Introducing AsterixDB

(A Next-Generation Big Data Management System)

Michael Carey (CMU EE '79, '81)

Information Systems Group

CS Department

UC Irvine

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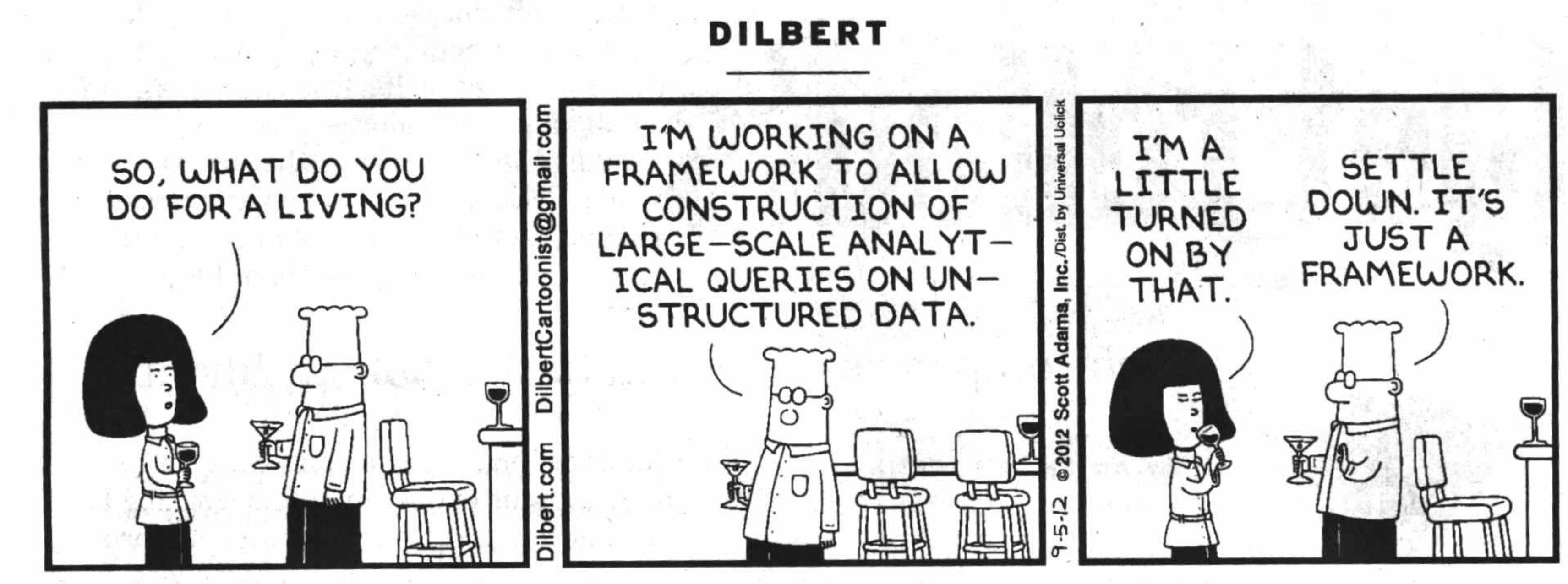
Rough Plan

- Context (a brief history of 2 worlds)
- AsterixDB: a next-generation BDMS
- The ASTERIX open software stack
  - AsterixDB: Big Data Management 2.0
  - Hivesterix: HiveQL on Algebricks
  - Pregelix: Pregel on Hyracks
  - IMRU: Big ML on Hyracks
- "One Size Fits a Bunch" (and Q&A)

Everyone's Talking About Big Data



- Driven by unprecedented growth in data being generated and its potential uses and value
  - Tweets, social networks (statuses, check-ins, shared content), blogs, click streams, various logs, …
  - *Facebook:* > 845M active users, > 8B messages/day
  - *Twitter:* > 140M active users, > 340M tweets/day

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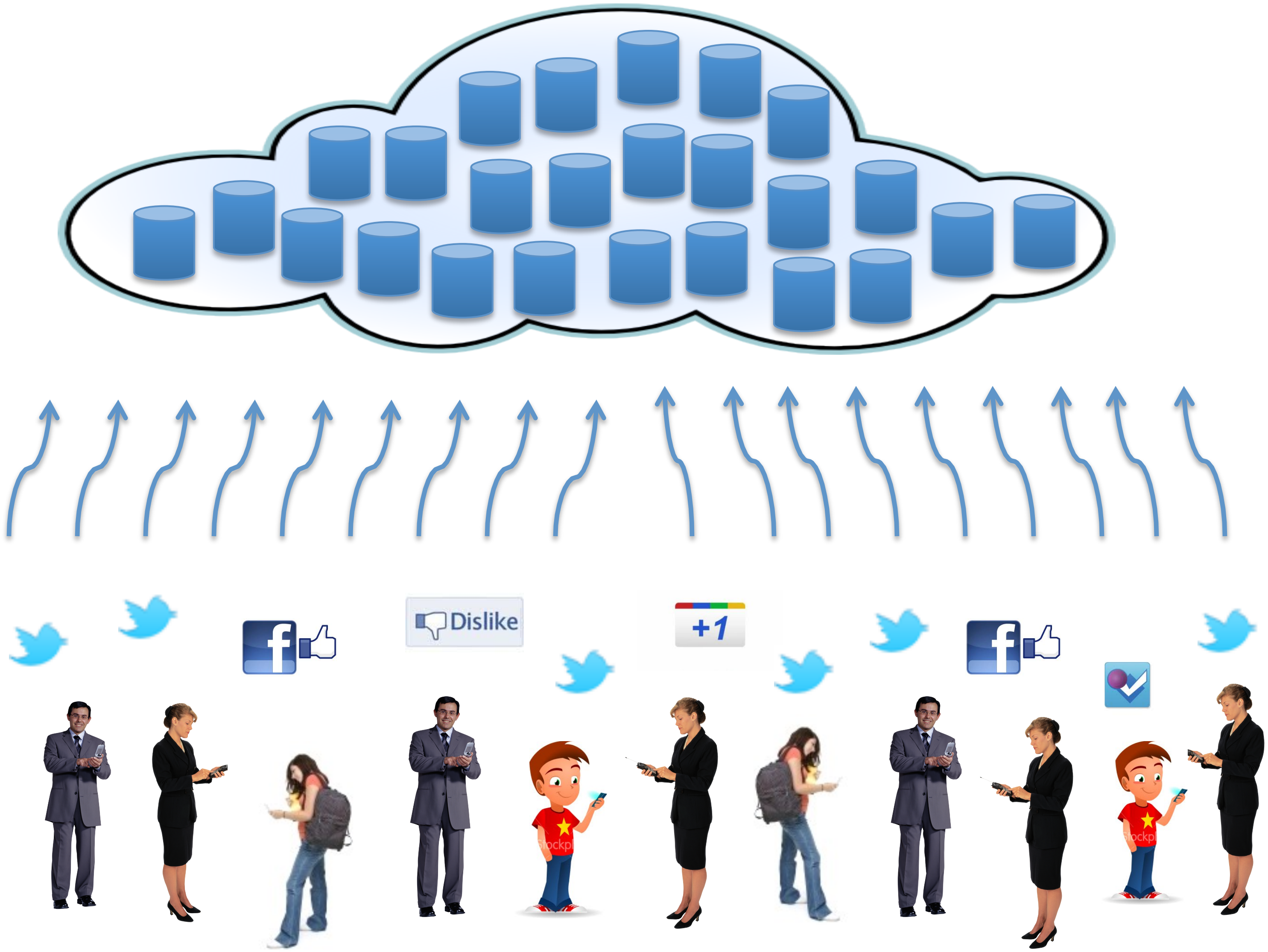
Big Data / Web Warehousing



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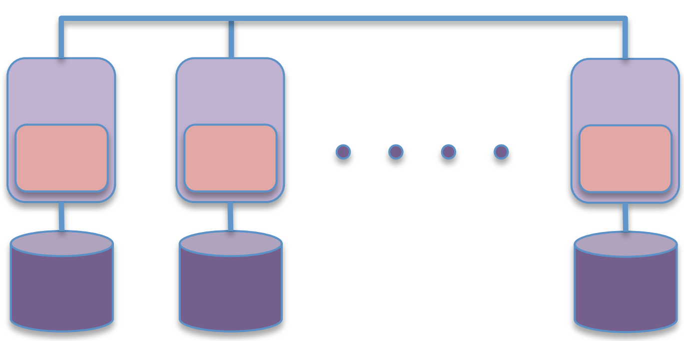
Big Data in the *Database* World

- Enterprises wanted to store and query historical business data (data warehouses)
  - 1970's: Relational databases appeared (w/SQL)
  - 1980's: Parallel database systems based on "shared-nothing" architectures (Gamma, GRACE, *Teradata*)
  - 2000's: Netezza, Aster Data, DATAllegro, Greenplum, Vertica, ParAccel, ... (Serious "Big $" acquisitions!)



