Integrating Big Initiatives into Enterprise Data Architectures - **the case of NoSQL**

Objectives :

- Introduce Big Data
- Confront Big Data with Data Warehouses - are DWs dead?
- NoSQL - and MongoDB

Big Data Initiatives

Big Data initiatives [*just google for more definitions*]**:**

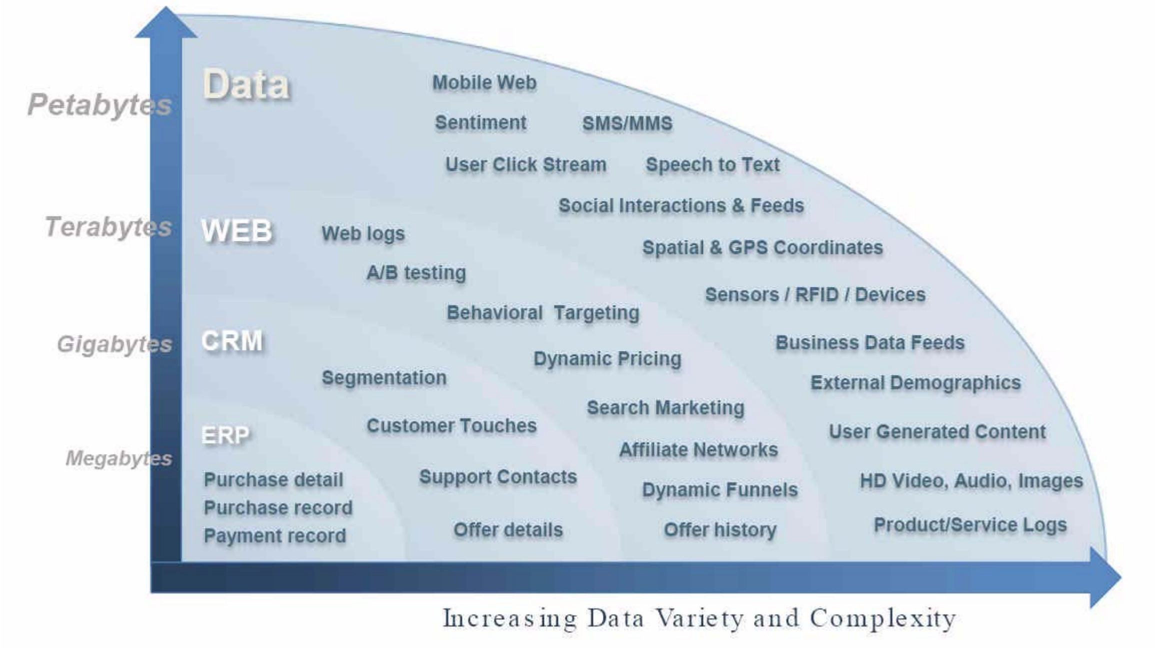
Initiatives focusing on the **analysis** of ...

huge volumes of data available in **varying degrees of complexity**, generated at **different velocities** and **varying degrees of ambiguity**, that can possibly **not be processed** using traditional technologies, methodologies, frameworks, algorithms, and/or traditional commercial applications.

Purpose: analyse that data - **all that data** - to gain insight in [to be able to predict] behaviour!

What Data?

ALL data - data as a **natural resource**



Observation: more data becomes **available**; yet **less data** gets **analysed** and turned into information!

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1. Big Data Initiatives
2. What about 'traditional' Data Warehousing?
3. Enterprise Data Architecture
4. NoSQL Databases
5. MongoDB

Why now?

- **because of change -** everything changes, we change, you change! and more-and-more data is being generated because of it!
  - **instrumentation**
    [sensors]
  - **inter-connectivity**
    - humans - social media, micro blogging, and the like
      [crowdsourcing] [social media analytics] [gamification]
    - machines - M2M
      [smart metering]
  - **intelligence**
    [ever so small microships are added *everywhere*!]
- **availability of commodity computing infrastructure**
- **new computing frameworks (Hadoop, NoSQL)**

resulting in lower costs and higher scalability!

Traditional Business Intelligence (BI) 2.1

The processes, techniques, and tools that support business decision making based on information technology - offering users what they need to make informed decisions!

A combination of '**architectures**' and '**technologies**':

- **Data Warehousing (DW) +** supporting environment ***(make available)***
- **BI 'Tools' & 'Technologies' for 'Analysis'** ***(enable)***
    - On-Line Analytical Processing
    - Data Mining
    - Data Visualization - Decision analysis (what-if)
    - CRM
    - Scorecards, Dashboards
    - ...

Data Warehousing (I)

Purpose and **founding principles**:

- create a data to store a '*single enterprise version of what is*', of '*the truth*'
- create a *'single data repository'* - the '*source*'!

Inmon

Corporate Information Factory (CIF) - third normal form modelling, close-source capture, additional layers added for diverse purposes

Kimball

Data Warehouse BUS - datamarts created using MDM, integration based on conformed dimensions

