Microsoft

Azure CosmosDB – AltGraph

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https://www.linkedin.com/in/chris-joakim-4859b89
https://github.com/cjoakim/azure-cosmosdb-altgraph
https://www.youtube.com/watch?v=SGih_Kj_1yk

What is AltGraph?

AltGraph is a set of *Alternative Graph Implementations* built on:

A Design:

- The Azure **CosmosDB SQL API**
- **Fast In-memory processing** vs DB and Disk Traversal
- RDF-like **"Triples" (v1)**, or the **JGraphT library (v2)**
- Azure Redis Cache or CosmosDB Integrated **Cache**

Two Reference Implementations – v1/NPM and v2/IMDb, using:

- The **Java** programming language
- **Spring Boot** and **Spring Data** frameworks
- https://github.com/cjoakim/azure-cosmosdb-altgraph

Presentation Outline

- **Influences**
  - Real-world Use Cases
  - Previous CosmosDB Live TV Sessions
  - LinkedIn / LIquid,

- **Perception**: How you See the Problem often determines your solution
  - Sample Database Diagrams
  - Types of Databases

- **Think Differently**: Why another Graph Implementation?

- **Design**

- **Demonstration** of the Reference Application

Influences

Real-World Customer Use-Cases

- Manufacturing **Bill-of-Material** (BOM)
- **Social Network Systems** - People, Messages, Posts, Tags, etc.
- Knowledge Graphs
- Java and Spring and Spring Data

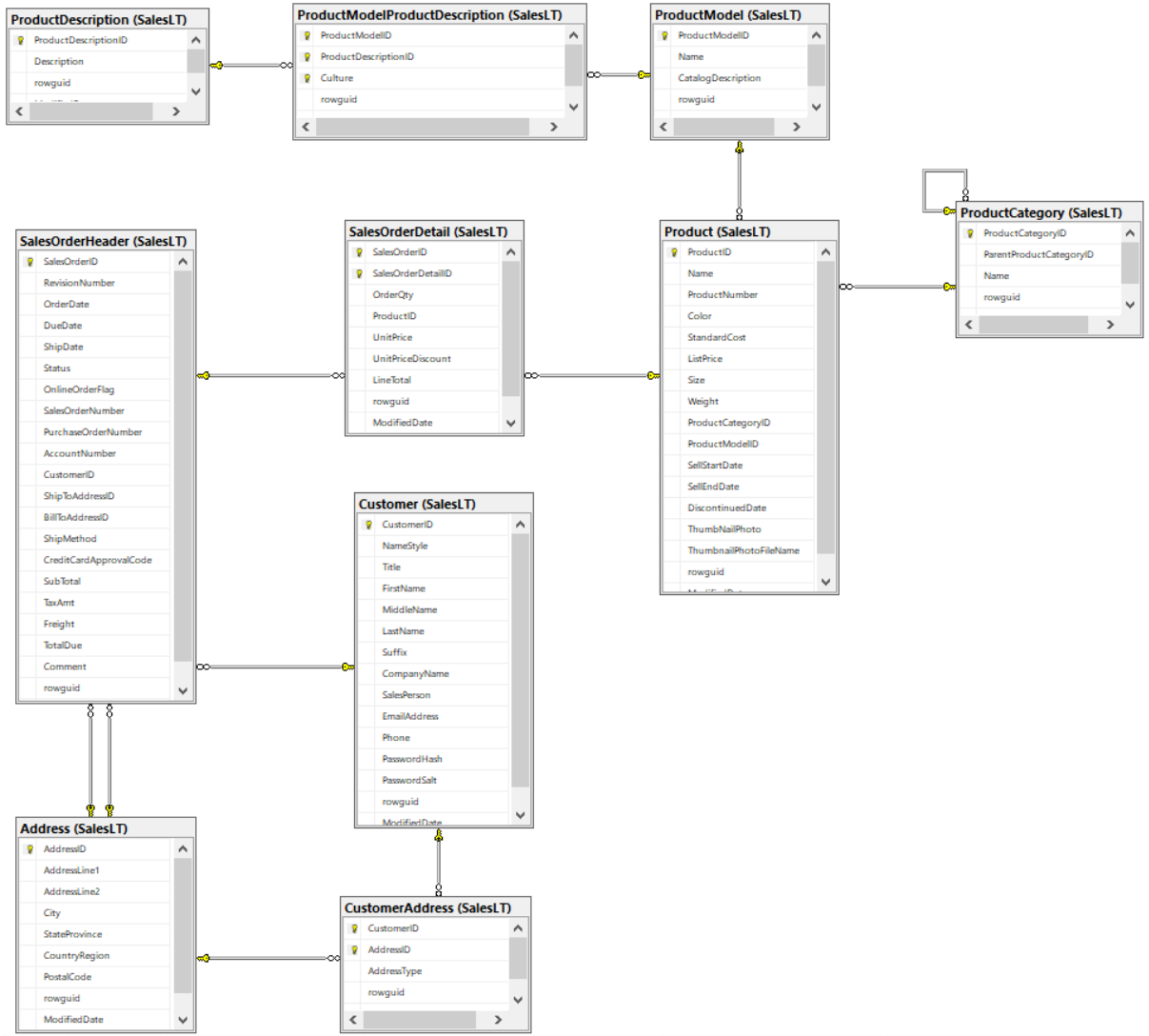
Previous CosmosDB Live TV Sessions

- Kushagra Thapar, Spring Data, 2022/02/03
- Mark Heckler, Spring Boot, 2022/06/23
  Spring Boot: Up and Running – O'Reilly Media Book
- List of Episodes
  https://www.youtube.com/playlist?list=PLmamF3YkHLoKMzT3gP4oqHiJbjMaiiLEh

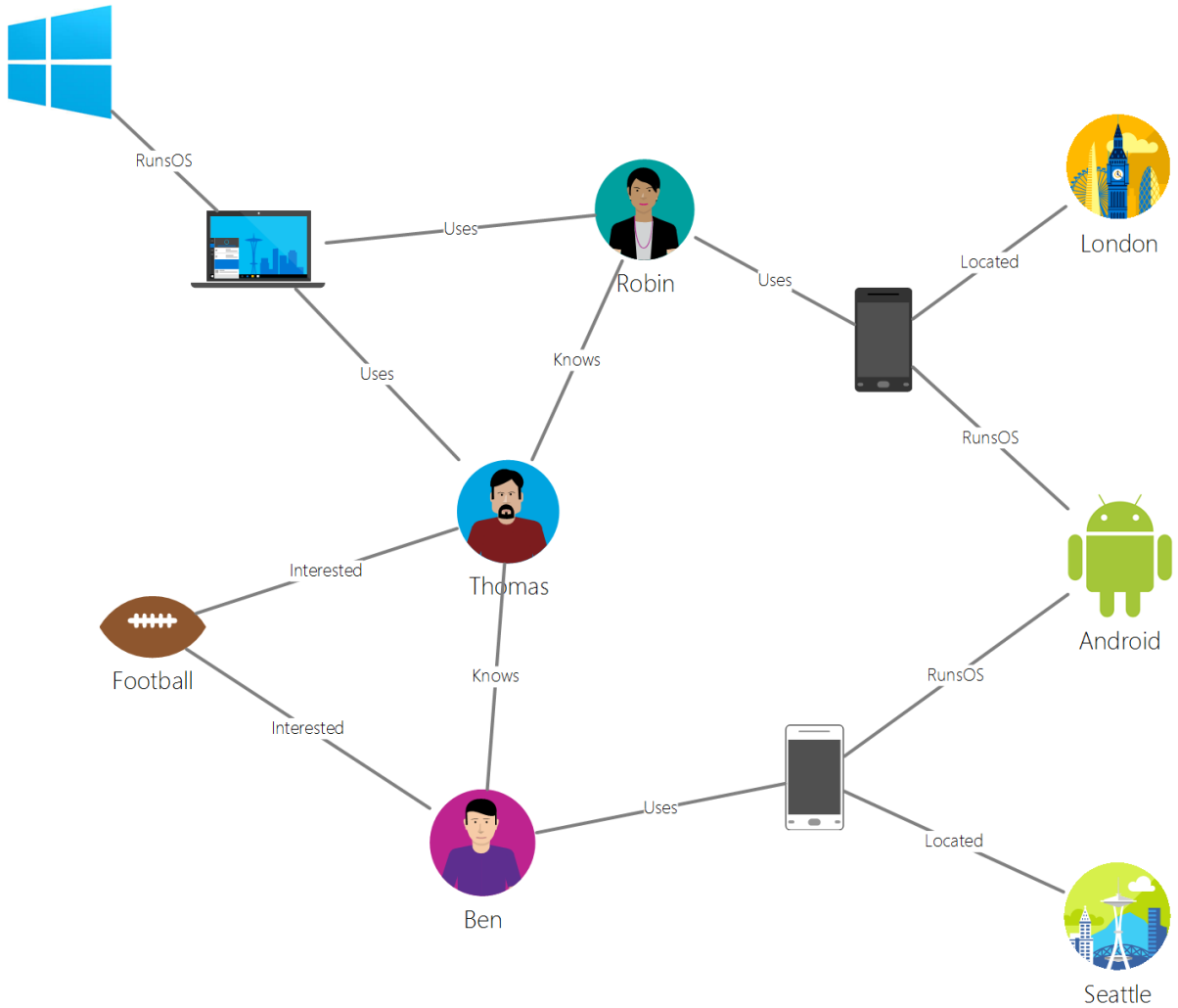
LinkedIn / LIquid

- In-memory graph
- https://engineering.linkedin.com/blog/2020/liquid-the-soul-of-a-new-graph-database-part-1

Perception: What solution would you use if the problem was drawn like this?



Perception: Or if the problem was drawn like this?

