Scalable SPARQL Querying of Large RDF Graphs

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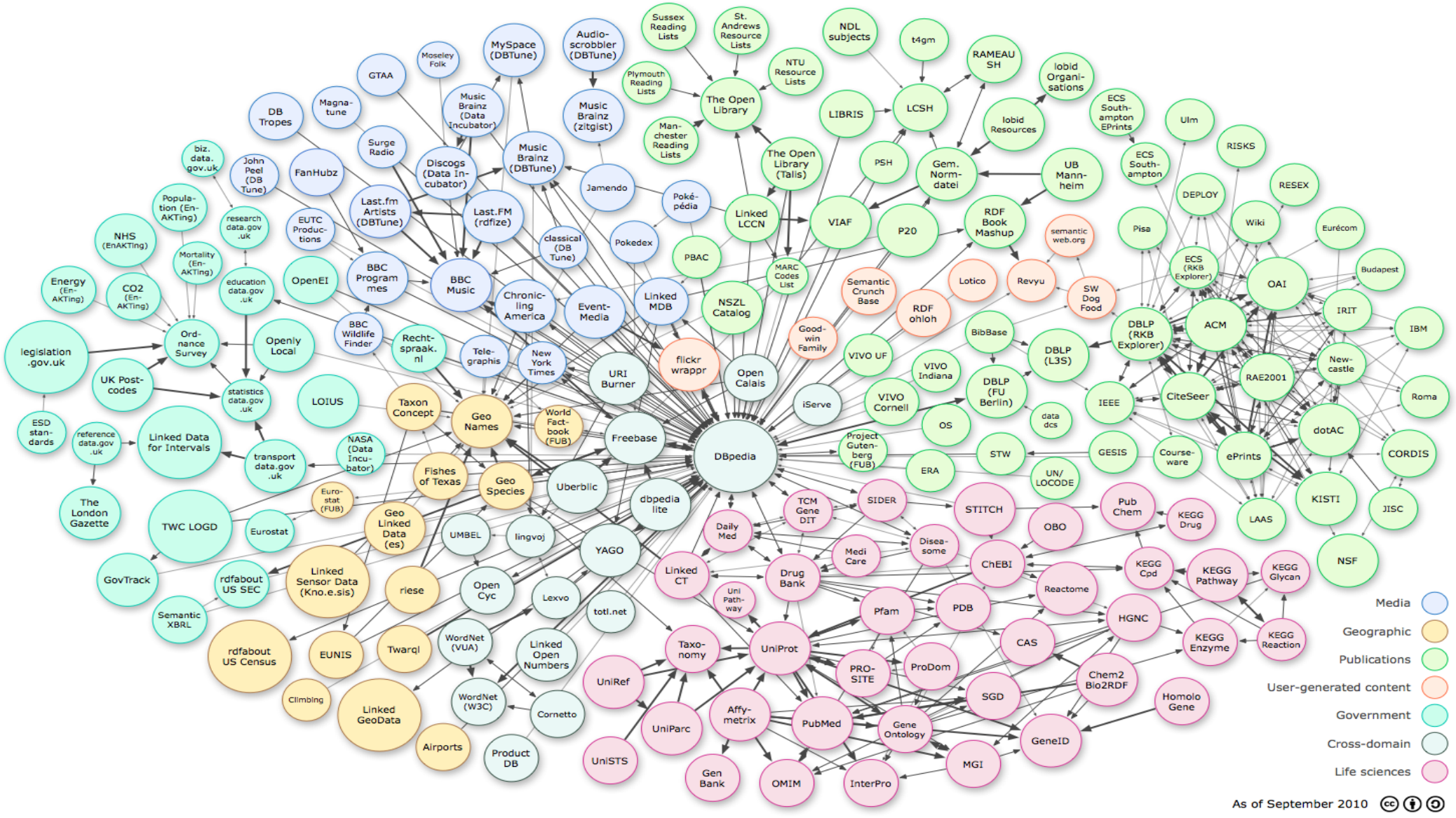
RDF Gaining Popularity

- Encouraged by major search engines
  - Google
  - Yahoo!
- More data sets available in RDF
  - Governments
  - Research communities

