AN INTRODUCTION TO BIG DATA

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Let’s start from few citations

Data creation is exploding.

With all the selfies and useless files people refuse to delete on the cloud. . . . The world’s data storage capacity will be overtaken. . . . Data shortages, data rationing, data black markets . . . data-geddon!

Gavin Belson, HBOs Silicon Valley

Data is the new oil

Clive Humby, UK Mathemetician, 2006

…

Qi Lu, the chief of Microsoft’s Applications and Services, 2016

Let's start from few citations

Information is the oil of the 21st century, and analytics is the combustion engine

Peter Sondergaard, Gartner Research, 2011

A relational database is like a garage that forces you to take your car apart and store the pieces in little drawers

Anonymous

An finally SQL is back!

Anonymous

Is there a definition of bigdata?

- *No unique definition!*
- *A buzzword often misused*

"Data whose volume, variety, velocity of production, and complexity require new architectures, techniques, algorithms and analytics to manage it and extract value and hidden knowledge from it"

The famous “Vs”

- The Vs of Bigdata
  - Volume: scale of data
    Data volume is increasing ..up to ZB!
  - Variety: different forms of data
    Text, images, numerical values, etc.
  - Velocity: speed of production and elaboration
    e.g., streaming data, logs
  - Veracity: uncertainty and imprecision of data → quality!
  - Value: exploit intrinsic value by data
    - to create business advantage, thus
    - *need for strong analytics and reasoning* → *Data Science*

WHAT IS BIGDATA?

Let's try to answer from a historical perspective

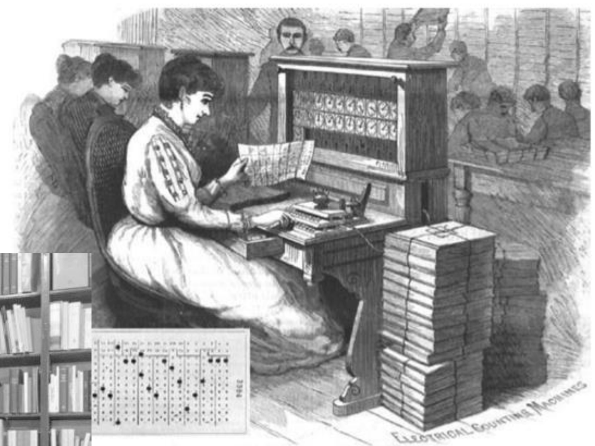
Three revolutions in data bases

The main factors driving the main changes were:

1. The emergence of the electronic computer
2. The emergence of the relational database
3. The need of global scope and continuous availability

Three revolutions in data bases

- The term database dates back to the late 1960s
- But, *collecting and organizing data has been an integral factor in the development of human civilization and technology*

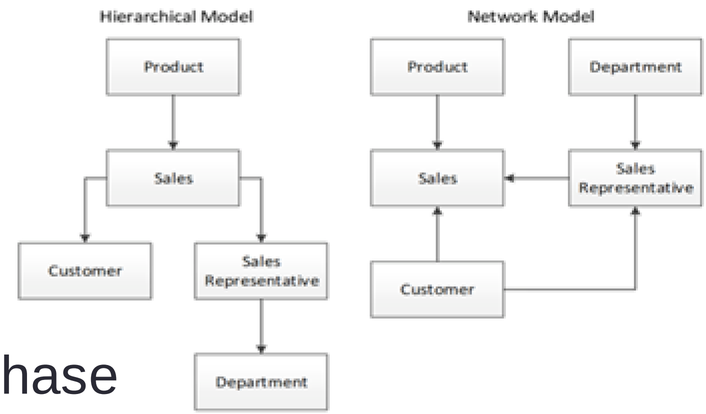


Three revolutions in data bases

- *The emergence of electronic computers following the Second World War ignited the first revolution in databases*
  - Direct high-speed access to individual records became possible in in the mid-1950s
  - ISAM (Index Sequential Access Method) made fast record-oriented access feasible
  - The birth of the first OLTP (On-line Transaction Processing) computer systems
    - These were completely under the control of the application
    - No *Database Management Systems* (*DBMS*)

First generation databases

- The first-generation databases ran exclusively on the mainframe computers (largely IBM mainframes)
- Two competing data models emerged in early 70-ties:
  - *Network model* (CODASYL standard)
  - *Hierarchical model* (somewhat simpler approach)
- "Navigational" in nature
  - Navigate using pointers or links
  - Dominated up until the late 1970s



- Extremely inflexible
  - Queries anticipated during the design phase
  - Complex analytic queries required complex coding
- The golden era of Cobol programmers!

