From DBMS to BDMS

After this lesson you will be able to:

- Explain at least 5 desirable characteristics of a Big Data Management System
- Explain the difference between ACID and BASE
- Describe what the CAP Theorem states
- List examples of BDMSs and describe some of their similarities and differences

Desired Characteristics of BDMS

- **A flexible, semistructured data model**
  - "schema first" to "schema never"
- **Support for today's common "Big Data data types"**
  - Textual, temporal, and spatial data values
- **A full query language**
  - Expectedly at least the power of SQL
- **An efficient parallel query runtime**

Desired Characteristics of BDMS

- **Wide range of query sizes**
- **Continuous data ingestion**
  - Stream ingestion
- **Scale gracefully to manage and query large volumes of data**
  - Use large clusters
- **Full data management capability**
  - Ease of operational simplicity

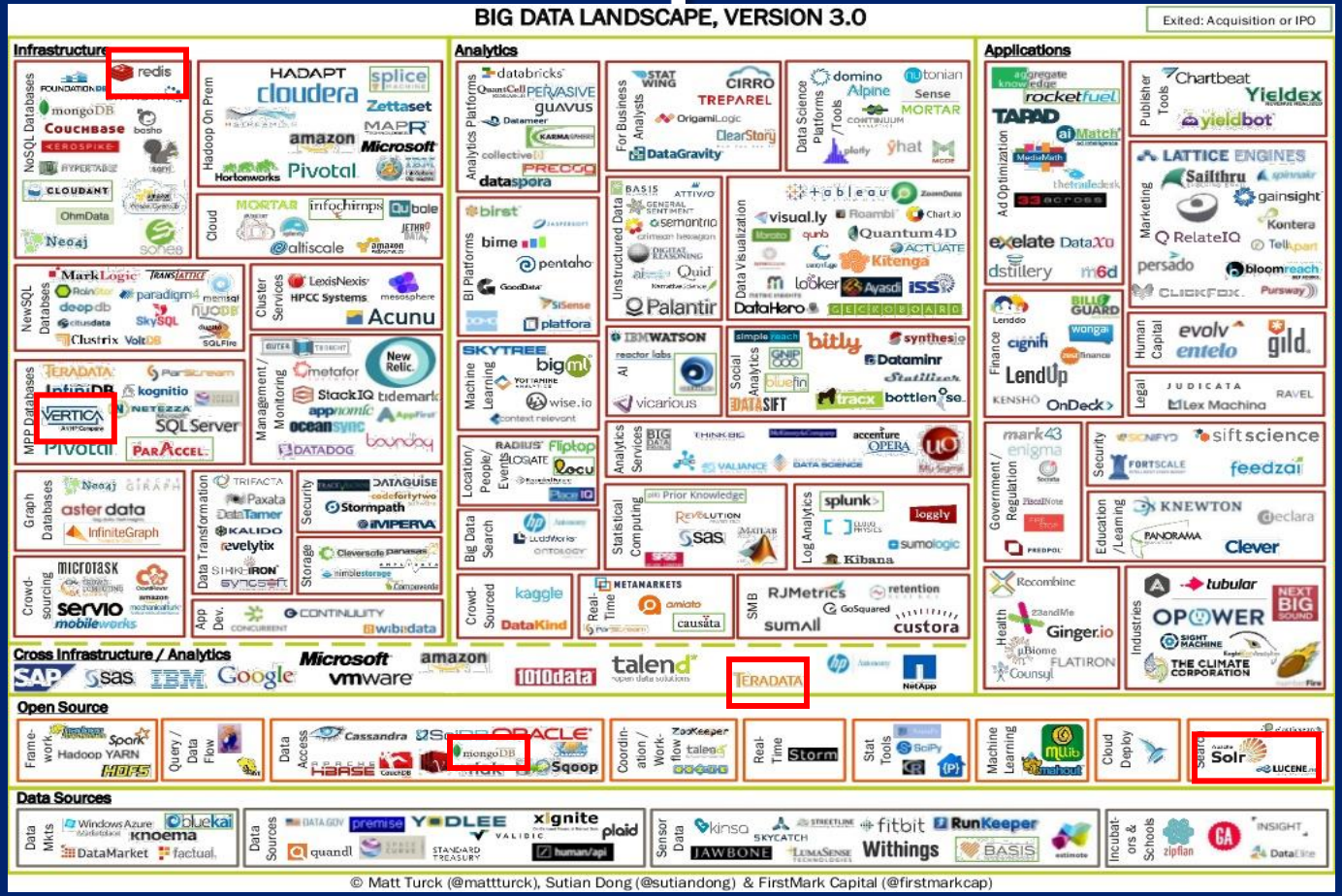
ACID and BASE

- **ACID properties hard to maintain in a BDMS**
- **BASE relaxes ACID**
  - BA: Basic Availability
  - S: Soft State
  - E: Eventual Consistency

CAP Theorem

- A distributed computer system cannot simultaneously achieve…
  - Consistency
  - Availability
  - Partition Tolerance

The Marketplace



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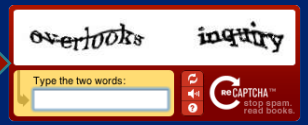
Redis – An Enhanced Key-Value Store

- **In-memory data structure store**
  - strings, hashes, lists, sets, sorted sets
