YarcData™
A DIVISION OF CRAY INC.

Cray XMT2
uRiKA
Overview

May 21, 2012

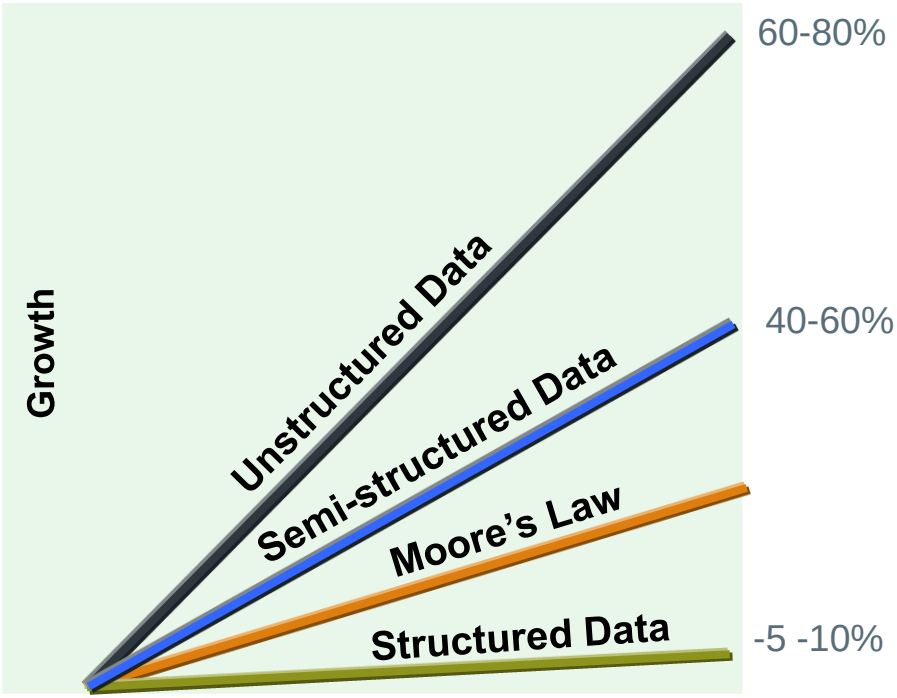
uRiKA == universal RDF integration Knowledge Appliance

Agenda

- Big Data Analysis
- The Cray XMT2
- The uRiKA Graph Analytics Appliance
- Customer Use Cases
- Early Performance Results
- Summary

Disruptive Change in Big Data Analysis

**Moore's Law vs.
Growth in Dataset Size**



- Exponential Growth in Overall Data Volume
- Variety of Data Types increasing
- Regulatory Requirements growing…
- *Unstructured and Semi-Structured Data becoming key!*
- Gartner: "Success goes to business which can leverage all available data… at the greatest Velocity"

- Structured: Databases, Spreadsheets…
- Semi-structured: XML, EDI, …
- Unstructured: E-mail, Docs, Multimedia, Wikis, Social Media, …

**Volume, Variety, Velocity:
New demands for Data Analytics**

Disruptive Change in Search Technology

Web 2.0:

- Hyperlinked Documents
- Keyword Search
- Standards:
  - HTML, XML
- Databases

Google bing YAHOO!

Web 3.0:

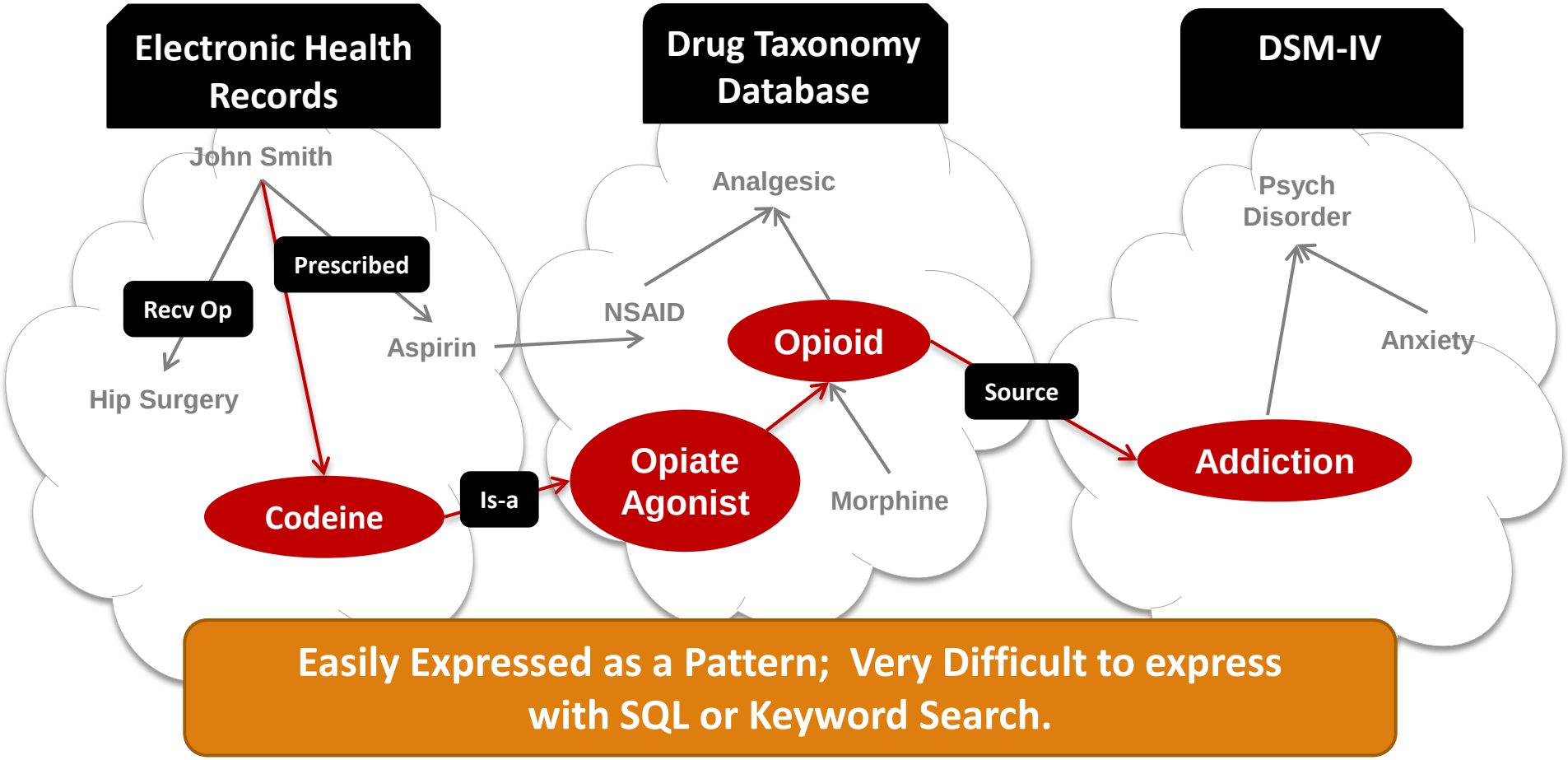
- Semantically linked Documents
- Semantic queries
- Standards:
  - RDF, SPARQL
- Graphs

Web 3.0 allows…

Merging data sources	Pattern based queries	Much More Meaningful Results

An Example from the Health Industry…

Query: What drugs are causing post-operative addictions in Hip Surgery patients?



