Clause-Iteration with Map-Reduce to Scalably Query Data Graphs: The SHARD Triple-Store

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Many thanks to:
Prakash Manghwani, Mike Dean,
Ian Emmons, Gail Mitchell, Doug Reid,
Chris Kappler from BBN
Hanspeter Pfister from Harvard SEAS
Phil Zeyliger from Cloudera

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Outline

- Challenge Problem: Scalably Query Graph Data
- Large-Scale Computing and MapReduce
- SHARD
- Design Insights

A Preface

SHARD is a cloud based graph store.

- High-performance scalable query processing.

SHARD released open-source.

- BSD license.

More information and code at:

  - My webpage
  - Sourceforge (SHARD-3store)

- Use svn to get code:

```
svn co https://shard-3store.svn.sourceforge.net/svnroot/shard-3store shard-3store
```

  - Don't worry - this command is on SourceForge!

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Scalable Graph Data Querying

- Emerging commercially
  - Use by NYTimes, BBC, Pharma, …
  - Numerous startups.
  - Oracle, MySQL have SemWeb support.

- Government use…

- See the SemWeb.

SPARQL-like Queries

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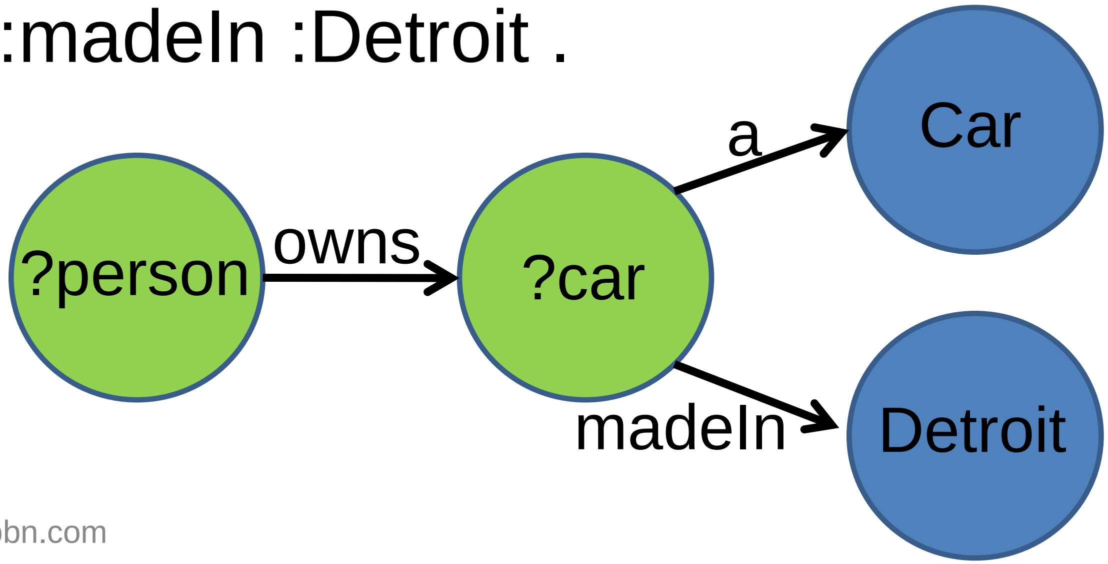
SPARQL Query to find all people who own a car made in Detroit:

```
SELECT ?person
WHERE  {
   ?person :owns ?car .
   ?car a :Car .
   ?car :madeIn :Detroit .
  }
```



