Using Pluggable Apache Spark SQL Filters to help GridPocket users keep up with the Jones' (and save the planet)

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Joint work with:
Tal Ariel, IBM
Filip Gluszak, GridPocket
Gal Lushi, IBM
Yosef Moatti, IBM
Papa Niamadio, GridPocket
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You have 5 minutes to pack your bags…

?

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- **Save $?**

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- **Save $?**
- **Save the planet ?**

Competing to Save Energy

- **Research shows that utility customers are most influenced by peer pressure to save energy**
- **=> Help utilities compare their customers' energy consumption with that of their neighbours**
  - Queries are anonymized

GridPocket

- A smart grid company developing energy management applications and cloud services for electricity, water and gas utilities
- HQ based in France
- http://www.gridpocket.com/
- Developed open source data generator
- Provided industry specific use cases and algorithms

The GridPocket Dataset

- Our target: 1 million meters reporting every 15 minutes
- Records are ~100 bytes
- Generated ~1TB in 3 months
- Allowing for 1 order of magnitude growth in each dimension gives 1PB in 3 months
- => Use object storage
- Typically at least order of magnitude lower storage cost than NoSQL databases
- NoSQL dataset – one large denormalized table containing meter reading information
  - SQL query for nearest neighbours

What is Object Storage ?

- **Objects contain data and metadata**
- **Written once and not modified**
  - Cannot append or update data
    - Can overwrite completely
    - Can update metadata
  - No rename operation
- **Accessed through RESTful HTTP**
  - PUT/GET/POST/DELETE object/bucket
  - Flat namespace
- **High capacity, low cost**
- **Storage of choice for Big datasets**
  - Analytics works best on equally sized objects
- **Examples**
  - Amazon S3, IBM COS, Google Cloud Storage, OpenStack Swift

Object Storage and Spark are separately managed microservices

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Want to query data on object storage directly

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APACHE Spark™

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Our goal:Minimize

1. **Number of bytes shipped**
2. **Number of REST requests**

THE key factors affecting cost (and performance)

How is this done today ?

1. **Use specialized column based formats such as Parquet, ORC**
   - Column wise compression
   - Column pruning
   - Specialized metadata

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We want one solution for all data formats

2. **Use Hive Style Partitioning to layout Object Storage data**
   - Partition pruning

Hive Style Partitioning and Partition Pruning

- **Relies on a dataset naming convention**
- **Object storage has flat namespace, but can create a virtual folder hierarchy**
  - Use '/' in object name
- **Data can be partitioned according to a column e.g. dt**
  - Information about object contents is encoded in object name e.g. **dt=2015-09-14**
- **Spark SQL can query fields in object name as well as in data e.g. "dt"**
  - Filters the objects which need to be read from Object Storage and sent to Spark

```
GPMeterStream/dt=2017-08-21/4-I-80000-120000.csv
GPMeterStream/dt=2017-08-21/4-I-800000-840000.csv
GPMeterStream/dt=2017-08-21/4-I-840000-880000.csv
GPMeterStream/dt=2017-08-21/4-I-880000-920000.csv
GPMeterStream/dt=2017-08-21/4-I-920000-960000.csv
GPMeterStream/dt=2017-08-21/4-I-960000-1000000.csv
GPMeterStream/dt=2017-08-22/1-I-0-40000.csv
GPMeterStream/dt=2017-08-22/1-I-120000-160000.csv
GPMeterStream/dt=2017-08-22/1-I-160000-200000.csv
GPMeterStream/dt=2017-08-22/1-I-200000-240000.csv
GPMeterStream/dt=2017-08-22/1-I-240000-280000.csv
```

Limitations of Today's Hive Style Partitioning in Spark

- **Only one hierarchy is possible**
  - Like database primary key, no secondary keys
- **Changing partitioning scheme requires rewriting entire dataset !**
  - Hierarchy cannot be changed without renaming all objects
- **No range partitioning**
  - Only supports partitioning with discrete types e.g. Gender:M/F, date, age etc.
  - doesn't work well for timestamps, arbitrary floating point numbers etc.
- **A deep hierarchy may result in small and non uniform object sizes**
  - May reduce performance

Can we do more ?

