Web data management on DHTs

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XSym workshop

Work supported by the ANR *WebContent* (2005-2009)
and *CODEX ANR-08-DEFIS-004* (2009-2012) grants

Outline

Motivation

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Still missing: the flexible federation

- high independence of the sites: when to be in, what to store
- data distribution transparency
- . . . with the usual performance requirements

Motivation: distributed warehouses of Web content

Web content

structured documents, schemas, annotations, concepts, mappings, Web services, inter-document links

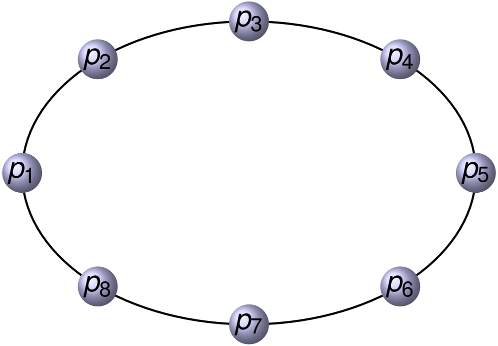
Web content warehouse

Distributed database of selected content, whose users may:

- publish resources
- connect (annotate, map, link...) existing resources
- update resources
- enhance resources by combining them

In the style of the RNTL WebContent project (2005-2009)

Distributed hash tables



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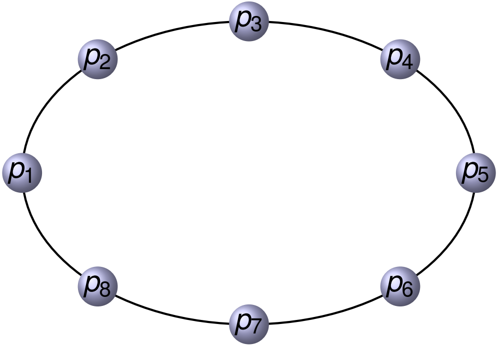

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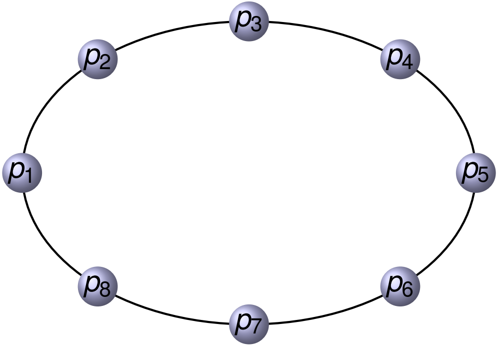

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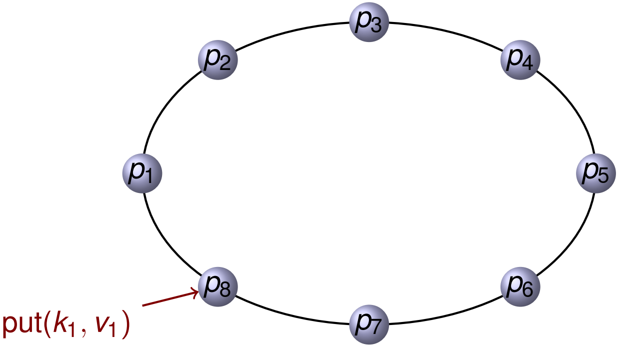

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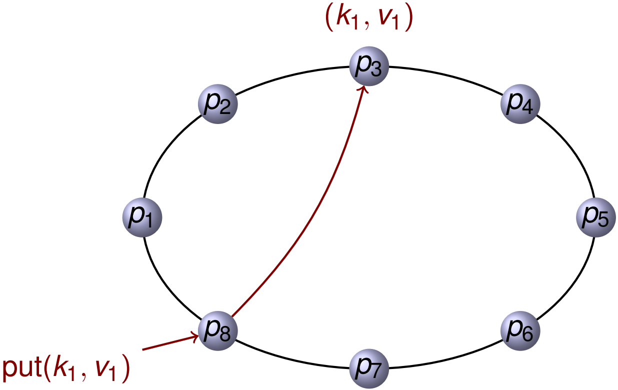

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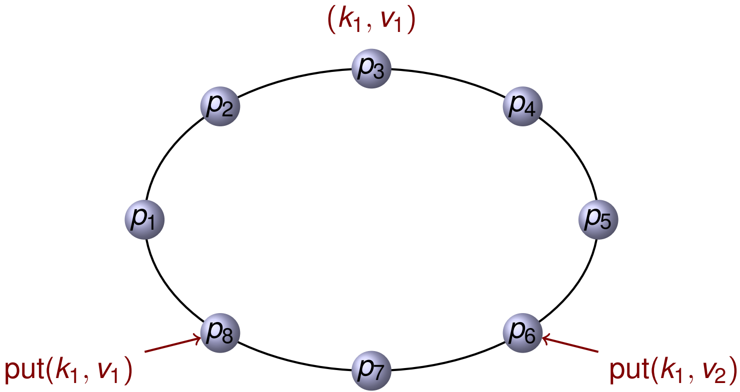

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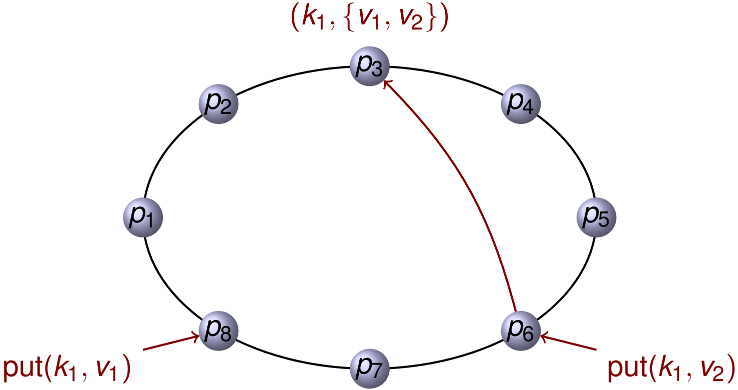

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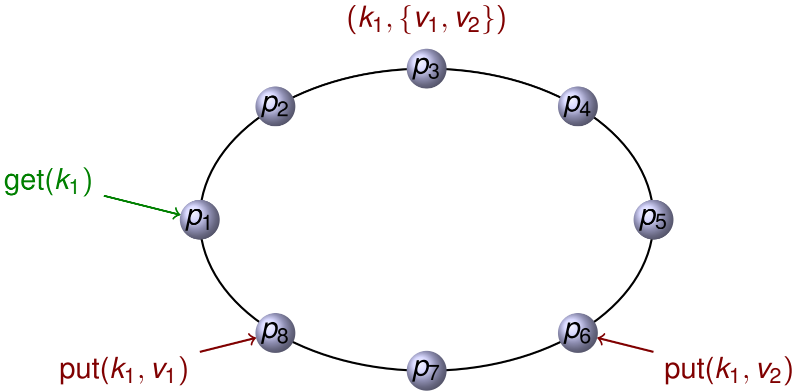

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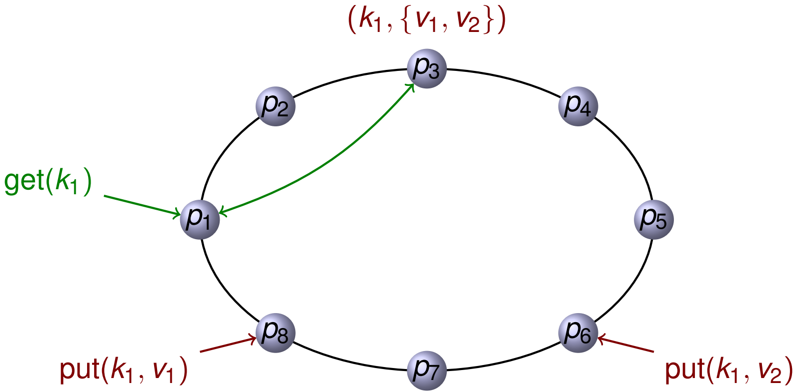