Answering Queries

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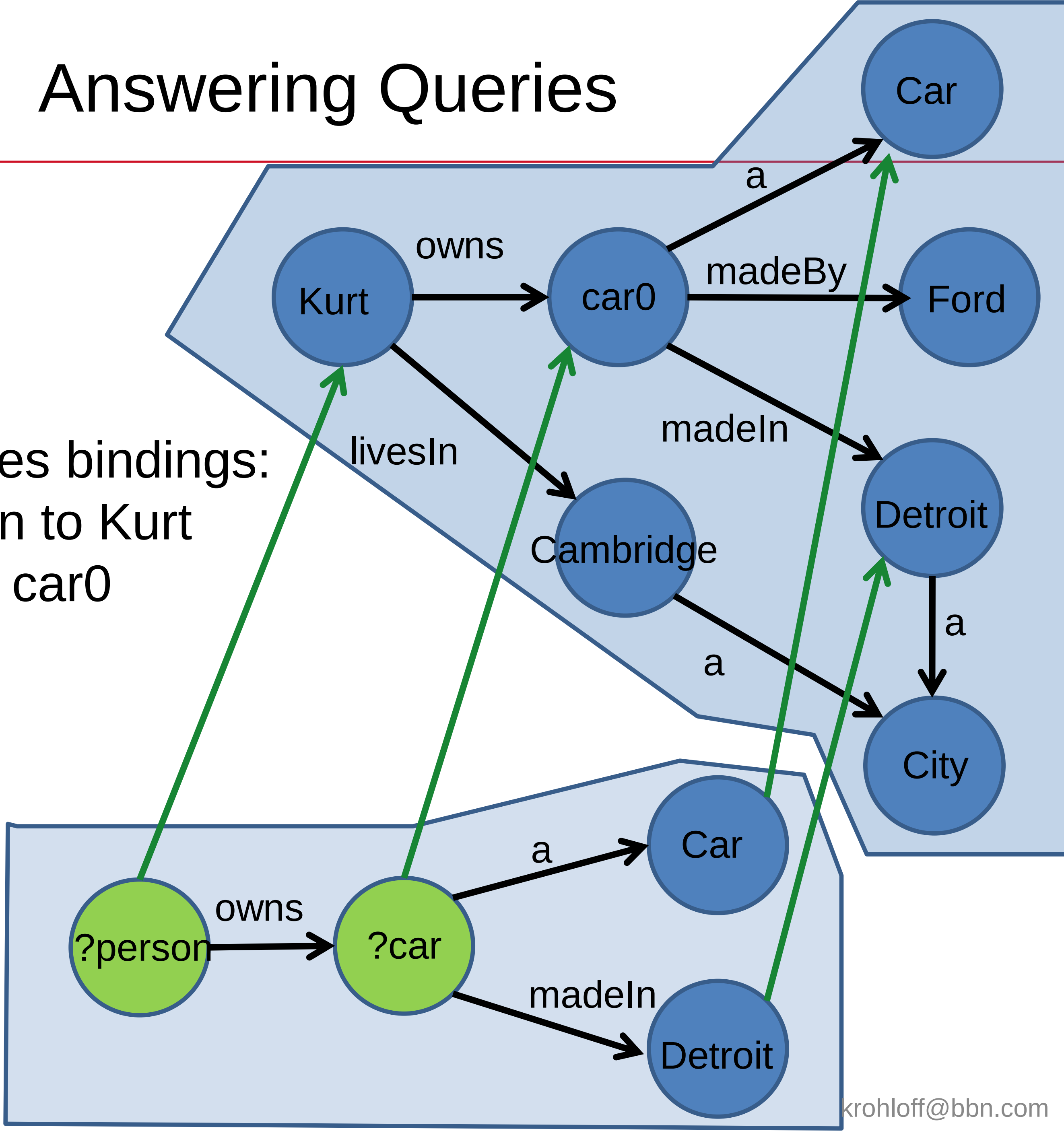

Variables bindings:
?person to Kurt
?car to car0

Design Considerations

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- Scalable – web-scale?
- High Assurance.
- Cost Effective – commodity hardware?
- Modular inferred data separation.
- Robustness.

- Considerations as endless as applications.

Scale Limitations!

- Triple-Store Study:
  - "An Evaluation of Triple-Store Technologies for Large Data Stores", SSWS '07 (Part of OTM).
- What about cloud computing?
  - Economic scalability…

General Programming for Scalable Cloud Computing

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From Experience:

- Inherently multi-threaded.
- Toolsets still young.
  – Not many debugging tools.
- Mental models are different...
  – Learn an algorithm, adapt it to choosen framework.
  – Ex: try to fit problem into PageRank design pattern.
    - (This isn't what we do, but this approach seems common.)

Scalable Distributed System (Cloud) Design Concept

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Abstraction of parallelization enables much easier scaling.

