MySQL Partitioning

When, Why and How

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Agenda

- What is Partitioning?
- Why Partition?
- Partitioning 101
  - Types of partitioning in MySQL
  - Managing Partitions
- Partitions and Indexes
- Short Term Rolling Data
- Long Term Rolling Data
- Maintenance by Partition
- Partition Evolution

What is Partitioning?

- Consider a set; 1-10
- Inserted order; 1,9,2,3,8,5,7,6,4
  - How to speed it up, Indexes
    - 1,9,2,3,8,5,7,6,4
    - Easy to do, but what about large datasets, data operations and reporting queries
  - How to speed it up Partitions
    - Map similar groupings to one location
    - In this case, we define a partition for 1-3, 4-6, 7-9 and 10. Each value is stored in its respective set or partition.

Indexing Example		**Partitioning Example**	
Record	Index	Record	Partition Assignment
1	1, 1	1	**P1**
9	2, 9	2	**P1**
2	3, 2	3	**P1**
3	4, 3	4	P2
8	5, 8	5	P2
5	6, 5	6	P2
7	7, 7	7	**P3**
6	8, 6	8	**P3**
4	9, 4	9	**P3**
10	10, 10	10	P4

What is Partitioning?

- Partitioning divides a table into smaller logical parts called “partitions”; Still looks like a table.
- Partitions are defined in a CREATE or ALTER

```
CREATE TABLE Sales ( saleDate date, ... )
        PARTITION BY KEY(saleDate)
        PARTITIONS 16 ;
```

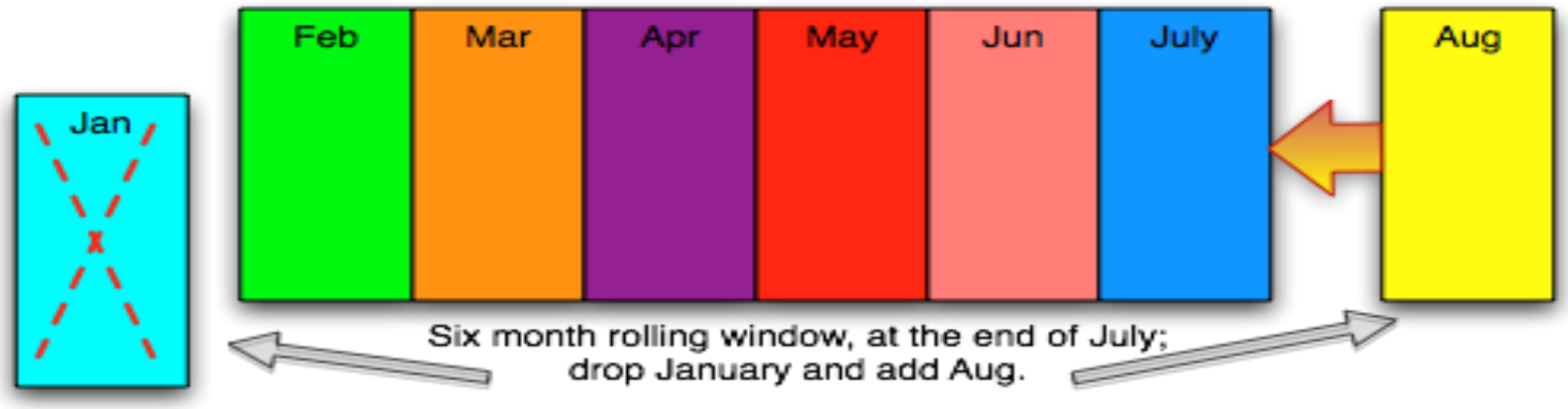
- MySQL knows how the table was divided into smaller parts and uses this information to speed up queries
- Operations on many smaller parts are often faster than on one big table
  - –Optimize
  - –Create INDEX, etc.

The way of Partitions

When and Why should you Partition

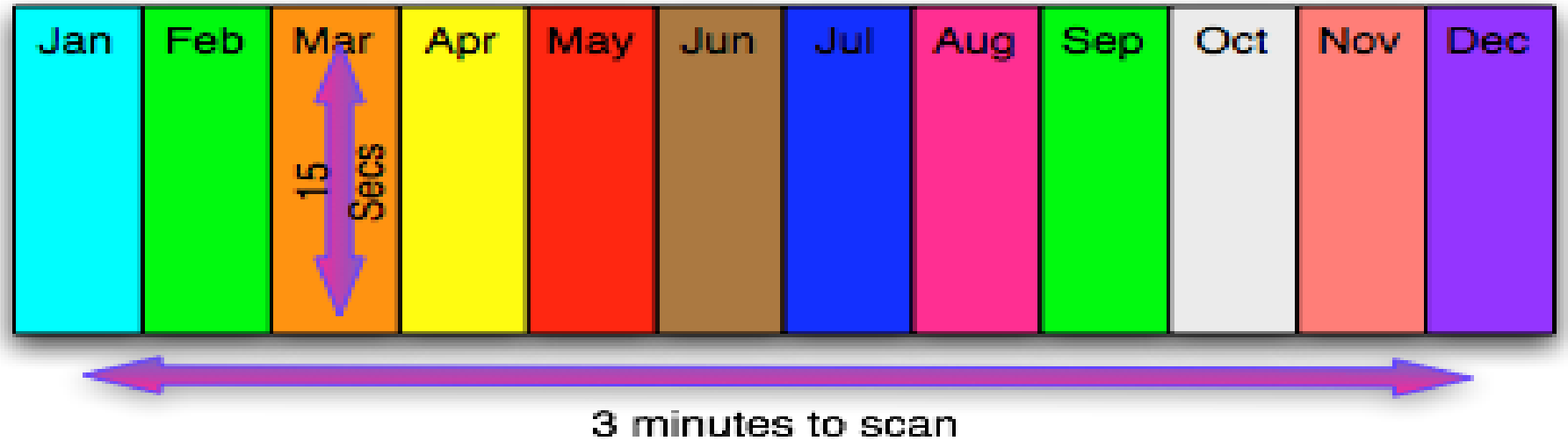
1) Deleting Data by Partition

- Partitions can support deleting data by dropping a partition
  - If you insert 1,000,000 rows a day, eventually you need to delete 1,000,000 rows a day
- Only works with **Range** and **List** partitioning
- Very useful for rolling date/time range
- Can be very useful even for small increments, i.e.1 hour
- Very fast, deleting a file, can be ~ 1-2 Sec



