Crossing Analytics Systems: A Case for Integrated Provenance in Data Lakes

12th eScience 2016 IEEE INTERNATIONAL CONFERENCE

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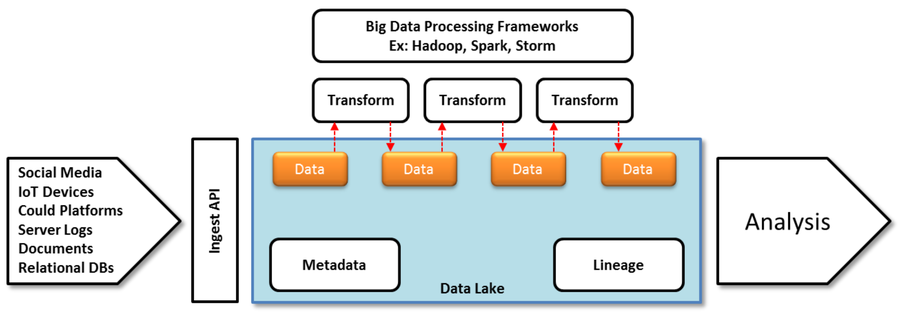
MOTIVATION

The Data Lake

- Gathers data from various sources like sensor data, social media, cloud platforms and server logs
- Supports structured, semi-structured or unstructured data with no schema enforced at ingest time
- Data products are subjected to series of data transformations through distributed Big Data processing frameworks like Apache Hadoop and Apache Spark for analysis



Problem

- Increased flexibility leads to harder manageability
- Can provenance contribute to safer and more efficient Data Lakes through real time assess-respond and post execution traceability?

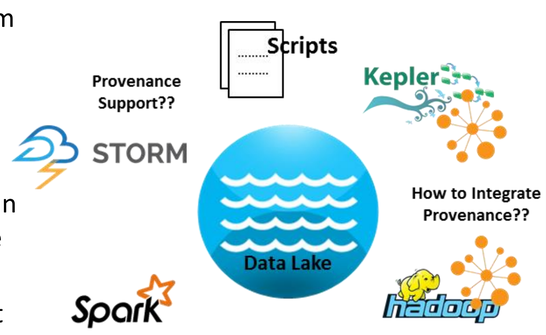
Provenance Use Cases in Data Lake

- **Use Case 1:** Suppose sensitive data are deposited into a Data Lake; social science survey data for instance. This dataset is processed by a chain of transformations. Can data provenance prevent improper leakage of sensitive parts into derived data?
- **Use Case 2:** Repeating a Big Data transformation in a Data Lake is expensive due to high resource and time consumption. Can live streaming provenance from experiments identify problems early in their execution?

PROVENANCE INTEGRATION

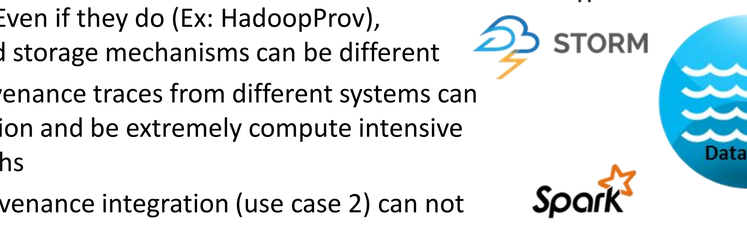
Challenge

- Comprehensive provenance should be integrated from ingest through all distributed transformations
- Transformation systems may or may not produce provenance. Even if they do (Ex: HadoopProv), standards and storage mechanisms can be different
- Stitching provenance traces from different systems can lose information and be extremely compute intensive for large graphs
- Real time provenance integration (use case 2) can not be achieved by post processing techniques



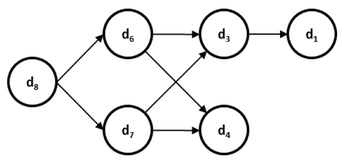
Methodology

- Central provenance collection sub system to which all distributed components within the Data Lake stream provenance events
- Provenance integration across distributed components is guaranteed by using unique identifiers for all data products within the Data Lake
- Provenance is commonly represented as a directed acyclic graph $G = (V, E)$
- A node $(v \in V)$ can be an activity, entity or agent while an edge $(e = < v_i, v_j > where\ e \in E\ and v_i, v_j \in V)$ is a relationship between two nodes
- In our model, a provenance ***event*** always represents an ***edge*** in the provenance graph
- Ex: If process p generates data product d, the provenance event adds a new edge $(e = < p, d > where\ p, d \in V)$ into the provenance graph representing 'generation' relationship