Linked Data Movement

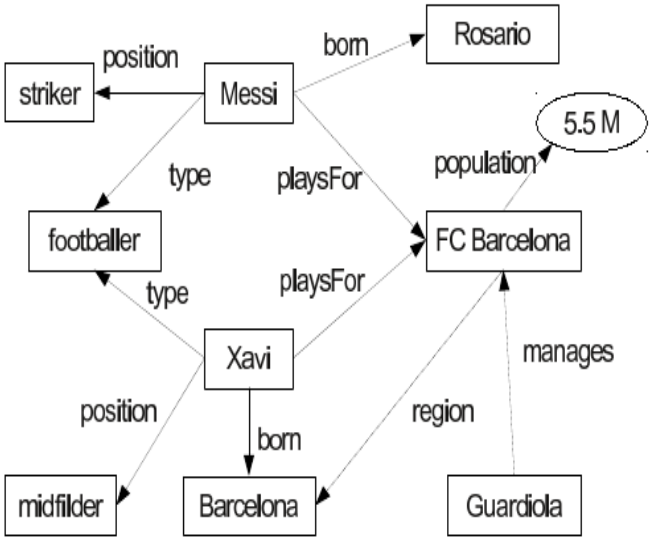


Scalable Processing

- Single-node RDF management systems are abundant
  - Sesame
  - Jena
  - RDF-3X
  - 3store
- Research in clustered RDF management is less significantly explored: *The focus of the talk*

RDF as Triples and a Graph

subject	predicate	object
Lionel Messi	type	footballer
Lionel Messi	playsFor	FC Barcelona
Lionel Messi	born	Rosario
Lionel Messi	position	striker
Xavi	type	footballer
Xavi	playsFor	FC Barcelona
Xavi	born	Barcelona
Xavi	position	midfilder
FC Barcelona	region	Barcelona
Barcelona, Spain	population	5,500,000
Josep Guardiola	manages	FC Barcelona



SPARQL

- RDF query language
- A basic graph pattern
- Answering SPARQL can be seen as finding subgraphs in the RDF data that match the graph pattern

Example for Star Pattern

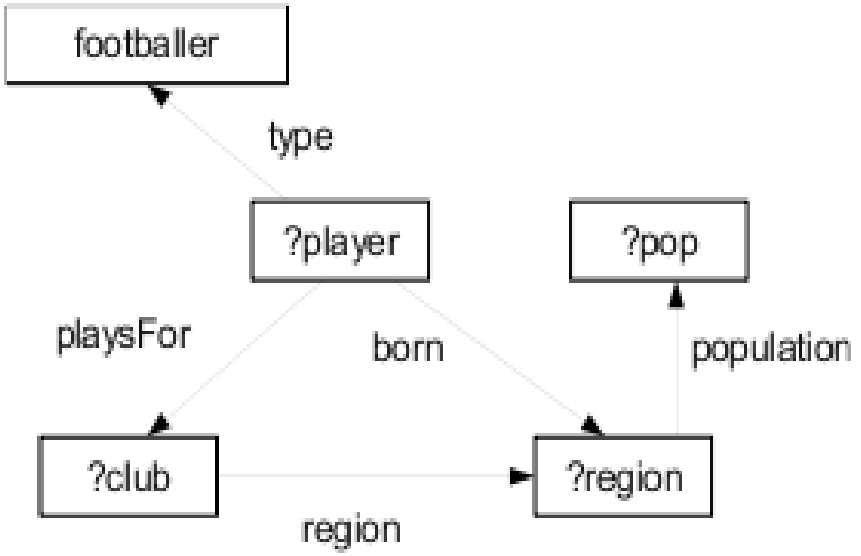
- Find the names of the strikers that play for FC Barcelona.

```
SELECT ?name
WHERE { ?player  type       footballer          .
        ?player  name       ?name               .
        ?player  position   striker             .
        ?player  playsFor   FC_Barcelona . }
```

