system to read 1MB??

- **Exadata full table scan rate is tens to hundreds of GB/sec …**

Data Volume and Number of Partitions

More is not always better

- Every partition represents metadata in the dictionary
- Every partition increases the metadata footprint in the SGA

Find your personal balance between the number of partitions and its average size

- There is nothing wrong about single-digit GB sizes for a segment on “normal systems”
- Consider more partitions >= 5GB segment size

Choosing your Partitioning Strategy

Customer Usage Patterns

Range (Interval) still the most prevalent partitioning strategy

- Almost always some time dependency

List more and more common

- Interestingly often based on time as well
- Often as subpartitioning strategy

Hash not only used for performance (PWJ, DML contention)

- No control over data placement, but some understanding of it
- Do not forget the power of two rule

Choosing your Partitioning Strategy

Extended Partitioning Strategies

Interval Partitioning fastest growing new partitioning strategy

- Manageability extension to Range Partitioning

Reference Partitioning

- Leverage PK/FK constraints for your data model

Interval-Reference Partitioning (new in Oracle Database 12c)

Virtual column based Partitioning

- Derived attributes without little to no application change

Any variant of the above

Flexibility has its price

Flexibility with Oracle Partitioning

One million partitions –the more the better?

Online operations – the holy grail?

PMOPs over DML all the time?

Data Volume and Number of Partitions

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One millions partitions – the more the better?

More is not always better

- Every partition represents metadata in the dictionary
- Every partition increases the metadata footprint in the SGA
- Large number of partitions can impact performance of catalog views

Find your personal balance between the number of partitions and its average size

- There is nothing wrong about single-digit GB sizes for a segment on “normal systems”
- Consider more partitions >= 5GB segment size

Online (Data Movement) Operations for Tables and Partitions

Partition Maintenance OPerations (PMOPs) are online

- Move: change location and storage attributes
- Merge: many partitions become one
- Split: one partition becomes many

Table conversion operation is online

- Modify nonpartitioned table to become partitioned table
- Change shape of partitioned table

All online operations support index maintenance

Online (Data Movement) Operations for Tables and Partitions

Plan for the best possible time window

Online operations sustain application transparency and minimize the business impact

- **Not** introduced to stop thinking about application workflow and design

Cost of online operations increases with concurrency

Minimize concurrent DML operations if possible

- Require additional disk space and resources for journaling
- Journal will be applied recursively after initial bulk move
- The larger the journal, the longer the runtime

Concurrent DML has impact on compression efficiency

- Best compression ratio with initial bulk move

PMOPs over DML all the time?

Partition maintenance operations are a fast and efficient way to load or unload data

... but it has its price:

- Recursive DML to update partition metadata
  - Most commonly linear to number of involved partitions (tables and indexes), with exceptions
- Cursor invalidation
  - Working hard on doing more fine-grained invalidation and incremental metadata invalidation/refresh

PMOPs over DML all the time?

Partition maintenance operations are a fast and efficient way to load or unload data

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  - Most commonly linear to number of involved partitions (tables and indexes), with exceptions
- Cursor invalidation
  - Working hard on doing more fine-grained invalidation and incremental metadata invalidation/refresh

DML is a viable alternative

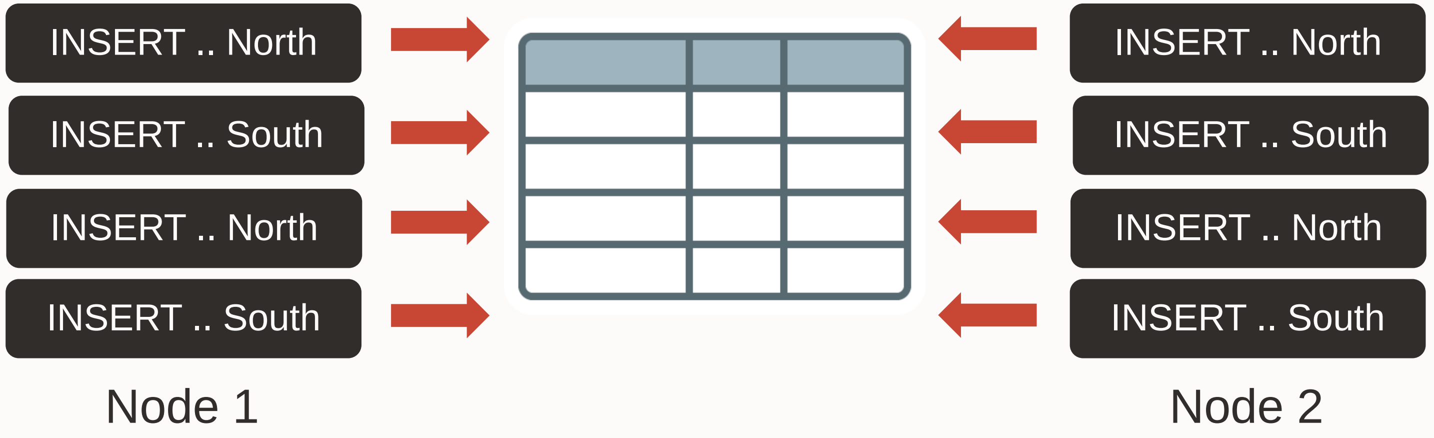
- Especially for smaller data volumes

Using partitioning to eliminate hot spots

Using Partitioning to eliminate Hot Spots
Nonpartitioned table

On RAC, high DML workload causes high cache fusion traffic

- Oracle calls this block pinging



Using Partitioning to eliminate Hot Spots

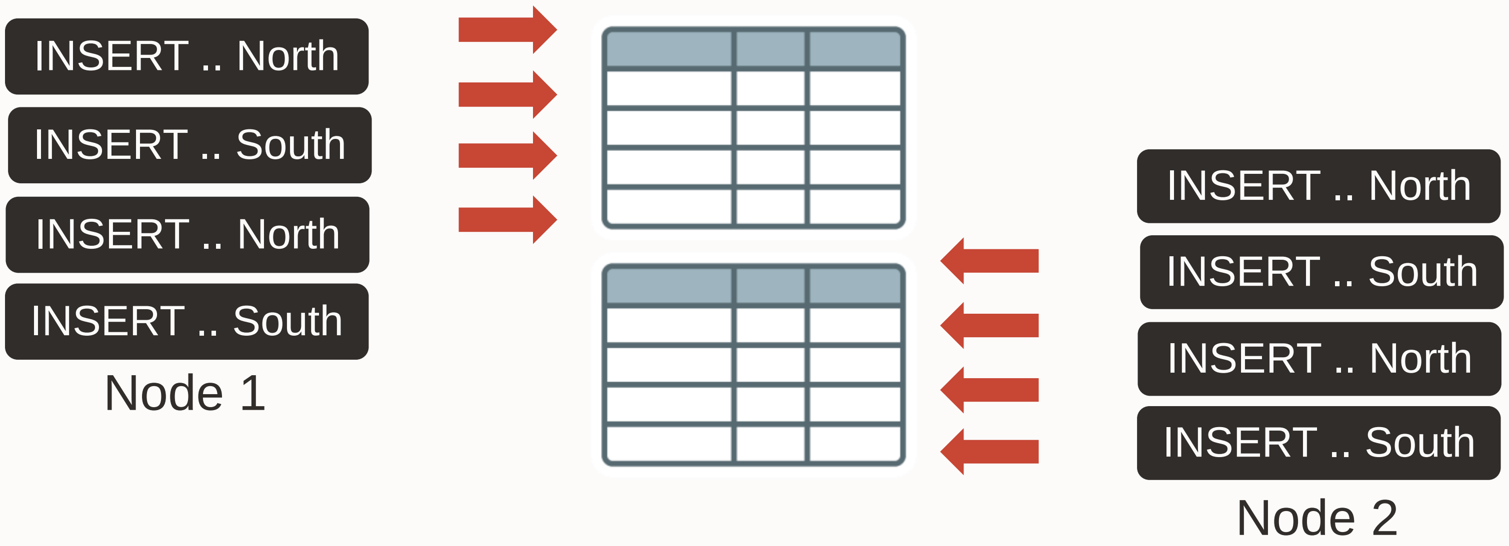
HASH partitioned table

On RAC, high DML workload causes high cache fusion traffic

- Oracle calls this block pinging

HASH (or LIST) partitioned table can alleviate this situation

- Caveat: Normally needs some kind of “application partitioning” or “application RAC awareness”