- We use maturing MapReduce framework in Hadoop to bulk process graph edges.
- This provides services layer to scale our graph query processing techniques.
- Innovation:
  - Iterative clause-based construction of queries.
  - Join partial query responses over multiple Map-Reduce jobs using flagged keys.

SHARD Triple-Store Built on Hadoop

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Prioritized goals:

- Commodity hardware, ONLY
- Web scalable
- Robust

What is good:

Design Considerations:

- Large query responses
- Complex queries

Clause Iteration Query Response Construction

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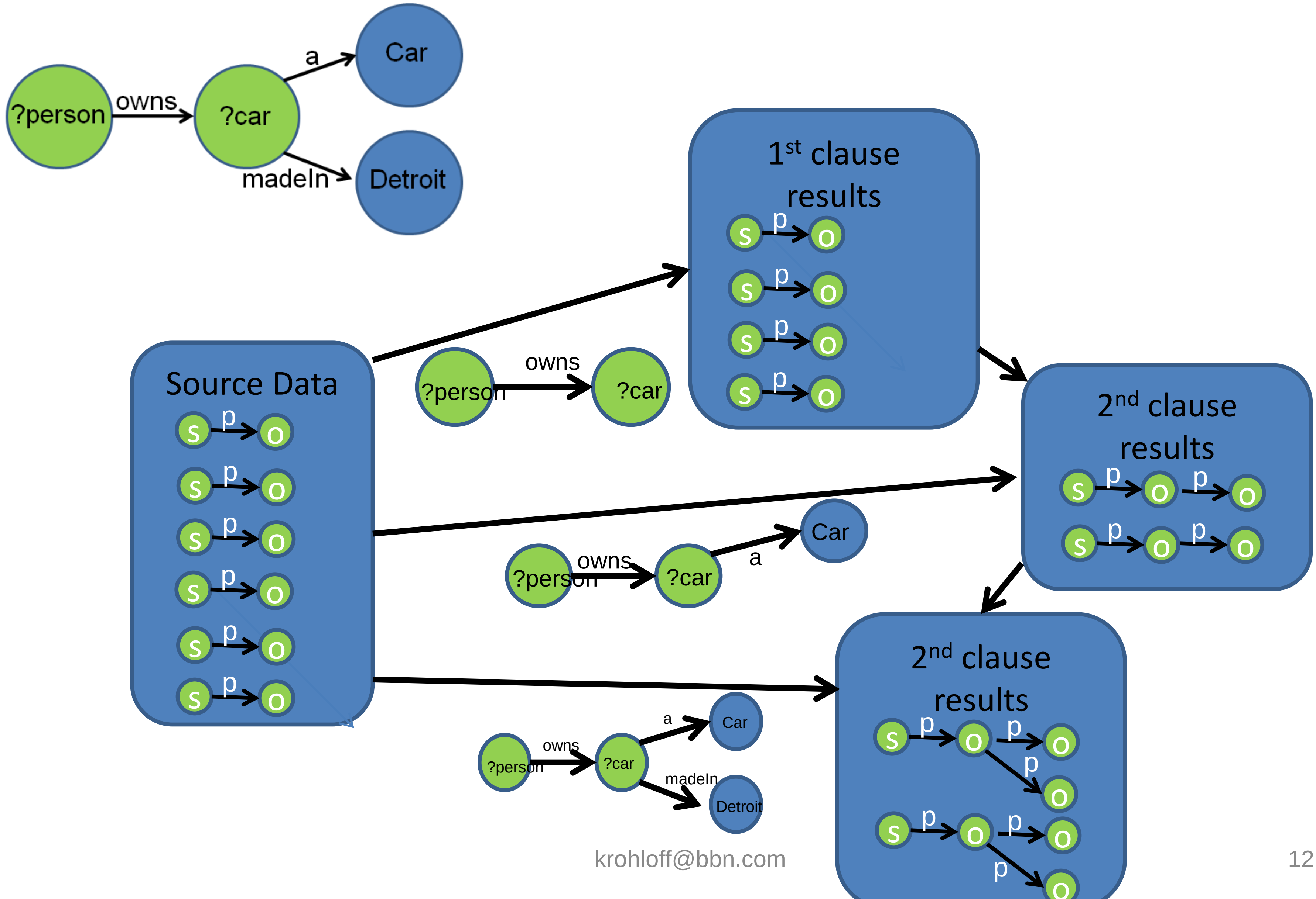
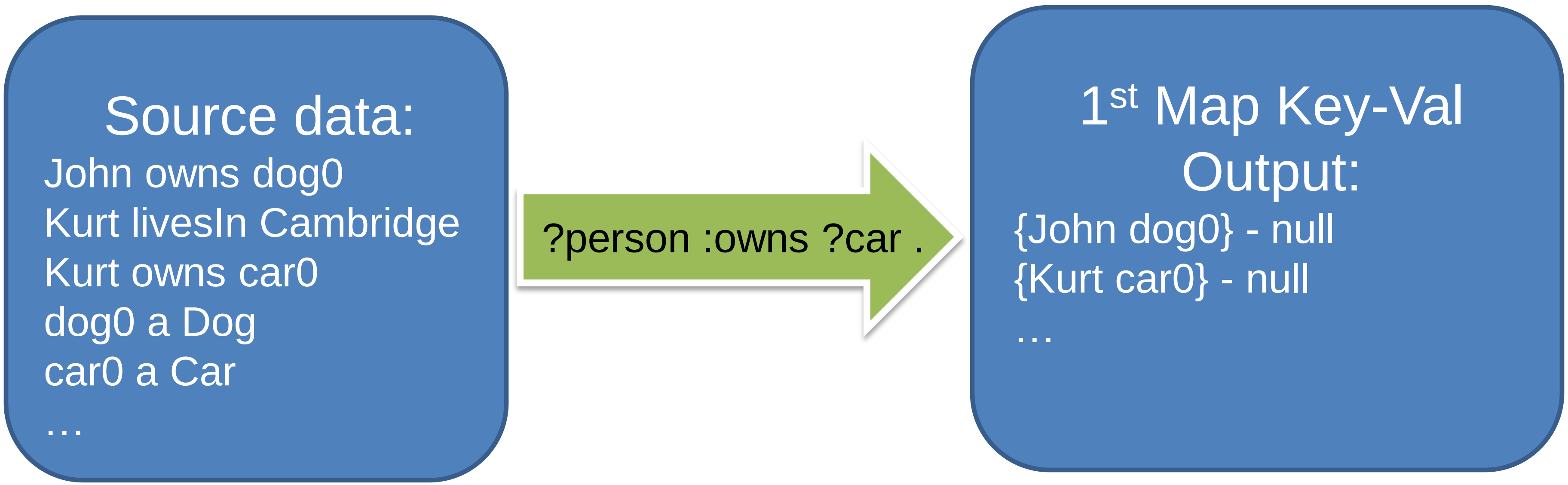


