D4M 2.0 Schema: A General Purpose High Performance Schema for the Accumulo Database

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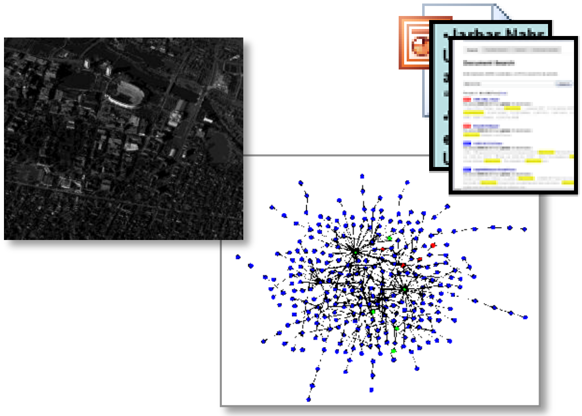
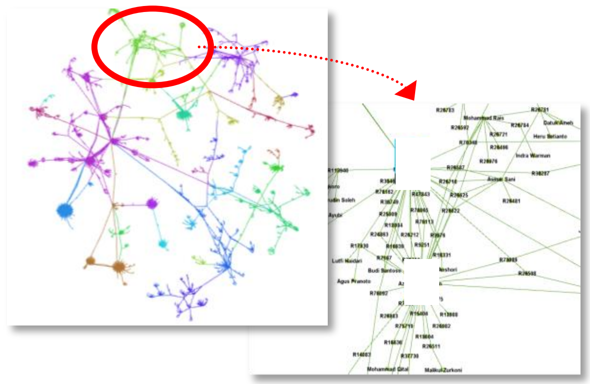
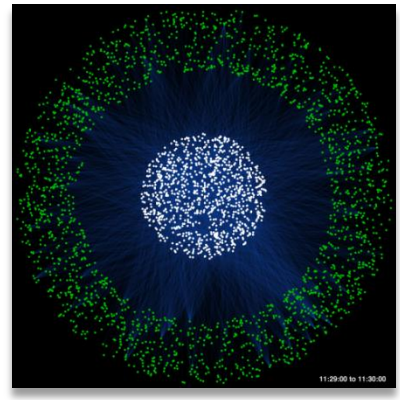
Outline

- Introduction
- D4M
- Schema
- Twitter
- Summary

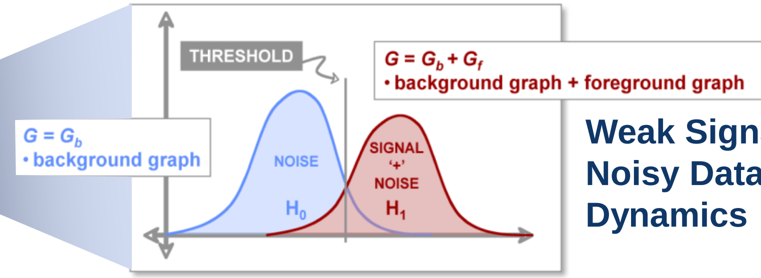
Example Big Data Applications

ISR	Social	Cyber
		
• Graphs represent entities and relationships detected through multi-INT sources • 1,000s – 1,000,000s tracks and locations • GOAL: Identify anomalous patterns of life	• Graphs represent relationships between individuals or documents • 10,000s – 10,000,000s individual and interactions • GOAL: Identify hidden social networks	• Graphs represent communication patterns of computers on a network • 1,000,000s – 1,000,000,000s network events • GOAL: Detect cyber attacks or malicious software

Cross-Mission Challenge: detection of subtle patterns in massive multi-source noisy datasets

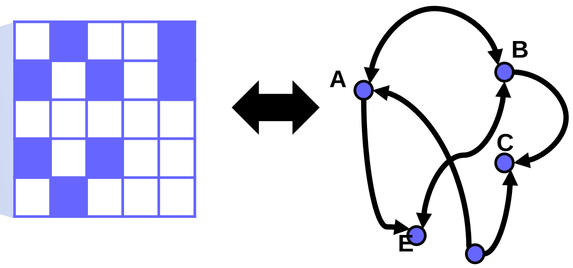
LLSuperCloud Software Stack: Big Data + Big Compute

Novel Analytics for: Text, Cyber, Bio



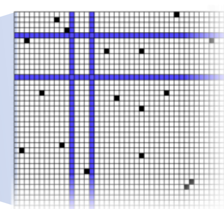
Weak Signatures, Noisy Data, Dynamics

High Level Composable API: D4M ("Databases for Matlab")



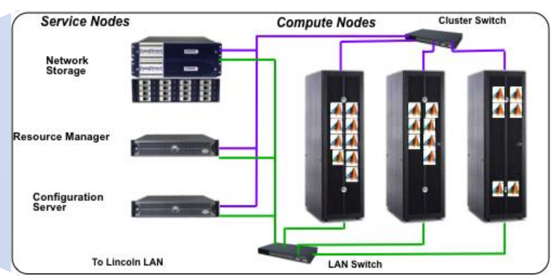
Array Algebra

Distributed Database: Accumulo (triple store)