- **Look-up Problem**
  - **Case 1: (key:string, value:string)**

Can this be a key?

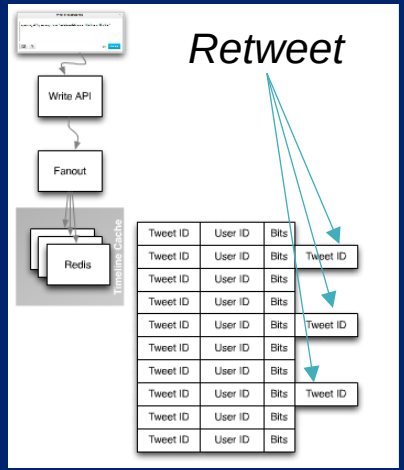


Value: "overlooks inquiry"

  - Keys may have internal structure and expiry
    - comment:1234:reply.to
    - Hierarchical keys: user.commercial, user.commercial.entertainment, user.commercial.entertainment.movie-industry

Redis and Data Look-up

- **Case 2: (key:string, value: list)**
  - userID: [tweetID1, tweetID2, …]
  - Ziplists compress lists
  - Twitter innovation: list of ziplists
    - http://www.infoq.com/presentations/Real-Time-Delivery-Twitter
    - https://www.youtube.com/watch?v=rP9EKvWtozo



Redis and Data Look-up

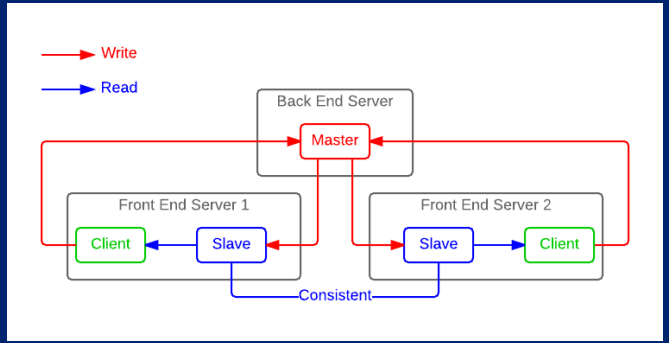
- **Case 3: (key:string, value: attribute-value pairs)**
  - REDIS Hashes
    - std:101 name:“John Smith" dob:01-01-2000 gender:M active:0 cgpa:2.9

Redis and Scalability

- **Partitioning and Replication**
  - Range partitioning
    - Example: User record number 1-10000 goes to machine 1, 10001-20000 goes to machine 2, …
  - Hash partitioning
    - Pick a key of a record, e.g., "abcde"
    - Using a hash function, turn it into a number, e.g., 152
    - 152 mod 10 is 2, so the record goes to machine 2

Redis and Scalability

- **Partitioning and Replication**
  - Master-Slave mode replication
    - Clients write to master, master replicates to slaves
    - Clients read from slaves to scale up read performance
    - Slaves are mostly consistent



