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Evolution of Data Management Systems for Big Data Applications

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*** Query Processing & Optimization in Parallel & Large-scale Distributed Environments (//, Grid, Cloud)**

0. Introduction: Main Problems of Data Management

[Sto 98, Ozsu 11, …]

- **Data Modelling & Semantic**
- **Query Processing & Optimization (OLAP)**
- **Concurrency Control/Transactions (OLTP)**
- **Replication & Caching**
- **Cost Models**
- **Security & Privacy**
- **Data Mining & Visualization**
- **Monitoring Services**
- **Resource Discovery**
- **Autonomic Data Management (Self-tuning, Self-repairing, …), …**
- **…**

➡ **Data Management Systems**

0. Introduction: Evolution of Data Management Systems [Gra 96, Ham 13]

➡ **"The present without past has not future"** Fernand Braudel

▶ <Concept ➔ Systems: *Objective*>

- ➔ File Management Systems: *Storage Device Independence*
- Uni-processor Rel. DB Systems DBMS [Codd 70]: *Data Independence*
- ➔ Parallel DBMS [Dew 92, Val 93]: *High Performance & Data Avail.*
- Distributed DBMS [Ozs 11]: *Location/Frag./Replication Transparency*
- Data Integration Systems [Wie 92]: *Uniform Access to Data Sources*

  Characteristics =<Distribution, *Heterogeneity,* Autonomy>

- Data Grid Systems [Fos 04, Pac 07]: *Sharing of Available Resources*

* ➡

- ➔ Cloud Data Manag. Systems: *<Pay-Per-Use>* ➡ *Economic Models*

  [Aba 09, Sto 10/13, Agr10/12, Cha 12, Col12, Kald 12, Zho 12, Sul 12, Gre 13, Li 14, Unt 14, Mes 16, Ham 16, ...]

  Characteristics *=<Elasticity, Fault-Tolerant >*

* ➡ **Evolution Or Crossroad ?**

Evolution of Data Management for Big Data Applications

Outline

I. Parallel Relational DBMSs [Dew 92, Val 93]

- Databases & Uni-Proc. Rel. DBMS: Objectives and Limitations
- Parallel DBMS: Motivations, Characteristics and Challenges

II. Big Data Management in Cloud Systems (Hadoop/MapReduce)

- Motivations ?
- Hot Debate: MapReduce MR **Versus** Parallel DBMS [Sto 2010]
- Reconciling Debate: Parallel DBMS **Meet** MapReduce [Zhou 2012]
- Advantages & Weakness of MR & Parallel DBMS [Ham 2016]
- Comparison between Parallel DBMS VS MR & Evolution of DML

III. Conclusion & References

I. Parallel Relational DB Systems [Dew 92, Val 93, Lu 94]

1. Databases DB and Relational DBMS [Codd 70]

- **DB Objectives:**
  - ▶ **Centralization of Data Structures (DB Schema)**
  - ▶ **Prog-Data Independence = <Physical & Logical> Independence**

- **Main Characteristics (Rel. DB)**
  - **Structured Data: Relation Concept**
  - **Relational Algebra: Commutative, Internal Law**
  - **From Procedural → Declarative Languages: SQL [Cham76], QUEL [Sto 76], QBE [Zlo77]**

    ▶ **The System will find the (near) Optimal Access Path**

    ➡ **Optimizer [Sel 79, Wong 76, Gan 92, …]**

I. Uni-proc. Rel. DBMS: Query Optimization [Sel 79]

- **Problem Position [Gan 92]:**

  q ∈ Query , p ∈ {Execution Plans}, $Cost_p$ (q):

  - Find p calculating q such as $Cost_p$ (q) is minimum
  - Objective : Find the best trade-off between

    Min (Response Time) & Min (Optimization Cost)

- **Optimizer Structure= < St, Sp, C> [Gan 92]**

  – St: Search Strategies
    - <Physical Optim., Parallelization, Resource Allocation, …>