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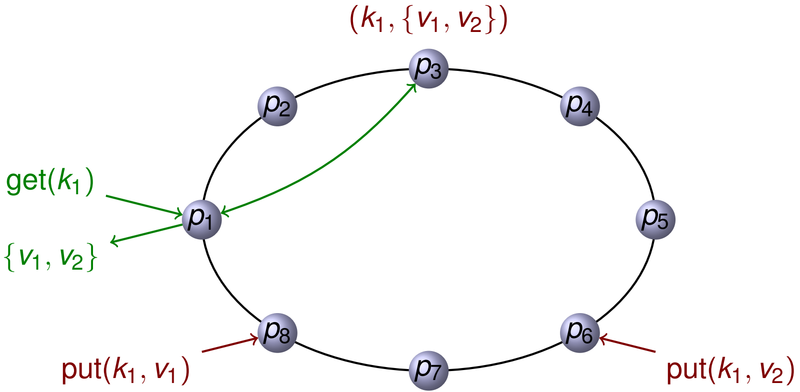

What distributed hash tables provide

Dynamic peer networks

- each peer is assigned an id $\Rightarrow$ address range
- bound of $log_2(N)$ hops to route a message to a given address (peer)
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- index the resources by keys
- look up resources by keys

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D

HTs provide location transparency

From DHTs to distributed data management

Functionalities to add:

- data indexing algorithms
- storage for application data and even DHT index data
- local query processing
- distributed query processing: operators, including data transfers, optimization . . .

Reliability provided:

- some peer will always answer at a given address, possible after some time
- some (key, value) replication to handle peer failures (broadcast to k replicas)

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Resilience to other loss of data or functionality needs to be implemented

DHT index queries

Query processing involves:

- operations on the DHT or (key, value) store
- other operations
  - evaluating sub-queries to extract partial results
  - combining several partial results
  - transferring results to query peer

Index query

The part of a user query that can be answered directly by consulting the DHT content index

Typically less precise than the user query

- Find the IDs of documents matching the query
- Find the IDs of documents which may match for the query

Trade-offs in DHT indexing and query processing

Level of detail of the indexing algorithm:

- index query precision $\nearrow \Rightarrow$ execution time $\searrow$
- data publication time $\nearrow$, possibly execution time $\nearrow$

Data re-placement or clustering:

- fewer peers contacted for a query (message no. $\searrow$, execution time ?)
- data transfers in the absence of queries (message no. $\nearrow$, total message size $\nearrow$)

Our experience building Web data stores on DHTs

Web data:

- standalone XML documents
- RDF data, RDF schemas, mappings
- annotations on XML fragments
- interconnected XML documents

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- interconnected XML documents

Choices:

- peers retain control over the data they store/publish
  - no global schema
  - documents published independently
  - annotations, triples, links can freely connect content
- peers collaborate (selflessly) for storing and exploring the index
- load balancing

Outline

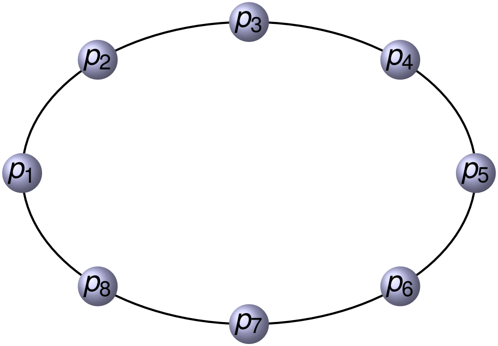
KadoP: DHT-based XML indexing

Joint work with:

Serge Abiteboul, Nicoleta Preda, Gabriel Vasile, Mohamed Ouazara (INRIA Gemo)
Neoklis Polyzotis, Chong Sun (UCSC) [AMP+08]

Content	XML documents
Queries	Conjunctive tree patterns (including keywords)
Index	Structural IDs of all nodes *and words*

KadoP: DHT-based XML indexing



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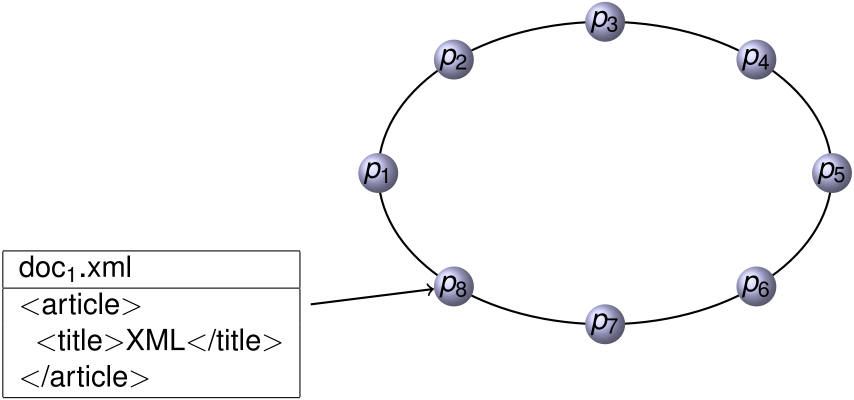

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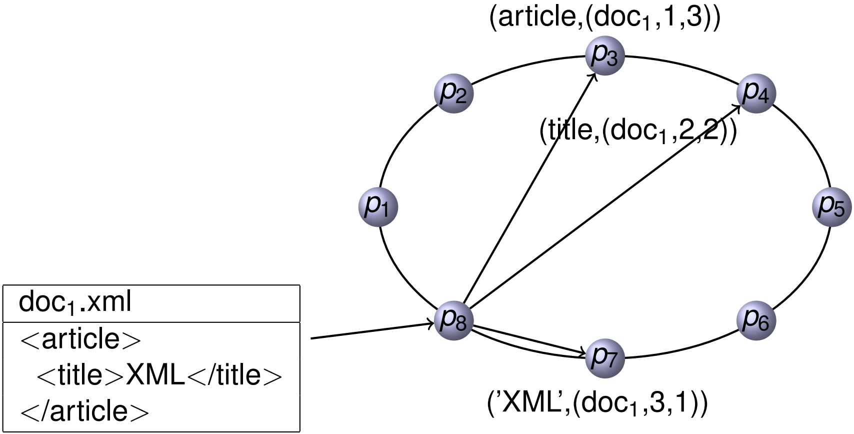

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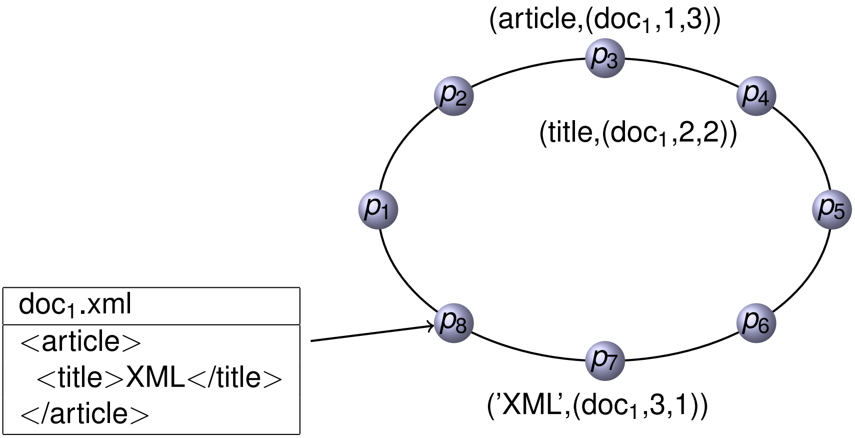