Can we do more ?

- **Generate metadata per object column and index it**
- **Various index types**
  - Min/max, bounding boxes, value lists
- **Filter objects according to this metadata**
- **Applies to all formats e.g. json, csv**

```
{
   "name": "GPMeterStream/dt=2017-08-17/part-00088.csv",
   "metadata": {
     "location": [
       {
         "lat": 47.5,
         "lon": 4.2
       },
        ...,
       {
         "lat": 47.6,
         "lon": 3.4
       }
     ],
     "city": {
       "set": [
         "Kilstett",
        ...,
         "Haussignémont"
       ]
     },
     "temp": {
       "min": 7.97,
       "max": 26.77
     }
   }
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```

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Min/max values

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One or more bounding boxes

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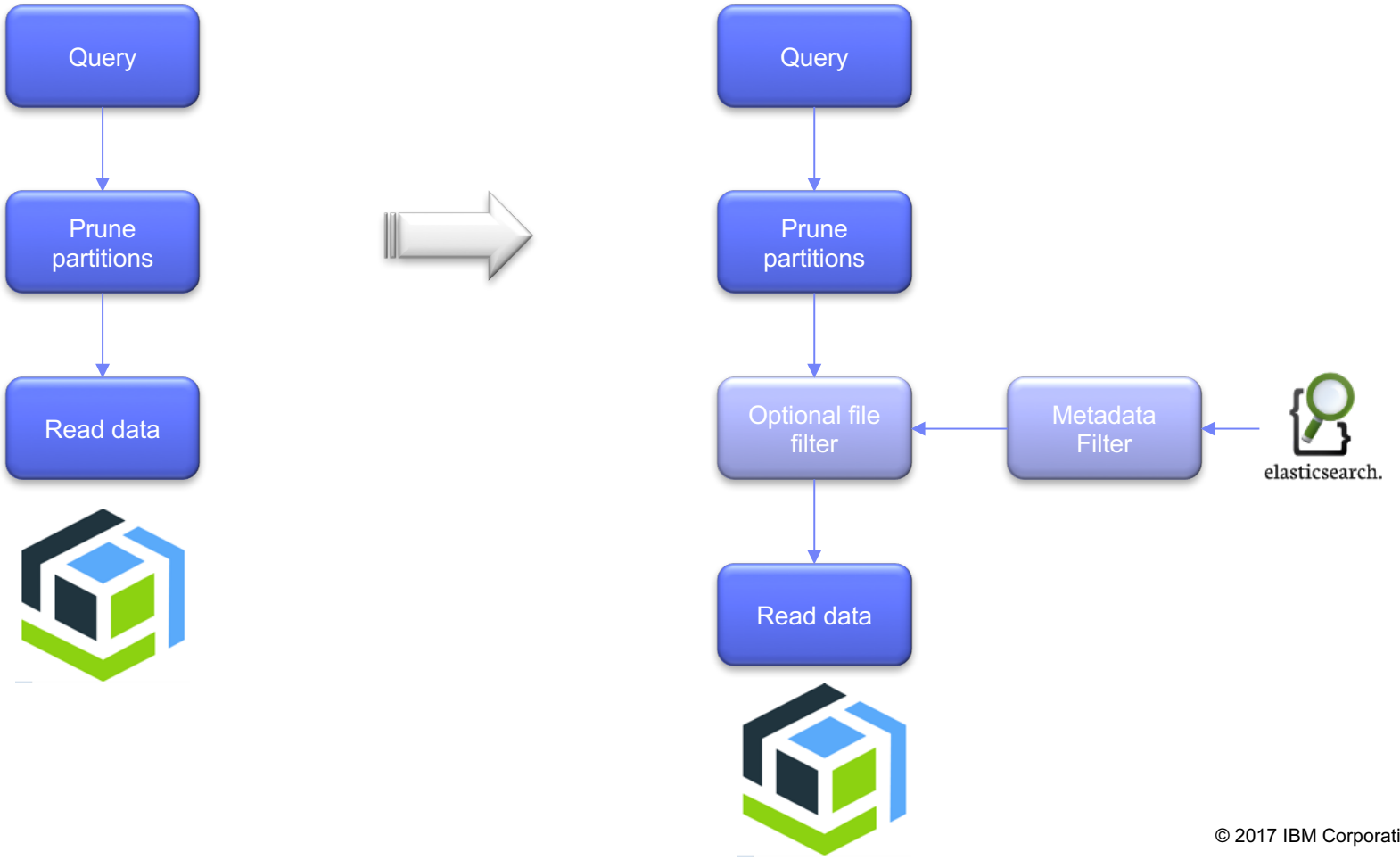
}
```