The Second Database Revolution

The main issues:

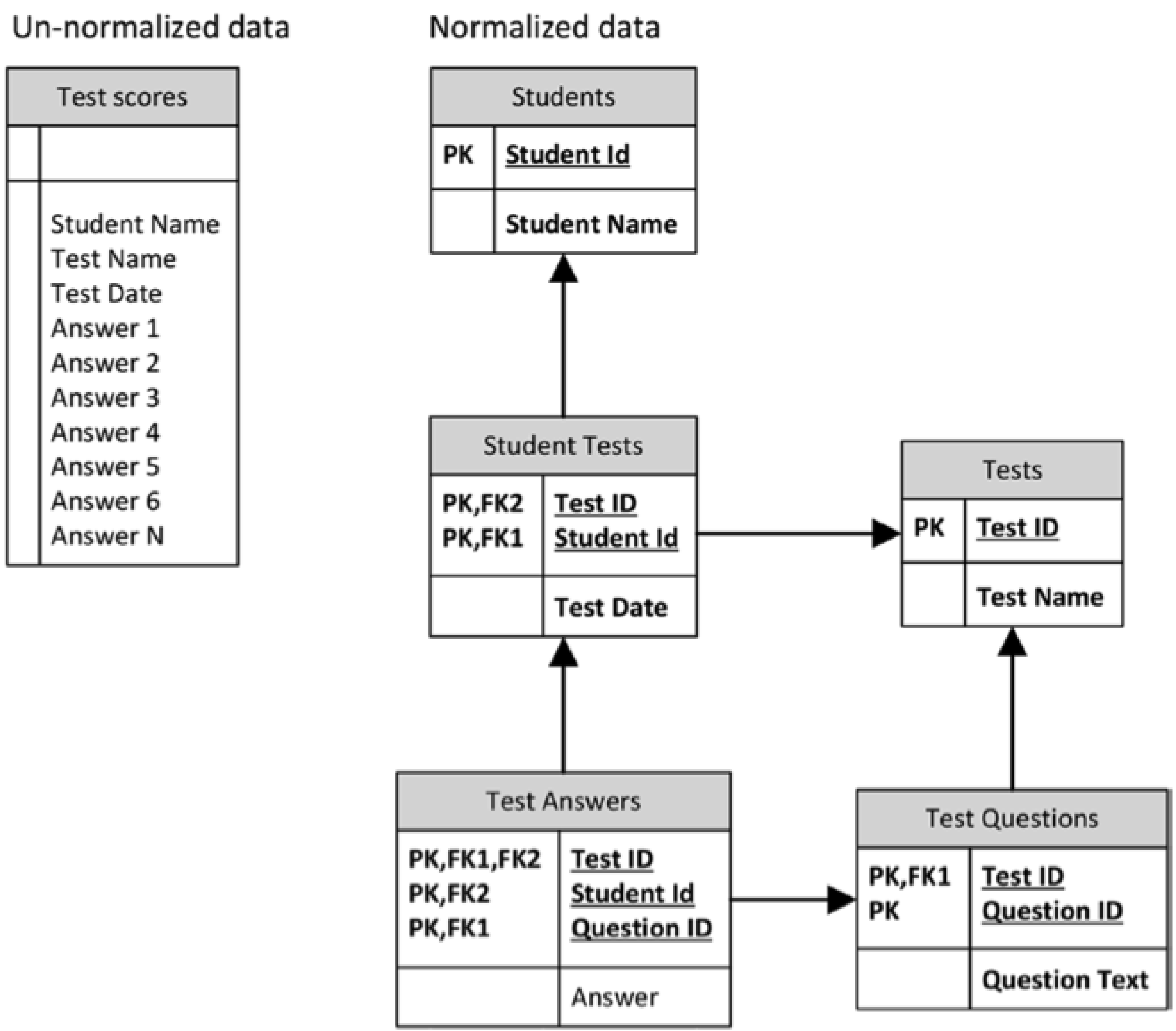
1. Existing databases were too hard to use
   - only for people with specialized programming skills
2. Lacked a solid mathematical foundation
   - no logical consistency, nor ability to deal with missing information
3. Mixed logical and physical implementations
   - physical storage incomprehensible to nontechnical users

- In 1970 Codd published
  "A Relational Model of Data for Large Shared Data Banks"
  - defined the *relational database model*
  - the most significant—almost universal—model for database systems for a generation

The Second Database Revolution

- The relational model by Codd
  - Clearly presents data to the user
  - Does not mention how it should be stored on disk or in memory
  - Solid mathematical foundations
  - Levels of conformance via “normal forms”

- Concurrent data change requests → transactions
  - ensure consistency and integrity of data
  - *A transaction is a transformation of state which has the properties of atomicity (all or nothing), durability (effects survive failures) and consistency (a correct transformation).*
  - ACID transactions: Atomic, Consistent, Isolated, and Durable.
    - Model defined by Jim Gray in the late 1970s
  - the standard for all serious database implementations


Un-normalized data
Normalized data
Test scores
Student Name
Test Name
Test Date
Answer 1
Answer 2
Answer 3
Answer 4
Answer 5
Answer 6
Answer N
Students
PK
Student Id
Student Name
Student Tests
PK,FK2
PK,FK1
Test ID
Student Id
Test Date
Tests
PK
Test ID
Test Name
Test Answers
PK,FK1,FK2
PK,FK2
PK,FK1
Test ID
Student Id
Question ID
Answer
Test Questions
PK,FK1
PK
Test ID
Question ID
Question Text