Easily Expressed as a Pattern; Very Difficult to express with SQL or Keyword Search.

Analytics Today

Big Data

- Structured
- Semi-structured
- Unstructured

Scale-out Analytics

- Unstructured Data
- Partitionable Datasets
- Keyword Search
- Example: Hadoop, MapReduce

Data Warehouses BI Tools

- Structured Data
- OLAP Cubes
- Regular Queries, Known Variables
- Example: Oracle Exadata

In-memory Analytics

- Structured AND Unstructured Data
- Non-partitionable
- Complex Queries ("Pattern Matching")
- Example: YarcData uRiKA

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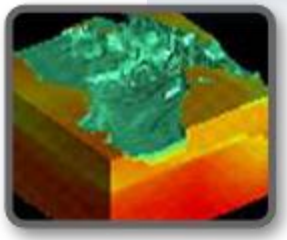
Cray Is Supercomputing

We build the world's largest and fastest supercomputers for the highest end of the HPC market

Targeting the growing capability needs of government agencies, research institutions and large enterprises

We help solve the "Grand Challenges" in science and engineering that require supercomputing

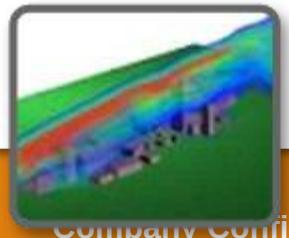


Earth Sciences
CLIMATE CHANGE &
EARTHQUAKE PREDICTION

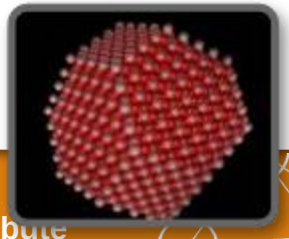
Life Sciences
PERSONALIZED MEDICINE

Defense
AIRCRAFT DESIGN

Computer-Aided Engineering
CRASH SIMULATION

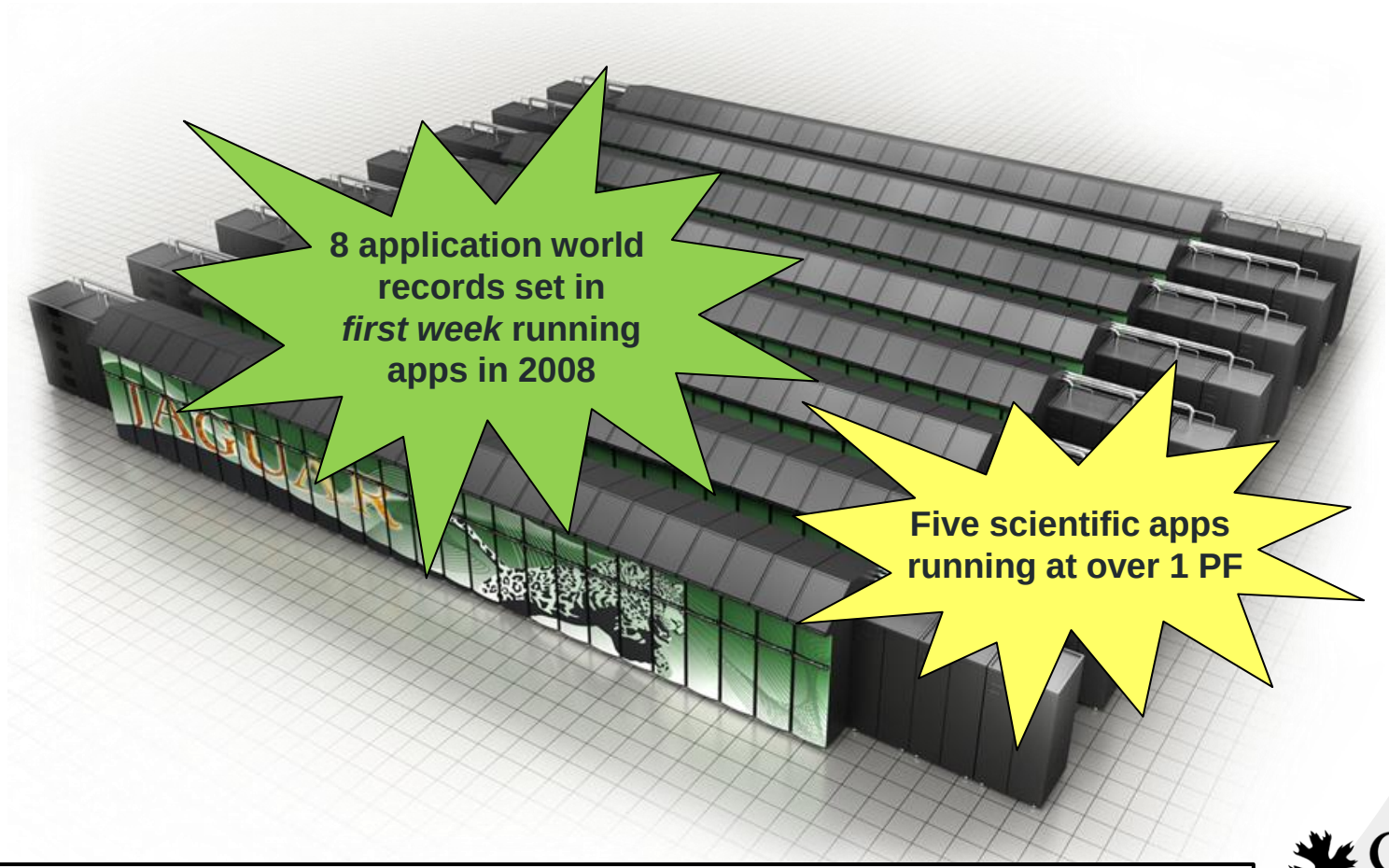


National Security
THREAT PREDICTION



Scientific Research
NEW ENERGY SOURCES &
NANOFUEL DEVELOPMENT

Sustained Petaflop Computing



Cray has four deployed PF systems (out of 10 worldwide, Nov'10)
Cray remains (for over 2 years) the *only* system that has sustained an application PF

OAK RIDGE National Laboratory

Standard Processors Can Constrain Algorithm Programming

To achieve high performance, you must…

- Place data near computation
- Access data in order and reuse data
- Partition program into independent, balanced computations (load balancing)
- Minimize synchronization and communication operations
- Avoid modifying shared data
- Avoid adaptive and dynamic computations

But what if your algorithm or application can't take advantage of these techniques?