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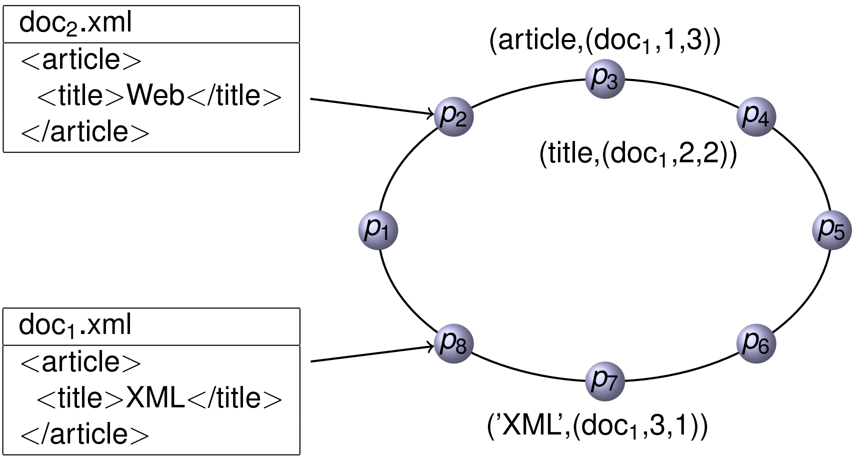

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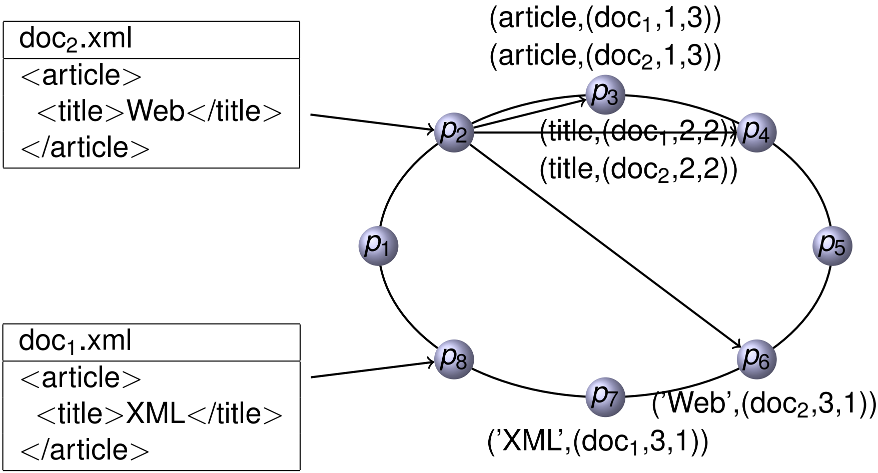

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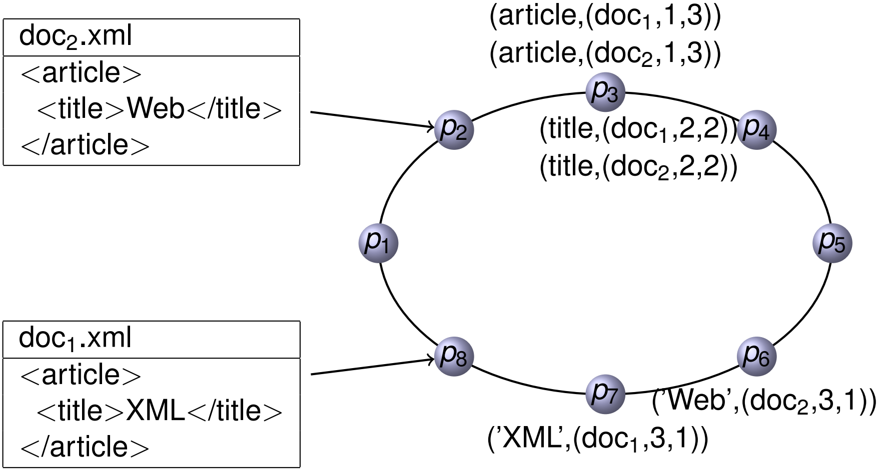

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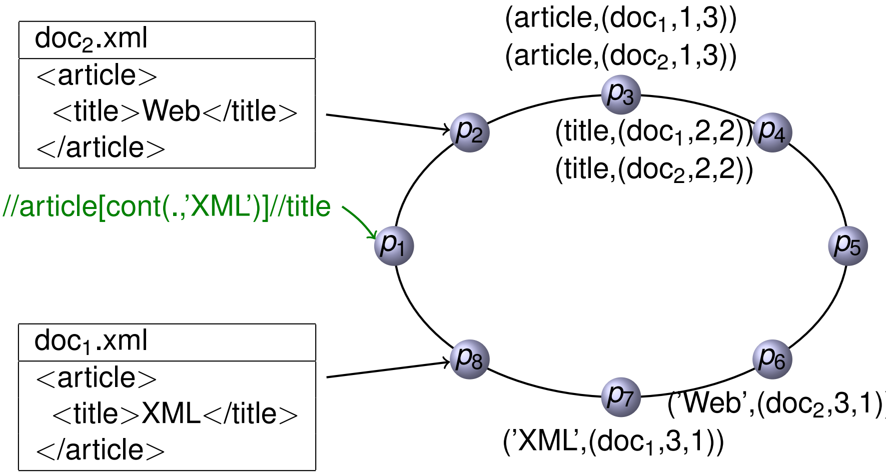

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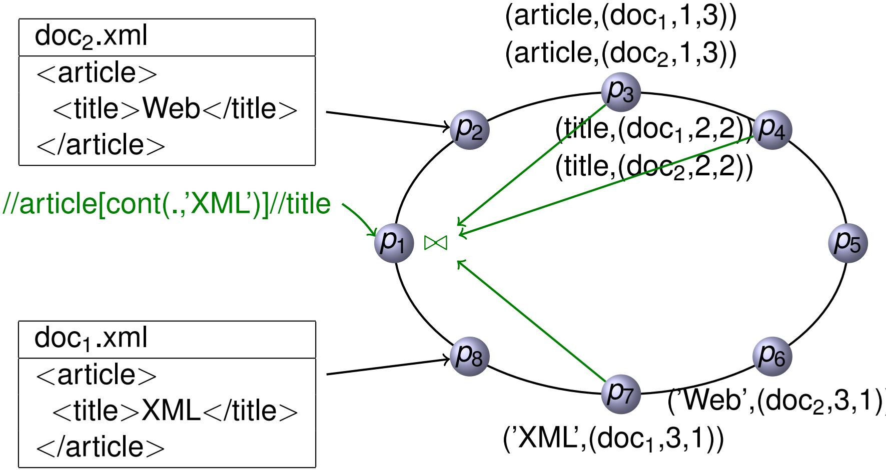