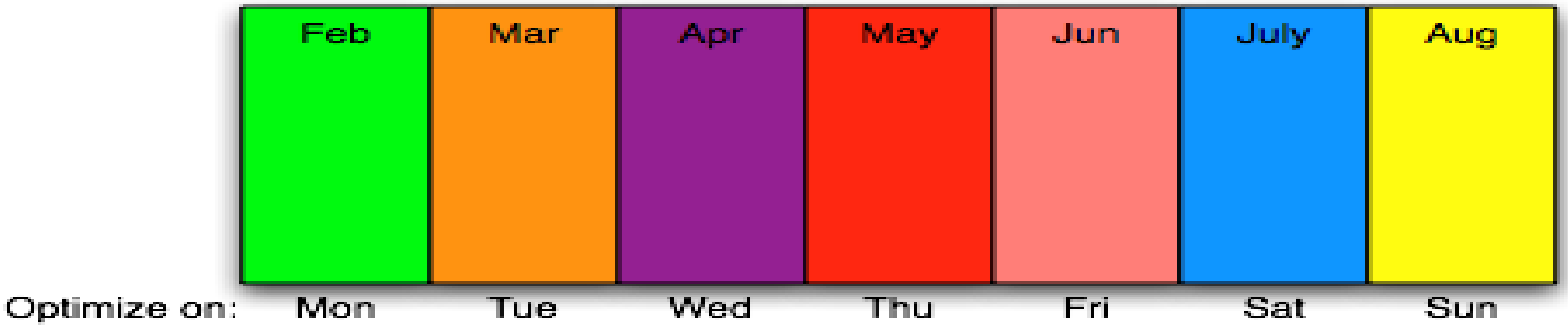
2) Faster non-index Data Access -Pruning

- The MySQL optimizer is aware of the partitioning expression and can eliminate partitions to scan when the columns used in the partitioning expression are in the queries where condition
- Reduce or even **eliminate** indexes (still need indexes for partition definition)!



3) Some operations are faster

- Adding indexes can be faster
- Optimizations can be done by partition
  - If data is only being added to one partition then you can OPTIMIZE *only that partition* instead of running OPTIMIZE on the whole table



Partitioning Types

Types of MySQL Partitioning

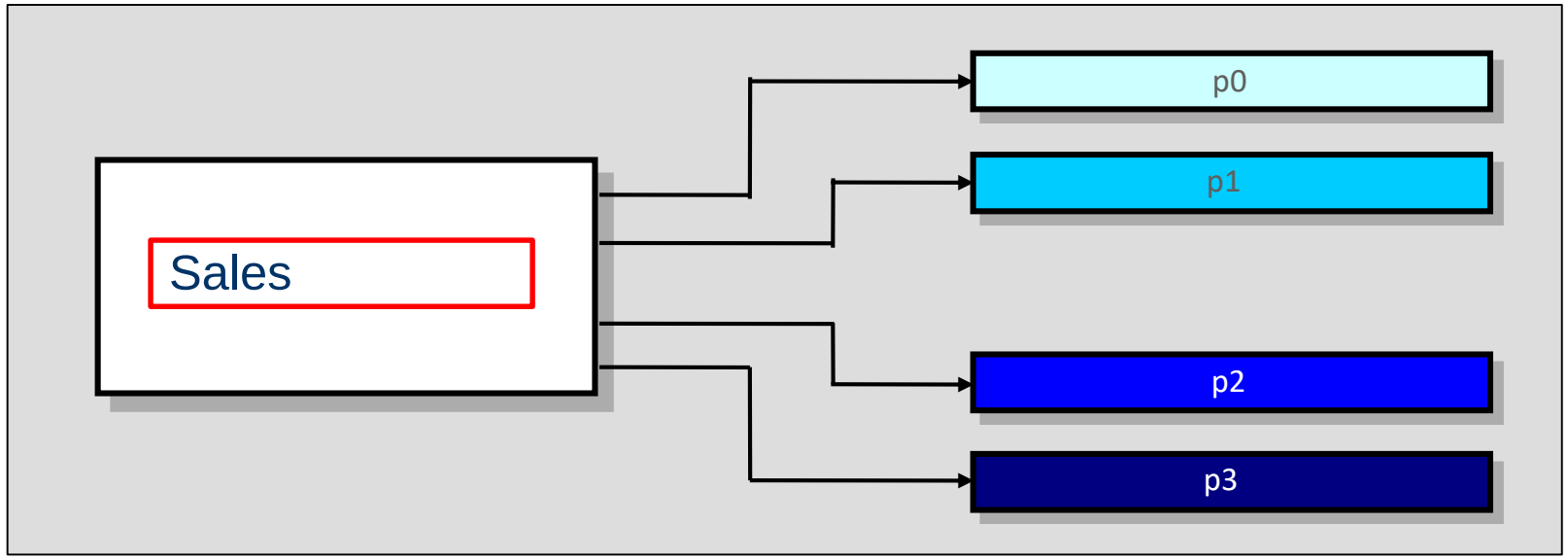
- **Key/Hash - Not useful for Deleting by partition**
  - **Key**(***column list***) - Uses internal hash function
  - **Hash**(**INT *expr***) - Mod on user expression
  - Both very easy to define and maintain

Types of MySQL Partitioning

- **List/Range - Supports Deleting by Partition**
  - **List**(**INT *expr***) - IN list partitioning
    - List of IN (A, ..., N) expressions
  - **Range**(**INT *expr***) - Range expressions
    - list of less than expressions
- **List** and **Range** can be sub-partitioned by **Key** or **Hash**