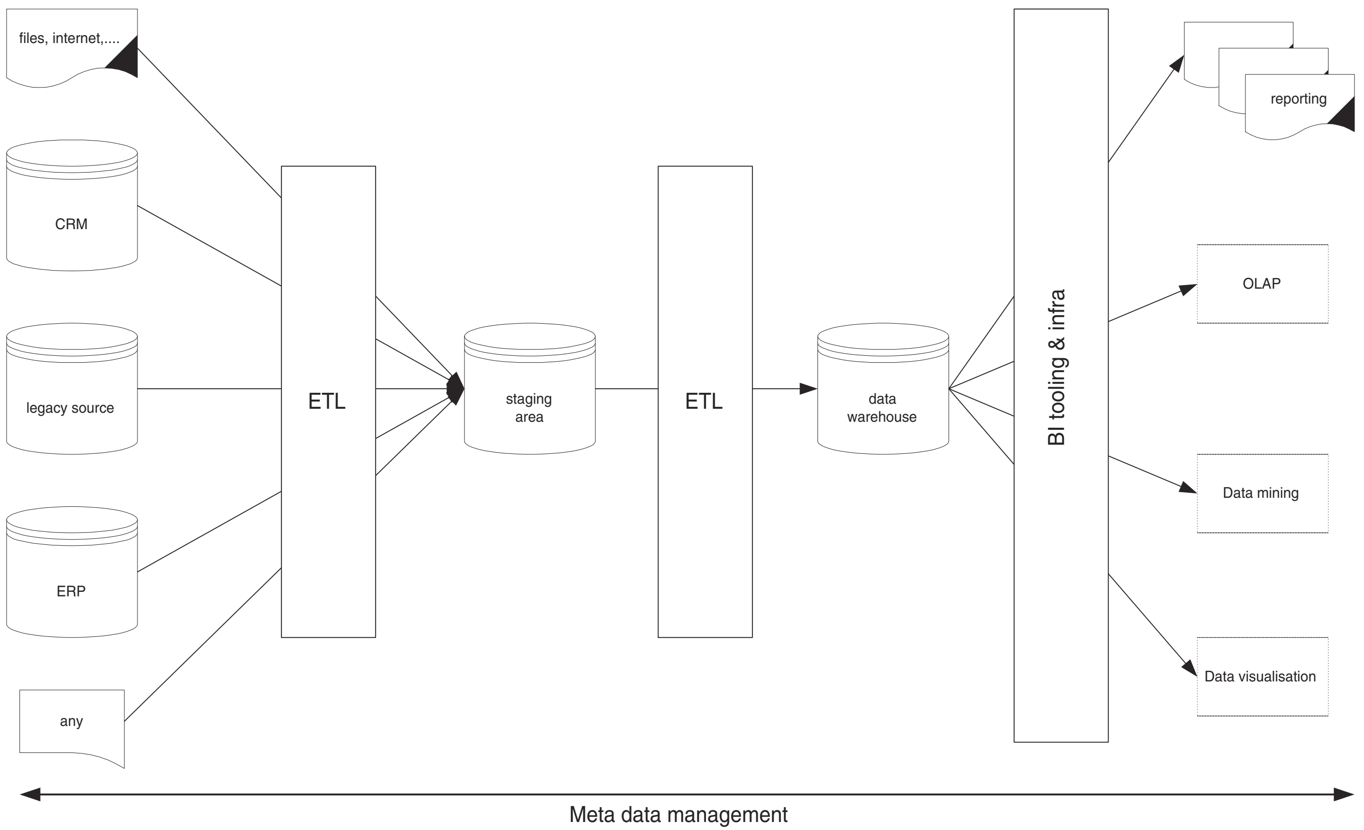
Data Warehousing (II)

Data Warehousing

- **subject oriented view:** organized around; concise view; focus on decision maker
- **integrated:** data extracted from various sources: internal, external; cleaning & integration techniques applied
- **time-variant:** historical data - summarised data - the *grain*
- **non-volatile:** reflect change without changing data
- **available:** for use when needed
- **separate**
- **time stamped:** analysis over time/time-tracking is required
- **accessible:** easy, understandable, self-explanatory, ...
- **IKIWISI:** end-user has control

Building the store -> a complex infrastructure required!

Data Warehousing (III) - infrastructure, architecture



Challenges for the Data Warehouse

- **Data:**
  - a data warehouse can only handle structured data, not **unstructured, nested, or multi-structured data**
- **Data volume:**
  - data warehouses can NOT cope with the amount of data to be stored
  - data warehouses can NOT cope with the data volatility, structure volatility, ...
- **Data loading**
  - [design of] ETT/ETL processes ‘*can not keep up*’ with the streams (volumes)/generation rate/nature/structure/... of the data to be processed for storage:
    - data quality, slowly changing dimensions, transformations, meta-data management
      => schema (r)evolution
  - The ETT/ETL process ‘massages’ data; analysis tools are biased as result of that [Data Vault]

Challenges for the Data Warehouse (II)

- **Data analysis:**

  needs to be '**agile**', rapid, volatile ... not possible given the complexities of **the ETL** process!

- **Performance:** query performance, storage system performance
- **Data transport**
- **Shared-something architecture** - suitable for DWs?
  More cost-effective alternatives exist?

Towards the end of Data Warehouses?

Are Data Warehouses **dead**?

Bill Inmon:

[‘Challenges for the Data Warehouse’, Inmon, BeyeNETWORK, November 7, 2013]

> “We find that a **big data solution is a technology** and that **data warehousing is an architecture**. They are two very different things.
>
> A **technology** is just that – **a means to store and manage large amounts of data**.
>
> A **data warehouse** is a **way of organizing data** so that there is corporate **credibility** and **integrity**. When someone takes data from a data warehouse, that person knows that other people are using the same data ... a basis for reconcilability of data when there is a data warehouse.”

‘Best-of-both-worlds’ - integrate **Data Warehouse** and **Big Data** initia-tives!

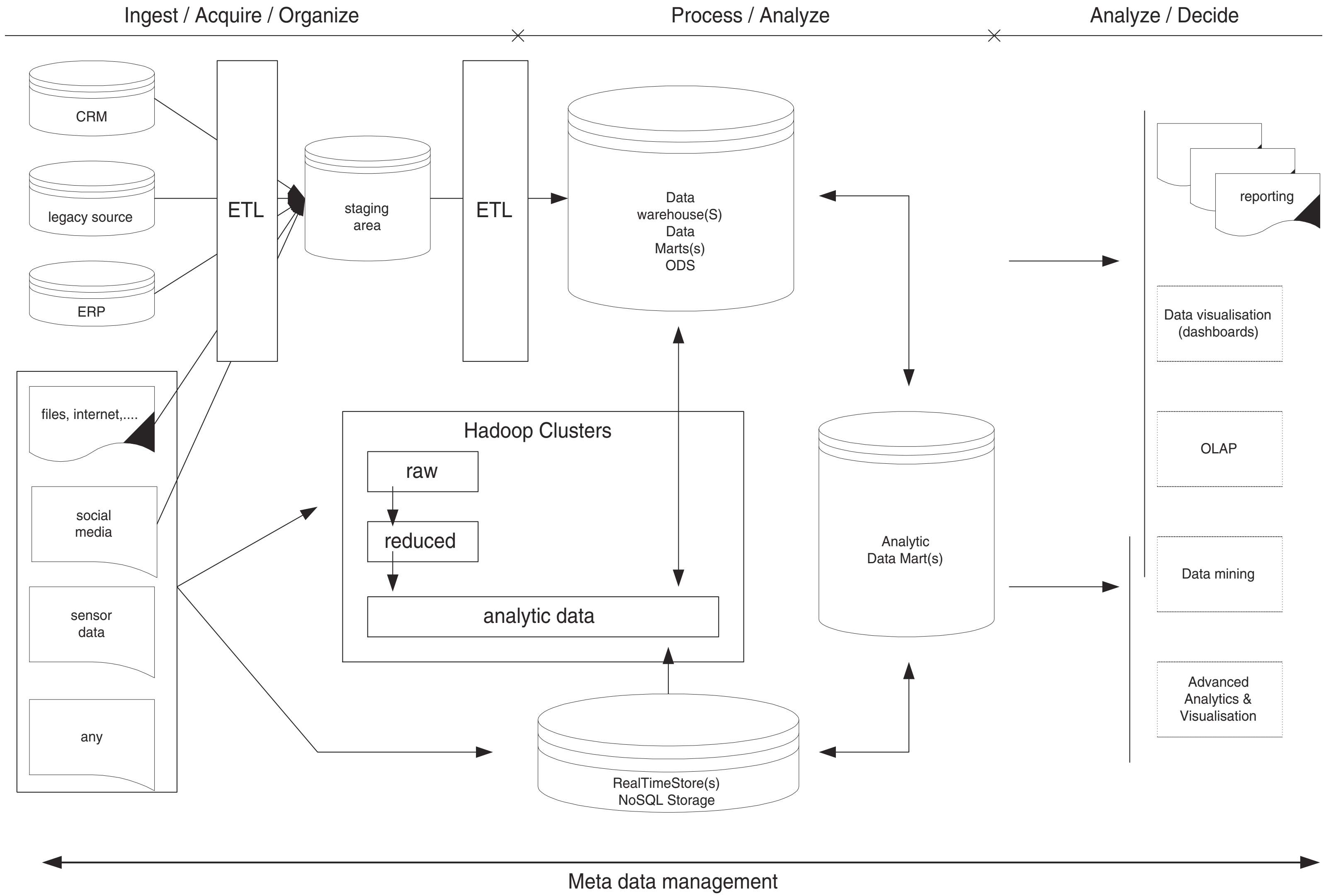
- **Data Warehouse**
  - analyses **structured** data from **structured sources** [stable, non-volatile]
  - insight into **well-know**, stable structures and measurements [built with questions (business requirements) in mind]
  - extensive **quality control** - ETL [clean data!]
  - data is ‘**public**’ [managed, secure, available, ...]
  - standard business reporting - to be used in **dashboards** (short-term KPIs) and **scorecards** (long-term KPIs)