1st Partial Query Match By Clause

In first Map Step, first query clause is used
to find partial query matches that satisfy first clause

- Keys are variable bindings
- Values are set to null



In first Reduce Step, repeated partial matches are removed

2^{nd} Clause Map – New Bindings

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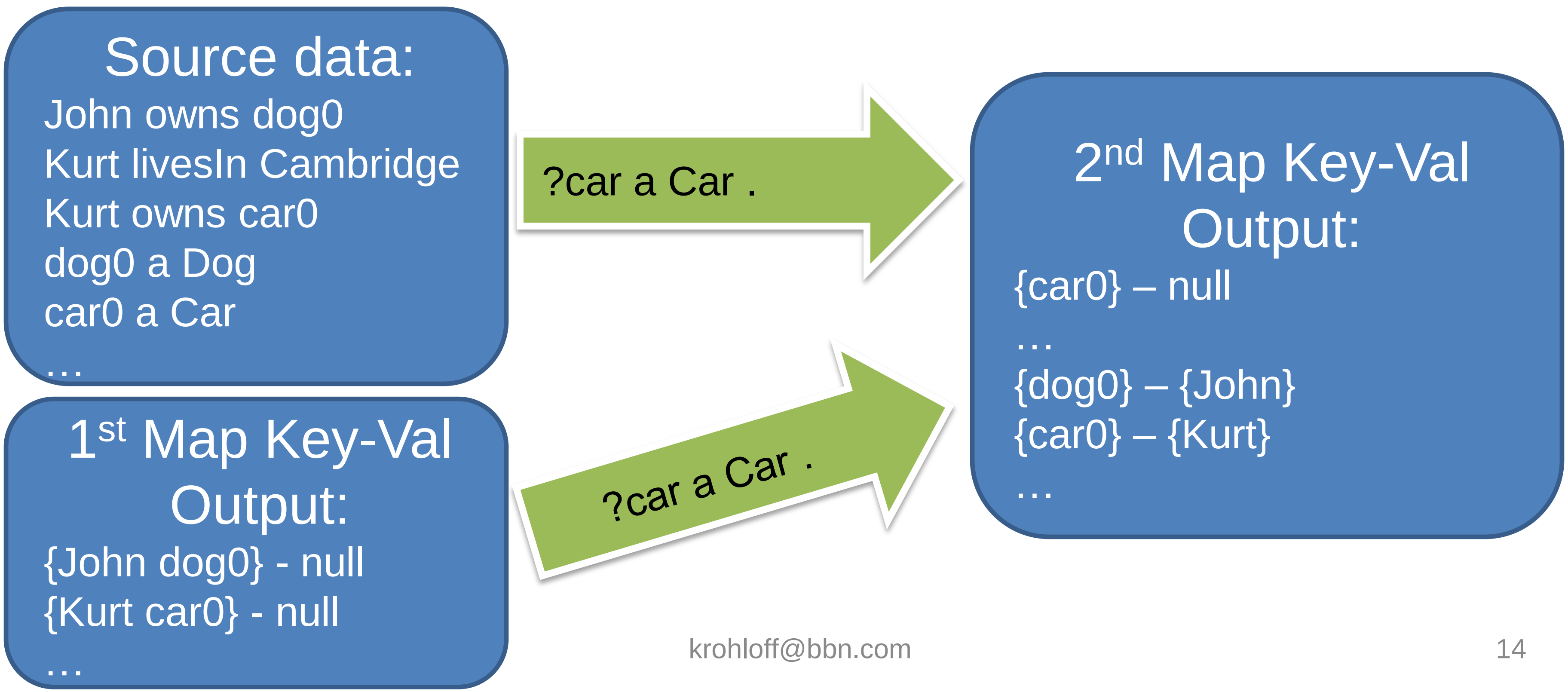
Map partial query matches from 2^{nd} query clause.
- Keys are variable bindings previously observed.
- Values are set to new variable bindings.

Map matches from previous clause for reordering.
- Keys are variable bindings common with current clause
- Values are previous non-common bindings