Each node runs an instance of an indexed, DBMS-style data storage and runtime system

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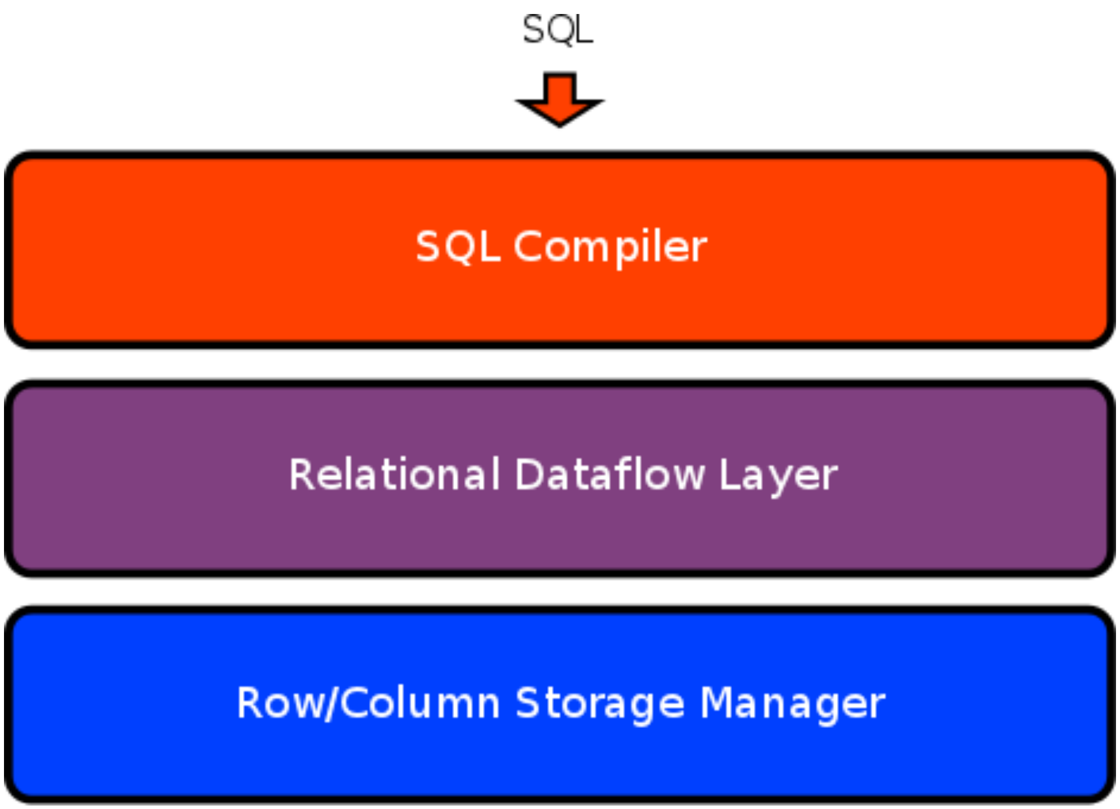
Also OLTP Databases

- On-line transaction processing is another key Big Data dimension
  - OLTP applications power daily business
  - Producers of the data being warehoused
- Shared-nothing also a serious architecture for OLTP
  - 1980's: Tandem's NonStop SQL

Parallel Database Software Stack



Notes:

- One storage manager per machine in a parallel cluster
- Upper layers orchestrate their shared-nothing cooperation
- ***One way in/out:*** through the SQL door at the top

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Big Data in the *Systems* World

- Late 1990's brought a need to index and query the rapidly exploding content of the Web
  - DB technology tried but failed (*e.g.,* Inktomi)
  - Google, Yahoo! *et al* needed to do something
- Google responded by laying a new foundation
  - Google File System (GFS)
    - OS-level byte stream files spanning 1000's of machines
    - Three-way replication for fault-tolerance (availability)
  - MapReduce (MR) programming model
    - User functions: Map and Reduce (and optionally Combine)
    - *"Parallel programming for dummies"* – MR runtime does the heavy lifting via partitioned parallelism

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Soon a Star Was Born…

- Yahoo!, Facebook, and friends cloned Google's "Big Data" infrastructure from papers
  - GFS → Hadoop Distributed File System (HDFS)
  - MapReduce → Hadoop MapReduce
  - In wide use for Web indexing, click stream analysis, log analysis, information extraction, some machine learning
- Tired of problem-solving with just two unary operators, higher-level languages were developed to hide MR
  - Pig (Yahoo!), Jaql (IBM), Hive (Facebook)
  - Now in heavy use over MR (Pig > 60%, HiveQL > 90%)
- Similar happenings at Microsoft
  - Cosmos, Dryad, DryadLINQ, SCOPE (powering Bing)

Also Key-Value Stores

- Another Big Data dimension, for applications powering social sites, gaming sites, and so on
  - Systems world's version of OLTP, roughly
- Need for simple record stores
  - Simple, key-based retrievals and updates
  - Fast, highly scalable, highly available
- Numerous "NoSQL" systems (see Cattell survey)
  - *Proprietary:* BigTable (Google), Dynamo (Amazon), …
  - *Open Source:* HBase (BigTable), Cassandra (Dynamo), …

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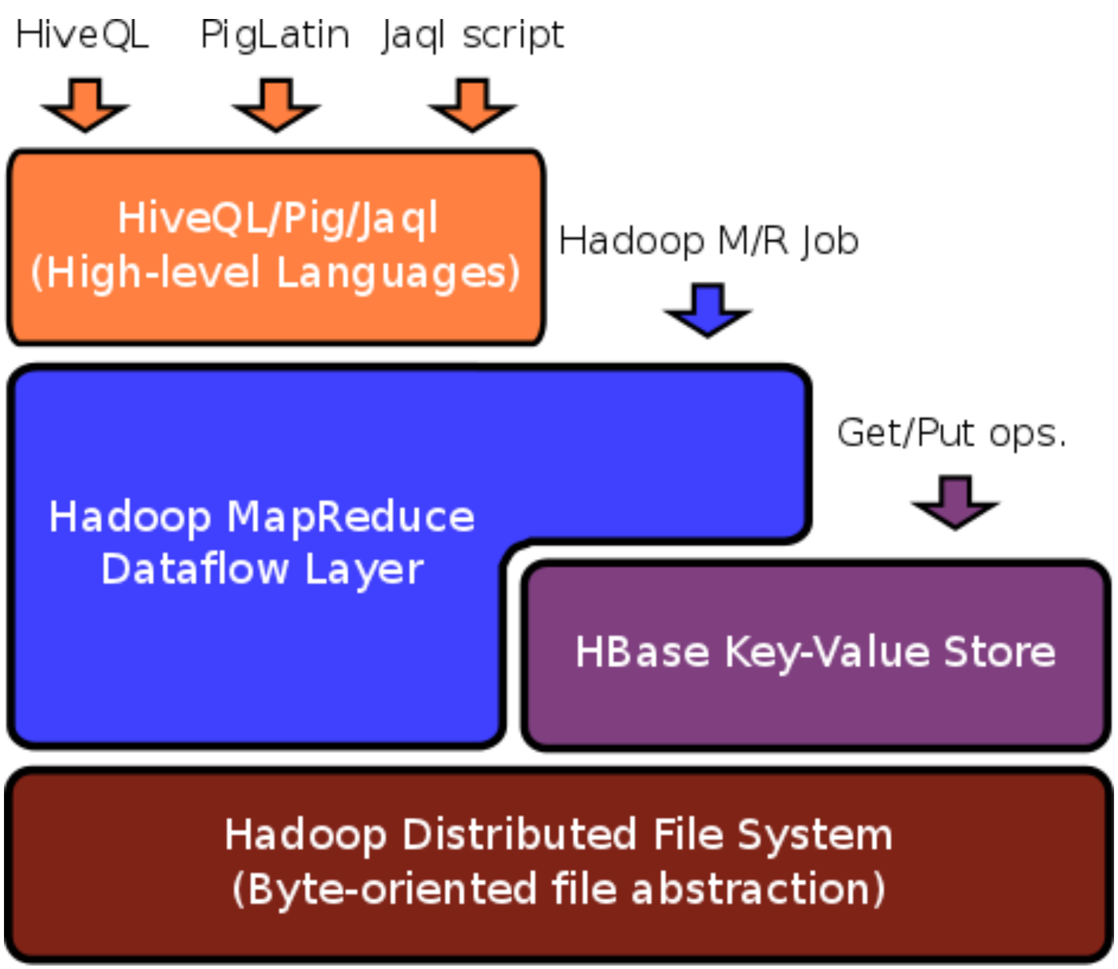
Open Source Big Data Stack



Notes:

- Giant byte sequence files at the bottom
- Map, sort, shuffle, reduce layer in middle
- Possible storage layer in middle as well
- ***Now at the top:*** HLL's

(Huh…?)