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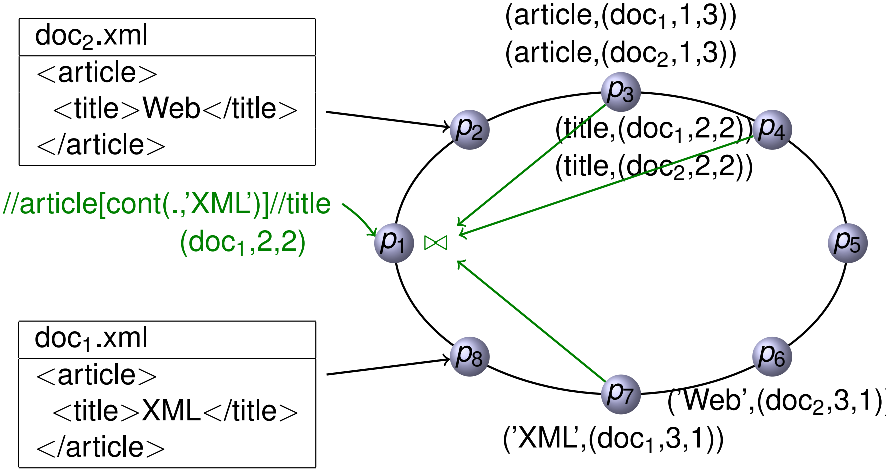

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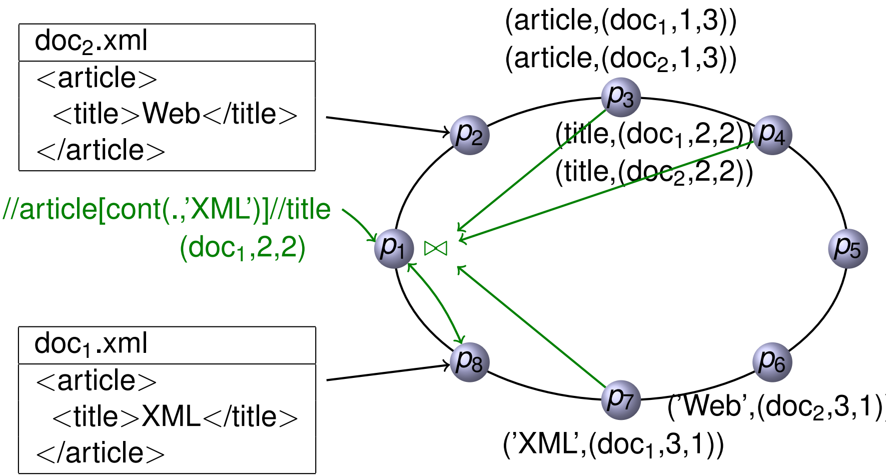

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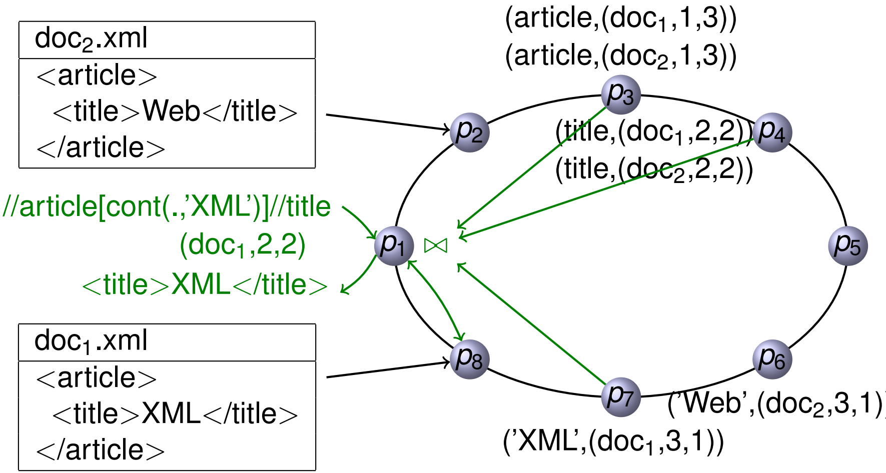


Scaling up KadoP

Engineering issues:

1. DHT values were (potentially large) posting lists; DHT store would not cope
   - simplistic XMLized storage
   - *gzip* compression
   - re-implemented
2. Blocking *get* operation; implemented block-based, pipelined method

Scalability issue: longest posting list involved in a query is the bottleneck

- long posting list = frequent term; known problem [LHSH04]
- organized posting lists in distributed B-tree style $\Rightarrow$ parallelized posting list transfers

Scaling up KadoP

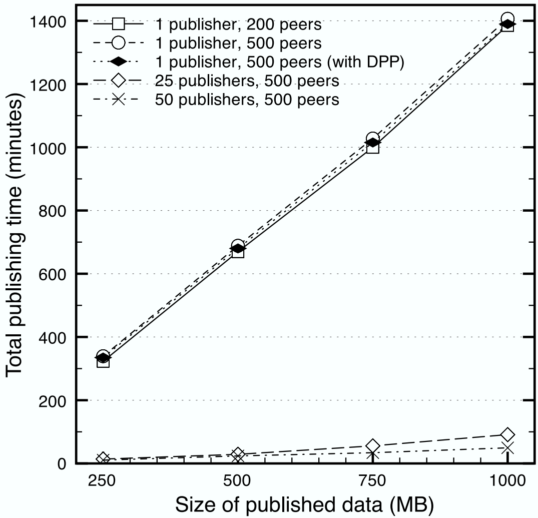
Scalability issue:

To compute //a//b, KadoP transfers the complete posting lists of //a and //b.

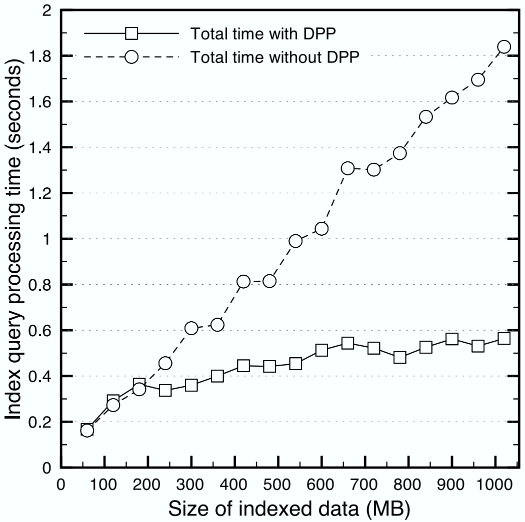
Bloom Filters for KadoP

- Semijoin-like idea
- Posting lists are ordered ⇒ compact representation of the interval covered by //a in the Bloom Filter of //a
- Reduce the transferred list //b by the Bloom Filter of //a
- Similar ancestor reduction

KadoP indexing experiments on Grid5K



KadoP querying experiments on Grid5K



Lessons learned with KadoP

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- (Some) DHTs were not built for intensive, detailed indexing. This somehow improved with time.
- Indexing takes time (orders of magnitude *wrt* first try)
- Parallelism a big plus

1. Introduction
2. KadoP XML indexing
   - Indexing and query processing
   - Scaling up
3. **ViP2P: mat. views on DHTs**
   - Algebraic query rewriting in ViP2P
   - View materialization
   - View indexing
   - Query rewriting
4. Summary

ViP2P: views in peer-to-peer

Joint work with:

Spyros Zoupanos, Alin Tilea, Konstantinos Karanasos, Silviu Julean, Julien Leblay (INRIA Gemo)