2nd Clause Reduce – Join

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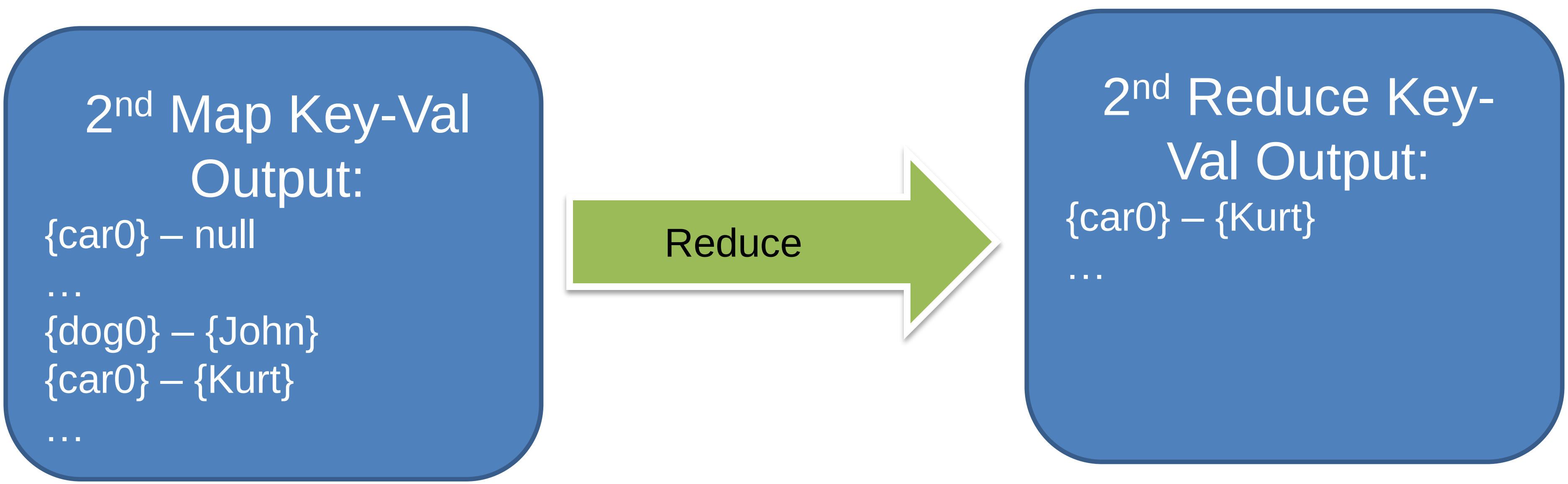
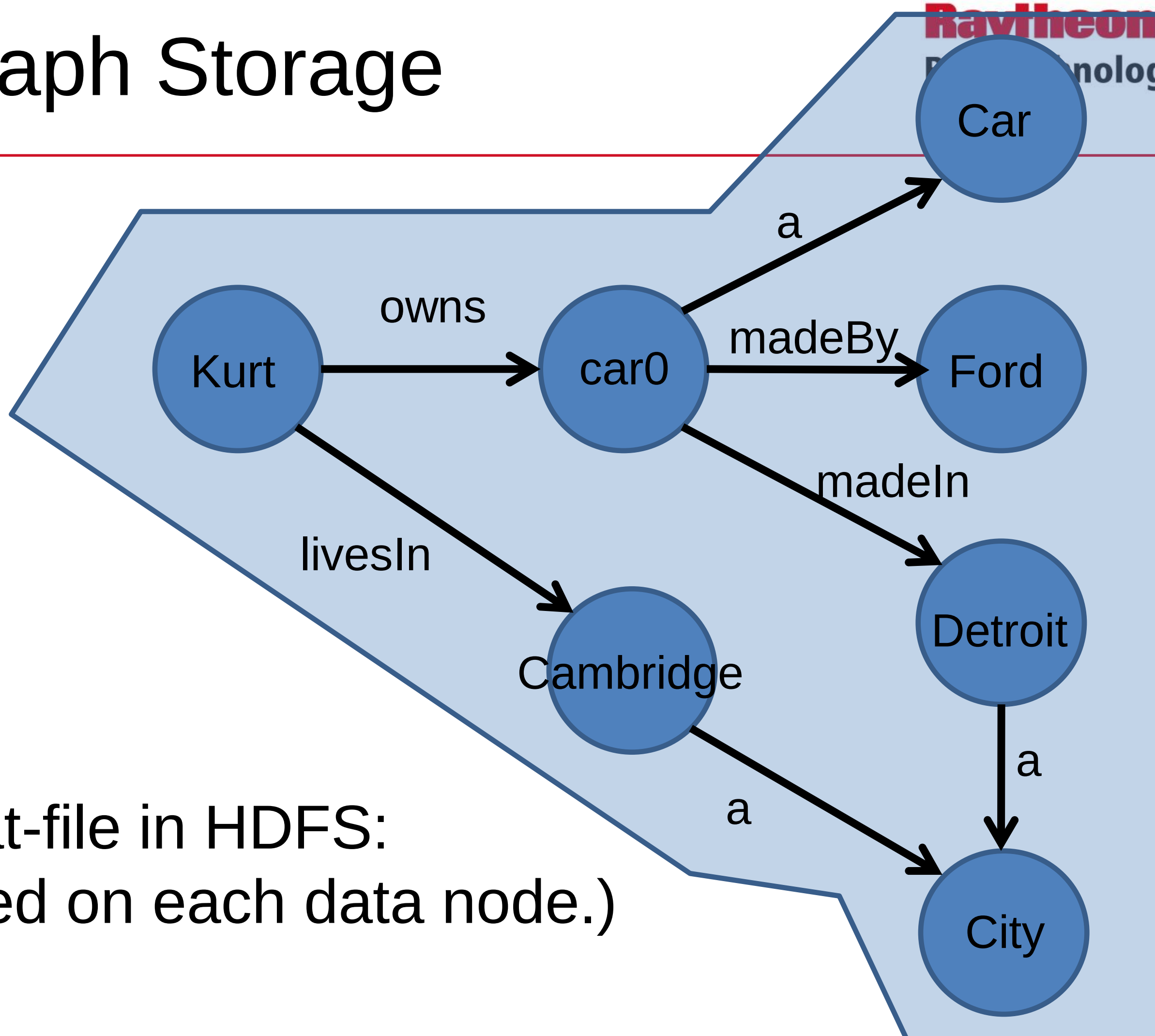
Reduce joins partial mappings on common variable bindings with flagged keys.