Distributed Database/ Distributed File System

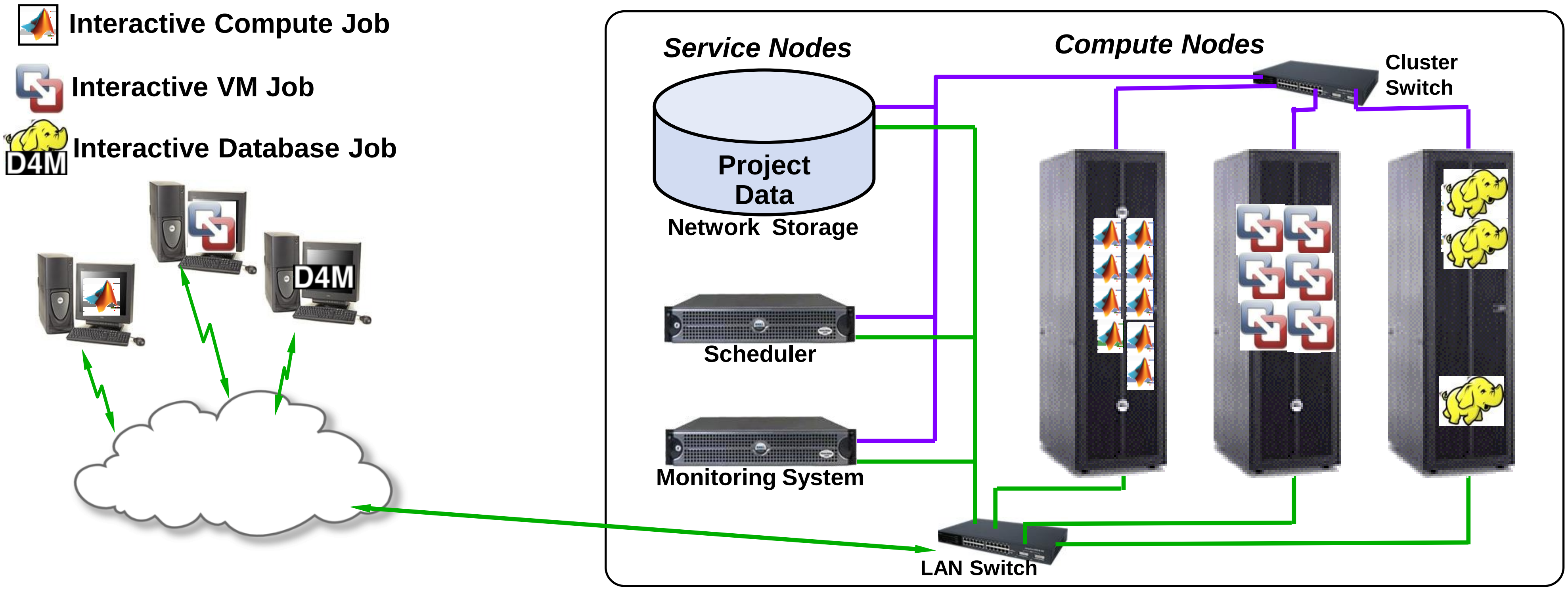
High Performance Computing: LLGrid + Hadoop



Interactive Super-computing

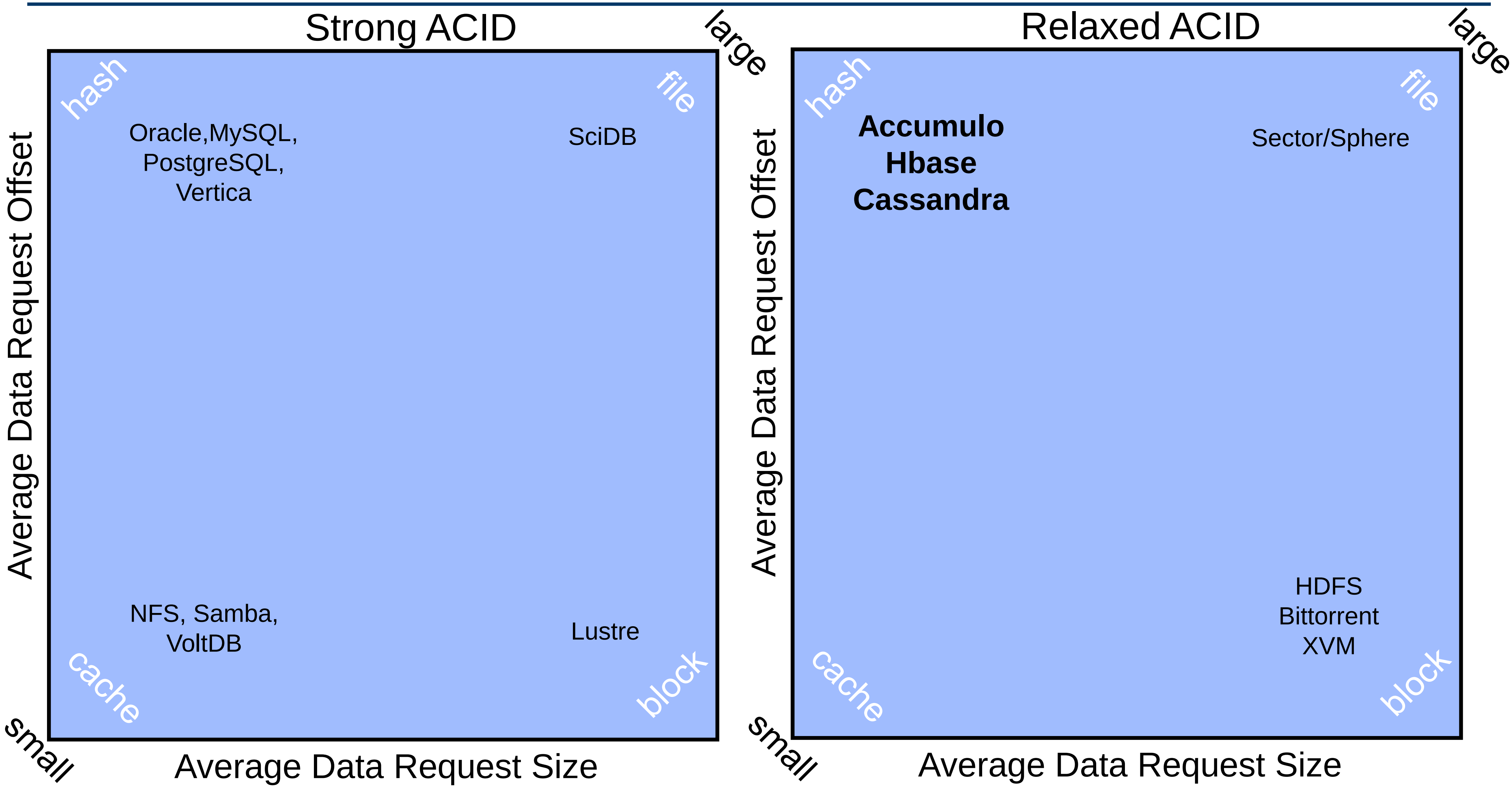
Combining Big Compute and Big Data enables entirely new domains