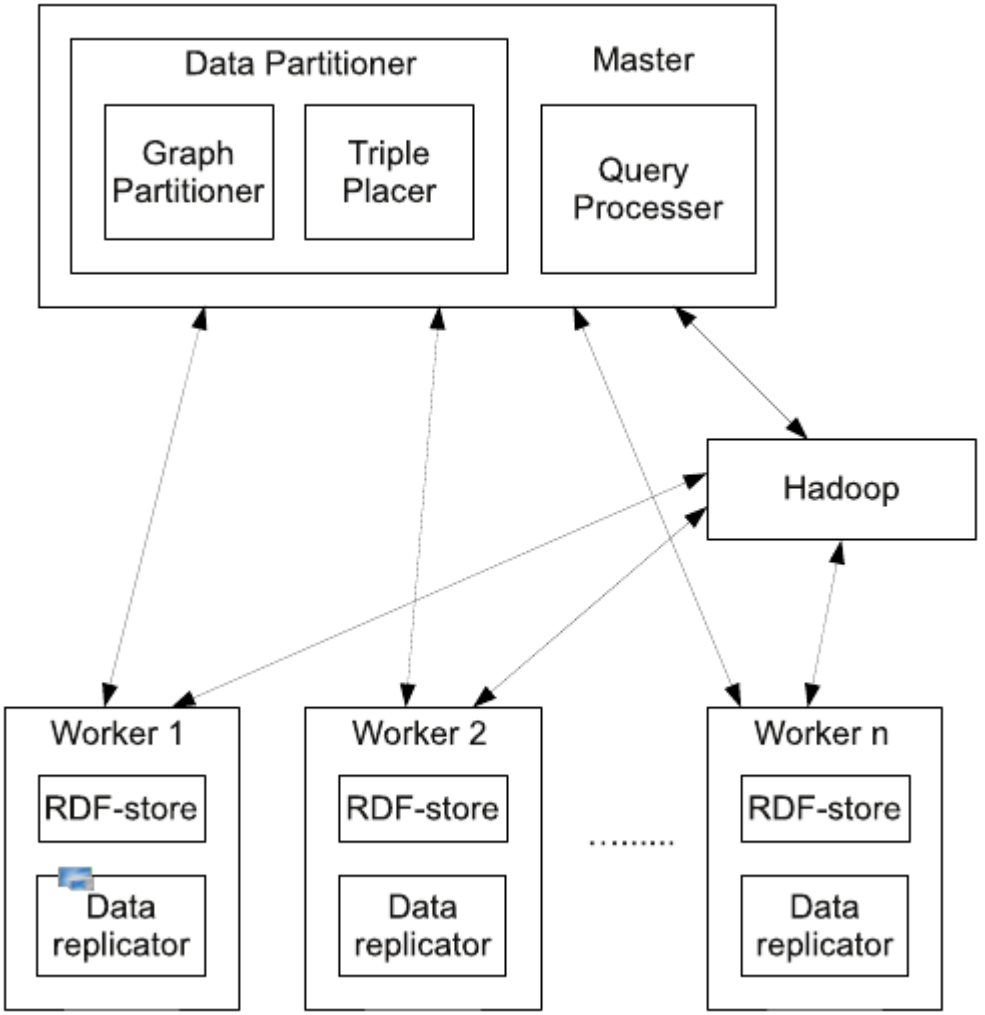
Another Example

- Find football players playing for clubs in a populous region where they were born.

```
SELECT ?player ?club ?region
WHERE  {  ?player type       footballer .
          ?player playsFor   ?club      .
          ?player born       ?region      .
          ?club   region     ?region    .
          ?region population ?pop       .
          FILTER (?pop > 2,000,000)  }
```