ViP2P: views in peer-to-peer

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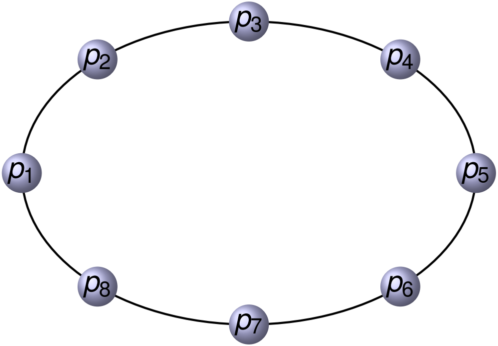
Materialized XML views on a DHT

- Declare tree pattern XML views over the network data
- Fill in the views with XML data
- Answer tree pattern queries using the existing views
  - View definition lookup
  - Query rewriting ⇒ logical plan
  - Execution of a (distributed) physical plan

ViP2P architecture



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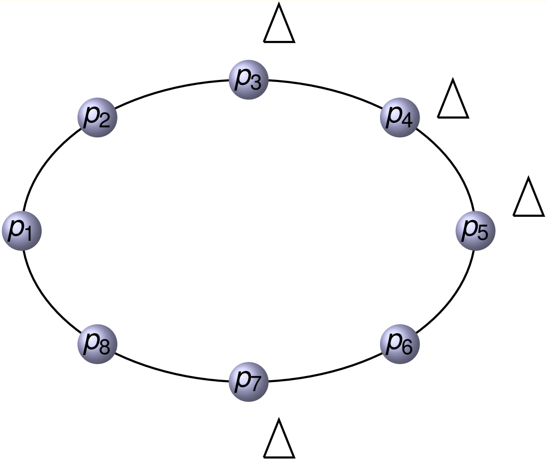

The peers may store:

- documents

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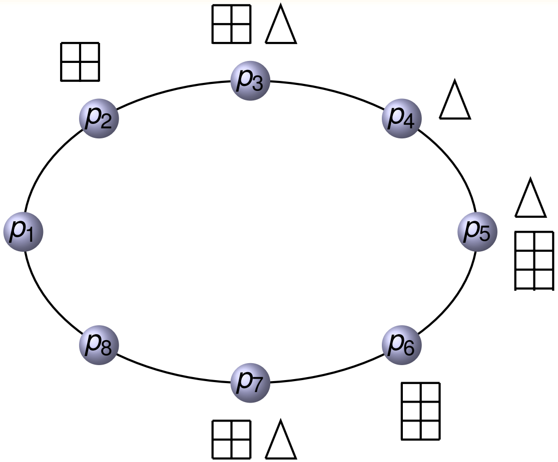

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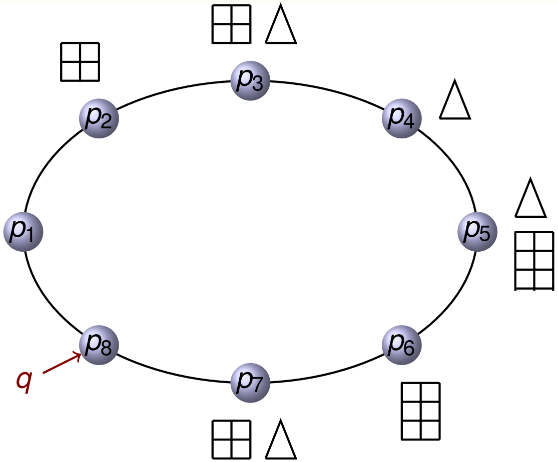
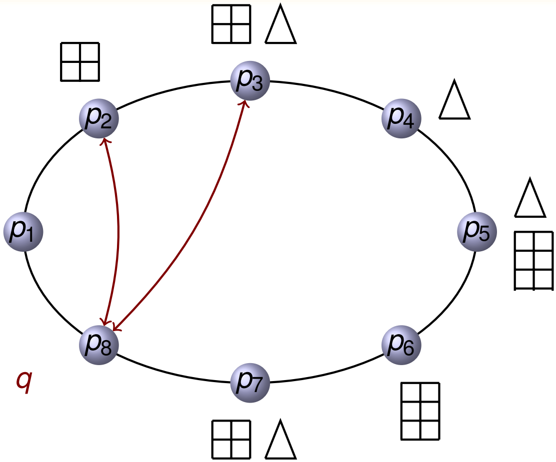


When q arrives:

ViP2P architecture



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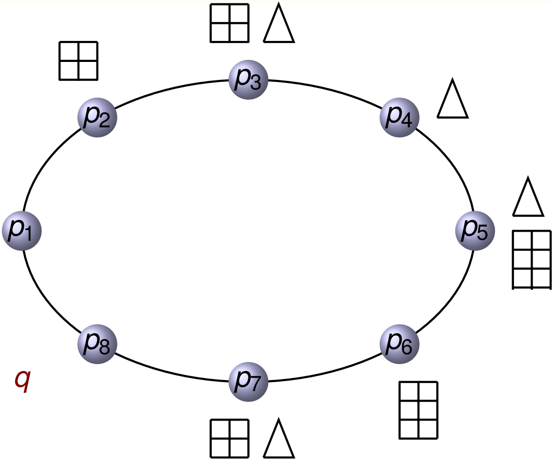

When q arrives:

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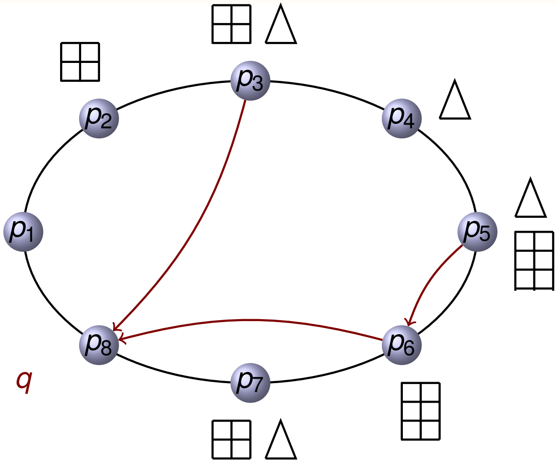

When q arrives:

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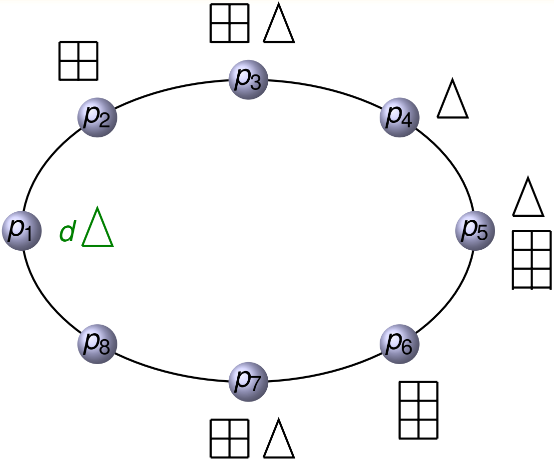

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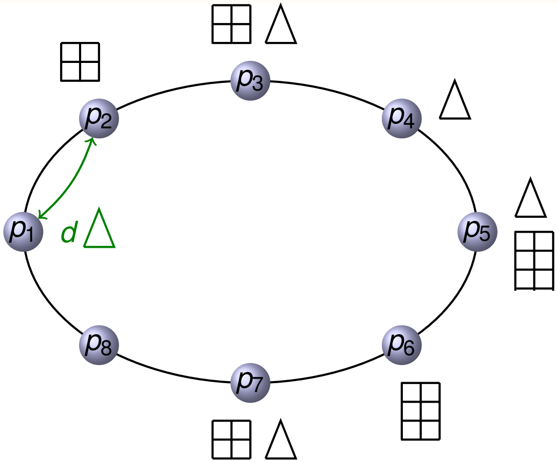