Process continues over all query clauses.

HDFS Graph Storage



Graphs saved as flat-file in HDFS:
(Portions of file saved on each data node.)

```
Kurt owns car0 livesIn Cambridge
Car0 a Car madeBy Ford madeIn Detroit
Cambridge a City
Detroit a City
```

HDFS data partitioning

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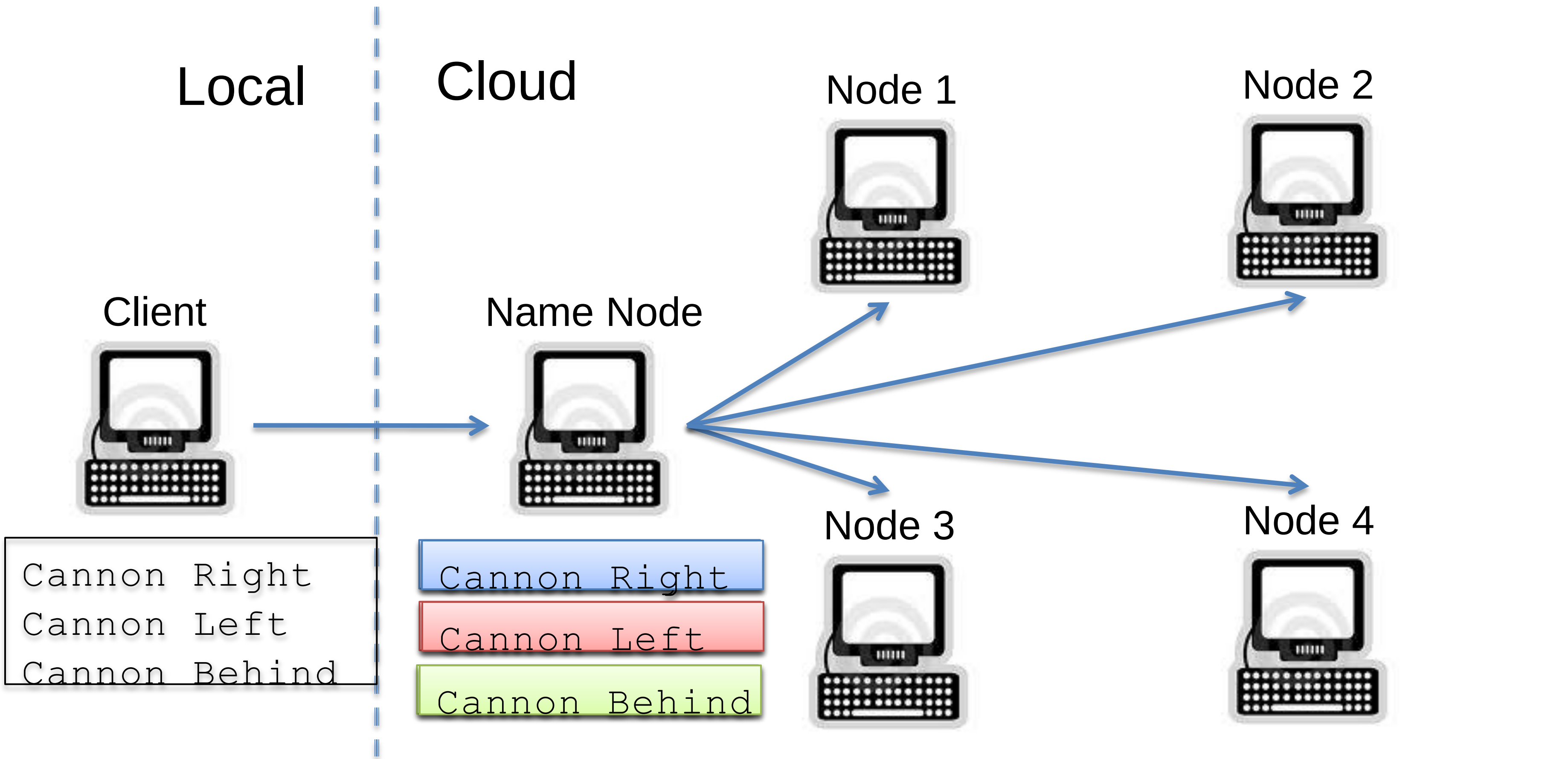