Hash Partitioning

- Easy to define like key, but supports expressions
- `CREATE TABLE Sales ( SaleDate date, ... )`
  `PARTITION BY HASH(MONTH(SaleDate))`
  `PARTITIONS 12 ;`

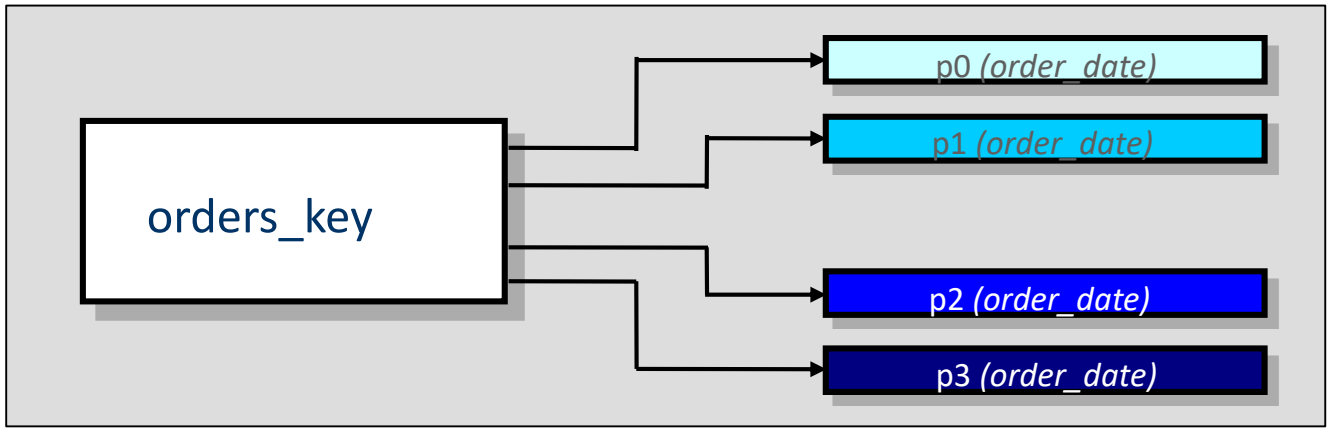


http://dev.mysql.com/doc/refman/5.5/en/partitioning-hash.html

Key Partitioning

- Uses internal hash function
- `CREATE TABLE Sales ( order_date date, ... )`

```
    PARTITION BY KEY(order_date)
    PARTITIONS 4 ;
```



http://dev.mysql.com/doc/refman/5.5/en/partitioning-key.html

Partitioning Expressions

- **HASH**, **RANGE** and **LIST** can use expressions
- Expression **must** return an ***integer*** (**5.1 only**) or NULL and can only use certain ***built-in functions***
  - ABS, CEILING, DAY, DAYOFMONTH, DAYOFWEEK,
  - DAYOFMONTH, DATEDIFF, EXTRACT, FLOOR, HOUR,
  - MICROSECEND, MINUTE, MOD, MONTH, QUARTER, SECOND,
  - TIME_TO_SEC, TO_DAYS, WEEKDAY, YEAR, YEARWEEK

Partitioning Expressions

- Not Allowed!
  - nested function calls, declared or user variables, stored functions or UDFs!

    http://dev.mysql.com/doc/refman/5.6/en/partitioning-limitations-functions.html

Managing KEY and HASH Partitions

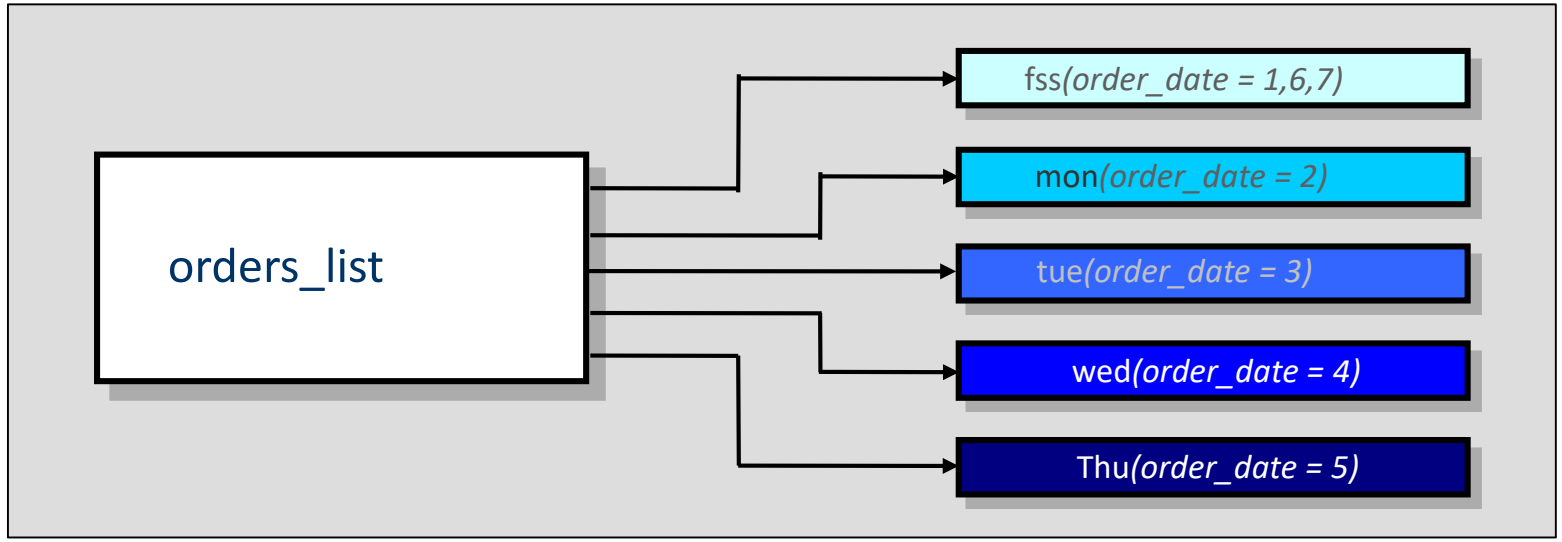
- Both operations change the number of partitions, ***but keep the same number of records***
- ADD - Adds more partitions and redistribute the data
  - `ALTER TABLE Sales ADD PARTITION PARTITIONS 4 ;`
  - Adds 4 more partitions to `Sales`
  - If `Sales` had 16 partitions before, it now has 20