What if the Application…

- **References very large data sets with very little locality?**
  - Caches don't work
  - Communication overhead can be overwhelming in clusters
  - Even in shared memory machines, translation hardware falls over
- **Has abundant thread-level parallelism, but very little concurrency per thread?**
  - Access pattern is data dependent
  - No computation to hide latency

  ⇒ Threads spend most of their time waiting on global memory refs

You need a machine that…

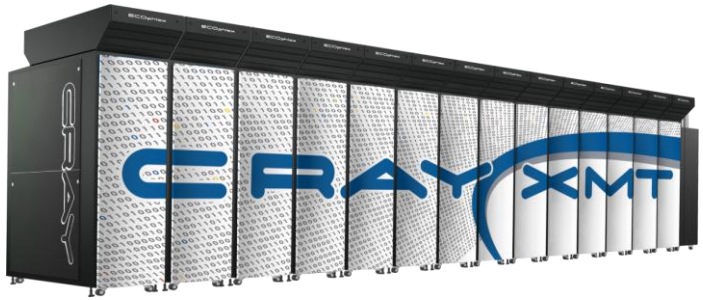
….can efficiently reference into a large, shared, global memory

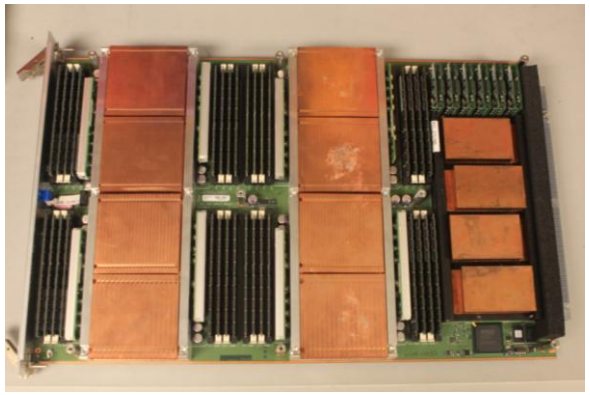
….and can tolerate long memory latencies without losing efficiency.

This motivates the design of the Cray XMT

Cray XMT System
Purpose-Built for Large-Scale, Graph-Based Data Analysis

- **Specialized performance**
  - Not designed for general-purpose HPC apps
  - *Outstanding* performance on graph analytics
- **Large, globally shared memory**
  - Architecture supports up to 512 TB of memory
  - Address translation supports sparse references across entire memory
- **Massive multithreading**
  - 128 simultaneous threads per processor
  - Tolerates long global latencies
- **Network support for single-word accesses**
  - Allows high rate of global references
- **Tagged memory (full/empty bits)**
  - Efficient lightweight synchronization
- **Sophisticated runtime to manage parallelism**
  - Parallelism grows naturally from algorithms
  - Runtime manages threads and load balancing





Programming Implications

- No longer need to place data near computation
- No longer need to access data with stride one
- No longer need to partition programs into balanced computations
- No longer need to minimize communication or synchronization events
- Adaptive and dynamic methods are okay
- Graph algorithms and sparse methods are okay
- Recursion, dynamics programming, branch-and-bound, dataflow are okay

History of the XMT Architecture

- **MTA-1 (Multi Threaded Architecture) launched in 1998**
  - 18 GaAs chips per processor blade, with custom memory
- **Cray MTA-2 launched in 2002**
  - 5 CMOS chips per processor on 1 large PC board with custom DIMMS
- **Cray XMT launched 2008**
  - Processor reduced to single CMOS chip in Opteron socket
  - 4 processors per PC board, standard DIMMS
  - Cray XT network, packaging, cooling and RAS features
- **First Next Generation XMT2 delivered to CSCS in 2011**

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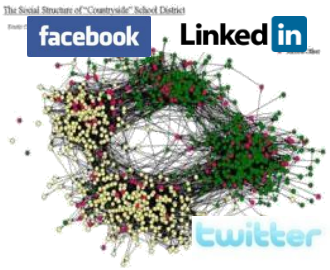
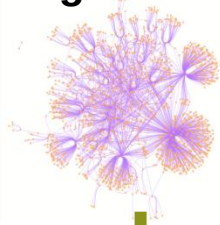
Many Big Data problems are based on Graphs