A set of values

Filter According to Metadata

- **Store one metadata record per object**
  - Unlike database fully inverted index
- **Various index types**
  - Min and max value for ordered columns
  - Bounding boxes for geospatial data
  - Bloom filters as space efficient value lists
- **Users can choose which columns to index and index type per column**
  - Can index additional columns later on
- **Main requirement: no false negatives**
- **Avoids touching irrelevant objects altogether**
- **Handles updates (PUT/DELETE object)**
  - Filtering out irrelevant objects always works

Spark SQL query execution flow



The Interface

Filters should extend this trait and implement application specific filtering logic.

```
trait ExecutionFileFilter {
 /**
   * @param dataFilters query predicates for data columns
   * @param f represents an object which exists in the file catalog
   * @return true if the object needs to be scanned during execution
   */
 def isRequired(dataFilters: Seq[Filter], f: FileStatus) : Boolean
}
```

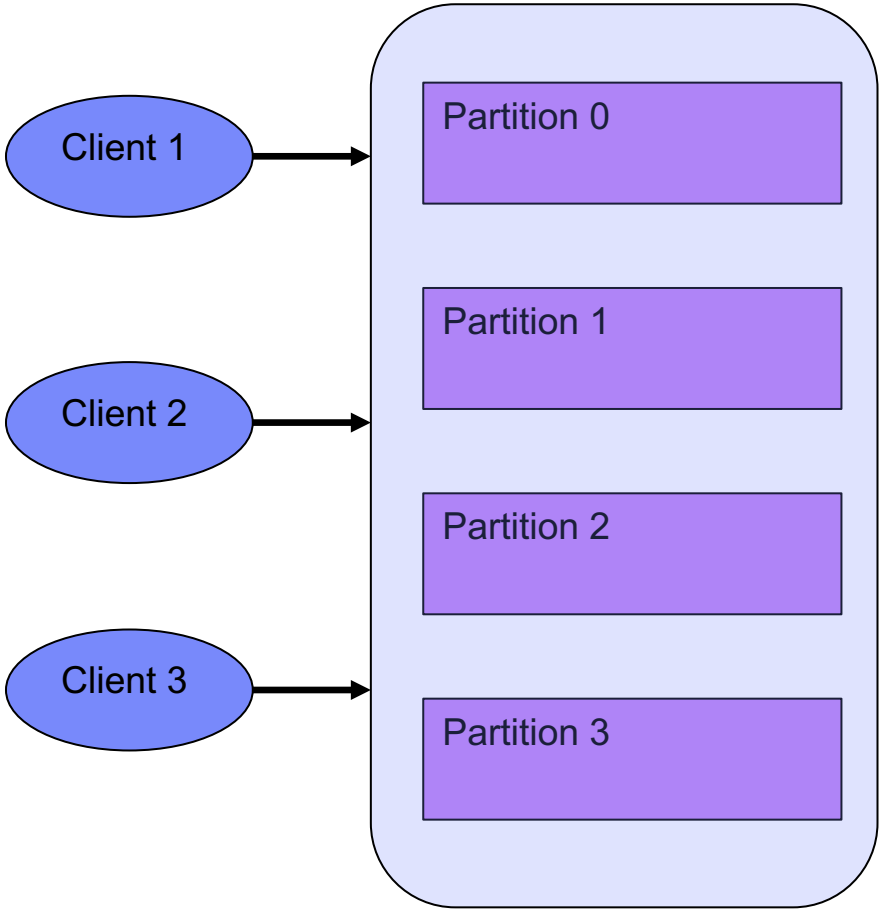
Turn filter on by specifying Filter class:

```
sqlContext.setConf("spark.sql.execution.fileFilter", “TestFileFilter”)
```

