IQN Routing: Integrating Quality and Novelty for P2P Web Search

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Outline

P2P Systems

Became famous through file-sharing applications, like Gnutella, KaZAA, Napster.
Applications like:

- Internet telephony (e.g. Skype)
- Filesharing
- Pub/Sub

Question:

Is there an interesting and legal P2P application?

Motivation

Why P2P Web Search?

- Benefit from intellectual input from a large user community. (Bookmarks, click-streams, ...)
- Break information monopolies
- Coverage of the web
- Exploit mostly idle resources

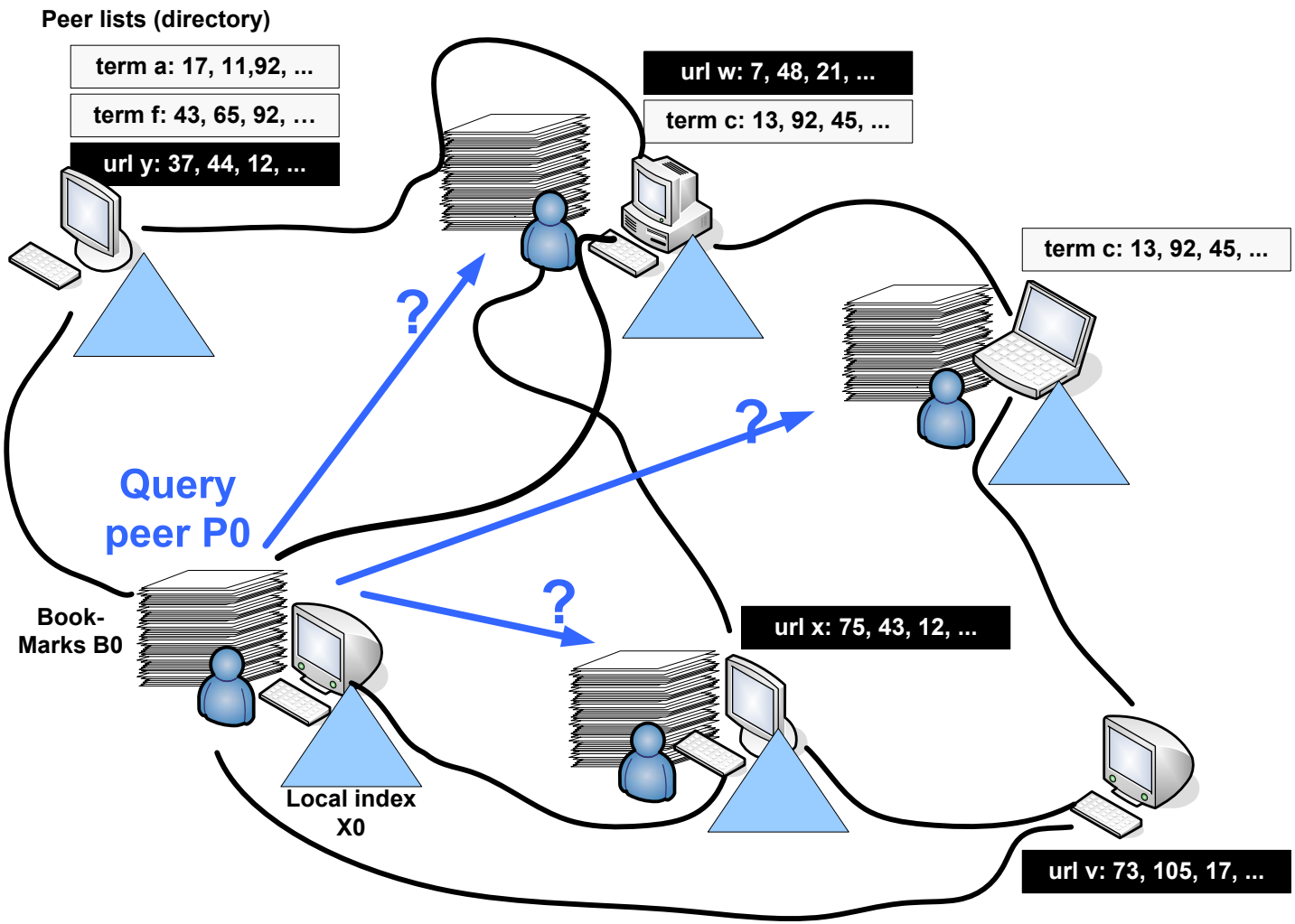
Related to distributed IR, but some additional aspects

- high dynamics
- each peer has its own collection
- peers are independently crawling the web