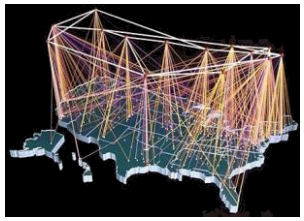
Social Networking



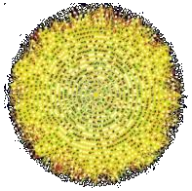
Intelligence/Security

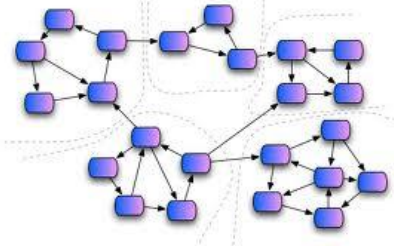


Telecom/Mobile

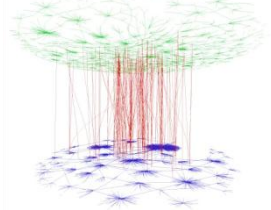


Life Sciences/Biology





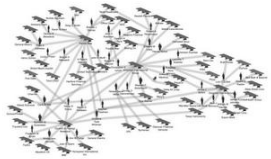
Healthcare/Medicine



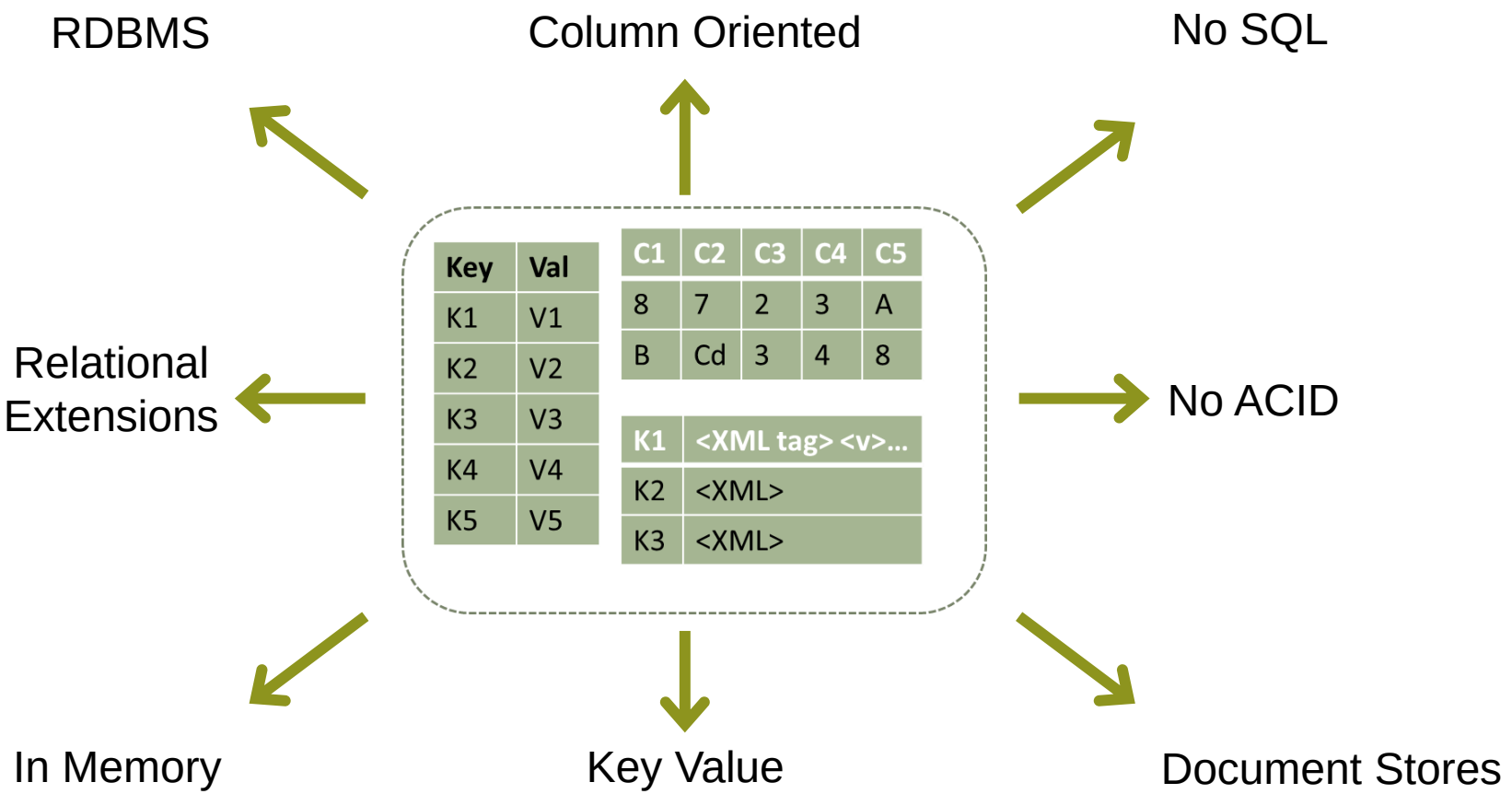
Supply Chain

Targeted Marketing

Finance

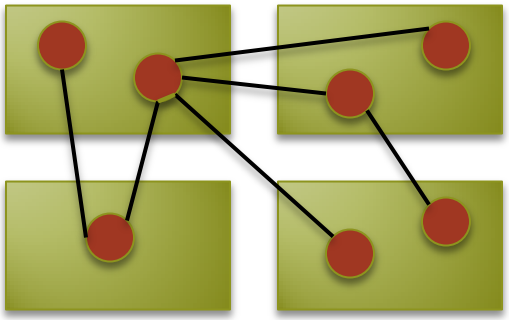


But most Big Data solutions are based on partitioned data structures that scale out on clusters



Current Big Data approaches (including graph databases) result in low performance on Graphs…

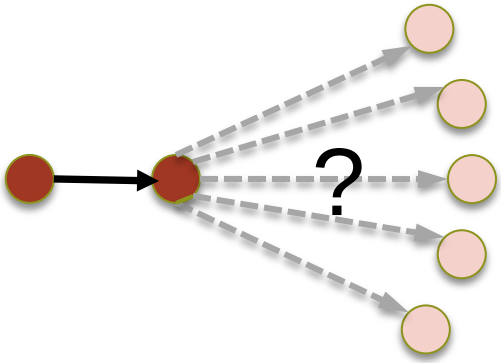
Graphs are hard to Partition



High cost to follow relationships that span Cluster Nodes

Network is 100 times SLOWER than Memory*

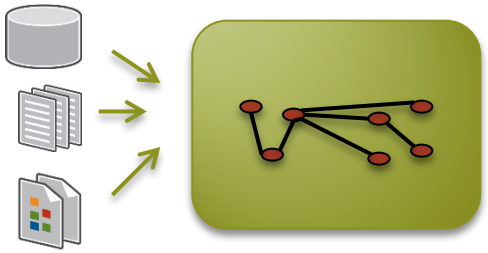
Graphs are not Predictable



High cost to follow multiple competing paths which cannot be pre-fetched/cached

Memory is 100 times SLOWER than Processor*

Graphs are highly Dynamic



High cost to load multiple, constantly changing datasets into in-memory graph models

Storage I/O is 1000 times SLOWER than Memory I/O*

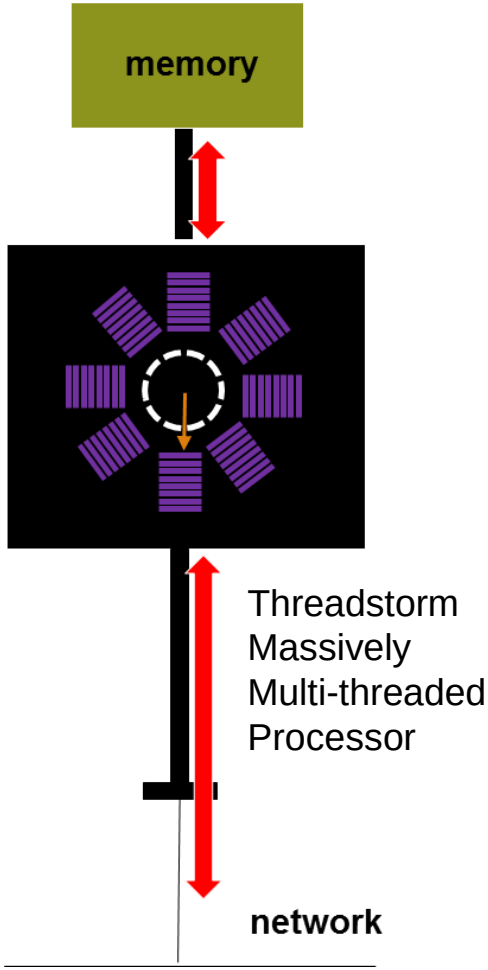
*Source: Hennessy, J. and Patterson, D., "Computer Architecture: A Quantitative Approach", 2012 edition