LLSuperCloud Test Bed



- LLSuperCloud allows traditional supercomputing, VMs and Hadoop/Accumulo to dynamically share the same hardware; allows users to:
- Dynamically stand up and test heterogeneous clouds
- Integrate different clouds for best mission solution
- Determine which clouds are best for which mission

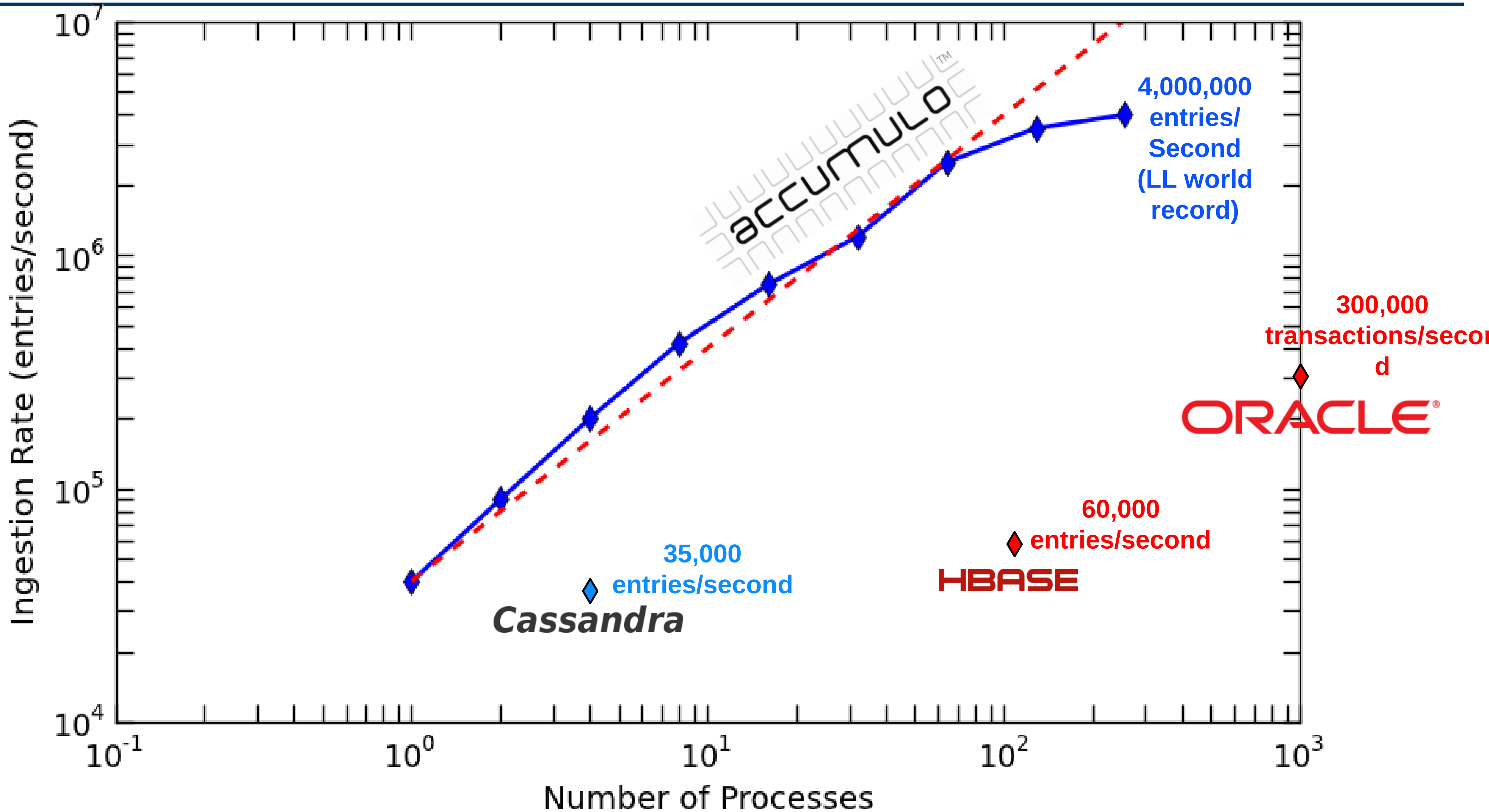
Data Storage Landscape



- Leading areas of innovation are in dense structured databases and sparse unstructured databases

ACID = Atomicity, Consistency, Isolation, Durability

Accumulo "Big Table" Database



- **Accumulo is the fastest open source database in the world**
- **Widely used for gov't applications**

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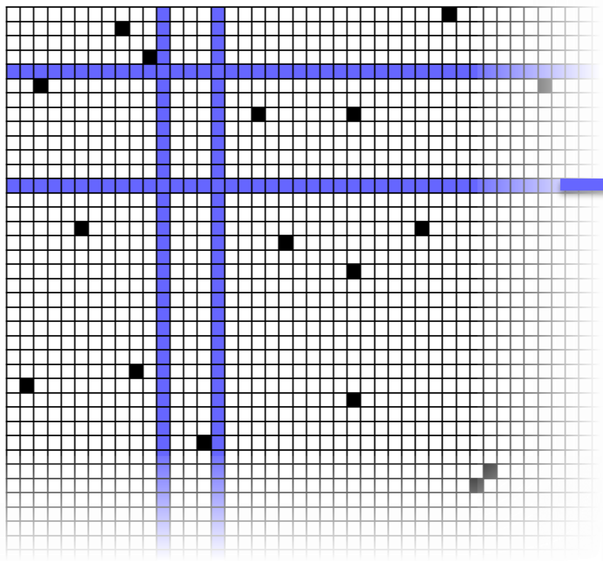
High Level Language: D4M