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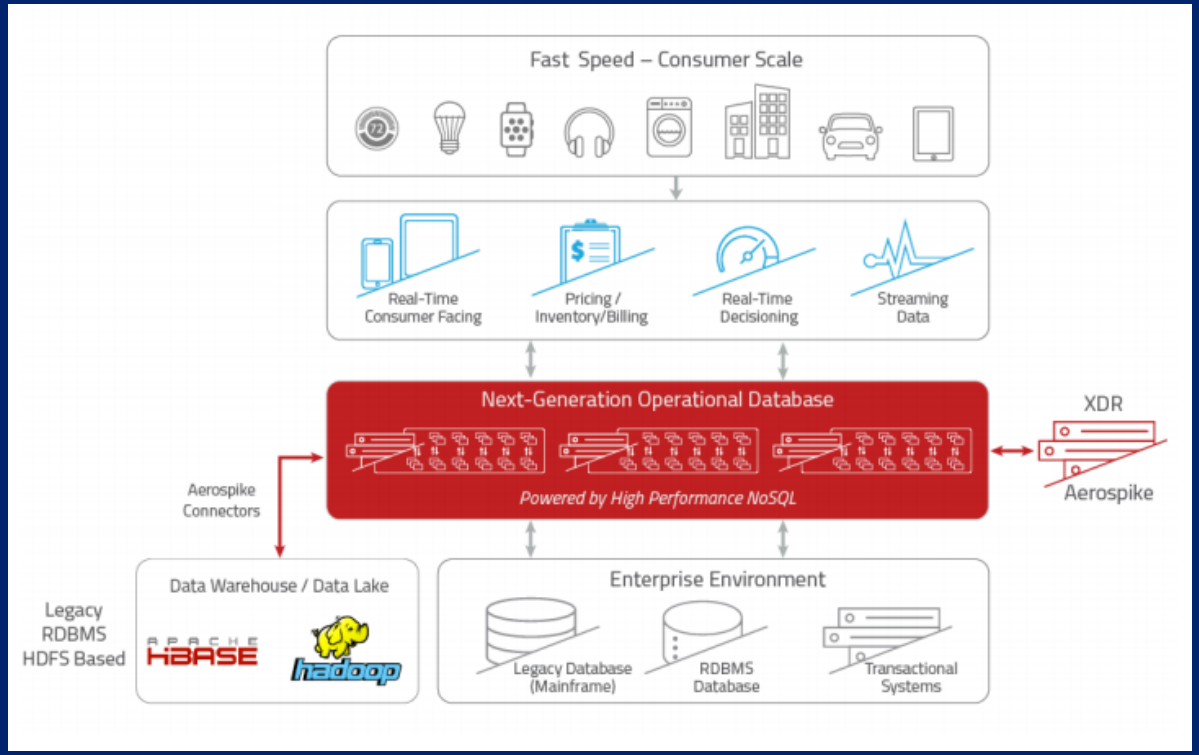
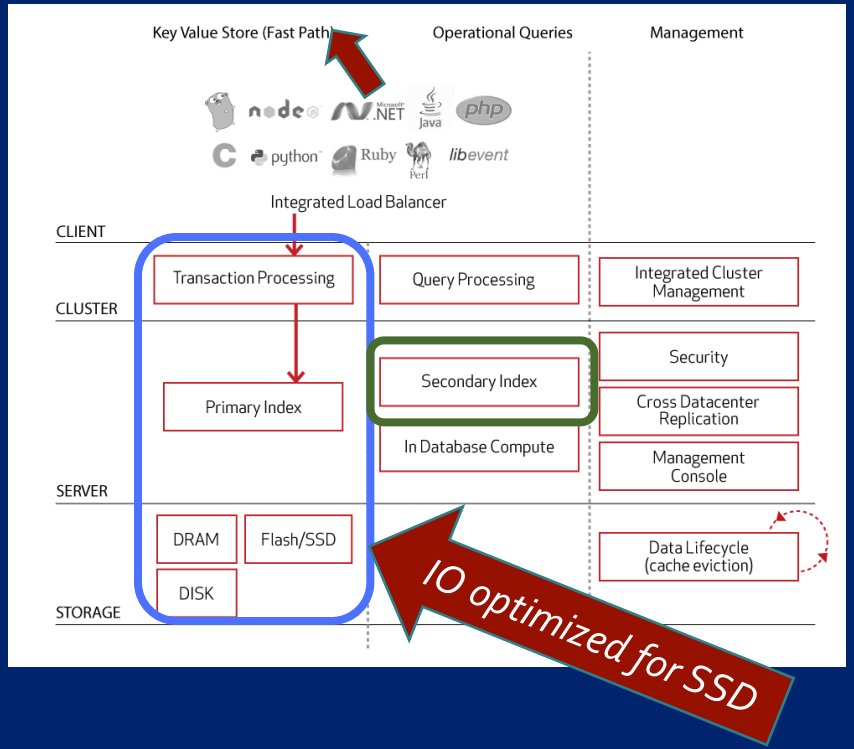
Aerospike – a New Generation KV Store