When d arrives:

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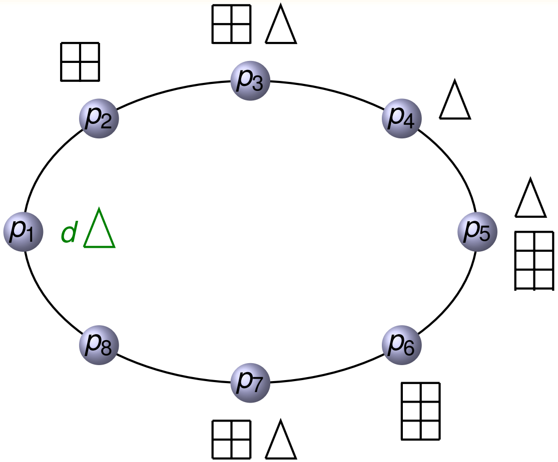

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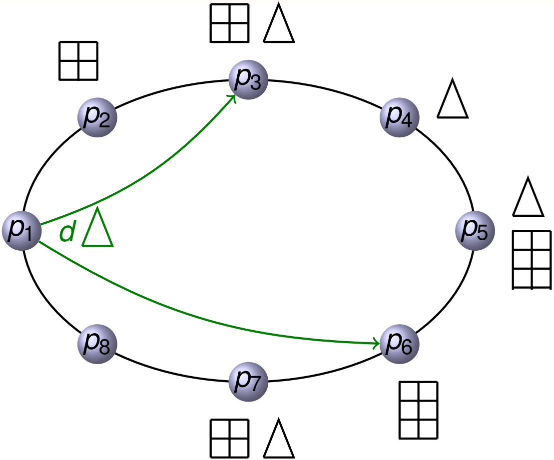

When d arrives:

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- send results

Tree pattern language for views and queries

a_{cont}

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$$\begin{array}{c} a_{id} \\ | \\ b_{val} \end{array}$$

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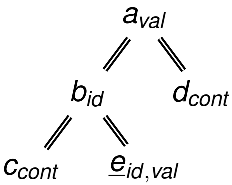
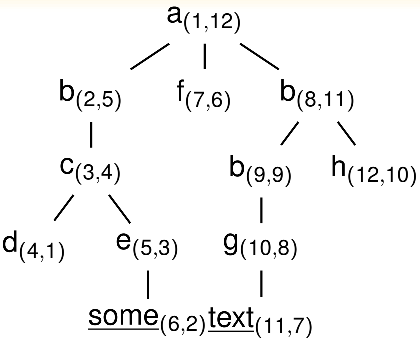
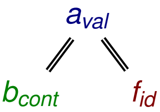


Tree pattern semantics





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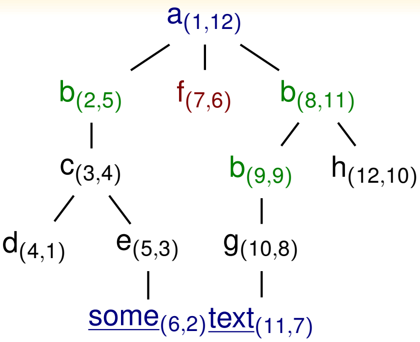

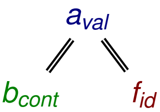

a_{val}	b_{cont}	f_{id}

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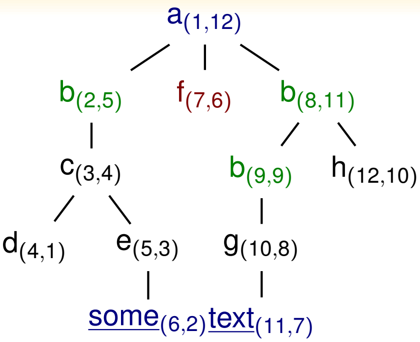

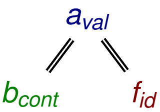

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some text	<c><d/><e>some</e></c>	(7,6)

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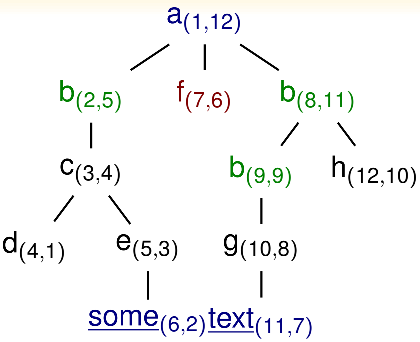

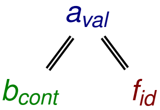

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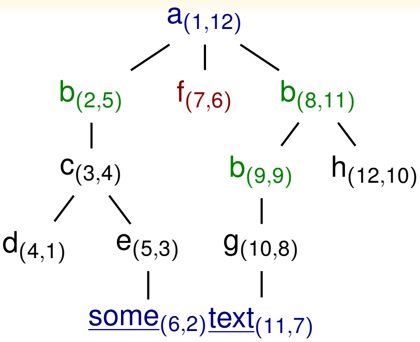

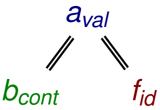

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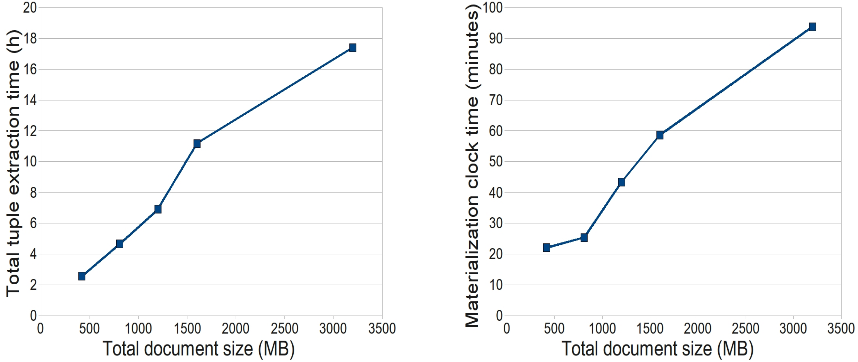
View materialization

1. Peer p has a view v, peer p_d publishes a document d
2. p indexes v on the DHT by the v labels
3. p_d looks up the labels and keywords of $d \Rightarrow$
   a superset of all the views v to which d contributes
4. p_d evaluates $v(d)$ for each v, sends the results to the peer storing v

View building

2000 XMark documents and 500 views (70 views contribute to all the documents)



Indexing views for query rewriting

Query q asked at peer $p \Rightarrow p$ needs to find useful views

4 different strategies

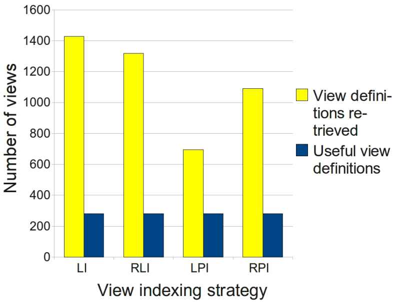
- **Label indexing** (LI):
  - Index v by each v node label
  - Look up by all node labels of q
- **Return label indexing** (RLI):
  - Index v by the labels of all v nodes which project some attributes
  - Look up by all node labels of q