Relational DBMSs

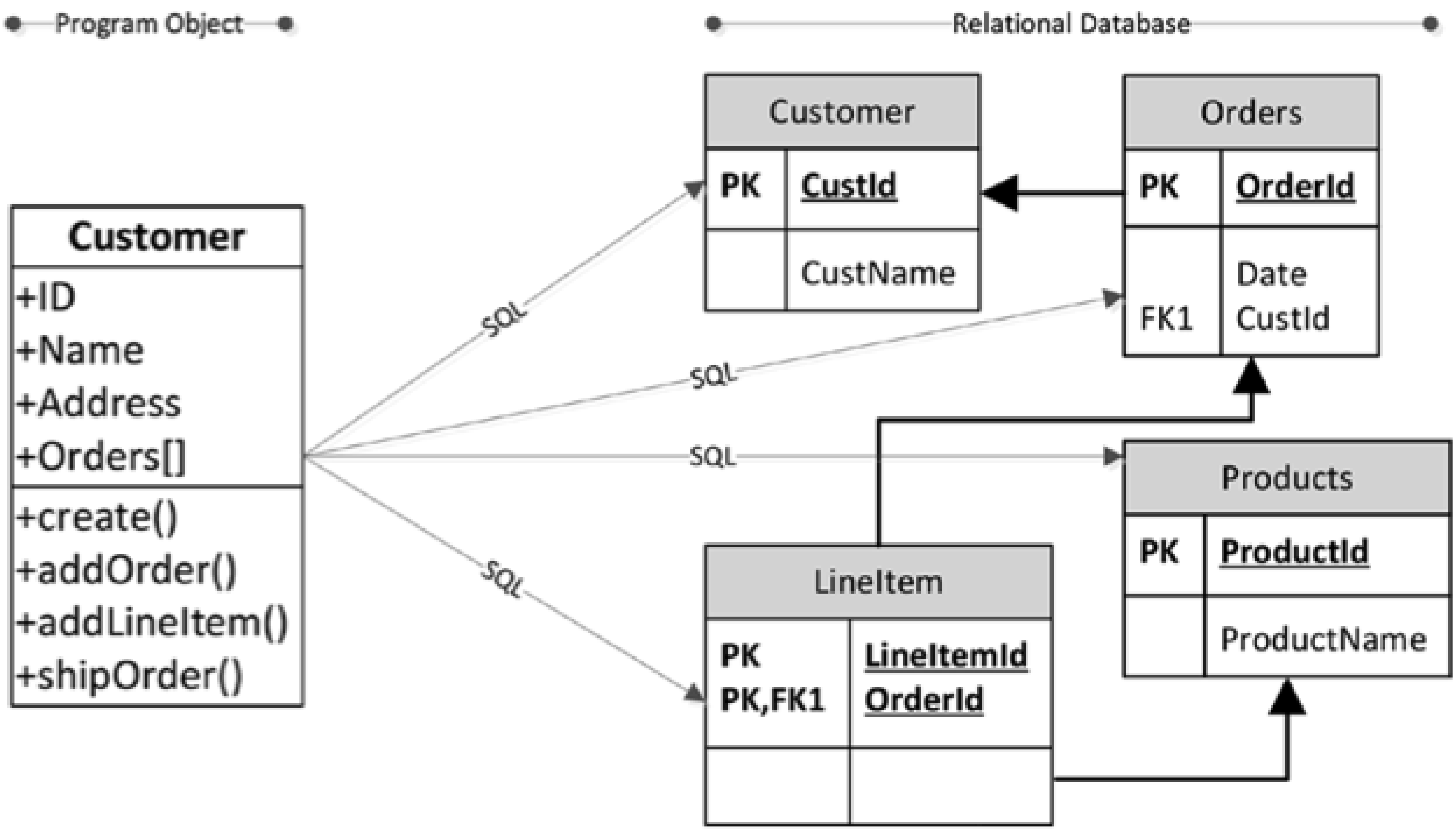
- Initially vendors including IBM did not like the idea
    - Can a relational DB deliver adequate performance?
- IBM initiate proved it in 1974 with System R
    - it pioneered the *SQL language*
- On the hardware side minicomputers replaced mainframes in the 80-ties
- In 10 about years many new DBMSs were introduced
    - E.g., Oracle, Sybase, SQL Server, Informix, MySQL, and DB2
- Today a Relational DBMS means:
    - Relational data model + ACID transactions + SQL
- Dominating technology, unchallenged until the latter half of the 2000s

Relational DBMS

- More than 30 years of commercial dominance!
- A triumph of computer science and software engineering
  - Strong theoretical foundations
  - Data independent of the physical storage implementation
  - ACID transaction model
  - Flexible query mechanisms that do not require sophisticated programming skills

The *unlucky* OODBMS

- Another significant paradigm shift impacted mainstream application-development languages:
  - *Object-oriented (OO) programming*
    - Encapsulation: An object class encapsulates both data and actions (methods) that may be performed on that data
    - Inheritance: Object classes can inherit the characteristics of a parent class
- The “impedance mismatch”
  - The first serious challenge to the relational database
  - Various differences in the models
    - From identity, to navigation, to association maintenance, etc.
  - Did not match current technology
  - Alleviated by Object Relational Matching (ORM)


Program Object
Relational Database
Customer
+ID
+Name
+Address
+Orders[]
+create()
+addOrder()
+addLineItem()
+shipOrder()
SQL
SQL
SQL
SQL
Customer
PK CustId
CustName
Orders
PK OrderId
Date
FK1 CustId
Products
PK ProductId
ProductName
LineItem
PK LineItemId
PK,FK1 OrderId