< 20 lines of code to integrate into Spark

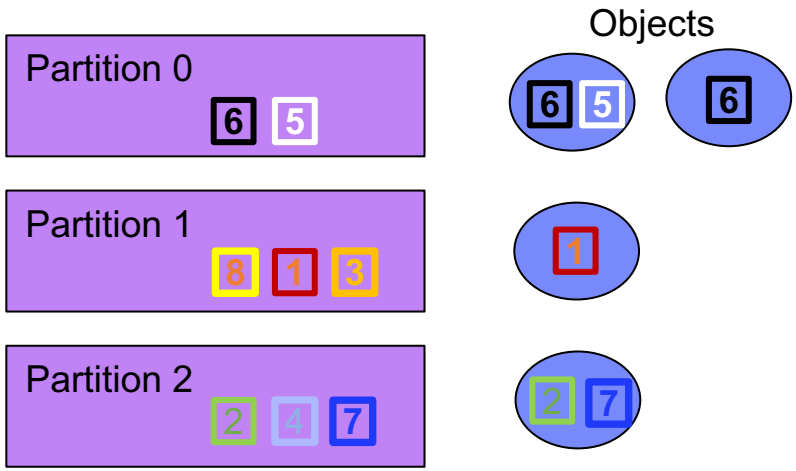
Data Ingest: How to best Partition the Data

- **Organizing data in objects in a smart way generates more effective metadata**
- **Partition during data ingestion**
- **Example: Kafka allows user to define partitioning function**
- **Needs to scale horizontally – want stateless partitioner**



Geospatial Partitioning: Grid Partitioner

- **Divide the world map into a grid**
  - Precision depends on use case
- **Each data point belongs to a cell**
- **Each cell is hashed to a partition**
- **A partition can contain multiple cells**
- **Partitions periodically generate objects**
- **Each object is described using a list of bounding boxes**
  - 1 per participating cell



Experimental Results

The GridPocket Dataset

- 1 million meters reporting every 15 minutes
- Records are ~100 bytes
- Generated ~1TB in 3 months
- Partitioned using Grid Partitioner using precision 1 (cells are roughly 10 km^2)
- Compared using 50 and 100 Kakfa partitions

Get my neighbours' average usage

```
SELECT AVG(usage)
FROM (
  SELECT vid as meter_id,
              (MAX(index)-MIN(index)) as usage
  FROM dataset
  WHERE (lat BETWEEN 43.300 AND 44.100)
  AND (lng BETWEEN 6.800 AND 7.600)
  GROUP BY vid
)
```