Managing KEY and HASH Partitions

- COALESCE - Merges partitions
  - `ALTER TABLE Sales COALESCE PARTITION 6 ;`
  - Removes 6 partitions from `Sales`
  - If `Sales` had 16 partitions before, it now has 10

Each partition is defined by an IN LIST

```
CREATE TABLE orders_list (
     order_id int,
     order_date date, ...)
PARTITION BY LIST(DAYOFWEEK(order_date)) (
 PARTITION fss VALUES IN (1,6,7),PARTITION mon VALUES IN (2),
 PARTITION tue VALUES IN (3),PARTITION wed VALUES IN (4),
 PARTITION thr VALUES IN (5));
```



Range Partitioning

- Ranges **must be defined in order, lowest to highest**
- Cannot insert a record outside of the defined ranges
- Ranges must not overlap
- Note that you cannot add a value larger than the highest range
  - Use less than (maxval).

Range Partitioning

- Example

```
CREATE TABLE Sales ( id int, saleDate date, ... )
  PARTITION BY RANGE(YEAR(SaleDate)) (
  PARTITION p199X VALUES LESS THAN (2000),
  PARTITION p2003 VALUES LESS THAN (2004),
  ...
  PARTITION p2007 VALUES LESS THAN (2008),
  PARTITION p2008 VALUES LESS THAN (2009),
  PARTITION p2009 VALUES LESS THAN (2010)
  );
```

Managing List and Range Partitions

- **Add** - Add empty partitions

```
ALTER TABLE Sales ADD PARTITION (
    PARTITION p2011 VALUES IN (2011) ) ;
```

- **Drop** - Deletes the data in the partitions

–Very fast!

–Requires DROP privilege

–Number rows dropped ***is not*** returned by server!

```
ALTER TABLE Sales DROP PARTITION p2003 ;
```

Managing List and Range Partitions

- **Reorganize** - Change the partitioning without losing data
  - Can be used to split, merge, or change all partitions
  - Reorganizes the data into the newly defined partitions

```
ALTER TABLE geoL REORGANIZE
    PARTITION p2002,p2004,p2003 INTO (
    PARTITION p20024 VALUES IN (2002,2003,2004)) ;
```

Rebuilding Partitions

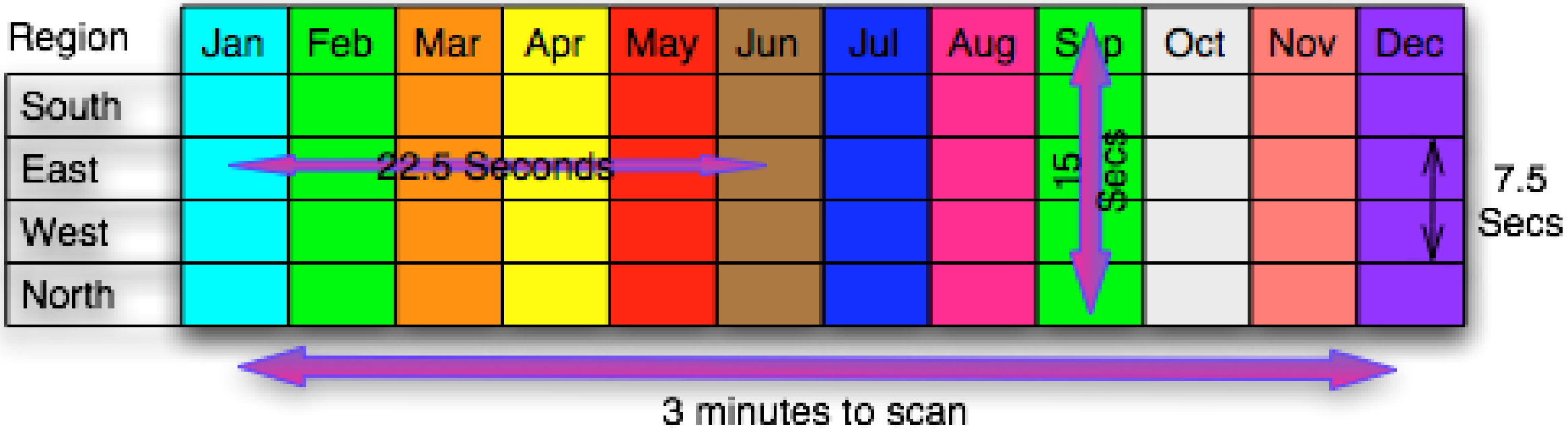
- All Work with Partitioned tables
  - `REBUILD, CHECK, OPTIMIZE, ANALYZE and REPAIR`
- Examples:
  - `ALTER TABLE Sales REBUILD PARTITION P1,P2 ;`
  - `ALTER TABLE Inv OPTIMIZE PARTITION I4 ;`

Rebuilding Partitions

- Smaller partitions make the above operations faster
  - Original Table 10 minutes
  - 16 way Partitioned table might be 10-15 seconds per partition

Sub-partitioning

- Range and List partitioning can be sub-partitioned with **key** and **hash**
- Range by Month sub-partitioned by region



Pruning

MySQL can handle lots of data, use it in smaller chunks

Partition pruning

- Pruning happens when the MySQL optimizer *only* references partitions needed for a particular query
  - Optimizer's partition pruning mechanism provides performance increase
  - *"Do not scan partitions where there can be no matching values."*

Partition pruning

- Example of **RANGE** pruning
  - Using the **orders_range** table, with the following partitions

```
+----------------+-----------------------------+
| PARTITION_NAME | PARTITION_DESCRIPTION       |
+----------------+-----------------------------+
| p0             | < 10000                     |
| p1             | < 20000                     |
| p2             | < 30000                     |
| p3             | < 40000                     |
| p4             | < 50000                     |
+----------------+-----------------------------+
```