The Third Database Revolution

- *No significant new databases were introduced for about 10 years (1995–2005)*
- The era of massive web-scale applications begins
  - RDBMS demonstrate scalability limits, and high costs
    - Scale-up vs scale-out
  - Google had to invent new hardware and software architectures
  - Amazon needed transactional processing capability that could operate at massive scale
  - MySpace and eventually Facebook faced similar challenges in scaling their infrastructure from thousands to millions of users

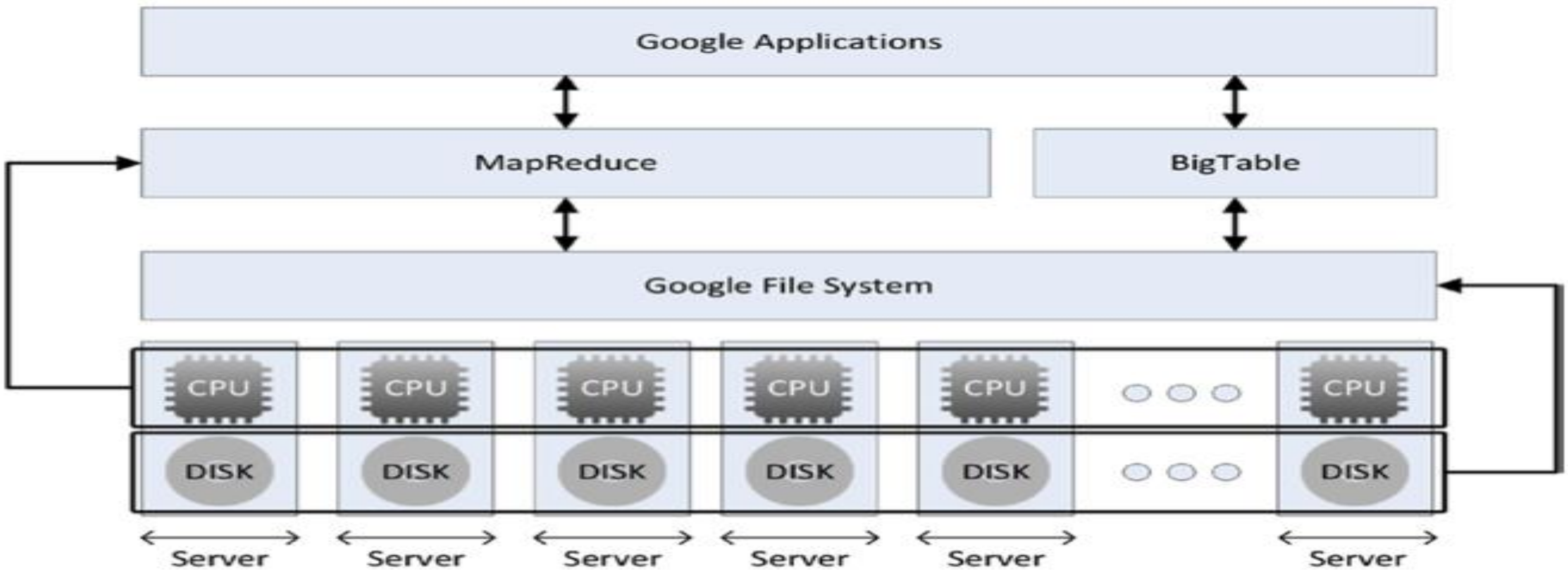
  - *Oracle could not provide sufficient scalability*

New database designs emerge

- Sharding (Facebook/Twitter) involves partitioning the data across multiple databases → ACID transactions are lost
- Amazon developed an alternative to strict ACID → key-value store (DynamoDB)
- Programmers unhappy with the impedance mismatch → Document databases (CouchBase and MongoDB)
  - Enabled by AJAX and diffusion of JSON
- NoSQL and NewSQL *"the Nonrelational Explosion"*
  - H-Store described a pure in-memory distributed database
  - C-Store specified a design for a columnar database