  – Sp: Search Space
    - Data Structures: Linear Spaces, Bushy Space
    - Type/Nature of Queries

  – C: Cost Models/Evaluator
    - <Metrics, System Environment Description>

I. Parallel Rel. DB Systems [Dew 92, Val 93, Lu 94]

2. Limitations of Uni-proc. Query Optimization Methods wrt Decision Support Systems (RDBMS)

- **Complex Queries**: *Number of Joins >6*
- **Size of Research Space [Tan 91]**: *Very Large (e.g. 2^{N-1})*
- **Optimization Cost [Lan91]**: *can be very expansive (e.g. Deterministic Strategies)*
- **Optimal Execution Plan**: *not guaranteed (e.g. Randomized Strategies)*

➡ *Requirements in:* **High Perf. HP & Resource Availability**

➡ **Introducing a New Dimension: Parallelism**

▶ **Parallel Relational Database Systems** [Dew 92]

I.3 Parallel Relational DB Systems [Dew 92, Val 93, Lu 94]

- **Motivations: Declarative Relational Languages (e.g. SQL)**
  - **Automatic Parallelization of <Partitioned, Independent, Pipelined> //**
  - **Regular Data Structures : ➔ *Static Annotations***
  - **Decision Support Queries: Complex Queries, Huge DB (TB, PB, …)**
- **Objectives [Dew 92]:**
  - **Best Trade-off Cost/Performance wrt Mainframe**
  - **High Performance HP**
    - **Minimizing the Response Time**
    - **Maximizing the Parallel System Throughput**
  - **Scalability (≠ Elasticity)**
    - **Adding New resources (CPU, Memory, Disk)**
    - **Adding New Users (Applications)**

      ➡ **Holding the Same Performance**
  - **Resource Availability: Complex Queries, Failures (Fault-Tolerant)**

I.3 Parallel Rel. DB Systems [Dew 92, Val 93, Ham 93, Lu 94]

- **Main Characteristics**
  - **Parallel Architect. Models: SM, SD, DM= Shared-Nothing Archi.**
  - **Parallelism Forms: <Partitioned, Independent, Pipelined> //**
  - **Data Partitioning:**
    - **Approaches: <Full Declustering, Partial Declustering>**
    - **Methods: <Round Robing, Range Partitioning, Hashing>**

- **Main Challenges:**
  - **Partitioning Degree of each Relation?**
  - **Parallelism Degrees of Rel. Operators (e.g. Join)**
  - **Parallelization Strategies: <One-Phase, 2-Phases> Approaches**
  - **Resource Allocation: Data & Tasks Placement**
  - **Optimization of Data Communications: Plague of Parallelism (Shuffle Issue in MapReduce)**

  …➔ Towards Cloud Computing & Big Data Manag. Why?

II. Cloud Computing/Systems & Big Data Management

[Aba 09, Sto 10/13, Agr 10-12, Chaud 12, Zhou 12, Kald 12, Gra 13, LI 14, Unt 14, Norvag 14, Akba 15, Bon 15/16, Aba 16, Ham 16, ...]

Outline

- **Towards Cloud Computing & MapReduce: Motivations?**
- **Main Characteristics of Cloud Systems [D. Agrawal et al. 2011]**
- **"Hot Debate" on: MapReduce Versus Parallel DBMS: Friends or Foes?**
  [M. Stonebraker et al., 2010], [D. Agrawal et al. 2010, S. Chaudhauri 2012]
- **"Reconciling Debate" [Zhou et al. 2012, Kaldewey et al. 2012/EDBT]**
  "SCOPE: Parallel Databases Meet MapReduce" [Zhou et al. 2012, VLDB Jo.]
- **Comparison (// DB Systems and MR) & Evolution of DML**

II.1 Towards Cloud Computing & MapReduce: Motivations(1/3)

- **"Big (Very Large?) Data" : Generated from**
  - Specific Requirements of Web Applications : Log Processing, Analysis of Streaming Sensor Data, Social Network, Document Indexing,.....
  - Computer Simulations, Satellites, Astronomy, Life Science, IS, etc....