http://www.mit.edu/~kepner/D4M

Accumulo Distributed Database

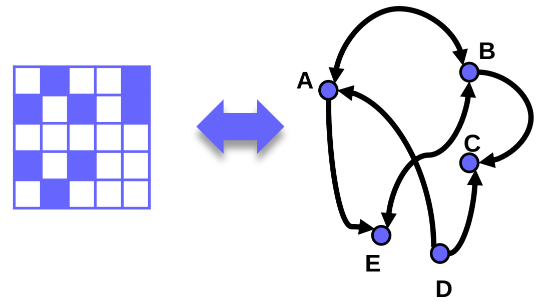


D4M
Dynamic
Distributed
Dimensional
Data Model

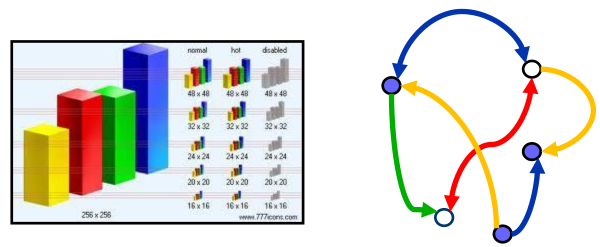
Query:
Alice
Bob
Cathy
David
Earl

Associative Arrays

Numerical Computing Environment



A D4M query returns a sparse matrix or a graph…



…for statistical signal processing or graph analysis in MATLAB

D4M binds associative arrays to databases, enabling rapid prototyping of data-intensive cloud analytics and visualization

D4M Key Concept: Associative Arrays Unify Four Abstractions

- **Extends associative arrays to 2D and mixed data types**

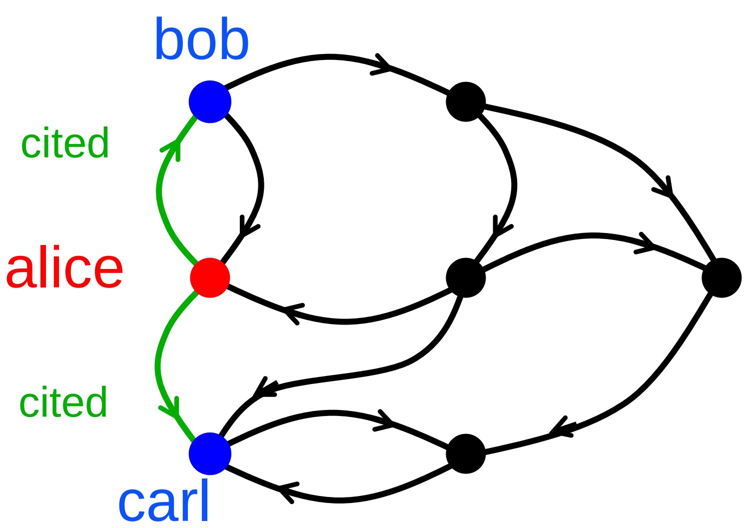
A('alice ','bob ') = 'cited '

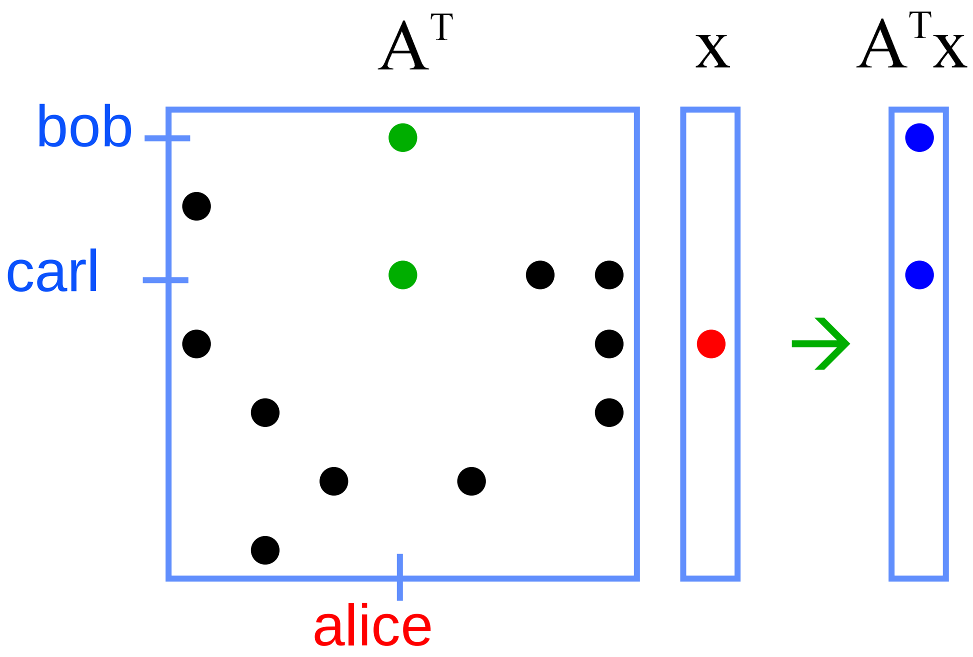
or A('alice ','bob ') = 47.0

- **Key innovation: 2D is 1-to-1 with triple store**

('alice ','bob ','cited ')

or ('alice ','bob ',47.0)





Composable Associative Arrays

- **Key innovation: mathematical closure**
  - **All associative array operations return associative arrays**
- **Enables composable mathematical operations**