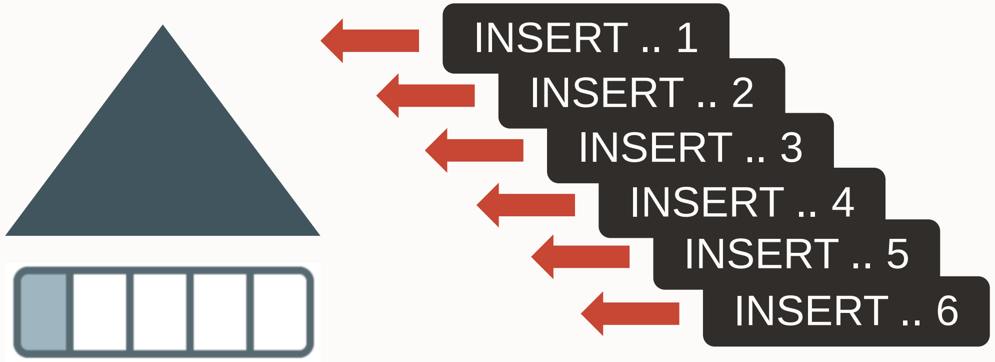


Using Partitioning to eliminate Hot Spots

HASH partitioned index

High DML workload can create hot spots (contention) on index blocks

- E.g. artificial (right hand growing) primary key index

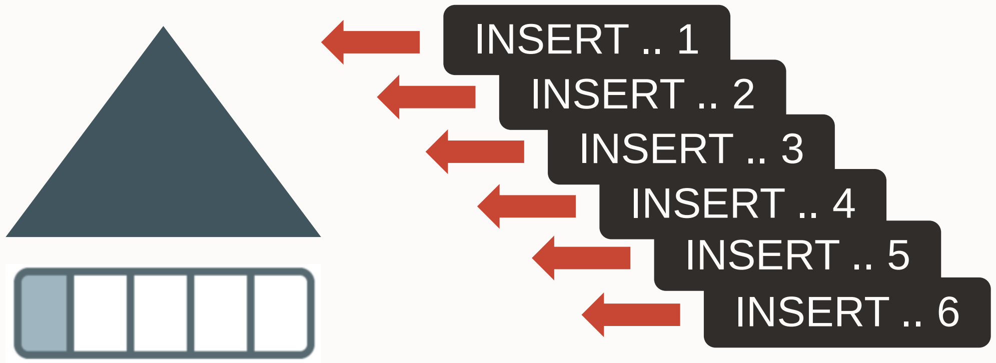


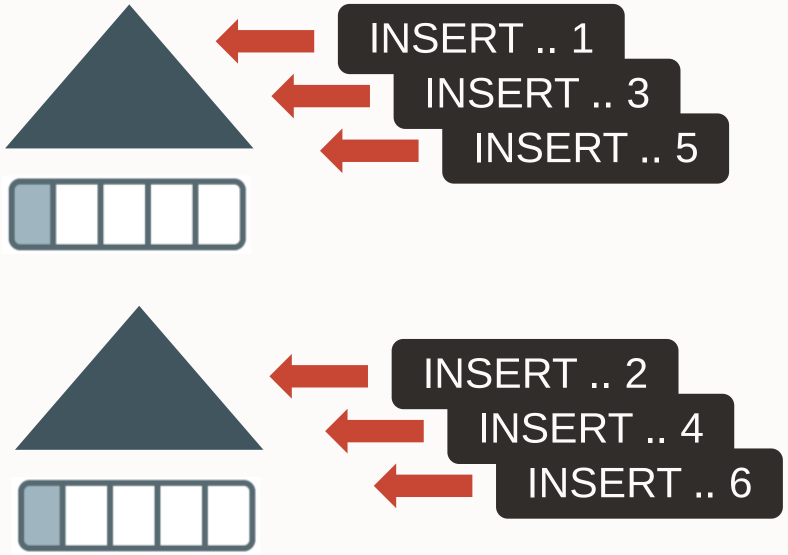
Using Partitioning to eliminate Hot Spots
HASH partitioned index

High DML workload can create hot spots (contention) on index blocks

- E.g. artificial (right hand growing) primary key index

With HASH partitioned index you get warm spots





Hot Spot Elimination – Use Case

Challenge

Retail application using object-relational mapping

Only “common” database functionality is used

Every single row needs to be updated in a single transaction

No bulk imports possible at all!

Thousands of small SQL-Statements issued

Sudden heavy peaks in user access

- e.g. Cyber Monday, Christmas trade, special offers, ..

Experienced sporadic contention

Hot Spot Elimination – Use Case

Performance without any application code change

Results from PoC (SKU data load)

Reference system: 120 SKU's per second

Exadata Machine (single node load)

- 2,500 SKU's per second (20x faster)

Exadata Machine X3-2 (two node load & without partitioning)

- "only" 1,900 SKU's per second (slower than single node load !!!)

Exadata Machine X3-2 (two node load & with proper partitioning)

- 4,800 SKU's per second (40x faster)

Proper partitioning enables linear scaling

Hot Spot Elimination – Use Case

How to (Alternative A, Hash Partitioning on store ID)

HASH Partitioning creates <n> entry points into the table

```
CREATE TABLE <table_name> (
  ID            NUMBER(10) NOT NULL,
  Cn             ...)
PARTITION BY HASH(ID) PARTITIONS <n>
TABLESPACE <tablespace_name> STORAGE ( ... );

CREATE UNIQUE INDEX <index_name> ON <table_name>
(ID) LOCAL TABLESPACE <tablespace_name> STORAGE ( ... );

INSERT INTO <table_name> (ID, ...)
SELECT SEQ_ID.nextval, ... ;
```


Hot Spot Elimination – Use Case

How to (Alternative B, List Partitioning on instance #)

Sequence SEQ_ID forces ID to be unique in each partition!