Aerospike Architecture



Querying Aerospike

- **Data types**
  - Standard scalar, lists, maps, geospatial, large objects
- **KV store operations**
  - Geospatial queries like point-in-polygon
- **AQL: an SQL-like language**
  - SELECT name, age FROM users.profiles

Transactions in Aerospike

- **Aerospike ensures ACID**
  - Consistency – all copies of a data item are in sync
    - Uses synchronous write to replicas
    - Mechanisms to relax immediate consistency
  - Durability
    - Flash storage
    - Replication management
  - Network partitioning reduced
    - Tighter cluster control

pause

AsterixDB – a DBMS for Semistructured Data

AsterixDB – a DBMS for Semistructured Data

An abbreviated Tweet


```
{
  "created_at": "Thu Oct 21 16:02:46 +0000 2010",
  "entities": {
     "user_mentions": [
      {
        "name": "Gnip, Inc.",
        "screen_name": "gnip"
      }
    ]
  },
"text": "what we've been up to at @gnip -- delivering data to happy customers http://gnip.com/success_stories",
  "id": 28039652140,
  “geo”: null,
  "retweet_count": null,
  "in_reply_to_user_id": null,
  "user": {
    "name": "Gnip, Inc.",
    "lang": "en",
    "followers_count": 260,
    "friends_count": 71,
    "statuses_count": 302,
    "screen_name": "gnip"
},
}
```

Semistructured Schema

```
create dataverse LittleTwitterDemo;

create type TwitterUserType as open {
        screen-name: string,
        lang: string,
        friends_count: int32,
        statuses_count: int32,
        id: int32,
        followers_count: int32
    }
create type TweetMessageType as closed {
        tweetid: string,
        user: TwitterUserType,
        geo: point?,
        created_at: datetime,
        referred-topics: {{ string }},
        text: string
    }
```

```
create dataset TweetMessages(TweetMessageType)
primary key tweetid;
```

Options for Querying in AsterixDB

- AQL is a natively-supported query language

```
for $user in dataset TwitterUsers order by
$user.followers_count desc, $user.lang asc return $user
```

- Hive queries

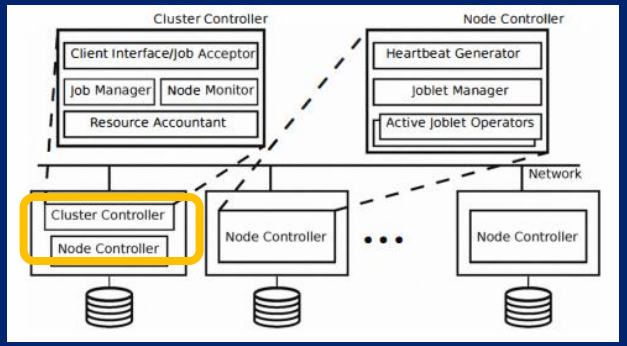
```
SELECT a.val, b.val FROM a LEFT OUTER JOIN b ON
(a.key=b.key)
```