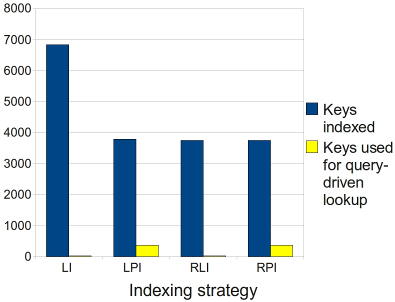
Indexing views for query rewriting

- **Leaf path indexing** (LPI):
  - Index *v* by all its distinct root-to-leaf paths
  - Look up all the sub-paths of root-to-leaf *q* paths
- **Return Path Indexing** (RPI):
  - Index *v* by all rooted paths ending in a return node
  - Look up all the sub-paths of root-to-leaf *q* paths

View look up performance

We used 1440 views related to but different from query *q*





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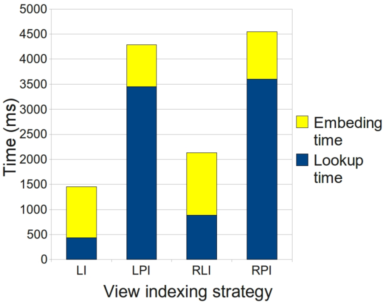

Finding query rewritings

Rewriting = equivalent algebraic expression over the views

Idea:

Compute covers of the query nodes with the view nodes.

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q	v_1	v_2
a_{id}		
$\|$		
b_{id}	a_{id}	b_{id}

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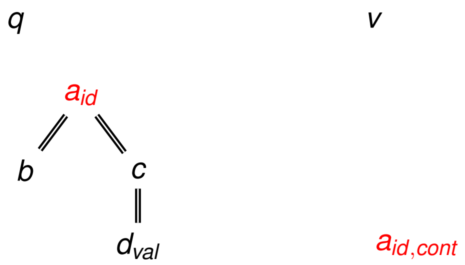

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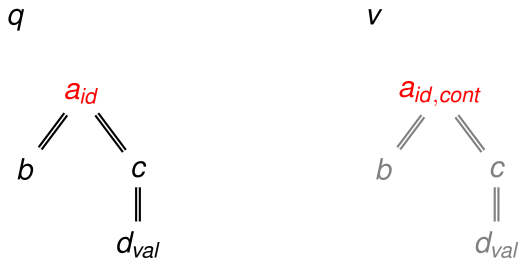

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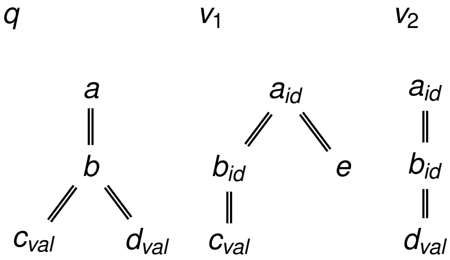

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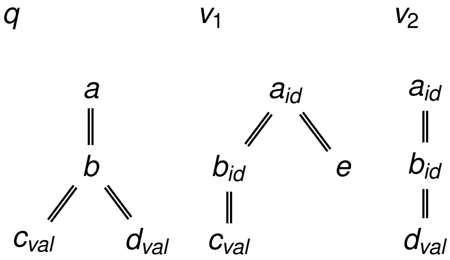

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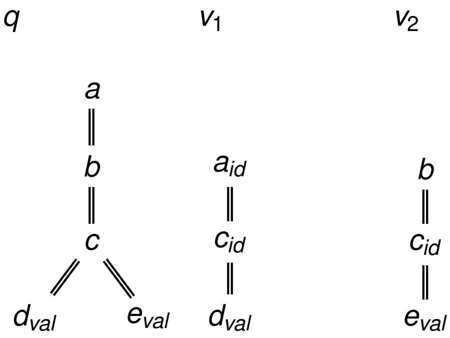

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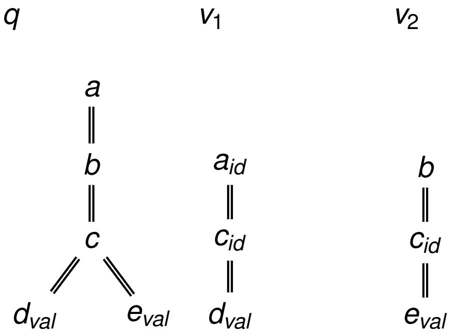

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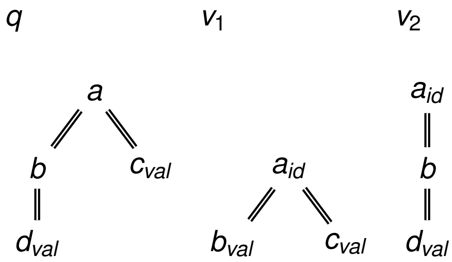

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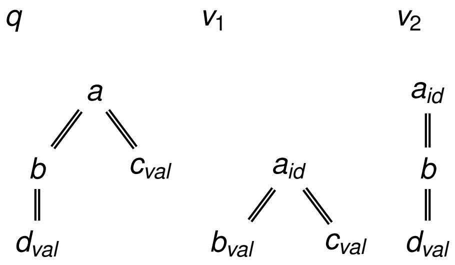

No rewriting

Rewriting algorithms

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SE (Subset Enumeration)

- Try all view subsets

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Use smaller partial rewritings to build bigger ones

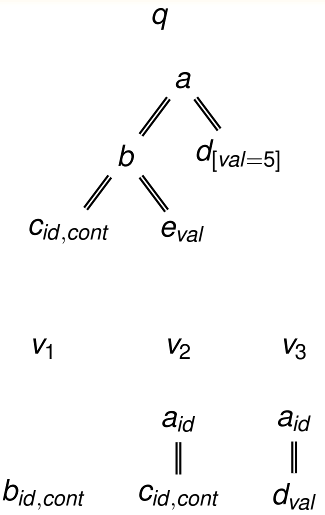
DPR (Dynamic Programming Rewriting)

- Dynamic programming style

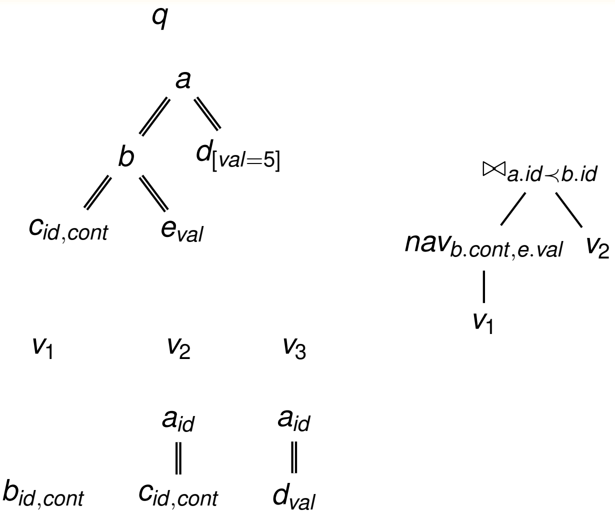
DFR (Depth First Rewriting)

- Greedy based on the biggest query coverage

Bottom-up rewriting



Bottom-up rewriting



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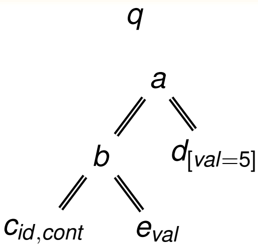