Remark: 43rd Intl. Conf. on Very Large DB; 36rth Intl . Conf. On Data Management.

Parallel DBMS: <TERADATA, ➔ 1984; DB: 11 Terabytes ➔ 1996>

➡ Big Data ➔ "Moving Target " [Val 16]

- **Big Data Characteristics [Sto13, Val 14]: The 4 V's**
  - **Volume:** Refers to Very Large Amounts of Data
  - **Velocity:** Data Streaming (Producer-Consumer Dataflow)
  - **Variety:** Heterogeneity of Data Formats and Semantics
  - **Veracity/Value:** Meaningful of the Results? (Data Mining)
  - **Other V's**
    - **Validity:** Correction and accuracy of data?
    - **Volatility:** Necessary period to store this data?

II.1 Towards Cloud Computing & MapReduce: Motivations(2/3)

- **Big Data Characteristics: a Solution for "the 3 V's" [Val 14] ?**
  - **Volume: Refers to very large amounts of Data**
    - ➡ **Parallel Rel. Database Systems [Dew 92]**
  - **Velocity: Streaming Data**
    - ➡ **Data Stream Management Systems [Ozu 11, Chapter 18]**
  - **Variety: Heterogeneity of Data Formats and Semantics**
    - ➡ **Data Integration Systems [Wied 92]**

However, why these systems are not naturally used?

II.1 Towards Cloud Computing & MapReduce: Motivations (3/3)

- **Current Solutions (Infrastructures & Software) are:**

  Proprietary & Expansive

  ➡ **Open Source Alternatives, Simple Programming Model ! (e.g. MapReduce), Low Costs (Commodity Hardware CH)**

- **How the systems should react "strongly" to Failures?**

  ➡ **Fault-Tolerance (Commodity Hard., Data Replication, HDFS)**

- **Ability to scale resources (up, down, out) dynamically on-demand : ➡ Elasticity (➔ Pay-Per-Use PPU)**

- **Cloud Environments do not to be Owned nor Managed (PPU Approach) by a Customer: Users ➔ Multi-tenant**

  ➡ **Performance Isolation**

II.2 Main Characteristics of Cloud Systems [Agra. et al. 2011]

- **Scalability (Infrastructure: Shared-nothing Architecture)**
- **Elasticity [Ozu 11]**

  «The ability to scale resources out, up, and down dynamically to accommodate changing conditions»

  ➔ **PhD: SLA-driven Cloud Elasticity Management Approach [Y. Kouri, Dec. 13]; Dir. P. Cointe, Nantes, France**
- **Performance Isolation [Nara 13]: Users ➔ Multi-tenant & SLA (Service Level Agreement) Meeting**
- **Strong Fault-Tolerance: (CH, Data Repli., HDFS (Hadoop Env))**
- **Ability to run on Commodity Hardware CH (Low Cost)**

➡ **New Context = <Dist., Large-scale, Stable Service on-demand, Multi-tenant, Commodity Hardware, >**

➡ **Introduction of Economic Models in the Resource Management**

II.3 "Hot Debate" ("Storm, Business War"...): MR VS // DBMSs

- **"MapReduce and Parallel DBMSs: Friends or Foes?"**

  [Stonebraker et al. 2010 Com. of the ACM, Jan. 2010, Vol 3. No. 1]

  - **The performance results (between MR system and 2 // DBMSs) show that the DBMSs are substantially faster than the MR system once the data is loaded.**

  ➡ **Conclusion: "MR complements DBMSs since DB are not designed for ETL (Extraction-Transform –Load) tasks, a MR specialty "**

- **"Big Data and Cloud Computing: New Wine or Just New Bottles? "**
  [Agrawal 2010 et al. , Univ of California/Santa Barbara] VLDB'2010 Tutorial

- **"An Interview with S. Chaudhuri", [Sept. 2012, XRD, Vol.19, No. 1]**

  "If I were to look at recent research publications, a disproportionately large fraction of them are focused on solving for MapReduce platforms the same problems we addressed for parallel database systems. We can and should do much more."