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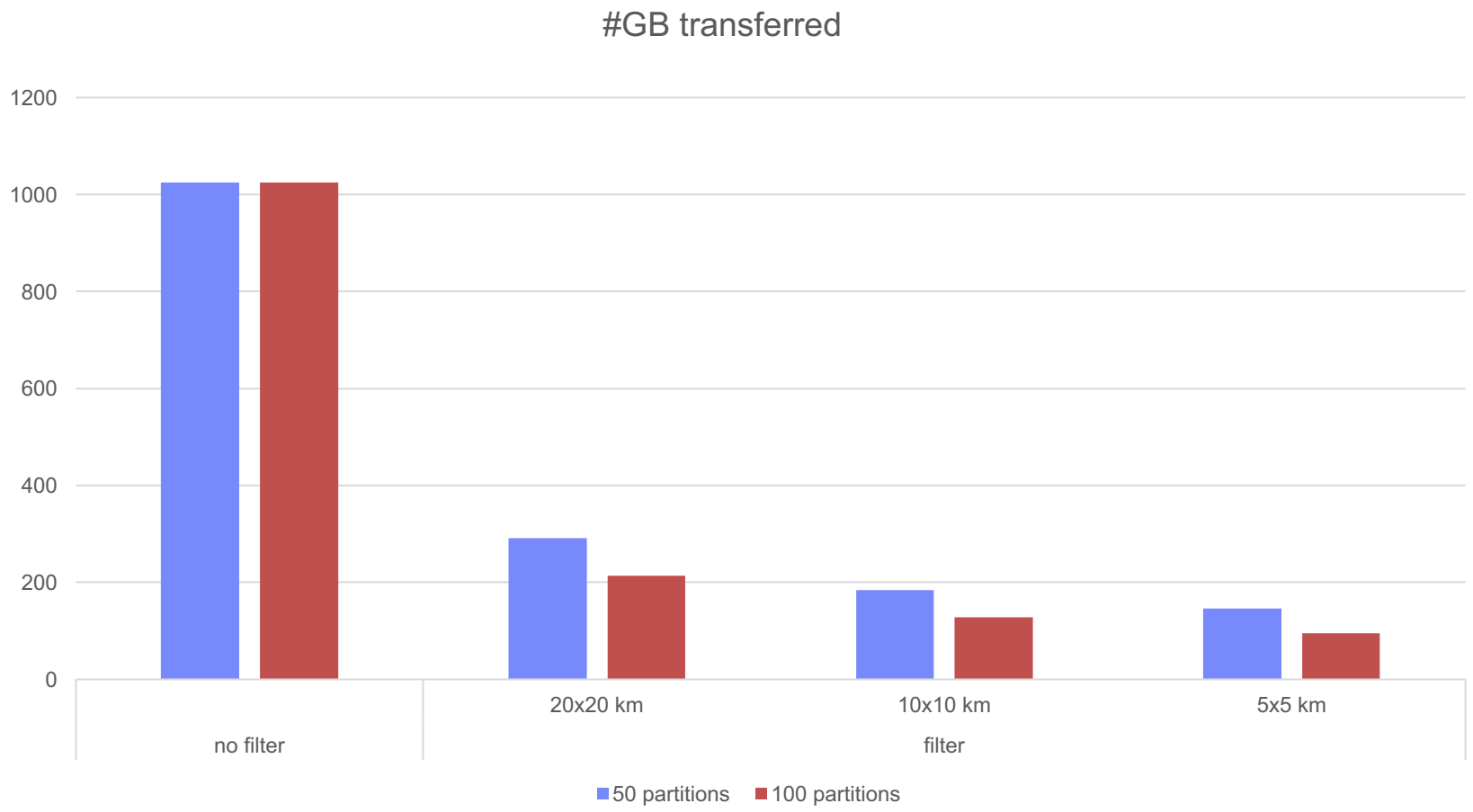
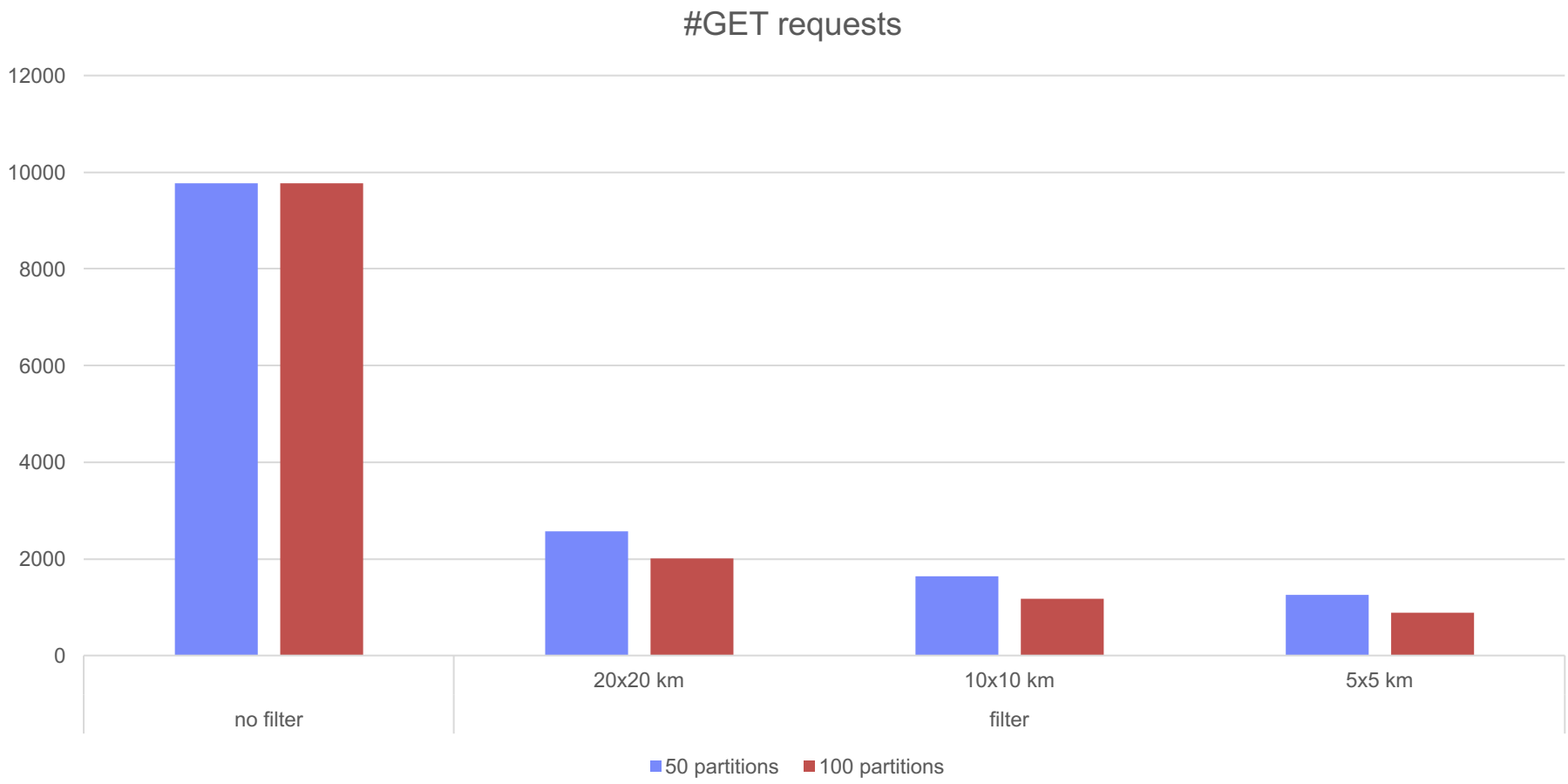
```

#GB Transferred for bounding box queries



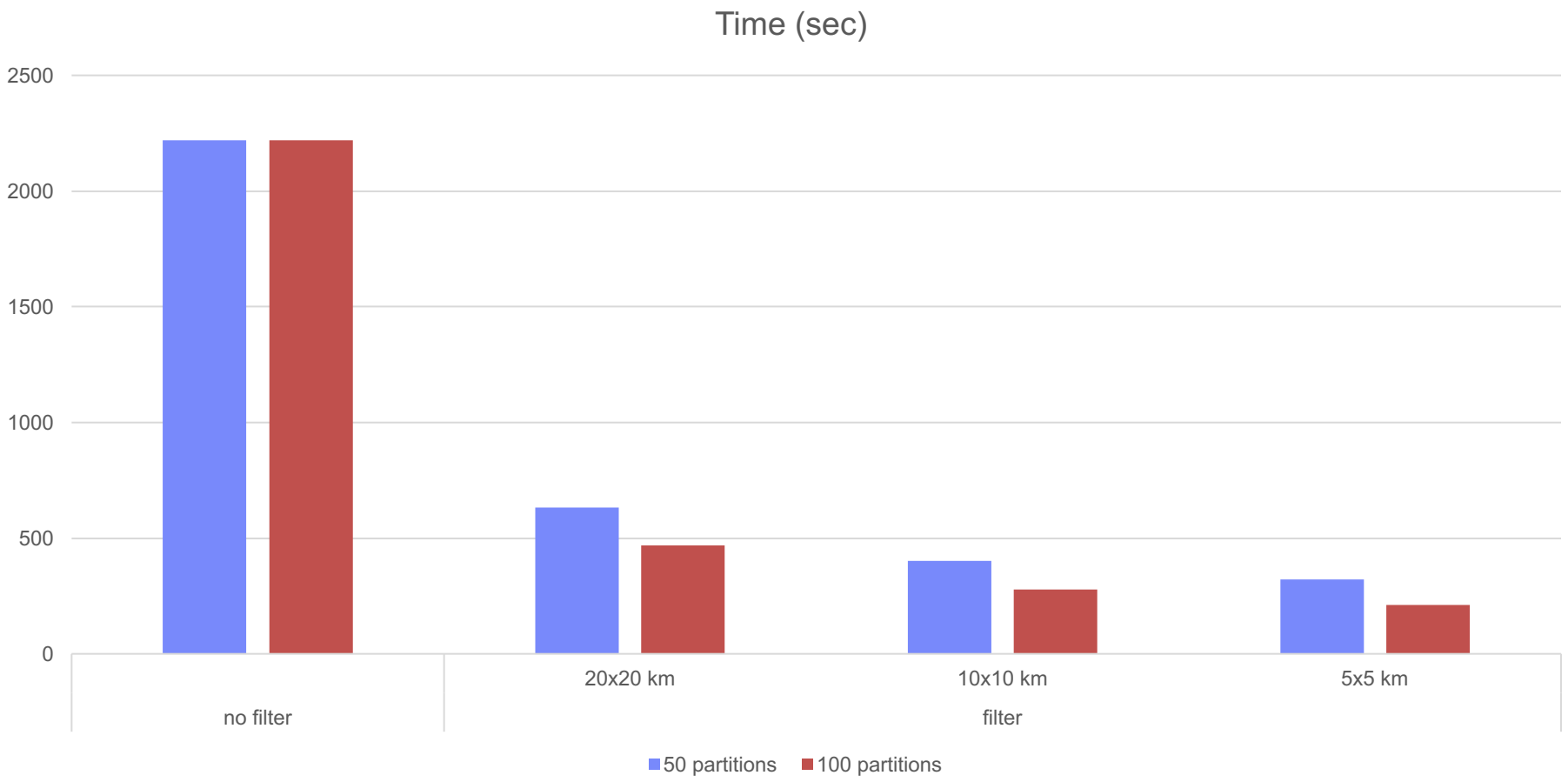
1 TB dataset, grid partitioner, precision 1, average of 10 randomly located queries

#GET Requests for bounding box queries



1 TB dataset, grid partitioner, precision 1, took average of 10 randomly located queries

Time (sec) for bounding box queries



1 TB dataset, precision 1, took average of 10 randomly located queries

Demo

- **Runs on IOSTACK testbed**
  - 3 Spark and 3 Object Storage nodes
- **Demo dataset**
  - 1 million meters
  - Report every 15 mins
  - 1 day's worth of data
  - 11 GB (csv)
- **Grid Partitioner Config**
  - Cells have precision 1
    - ~10 km^2
  - 100 partitions

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  GROUP BY vid
)
```