high known value per byte!

Enterprise Data Architecture (II)

- **Big Data**
  - **semi-structured/unstructured data**
    [built with discovery in mind]
    [volatile]
  - **less/no quality control - raw data**
  - **data is 'not' public**
  - **exploratory -** analysis <u>and</u> discovery are key
    insight is created through analysis, discovery, ...
    NO specific requirements known in advance

unknown, low know value per byte!
as value increases, conclusions will have an impact - changes - on the data warehouse!



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Enterprise Data Architecture (III)

- **Oracle:**

  Oracle Information Management Reference Architecture, (IMRA),
  Oracle White Papers (2013)

- **IBM:**
  - The Logical Data Warehouse (IOD 2013)
  - Next Generation Data Warehouses (IOD 2013)

- **Microsoft:**

  Microsoft SQL Server Parallel Data Warehouse:
  PolyBase, HDInsight
  Microsoft publications (2013)

NoSQL Databases

New ‘storage’ systems have emerged to address requirements of ‘Big Data’ data management

NoSQL data stores - ie.

- Not Only SQL data stores
- NoSQL data stores

In short:

- **scalable SQL databases, horizontal scaling (shared nothing architectures)**
- **replicating and partitioning data over thousands of nodes**
- **distribute “simple operation” workload over thousands of nodes** (key lookups, read and writes a small number of records, no complex queries/joins)

Multiple types
[not all are introduced below - see http://nosql-database.org/]

What is the problem with relational databases?

P#1: You have to convert all your information from their natural representations into tables

P#2: You have to reconstruct your information from tabular data

P#3: You have to model your data into tables before you can store it

P#4: Columns of tables can only store similar data

P#5: Relational systems may not scale as well other systems

P#6: Joins between foreign systems with different record identifiers tend to be difficult

P#7: SQL dialects vary making it difficult to port applications between databases

P#8: Complex business rules are not easily expressible in SQL

P#9: SQL systems frequently do not perform well using approximate terms and fuzzy searches

P#10: SQL systems don't store and validate complex documents efficiently

Key features

1. ability to **horizontally scale** simple operations across nodes

2. ability to **replicate and distribute (partition)** data across nodes

3. **data-to-function** or **function-to-data**

4. **simple call level interface** (in contrast to SQL considered *too complex*)

5. **weak concurrency model**: forget ACID - go for BASE

6. efficient use of **distributed indexes** and RAM for data storage

7. ability to **dynamically add new attributes** to data records

Scale up - Scale out

- **Scale up - vertical scaling**

  remove I/O constraints to improve CPU consistency
  [perhaps using RAM storage caches]

  typically a 'shared something' architecture
  [shared disk?]

  most frequently used today

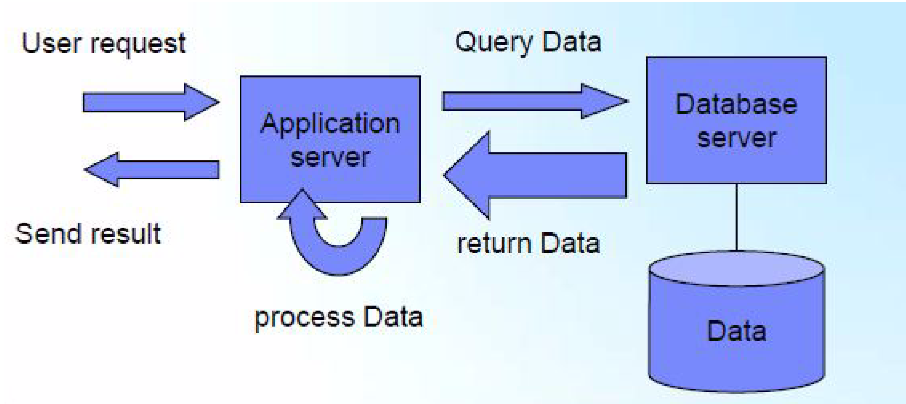
- **Scale out - horizontal scaling**

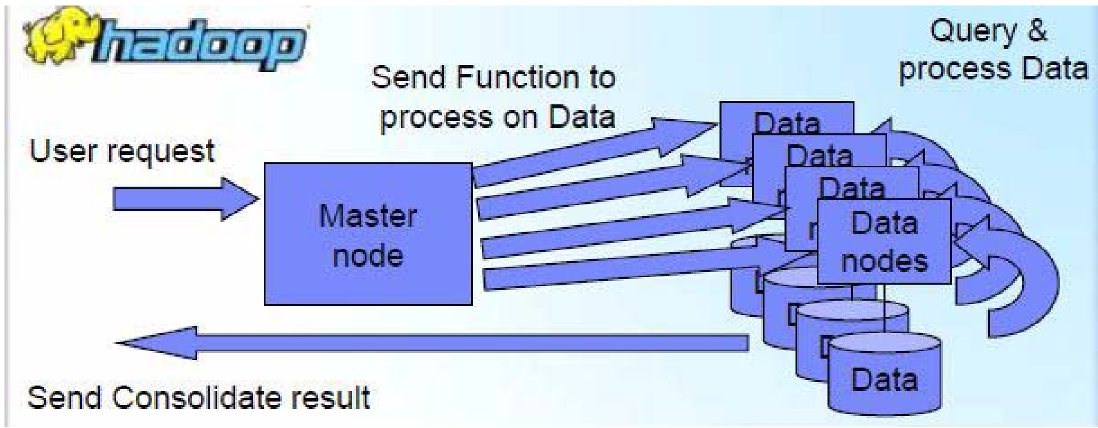
  combine 'commodity hardware' servers/clusters/racks
  [truly distributed]

  typically a 'shared nothing architecture'