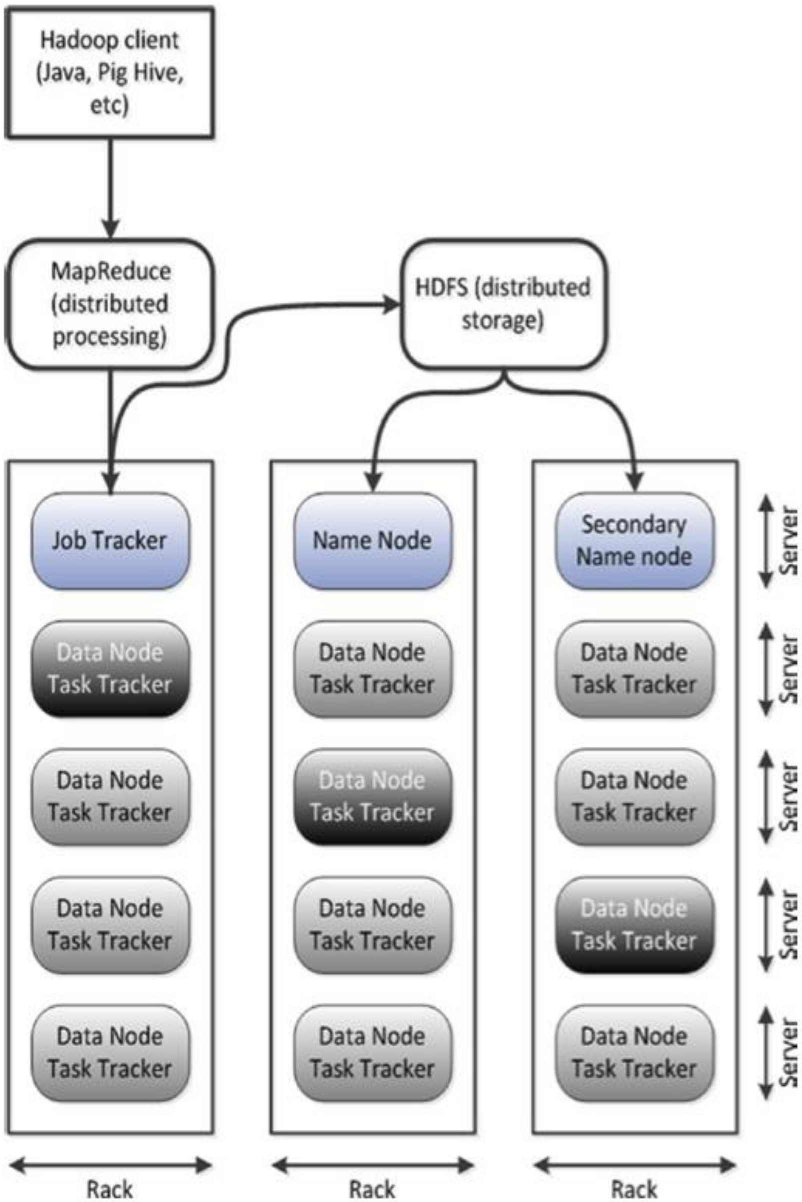
Google solutions

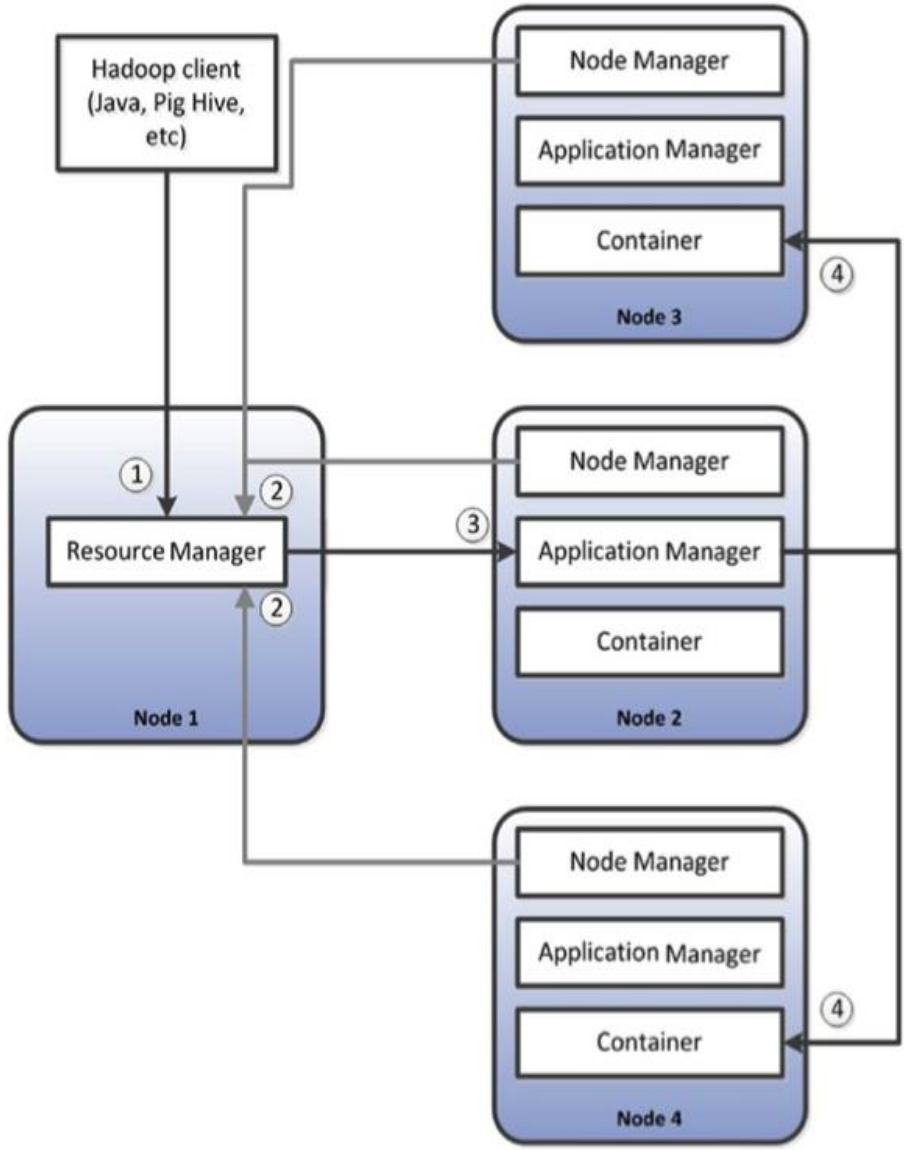
- In 2003, Google revealed
  - the distributed file system GFS
  - the parallel processing algorithm MapReduce
  - its BigTable distributed structured database