- Hash Partitioning by Default.
- Neighborhood partitioning would probably provide better performance.
  - R&D opportunity!

Query Processing Implementation

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- BBN-developed query processor.
  - Starting integration with “standard” interfaces
    - Jena, Sesame.
- SHARD supports “most” of SPARQL.
  - Like most commercial triple-stores.
- Large performance improvements possible with improved query reordering.

Data Persistence Advice from SHARD

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- Down to "bare metal" in HDFS for large-scale efficiency.
  - No Berkeley DB, no C-stores, …. Nothing.
- Simple data storage as flat files.
  - Lists of (predicate, object) pairs for every subject by line.
  - Ex: Kurt owns car0 livesin Cambridge
- Simple often really is better…

Test Data

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- Deployed code on Amazon EC2 cloud.
  - 19 XL nodes.
- LUBM (Lehigh Univ. BenchMark)
  - Artificial data on students, professors, courses, etc… at universities.
- 800 million edge graph.
  - 6000 LUBM university dataset.
- In general, performed comparably to “industrial” monolithic triple-stores.

Performance Comparison

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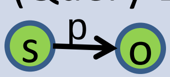
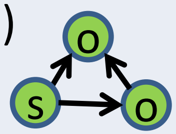
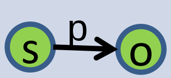
Query Type	SHARD	Parliament+Sesame	Parliament+Jena
Simple Query, Small Response: Triple Lookup (Query 1) 	404 sec. (approx 0.1 hr.)	0.1hr	0.001hr
Triangular Query (Query 9) 	740 sec. (approx 0.2 hr.)	1hr	1hr
Simple Query, Large Response: (Query 14) 	118 sec. (approx 0.03 hr.)	1hr	5hr

Insight from Query Performance

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- SHARD is not optimal for edge look-ups.
  - This could be expected – SHARD (and MapReduce implementations) have no real indexing support.
- SHARD does well where large portions of dataset need to be processed.
  - Ex:
    - Multiple join operations
    - Return large datasets
  - This behavior is an artifact of parallel searching and joining operation native to Clause-Iteration.

Design Insights

- Abstraction is a big win.
  - Surprisingly economical for development.
- Lack of indexing limits look-up capabilities.
  - This may not be so bad for some applications
  - Index will also need to be continually updated as data added.

Design Insights – Data Partitioning

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- Data linking may be a big win to reduce join overhead and reduce need for iterations over clauses.
  - A first step would be advanced data partitioning.
  - Done some in Cloud9, but still wide open for even basic R&D implementations.

- Advanced data partitioning would also minimize overhead of moving intermediate results between compute nodes.
  - This seemed to be biggest bottleneck.

Design Insights – Query Processing

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- Query pre-processing may also be a big win.
  - Could also greatly reduce amount of data carried between nodes during join operations.

- Subject-Iteration may be an alternative approach for queries with strongly connected source nodes.
  - Iterate over query subject rather than clauses.

Thanks!
Questions?

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