  - functional scaling
    [one server per function idea]
  - sharding
    [multiple server 'serve' a function

Data-to-function or Function-to-data





Schema-less data storage

Most NoSQL databases at least offer the possibility to work:

- schema-less
- with dynamically changing schema's

Transactions, Consistency, Availability

The CAP theorem / Brewer's Conjecture

Real world distributed data storage systems require three properties:

- [data]**Consistency**
- **Availability**
- **Partition tolerance**

Conjecture: in a distributed shared nothing environment, it is not possible to satisfy all three requirements effectively with acceptable throughput rates!

In a 'shared something' environment (not distributed), there is no P, so only C and A need to be considered.

Transactions, Consistency, Availability

- **In 'Shared something' environments, C means ACID:**

  Pessimistic behaviour - force consistency at the end of every transaction!

  - **Atomicity:** all or nothing
  - **Consistency:** transactions never observe or result in inconsistent data
  - **Isolation:** transactions are not aware of concurrent transactions
  - **Durability:** once committed, the state of a transaction is permanent

  Standard request in typical *core business processes***!**

Transactions, Consistency, Availability

- **In a 'Shared nothing' environment, BASE is implemented:**
  [basically available soft state eventually consitent]

  Optimistic behaviour - accepts database inconsistencies for a short period of time

  - **C/P => Basically Available/Soft state**
    [amongst other implemented using replication]

  - **A/P => Eventually consistent**
    [weak consistency: in the absence of failures, everything will be consistent in the end]

Most NoSQL databases implement BASE; depending on the actual NoSQL database in use, different flavours of BASE might be implemented, and some might even optionally implement ACID.

SQL vs NoSQL

	SQL	NoSQL
types	one 'logical' database, with somewhat distinct 'physical' implement	many different types [columnar, key/value, document, graph, array, other]
history	1970	2000
storage	table/row/column aka. file/record/field storage	depends - records, documents ++unstructured++
schema	'static' schema's - structure pre-determined	'dynamic' schema - is there a schema? ++unstructured++ ++schema free++
scaling	vertical	horizontal ++easier, cheaper++

SQL vs NoSQL (II)

	SQL	NoSQL
development model	initially: propraiatary; later: open source	open source ++agile++
transaction support	yes ++	depends - not always
DML	SQL ++SQL++	OO APIs (perhaps also SQL) -- complex!! --infancy--
security & access control	fully implemented ++	
constraints	implemented, depending on... ++	often not enforced --
optimizer	present + 'predictable'	present optimized by the developer
consistency	typically strong ACID-like	typically wealker BASE-like

NoSQL database types

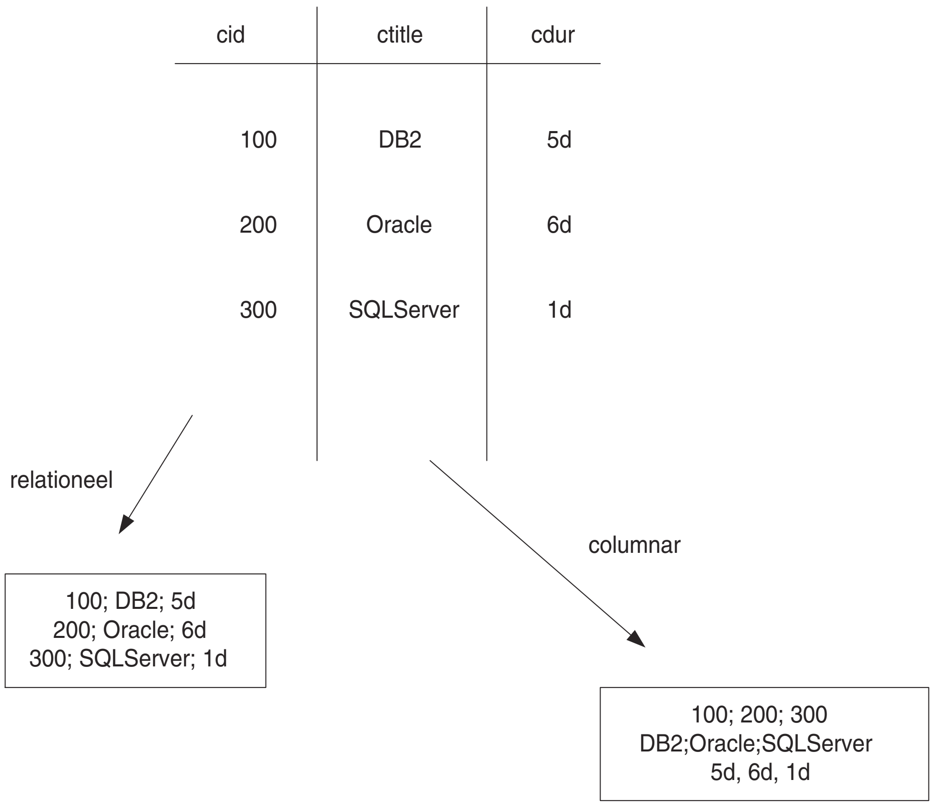
- **Columnar Databases**
  [wide column store - 'big table' clones]

  - **stores data tables as sections of columns of data**
    [rather than as rows of data]
    [hybrid row/column structure]
  - **data stored together with meta-data ('a map')**
    [typically including row identification, attribute name, attribute value, and timestamp]
  - **sparse - or not**

-

for example: Bigtable, HBase, Hypertable, Cassandra

NoSQL database types (II)

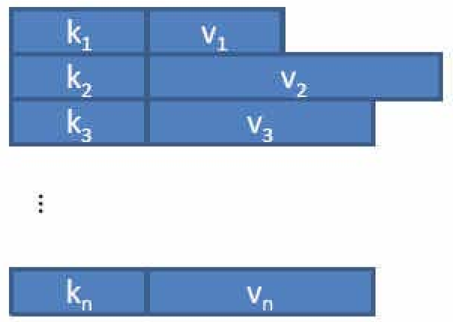


[easier aggregation, compression, self indexing]