  A + B   A - B   A & B   A|B   A*B

- **Enables composable query operations via array indexing**

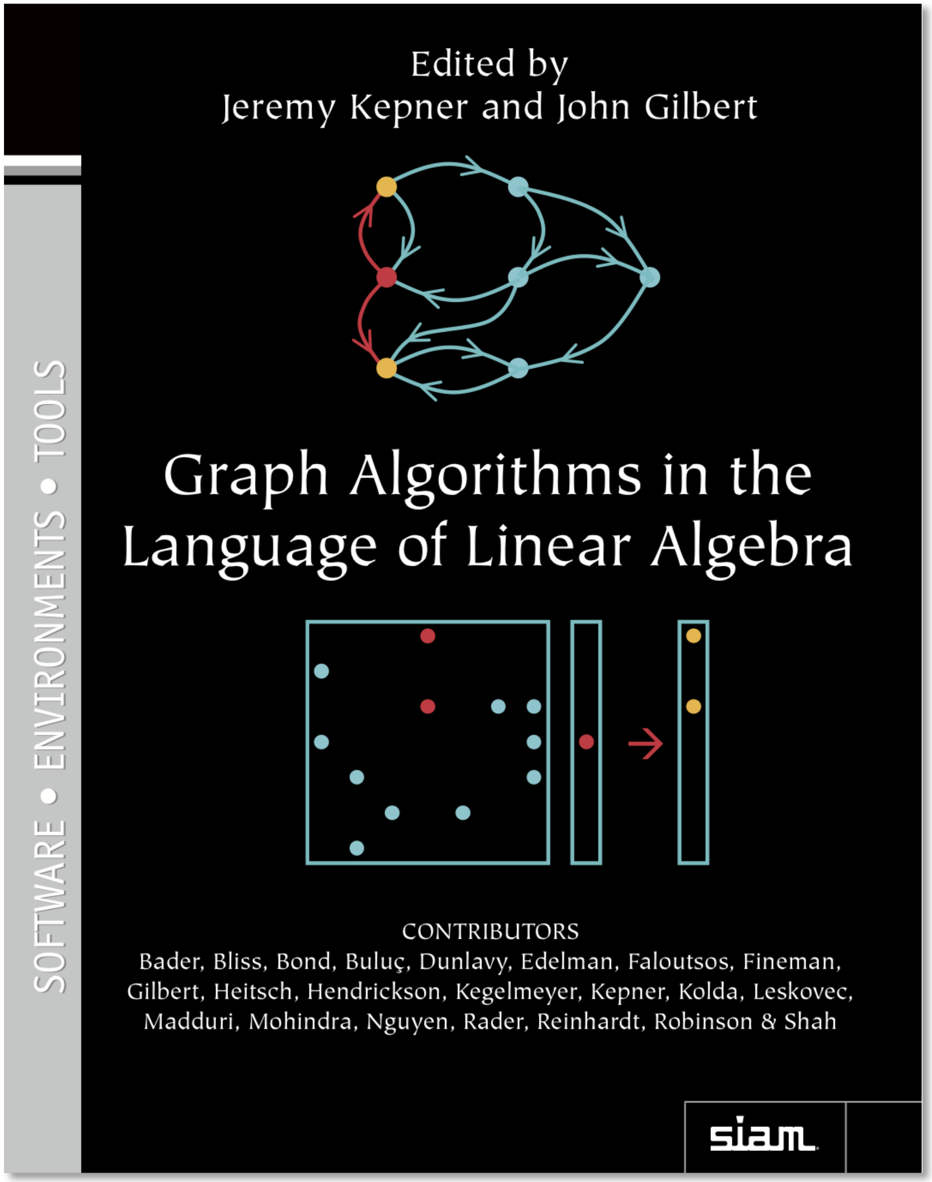
  A('alice bob ',:)   A('alice ',:)   A('al* ',:)

  A('alice : bob ',:)   A(1:2,:)   A == 47.0

- **Simple to implement in a library (~2000 lines) in programming environments with: 1st class support of 2D arrays, operator overloading, sparse linear algebra**

- **Complex queries with ~50x less effort than Java/SQL**
- **Naturally leads to high performance parallel implementation**

Reference & Database Workshop



Database Discovery Workshop

3 day hands-on workshop on:

Systems

- Parse, ingest, query, analysis & display

Usage

- Files vs. database, chunking & query planning

Detection theory

- Clutter, background, detection & tracking

Technology selection

- Knowing what to use is as important as knowing how to use it

Using state-of-the-art technologies:

D4M

Python

R

accumulo

Hadoop

SciDB

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Generic D4M Triple Store Exploded Schema

Accumulo Table: Ttranspose

	01-01-2001	02-01-2001	03-01-2001
Col1|a	1		
Col1|b		1	
Col2|b		1	
Col2|c			1
Col3|a	1		
Col3|c			1

Input Data

Time	Col1	Col2	Col3
2001-01-01	a		a
2001-01-02	b	b	
2001-01-03		c	c

	Col1|a	Col1|b	Col2|b	Col2|c	Col3|a	Col3|c
01-01-2001	1				1	
02-01-2001		1	1			
03-01-2001				1		1

Accumulo Table: T

- Tabular data expanded to create many type/value columns
- Transpose pairs allows quick look up of either row or column
- Flip time for parallel performance

Tables: SQL vs D4M+Accumulo

SQL Dense Table: T

log_id	src_ip	srv_ip
001	128.0.0.1	208.29.69.138
002	192.168.1.2	157.166.255.18
003	128.0.0.1	74.125.224.72 208.29.69.138

Use as row indices

Create columns for each unique type/value pair

	src_ip|128.0.0.1	src_ip|192.168.1.2	srv_ip|157.166.255.18	srv_ip|208.29.69.138	srv_ip|74.125.224.72
log_id|100	1			1	
log_id|200		1	1		
log_id|300	1			1	1

Accumulo D4M schema (aka NuWave) Tables: E and E^T

- **Both dense and sparse tables stored the same data**
- **Accumulo D4M schema uses table pairs to index every unique string for fast access to both rows and columns (ideal for graph analysis)**

Queries: SQL vs D4M

Query Operation	SQL	D4M
Select all	SELECT * FROM T	E(:,:)
Select column	SELECT src_ip FROM T	E(:,StartsWith('src_ip| '))
Select sub-column	SELECT src_ip FROM T WHERE src_ip=128.0.0.1	E(:,'src_ip|128.0.0.1 ')
Select sub-matrix	SELECT * FROM T WHERE src_ip=128.0.0.1	E(Row(E(:,'src_ip|128.0.0.1 ')),:)

- Queries are easy to represent in both SQL and D4M
- Pedigree (i.e., the source row ID) is always preserved since no information is lost

Analytics: SQL vs D4M

Query Operation	SQL	D4M
Histogram	SELECT COUNT(src_ip) FROM T GROUP BY src_ip	sum(E(:,StartsWith('src_ip| ')),2)
Graph traversal	SELECT * FROM T WHERE src_ip=128.0.0.1 ...	v0 = 'src_ip|128.0.0.1 ' v1 = Col(E(Row(E(:,v0)),:)) v2 = Col(E(Row(E(:,v1)),:))
Graph construction	… many lines …	A = E(:,StartsWith('src_ip| ')). ' * E(:,StartsWith('srv_ip| '))
Graph eigenvalues	… many lines …	eigs(Adj(A))