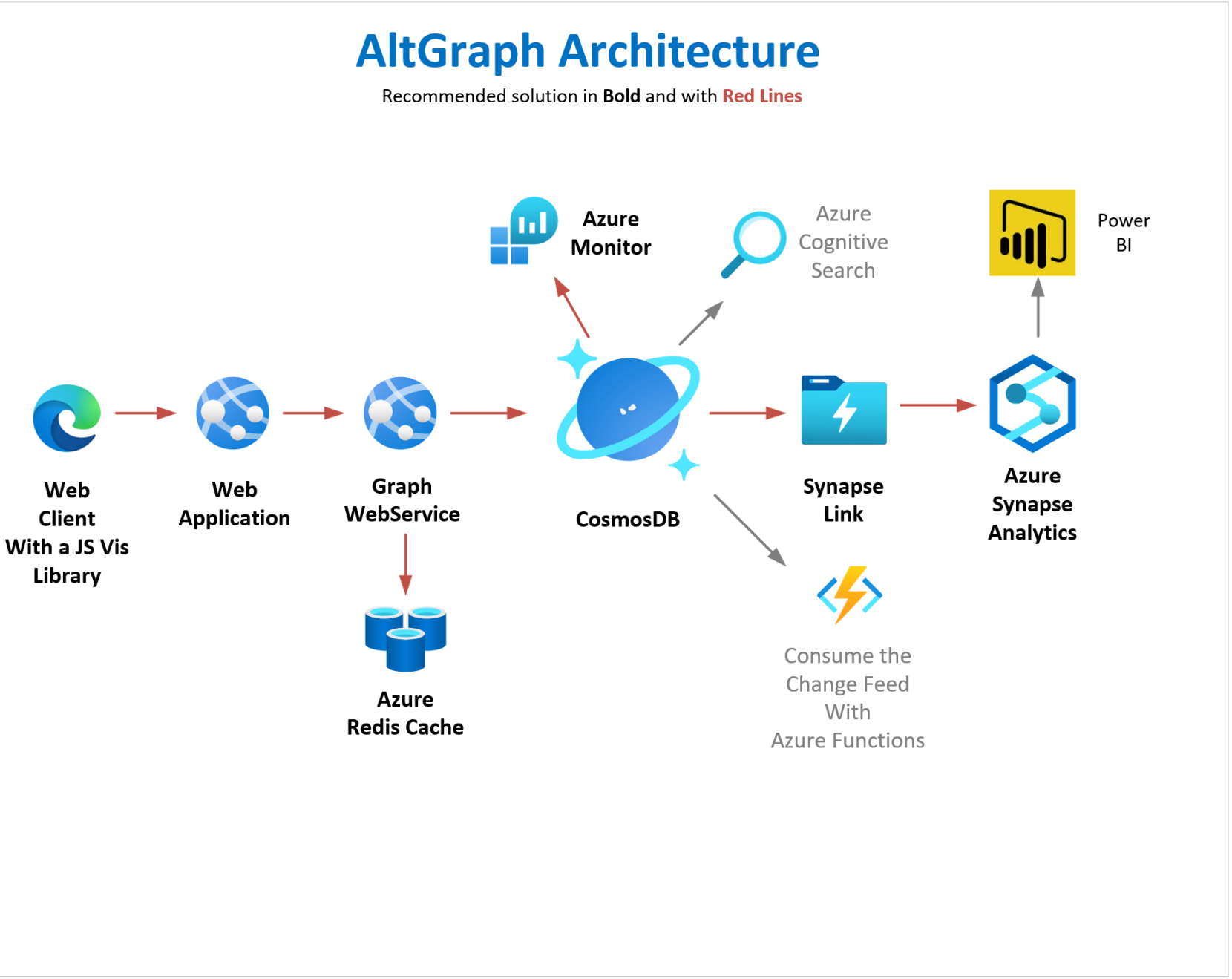


We see this a lot in the field.

A Total Solution involves **more than just the Database**.

Database Integrations are important.

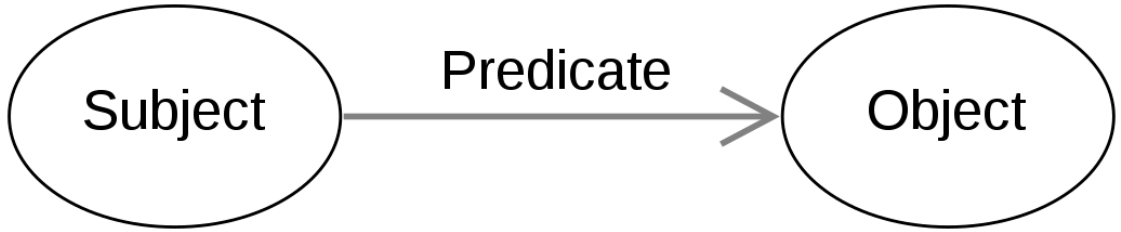
The **CosmosDB SQL API** offers excellent integration with other Azure Paas Services.



Database Solutions

- **Types of Databases**
  - **Relational**: Transactional use-cases
  - **Graph**: Graph-specific use-cases. **RDF** (**triplestores**) and **LPG** (**vertices, edges**)
  - **NoSQL:** including the CosmosDB SQL API: **General Purpose**
- **Think Differently; Why another Graph Solution?**
  - **Fast execution speed**, and **lower CosmosDB RU costs**
  - Lower barrier to entry for new apps: **conceptual simplicity, based on SQL**
  - **Reusable design**
  - **Faster time-to-market.** Zero to POC in days. A Reference Implementation
  - Enables **better integration** with the rest of Azure

Design Foundations: The concept of RDF Triples and Triplestores



Examples:

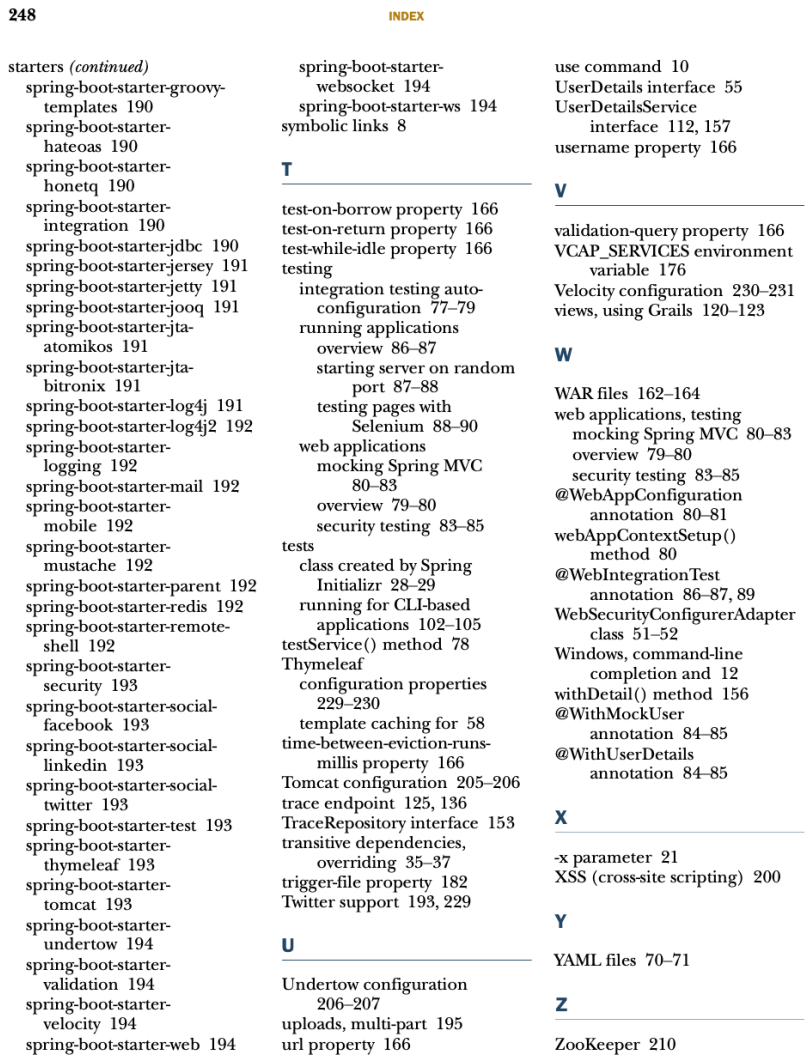
Microsoft	is_a	Technology Company
Java	is_a	Programming Language
C	is_a	Programming Language
CosmosDB	is_a	Database System
CosmosDB	is_a	NoSQL Database System
CosmosDB	has_a_sdk_for	Java
CosmosDB	has_a_sdk_for	C#
Chris	works_at	Microsoft
Chris	has_role	GBB

The triples are quite granular, typical solution has many many of these

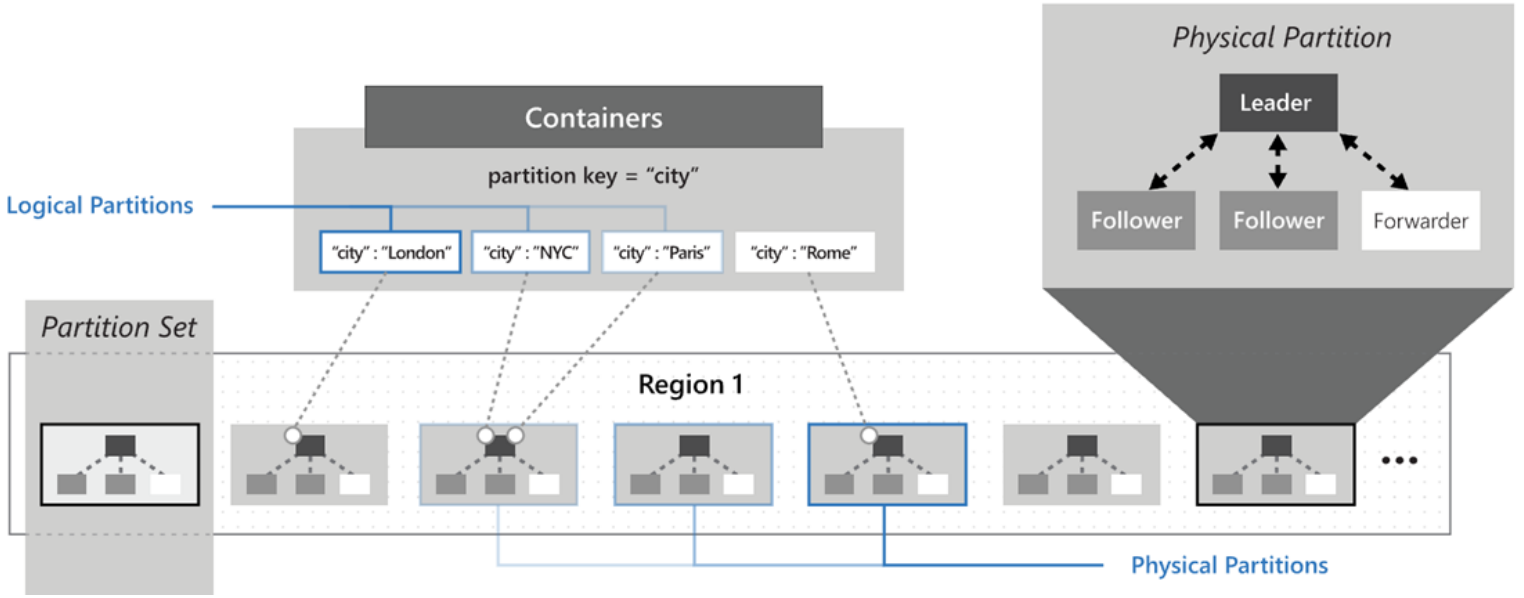
Design Foundations: The concept of an Index (as in Book)

Indexes enable you to quickly find what you're looking for.

It's quite small relative to the size of the Book it indexes.



Design Foundations: CosmosDB Partitioning



Reads within the same logical and physical partition are faster.
The **Triples** and **Seed Data** (see following pages) can reside in the same logical partition.