System Architecture



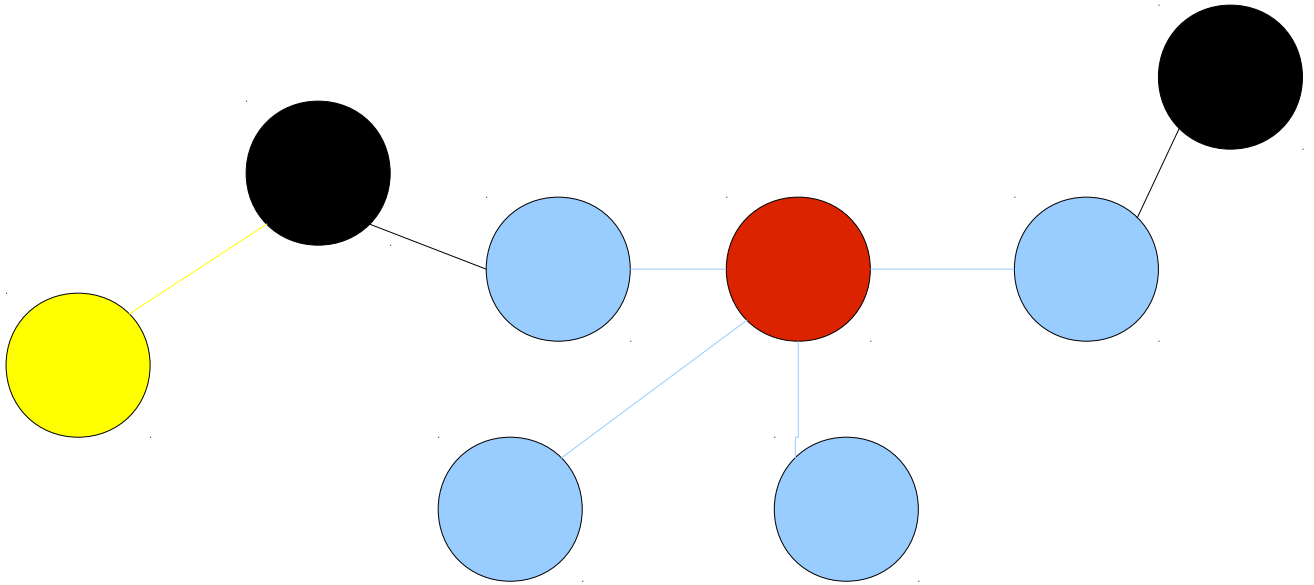
Data Partitioning

- Hash vs Graph partitioning
  - Hash: Only efficient for star patterns
  - *Graph: Taking advantage of graph model*
- Edge vs Vertex partitioning
  - Edge: Natural but inefficient for query execution
  - *Vertex: Superior for common graph patterns*

Edge/Triple Placement

- Minimizing data shuffling/exchange
  - Allowing data overlap
- N-hop guarantee
  - The extent of data overlap
  - If a vertex is assigned to a machine, any vertex that is within n-hop of this vertex is also stored in this machine

Example for N-Hop Guarantee



Query Processing

- Query execution is more efficient in RDF-stores than in Hadoop
  - Pushing as much of the processing as possible into RDF-stores
  - Minimizing the number of Hadoop jobs
  - The larger the hop guarantee, the more work is done in RDF-stores

To Communicate, or not to Communicate

- Given a query and n-hop guarantee, is communication (Hadoop job) between nodes needed?
  - Choose the “center” of the query graph
  - Calculate the distance from the “center” to the furthest edge
  - If distance > n, communication is needed; not needed otherwise

Back to the Example

- Find football players playing for clubs in a populous region where he was born.