NoSQL database types (III)

- **Key/Value Databases**
  - **values (data) stored based on programmer-defined** keys [hash table approach]
  - **system is agnostic as to the semantics of the value**
  - **requests are expressed in terms of keys**

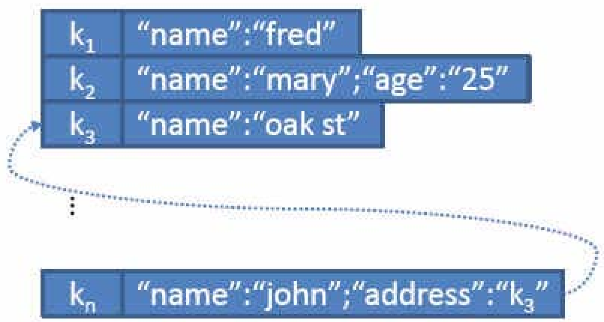
    put(key, value)
    get(key): value
  - **indexes can be/are defined over keys**
    [some systems support secondary indexes over (part of) the value]



for example: Berkley DB, Oracle NoSQL, LevelDB, AmazonDynamo, Mem-cached, ...

NoSQL database types (IV)

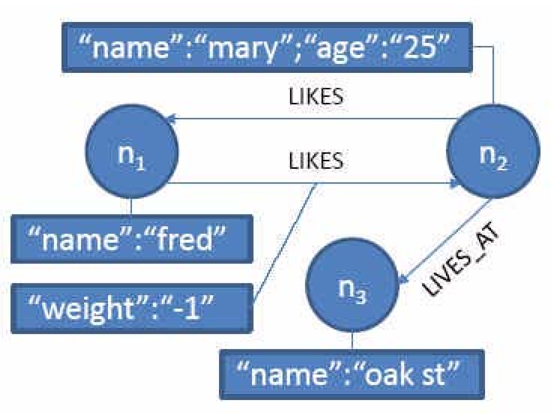
- **Document Data Model**
  - **documents are stored based on programmer-defined key** [a key-value store]
  - **system is aware of the arbitrary document structure**
  - **support for lists, pointers and nested documents**
  - **requests are expressed in terms of key (or attribute, if index exists)**
  - **support for key-based indexes and secondary indexes**



for example: MongoDB, CouchDB, RaptorDB, Riak, *IBM Lotus Notes*

NoSQL database types (V)

- **Graph Data Model**
  - **data is stored in terms of nodes and links**
    both can have (arbitrary) attributes
  - **requests are expressed based on system ids (if no indexes exist)**
    secondary indexes for nodes and links are supported
  - **SPARQL query language:** retrieve nodes by attributes and links by type, start and/or end node, and/or attributes



for example: Neo4j, InfoGrid, IMS

Vendors are embracing NoSQL

... as they did with MDM, XML, OO, ... ??

- **Oracle [key value] :** BerkleyDB, NoSQL DB
- **IBM:**

  [key value, columnar] : BigInsights HBase, IBM DB2 + BLU accelerator

  [document] : IBM DB2 + MongoDB support

  [graph] : IBM DB2 + Triple-Graph Store option

MongoDB 5

Introduction 5.1

- **JSON-style documents (BSON)**
  [document-based queries]
- **schema-free**
  - written in C++ for high performance
  - full index support
  - memory mapped files
  - no transactions (but supports atomic operations)
  - not relational
- **scalability**
  replication - sharding
- **MongoDB = CP, optionally AP** [on top of CP]

Introduction

- **‘utilities’ available:**
  - mongoexport
  - mongoimport
  - *others*
- **language drivers available:** C, C++, Java, Javascript, perl, PHP, Python, Ruby, C#, Erlang, Delphi, ... [*community supported*]
- **OS:** OS X, Linux, Windows, Solaris
- **Opens source, free -** commercial edition available

Concepts and Structures

- **A Mongo deployment (server or instance) holds a set of databases**
  - a database holds a set of collections
  - a collection holds a set of documents
  - a document is a set of fields: key-value pairs (JSON - BSON)
  - key-value-pairs:

    a *key* is a name (string)

    a *value* is a basic type like string, integer, float, timestamp, binary, etc., an embedded document, or an array of values
  - a '*special pair*': _objectid - default artificial key

'Lazy' - [most] collections and databases are created when the first document in inserted into them...

Concepts and Structures (II)

- **collections can be 'capped'**

  need to be created before **they can be used!**

  [no deletes, limited updates tolerated]

  have a 'fixed' size

db.createcollection('courseColCapped', ..., ...)

Concepts and Structures (III)

Document - oriented : collections **store** documents **in BSON format**
[collection=?= table]

- **JSON-style documents: BSON (Binary JSON)**
- **support for 'non-traditional' data types:** Date **type and a** BinData **type**
  - can reference other documents
  - lightweight (*minimal spatial overhead*), traversable (*find data quickly*), efficient (*linked to C/C++ data types*) - VERY FAST
- **all documents belonging to one and the same collection** can have **heterogeneous data structures!**
  [remember: no schema's]
- **typically** [check version]**: 4MB document limit**

Concepts and Structures (IV) - JSON

Let's first introduce JSON...

JavaScript Object Notation

°) a collection of (nested) key-value pairs

°) supporting ordered lists

°) record oriented

... and then talk about BSON [Binary JSON] **- an 'efficient' implementation of JSON.**

- **efficient use of storage space**
- **increased scan-speed**
  [large elements in a BSON document are prefixed with a length field]
- **array indices explicitely stored**

Concepts and Structures (V) - JSON


```
{
   "glossary": {
      "title": "example glossary",
        "GlossDiv": {
         "title": "S",
             "GlossList": {
             "GlossEntry": {
                "ID": "SGML",
                      "SortAs": "SGML",
                      "GlossTerm": "Standard Generalized Markup Language",
                      "Acronym": "SGML",
                      "Abbrev": "ISO 8879:1986",
                      "GlossDef": {
                   "para": "A meta-markup language, used to create DocBook.",
                           "GlossSeeAlso": ["GML", "XML"]
                },
                      "GlossSee": "markup"
             }
         }
      }
   }
}
```

MongoDB

- **Installation**

  download, unzip, create data directory, create default config file, and get started!

- **Start the MongoDB 'server'**

./bin/mongod

[*bin\mongod.exe*]

- **Start MongoDB 'client' -** interactive JavaScript shell

./bin/mongo

[*bin\mongo.exe*]

[root@everest bin]# ./mongod --dbpath /data/db **--port** 27017 **--config** /etc/mongod.conf

MongoDB (II)

Basic commands - examples

use [db name]

show dbs

show collections

Basic operations - an introduction into ...