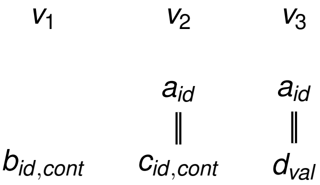

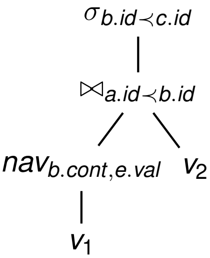

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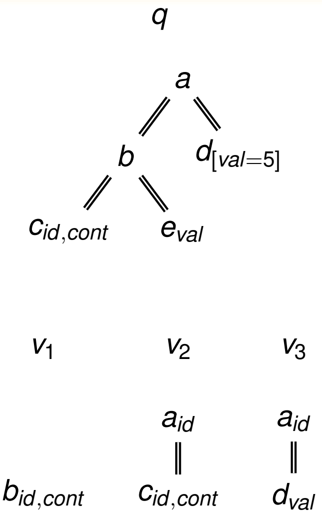

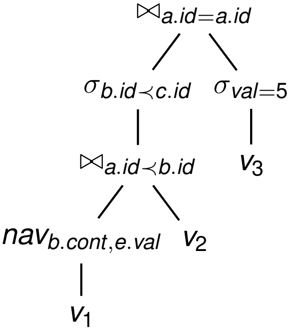

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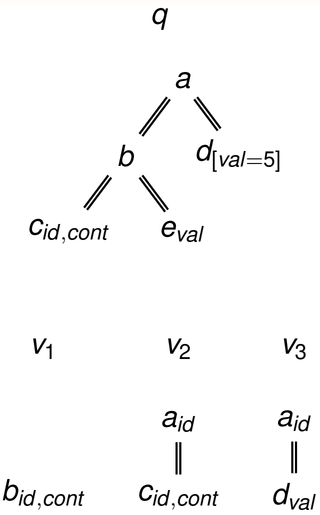
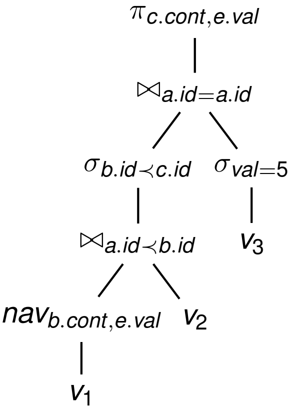




Rewriting algorithms trade-offs

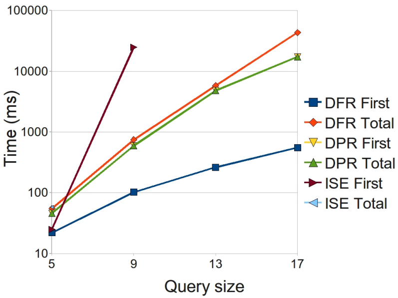
SE, ISE, DPR and DFR are correct and complete.
They produce all minimal canonical rewritings of q given $\mathcal{V}$.

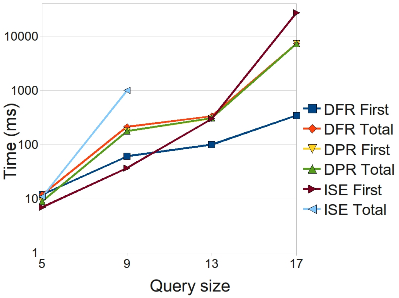
Heuristic for quality of rewriting: number of views

- DFR typically finds one rewriting fast. Not guaranteed to be the best
- ISE, DPR find the best rewriting first, but may take much longer

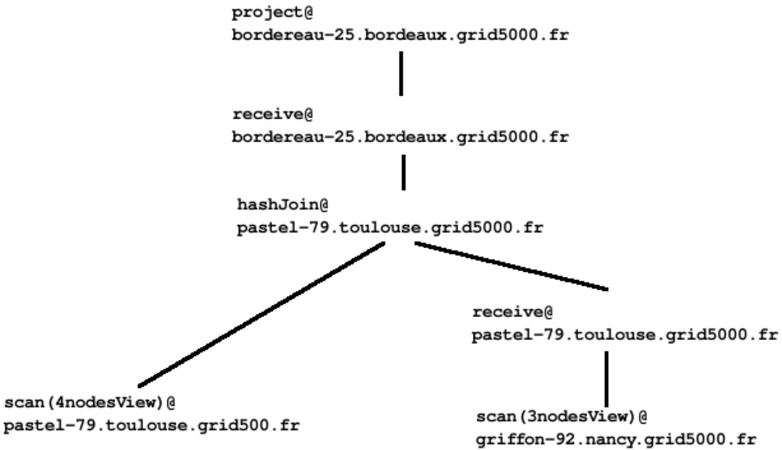
Could also consider closeness among views, query peers

Performance of rewriting algorithms

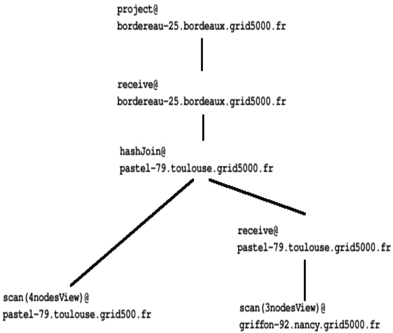


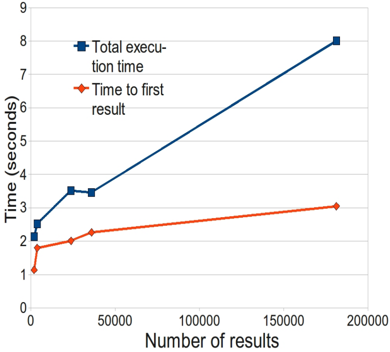


Query execution: sample plan



Query execution





Outline

Closest related works

DHT-based sharing of relations [LHSH04]

DHT-based XML indexing [GWJD03, BC06, SHA05, AMP+08]

DHT-based shared XML caches [LP08]

XPath query rewriting [BOB+04, XO05, CDO08, TYÖ+08]

- XPath: wildcard *, union
- Rewritings: intersection, navigations, joins

Rewriting with structural constraints [ABMP07]

- Centralized setting
- Dataguide [GW97] constraints

Layered architecture for Web content warehousing [AAC+08]

RDF querying and reasoning on DHT [KMK08, LIK06]

Perspectives and ongoing work

Our work:

- Consolidate the lower layers (reliability)
- Native support for RDF, annotated documents, mappings, inter-document links
- RDF views

Other issues:

- Persistence model
- Benchmarks, repeatability
- Connection with other annotated databses

Thank you!

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[ABMP07] **Andrei Arion, Véronique Benzaken, Ioana Manolescu, and Yannis Papakonstantinou.**
Structured materialized views for XML queries.
In *VLDB*, pages 87–98, 2007.

[AMP+08] **Serge Abiteboul, Ioana Manolescu, Neoklis Polyzotis, Nicoleta Preda, and Chong Sun.**
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[BC06] **Angela Bonifati and Alfredo Cuzzocrea.**

Storing and retrieving XPath fragments in structured P2P networks.
Data Knowl. Eng., 59(2), 2006.

[BOB+04] **A. Balmin, F. Ozcan, K. Beyer, R. Cochrane, and H. Pirahesh.**
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In *VLDB*, 2004.

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[GWJD03] **L. Galanis, Y. Wang, S.R. Jeffery, and D.J. DeWitt.**
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In *International Semantic Web Conference*, pages 399–413, 2006.

[LP08] **Kostas Lillis and Evaggelia Pitoura.**
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[SHA05] **Gleb Skobeltsyn, Manfred Hauswirth, and Karl Aberer.**
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[TYÖ+08] **Nan Tang, Jeffrey Xu Yu, M. Tamer Özsu, Byron Choi, and Kam-Fai Wong.**
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