# Domino: An Incremental Computing Framework in Cloud with Eventual Synchronization

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# Outline

- Motivation
- Domino Model
- Design and Implementation
- Evaluations
- Q & A

# Motivation

- Continuous data streams are more and more important today.
- To process these streaming data, event-driven models have emerged, including Percolator, Oolong, etc.
- Event-Driven tasks are distributed into multiple servers and run in parallel.
- **How to synchronize them becomes a big challenge**

# Motivation - Cont.

- Multi-iteration trigger-based applications requires synchronization between iterations
- We show two typical strategies to synchronize
  - Fig.(a): Sync needs to wait all triggers to finish. In streaming case, this is not possible as we do not know when previous triggers will finish.
  - Fig.(b): Each sync waits for a time window to start. This may introduce lots of unnecessary syncs.
- Our goal:
  - ***trigger-based programming model with flexible sync mechanism for streaming data to avoid these limitations***


(a) Wait-based synchronization




(b) TimeWindow-based synchronization

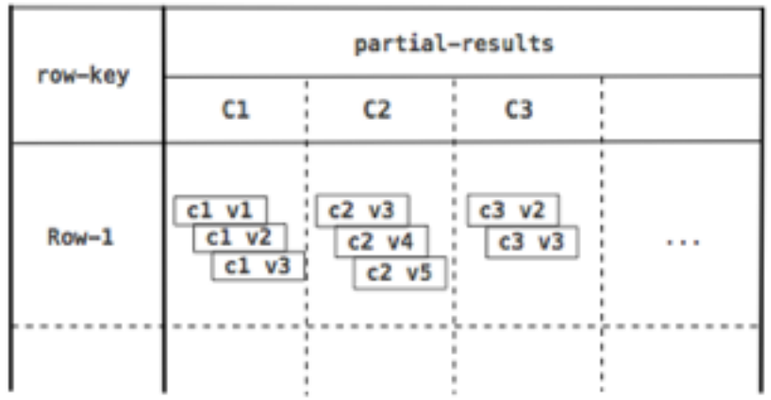
# Domino Model

- Sparse table
  - Data streams are viewed as *insert* or *update* on table
  - Similar with Bigtable with multi-columns in different column families
  - Each data cell stores multi-version data
- Programming model
  - **Event**: Generated from the data modifications; Applications need to declare which columns, column-families, or table they are monitoring to detect the events.
  - **Condition**: Filter events to control the execution of triggers. It is user-defined function that returns true or false to denote whether current event should be processed or not.
  - **Action**: The real logic of application. It consumes the events and write the results back into sparse table persistently. Actions always run locally.
- **Event + Condition + Action => A Trigger**

# Trigger Types

- ***Plain trigger***
  - The simplest case. It responses to new data streams and executes independently in different servers in parallel.
- ***Async accumulator trigger***
  - Accumulate partial results from other triggers in an async way.
  - Partial results arrive and activate the execution of accumulator triggers without any coordination.
- ***Sync accumulator trigger***
  - Similar with Async accumulator trigger
  - Provide a self-managed eventual synchronization mechanism between partial results.
  - Avoid global blocking and make progress all the time.

# Accumulator, Sync




- **Accumulator trigger**
  - For each accumulator trigger, Domino implicitly creates a table.
  - The *partial-results* is automatically monitored by accumulator trigger
  - Previous results will be written into this table under the same column-family and trigger actions
  - For the sync accumulator, Domino will use version management to guarantee the right results
- **Version Management**
  - The sparse table stores multi-version data in each cell, which allows us to trace the execution status of each data
  - We introduce two ids to trace the data: one represents the iteration round; one indicates the external data version.
  - The actions also have version information inherited from those two ids.
  - Whenever an action is triggered, it only can access the data with lower version number comparing the version number of itself.

# PageRank Example

- Sparse table *WebRepo* stores the web repository.
- Application has two triggers:
  - ***Plain trigger***.
    - Monitor the *Meta* column-family (*Event*);
    - If the changes are large enough (*Condition*);
    - Calculate all the out-edges' weights (*Action*);
    - Write the out-edges' weights to accumulator trigger (*Key=edge.dst, Value=weights)*
  - ***Sync accumulator trigger***.
    - Monitor the implicit table, which stores the *urls* and the incoming edges' weights (*Event*);
    - Accumulate all weights for each *url* to form a new page rank value (*Action*)
    - Write new page rank value to *Meta:Rank* column to activate next round.