Design Foundations: Performance Optimizations

- **CosmosDB Indexing and Composite Indexes**
  Index individual attributes, and as well as sets of attributes (i.e. – composite indexes) to match your queries

- **CosmosDB "Point Reads"**
  Read by Document ID and Partition Key for fastest speed and lowest cost

- **In-Memory Processing is much faster than DB Processing**
  Traversing an in-memory data structure is 1000s of times faster than reading a DB or disk

- **Caching**
  - Eliminate costly and redundant reads to the database
  - **Azure Redis Cache**
    - https://azure.microsoft.com/en-us/services/cache/
  - **CosmosDB Integrated Cache** (currently in preview mode)
    - https://docs.microsoft.com/en-us/azure/cosmos-db/integrated-cache

Design Foundations: Spring Boot, Spring Data, Project Lombok

- **Spring Boot**
  - Dependency Injection, “Convention over Configuration”
  - Similar to Ruby on Rails – lots of magick happens if you follow the conventions
  - Thus, high Developer productivity
  - https://spring.io/projects/spring-boot

- **Spring Data**
  - Nice abstraction and simplification for database access. Repositories, Templates
  - https://spring.io/projects/spring-data
  - **Spring Data for CosmosDB SDK**
    - https://docs.microsoft.com/en-us/azure/developer/java/spring-framework/how-to-guides-spring-data-cosmosdb

- **Project Lombok**
  - Eliminates verbose and low-value boilerplate code. Getters, setters, constructors, etc.
  - Generates bytecode at compile time. Nice IDE support, too
  - https://projectlombok.org

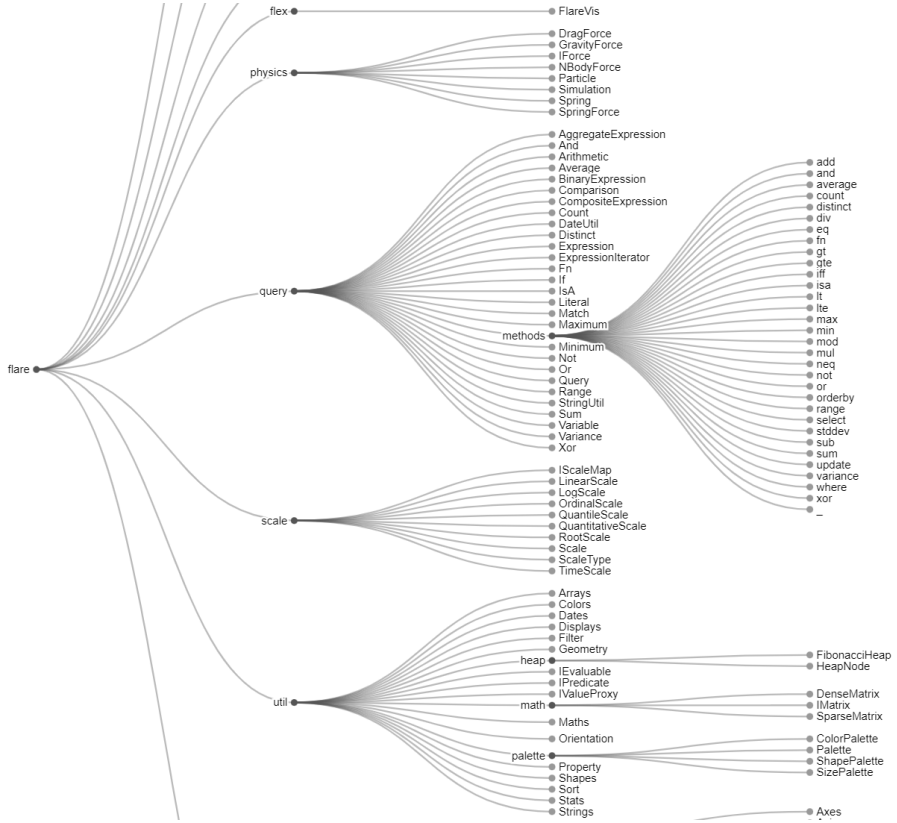
Design Foundations – v2: Java Graph Libraries, intern() Strings

- **JGraphT**
  - A mature widely-used in-memory graph Java library
  - Implements many graph algorithms so you don't have to
    - Page Rank
    - Katz Centrality
    - Dijkstra Shortest Path
    - Others
  - https://jgrapht.org/

- **Java String intern()**
  - Use a single value in the JVM for a frequently occurring value
  - For example, use just one instance of "nm0000102" (Kevin Bacon) instead of dozens/hundreds. This conserves JVM memory, thus enabling large in-memory graphs.
  - Similar to a Ruby programming language Symbol. 'kevin_bacon' vs :kevin_bacon

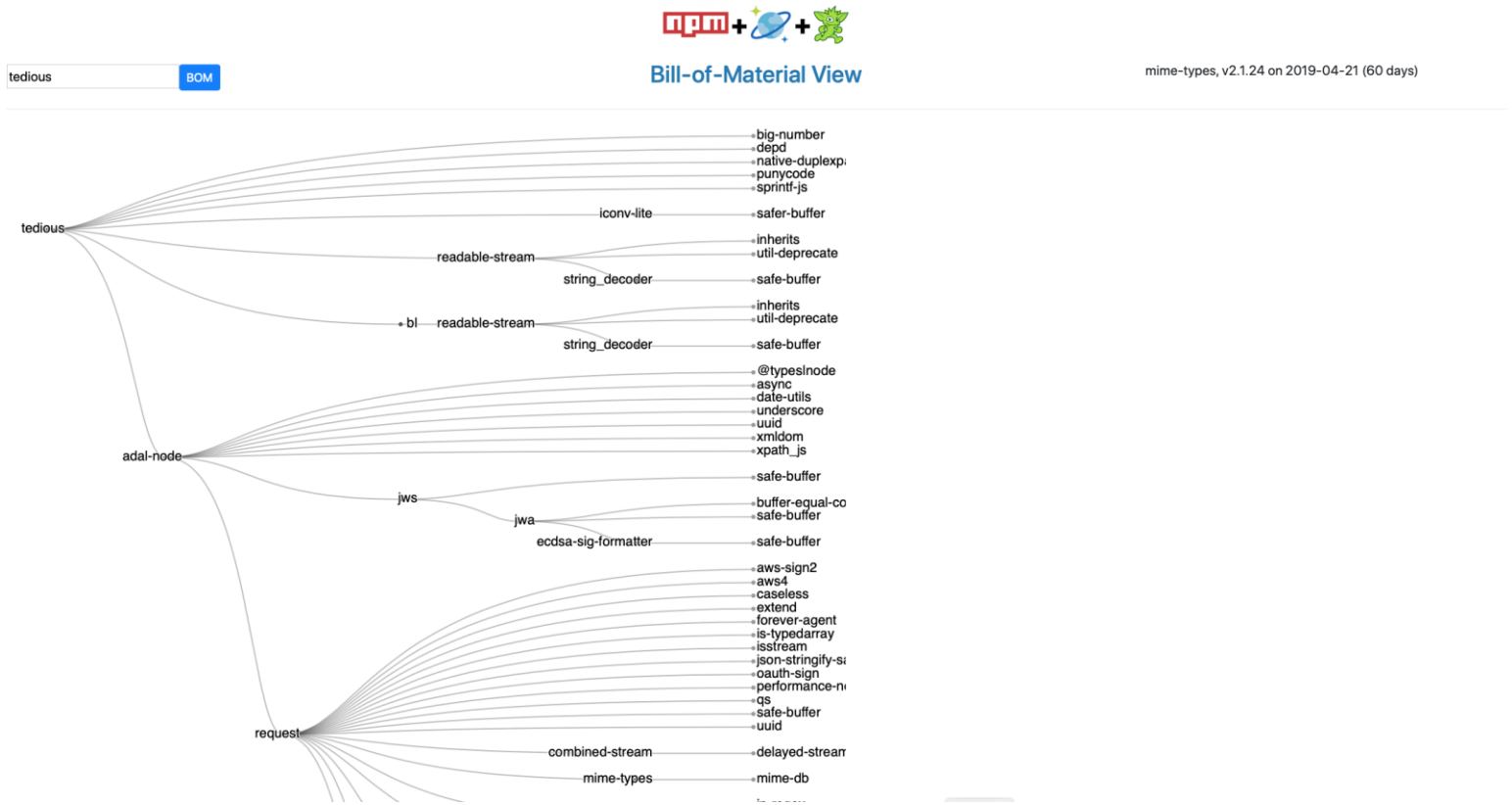
Design Foundations: D3.js

- **D3.js JavaScript library for in-browser data visualizations**
  - Implements many out-of-the-box visualizations. Open-source. https://d3js.org
  - Alternatively, Bring-Your-Own-Visualization-Library (BYOViz)
  - https://learn.microsoft.com/en-us/azure/cosmos-db/graph/graph-visualization-partners



Design Foundations: Previous Implementation

- **CosmosDB Gremlin API Implementation of a Node.js NPM "Bill-of-Material" Graph**
  - AltGraph v1 uses the **same NPM data** as this previous implementation
  - https://github.com/Azure-Samples/azure-cosmos-db-graph-npm-bom-sample



Implementation – v1/NPM: CosmosDB SQL API

- **Use a Single Container: npm_graph**
  - Partition key is **/pk**
  - Each document has a **doctype** attribute to distinguish the various entities
  - Reference implementation has a **tenant Id** attribute for multi-tenant use-cases
  - Reference implementation has a **lob** attribute for multiple lines-of-business in a tenant
  - Document types for this NPM graph are: **triple, library, author, maintainer**

  - Enabling **Synapse Link** is optional, depending on your requirements
    - This is one of the excellent integrations that CosmosDB offers
    - https://docs.microsoft.com/en-us/azure/cosmos-db/synapse-link
    - https://github.com/cjoakim/azure-cosmosdb-synapse-link

  - **Heirarchical Partition Keys** (currently in preview mode) may also be used
    - https://docs.microsoft.com/en-us/azure/cosmos-db/hierarchical-partition-keys

  - Provision the Request Units (RU) as necessary – Serverless, Manual, or Autoscale
    - https://docs.microsoft.com/en-us/azure/cosmos-db/set-throughput
    - https://docs.microsoft.com/en-us/azure/cosmos-db/serverless

Implementation – v2/IMDb: CosmosDB SQL API

- **Use Two Containers: imdb_graph** and **imdb_seed**
  - Partition key is **/pk** for each container
  - Each document has a **doctype** attribute to distinguish the various entities
    - **imdb_graph** container contains the **people** and **movie** documents
    - **imdb_seed** container **contains the "seed data" to reload the graph into memory**
      - The seed data is used instead of the "RDF Triples" in the v1 implementation
      - The movie data, for example, all resides in the same logical partition
      - Reference data contains over 1-million vertices and 3.9 million edges
      - Load time is approximately 50-seconds from home network
      - Larger in-memory graphs are possible
      - The in-memory graph is mutable for realtime use-cases
  - Navigation of the graph is mostly done with the built-in functionality in **JGraphT**
  - Load the data into memory once, then apply surgical changes to the mutable graph
  - **Graph Traversal is fast and consumes zero CosmosDB RUs**

Implementation – v1/NPM: Sample Library Document

This is a JSON document which describes a Node.js NPM Library. Libraries are the "raw material" for the graph.