uRiKA: Purpose-built Graph Appliance…

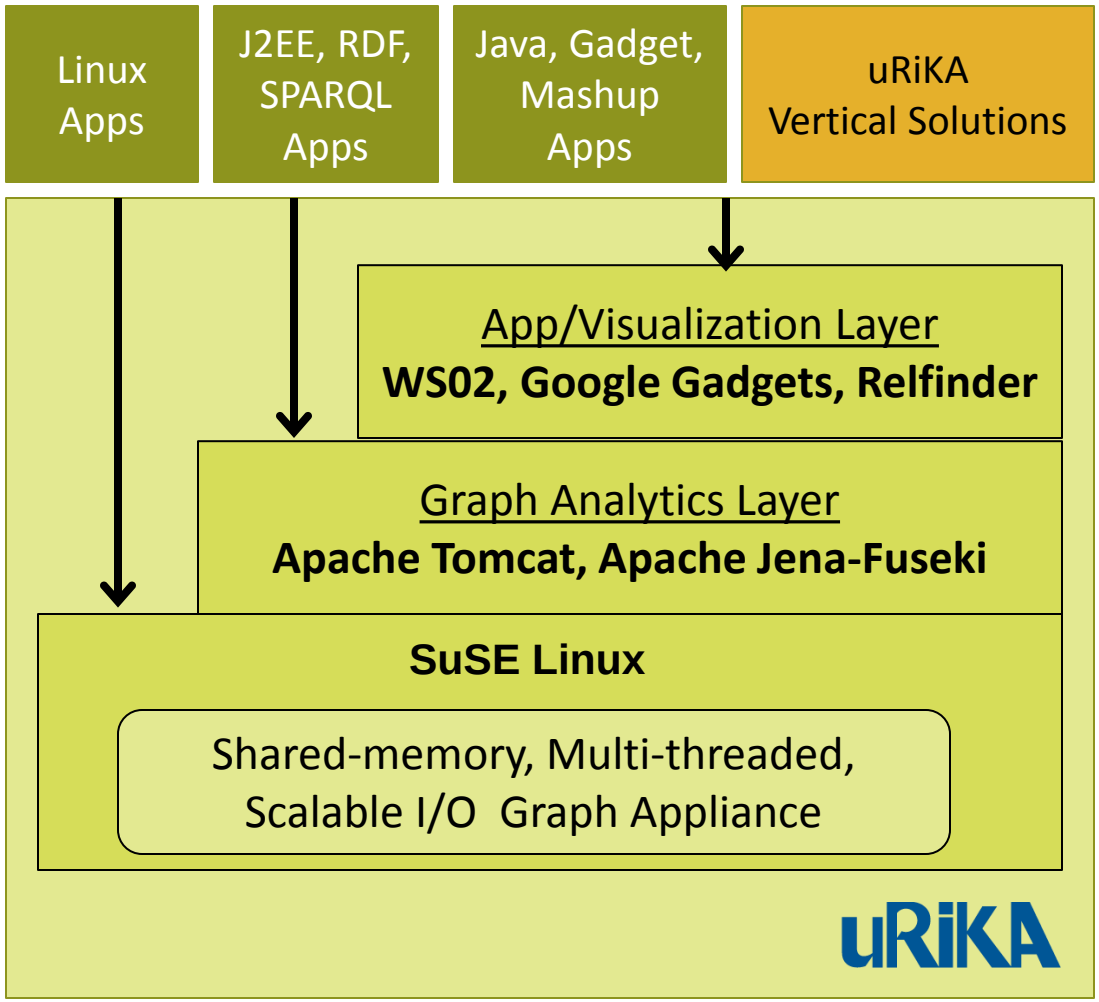
Graphs are hard to Partition → Large Shared Memory
Up to 512 TB

Graphs are not Predictable → Massively Multi-threaded
128 threads/processor

Graphs are highly Dynamic → Highly Scalable I/O
Up to 350 TB/hr



uRiKA: … optimized for Enterprise Applications



- **Industry-standard, Open-source Software Stack**
  - Linux, Java, Apache, WS02, Gadgets, Mashups…
- **Reusable Existing Skillsets**
  - OSGI, App Server, SOA, ESB, Web toolkit…
- **No Lock-in**
  - All applications and artifacts built on uRiKA can be run on other platforms
- **Subscription Pricing model**

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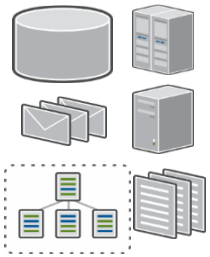
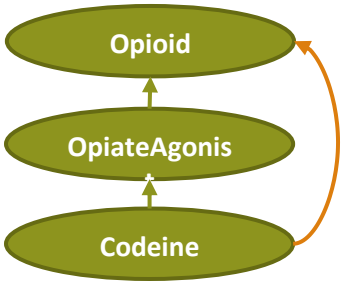
The uRiKA Moment: Discovery of Unknown/Hidden Relationships in Big Data

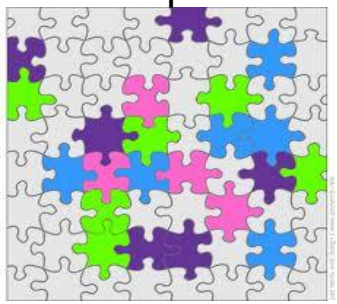
1. Aggregate data and relationships from multiple sources



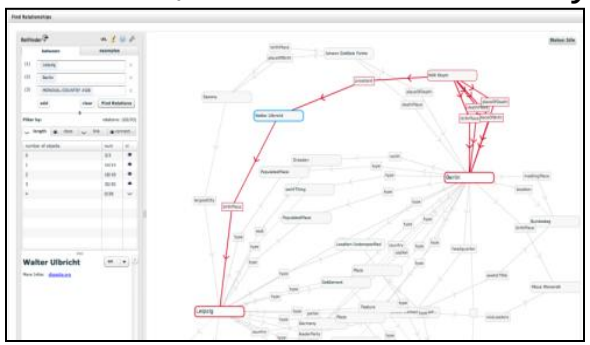
2. Augment Relationships through automated inference and deduction



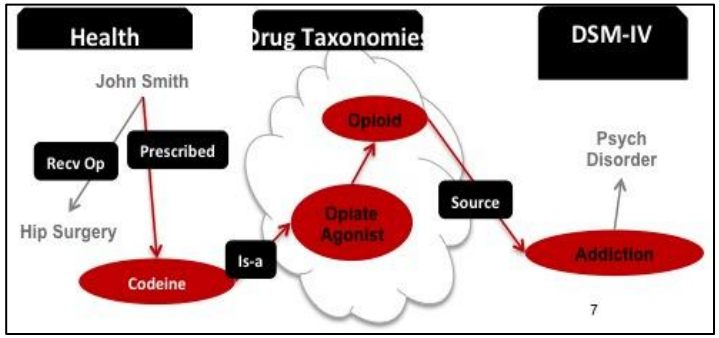
3. Build a Dynamic Relationship Warehouse



Visualize relationships for real time, interactive Discovery



Search for relationships based on partially specified Patterns/Templates



uRiKA Customer Use Case: Government Organization

"Connecting the dots" to identify Persons of Interest

The Challenge

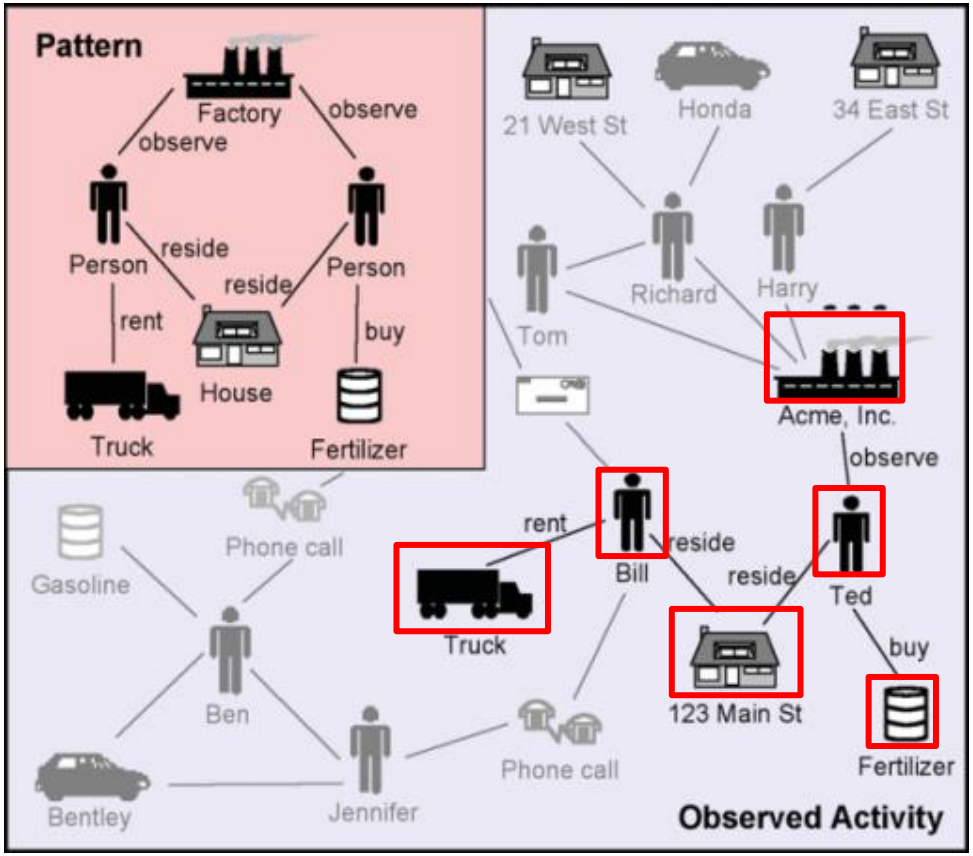
- Massive data stores of multiple data types from multiple sources
- Inaccurate, Incomplete and Falsified data
- Continuous stream of incoming data