Partition pruning example

```
mysql> EXPLAINSELECT * FROM orders_range
  -> WHERE id > 19997 AND id < 20003  PARTITIONS \G
    *************************** 1. row ***************************
               id: 1
      select_type: SIMPLE
            table: orders_range
       partitions: p1,p2
             type: system
    possible_keys: PRIMARY
              key: PRIMARY
          key_len: 4
              ref: NULL
             rows: 2
            Extra:
    1 row in set (0.06 sec)
```

- The partitions **p0**, **p3**, and **p4** are not scanned since they do not contain any of the values from the range of the query

Unique Indexes and Partitioning

- Every column used in a partitioning expression for a table ***must*** be part of every unique key on that table
  - This does not mean you must have unique keys
  - If you do, then every one of them must include all of the values used in the partitioning expression!

Unique Indexes and Partitioning

- Partitioning column(s) can appear anywhere in the unique index:

```
CREATE TABLE t1 (
    col1 INT NOT NULL,
    col2 INT NOT NULL,
      col3 INT NOT NULL,
    col4 INT NOT NULL,
    UNIQUE KEY (col1, col2, col3) )
PARTITION BY HASH(col3)
PARTITIONS 4;
```

Non-Unique Indexes

- You can always have non-unique indexes on a partitioned table.
- The partition engine will execute a separate *non-parallel* index lookup ***on each partition !***

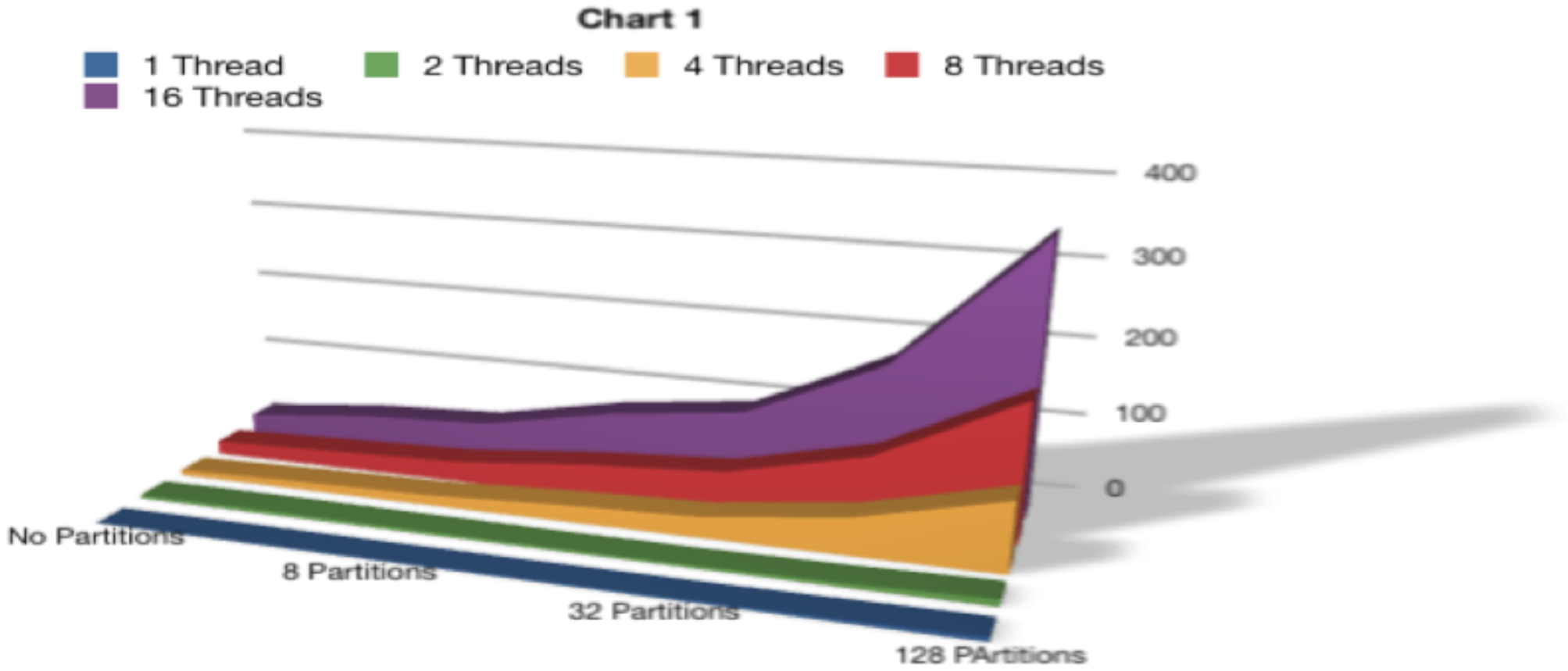
- Performance may be OK with a very small number (4) of partitions, but gets really bad with large numbers of partitions
- If you must have non-unique indexes, keep the number of partitions low (<16)

Multi-Query Non-Unique Index Performance with Partitions Table
(Simple index scan of ~1000 records on laptop)

Column1	1 Thread	2 Threads	4 Threads	8 Threads	16 Threads
No Partitions	1	4	7	18	28
4 Partitions	1	5	11	22	44
8 Partitions	1	4	13	27	51
16 Partitions	2	4	21	43	83
32 Partitions	2	4	27	53	102
64 Partitions	4	5	49	92	180
128 Partitions	6	9	91	180	348

Multi-Query Non-Unique Index Performance with Partitions Chart

```
select count(*) from geo where population between 1100000 and 1500000
```



Indexes and Partitioning

- A well designed partitioned table has few or even **NO** indexes!
  - ***Should always have less than the non-partitioned table!***

- Need to re-design indexes!
- Too many partitions over 124 start to really slow down non-unique index lookups