Existing Solution(s)

(Pig)

ly scalable, eventually consistent, distributed, structured key-value store.

AsterixDB: "One Size Fits a Bunch"

Semistructured Data Management

Parallel Database Systems

Data-Intensive Computing

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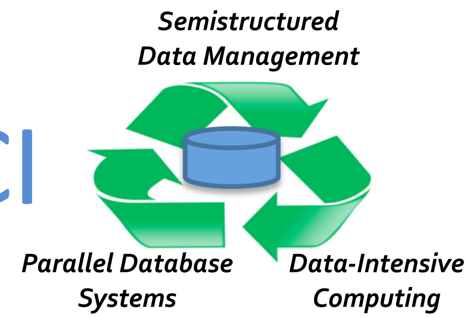
ASTERIX Project @ UCI



- Build a new Big Data Management System (BDMS)
  - Run on large commodity clusters
  - Handle mass quantities of semistructured data
  - Openly *layered*, for selective reuse by others
  - Share with the community via open source (June 2013)
- Conduct scalable information systems research
  - Large-scale query processing and workload management
  - Highly scalable storage and index management
  - Fuzzy matching, spatial data, date/time data (all in parallel)
  - Novel support for "fast data" (both in and out)
- Train next generation of "Big Data" graduates

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ASTERIX Hadoop Influences

- Open source availability ("price is right")
- Non-monolithic layers or components
- Support for external data access (in files)
- Roll-forward recovery of jobs on failures
- Automatic data placement, migration, replication

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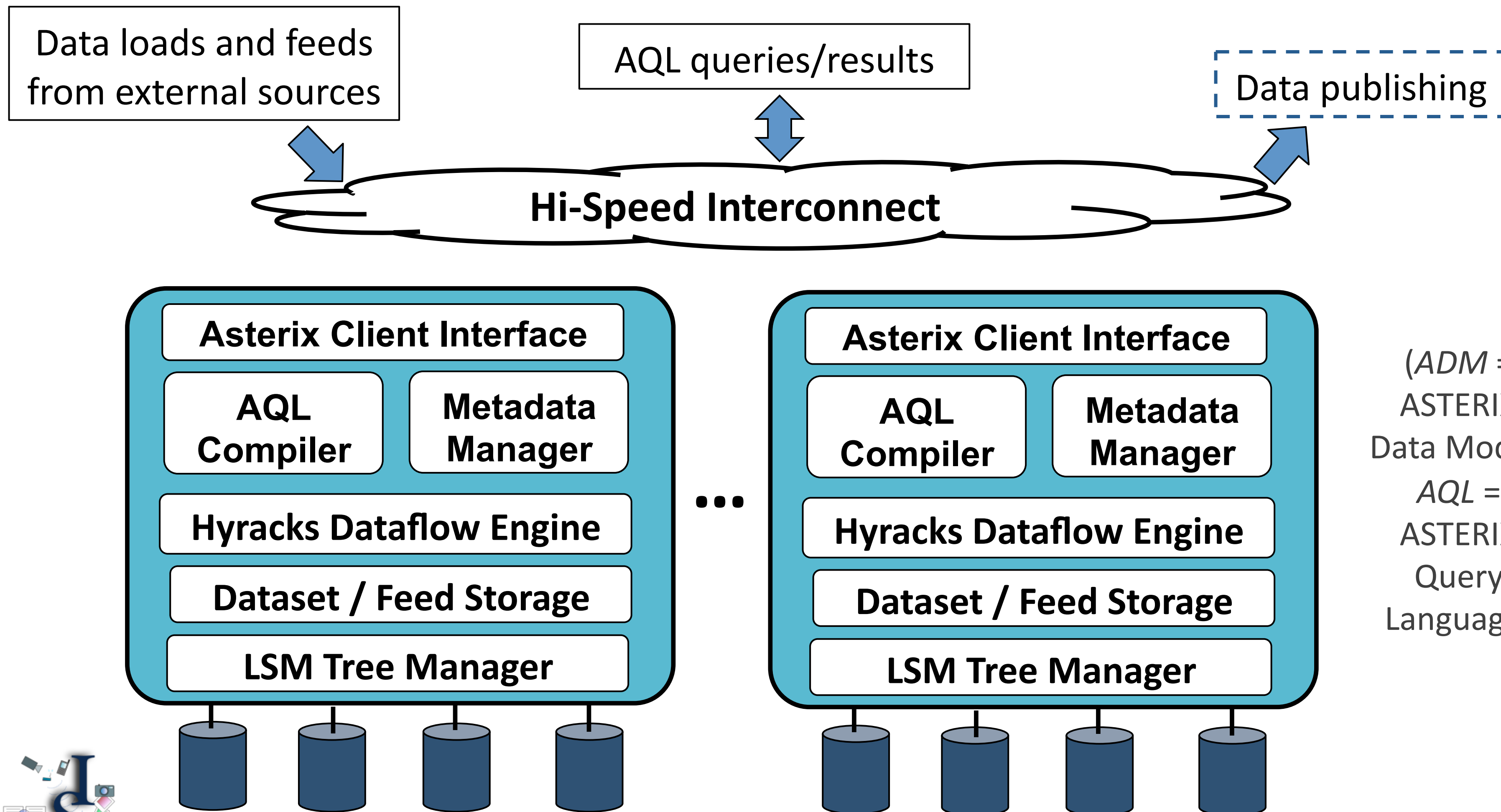
AsterixDB System Overview



ASTERIX Cluster

(*ADM* = ASTERIX Data Model; *AQL* = ASTERIX Query Language)

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ASTERIX Data Model (ADM)

```
create dataverse LittleTwitterDemo;

create type TweetMessageType as open {
  tweetid: string,
  user: {
    screen-name: string,
    lang: string,
    friends_count: int32,
    statuses_count: int32,
    name: string,
    followers_count: int32
  },
  sender-location: point?,
  send-time: datetime,
  referred-topics: {{ string }},
  message-text: string
};
```

```
create dataset TweetMessages(TweetMessageType)
partitioned by key tweetid;
```

Highlights:

- JSON++ based data model
- Rich type support (spatial, temporal, …)
- Records, lists, bags
- ***Open vs. closed types***
- External data sets and datafeeds

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Ex: TweetMessages Dataset

```
{{  {
      "tweetid": "1023",
      "user": {
        "screen-name": "dflynn24",
        "lang": "en",
        "friends_count": 46,
        "statuses_count": 987,
        "name": "danielle flynn",
        "followers_count": 47
      },
      "sender-location": "40.904177,-72.958996",
      "send-time": "2010-02-21T11:56:02-05:00",
      "referred-topics": {{ "verizon" }},
      "message-text": "i need a #verizon phone like nowwwww! :("
    },
    {
      "tweetid": "1024",
      "user": {
        "screen-name": "miriamorous",
        "lang": "en",
        "friends_count": 69,
        "statuses_count": 1068,
        "name": "Miriam Songco",
        "followers_count": 78
      },
      "send-time": "2010-02-21T11:11:43-08:00",
      "referred-topics": {{ "commercials", "verizon", "att" }},
      "message-text": "#verizon & #att #commercials, so competitive"
    },
        ⋮
        ⋮
    {
      "tweetid": "1025",
      "user": {
        "screen-name": "dj33",
        "lang": "en",
        "friends_count": 96,
        "statuses_count": 1696,
        "name": "Don Jango",
        "followers_count": 22
      },
      "send-time": "2010-02-21T12:38:44-05:00",
      "referred-topics": {{ "charlotte" }},
      "message-text": "Chillin at dca waiting for 900am flight to
        #charlotte and from there to providenciales"
    },
    {
      "tweetid": "1026",
      "user": {
        "screen-name": "reallyleila",
        "lang": "en",
        "friends_count": 106,
        "statuses_count": 107,
        "name": "Leila Samii",
        "followers_count": 52
      },
      "send-time": "2010-02-21T21:31:57-06:00",
      "referred-topics": {{ "verizon", "at&t", "iphone" }},
      "message-text": "I think a switch from #verizon to #at&t may be
        in my near future... my smartphone is like a land line
        compared to the #iphone!"
    }  }}
```