List Partitioning completely separates the entry points per instance

```
CREATE TABLE <table_name> (
  ID              NUMBER(10) NOT NULL,
  Cn               ...            ...,
  INSTANCE_NUMBER NUMBER(1) DEFAULT sys_context('USERENV','INSTANCE') NOT NULL)
PARTITION BY LIST (INSTANCE_NUMBER)
( PARTITION P1 VALUES(1),
  PARTITION P2 VALUES(2),
  ...
  PARTITION Pn VALUES(n))
TABLESPACE <tablespace_name> STORAGE ( ... );

CREATE UNIQUE INDEX <index_name> ON <table_name>
(ID, INSTANCE_NUMBER) LOCAL TABLESPACE <tablespace_name> STORAGE ( ... );

INSERT INTO <table_name> (ID, ...) SELECT SEQ_ID.nextval, ... ;
```


Hot Spot Elimination – Use Case

How to (Enhanced alternative B, Hash Partitioning on instance #)

Sequence SEQ_ID forces ID to be unique in each partition!

```
CREATE TABLE <table_name> (
  ID              NUMBER(10) NOT NULL,
  Cn              ...            ...,
  INSTANCE_NUMBER NUMBER(1) DEFAULT sys_context('USERENV','INSTANCE') NOT NULL)
PARTITION BY LIST (INSTANCE_NUMBER)
SUBPARTITION BY HASH (ID) SUBPARTITIONS <m>
( PARTITION P1 VALUES(1),
  PARTITION P2 VALUES(2),
  ...
  PARTITION Pn VALUES(n))
TABLESPACE <tablespace_name> STORAGE ( ... );
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```


Find the Best Technique

Scaling with heavy parallel insert operations across instances

Reverse Key Indexes

Range Scans no longer available

HASH Partitioned Indexes

Alleviates hot spot for right hand growing index

Still concurrency on table blocks and block pinging for index blocks

Hash Partitioned tables w/ local indexes

Much better, however still concurrency on x-instance inserts

Composite List by Instance and Hash Subpartitioning w/ local indexes

Optimal solution, “eliminates” concurrency and brings load job to scale linearly

Smart partial partition exchange

Enhanced “filtered partition maintenance”

Partition Exchange for Loading and Purging

Remove and add data as metadata only operations

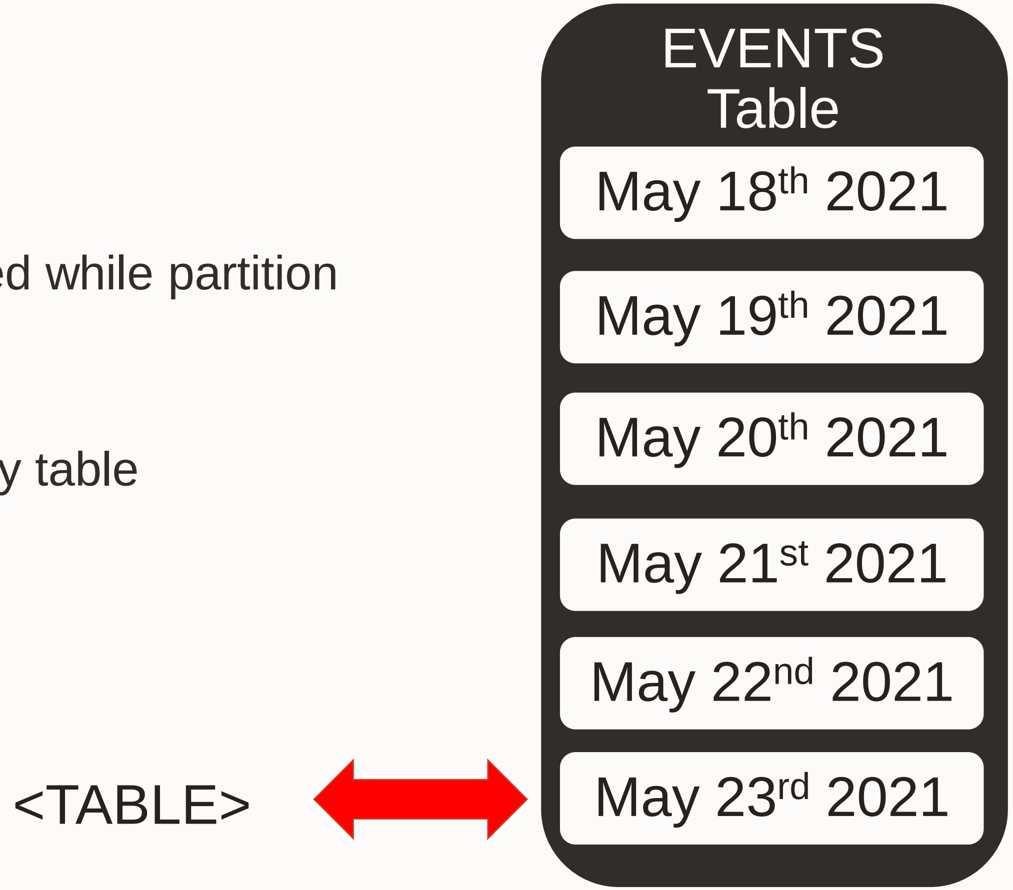
- Exchange the metadata of partition and table

Data load: standalone table contains new data to being loaded while partition for exchange is normally empty

Data purge: partition containing data is exchanged with empty table

Drop partition alternative for purge

- Data is gone forever



Smart Partial Partition Exchange

Sounds easy but …

What to do if partition boundaries are not 100% aligned?

- “Partial Purging”

Use cases

- Phone calls that spawn day’s boundary
- Old orders that are not paid
- Old orders that are not delivered
- Some other “not-being-done-with-the-record-yet” scenario

Smart Partial Partition Exchange

Partial Purging

Set partition to being purged to read only

- Lock partition not applicable since CTAS below does implicit commit

```
ALTER TABLE ...    MODIFY PARTITION ...
                   READ ONLY
```

Smart Partial Partition Exchange

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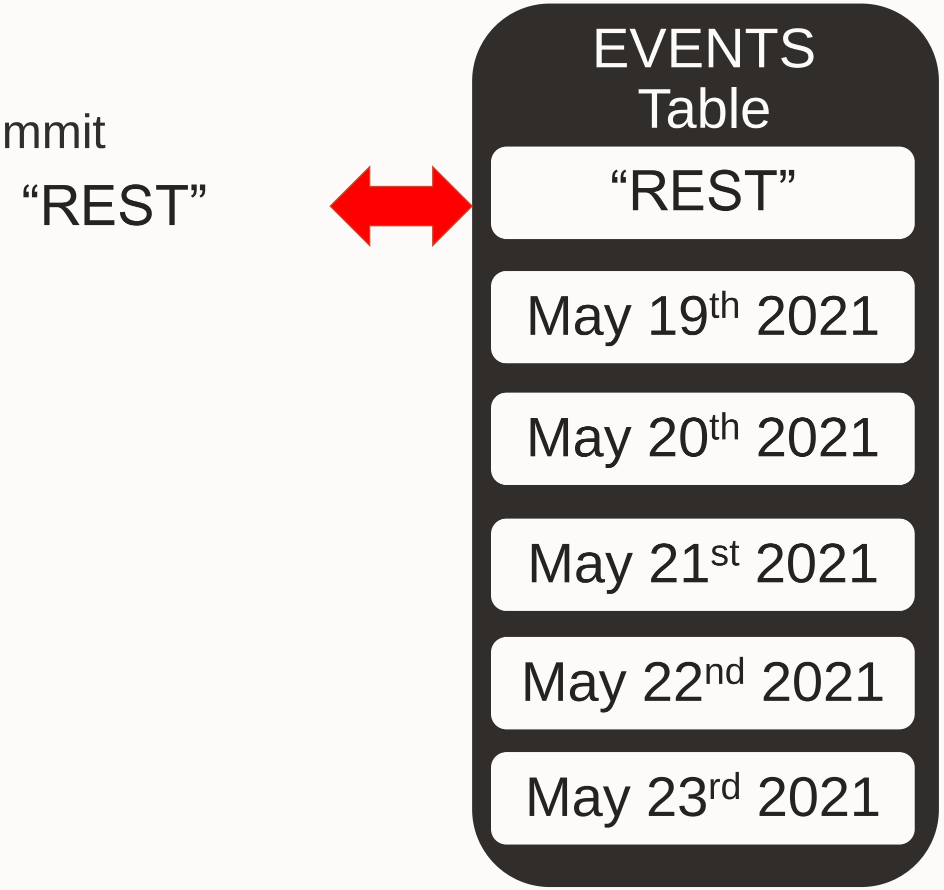
Create table containing remaining data set

- Predicate can be complex and involve multiple tables