uRiKA Solution

- uRiKA holds entire relationship graph in memory – updated constantly
- Search for Patterns of suspicious behavior and activities
- Graphical interactive exploration of relationships between people, places, things, organizations, communications, etc.

Business Value

- Proactive identification of terrorists, criminals and plots



uRiKA Customer Use Case: Personalized Treatment

MAYO CLINIC

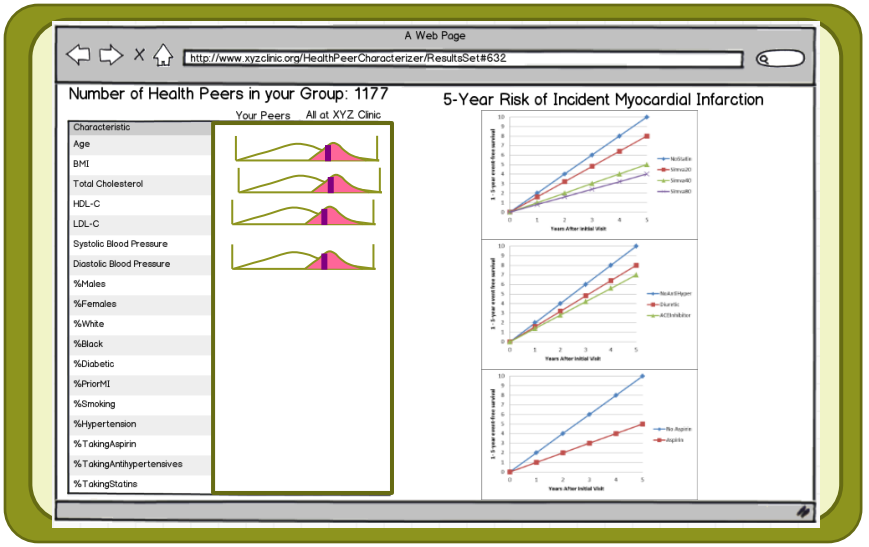
Identify “similar” Patients to optimize Treatment

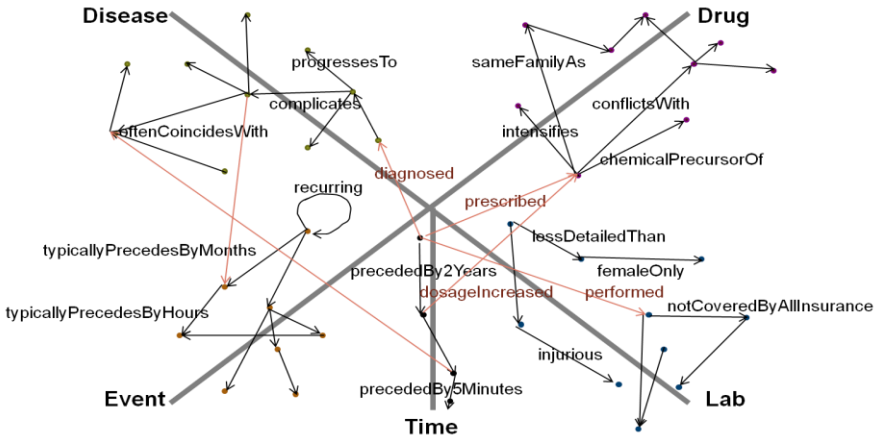
The Challenge

- Longitudinal, historical data spanning all events, symptoms, diagnoses, diseases, treatments, prescriptions, etc of 10M patients including genetics and family history
- Ad-hoc, constantly changing definition of “similarity” based on thousands of parameters
- Interactive, real-time response during consultation

uRiKA Solution

- uRiKA holds entire relationship graph in memory – updated constantly
- Identify “similar” patients based on ad-hoc physician specified patterns
- Interactive, real-time access by entire physician community



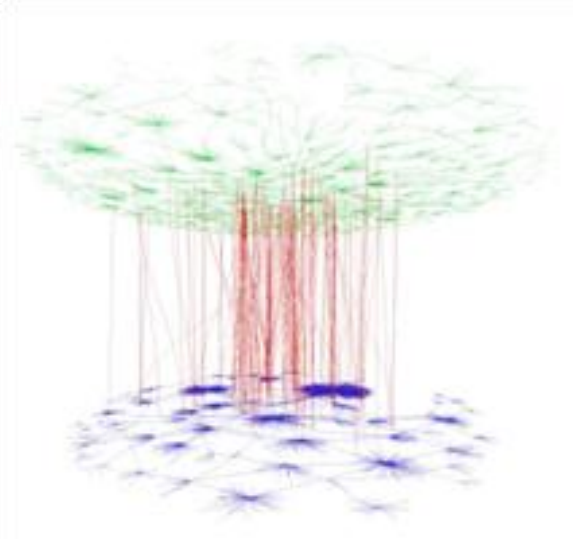


uRiKA Customer Use Case: Cancer Research Institute

Integrate information across species, tumor types, sub-specialties to see fuller picture of cancer

The Challenge

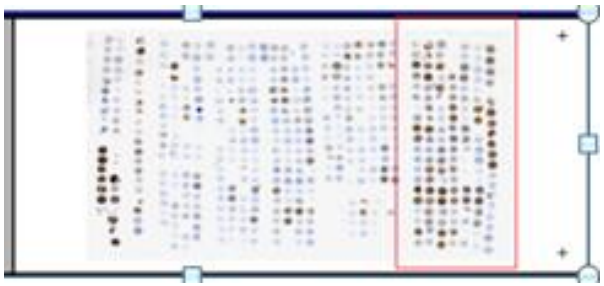
- Multiple massive datasets describing biological network graphs in cancer cells from published literature and experimental data, constantly updated
- Non-partitionable, densely and irregularly connected graphs
- Multiple researchers concurrently searching for relationships not found in published literature



uRiKA Solution

- uRiKA holds un-partitioned fused cell network graph in memory, combined with data from Medline
- Contrast experimental models and theories with published results to discover previously unknown relationships
- Interactive, real time access by multiple researchers