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ASTERIX Query Language (AQL)

- *Ex:* List the topics being Tweeted about, along with their associated Tweet counts, in Verizon-related Tweets:

```
for $tweet in dataset('TweetMessages')
where some $topic in $tweet.referred-topics
        satisfies contains($topic, "verizon")
for $topic in $tweet.referred-topics
group by $topic with $tweet
return {
  "topic": $topic,
  "count": count($tweet)
}
```

```
{{
  { "topic": "verizon", "count": 3 },
  { "topic": "commercials", "count": 1 },
  { "topic": "att", "count": 1 },
  { "topic": "at&t", "count": 1 },
  { "topic": "iphone", "count": 1 }
}}
```

Highlights:
- Lots of other features (see papers)
- Set-similarity matching (~= operator)
- Spatial predicates and aggregation
- Plans for windowing and continuous query support

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Fuzzy Joins in AQL

- *Ex:* **Find Tweets** with similar content:
- *Or:* **Find Tweets** about similar topics:

```
for $tweet1 in dataset('TweetMessages')
for $tweet2 in dataset('TweetMessages')
where $tweet1.tweetid != $tweet2.tweetid
   and $tweet1.message-text ~= $tweet2.message-text
   and $tweet1.referred-topics ~= $tweet2.referred-topics
return {
   "tweet1-text": $tweet1.message-text,
   "tweet2-text": $tweet2.message-text
}
```

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Continuous Data Feeds

- *Ex:* Create “Fast Data” feeds for Tweets and News articles:

create **feed dataset** TweetMessages(TweetMesageType)
using TwitterAdapter ("interval"="10")
apply function addHashTagsToTweet
partitioned by key tweetid**;**

create **feed dataset** NewsStories(NewsType)
using CNNFeedAdapter ("topic"="politics","interval"="600")
apply function getTaggedNews
partitioned by key storyid**;**

create index locationIndex **on** Tweets(sender-location) **type rtree;**

begin feed TweetMessages;
begin feed NewsStories;

Highlights:

- Philosophy: “keep everything”
- Data ingestion, not data streams
- Previous queries unchanged

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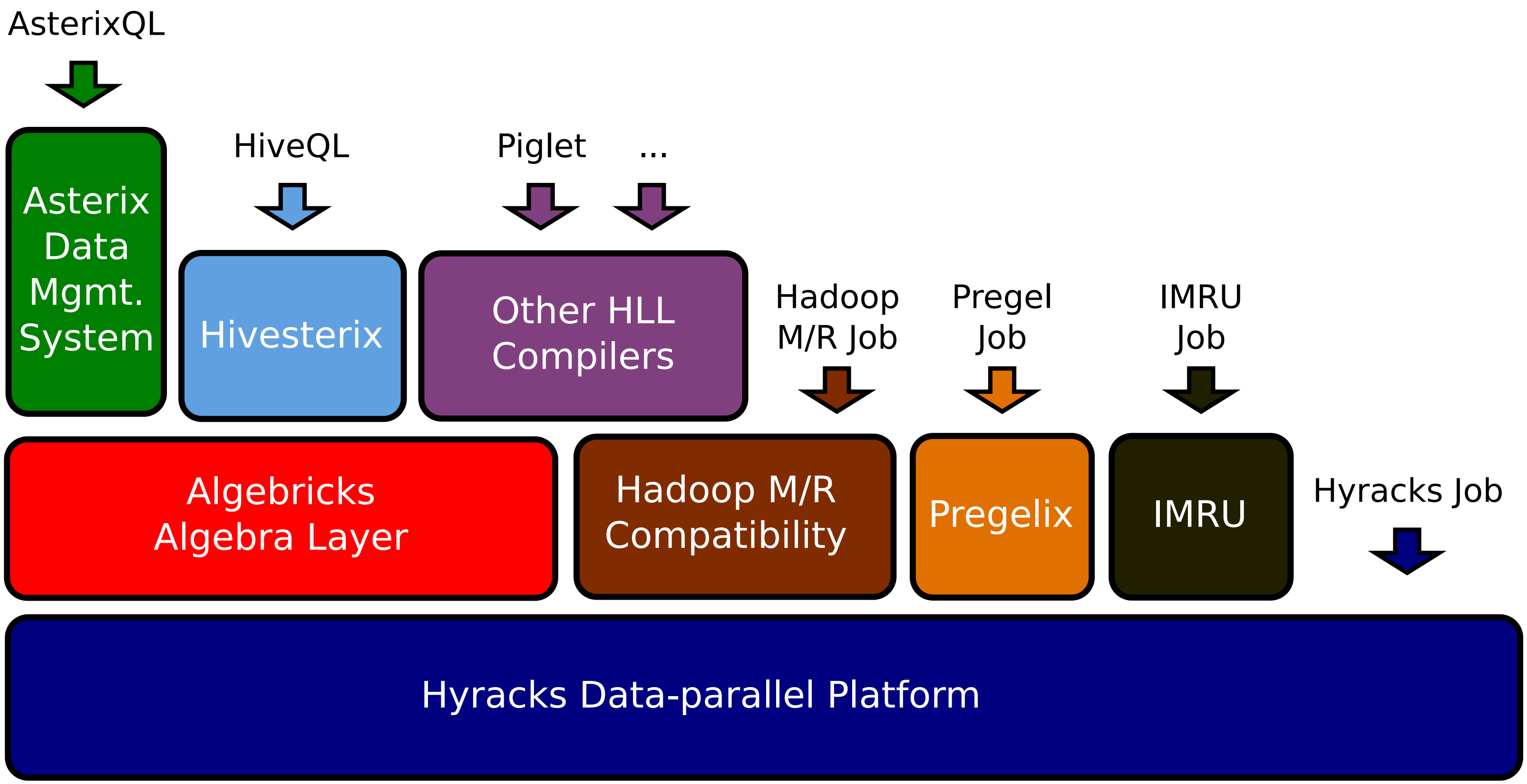
The ASTERIX Software Stack