```
CREATE TABLE ... AS SELECT WHERE ...
```



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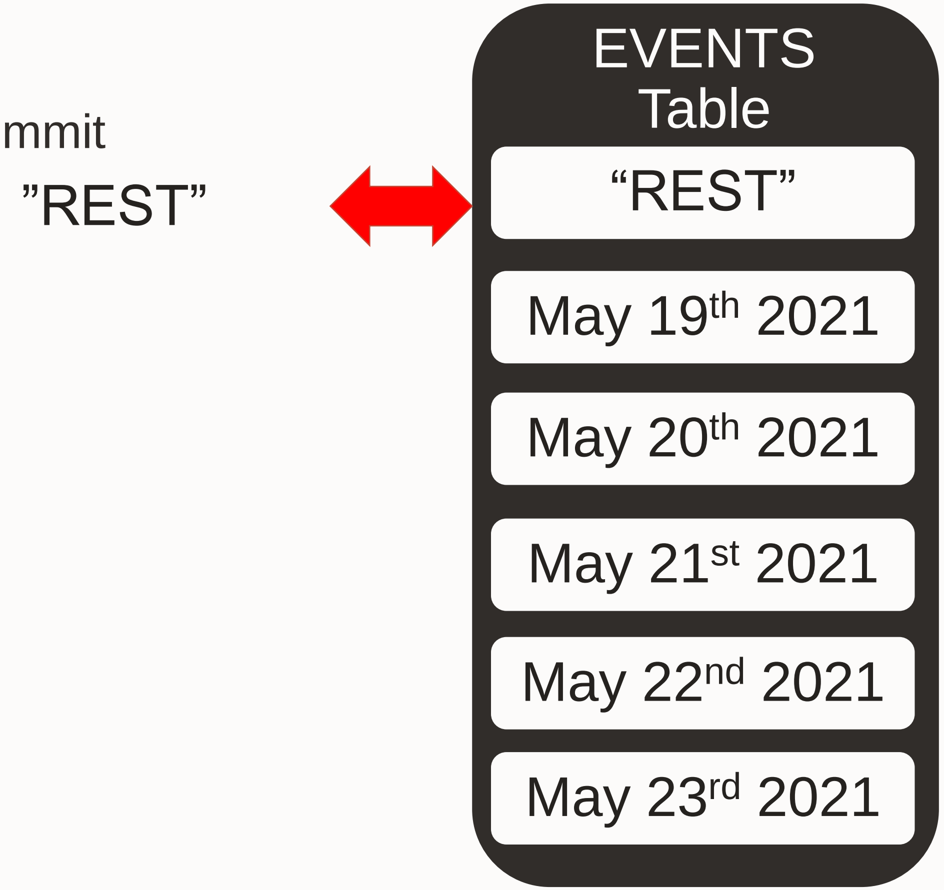
Create necessary indexes, if any



Smart Partial Partition Exchange

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                    READ ONLY
```

Create table containing remaining data set

- Predicate can be complex and involve multiple tables

```
CREATE TABLE ... AS SELECT WHERE ...
```

Create necessary indexes, if any

Exchange partition

```
ALTER TABLE ... EXCHANGE PARTITION ...
```

Exchange in the presence of unique and primary key constraints

Unique Constraints/Primary Keys

Unique constraints are enforced with unique indexes

- Primary key constraint adds NOT NULL to column
- Table can have only one primary key (“unique identifier”)