The **dependencies** object (at line 14) is the data that we'll use to build a graph. This sample document is intentionally small. This library has only one dependency: **xml2js**

Note the **author** and **maintainers** attributes, as well. The graph will include these.

```
1  {
2    "doctype" : "library",
3    "label" : "tcx-js",
4    "id" : "f0b734d9-3240-44c5-9868-cb25597f1e3b",
5    "pk" : "tcx-js",
6    "_etag" : "\"9c00f125-0000-0100-0000-62d9c5440000\"",
7    "tenant" : "123",
8    "lob" : "npm",
9    "cacheKey" : "library|tcx-js",
10   "graphKey" : "library^tcx-js^f0b734d9-3240-44c5-9868-cb25597f1e3b^tcx-js",
11   "name" : "tcx-js",
12   "desc" : "A Node.js library for parsing TCX/XML files, such as from a Garmin GPS device.",
13   "keywords" : [ "tcx", "garmin", "forerunner", "gps" ],
14   "dependencies" : {
15     "xml2js" : "^0.4.19"
16   },
17   "devDependencies" : {
18     "mocha-multi-reporters" : "^1.1.7",
19     "chai" : "^4.2.0",
20     ... others omitted ...
21     "typescript" : "^3.5.2"
22   },
23   "author" : "Chris Joakim",
24   "maintainers" : [ "cjoakim <christopher.joakim@gmail.com>" ],
25   "version" : "1.0.1",
26   "versions" : [ "0.0.1", "0.1.0", "0.1.1", "0.1.2", "1.0.0", "1.0.1" ],
27   "homepage" : "https://github.com/cjoakim/tcx-js",
28   "library_age_days" : 1755,
29   "version_age_days" : 32
30 }
```

Implementation – v1/NPM: Sample Array of Triples

Triple documents have a Subject, Predicate, and Object just like RDF triples. Up to **20 million** of these 1K docs can reside in the same **logicical partition** (20GB limit).

This graph contains 6382 triples. They are small in size (1kb) and many can be read into the JVM for **in-memory processing** and traversal. Pagination-based processing is also possible.

They point to the adjacent "Vertices" via the Id/Pk attributes for **point-reads**.

The **tags** enable optimized searching of important Vertex attributes.

```
22949    }, {
22950      "id" : "0e2cc67f-b566-4b22-aba3-b9a9a7cb6b81",
22951      "pk" : "triple|123",
22952      "_etag" : "\"0f0082b6-0000-0100-0000-62d9c5840000\"",
22953      "tenant" : "123",
22954      "lob" : "npm",
22955      "doctype" : "triple",
22956      "subjectType" : "library",
22957      "subjectLabel" : "tedious",
22958      "subjectId" : "4cc0e552-e501-47d4-ada1-2e0cfdafc388",
22959      "subjectPk" : "tedious",
22960      "subjectKey" : "library^tedious^4cc0e552-e501-47d4-ada1-2e0cfdafc388^tedious",
22961      "subjectTags" : [ "author|Mike D Pilsbury <mike.pilsbury@gmail.com>", "maintaine
22962      "predicate" : "used_in_lib",
22963      "objectType" : "library",
22964      "objectLabel" : "mssql",
22965      "objectId" : "2aa4fc9e-7cd5-41a7-a521-b303ff184303",
22966      "objectPk" : "mssql",
22967      "objectKey" : "library^mssql^2aa4fc9e-7cd5-41a7-a521-b303ff184303^mssql",
22968      "objectTags" : [ "author|Patrik Simek (https://patriksimek.cz)", "maintainer|art
22969    }, {
```

Implementation – v1/NPM: Primary Java Classes

Cache.java - implements caching logic, to local disk or Azure Redis Cache
D3CsvBuilder.java - Creates node and edge CSV files for D3.js
Graph.java - An in-memory graph created from a TripleQueryStruct
GraphBuilder.java - Builds a graph by iterating an in-memory TripleQueryStruct

TripleQueryStruct.java - Represents **an Array of the Triples** for your graph. It is the "Index".

Library.java - An NPM library document
Triple.java - One Triple document
LibraryRepository.java - **Spring Data Repository** for Libraries
TripleRepository.java - Spring Data Repository for Libraries
TripleRepositoryExtensions.java - Extensions of the Repository for more complex SQL
TripleRepositoryExtensionsImpl.java
GraphController.java - The primary Controller, handles interaction with the UI

Implementation – v1/NPM: The Spring Data TripleRepository

```
17  @Component
18  @Repository
19  public interface TripleRepository extends CosmosRepository<Triple, String>, TripleRepositoryExtensions {
20      Iterable<Triple> findBySubjectType(String subjectType);
21      Iterable<Triple> findBySubjectLabel(String subjectLabel);
        1 usage
22      Iterable<Triple> findByTenantAndSubjectLabel(String tenant, String subjectLabel);
        1 usage
23      @Query("select value count(1) from c")
24      long countAllTriples();
        1 usage
25      @Query("select value count(1) from c where c.subjectLabel = @subjectLabel")
26      long getNumberOfDocsWithSubjectLabel(@Param("subjectLabel") String subjectLabel);
        1 usage
27      @Query("select * from c where c.pk = @pk and c.lob = @lob and c.subjectType = @subjectType and c.objectType = @objectType")
28      List<Triple> getByPkLobAndSubjects(
29              @Param("pk") String pk,      // "pk": "triple|123"
30              @Param("lob") String lob,
31              @Param("subjectType") String subjectType,
32              @Param("objectType") String objectType);
33
```

Method **getByPkLobAndSubjects** is used to query the Triples and load them into memory as a **TripleQueryStruct** that can then be **cached**. It is the “Index” to your graph.

Implementation – v1/NPM: Building the Graph and Creating D3.js CSV

- **Ok, great, we have a TripleQueryStruct in memory, now what?**

- **Optionally Cache it for the next Web Request**
  - Class **Cache**

- **Build The Graph in Memory**
  - Class **GraphBuilder**
  - **Iterates, in memory, the many Triples** in the TripleQueryStruct to build the Graph object
  - Alternatively, for huge graphs, paginate the Triples and build the graph with each page

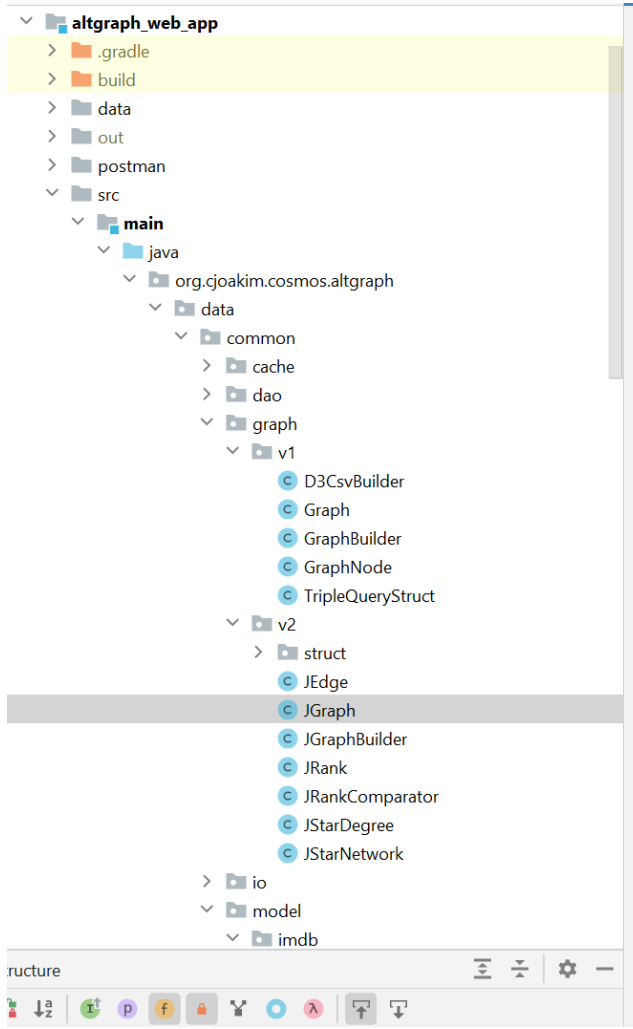
- **Build the two CSV files for D3.js UI visualizations**
  - Class **D3CsvBuilder**

- **Can we please see the demo now?**

Implementation – v2/IMDb: Primary Java Classes

See the classes in package org.cjoakim.cosmos.altgraph.data.common.graph.v2.