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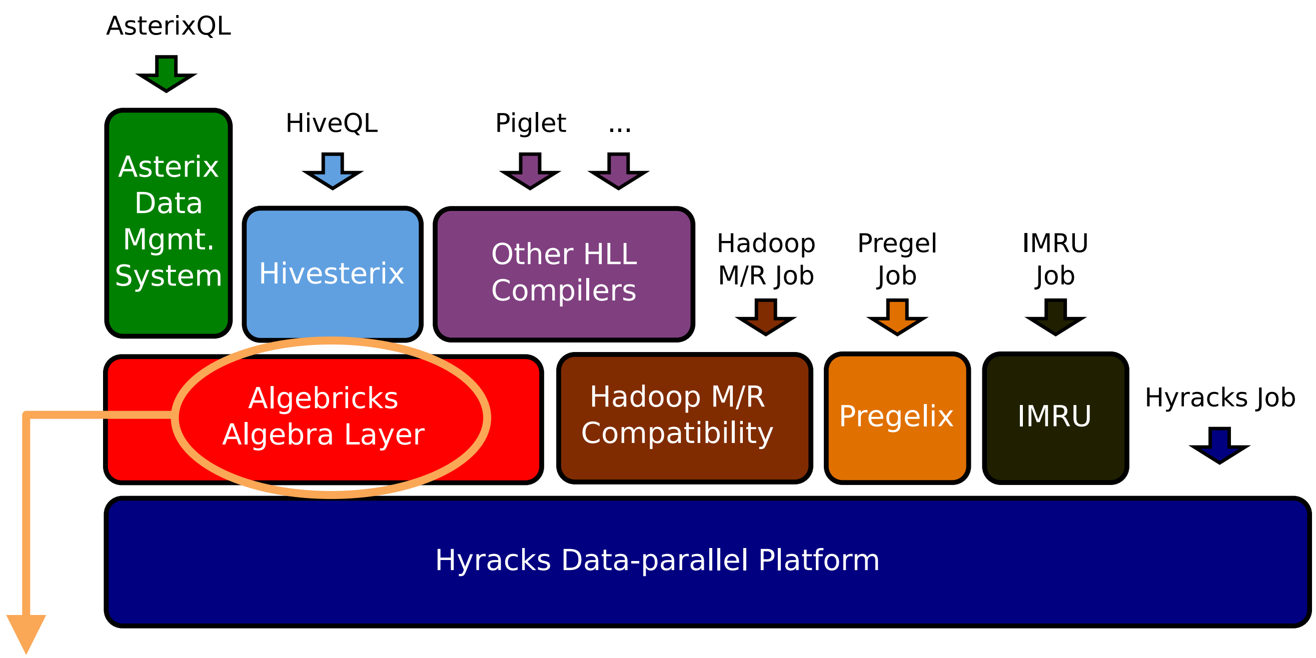
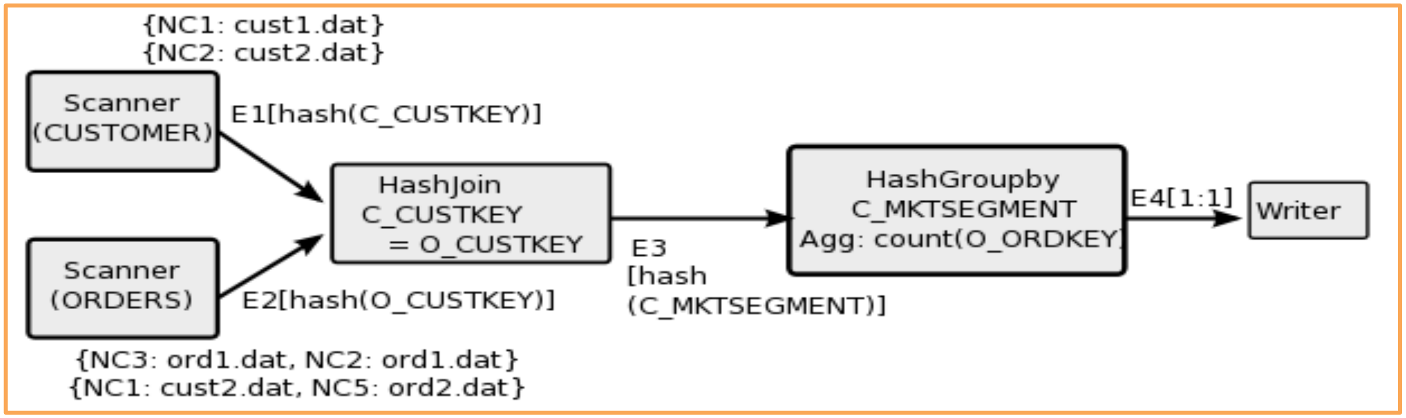
Algebricks



- Set of (data model agnostic) logical operations
- Set of physical operations
- Rewrite rule framework (logical, physical)
- Generally applicable rewrite rules (including *parallelism*)
- Metadata provider API (catalog info for Algebricks)
- Mapping of physical operations to Hyracks operators

Hyracks

- Partitioned-parallel platform for data-intensive computing
- Job = dataflow DAG of operators and connectors
  - Operators consume and produce *partitions* of data
  - Connectors *route* (repartition) data between operators



- Hyracks *vs.* the "competition"
  - Based on time-tested parallel database principles
  - *vs.* Hadoop: More flexible model and less "pessimistic"
  - *vs.* Dryad: Supports data as a first-class citizen

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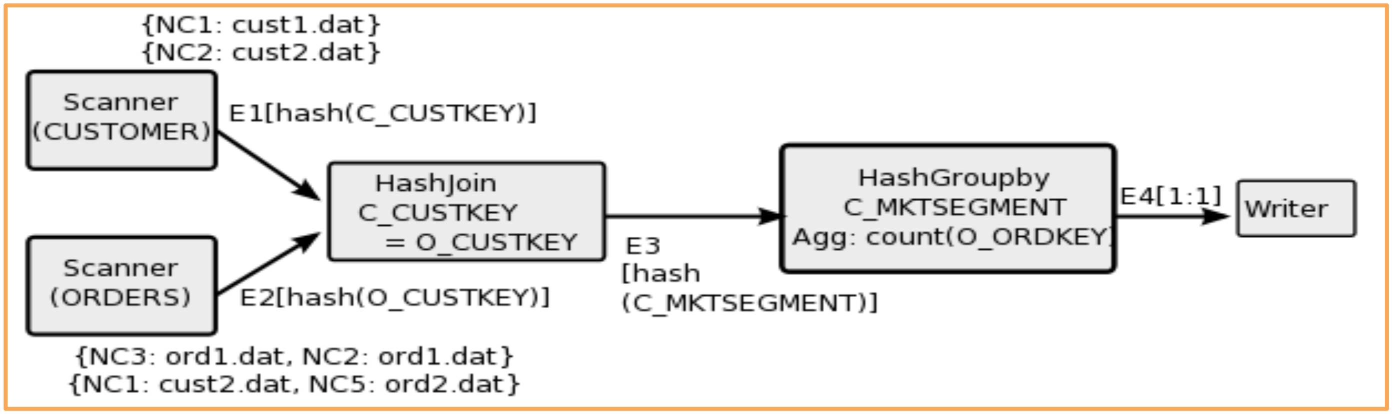
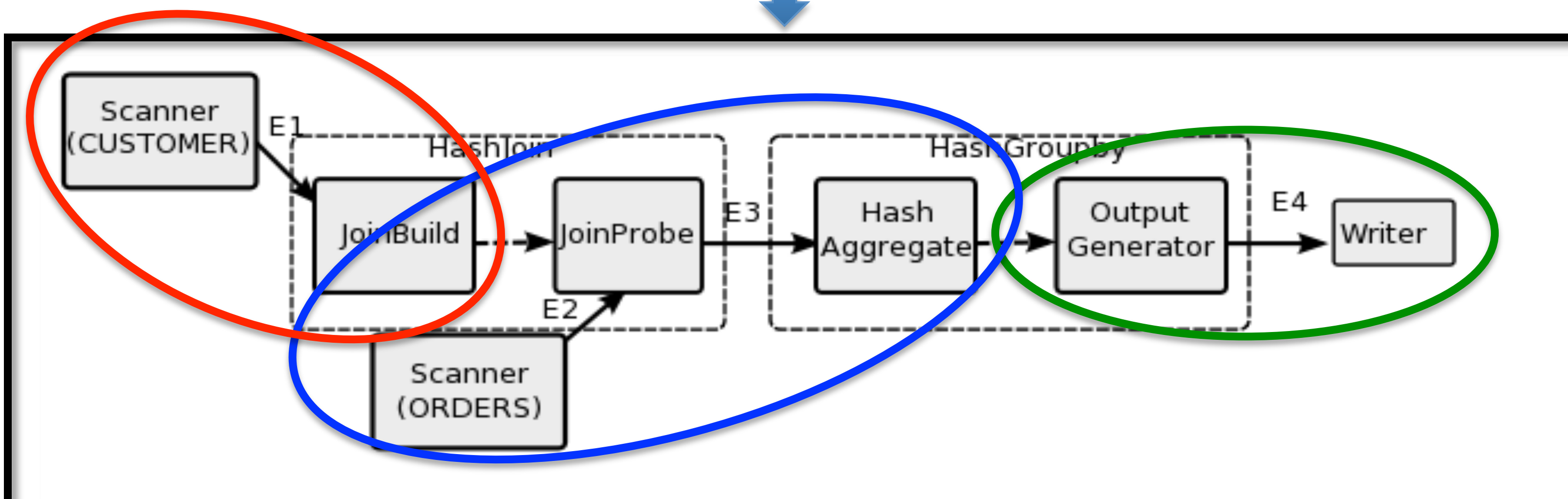
Hyracks *(cont.)*