Partitioned tables offer two types of indexes

- Local indexes
- Global index, both partitioned and non-partitioned

Partition Exchange

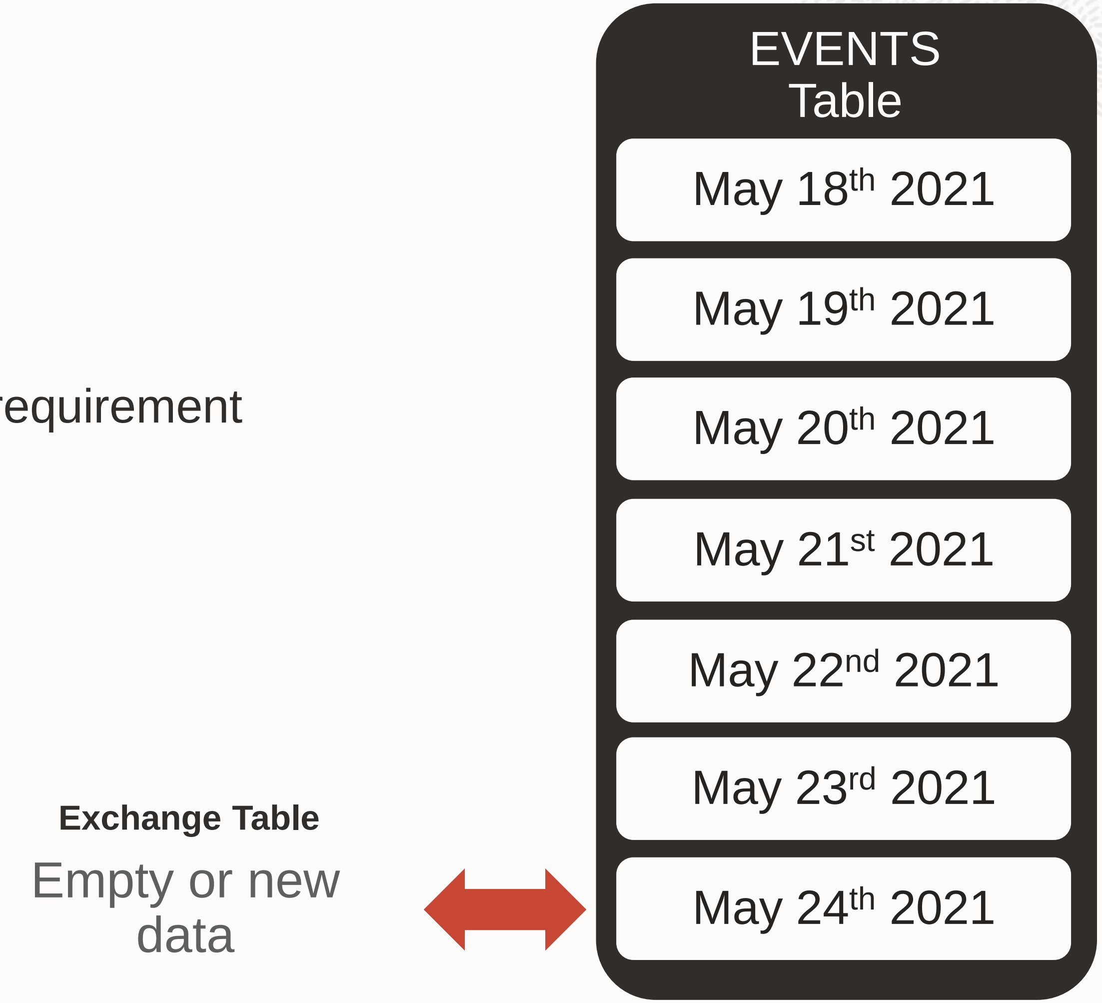
A.k.a Partition Loading and Purging

Remove and add data as metadata-only operation

- Exchange the metadata of partitions

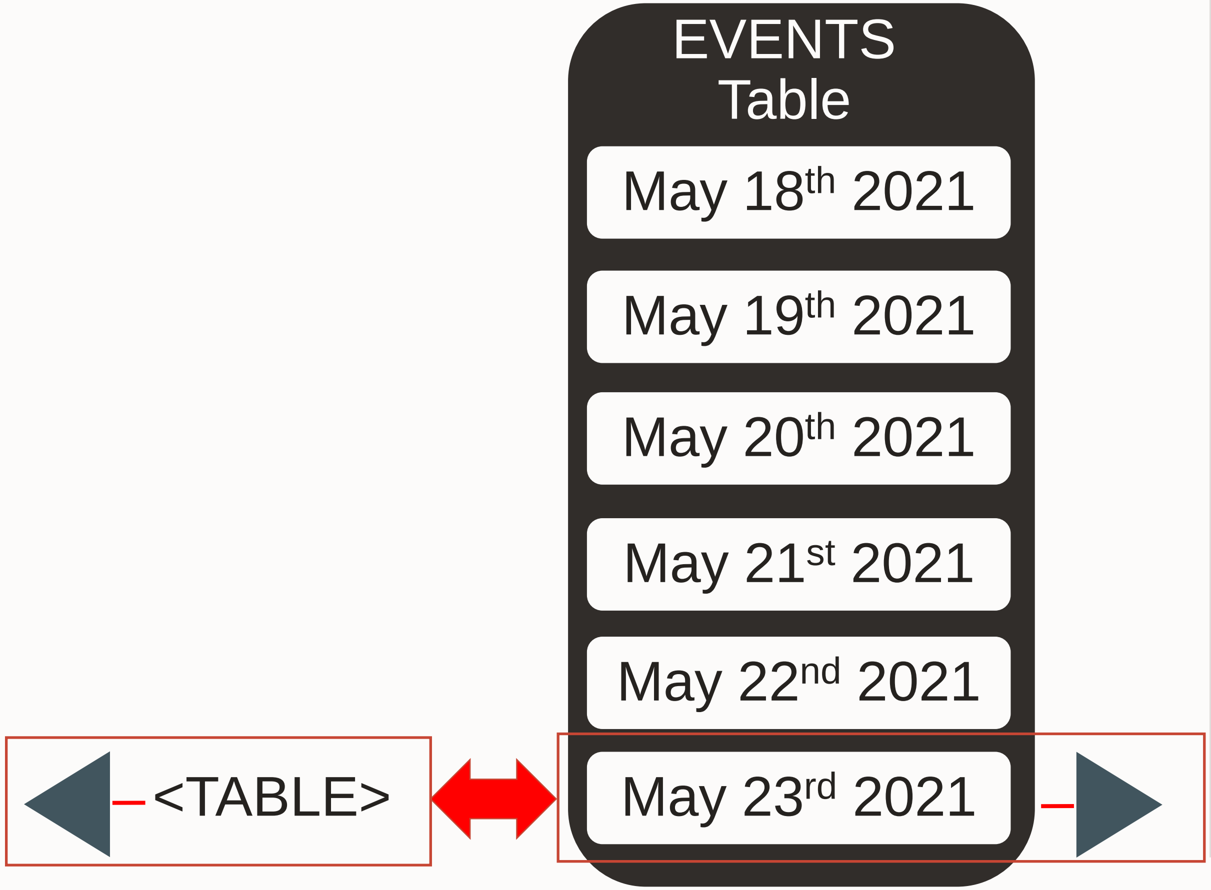
Same logical shape for both tables is mandatory pre-requirement for successful exchange

- Same number and data type of columns
  - Note that column name does not matter
- Same constraints
- Same number and type of indexes



Partition Exchange

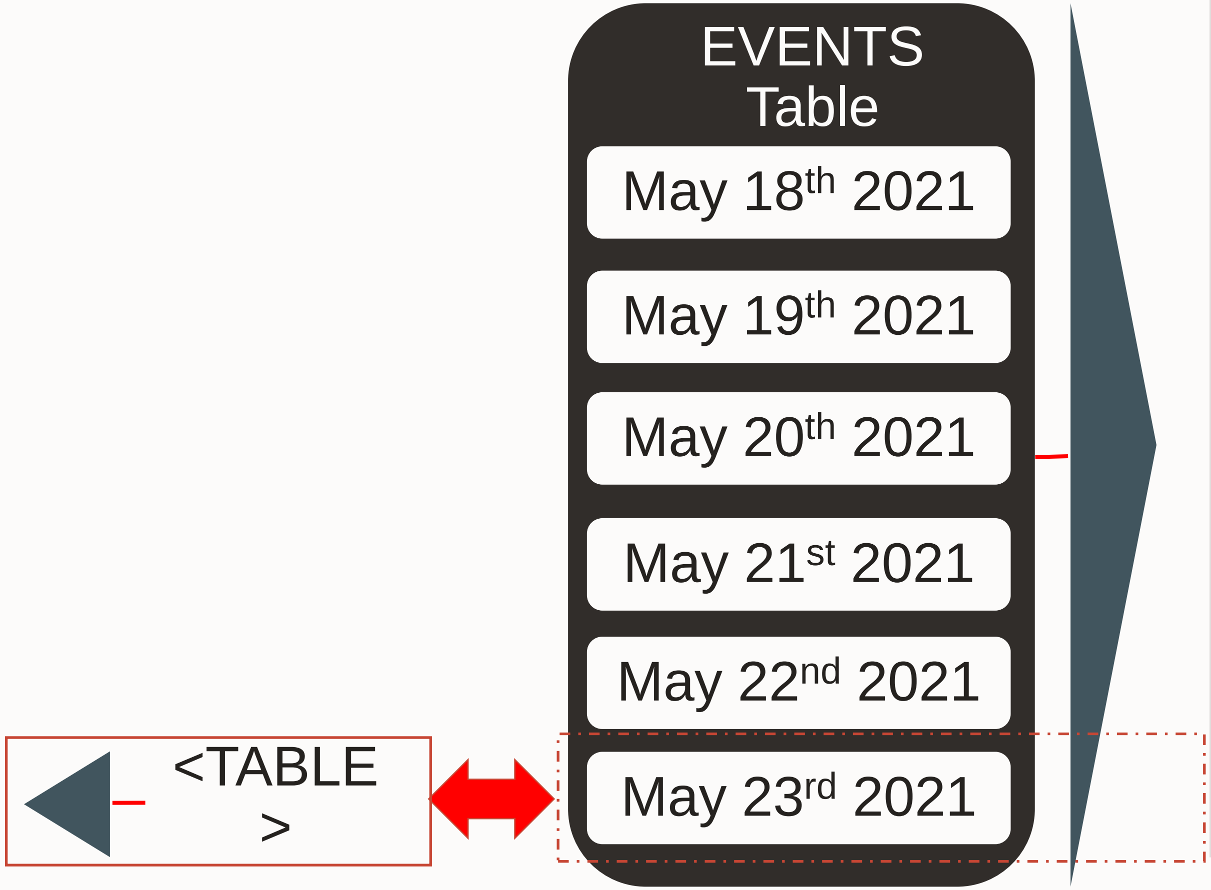
Local Indexes



Any index on the exchange table is equivalent to a local partitioned index

Partition Exchange

Local Indexes



Any index on the exchange table is equivalent to a local partitioned index

What do I do when the PK index on the partitioned table needs global index enforcement?