**Table 1: WebRepo Table**

| RowKey | *Meta:Rank* | *Meta:OutEdges* | *Cot:En* |
|---|---|---|---|
| $url_1$ | 1.0 | $url_{11}, url_{12}, ...$ | ... |
| $url_2$ | 1.0 | $url_{112}, url_{21}, ...$ | ... |
| ... | ... | ... , ... | ... |

**Table 2: Accumulation Table**

| *RowKey* | *Partial-results:c1* | *Partial-results:c1* | ... |
|---|---|---|---|
| $p_1$ | 0.1 | 0.15 | ... |
| $p_2$ | 0.25 | 0.32 | ... |
| ... | ... | ... , ... | ... |

# Implementation

- Current tightly integrated with HBase,
    - Can work on any storage layers that support *spare table* and *multi-version persistent storage*.
- Event detector
    - Detects the updates on spare table
    - Intercept the core execution path of WAL (write-ahead-log) appending in HBase.
- Gathered I/O
    - Encapsulates all the data accesses in action function into a delegate to accelerate I/O operations.

# Evaluations

- 12-node local cluster and 64-node EC2
- Word-count and PageRank
- Compare with MapReduce, Mimic Percolator, Oolong.

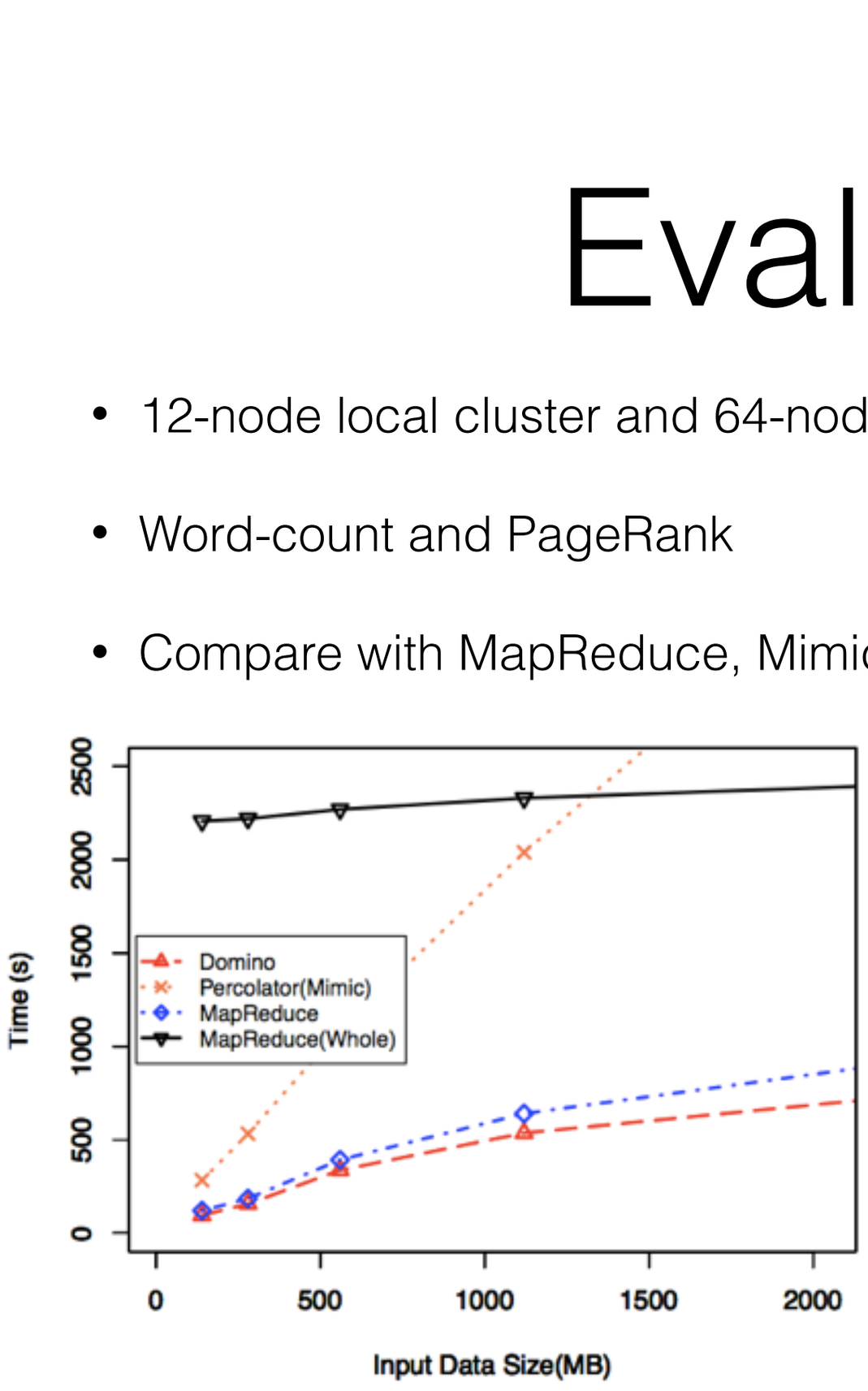



**Figure 3: WordCount under different sizes.**

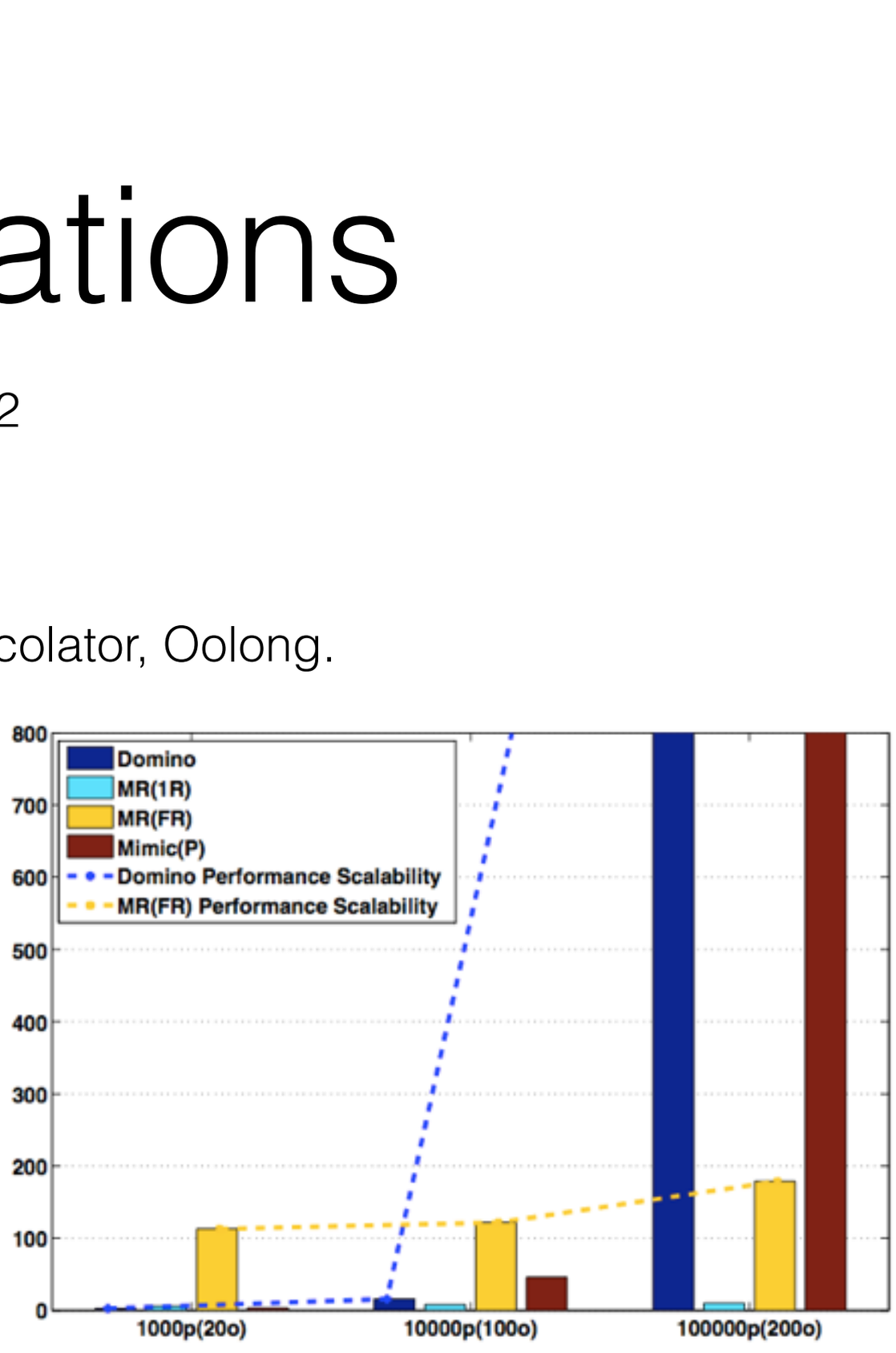



**Figure 4: PageRank under different changing sets.**

# Thanks! Q & A