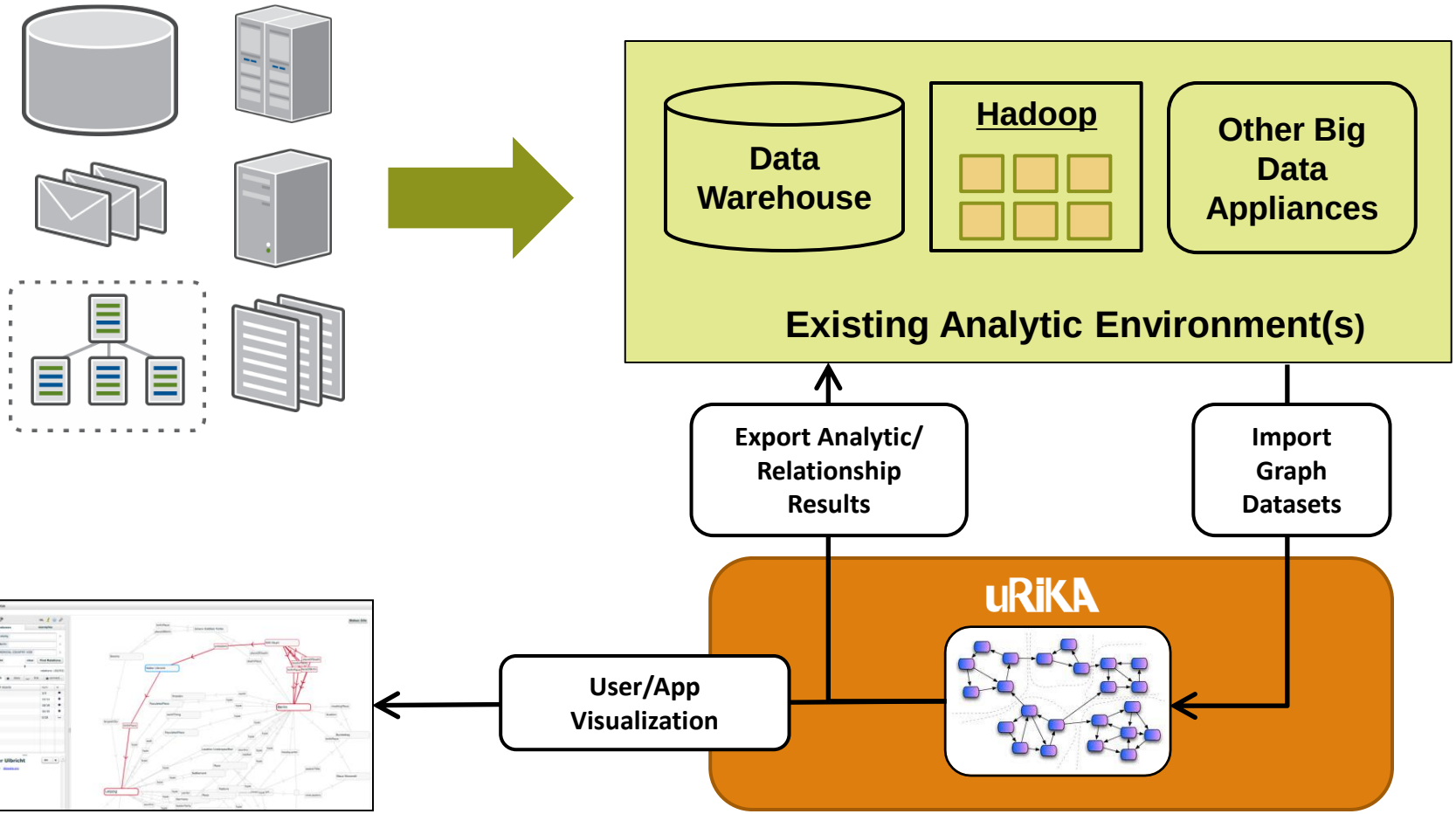
Confirmation of elevated VEGF levels by tissue microarray:



Business Value

- Identify new pathways in cell models to refine cancer treatments

uRiKA complements existing Data Warehouse/Hadoop environment by offloading Graph Analytics



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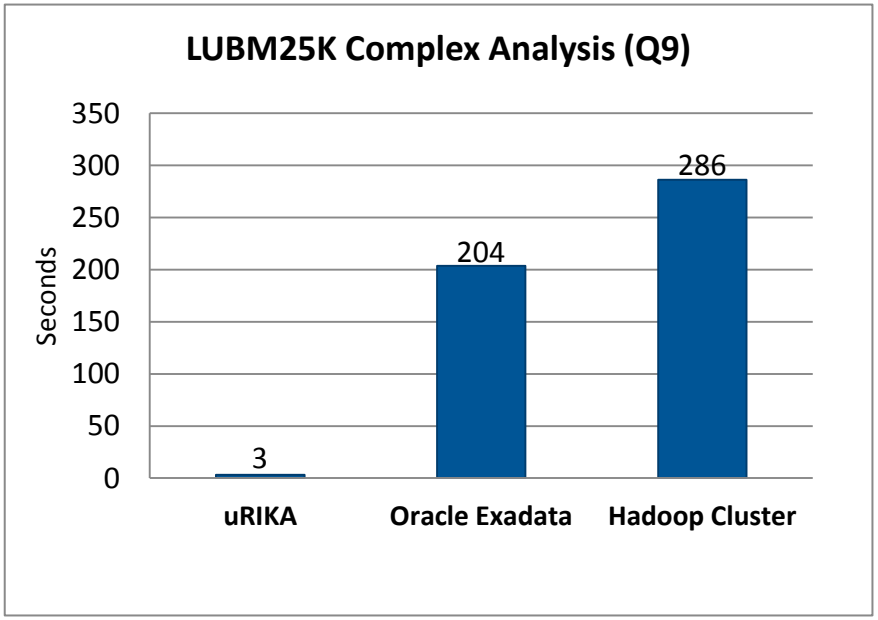
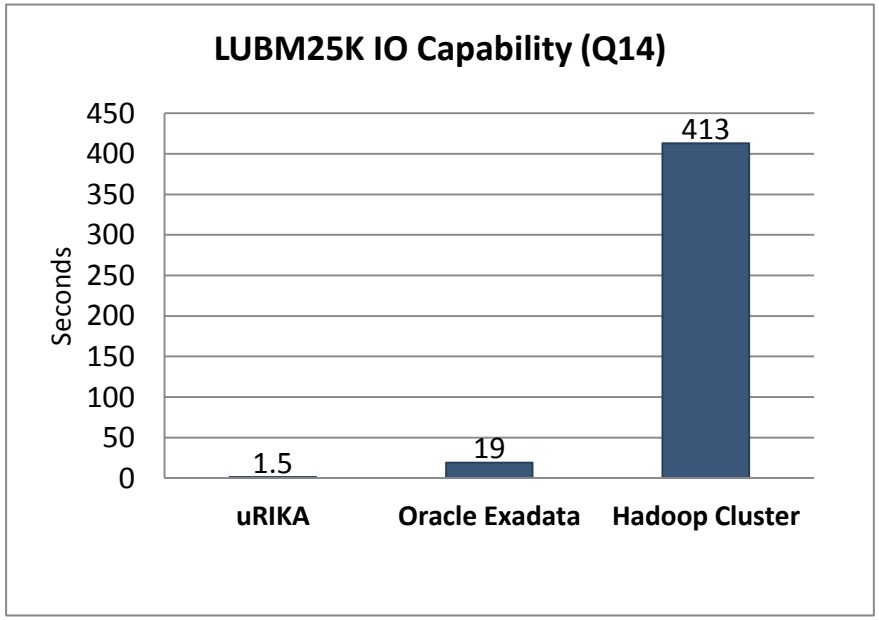
Early Performance Results