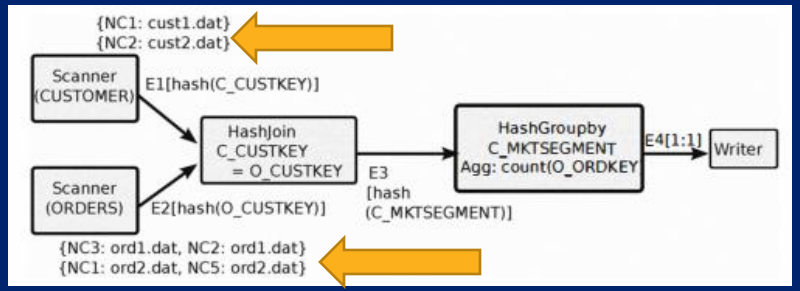
- Xquery
- Hadoop MR jobs
- SQL++ (coming up)

Operating Over a Cluster

- **Hyracks**
  - Query execution engine for partitioned parallel execution of queries
- **Example**
  - CUSTOMER (C_CUSTKEY, C_MKTSEGMENT, …)
  - ORDERS (O_ORDERKEY, O_CUSTKEY, …)

Hyracks Job Management





Accessing External Data

- Real-time data *from files in a directory path*

```
create dataset Tweets (Tweet)
    primary key id;

create feed TestFileFeed using localfs
 (("path"="127.0.01:///Users/adc/text/"),
 ("format"="adm"), ("type-name"="Tweet"),
 ("expression"=".*\\.adm"));

connect feed TestFileFeed to dataset Tweets;
```

Accessing External Data

- Real-time data *from an external API*

```
use dataverse feeds;
create dataset Tweets (Tweet)
    primary key id;
create feed TwitterFeed if not exists using "push_twitter"
    (("type-name"="Tweet"),
     ("consumer.key"="some-key"),
     ("consumer.secret"="some-secret"),
     ("access.token"="some-token"),
     ("access.token.secret"="some-token-secret"));
connect feed TwitterFeed to dataset Tweets;
```

pause

Solr – Managing Text

- **Basic challenges with text**
  - Defining a match
    - Analyze ≈ Analyse ≈ ANALYZE? Lexical difference, capitalization
    - abc:def-230-39 ≈ abcdef23039? Structural punctuations
    - "Barak Hussein Obama" ≈ "Barak Obama" ≈ "Barak H. Obama" ≈ "B. H. Obama"? Nominal Variations
    - Mom ≈ mother? Synonyms
    - Dr. ≈ Doctor Abbreviation
    - USA ≈ "United States of America" Initialism
    - "The tradition is completely American. Students should …"
      - Should this match the query "American students"?
    - "Mrs. Clinton also said …"
      - Should this match the query "mrs Clinton"?

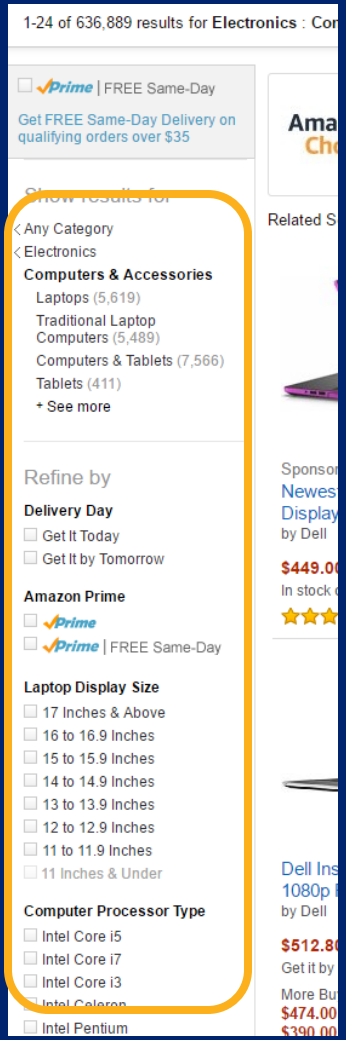
Inverted Index

- **Vocabulary**
  - All terms in a collection of documents
    - Multi-word terms, synonym sets
- **Occurrence**
  - For each term in the collection
    - List of doc ID
    - List of doc ID, [position of occurrence]
    - Other statistics like tf, idf, …