II.3’ Petasky – Mastodons Project (CNRS, LIMOS/LIRIS)

“Benchmarking SQL on MapReduce systems using large astronomy databases”; A. Mesmoudi et al.; In: Intl journal PDBD, 34(3), 2016

- **Objectives:** **“They report on the capability of 2 MR systems (Hive and HadoopDB) to accommodate LSST data management requirements” in terms of loading & execution times : < Data Loading & Indexing and Queries (Selection, Group By, Join) >**
- **Conclusions [Mes 2016] :**

  ➡ **“We believe that the model is efficient for queries that need one pass on the data (e.g. Selection and Group By)”**

  ➡ **“ We believe that MR model is not suitable for handling Join queries ”**

II.4 "Reconciling Debate "(Peace!) (1/2) [Zhou 2012, VLDB Jo., …]

"SCOPE: Parallel Databases Meet MapReduce" ; MicroSoft

- **Objective : combines benefits from execution engines**
  - Parallel DB Systems

    & ➔ for Large-scale Data Analysis
  - MapReduce

    ➔ <Easy Programmability, Massive Scalability, HP >

- **Advantages of // DB Systems [Dew 92]**
  - Relational Schema (➔ Easy Annotations)
  - Declarative Query Language (➔ Automatic Optimization Process)
  - Sophisticated Query Optimizers-Parallelizers : {Partitioned, Indep., Pipelined //}
  - +/- Comm. Costs : Avoid the Data Redistribution (+/-: in some cases)
- **Weakness of // DB Systems (in Massive Large Scale):**
  - Run Only on Expensive Servers
  - Fault - Tolerance (in the case of massive // DB)
  - Web Data Sets are not structured
  - Communication Costs: Data Redistribution (=Reshuffling in MR)

II.4 "Reconciling Debate" (2/2) [Zhou 2012, Kalde 2012]

"SCOPE*: Parallel Databases Meet MapReduce"; MicroSoft

Advantages of MR

- Scaling very well (to manage massive data sets)
- Strong Fault -Tolerance (Data Replication, HDFS)
- Mechanism to achieve Load-Balancing
- Support the Intra-operation & Independent Parallelisms

Weakness of MR: Side Applications

Developers:

- Are forced to translate their business logic to MR model
- Have to provide implementation for the M & R functions
- Have to give the best scheduling of M & R operations

➡ More Hot Problems!

- \+ Data Dependence (Data Independence of DB Concept!)
- \+ Extensive Materialization (I/O)
- \+ Data Reshuffling (Repartitioning) between M & R ➡ Plague of Parallelism

*: SCOPE Proposals (Structured Computations Optimized for Parallel Execution)

II.5 Classification & Evolution of Cloud Data Manag. Systems (1/3)

- **Early Generation of Big Data Manag. Systems BDMS:**
  - **NoSQL Databases/MapReduce Systems based on Type of Data Store (near 135 Systems!)**
- **Next Generation of BDMS (Evolution of NoSQL Systems):**
  - **New SQL = Scalable Power of NoSQL Systems + ACID Properties (of Rel. DBMS!)**
- **Latest Generation of BDMS: Data Integration Approach based on Mediator –Wrapper Architecture [Wied 92]**

➡ **Insure a Uniform Access to Heterogeneous, Autonomous, and Distributed Data Sources**