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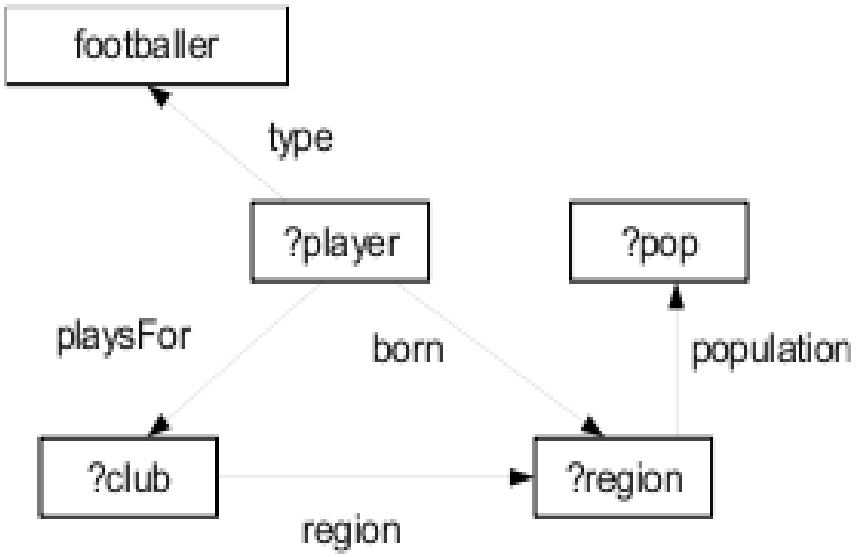
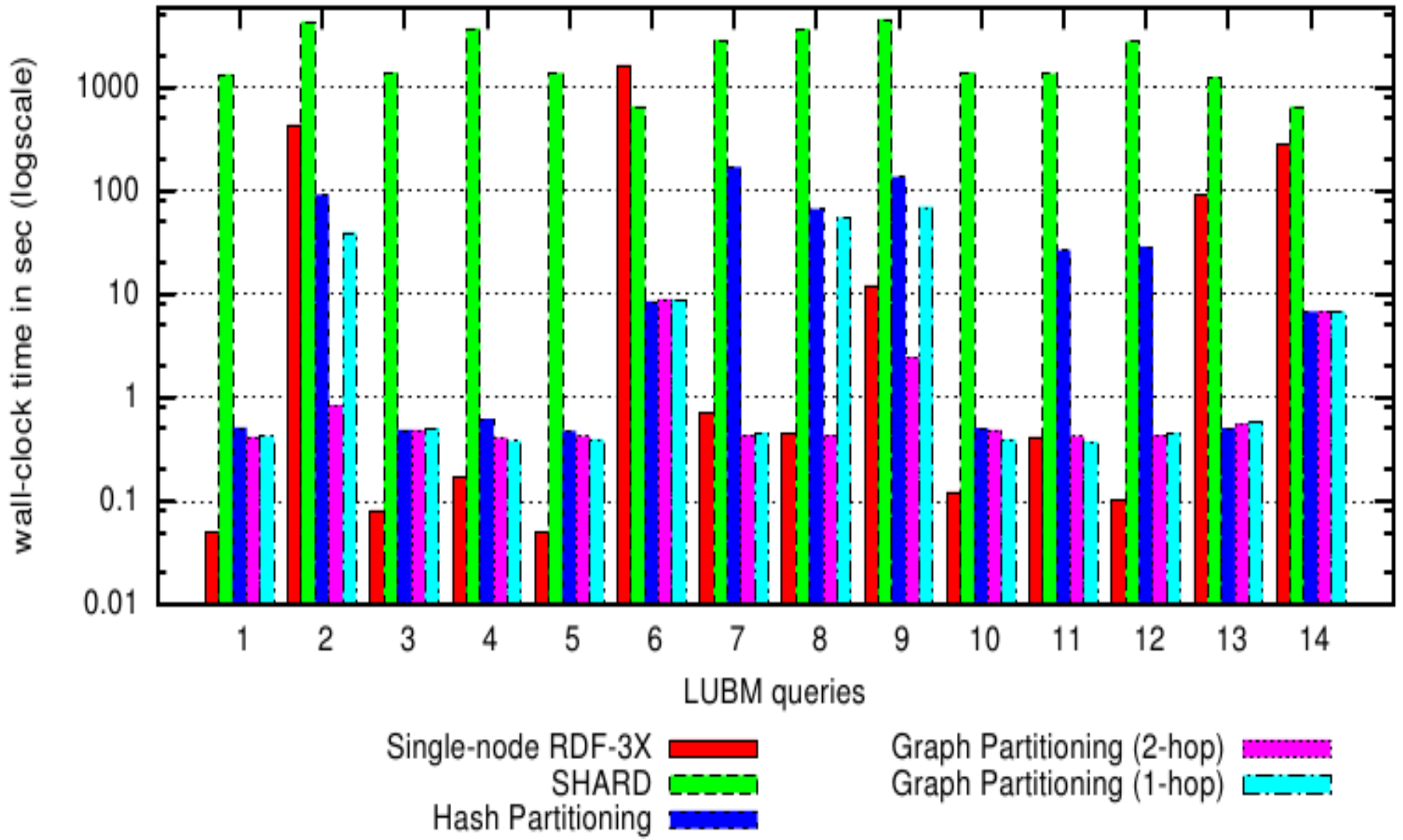