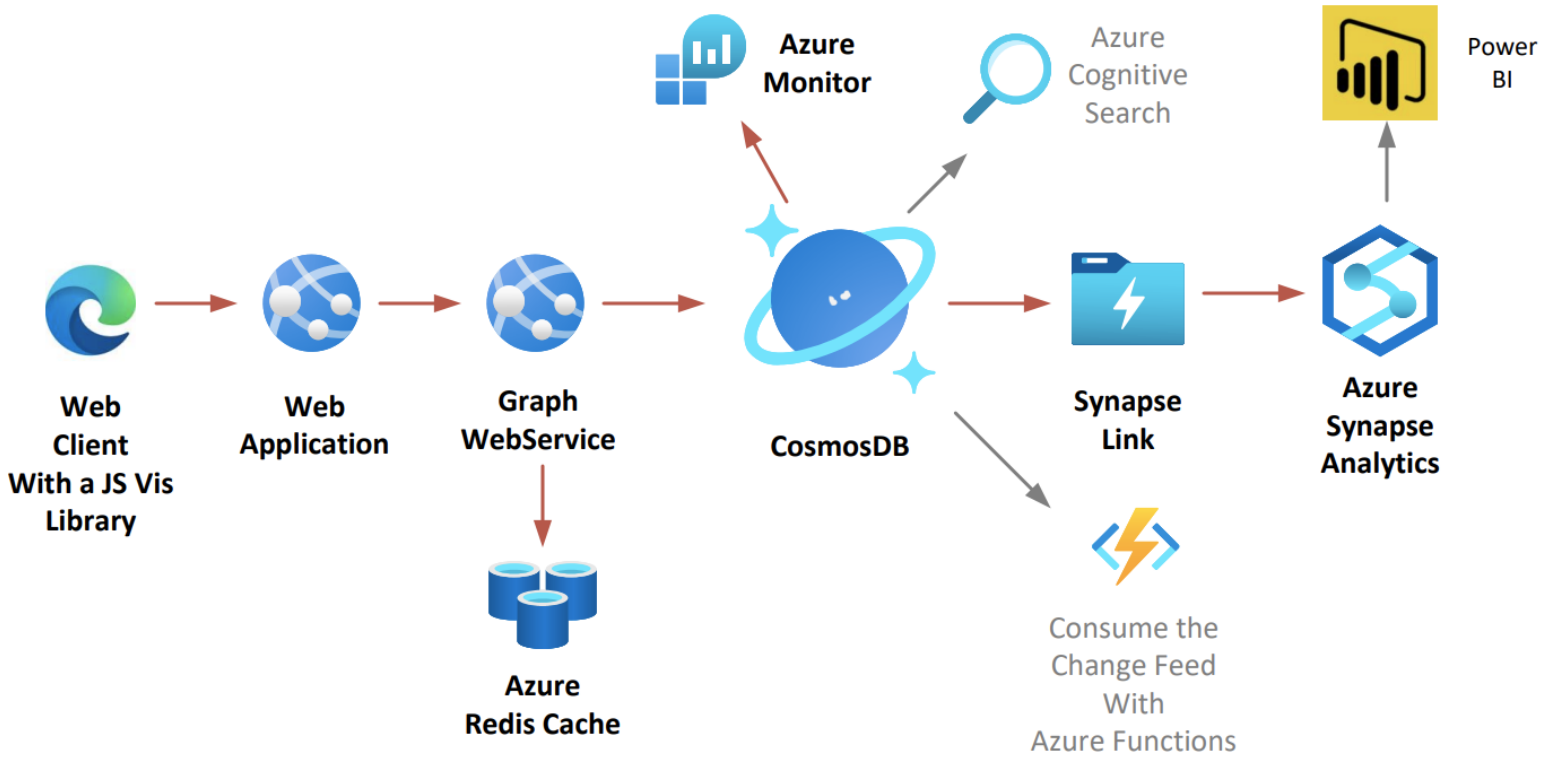
Example shows the use of the JGraphT **DijkstraShortestPath.*findPathBetween*** method on line 64




```
51      /**
52       * Find the shortest path with the DijkstraShortestPath class in JGraphT.
53       */
        1 usage
54      public GraphPath<String, DefaultEdge> getShortestPath(String v1, String v2) {
55          log.warn("getShortestPath, v1: " + v1 + " to v2: " + v2);
56          long start = System.currentTimeMillis();
57          if (!isVertexPresent(v1)) {
58              return null;
59          }
60          if (!isVertexPresent(v2)) {
61              return null;
62          }
63          GraphPath<String, DefaultEdge> path =
64                  DijkstraShortestPath.findPathBetween(graph, v1, v2);
65          long elapsed = System.currentTimeMillis() - start;
66
67          if (path == null) {
68              log.warn("path is null");
69          } else {
70              log.warn("elapsed milliseconds: " + elapsed);
71              log.warn("path getLength:       " + path.getLength());
72              log.warn("path getStartVertex:  " + path.getStartVertex());
73              log.warn("path getEndVertex:    " + path.getEndVertex());
74          }
75          return path;
76      }
```

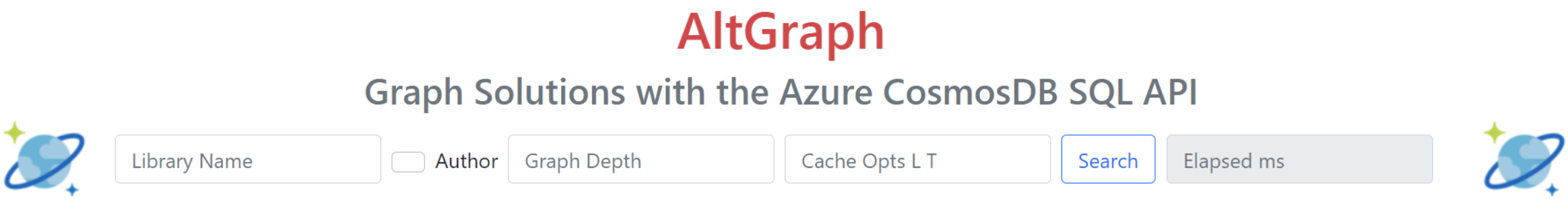
AltGraph Architecture

Recommended solution in **Bold** and with Red Lines



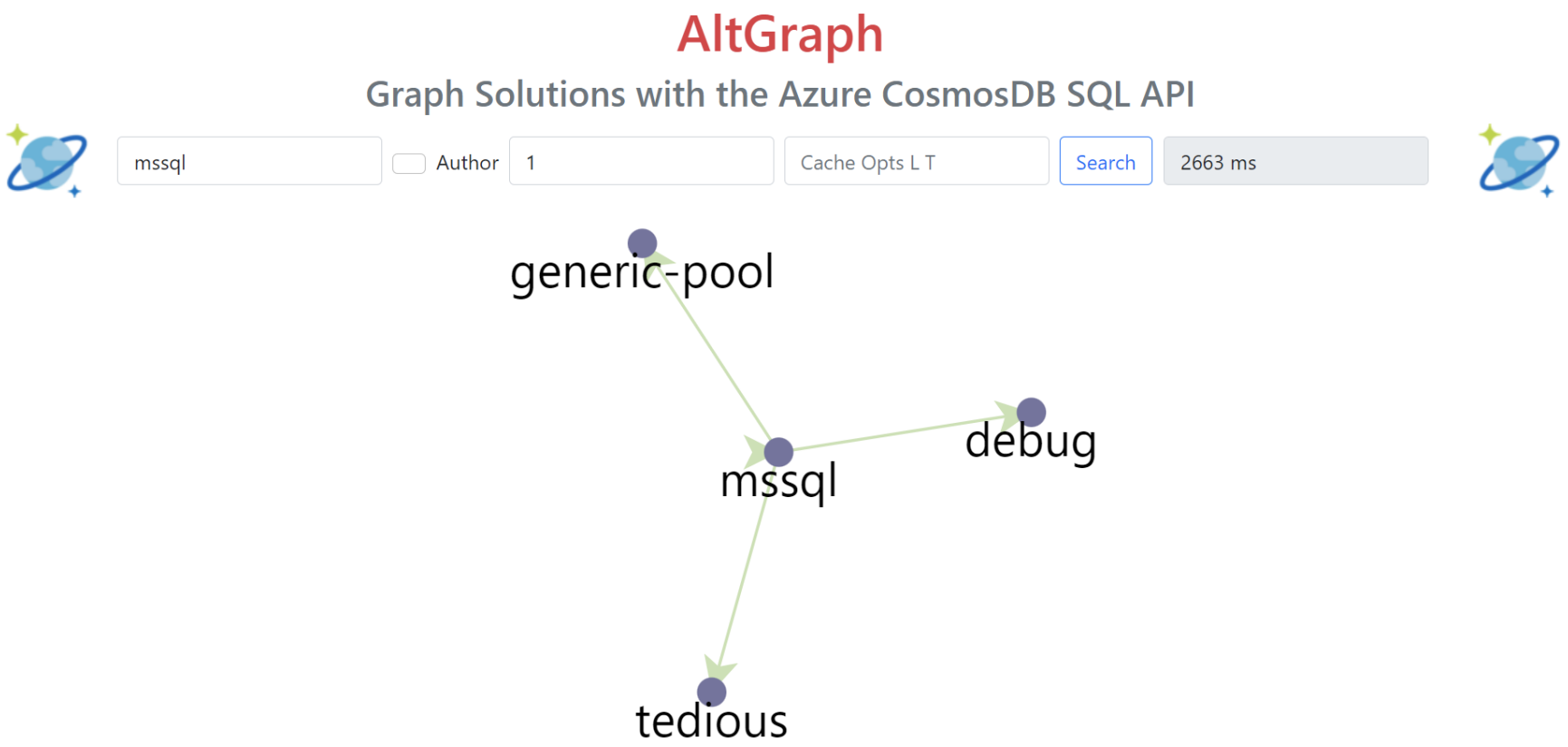
For demonstration purposes, the Web Application and Graph Web Service logic can run in just one **Azure Container Instance**.
Optionally use the CosmosDB Integrated Cache.

Demonstration – v1/NPM: The Search Form



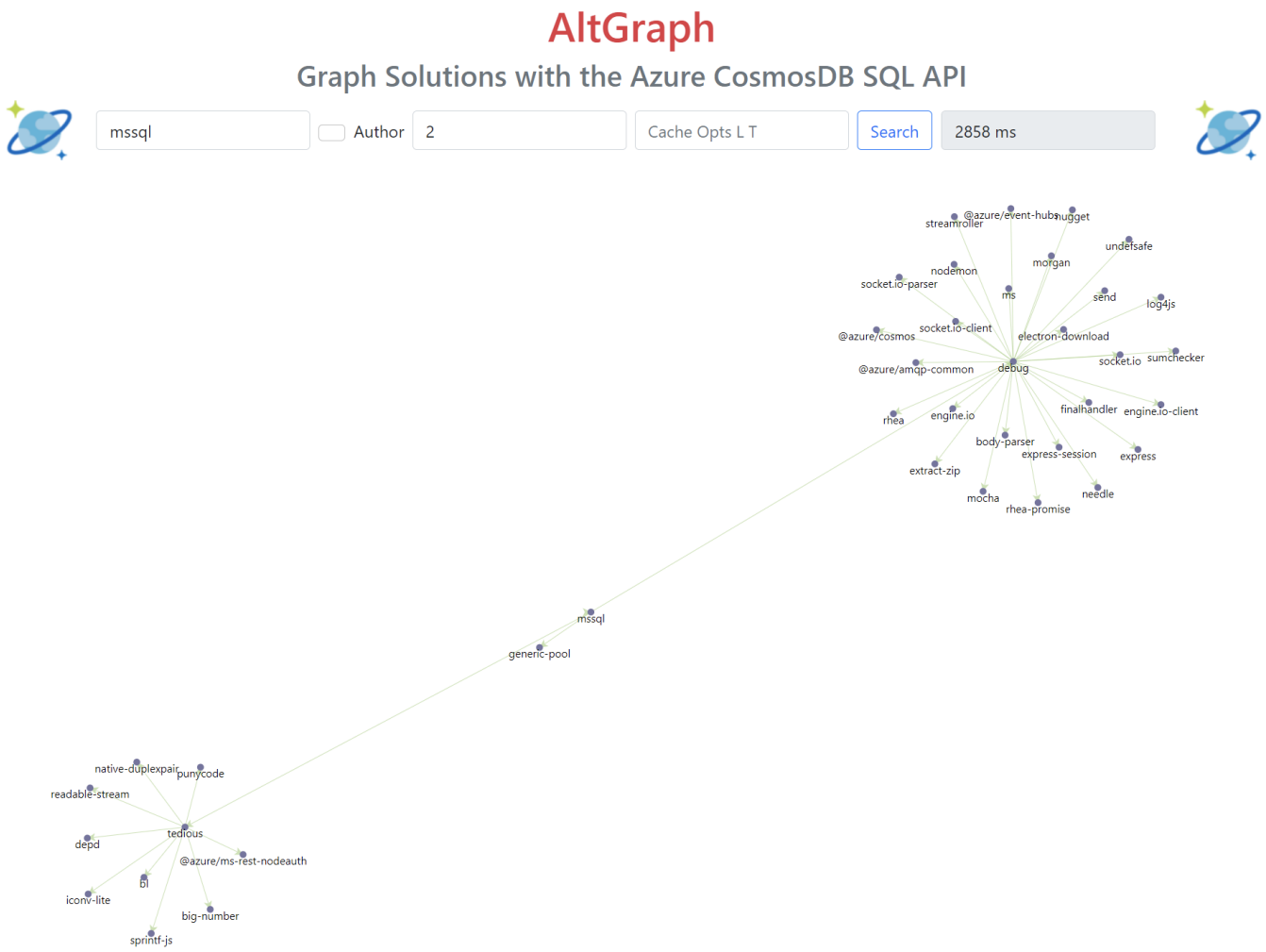
Enter a Library name, and integer graph “depth”.
Optional **Cache Opts** - “**L**” for Library caching, “**T**” for Triple caching.
The Elapsed ms field will be populated when the graph is displayed.
The Author checkbox will toggle between a Library and Author graph.