- **Multistore Systems :**

Polybase [Dew 13], SCOPE [Zho 12] , CoherentPaas Proj. [Bon 15], …

II.6 Evolution of DML Data Manipulation Languages

Charact. ➔ Nature of Languages	Functions (Power)	Advantages	Drawbacks
L1: Procedural Languages (e.g.MapReduce) [Bigtable, PNUTS]	Filter & Project Google, Yahoo!	– Simplicity of Programming Model	– Complexity to read and optimize prog. – Data Str. Dependency ➔ Rewriting similar code on different data sets
L2: PL with Relational Operators (RO) [PIG Latin, Jaql]	Rel. Operators Towards SQL func Yahoo!, IBM	– Prog. are more readable – Automatic Logical Optim. Proc.	Developers provide Scheduling of RO ➔ No Physical Optimization
L3: Declarative Languages [HiveQL, SCOPE, CloudMdsQL,…]	Close to SQL + Specific Operators MS, FB, IBM & Goo	Automatic: – Optimization – Parallelization (➔ avoid Data Reshuffling)	"Lack of statistics stored in the catalog" ➔"Blinds the Optimization Process"

II.7 Comparison between // Rel. DBMS & MapReduce Systems

Systems Parameters	DB & // Rel. DBMS	MapReduce (Hadoop Env.)/ Cloud. Systems
Applications	OLAP & OLTP (ACID)	OLAP: Yes; **OLTP: Not suitable (Initially!)** ➔ New SQL
Data Models	Data Structured (Data Schema)	Unstructured or semi-Structured , ...(more Flexible!)
Data Independence	Yes	No (Initially)
Query Languages	Declaratives	Procedurals (initially)
Optimization & Parallelization	Automatic Optim. & // Annotations: Easy	Explicit Optim. (initially) Annotations: Very difficult
Scalability & Elasticity	Scalable & Dynamic	Scalable & Elastic
Fault-Tolerance	Weak	Strong
Location -------------------- Maturity	Known in advance ------------------ Strong	SLA Negotiation ------------------------- Weak (at this moment!)

III. Conclusion (1/4): <Maturity, Scientific & Social Aspects>

1. Maturity Degree of Big Data Management Systems

- **Query Languages**
  - **Declarative Languages**
  - **Standardization**

- **More Experimentation & Benchmarking**
  - **TPC – H; TPC – DS**

- **Administration & Tuning/Supervision Tools**

➡ **Let time do its work!**

III. Conclusion (2/4) : Scientific Aspects

2. Scientific Aspects (1/3) [Abadi et al., Feb. 2016, Comm. of the ACM, 59(2)] "The Beckman Report on Database Research"

- "Many early Big Data Systems BDS **Abandoned of DBMS Principles** (e.g. Declarative Programming and Transactional Data Consistency) in Favor of Scalability/Elasticity & Fault-Tolerance on Commodity Hardware" .

- "The latest generation of BDS is **rediscovering the value of these principles and is adopting concepts and methods....**" **that have been mastered by the DB Community DBC .**

➡ "**Building these systems on these Principles, the DBC is well positioned to drive improvements .....**"

III. Conclusion (3/4): Scientific Aspects

2. Scientific Aspects (2/3)

- **New "Concept" introduced by the Cloud Computing CC?**

  New dimensions of CC = <Elasticity , Perf. Isolation, ?...>

  ▶ **Introduc. of Economic Models (Rationalization & Cost effectiveness)**

  ➡ **Objective Function: Find the best trade-off between**

  - **Multi-tenant Satisfaction (QoS (e.g. Response Time/High Perf.))**
  - **Cost-effectiveness of Provider Services (Xaas=Iaas , Paas, Saas)**

III. Conclusion (4/4): Scientific & Social Aspects

2. Scientific Aspects (3/3)

- **Risk of a Gradual Shift of Fundamental Research Activities towards only Engineering Activities ("Programming Activities") :**

  ➡ **Best trade-off between: < Fund. Research & R&D>**

<Concepts, Approaches/Methods, Tech./Techno>

& <Applications>

3. Social Aspects

What are the Economic/Social Impacts of Public Clouds?

➡ **Wealth of Enterprises/Org. will be improved or decreased by using (intensively) Public Clouds?**

Thank you for your attention

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