- **Insert operations**
  [sample]

```
> use coursedb
switched to db coursedb
> db.courseCol.insert({"Coursename":"DB2","Coursedur":3})
> db.courseCol.insert({"Coursename":"Oracle","Coursedur":5})
> db.courseCol.insert({"Coursename":"SQLServer","Coursedur":2})
> show collections
courseCol
system.indexes
```

Basic operations - an introduction into ... (II)

- **Select operations**
  [sample]

```
> db.courseCol.find({"Coursename":"Oracle"})

{ "_id" : ObjectId("51a089ad17338b27674af7a2"), "Coursename" : "Oracle", "Coursedur" : "5" }

> db.courseCol.find({"Coursename":"Oracle"},{"Coursedur":1});

{ "_id" : ObjectId("51a089ad17338b27674af7a2"), "Coursedur" : "5" }

> db.courseCol.find({Coursedur:{"$gt":2}});

{ "_id" : ObjectId("51a08fc295ce664a0e633cfb"), "Coursename" : "Oracle", "Coursedur" : 5 }
{ "_id" : ObjectId("51a08fd795ce664a0e633cfd"), "Coursename" : "DB2", "Coursedur" : 3 }
```

conditional ops: $gt, $gte, ..., $and, $in, $or, $nor, ...
$limit, $offset, ..., $sort, ...

Basic operations - an introduction into ... (III)

- **...**
  [sample]

```
> db.courseCol.insert({"Coursename":"DB2","Coursedur":3, "Instructor" : "Kris"})

> db.courseCol.find({"Coursename":"DB2"});
{ "_id" : ObjectId("51a08fd795ce664a0e633cfd"), "Coursename" : "DB2", "Coursedur" : 3 }
{ "_id" : ObjectId("51a090dd95ce664a0e633cfe"), "Coursename" : "DB2", "Coursedur" : 3,
"Instructor" : "Kris" }

> db.courseCol.find({"Coursename":"DB2"},{"Instructor":1});
{ "_id" : ObjectId("51a08fd795ce664a0e633cfd") }
{ "_id" : ObjectId("51a090dd95ce664a0e633cfe"), "Instructor" : "Kris" }

> db.courseCol.find({"Instructor":"Kris"});
{ "_id" : ObjectId("51a090dd95ce664a0e633cfe"), "Coursename" : "DB2", "Coursedur" : 3,
"Instructor" : "Kris" }
>
```

Basic operations - an introduction into ... (IV)

- **Update**
  [sample] - !! default !! - only the first doc is updated

> db.courseCol.insert({"Coursename":"DB2","Coursedur":3, "Instructor" : "Kris"})

> db.courseCol.find({"Coursename":"DB2"});

{ "_id" : ObjectId("51a09e6595ce664a0e633cff"), "Coursename" : "DB2", "Coursedur" : 3, "Instructor" : "Kris" }

> db.courseCol.update({"Coursename":"DB2"},{$set : {"Coursedur":6}})

> db.courseCol.find({"Coursename":"DB2"});

{ "_id" : ObjectId("51a09e6595ce664a0e633cff"), "Coursename" : "DB2", "Coursedur" : 6, "Instructor" : "Kris" }

> db.courseCol.update({"Coursename":"DB2"},{$set : {"CoursedurUSA":8}})

> db.courseCol.find({"Coursename":"DB2"});

{ "Coursedur" : 6, "CoursedurUSA" : 8, "Coursename" : "DB2", "Instructor" : "Kris", "_id" : ObjectId("51a09e6595ce664a0e633cff") }

alternatives: $inc, $set, $push, $pushall, ...

Basic operations - introduction (V)

- **Remove**
  [sample]

```
> db.courseCol.remove()

db.courseCol.remove({"Coursedur" : {$lt : 7}})
> db.courseCol.find({"Coursename":"DB2"});
```

Indexes

- **full index support**
  [index on any attribute (including multiple, list/arrays, nested)]
  [blocking by default]
- **increase query performance**
- **indexes are implemented as “B-Tree” indexes**
  [unique or not][asc, desc]
  [missing keys: null by default - sparse index]
- **as always: data overhead for inserts and deletes**
- **document TTL in index can be specified**
- **implementation:**
  - **db.<col>.ensureIndex()**
  - **db.<col>.getIndexes(), getIndexKeys(), dropIndex(), reIndex()**
  - **db.system.indexes.find**

Indexes (II)

```
> db.courseCol.ensureIndex( {"Coursename" : 1 })
> db.courseCol.getIndexes()
[
    {},
    {
        "v" : 1,
        "key" : {
            "Coursename" : 1
        },
        "ns" : "test.courseCol",
        "name" : "Coursename_1"
    }
]
```

Indexes (III)

Limitations:

- **collections : max 64 indexes**
- **index key length max 1024 bytes**
- **queries can only use 1 index**
  [carefull with concatenated indexes, carefull with negation, carefull with regexp]
- **indexes have storage requirements, and impact the performance of writes**
- **in memory sort (no-index) limited to 32 MB**

Indexes (IV) - explain, caching

```
> db.courseCol.find({"Coursename":"Oracle"}).explain()
{
    "cursor" : "BtreeCursor Coursename_1",
    "isMultiKey" : false,
    "n" : 1,
    "nscannedObjects" : 1,            "nscanned" : 1,
    "nscannedObjectsAllPlans" : 1,   "nscannedAllPlans" : 1,
    "scanAndOrder" : false,          "indexOnly" : false,
    "nYields" : 0,                    "nChunkSkips" : 0,
    "millis" : 0,                     "indexBounds" : {
        "Coursename" : [
            [
                "Oracle",
                "Oracle"
            ]
        ]
    },
    "server" : "everest.abis.be:27017"
}
```