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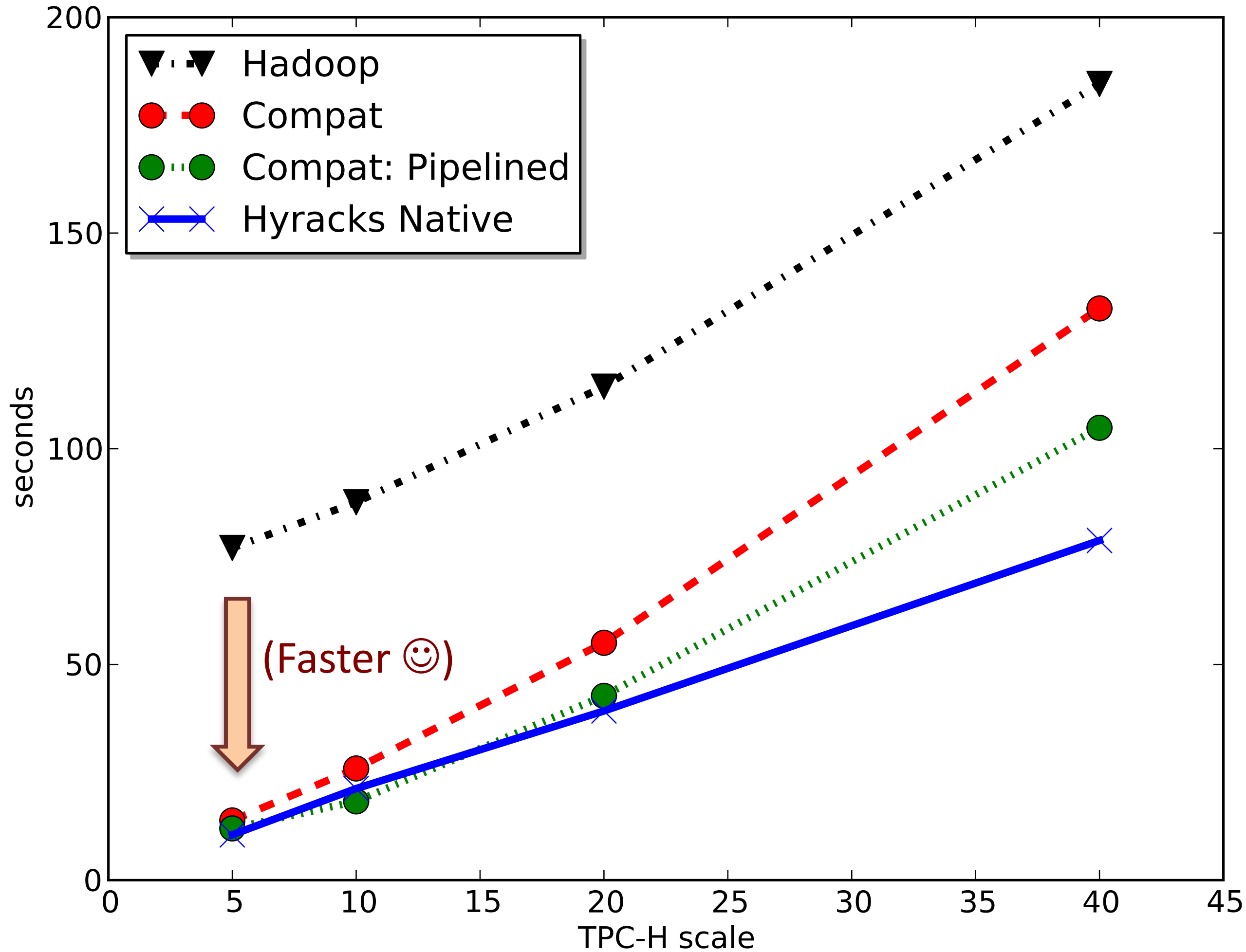
Hyracks Performance

(On a small cluster with 40 cores & 40 disks in 2011)



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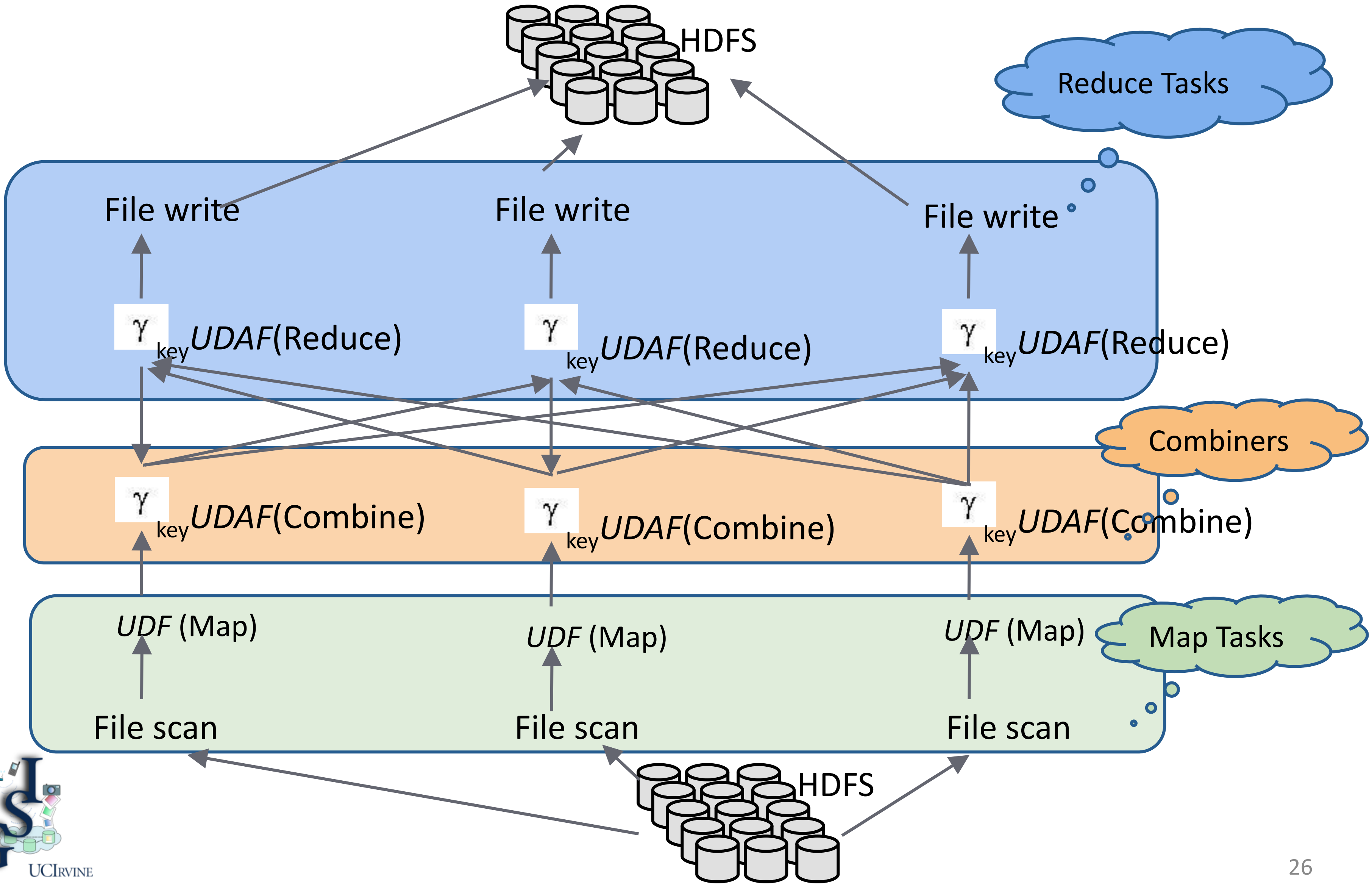
Hadoop M/R Compatibility



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Hyracks Performance Benefits*

- K-Means (Hadoop M/R compatibility layer)
  - Push-based (eager) job activation
  - Default sorting/hashing is on serialized (binary) data
  - Pipelining (w/o disk I/O) between Mapper and Reducer
  - Relaxed connector semantics exploited at network level
- TPC-H Query (in *addition* to the above)
  - Hash-based join strategy doesn't require sorting or artificial data multiplexing and de-multiplexing
  - Hash-based aggregation is similarly more efficient
- Fault-Tolerant TPC-H Experiment
  - Faster → smaller failure target, more affordable retries
  - Need incremental recovery, but not blind pessimism

*V. Borkar, M. Carey, R. Grover, N. Onose, and R. Vernica.
"Hyracks: A Flexible and Extensible Foundation for Data-Intensive Computing",
Proc. 27th ICDE Conf., Hannover, Germany, April 2011.