Data Rolling

Short Term Rolling Data

- **Goal:**
  - Reduce or eliminate **delete overhead**
- **When to Use:**
  - Data only needs to be kept for a few hours or days
  - Not a lot of data, indexes work fine for lookups
  - It's hard to balance the deletes against other operations

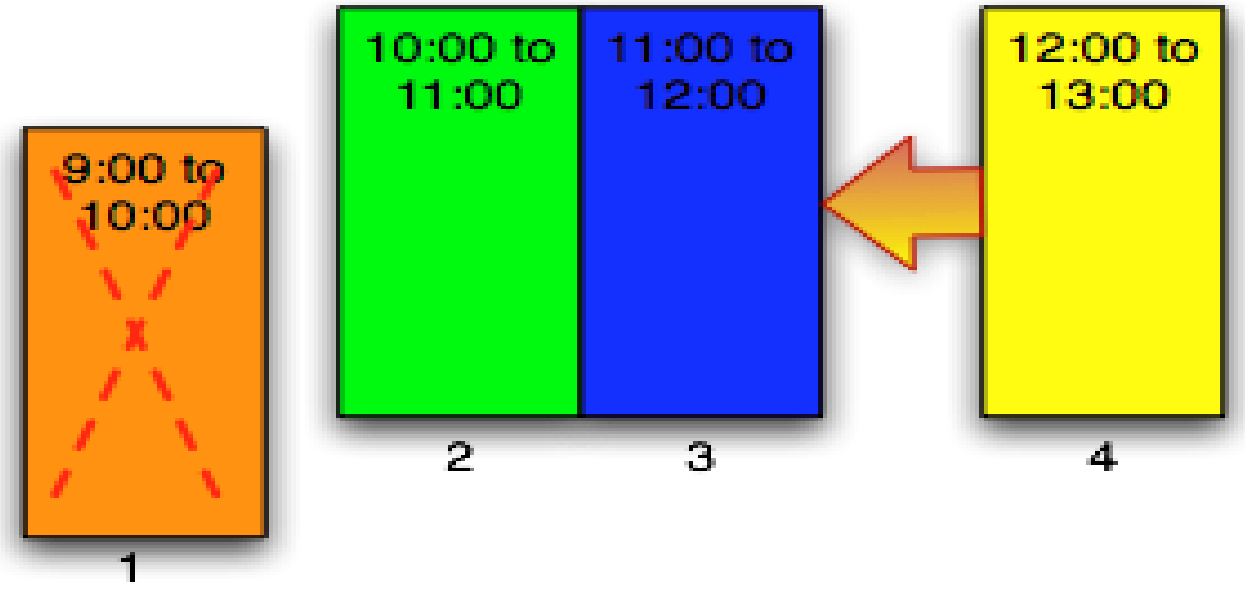
Short Term Rolling Data

- **Steps**:
  - Create a table (**LIST** or **RANGE**) with at least three partitions
  - Let partitions 1 and 2 fill
  - Drop part 1 and add part 3

- Goal: **not for select query performance**, only for **fast deletes**

Short Term Rolling Data

- Example: Session data is only needed for 1 hour after it is created.
  - If you create 10,000 sessions an hour you also need to delete 10,000 session an hour.
- Range Partition with hourly
- partitions on “CreateTime”



Short Term Rolling

- Table:

```
CREATE TABLE session (
    CreateTime time,
    SessionData varchar(2048) )
PARTITION BY LIST (hour(CreateTime))(
     PARTITION p09 VALUES IN (9),
     PARTITION p10 VALUES IN (10),
     PARTITION p11 VALUES IN (11) ) ;
```

Short Term Rolling

- Add a partition for the 12:00 to 13:00 Sessions

```
alter table session add partition (
    partition p12 values in (12) ) ;
```

- Drop the 9:00 to 10:00 Sessions

```
alter table session drop partition p09 ;
```

Long Term Rolling Data

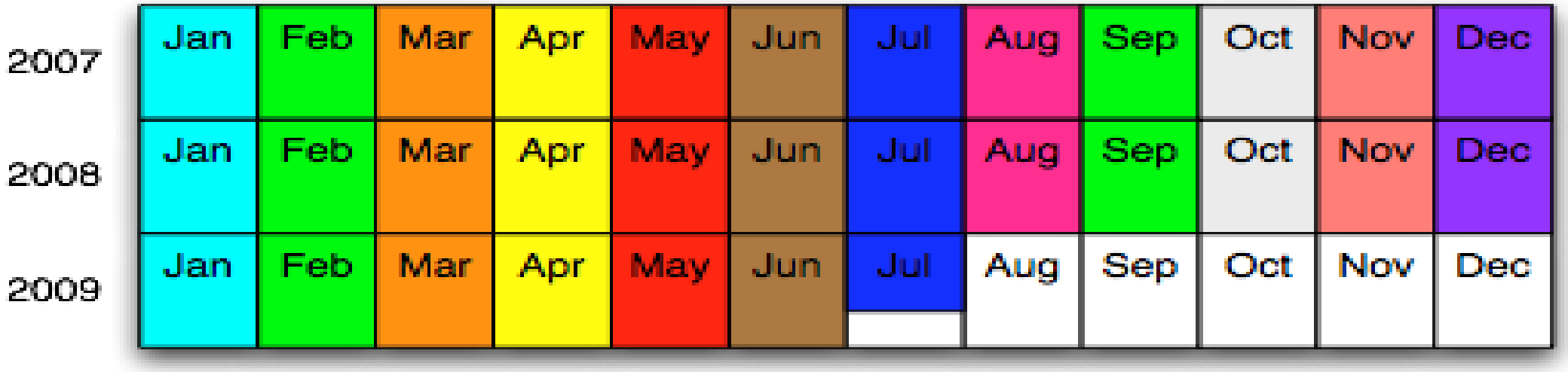
- **Goals:**
  - ***Reduce optimize and other maintenance overhead***
  - ***Eliminate delete overhead***
  - Speed up selects and inserts
- **Steps:**
  - Partition the table into many (usually 32+) partitions
  - Roll N partitions out for each N you add.