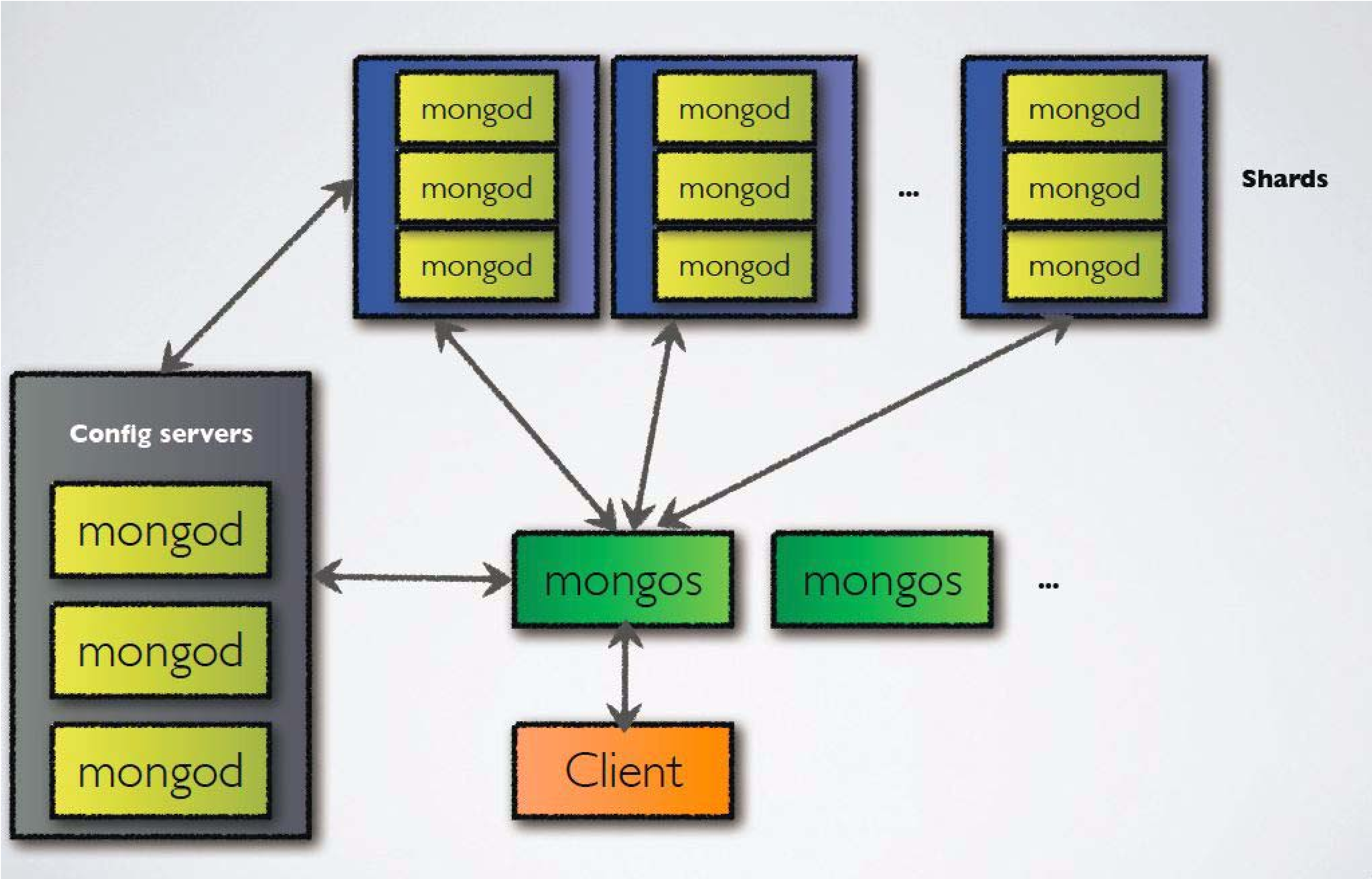
Indexes (IV) - explain, caching

The Query Optimizer:

- for each "type" of query, MongoDB periodically tries all useful indexes
- aborts the rest as soon as one plan wins
- the ‘winning plan’ is temporarily cached for each “type” of query

Hints are supported.

Architecture revisited



Shards

- **a shard is a node on a cluster**
- **a shard can be**
  - **a single mongod**
  - **a replica set**
    [multiple mongod]
- **data is stored on a** shard **in** chunks **of a specific** size
  [by default 64M]
- **MongoDB automatically** splits **and** migrates **chunks as needed**
- **Why use shards?**
  - **scale read/write performance**
  - **increase total RAM - keep 'working set' (index + data) in memory**

Config servers

- **stored meta data:**
  store cluster chunk ranges and locations
- **can have only 1 or 3**
  [production: use 3 if not ...]
- **2PC commit (not a replica set)**

[root@everest bin]# ./mongod --configsvr --port 27019

[root@zion bin]# ./mongod --configsvr --port 27019

[root@bryce bin]# ./mongod --configsvr --port 27019

MongoS

- **acts as a router / balancer**
  installed next to the application server
  routes application requests to the data
  balances chunks
- **no local data (persists to config database)**
- **can have 1 or many**

[root@thegrand bin]# ./mongos --configdb everest:27019, zion:27019, bryce:27019

Start, add, enable shard(ing)

- **start the shard database**
  [can be an already running, non-sharded db]

[root@xenophon bin]# ./mongod --shardsvr --dbpath /data/db **--port** 27018 **--config** /etc/mongod.conf

[root@socrates bin]# ./mongod --shardsvr --dbpath /data/db **--port** 27018 **--config** /etc/mongod.conf

- **add the shard definition on MongoS**

> sh.addShard('xenophon:27018')
> sh.addShard('socrates:27018')

- **enable sharding**

> sh.enableSharding("coursedb");
> sh.shardCollection("coursedb.courseCol", {"coursedur":1})

Sharding - chunks

- **based on** range-partitioning**!**
- **a chunk is a** section **of a range**
  - **a chunk is** split **once it exceeds the maximum size**
    [configuration, default 64M]

    There is no split point if all documents have the same shard key
  - **chunk split is a logical operation**
    [no data is moved]
  - **if split creates too large of a discrepancy of #chunks across shards: rebalancing starts**
    [configuration parameter]

Sharding - chunks (II)

- **rebalancing:**
  - **balancer part of mongos**
  - **migration - balancer lock:**
    - mongos sends *moveChunk* to source shard
    - source shard notifies destination shard
    - destination shard claims the chunk shard-key range
    - destination shard pulls documents from source shard
    - destination shard updates config server - new location of copied chunks
  - **cleanup:**
    - **source shard deletes moved data**
      [waits for open cursors to either close or time out]
    - **mongos releases the balancer lock after old chunks are deleted**

Sharding - chunks (III)

Shard key:

- **use a field commonly used in queries**
- **shard key is immutable; shard key values are immutable**
- **shard key requires index on fields contained in key**
- **shard key limited to 512 bytes in size**
- **things to think about:**
  [use your RDBMS skills]
  - cardinality
  - write distribution
  - query isolation
  - data distribution