- Remember the requirement of logical equivalence …

Partition Exchange and PK/Unique Constraint

The Dilemma

Global indexes only exist for a partitioned table

- But I need the index for the exchange table for uniqueness …

Partition Exchange and PK/Unique Constraint

Not Really a Dilemma

Global indexes only exist for a partitioned table

- But I need the index for the exchange table for uniqueness …

Not generically true

- Unique index only needed for enabled constraints
- Enforcement for new or modified data through index probe

Partition Exchange and PK/Unique Constraint

Not Really a Dilemma

Global indexes only exist for a partitioned table

- But I need the index for the exchange table for uniqueness …

Not generically true

- Unique index only needed for enabled constraints
- Enforcement for new or modified data through index probe
- Disabled constraint prevents data insertion

```
SQL> alter table tt add(constraint x unique (col1) disable validate);

Table altered.

SQL> insert into tt values(1,2);
insert into tt values(1,2);
*
ERROR at line 1;
ORA-25128: No insert/update/delete on table with constraint (SCOTT.X)
disabled and validated
```


Partition Exchange and PK/Unique Constraint

The solution

The partitioned target table

- PK or unique constraint that is enforced by global index (partitioned or non-partitioned)

The standalone table to be exchanged ("exchange table")

- Equivalent disabled validated constraint
- No index for enforcement, no exchange problem

Partition Exchange and PK/Unique Constraint

A simple example

```
SQL > CREATE TABLE tx_simple
        (
          TRANSACTION KEY          NUMBER,
          INQUIRY_TIMESTAMP        TIMESTAMP(6),
          RUN_DATE                 DATE
        )
        PARTITION BY RANGE (RUN_DATE)
        (
          PARTITION TRANSACTION_202105 VALUES LESS THAN (TO_DATE(‘20210601’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_202106 VALUES LESS THAN (TO_DATE(‘20210701’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_202107 VALUES LESS THAN (TO_DATE(‘20210801’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_202108 VALUES LESS THAN (TO_DATE(‘20210901’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_202109 VALUES LESS THAN (TO_DATE(‘20211001’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_202110 VALUES LESS THAN (TO_DATE(‘20211101’, ‘yyyymmdd’)),
          PARTITION TRANSACTION_MAX VALUES LESS THAN (MAXVALUE)
        )
      /

Table created.
```


Partition Exchange and PK/Unique Constraint

A simple example

```
SQL > CREATE TABLE tx_simple
  2       (
  3         TRANSACTION_KEY          NUMBER,
  4         INQUIRY_TIMESTAMP        TIMESTAMP(6),
  5         RUN_DATE                 DATE
  6       )
  7       PARTITION BY RANGE (RUN_DATE)
  8       (
  9         PARTITION TRANSACTION_202105 VALUES LESS THAN (TO_DATE('20210601', 'yyyymmdd')),
 10         PARTITION TRANSACTION_202106 VALUES LESS THAN (TO_DATE('20210701', 'yyyymmdd')),
 11         PARTITION TRANSACTION_202107 VALUES LESS THAN (TO_DATE('20210801', 'yyyymmdd')),
 12         PARTITION TRANSACTION_202108 VALUES LESS THAN (TO_DATE('20210901', 'yyyymmdd')),
 13         PARTITION TRANSACTION_202109 VALUES LESS
 14         PARTITION TRANSACTION_202110 VALUES LES
 15         PARTITION TRANSACTION_MAX VALUES LESS T
 16       )
 17    /

Table created.
```

```
SQL > INSERT into tx_simple (
  2       select object_id, LAST_DDL_TIME,
  3          add_months(TO_DATE('20210501', 'yyyymmdd'), mod(OBJECT_ID,
12))
  4       from DBA_OBJECTS
  5       where object_id is not null)
  6    /

73657 rows created.
```

Partition Exchange and PK/Unique Constraint

A simple example

```
SQL > CREATE TABLE tx_simple
        (
          TRANSACTION_KEY         NUMBER,
          INQUIRY_TIMESTAMP       TIMESTAMP(6),
          RUN_DATE                DATE
        )
        PARTITION BY RANGE (RUN_DATE)
        (
          PARTITION TRANSACTION_202105 VALUES LESS THAN (TO_DATE('20210601', 'yyyymmdd')),
          PARTITION TRANSACTION_202106 VALUES LESS THAN (TO_DATE('20210701', 'yyyymmdd')),
          PARTITION TRANSACTION_202107 VALUES LESS THAN (TO_DATE('20210801', 'yyyymmdd')),
          PARTITION TRANSACTION_202108 VALUES LESS THAN (TO_DATE('20210901', 'yyyymmdd')),
          PARTITION TRANSACTION_202109 VALUES LESS
          PARTITION TRANSACTION_202110 VALUES LES
          PARTITION TRANSACTION_MAX VALUES LESS T
        )
```

```
SQL > INSERT into tx_simple (
        select object_id, LAST_DDL_TIME,
          add months(TO_DATE('20210501', 'yyyymmdd'), mod(OBJECT_ID,
12))
```

```
SQL > CREATE UNIQUE INDEX tx_simple_PK ON tx_simple (TRANSACTION_KEY) nologging
              GLOBAL PARTITION BY RANGE (TRANSACTION_KEY) (
              PARTITION P_Max VALUES LESS THAN (MAXVALUE)
              )
      /

Index created.

SQL > ALTER TABLE tx_simple ADD ( CONSTRAINT tx_simple_PK PRIMARY KEY (TRANSACTION_KEY)
        USING INDEX nologging);

Table altered.
```

Partition Exchange and PK/Unique Constraint

A simple example, cont.

```
SQL > create table DAILY_ETL_table
  2     as
  3     select * from tx_simple partition (TRANSACTION_202107);

Table created.

SQL > alter table daily_etl_table add ( constraint pk_etl primary key (transaction_key) disable validate);

Table altered.
```

```
SQL > alter table tx_simple
  2     exchange partition TRANSACTION_202107
  3     with table daily_ETL_table
  4     including indexes
  5     --excluding indexes
  6     WITHOUT VALIDATION
  7     UPDATE GLOBAL INDEXES
  8   /

Table altered.
```


Attribute Clustering and Zone Maps

Introduced in Oracle 12c Release 1 (12.1.0.2)

Exadata and Cloud only

Zone Maps with Attribute Clustering

Attribute Clustering

Orders data so that columns values are stored together on disk

Zone maps

Stores min/max of specified columns per zone

Used to filter un-needed data during query execution

Combined Benefits

Improved query performance and concurrency

- Reduced physical data access
- Significant IO reduction for highly selective operations

Optimized space utilization

- Less need for indexes
- Improved compression ratios through data clustering

Full application transparency

- Any application will benefit

Attribute Clustering

Concepts

Orders data so that it is in close proximity based on selected columns values: “attributes”

Attributes can be from a single table or multiple tables

- e.g. from fact and dimension tables

Benefits

Significant IO pruning when used with zone maps

Reduced block IO for table lookups in index range scans

Queries that sort and aggregate can benefit from pre-ordered data

Enable improved compression ratios

- Ordered data is likely to compress more than unordered data

Attribute Clustering for Zone Maps

Ordered rows

```
ALTER TABLE EVENTS
ADD CLUSTERING BY
LINER ORDER (category);

ALTER TABLE EVENTS
   MOVE;
```

Category	Country
BOYS	AR
BOYS	JP
BOYS	SA
BOYS	US
GIRLS	AR
GIRLS	JP
GIRLS	SA
GIRLS	US
MEN	AR
MEN	JP
MEN	SA
MEN	US
WOMEN	AR
WOMEN	JP
WOMEN	SA
WOMEN	US

Ordered rows containing category values BOYS, GIRLS and MEN.