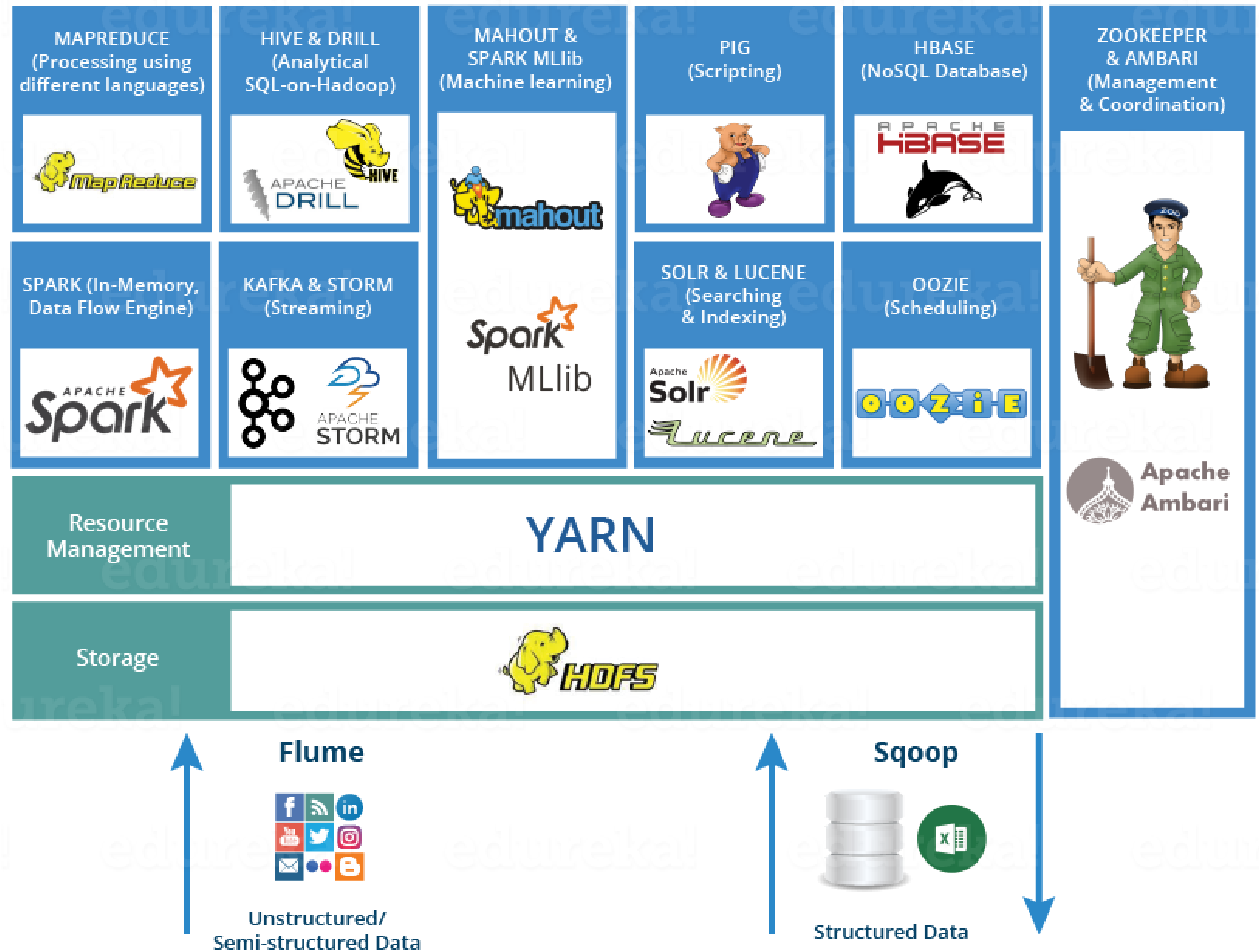


Hadoop ecosystem

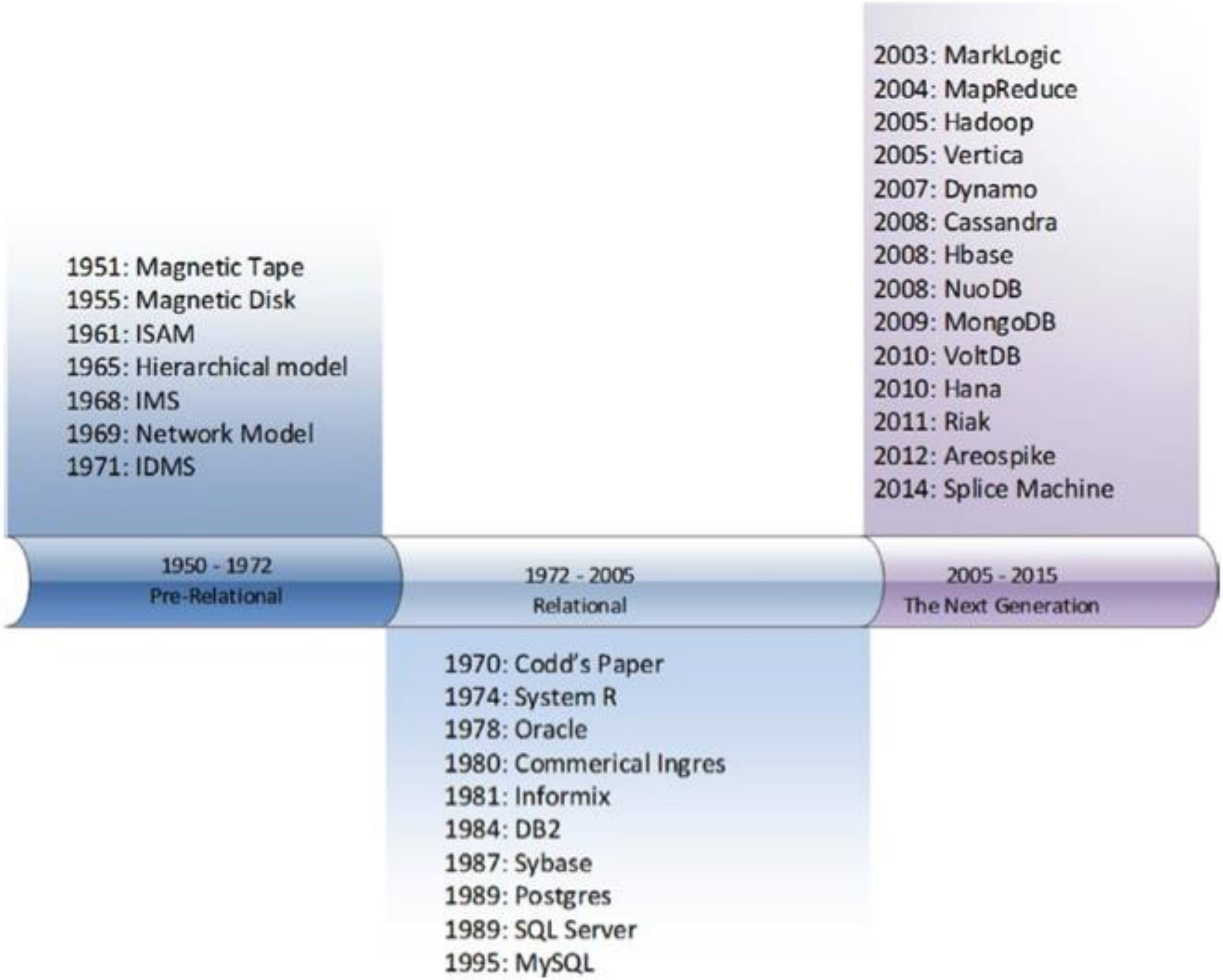
- The Hadoop project (by Yahoo!)
  - Opens source inspired to Google solutions
  - a rapid uptake from 2007 on become an ecosystem
  - a technology enabler for Big Data
  - the de facto solution for massive unstructured data
- Hadoop
  - *Hadoop Distributed File System* (*HDFS*)
  - *YARN* (*Yet Another Resource Negotiator)*
- *Hadoop ecosystem*
  - Hbase, Hive, Pig, Sqoop, Spark, Mahout, etc.
- Spark
  - in-memory, distributed, fault-tolerant processing framework
  - Implemented in Scala, higher-level than MapReduce, no IO bottlenecks