About Replication

- **Why?**
  - **high availability**
    - if a node fails, another node can step in
    - extra copies of data for recovery
  - **Scaling reads = applications with high read requirements can read from replicas**
- **a** *replica set* **- a set of mongod servers**
  - **minimum of 3**
  - **election of a primary (consensus)**
  - **writes go to primary; secondaries replicate from primary**
- **define and start the replica set -**'named' **set**

mongod --replSet <name>

<name> uses a configuration file, listing the other servers in the set

About Replication (II) - oplog

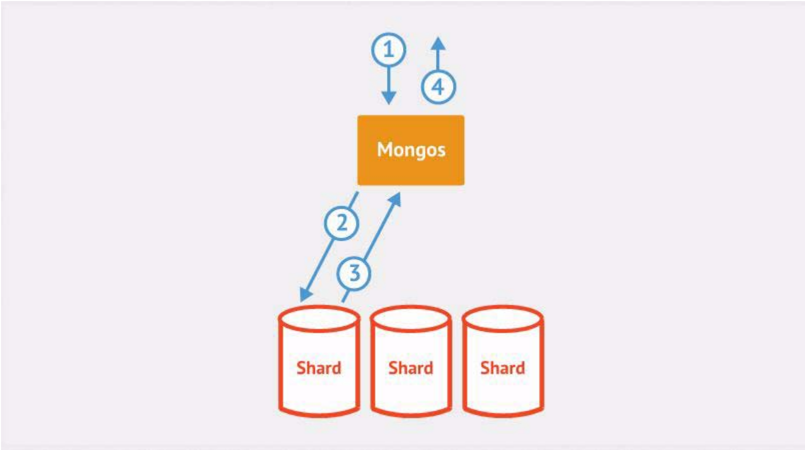
- **change operations are written to the** oplog **of the primary**
  - **a capped collection**
  - **must have enough space to allow new secondaries to catch up after copying from a primary**
  - **must have enough space to cope with any applicable** slaveDelay
  - **secondaries query the primary’s oplog and apply what they find**

About Replication (II) - failover

Failover:

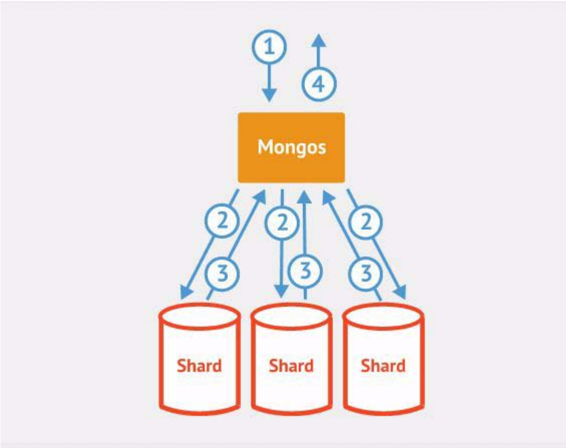
- **replica set members monitor other set members [heartbeats]**
- **if primary not reachable, a new one is elected**
- **the secondary with the** most up-to-date oplog **is chosen**
  [priority can be set to influence election; secondaries can be banned from becoming primary]
- **if, after election, a secondary has changes not on the new primary, those are** undone**, and moved aside**
- **if you require a guarantee, ensure data is written to a majority of the replica set**

Targeted Queries



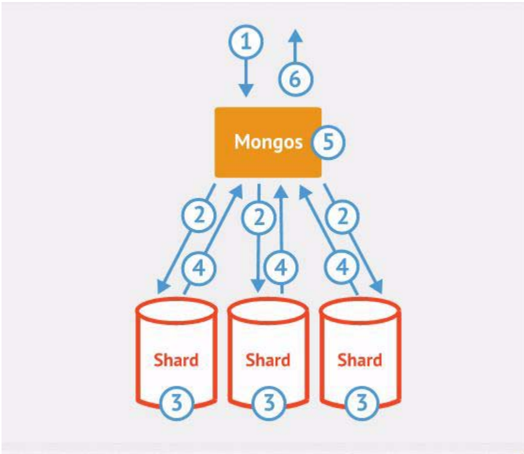
Request Routing (II)

Scatter Gather Queries



Request Routing (III)

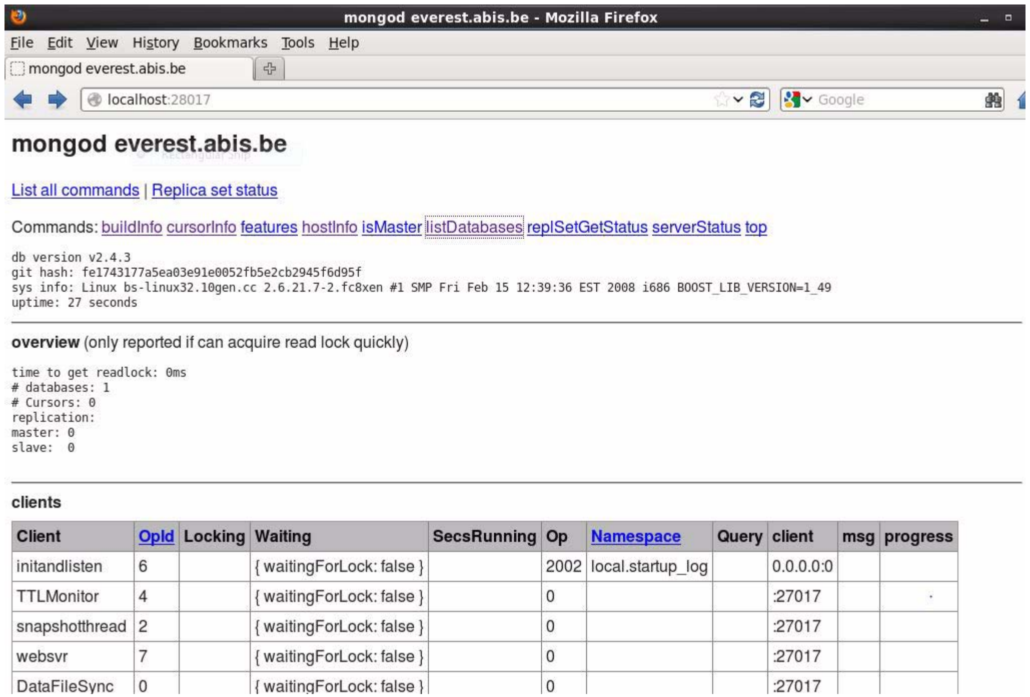
Scatter Gather Queries with Sort



REST interface

- **mongod provides a basic REST interface**
  [-- rest, default port 28017]

[root@everest bin]# ./mongod --dbpath /data/db --port 27017 --config /etc/mongod.conf --rest



Other features...

- **GridFS**
  - **store files of any size** (exceeding binary storage data max size)
  - **GridFS leverages existing** replication **or** autosharding **that has been set up**
- **Map Reduce**
  - **queries** [jscript function] **run in all shards parallel** [one thread per node]
  - **flexible aggregation and data processing**
  - **often used**
- **Geospatial Indexing**

  two-dimensional indexing for location-based queries
  [find objects based on location? Find closest n items to x]

```
db.map.insert({location : {longitude : -40, latitude : 78}})
db.map.find({location : {$near : [ -30, 70]}})
```

Thank you!

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