Zone maps catalogue regions of rows, or zones, that contain particular column value ranges.

- By default, each zone is up to 1024 blocks.

For example, we only need to scan this zone if we are searching for category “GIRLS”. We can skip all other zones.

Attribute Clustering
Basics

Two types of attribute clustering

- LINEAR ORDER BY
  - Classical ordering
- INTERLEAVED ORDER BY
  - Multi-dimensional ordering

Simple attribute clustering on a single table

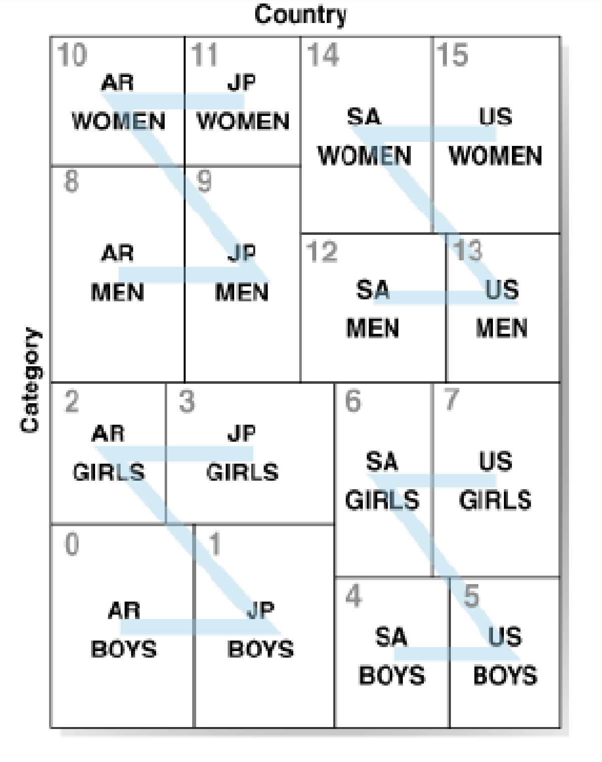
Join attribute clustering

- Cluster on attributes derived through join of multiple tables
  - Up to four tables
  - Non-duplicating join (PK or UK on joined table is required)

Attribute Clustering
Example

LINEAR ORDER (category, country) vs INTERLEAVED ORDER (category, country)

Category	Country
BOYS	AR
BOYS	JP
BOYS	SA
BOYS	US
GIRLS	AR
GIRLS	JP
GIRLS	SA
GIRLS	US
MEN	AR
MEN	JP
MEN	SA
MEN	US
WOMEN	AR
WOMEN	JP
WOMEN	SA
WOMEN	US



Attribute Clustering

Basics

Clustering directive specified at table level

- ALTER TABLE ... ADD CLUSTERING ...

Directive applies to new data and data movement

Direct path operations

- INSERT APPEND, MOVE, SPLIT, MERGE
- Does not apply to conventional DML

Can be enabled and disabled on demand

- Hints and/or specific syntax

Zone Maps

Concepts and Basics

Stores minimum and maximum of specified columns

- Information stored per zone
- [Sub]Partition-level rollup information for partitioned tables for multi-dimensional partition pruning

Analogous to a coarse index structure

- Much more compact than an index
- Zone maps filter out what you don’t need, indexes find what you do need

Significant performance benefits with complete application transparency

- IO reduction for table scans with predicates on the table itself or even a joined table using join zone maps (a.k.a. “hierarchical zone map”)

Benefits are most significant with ordered data

- Used in combination with attribute clustering or data that is naturally ordered

Zone Maps
Basics

Independent access structure built for a table

- Implemented using a type of materialized view
- For partitioned and non-partitioned tables

One zone map per table

- Zone map on partitioned table includes aggregate entry per [sub]partition

Used transparently

- No need to change or hint queries

Implicit or explicit creation and column selection

- Through Attribute Clustering: CREATE TABLE … CLUSTERING
- CREATE MATERIALIZED ZONEMAP … AS SELECT …

Attribute Clustering With Zone Maps

CLUSTERING BY LINEAR ORDER (category, country)

Zone map benefits are most significant with ordered data

- Pruning only when predicates are specified on ordering columns
- No pruning when ordered columns are skipped

Category	Country
BOYS	AR
BOYS	JP
BOYS	SA
BOYS	US
GIRLS	AR
GIRLS	JP
GIRLS	SA
GIRLS	US
MEN	AR
MEN	JP
MEN	SA
MEN	US
WOMEN	AR
WOMEN	JP
WOMEN	SA
WOMEN	US

Pruning with:

```
SELECT ..
FROM table
WHERE category =
   ‘BOYS’;
```

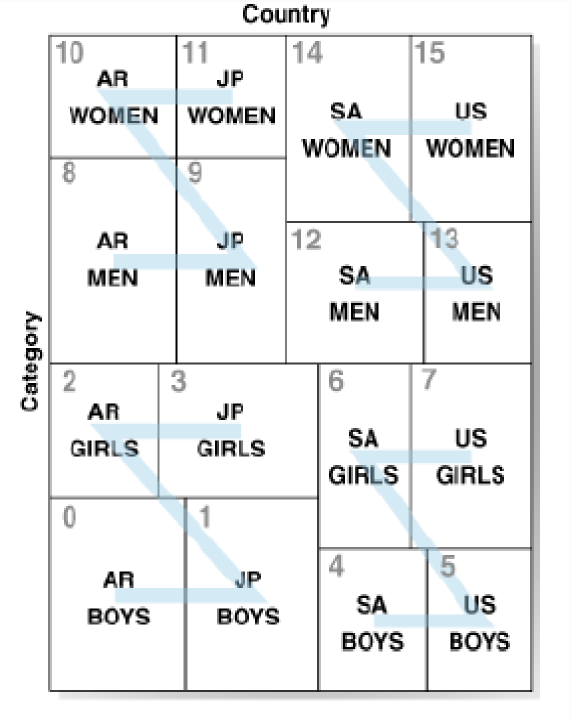
```
SELECT ..
FROM table
WHERE category =
   ‘BOYS’;
AND country = ‘US’;
```


Attribute Clustering With Zone Maps

CLUSTERING BY INTERLEAVED ORDER (category, country)

Zone map benefits are most significant with ordered data

- Less efficient pruning on all ordered columns
- Pruning with trailing ordered columns



Pruning with:

```
SELECT ..
FROM table
WHERE category =
   'BOYS';
```

```
SELECT ..
FROM table
AND country = 'US';
```

```
SELECT ..
FROM table
WHERE category =
   'BOYS'
AND country = 'US';
```


Zone Maps
Staleness

DML and partition operations can cause zone maps to become fully or partially stale

- Direct path insert does not make zone maps stale

Single table 'local' zone maps

- Update and insert marks impacted zones as stale (and any aggregated partition entry)
- No impact on zone maps for delete

Joined zone map

- DML on fact table equivalent behavior to single table zone map
- DML on dimension table makes dependent zone maps fully stale

Zone Maps
Refresh

Incremental and full refresh, as required by DML

- Zone map refresh does require a materialized view log
  - Only stale zones are scanned to refresh the MV
- For joined zone map
  - DML on fact table: incremental refresh
  - DML on dimension table: full refresh

Zone map maintenance through

- DBMS_MVIEW.REFRESH()
- ALTER MATERIALIZED ZONEMAP <xx> REBUILD;

Example – Dimension Hierarchies

ORDERS

id	product_id	location_id	amount
1	3	23	2.00
2	88	55	43.75
3	31	99	33.55
4	33	62	23.12
5	21	11	38.00
6	33	21	5.00
7	44	71	10.99

Note: a zone typically contains many more rows than show here. This is for illustrative purposes only.