- **Analytics are easy to represent in D4M**
- **Pedigree (i.e., the source row ID) is usually lost since analytics are a projection of the data and some information is lost**

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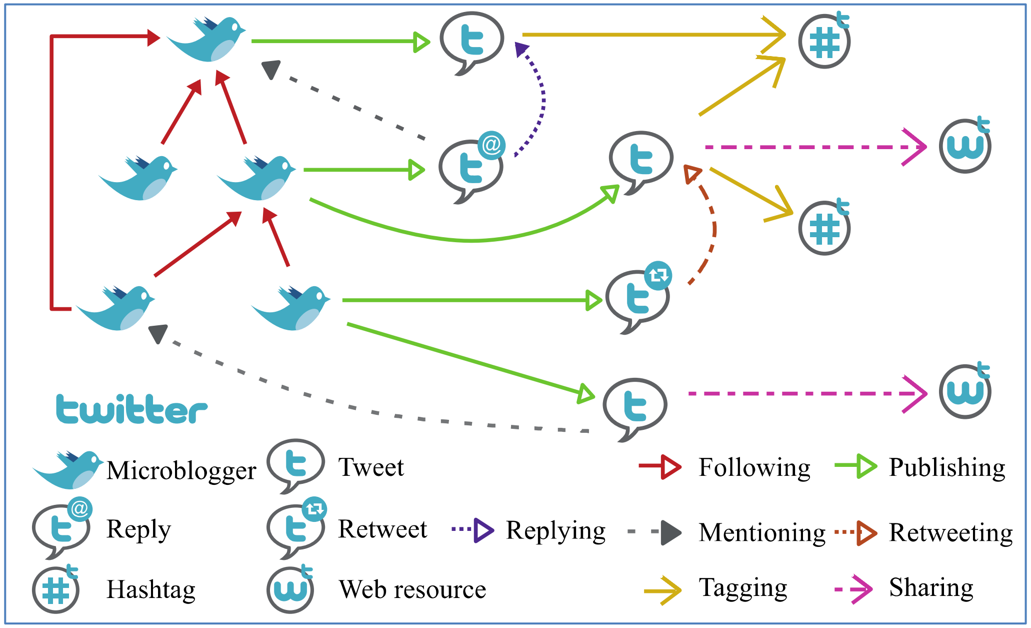
Tweets2011 Corpus
http://trec.nist.gov/data/tweets/

- **Assembled for Text REtrieval Conference (TREC 2011)***
  - **Designed to be a reusable, representative sample of the twittersphere**
  - **Many languages**
- **16,141,812 million tweets sampled during 2011-01-23 to 2011-02-08 (16,951 from before)**
  - **11,595,844 undeleted tweets at time of scrape (2012-02-14)**
  - **161,735,518 distinct data entries**
  - **5,356,842 unique users**
  - **3,513,897 unique handles (@)**
  - **519,617 unique hashtags (#)**



Ben Jabur et al, ACM SAC 2012

*McCreadie et al, "On building a reusable Twitter corpus," ACM SIGIR 2012

Twitter Input Data

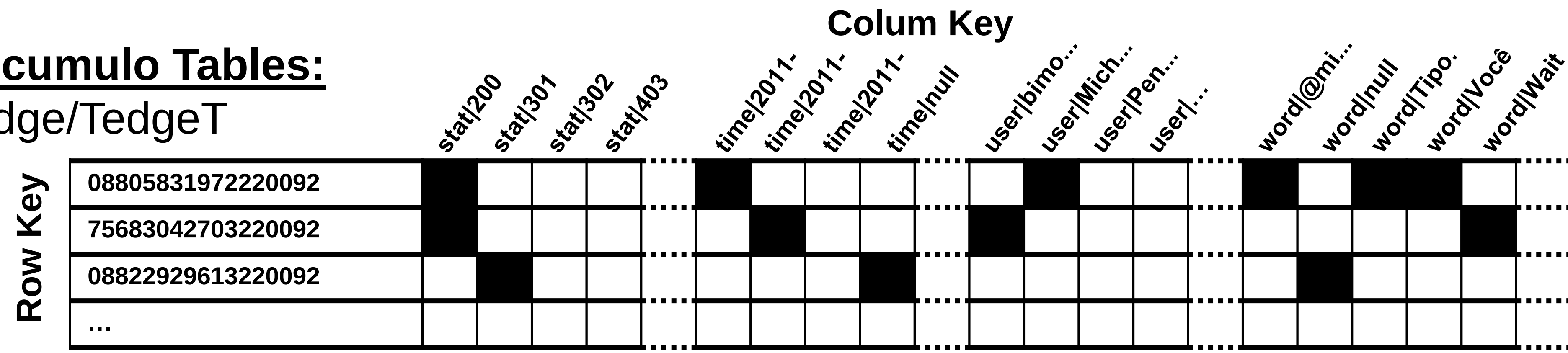
TweetID	User	Status	Time	Text
29002227913850880	Michislipstick	200	Sun Jan 23 02:27:24 +0000 2011	@mi_pegadejeito Tipo. Você ...
29002228131954688	__rosana__	200	Sun Jan 23 02:27:24 +0000 2011	para la semana q termino ...
29002228165509120	doasabo	200	Sun Jan 23 02:27:24 +0000 2011	お腹すいたずえ
29002228937265152	agusscastillo	200	Sun Jan 23 02:27:24 +0000 2011	A nadie le va a importar ...
29002229444771841	nob_sin	200	Sun Jan 23 02:27:24 +0000 2011	さて。札幌に帰るか。
29002230724038657	bimosephano	200	Sun Jan 23 02:27:25 +0000 2011	Wait :)
29002231177019392	_Word_Play	200	Sun Jan 23 02:27:25 +0000 2011	Shawty is 53% and he pick ...
29002231202193408	missogeeeeb	200	Sun Jan 23 02:27:25 +0000 2011	Lazy sunday ╰(◣﹏◢)╯ oooo !
29002231692922880	PennyCheco06	301	null	null
…	…	…	…	…