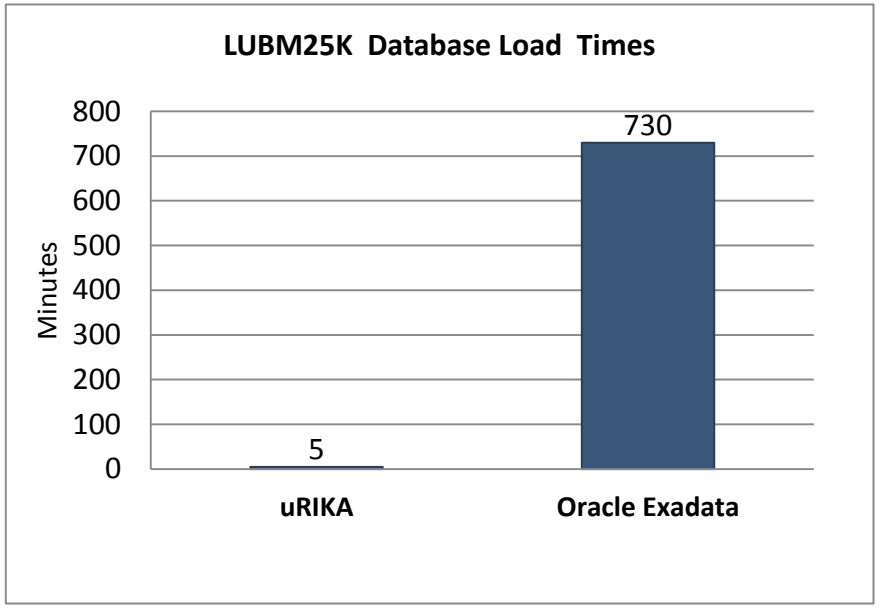
- Using a standard Semantic database benchmark (LUBM) to compare Cray uRiKA against:
  - Oracle Exadata published results
  - Hadoop on a large (72 socket) cluster
- The goal is to establish differentiation of Cray uRiKA as the size of data and complexity of query increases
- Results clearly demonstrate several orders of magnitude relative performance advantage

Performance LUBM25K

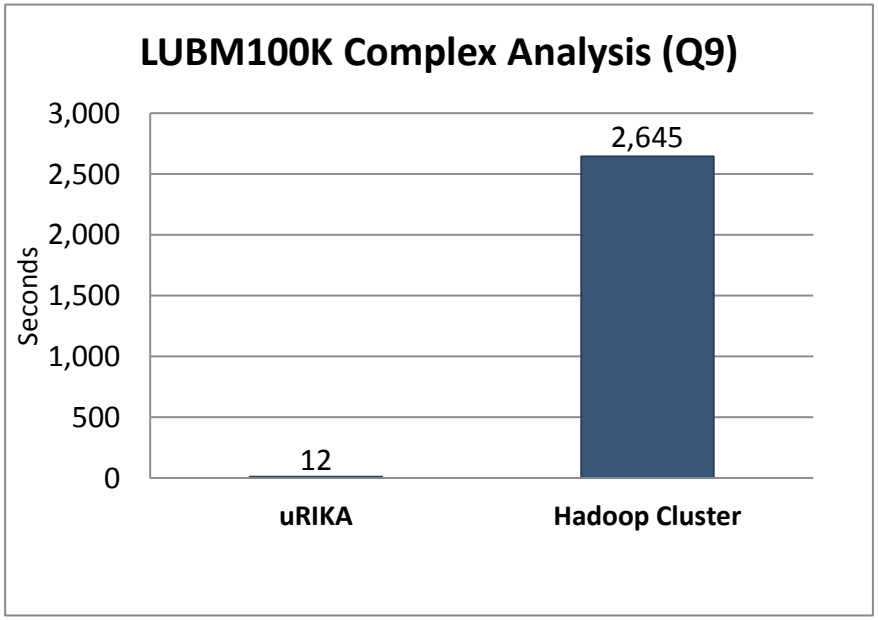


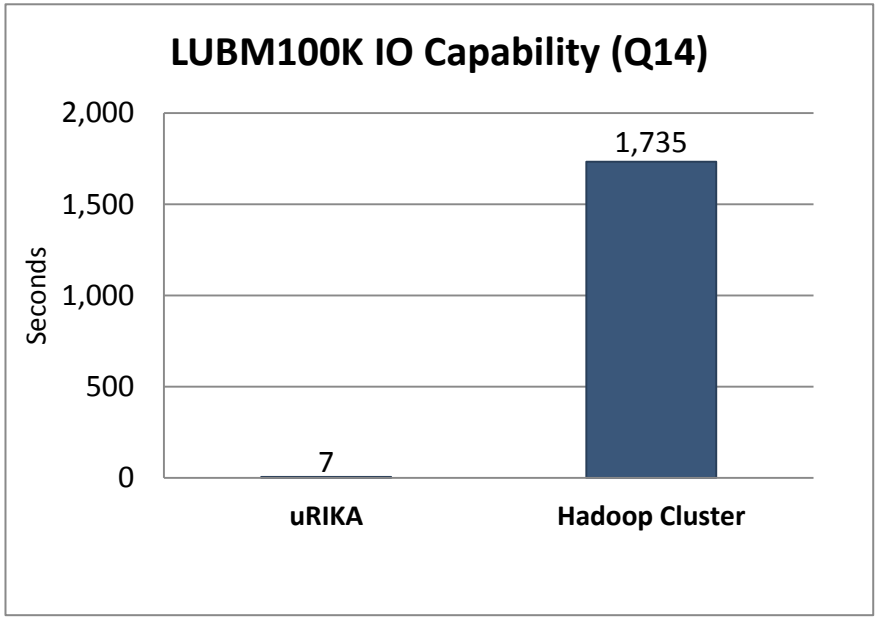


Cray uRiKA vs. Oracle Exadata Load Performance



Performance LUBM100K





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uRiKA: Big Data Graph Appliance for Relationship Analytics

Discover Unknown and Hidden Relationships in Big Data

- *Relationship Warehouse supporting Inferencing/Deduction, Pattern-based queries and Intuitive Visualization*

Perform Real-time Analytics on Big Data Graphs

- *High-performance, Graph Appliance with large shared-memory, massive multi-threading and scalable I/O*

Realize Rapid Time to Value on Big Data Solutions

- *Ease of Enterprise adoption with industry-standards, open-source software stack enabling reuse of existing skillsets and no lock-in*

Thank you!

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