Long Term Rolling Data

- **When to use:**
  - Very large tables 100 GB or more, **too big for cache**
  - **date column** or similar to partition on
  - Most of your queries filter on the partitioning column
  - Most queries currently do **large index scans**
  - Inserts are getting too slow
  - **Optimize, add index**, etc. are taking far too long

Long Term Rolling Data

- More traditional Data Warehouse usage
- Avoid Index = Partitioning column
- Only the active month needs optimization, etc.
- Data can be deleted by month, quarter, or year



Long Term Rolling Data

```
CREATE TABLE Sales (
       salesDate    TIMESTAMP,
       storeID      smallint,
       regionID     tinyint,
       amount       decimal(10,2)
)
PARTITION BY RANGE ( UNIX_TIMESTAMP(SalesDate) ) (
    PARTITION p200701 VALUES LESS THAN ( UNIX_TIMESTAMP('2007-02-01 00:00:00') ),
    PARTITION p200702 VALUES LESS THAN ( UNIX_TIMESTAMP('2007-03-01 00:00:00') ),
    ...
    PARTITION p200911 VALUES LESS THAN ( UNIX_TIMESTAMP('2009-12-01 00:00:00') ),
    PARTITION p200912 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-01-01 00:00:00') )
);
```

Long Term Rolling Data

- Add new partitions

```
alter table Sales add partition (
  PARTITION p201001 VALUES LESS THAN ( UNIX_TIMESTAMP('2010-02-01 00:00:00')),
  ...
  PARTITION p201012 VALUES LESS THAN ( UNIX_TIMESTAMP('2011-01-01 00:00:00')) ) ;
```

- Drop old partitions for Jan 2007 to Dec 2007

```
alter table sales drop partition p200701, p200702, ... , p200712 ;
```

Partition Maintenance

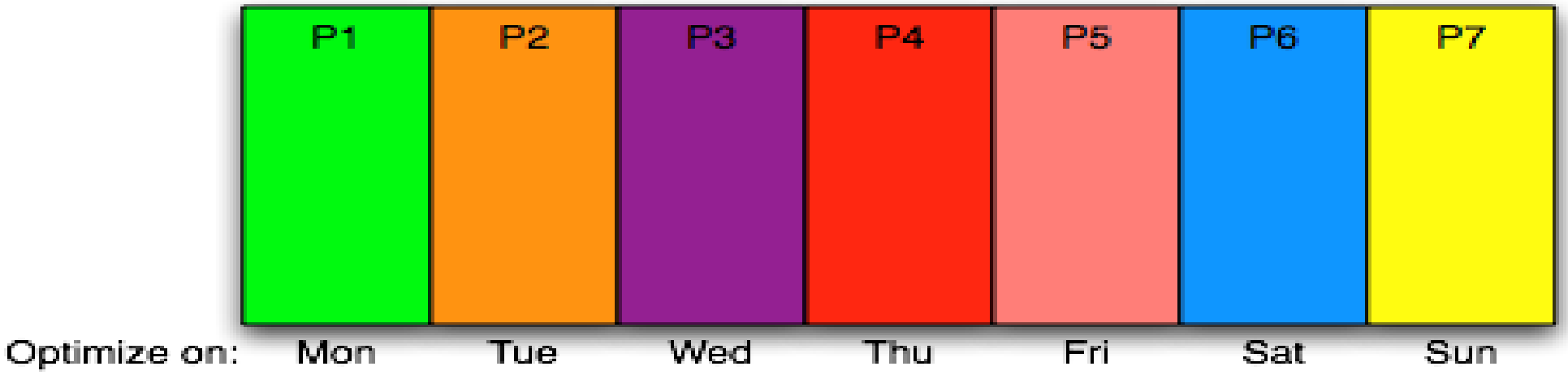
Optimize, Analyze, etc. by Partition

- **Steps:**
  - Partition the table into partitions using HASH on an ID or similar
  - Optimize, Analyze, etc. 1 partition a night or as needed

- Can turn Hours long process to 5-10 minutes a nightly batch job

Optimize, Analyze, etc. by Partition

- Insert, Update, and Delete as usual
- Fix indexes if needed
- Try to keep to 16 partitions or less, 8 or less best
- **Cycle Optimize, Analyze**, etc. through the partitions



Optimize, Analyze, etc. by Partition

- Original Table definition

```
CREATE TABLE Sale (
       saleID        INT AUTO_INCREMENT PRIMARY KEY,
       salesDate     TIMESTAMP,
       storeID       smallint,
       amount        decimal(10,2)
);
```

Optimize, Analyze, etc. by Partition

- Add partitions

```
Alter table Sale Partition by hash(saleID)
  partitions 7 ;
```

- Optimize the first partition (Partitions are P0 to P6)

```
alter table sale optimize partition P0 ;
```

Evolution of MySQL Partitioning

Changes from 5.1, 5.5, 5.6 to 5.7

MySQL 5.1 Partitioning

Use dates indirectly

- MySQL 5.1:

```
PARTITION BY RANGE (TO_DAYS(dt))
  PARTITION p01 VALUES LESS THAN (733042),
  PARTITION p02 VALUES LESS THAN (733407),
  PARTITION p03 VALUES LESS THAN (733773),
  PARTITION p04 VALUES LESS THAN MAXVALUE)
```

MySQL 5.5 Partitioning Enhancements

Use dates directly (partition pruning will work)

- MySQL 5.5:

```
PARTITION BY RANGE COLUMNS (dt) (
  PARTITION p01 VALUES LESS THAN ('2007-01-01'),
  PARTITION p02 VALUES LESS THAN ('2008-01-01'),
  PARTITION p03 VALUES LESS THAN ('2009-01-01'),
  PARTITION p04 VALUES LESS THAN (MAXVALUE));
```

MySQL 5.5 Partitioning Enhancements

- New **RANGE COLUMNS** and **LIST COLUMNS** added to the **CREATE TABLE** statement