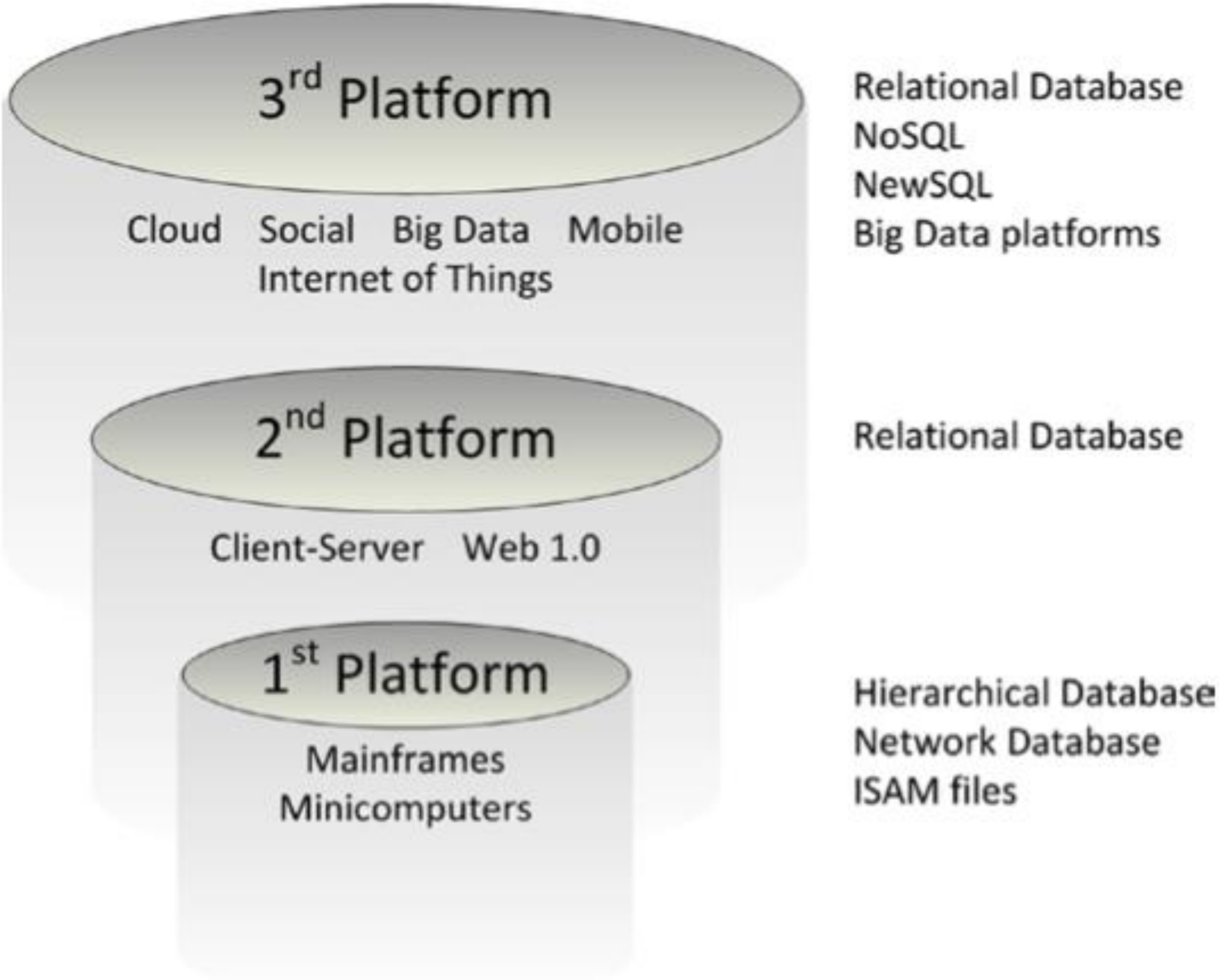

Hadoop client (Java, Pig Hive, etc)
MapReduce (distributed processing)
HDFS (distributed storage)
Job Tracker
Name Node
Secondary Name node
Data Node Task Tracker
Server
Rack


Hadoop client (Java, Pig Hive, etc)
Resource Manager
Node 1
Node Manager
Application Manager
Container
Node 3
Node 2
Node 4
1
2
3
4



MAPREDUCE
(Processing using different languages)
MapReduce
HIVE & DRILL
(Analytical SQL-on-Hadoop)
HIVE
APACHE DRILL
MAHOUT & SPARK MLlib
(Machine learning)
mahout
Spark
MLlib
PIG
(Scripting)
HBASE
(NoSQL Database)
APACHE HBASE
ZOOKEEPER & AMBARI
(Management & Coordination)
ZOO
Apache Ambari
SPARK (In-Memory, Data Flow Engine)
APACHE Spark
KAFKA & STORM
(Streaming)
APACHE STORM
SOLR & LUCENE
(Searching & Indexing)
Apache Solr
Lucene
OOZIE
(Scheduling)
OOZIE
Resource Management
YARN
Storage
HDFS
Flume
Unstructured/ Semi-structured Data
Sqoop
Structured Data


1951: Magnetic Tape
1955: Magnetic Disk
1961: ISAM
1965: Hierarchical model
1968: IMS
1969: Network Model
1971: IDMS
1950 - 1972
Pre-Relational
1972 - 2005
Relational
1970: Codd's Paper
1974: System R
1978: Oracle
1980: Commerical Ingres
1981: Informix
1984: DB2
1987: Sybase
1989: Postgres
1989: SQL Server
1995: MySQL
2005 - 2015
The Next Generation
2003: MarkLogic
2004: MapReduce
2005: Hadoop
2005: Vertica
2007: Dynamo
2008: Cassandra
2008: Hbase
2008: NuoDB
2009: MongoDB
2010: VoltDB
2010: Hana
2011: Riak
2012: Areospike
2014: Splice Machine


3rd Platform
Cloud Social Big Data Mobile
Internet of Things
Relational Database
NoSQL
NewSQL
Big Data platforms
2nd Platform
Client-Server Web 1.0
Relational Database
1st Platform
Mainframes
Minicomputers
Hierarchical Database
Network Database
ISAM files

New database designs emerge

- In 2007, Michael Stonebraker
  - *“the hardware assumptions that underlie the consensus relational architecture no longer applied, a single architecture might not be optimal across all workloads”*

- *NoSQL, NewSQL, and Big Data*
  vaguely defined, overhyped, and overloaded terms
  - *NoSQL → reject the constraints of the relational model*
  - *NewSQL → retain many features of the relational model but new technology*
  - *Big Data systems*
    → generally technologies within the Hadoop ecosystem, increasingly including Spark