Demonstration – v1/NPM: Graph with a Depth of 1



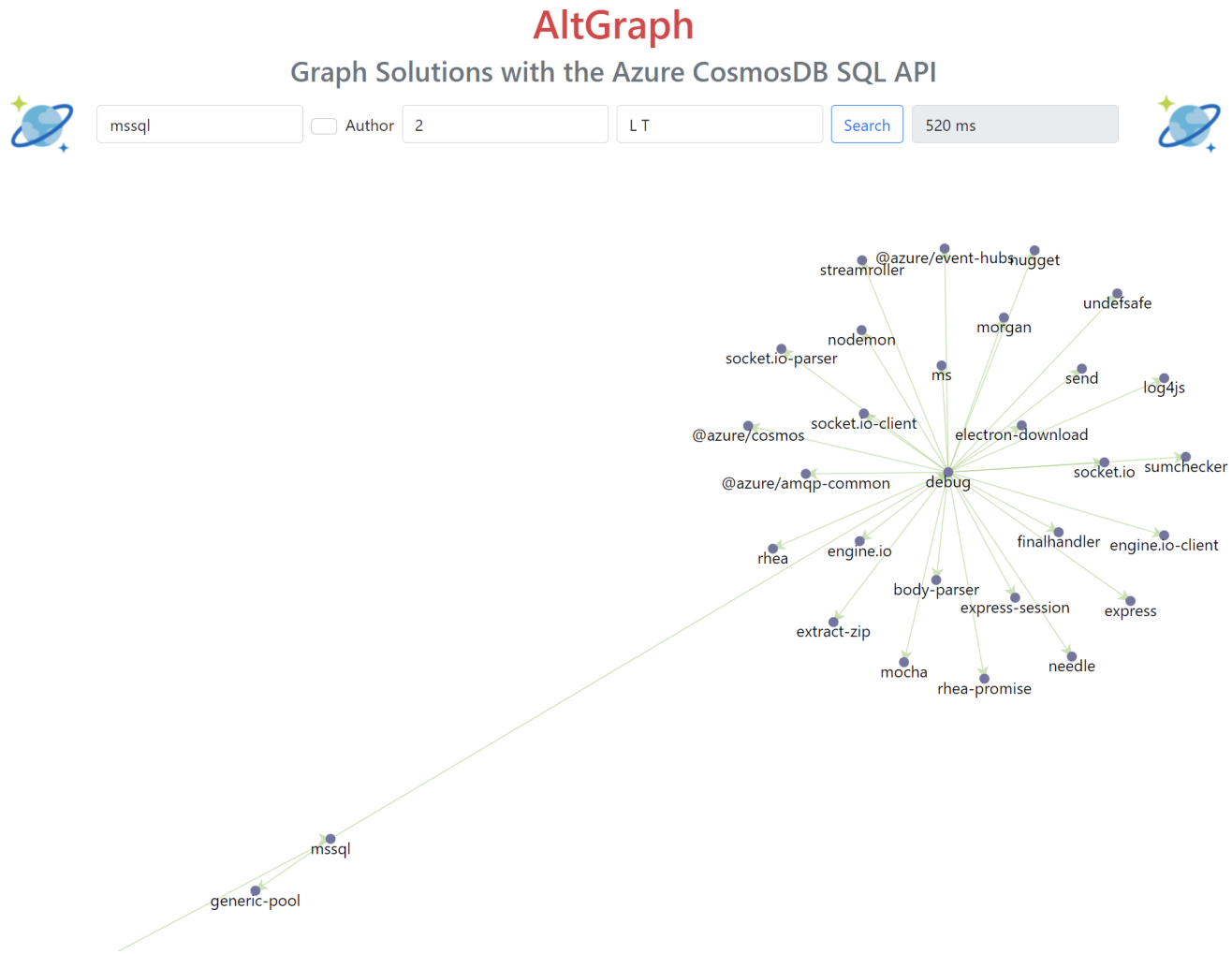
Graph with a depth of 1 and no caching.
Single click a node for Library info. Double-click to show the graph for that node.

Demonstration – v1/NPM: Graph with a Depth of 2



Graph with a depth of 2 and no caching. D3.js positions the nodes.

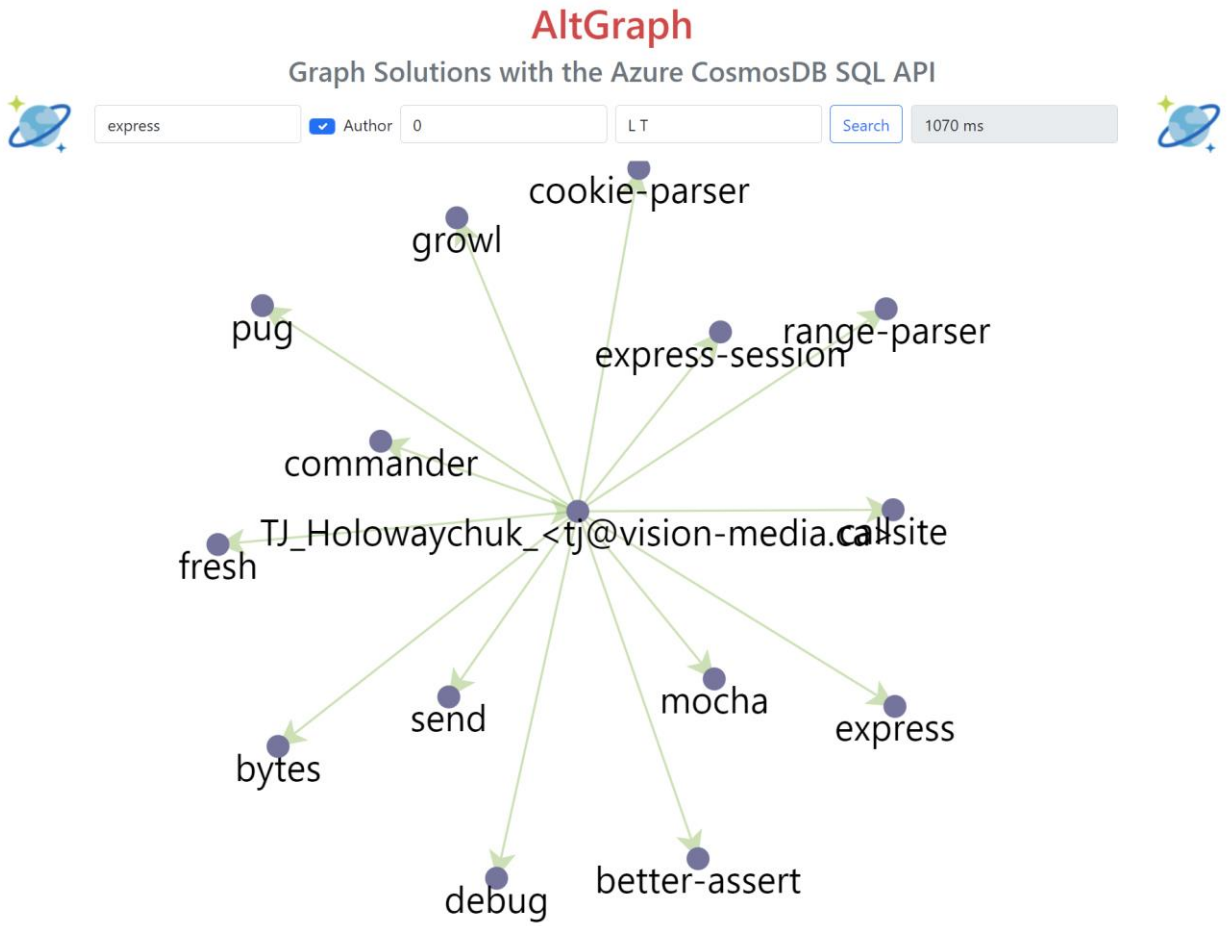
Demonstration – v1/NPM: Graph with a Depth of 2, with Caching



Graph with a depth of 2 and **caching**. Notice the **speed improvement**.
This example used Azure Redis Cache from my (slow) home WiFi network.