Inverted index

Solr Functionality

- Enterprise Search Platform
- Inverted index
  - For every field in a structured text document
    - indexes text, numbers, geographic information, …
- Faceted Search
- Term highlighting



Solr Functionality

- **Index-time Analyzers**
  - Tokenizers
  - filters

```
<fieldType name="text" class="solr.TextField">
  <analyzer type="index">
    <tokenizer class="solr.StandardTokenizerFactory"/>
    <filter class="solr.StandardFilterFactory"/>
    <filter class="solr.LowerCaseFilterFactory"/>
    <filter class="solr.SynonymFilterFactory"
synonyms="synonyms.txt" ignoreCase="true" expand="true" />
    <filter class="solr.EnglishPorterFilterFactory"/>
  </analyzer>
</fieldType>
```

Solr Functionality

- Query-time Analyzers

```
<analyzer type="query">
   <tokenizer class="solr.PatternTokenizerFactory"
pattern="[\s,\.;]+"/>
      <filter class="solr.StandardFilterFactory"/>
      <filter class="solr.LowerCaseFilterFactory"/>
      <filter class="solr.CommonGramsFilterFactory"
words="stopwords.txt" ignoreCase="true"/>
      <filter class="solr.StopFilterFactory"
ignoreCase="true" words="stopwords.txt"/>
      <charFilter
class="solr.HTMLStripCharFilterFactory"/>
      <filter class="solr.PorterStemFilterFactory"/>
 </analyzer>
```

Solr Queries

Consider the CSV file

```
id,cat,pubyear_i,title,author,series_s,sequence_i
book1,fantasy,2001,American Gods,Neil Gaiman,American Gods,
book2,fantasy,1996,A Game of Thrones,George R.R. Martin,A Song of Ice and Fire,1
book3,fantasy,1999,A Clash of Kings,George R.R. Martin,A Song of Ice and Fire,2
book4,sci-fi,1951,Foundation,Isaac Asimov,Foundation Series,1
book5,sci-fi,1952,Foundation and Empire,Isaac Asimov,Foundation Series,2
book6,sci-fi,1992,Snow Crash,Neal Stephenson,Snow Crash,
book7,sci-fi,1984,Neuromancer,William Gibson,Sprawl trilogy,1
book8,fantasy,1985,The Black Company,Glen Cook,The Black Company,1
book9,fantasy,1965,The Black Cauldron,Lloyd Alexander,The Chronicles of Prydain,2
```

Solr Queries

- All books
  - http://localhost:8983/solr/query? q=*.*
- All books with “black” in the title field, return author, title
  - http://localhost:8983/solr/query? q=title:black &fl=author,title
- All books sort by pubyear_i in descending order
  - http://localhost:8983/solr/query? q=*.*&sort=pubyear_i desc
- Above query but facet by all values in the cat field
  - http://localhost:8983/solr/query? q=*.*&sort=pubyear_i desc &facet=true&facet.field=cat