Conclusions: Don’t let your vacation turn into a relocation

- Running SQL queries directly on Big Datasets in Object Storage is viable using metadata
- A small change to Spark enables dramatic performance improvements
- We focused here on geospatial data and the GridPocket use case, although it also applies to other data types and use cases
- IBM is investing in Spark SQL as a backbone for SQL processing services in the cloud

Thanks!

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Backup

GridPocket Use Case and Dataset

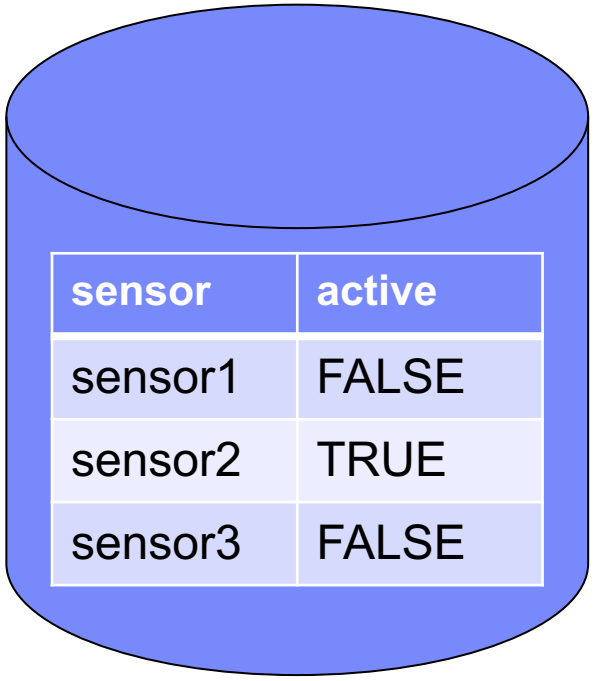
- NoSQL dataset – one large denormalized table
  - **date, index, sumHC, sumHP, type, vid, size, temp, city, region, lat, lng**
  - Index = meter reading
  - sumHC = total of energy consumed since midnight in off-hours
  - sumHP = total of energy consumed since midnight in rush-hours
  - Type = elec/gas/water
  - Vid = meter id
  - Size = apartment size in square meters

Example Filter Scenario

- **Want to analyze data from active sensors only**
- **External DB contains sensor activity info**

Data Layout

Archives/dt=01-01-2014
Archives/dt=01-01-2014/sensor1.json (500MB)
Archives/dt=01-01-2014/sensor2.json (500MB)
Archives/dt=01-01-2014/sensor3.json (500MB)
Archives/dt=02-01-2014
Archives/dt=02-01-2014/sensor1.json (500MB)
Archives/dt=02-01-2014/sensor2.json (500MB)
Archives/dt=02-01-2014/sensor3.json (500MB)
more...



sensor	active
sensor1	FALSE
sensor2	TRUE
sensor3	FALSE

Example Filter

```
class LiveSensorFilter extends ExecutionFileFilter {

 //get a list of live sensors from an external Service
 val activeSensors = SensorService.getLiveSensors

 //returns true if object represents a live sensor
 @Override
 def isRequired(dataFilters:Seq[org.apache.spark.sql.sources.Filter],
                fileStatus: FileStatus) : Boolean = {
   activeSensors.contains(Utils.getSensorIdFromPath(fileStatus))
 }
```

Turn filter on:

```
sqlContext.setConf("spark.sql.execution.fileFilter", “LiveSensorFilter ”)
```