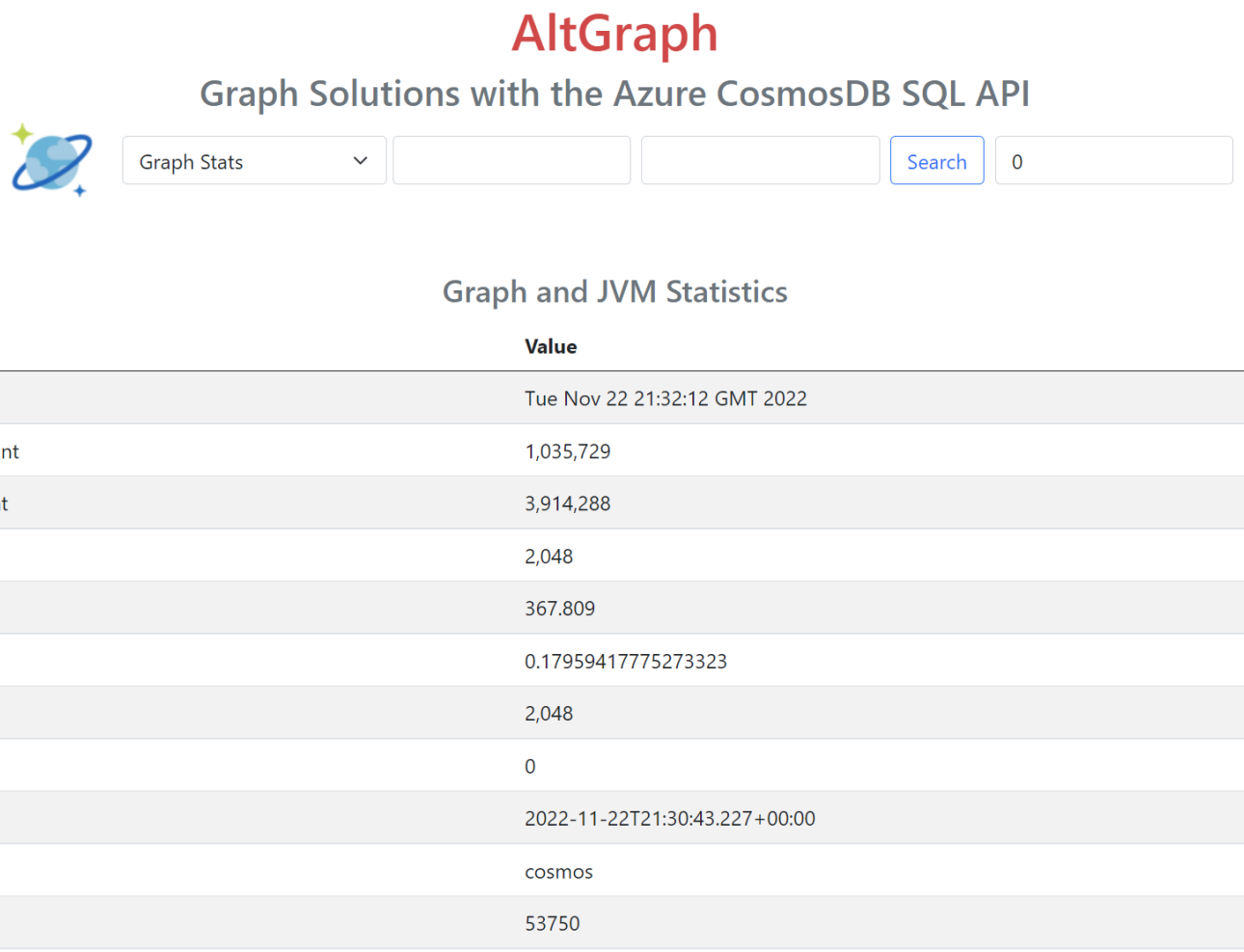
Demonstration – v1/NPM: Author-to-Library Graph using the Triple tag values


```
}, {
  "id" : "7da48a99-23d3-44bf-a878-c3d41c833f32",
  "pk" : "triple|123",
  "_etag" : "\"0f001bb8-0000-0100-0000-62d9c5920000\"",
  "tenant" : "123",
  "lob" : "npm",
  "doctype" : "triple",
  "subjectType" : "library",
  "subjectLabel" : "pug",
  "subjectId" : "0b92a30f-8341-4739-8225-a3287afdb54d",
  "subjectPk" : "pug",
  "subjectKey" : "library^pug^0b92a30f-8341-4739-8225-a3287afdb54d^pug",
  "subjectTags" : [ "author|TJ Holowaychuk <tj@vision-media.ca>", "mainta
  "predicate" : "uses_lib",
  "objectType" : "library",
  "objectLabel" : "pug-linker",
  "objectId" : "3649661e-f7ba-4a57-9b40-4ba3034cdf3b",
  "objectPk" : "pug-linker",
  "objectKey" : "library^pug-linker^3649661e-f7ba-4a57-9b40-4ba3034cdf3b
  "objectTags" : [ "author|Forbes Lindesay", "maintainer|forbeslindesay
}, {
```

Graph, from tags, showing the Libraries authored by TJ Holowaychuk

Demonstration – v2/IMDB: Graph and JVM Statistics



Metric	Value
Date	Tue Nov 22 21:32:12 GMT 2022
In-Memory Vertex Count	1,035,729
In-Memory Edge Count	3,914,288
JVM Total MB	2,048
JVM Free MB	367.809
JVM Pct Free	0.17959417775273323
JVM Max MB	2,048
Elapsed Ms	0
Refresh Date	2022-11-22T21:30:43.227+00:00
Refresh Source	cosmos
Refresh Ms	53750

Query the size and JVM memory-consumption of the graph. This query typically takes 0 to 1 ms.

Demonstration – v2/IMDB: Graph and JVM Statistics

AltGraph

Graph Solutions with the Azure CosmosDB SQL API

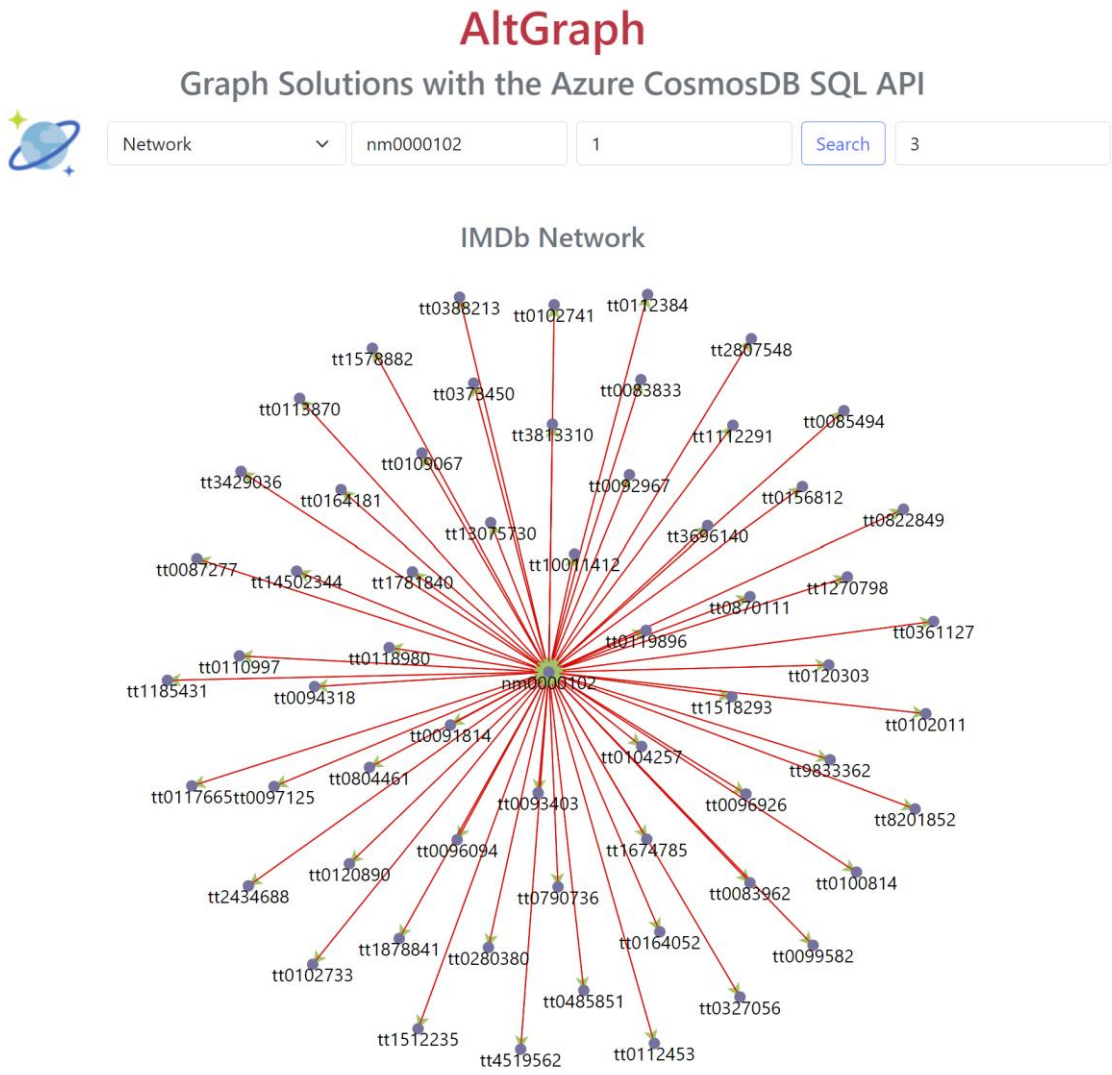
Graph Stats | reload | | Search | 53751

Graph and JVM Statistics

Metric	Value
Date	Tue Nov 22 21:29:49 GMT 2022
In-Memory Vertex Count	1,035,729
In-Memory Edge Count	3,914,288
JVM Total MB	2,048
JVM Free MB	399.818
JVM Pct Free	0.19522367045283318
JVM Max MB	2,048
Elapsed Ms	53,751
Refresh Date	2022-11-22T21:30:43.227+00:00
Refresh Source	cosmos
Refresh Ms	53750