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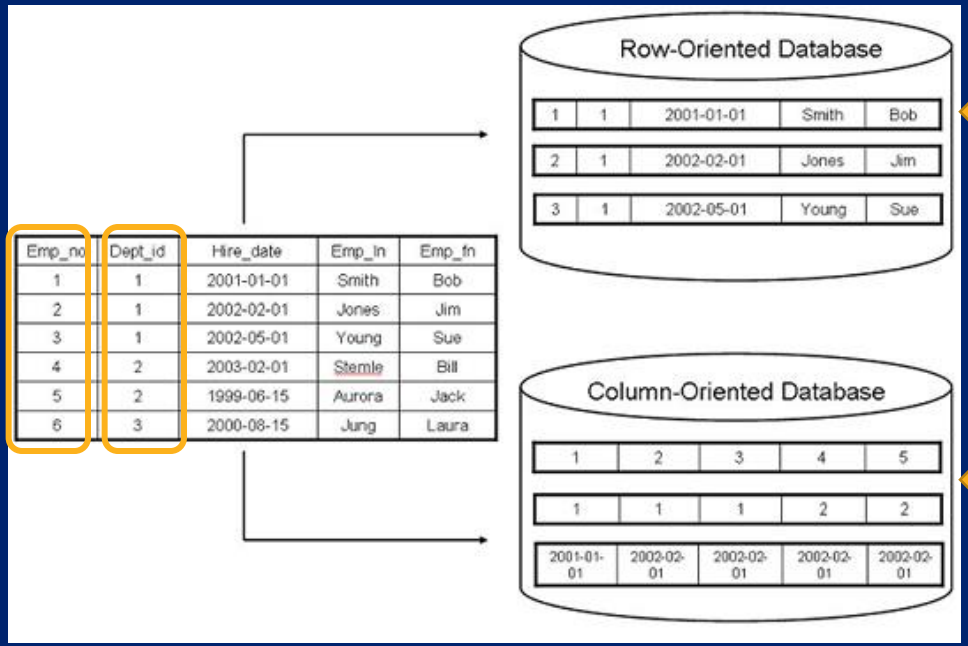
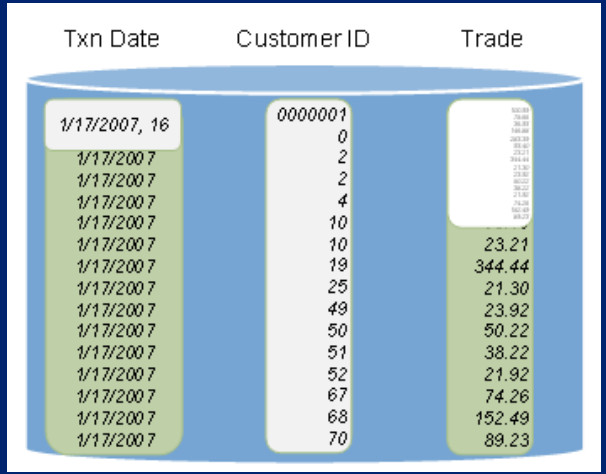
Vertica – a Columnar DBMS



- **Column Store**
  - Store data column-wise
  - A query only uses the columns needed
  - Usually must faster for queries even for large data

Space Efficiency

- Column stores keep columns in sorted order
- Values in columns can be compressed
  - Run-length encoding
    - 1/1/2007 – 16 records
  - Frame-of-reference encoding
    - Fix a number and only record the difference
- Compression saves storage space



Working with Vertica

- **Column-Groups**
  - Frequently co-accessed columns behave as mini row-stores within the column store
- **Update performance slower**
  - Internal conversion from row-representation to column-representation
- **Enhanced suite of analytical operations**
  - Window statistics
    - Ticks (ts TIMESTAMP, Stock varchar(10), Bid float

Vertica and Analytic Functions

```
'2011-07-12 10:23:54', 'abc', 10.12
'2011-07-12 10:23:58', 'abc', 10.34
'2011-07-12 10:23:59', 'abc', 10.75
'2011-07-12 10:25:15', 'abc', 11.98
'2011-07-12 10:25:16', 'abc'
'2011-07-12 10:25:22', 'xyz', 45.16
'2011-07-12 10:25:27', 'xyz', 49.33
'2011-07-12 10:31:12', 'xyz', 65.25
'2011-07-12 10:31:15', 'xyz'
```

```
SELECT ts, bid, AVG(bid)
   OVER(ORDER BY ts
      RANGE BETWEEN INTERVAL '40
seconds'  PRECEDING AND CURRENT ROW)
FROM ticks
WHERE stock = 'abc'
GROUP BY bid, ts
ORDER BY ts;
```

```
 ts          | bid |     ?column?
---------------------+-------+------------------
 2011-07-12 10:23:54 | 10.12 |           10.12
 2011-07-12 10:23:58 | 10.34 |           10.23
 2011-07-12 10:23:59 | 10.75 | 10.4033333333333
 2011-07-12 10:25:15 | 11.98 |           11.98
 2011-07-12 10:25:16 |       |           11.98
(5 rows)
```

Vertica and Distributed R

- **Distributed R**
  - High-performance statistical analysis
  - Master node: schedules tasks and sends code
  - Worker nodes: maintain data partitions and compute
  - Uses a data structure called dArray or distributed array