- **Mixture of structured (TweetID, User, Status, Time) and unstructured (Text)**
- **Fits well into standard D4M Exploded Schema**

Tweets2011 D4M Schema

Accumulo Tables:

Tedge/TedgeT



TedgeDeg^t

Row Key

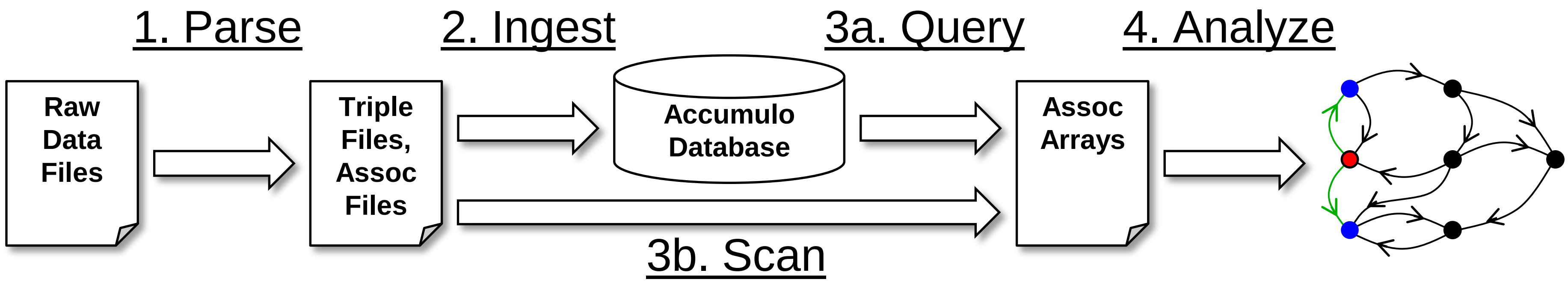
	stat|200	stat|301	stat|302	stat|403	...	time|2011-	time|2011-	time|2011-	time|null	...	user|bimo...	user|Mich...	user|Pen...	user|...	...	word|@mi...	word|null	word|Tipo.	word|Você	word|Wait	...
Degree	10864273	2861507	836327	825822		6	7	7	4545968		6	7	3			3	4546039	16	10223	1624	

TedgeTxt

Row Key	text
08805831972220092	@mi_pegadejeito Tipo. Você fazer uma plaquinha pra mim, com o nome do FC pra você tirar uma foto, pode fazer isso?
75683042703220092	Wait :)
08822929613220092	null
...	

- **Standard exploded schema indexes every unique string in data set**
- TedgeDeg **accumulate sums of every unique string**
- TedgeTxt **stores original text for viewing purposes**

D4M Pipeline



Tweets2011 (single node database)

- **Raw Data: 1.8GB (1621 Files; 100K tweets/file)**

1. Parse: 20 minutes (N_p = 16)

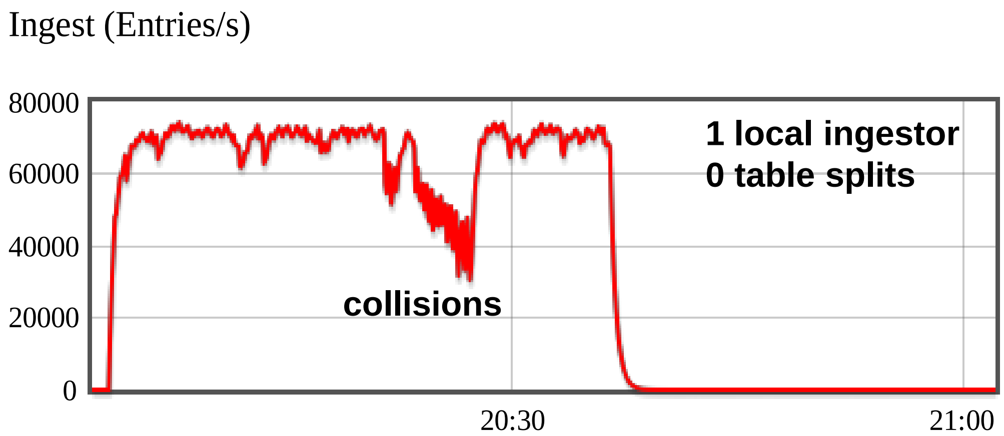
- **Triple Files & Assoc Files: 6.7GB (7x1621 files)**

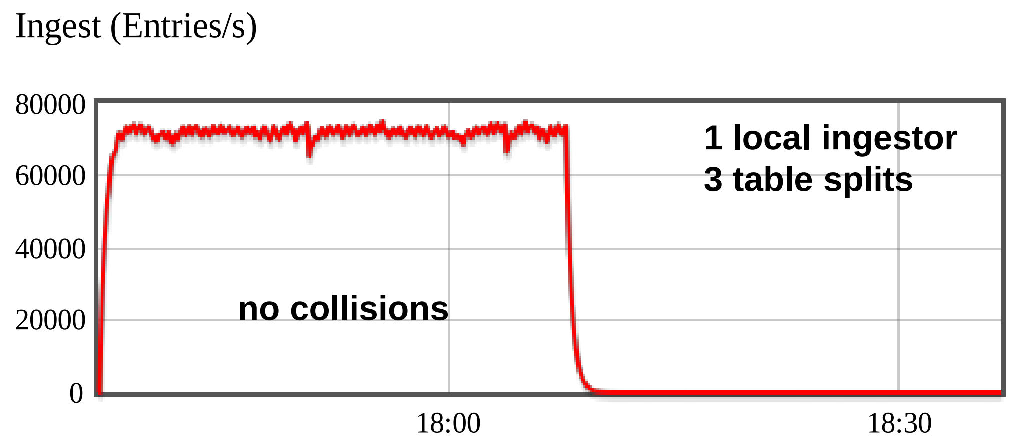
2. Ingest: 40 minutes (N_p = 3); 20 entries/tweet, 200K entries/second