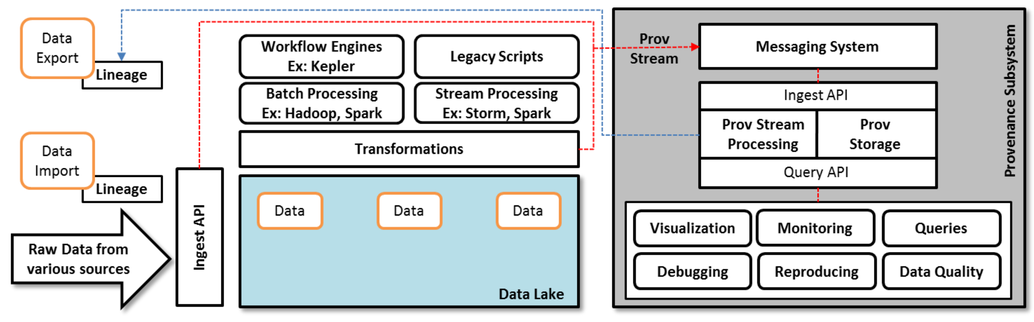


A Simplified Data Flow Scenario in a Data Lake

- Data product d_1 is subjected to transformation T_1 and it generates d_2 and d_3. T_2 uses d_3 with a new data product d_4 to generate d_5, d_6 and d_7. Finally T_3 uses d_6 and d_7 to generate d_8
- Individual distributed transformations T_1, T_2 and T_3 stream provenance notifications to the central provenance store
- Figure shows the provenance graph which represents the data lineage of the data product

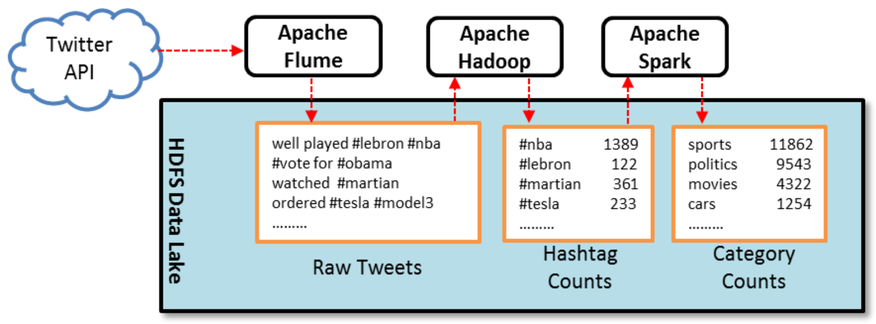


REFERENCE ARCHITECTURE



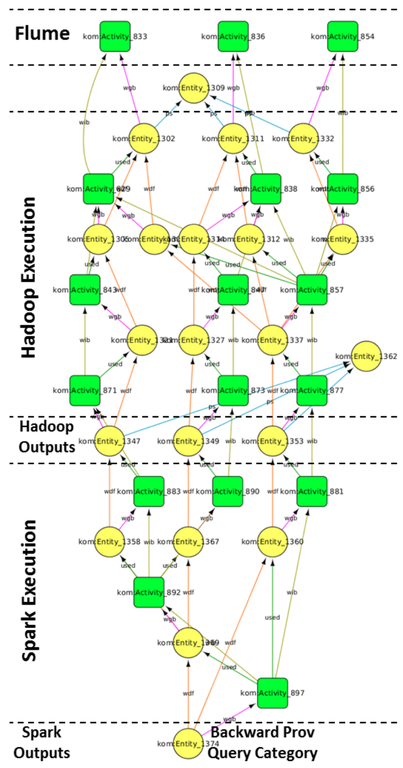
- Provenance Stream Processing and Storage sub-system: heart of system; accepts provenance notifications through Ingest API and supports queries through Query API
- Messaging System: guarantees reliable message delivery into Provenance Storage
- Instrumented transformations: stream provenance events into Provenance Subsystem
- To capture information about origins of data products, provenance must be captured at Ingest
- Exported data products should be coupled with their provenance for better usability
- Both live and post-execution queries over collected provenance with Monitoring and Visualization helps in scenarios like the two use cases that we discussed above

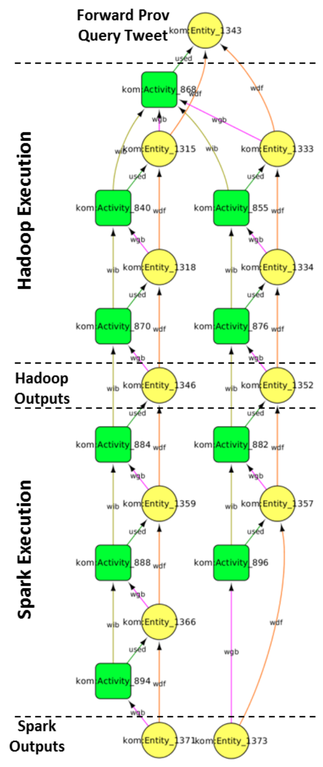
PROTOTYPE IMPLEMENTATION



- **Use Case:** A Twitter data processing chain
- Three different frameworks used for data processing
- Komadu as the central provenance store
- Flume, Hadoop and Spark jobs were instrumented using Komadu client libraries
- Generated UUIDs are assigned for data products and persisted with them

Integrated Provenance Traces





FUTURE WORK

- Live provenance stream processing for real time monitoring and computational steering
- Efficient provenance graph storage/querying to handle "Big Provenance"
- Better usage of persistent identifiers through a Handle System or DOIs

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