LOCATIONS

location_id	State	county
23	California	Inyo
102	New Mexico	Union
55	California	Kern
1	Ohio	Lake
62	California	Kings

```
CREATE TABLE orders ( ... )
CLUSTERING orders
JOIN locations ON (orders.location_id = locations.location_id)
BY INTERLEAVED ORDER (locations.state, locations.county)
WITH MATERIALIZED ZONEMAP …
```


Example – Dimension Hierarchies

ORDERS

id	product_id	location_id	amount
1	3	23	2.00
2	88	55	43.75
3	31	99	33.55
4	33	62	23.12
5	21	11	38.00
6	33	21	5.00
7	44	71	10.99

Scan Zone

LOCATIONS

location_id	State	county
23	California	Inyo
102	New Mexico	Union
55	California	Kern
1	Ohio	Lake
62	California	Kings

```
SELECT SUM(amount)
FROM orders
JOIN locations ON (orders.location.id = locations.location.id)
WHERE state = 'California';
```

Note: a zone typically contains many more rows than show here.
This is for illustrative purposes only.

Example – Dimension Hierarchies

ORDERS

id	product_id	location_id	amount
1	3	23	2.00
2	88	55	43.75
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Scan Zone

LOCATIONS

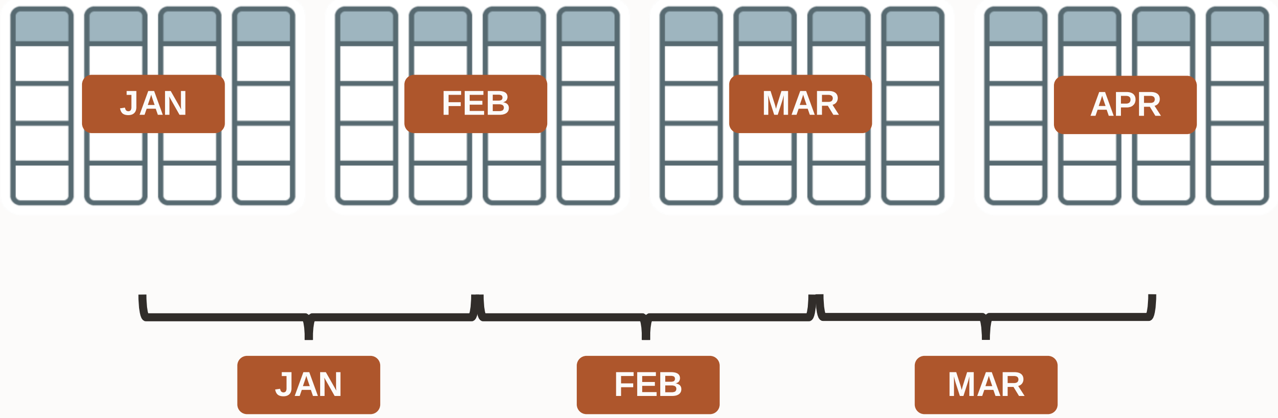
location_id	State	county
23	California	Inyo
102	New Mexico	Union
55	California	Kern
1	Ohio	Lake
62	California	Kings

```
SELECT SUM(amount)
FROM orders
JOIN locations ON (orders.location.id = locations.location.id)
WHERE state = 'California'
AND county = 'Kern';
```

Note: a zone typically contains many more rows than show here.
This is for illustrative purposes only.

Zone Maps and Partitioning

Partition Key:
ORDER_DATE



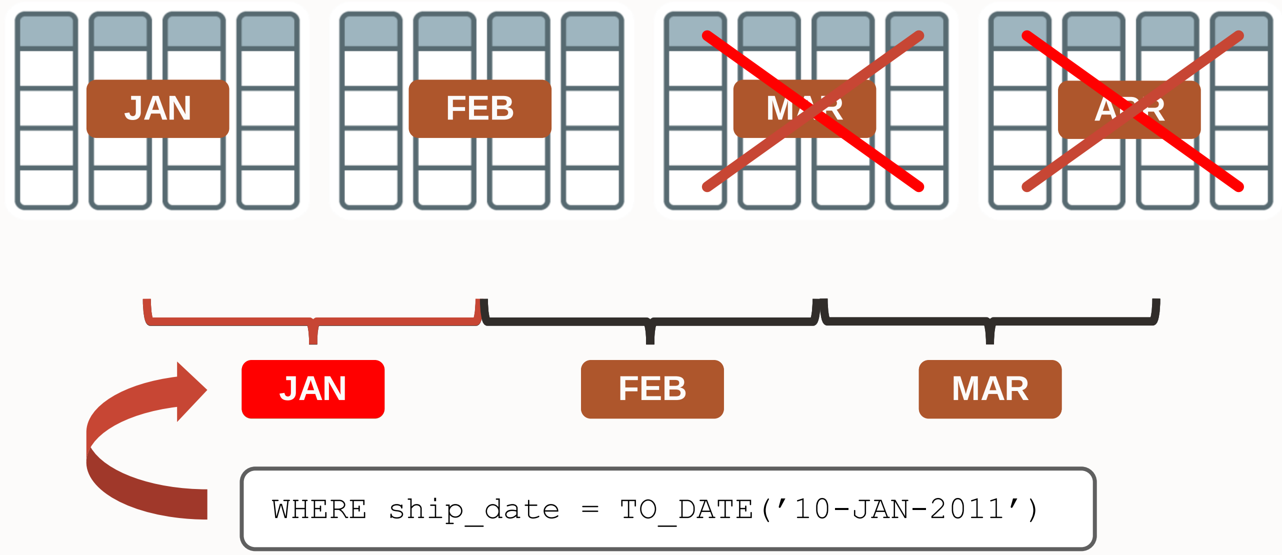
Zone map column
SHIP_DATE
correlates with
partition key
ORDER_DATE

Zone map:
SHIP_DATE

Zone maps can prune partitions for columns that are not included in the partition (or subpartition) key

Zone Maps and Partitioning

Partition Key:
ORDER_DATE



MAR and APR partitions are pruned

Zone map:
SHIP_DATE

Zone maps can prune partitions for columns that are not included in the partition (or subpartition) key

Zone Maps and Storage Indexes

Attribute clustering and zone maps work transparently with Exadata storage indexes

- The benefits of Exadata storage indexes continue to be fully exploited

In addition, zone maps (when used with attribute clustering)

- Enable additional and significant IO optimization
  - Provide an alternative to indexes, especially on large tables
  - Join and fact-dimension queries, including dimension hierarchy searches
  - Particularly relevant in star and snowflake schemas
- Are able to prune entire partitions and sub-partitions
- Are effective for both direct and conventional path reads
- Include optimizations for joins and index range scans
- Part of the physical database design: explicitly created and controlled by the DBA

Our mission is to help people see data in new ways, discover insights, unlock endless possibilities.