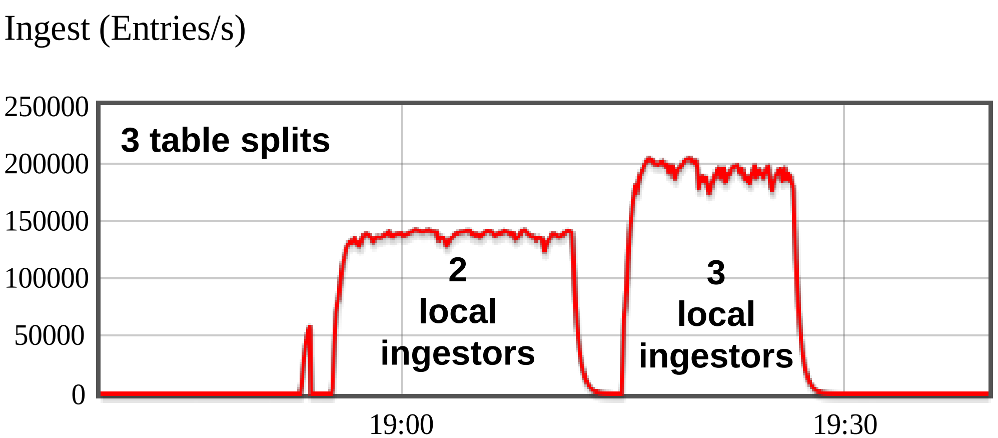
- **Accumulo Database: 14GB in 350M entries**

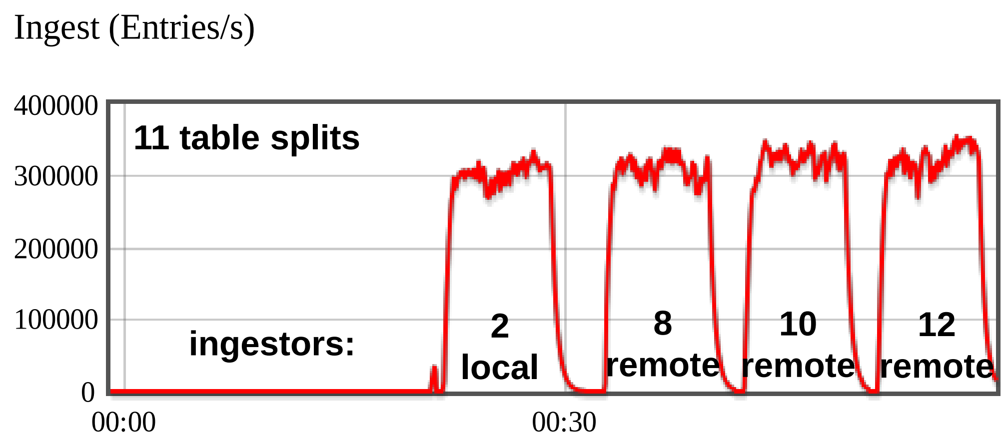
- **Raw data to fully indexed database < 1 hour**
- **Database good for queries, assoc files good for complete scans**

Accumulo Ingest Performance
Single Node Graph500 Benchmark Data









- Single node high performance ingest requires pre-splitting tables
- Can achieve high parallel ingest on single node with proper splitting

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- Capabilities
- Data
- Analytics
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Word Tallies

- **D4M Code**

```
Tdeg = DB('TedgeDeg');
str2num(Tdeg(StartsWith('word|: '),:)) > 20000
```

- **D4M Result (1.2 seconds, N_p = 1)**

word|:	77946
word|:(	80637
word|:)	263222
word|:D	151191
word|:P	34340
word|:p	56696

- **Sum table** TedgeDeg **allows tallies to be seen instantly**

Users Who ReTweet the Most
Problem Size

- **D4M Code to check size of status codes**

```
Tdeg = DB('TedgeDeg');
Tdeg(StartsWith('stat| '),:))
```

- **D4M Results (0.02 seconds, N_p = 1)**

stat|200	10864273	**OK**
stat|301	2861507	**Moved permanently**
stat|302	836327	**ReTweet**
stat|403	825822	**Protected**
stat|404	753882	**Deleted tweet**
stat|408	1	**Request timeout**

- **Sum table** TedgeDeg **indicates 836K retweets (~5% of total)**
- **Small enough to hold all TweeetIDs in memory**
- **On boundary between database query and complete file scan**

Users Who ReTweet the Most
Parallel Database Query

- **D4M Parallel Database Code**

```
T = DB('Tedge','TedgeT');        Ar = T(:,'stat|302 ');
my = global_ind(zeros(size(Ar,2),1,map([Np 1],{},0:Np-1)));
An = Assoc('','','');            N = 10000;
for i=my(1):N:my(end)
  Ai = dblLogi(T(Row(Ar(i:min(i+N,my(end)),:)),:));
  An = An + sum(Ai(:,StartsWith('user|,')),1);
end
Asum = gagg(Asum > 2);
```

- **D4M Result (130 seconds, N_p = 8)**

user|Puque007 103, user|[redacted]Say 113,
user|carp_fans 115, user|habu_bot 111,
user|kakusan_RT 135, user|umaitofu 116

- **Each processor queries all the retweet TweetIDs and picks a subset**
- **Processors each sum all users in their tweets and then aggregate**

Users Who ReTweet the Most
Parallel File Scan

- **D4M Parallel File Scan Code**

```
Nfile = size(fileList);
my = global_ind(zeros(Nfile,1,map([Np 1],{},0:Np-1)));
An = Assoc('','','');
for i=my
  load(fileList{i});
  An = An + sum(A(Row(A(:,'stat|302,')),StartsWith('user|,')),1);
end
An = gagg(An > 2);
```

- **D4M Result (150 seconds, N_p = 16)**

user|Puque007 100, user|[redacted]Say 113,
user|carp_fans 114, user|habu_bot 109,
user|kakusan_RT 135, user|umaitofu 114

- **Each processor picks a subset of files and scans them for retweets**
- **Processors each sum all users in their tweets and then aggregate**

Summary

- **Big data is found across a wide range of areas**
  - **Document analysis**
  - **Computer network analysis**
  - **DNA Sequencing**
- **Non-traditional, relaxed consistency, triple store databases are the backbone of many web companies**
- **D4M Schema provides a general, high performance approach for harnessing the power of these databases**