Experimental Setup

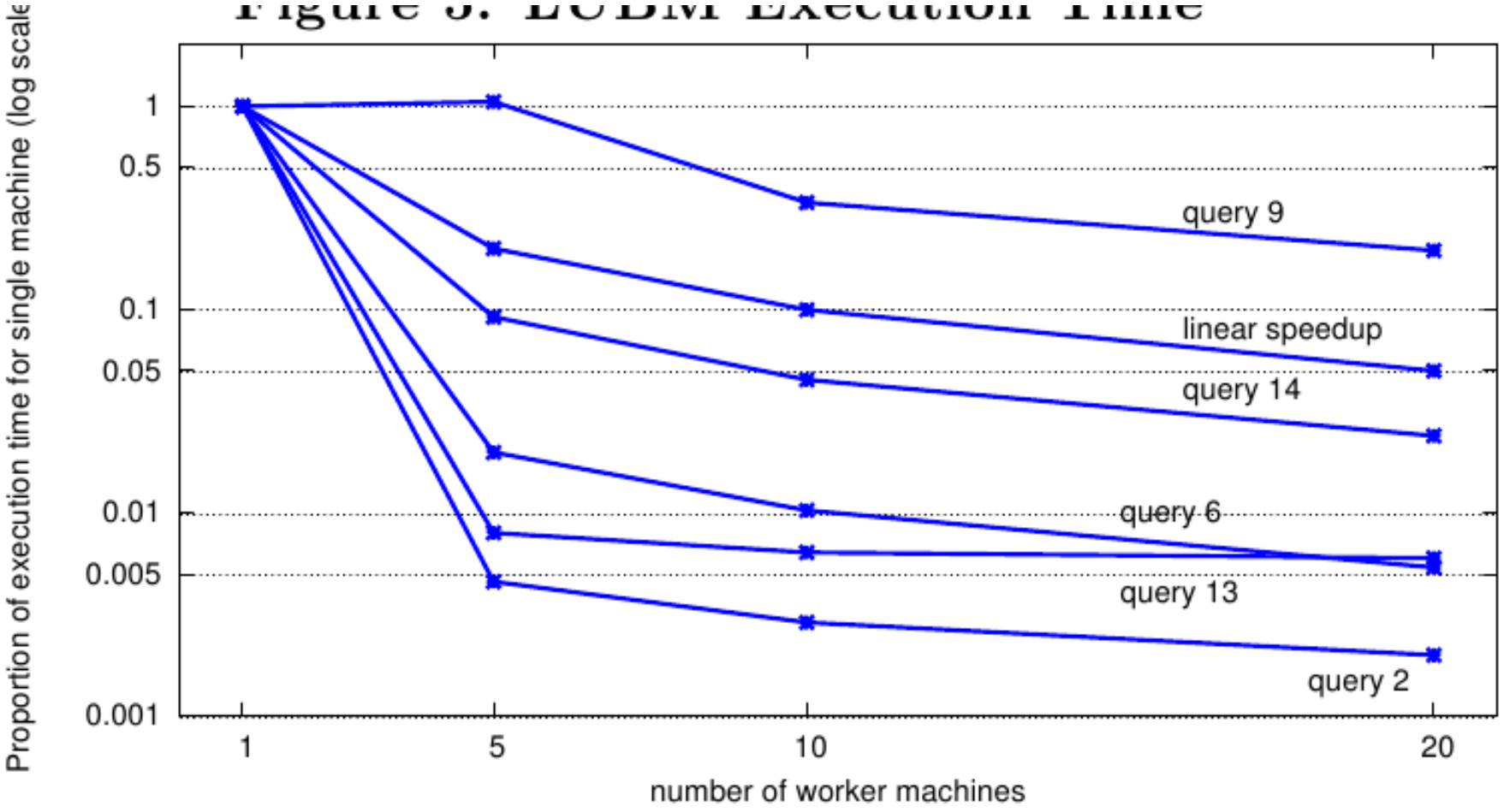
- 20-machine cluster
- Leigh University Benchmark (LUBM): 270 million triples
- Competitors:
  - Single-node RDF-3X
  - SHARD: triple-store system in Hadoop
  - Graph partitioning (the proposed system)
  - Hash partitioning on subjects

Performance Comparison



Speedup

- Better than linear speedup



Summary

- We propose a new architecture for scalable RDF data management: *RDF-stores + Hadoop*
- We propose a new approach for data placement and corresponding query processing: *Graph partitioning + N-hop guarantee*
- The techniques in the talk can be generalized to the problems of subgraph pattern matching in other graphs
- The lesson we learned: Inter-node communication is expensive, avoid it.

Thank you!

Backup Slides: Optimization

- Problem: High-degree vertexes make the graph well-connected and difficult to partition
- Solution: Removing them in graph partitioning

- Problem: High-degree vertexes cause data explosion in n-hop guarantee
- Solution: Weakened n-hop guarantee