- Single or multiple column names can be used instead of expressions

- Range and list partitions can be based in integers, **DATE**, **DATETIME**, **CHAR** or **VARCHAR**

```
CREATE TABLE expenses ( expense_date DATE NOT NULL,
                        category VARCHAR(30),
                        amount DECIMAL (10,3) );

ALTER TABLE expenses PARTITION BY LIST COLUMNS (category)
(     PARTITION p01 VALUES IN ( 'lodging', 'food'),
      PARTITION p02 VALUES IN ( 'flights', 'ground
transportation'),
      PARTITION p03 VALUES IN ( 'leisure', 'customer
entertainment'),
      PARTITION p04 VALUES IN ( 'communications'),
      PARTITION p05 VALUES IN ( 'fees'));

CREATE TABLE employees ( emp_no int(11) NOT NULL,
                         birth_date date NOT NULL,
                         first_name varchar(14) NOT NULL,
                         last_name varchar(16) NOT NULL,
                         gender char(1) DEFAULT NULL,
                         hire_date date NOT NULL )
ENGINE=MyISAM
     PARTITION BY RANGE COLUMNS(gender,hire_date)
     (PARTITION p01 VALUES LESS THAN ('F','1990-01-01'),
      PARTITION p02 VALUES LESS THAN ('F','2000-01-01'),
     PARTITION p03 VALUES LESS THAN ('F',MAXVALUE),
      PARTITION p04 VALUES LESS THAN ('M','1990-01-01'),
      PARTITION p05 VALUES LESS THAN ('M','2000-01-01'),
      PARTITION p06 VALUES LESS THAN ('M',MAXVALUE),
      PARTITION p07 VALUES LESS THAN (MAXVALUE,MAXVALUE)
```

MySQL 5.5 Partitioning Enhancements

- Other enhancements

```
ALTER TABLE t1 TRUNCATE PARTITION p0;
```

- Multiple columns

```
PARTITION BY RANGE COLUMNS (a,b)
(
  PARTITION p01 VALUES LESS THAN (10,20),
  PARTITION p02 VALUES LESS THAN (20,30),
  PARTITION p03 VALUES LESS THAN (30,40),
  PARTITION p04 VALUES LESS THAN (40,MAXVALUE),
  PARTITION p05 VALUES LESS THAN (MAXVALUE,MAXVALUE)
);
```

http://dev.mysql.com/tech-resources/articles/mysql_55_partitioning.html

MySQL 5.6: Improved Partitioning

- Up to 8k partitions/sub-partitions per table

  Fun fact, 8192 hour partitions is ~341 days and 8192 day partitions is ~22.4 years

- Explicit partition selection in queries, DML (`SELECT`, `INSERT`, `UPDATE`, `DELETE`, `REPLACE`, `LOAD DATA`, `LOAD XML`)

```
SELECT * FROM t PARTITION (p0, p1) WHERE c < 5
```

- Import/export partitions to/from partitioned tables to/from non-partitioned tables

```
ALTER TABLE t EXCHANGE PARTITION p0 WITH TABLE t2;
```

dev.mysql.com/doc/refman/5.6/en/partitioning-management.html

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MySQL 5.7.3: Partitioning

Improved performance, but first a definition!

- ICP, Index Condition Pushdown
- It pushes filtering of where clauses to the storage engine. It is a key performance lynchpin introduced in 5.6.
- It requires an index to work
- Why is this important
  - It saves the database engine (top half of MySQL) the effort of loading, sorting, buffering and filtering huge datasets that may not be needed

MySQL 5.7.3: Partitioning

Improved performance

- Via support for Index Condition Pushdown (ICP)
  - For Partitioned Tables
- Classical issue in 5.6
  - DBA moves from a default (non-partitioned) table
  - Previously resulted in performance drop
    - As ICP optimization was lost
  - Now
    - ICP is maintained with moving to a partitioned table structure

- Partitions – support for Transportable Tablespaces (TTS)
  - TTS support for individual partitions
  - This is huge for data management and data recovery

Q & A : Prequel

Q & A : Prequel

- **Is Partitioning with Partition Elimination always faster than using an Index?**
  - No, many queries are much faster with indexes
- **Does partitioning use parallel access for each query?**
  - No, MySQL uses a pruning algorithm and is not parallel
  - Good partitioning design is required to benefit from pruning, concentrate on aligning query filters to partitioning scheme
- **When is Partitioning faster?**
  - When the index scan would have scanned 10-20% or more of the non-Eliminated partitions
  - Typically reporting queries

Q & A : Prequel

- **Why is Partitioning faster in this case (large index scans)?**
  - Because a table scan (used by partition based queries) is faster than an index scan on a row by row basis.
  - This advantage is multiplied when all of the data will not fit into cache

- **Can a partitioned table have NO INDEXES?**
  - Yes in many cases
  - Best practice for very large tables (fact tables)
  - Use Memory engine for Dimensions

Additional Resources

Resources and Q&A

Links I find valuable

Documents

- “Guide to MySQL Partitioning” white paper
  - http://mysql.com/why-mysql/white-papers/mysql_wp_partitioning.php

- “MySQL Partitioning” Topic Guide for 5.6
  - http://downloads.mysql.com/docs/mysql-partitioning-excerpt-5.6-en.pdf

Resources and Q&A

Links I find valuable

Recorded Webinars

- 50 tips to improve MySQL Performance
  - http://www.mysql.com/news-and-events/web-seminars/50-tips-to-boost-mysql-performance/
- Tuning MySQL for Great Performance
  - http://www.mysql.com/news-and-events/web-seminars/tuning-mysql-for-great-product-performance-the-fundamentals-updated-for-mysql-5-6/
- MySQL Explain, Explained
  - http://www.mysql.com/news-and-events/web-seminars/mysql-explain-explained/

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Resources and Q&A

- MySQL Resources – select by topic, type and language
  - http://www.mysql.com/why-mysql/

- Questions?
  - http://www.mysql.com/about/contact/
  - Phone: USA=+1-866-221-0634; Outside USA = +1-208-327-6494

MySQL Partitioning: When, Why and How

John Kehoe, OCP, OCE
MySQL Cluster Technical Consultant