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Hivesterix (HiveQL on Hyracks)

- Replace Hive's runtime: Hadoop → Hyracks
  - One DAG Hyracks job per HiveQL query
  - More algorithm choices for joining, grouping, sorting
  - Binary data representation
- Build Hive on Algebricks
  - More optimization opportunities, e.g., data properties
  - *Goal:* Validate the Algebricks value proposition
- Reuse Hive package as a library
  - Semantic analysis, optimizations, UDFs, types, formats, and SerDes are all reused (to potentially track Hive)
  - Input data comes from HDFS in Hive's native format

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Hivesterix (*cont.*)

Query

Hive

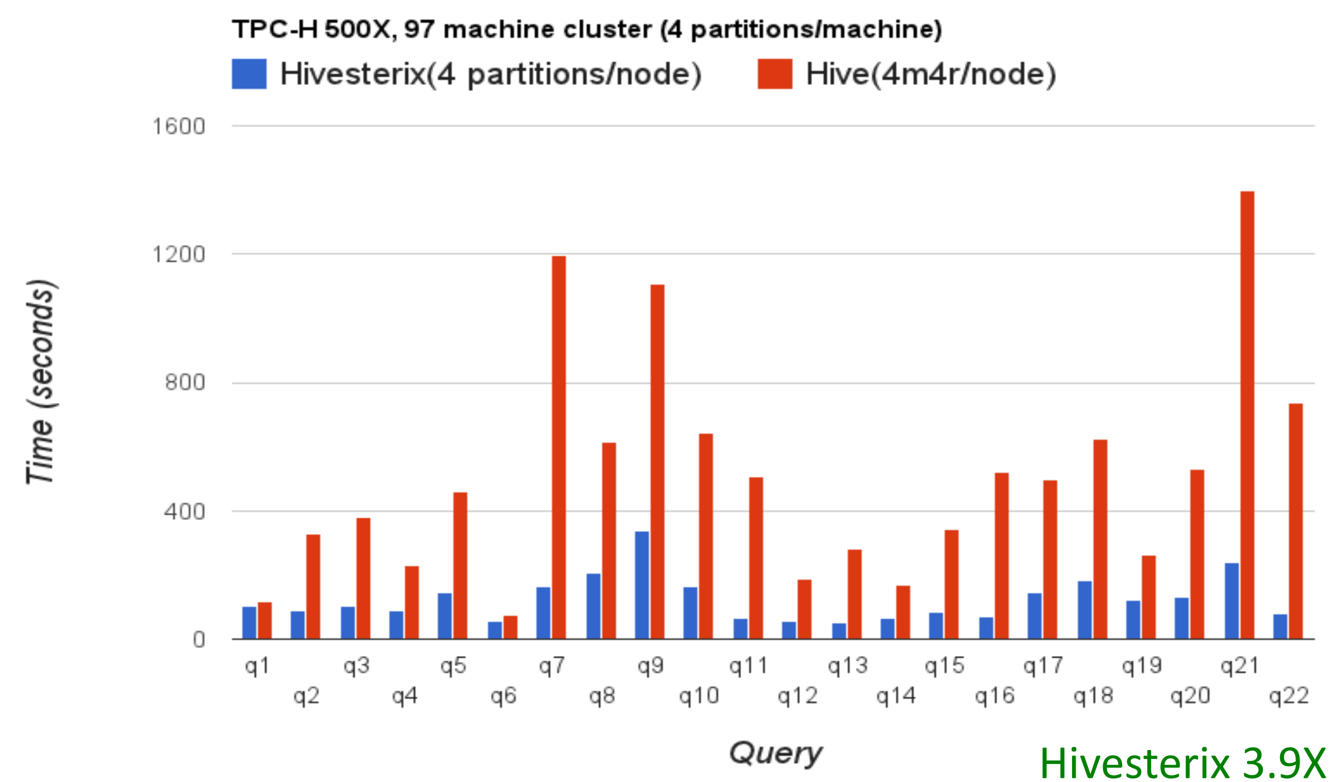
Hive compiler

Hive UDF

Hive format, SerDe

Hivesteri

Optimize
& JobGe



Hivesterix 3.9X faster (avg)

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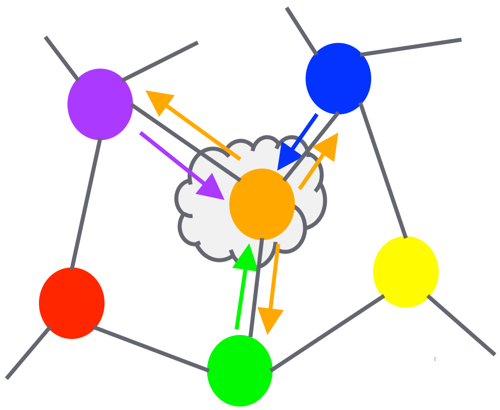
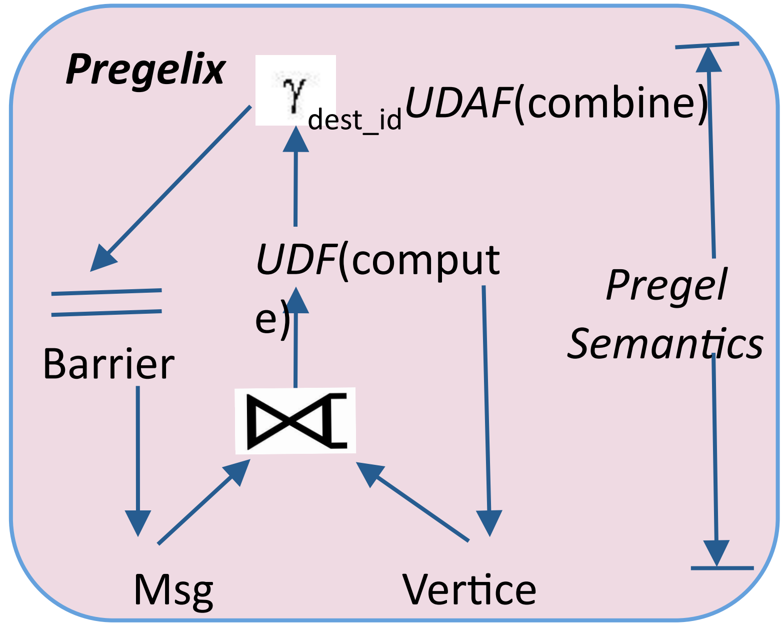
Pregelix (Joint w/Yahoo!)



Think like a Vertex:

Pregel
Giraph
GraphLab
……



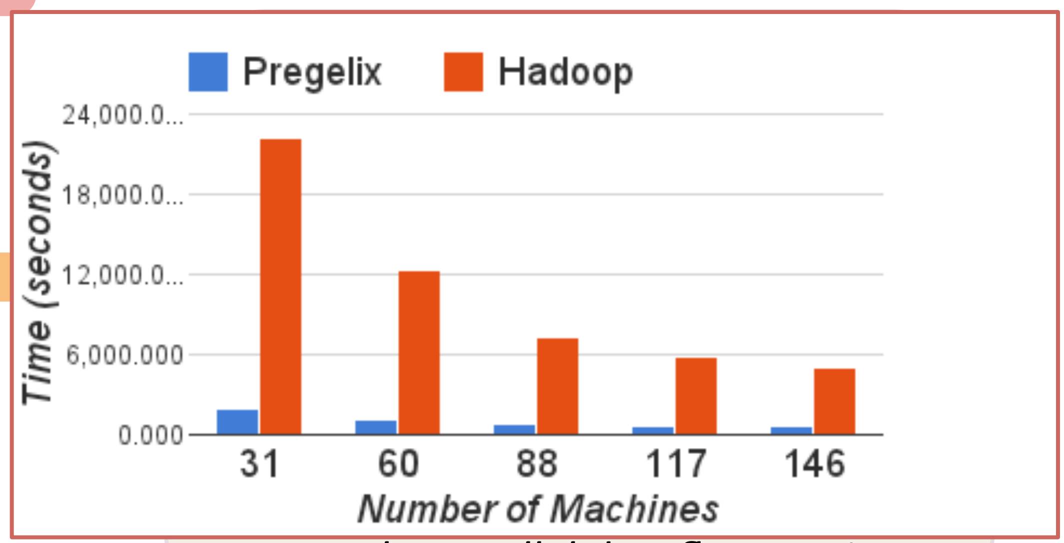
Vertex/map/msg data structures

Task scheduling

Memory management

Message delivery

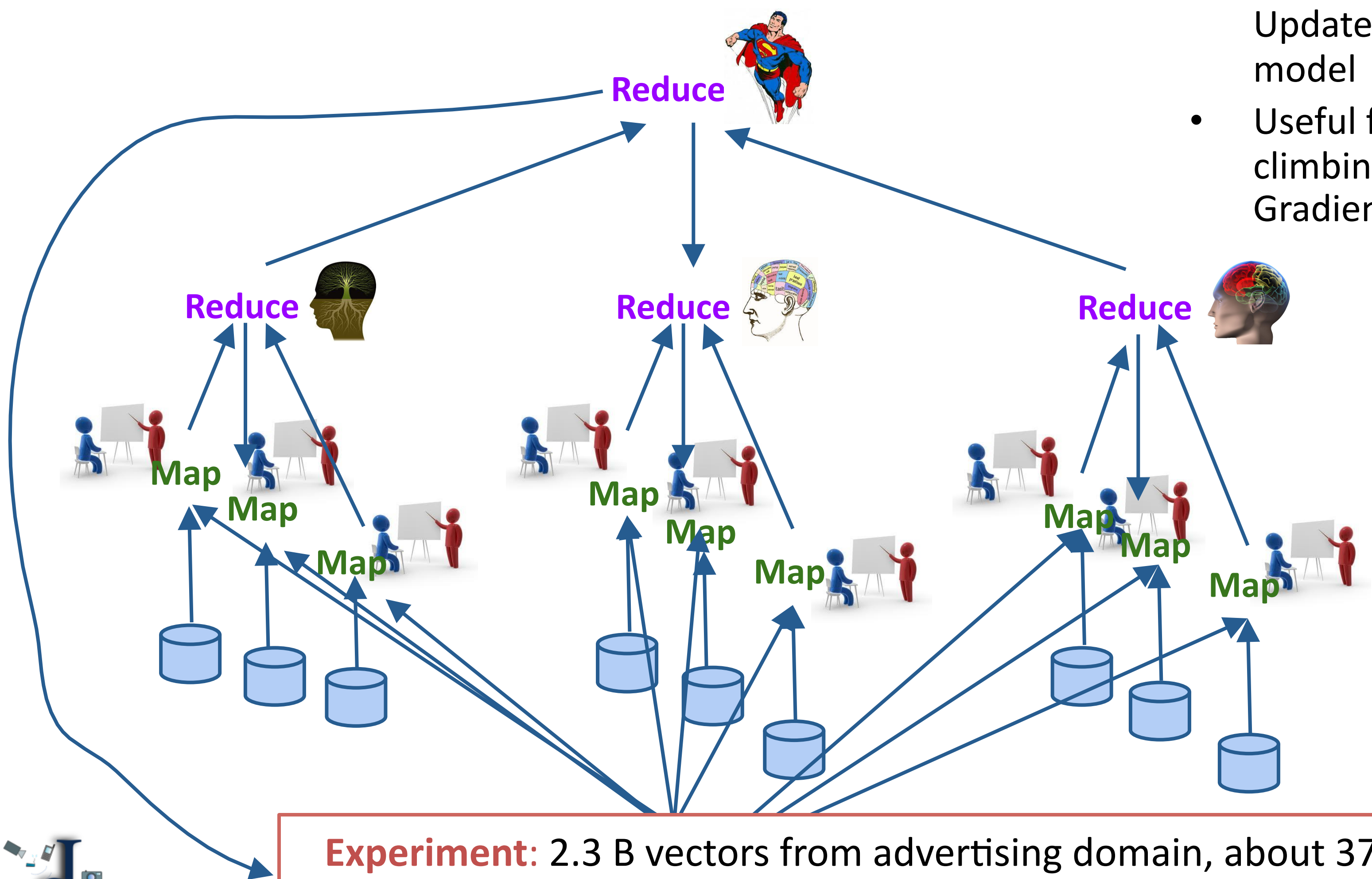
Network management



Hyracks parallel dataflow engine

IMRU (Joint w/UCSC, Yahoo!)

- Iterative Map-Reduce-Update programming model
- Useful for iterative hill-climbing ML (e.g., Batch Gradient Descent)



Experiment: 2.3 B vectors from advertising domain, about 37.1B features. Used 30 machines to compare Hyracks with Vowpal Wabbit (VW): 114.54s on Hyracks *vs.* 124.41s on VW

Why AsterixDB?

AsterixDB more engine less trunk

- "One Size Fits a Bunch" can offer better functionality, manageability, and performance than gluing together multiple point solutions (*e.g.,* Hadoop + Hive + MongoDB):
  - LSM indexes for dynamic data with queries
  - Spatial indexing and spatial query capabilities
  - Fuzzy indexing and query processing for similarity
  - External datasets (and datafeeds) for external data
  - Powerful graph-processing module: *Pregelix*
- Hyracks is a more powerful, flexible, and efficient run-time dataflow engine than Hadoop – and supports an open stack
  - Operators/primitives based on parallel DBMS best practices
  - Experiments show up to 10x performance speedups at scale (on disk-resident problems and data sizes)

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Current Status

AsterixDB
more engine less trunk

- Approaching 4 years of initial NSF project (~250 KLOC)
- Code scale-tested on a 6-rack Yahoo! Labs cluster with roughly 1400 cores and 700 disks
- Hyracks and Pregelix ready now, IMRU very soon
- AsterixDB BDMS: Beta out in June! (June 6th, 2013)
  - Semistructured "NoSQL" style data model
  - Declarative parallel queries, inserts, deletes, …
  - LSM-based storage/indexes (primary & secondary)
  - Internal and external datasets both supported
  - Fuzzy and spatial query processing
  - NoSQL-like transactions (for inserts/deletes)

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Partial Cast List

- Faculty and research scientists
  - UCI: Michael Carey, Chen Li; Vinayak Borkar, Nicola Onose (Google)
  - UCR: Vassilis Tsotras
- PhD students
  - UCI: Rares Vernica (HP Labs), Alex Behm (Cloudera), Raman Grover, Yingyi Bu, Sattam Alsubaiee, Yassar Altowim, Hotham Altwaijry, Pouria Pirzadeh, Zachary Heilbron, Young-Seok Kim
  - UCR/UCSD: Jarod Wen, Preston Carman, Nathan Bales (Google)
- MS students
  - UCI: Guangqiang Li (MarkLogic), Vandana Ayyalasomayajula (Yahoo!), Siripen Pongpaichet, Ching-Wei Huang, Manish Honnatti (Zappos), Xiaoyu Ma, Madhusudan Cheelangi (Google), Khurram Faraaz (IBM DB2), Tejas Patel
- BS students (alumni)
  - UCI: Roman Vorobyov, Dustin Lakin
- Foreign affiliates
  - Thomas Bodner (T.U. Berlin), Markus Dressler (HPI), Rico Bergmann (Humboldt U.)

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Collaborators

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- Facebook
  - Funded Facebook Fellowship
  - Provided access to Hive data warehouse workload information
- Yahoo! Research
  - Hyracks as infrastructure for ScalOps language
  - Provided access to 200-node cluster (and data)
  - Funded 3 Key Scientific Challenge graduate student awards
- Rice University
  - Hyracks for online aggregation
- UC Santa Cruz
  - Hyracks for IMRU programming model
  - Added support for asynchronous fixpoint computations
- UC San Diego
  - Added fine-grained lineage capture capability to Hyracks
- Apache Software Foundation
  - Hyracks/Algebricks as foundation for parallel XQuery engine
  - One student funded by Google Summer of Code 2012.

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For More Info

NSF project page: http://asterix.ics.uci.edu

Open source code base:

- ASTERIX: http://code.google.com/p/asterixdb/
- Hyracks: http://code.google.com/p/hyracks
- Pregelix: http://hyracks.org/projects/pregelix/

AsterixDB

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Questions…?

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