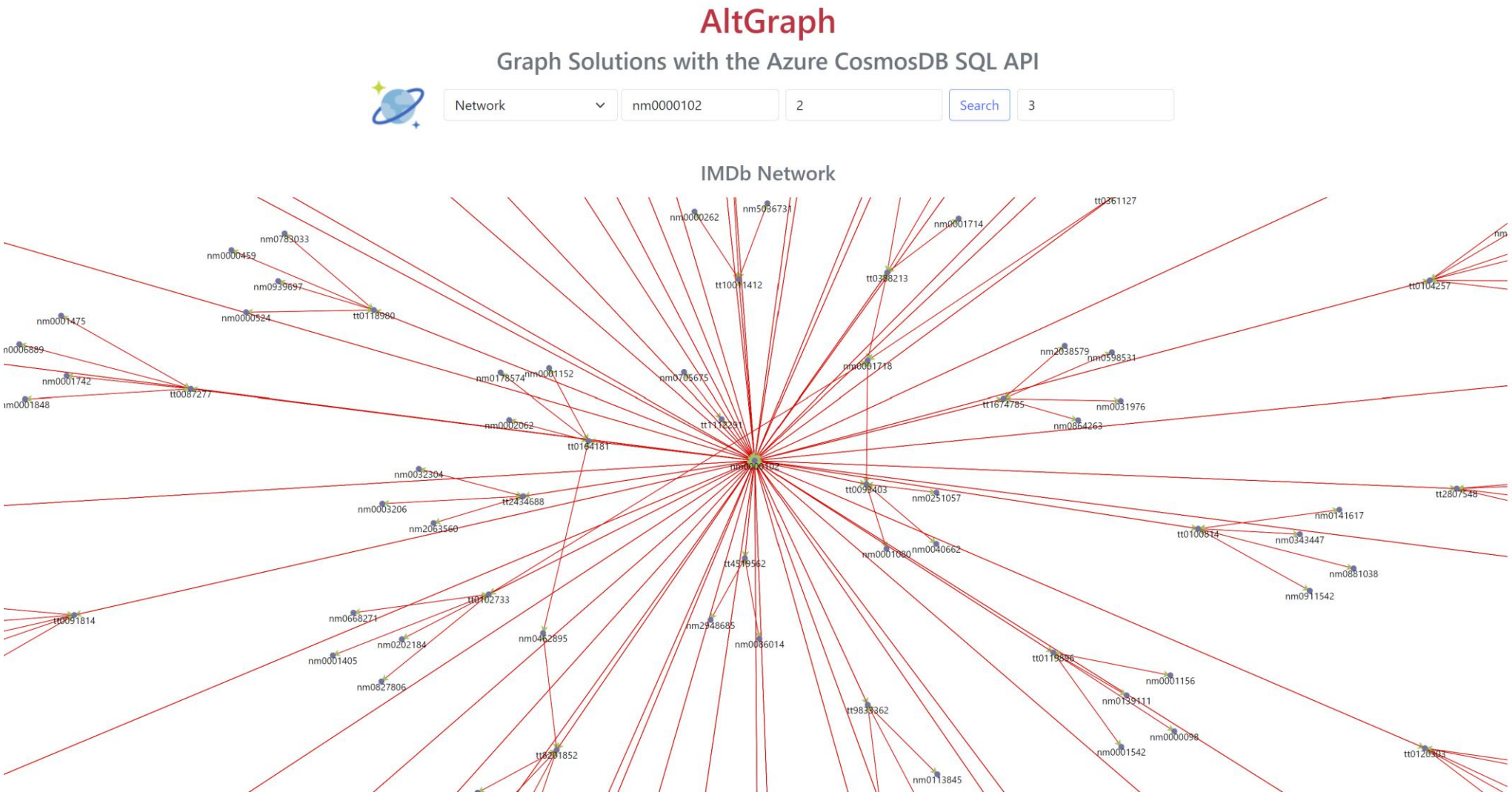
Trigger a reload of the in-memory graph from the CosmosDB imdb_seed container.
The JVM can be running for days/weeks or longer. Note **the 1m Vertices and 3.9m edges**.

Demonstration – v2/IMDB: Network Graph, “One Degree of Kevin Bacon”

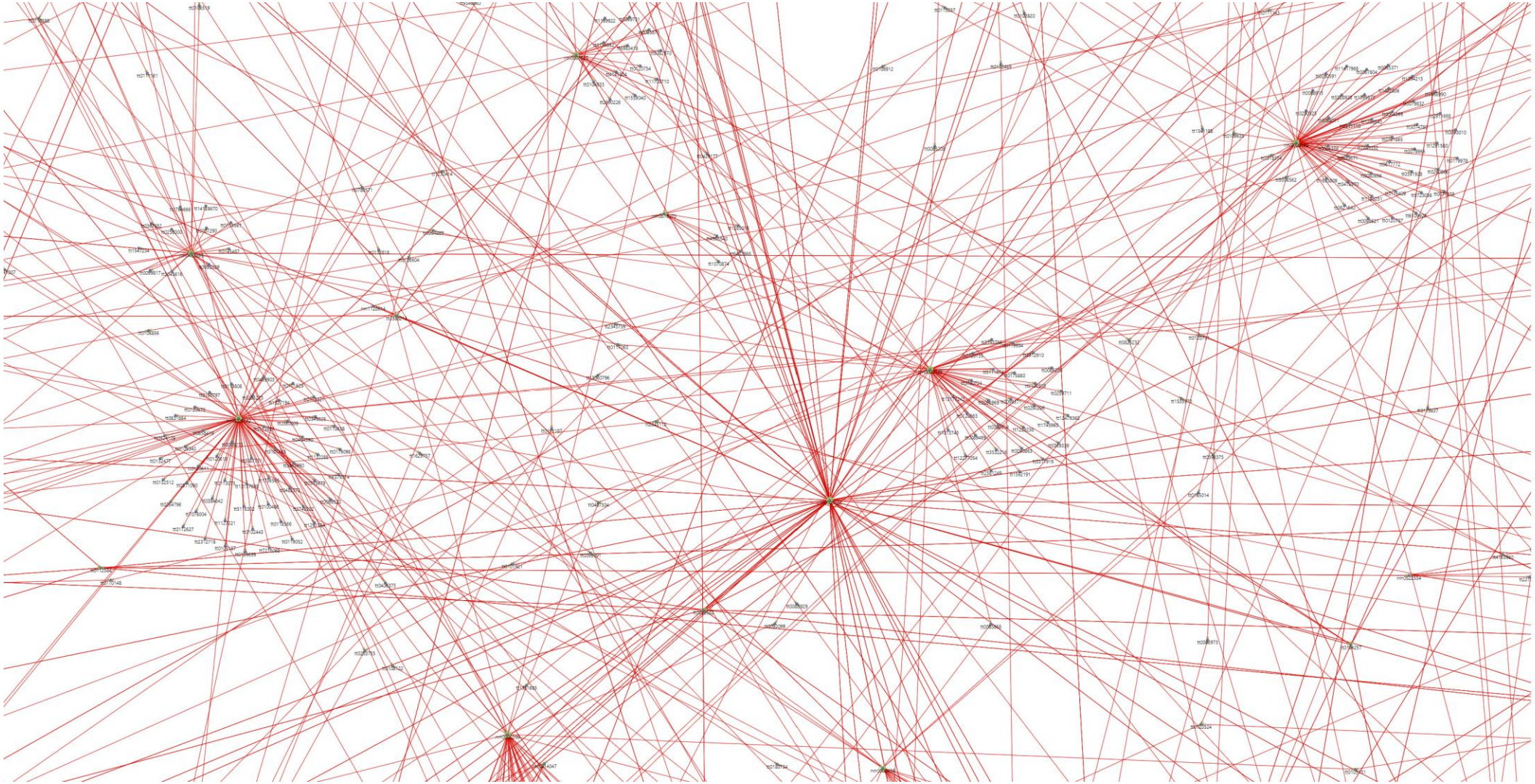


Traverses the adjacent vertices in 3 milliseconds, consumes zero CosmosDB RUs.

Demonstration – v2/IMDB: Network Graph, “Two Degrees of Kevin Bacon”



Demonstration – v2/IMDB: Network Graph, "Three Degrees of Kevin Bacon"



This is a very connected social network! But how do I find the path from Kevin Bacon to Charlotte Rampling?….

Demonstration – v2/IMDB: Shortest Path – Kevin Bacon to Charlotte Rampling

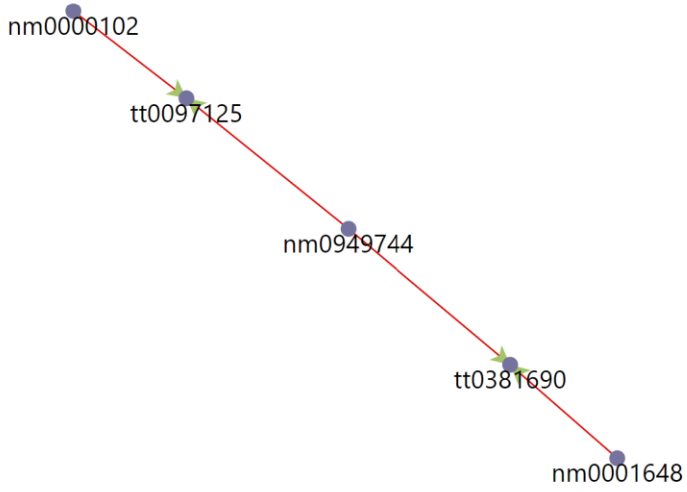
AltGraph

Graph Solutions with the Azure CosmosDB SQL API

Shortest Path | nm0000102 | nm0001648 | Search | 87

Shortest Path between Two Vertices

Vertex 1		Vertex 2
nm0000102	-->	tt0097125
nm0949744	-->	tt0097125
nm0949744	-->	tt0381690
nm0001648	-->	tt0381690



This query takes only 87 milliseconds to execute, and consumes zero CosmosDB RUs

Demonstration – v2/IMDB: Shortest Path – Kevin Bacon to Fred Aistaire

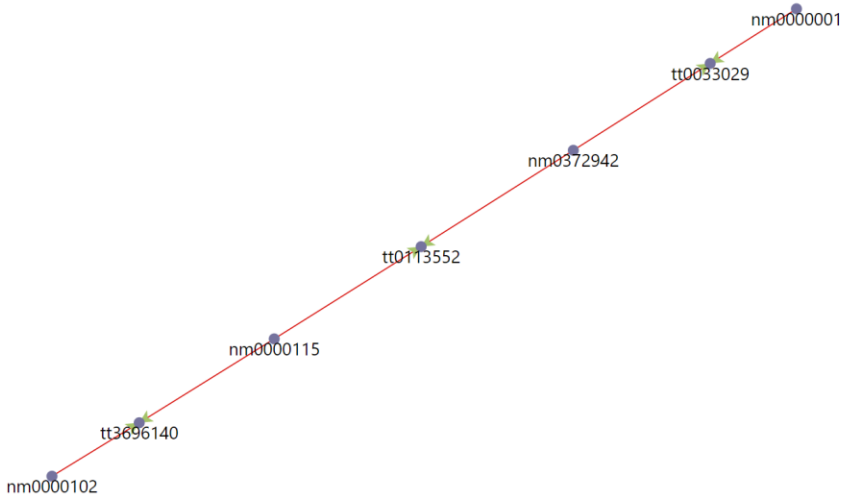
AltGraph

Graph Solutions with the Azure CosmosDB SQL API

Shortest Path | nm0000102 | nm0000001 | Search | 1048

Shortest Path between Two Vertices

Vertex 1		Vertex 2
nm0000102	-->	tt3696140
nm0000115	-->	tt3696140
nm0000115	-->	tt0113552
nm0372942	-->	tt0113552
nm0372942	-->	tt0033029
nm0000001	-->	tt0033029



Azure

Demonstration – v2/IMDB: Page Rank Algorithm

AltGraph

Graph Solutions with the Azure CosmosDB SQL API

PageRank | 100 | | Search | 3743

Vertex PageRanks

Rank	Vertex	Value	Comment
1	nm0183659	0.00014375625797007131	
2	nm0756966	0.00010948154781558972	
3	nm0644554	0.00006151494573422499	
4	nm0462051	0.00005744026497552381	
5	nm0457554	0.000056200687467845174	
6	nm0619107	0.00005216369278385738	
7	nm0997109	0.00004890868058151003	
8	nm0297876	0.000042653495383222324	
9	nm0103977	0.000042239964918056494	
10	nm3266654	0.00003957139305846257	
11	nm0793813	0.000039275210592778356	

Computes the Page Rank of all Vertices and lists the top 100. 3743 ms, 0 RUs.

Microsoft

Thank you!

Questions?