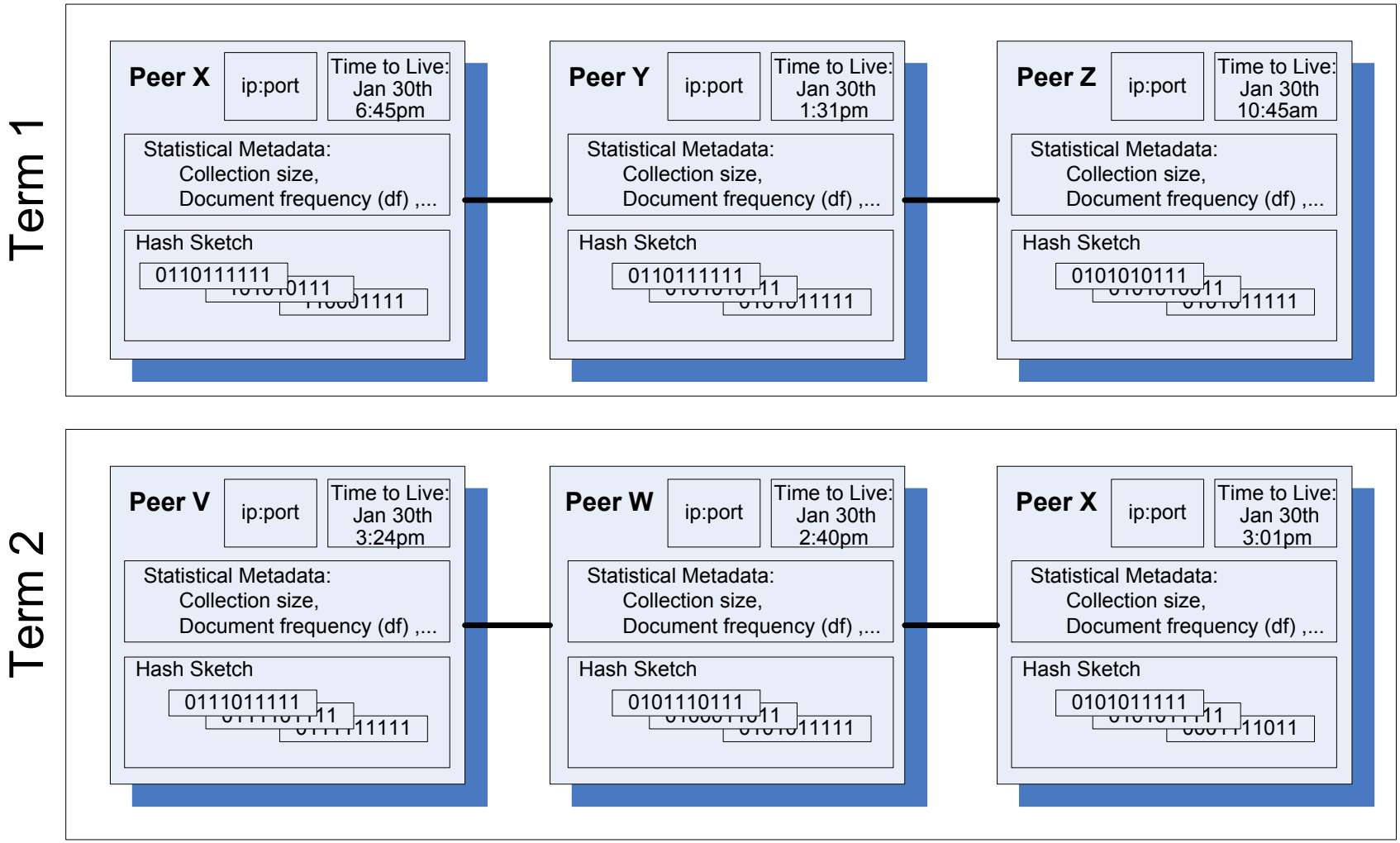
Minerva Design Fundamentals

- Peers with local collections, e.g., built by focused crawler. Tailored to the users' specific interest profiles.
- Peers share metadata about local indexes
- Form physically distributed *term* $\longrightarrow$ *peer* directory
- Layered on top of DHT
- Peers use directory to discover promising peers for query

Minerva System Architecture



Inside Peerlists ...



How to find promising Peers?

State of the art: Find peers with high quality documents.

Existing Strategies:

- based on per-term metadata
- combine metadata for all query terms
- select peers with highest expected result quality

Why Quality-Only is not Enough!

Problem:

Peers crawl the web independently.

$\longrightarrow$ **overlapping collections**

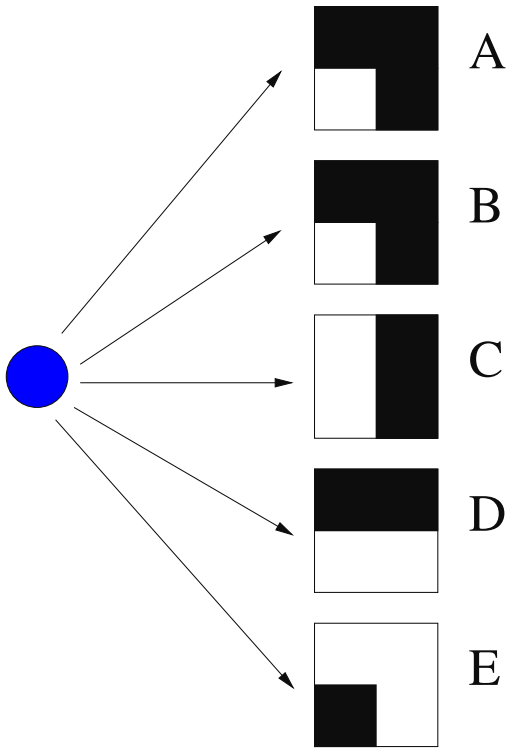
(For instance, cnn.com might have been crawled by a lot of peers)

Goal: Integrate Quality and Novelty (IQN).

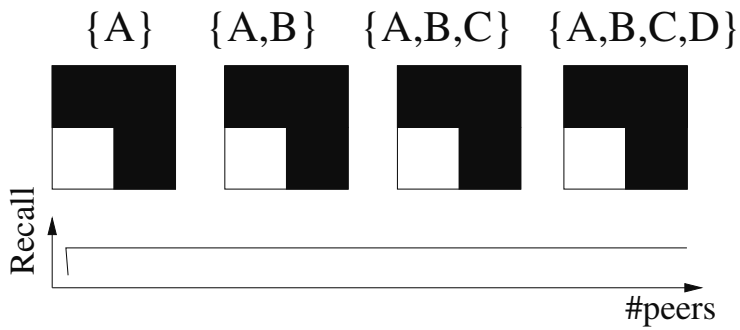
$\longrightarrow$ achieve high recall with fewer peers than traditional approaches

- **We define:** *Usefulness* $:=$ *quality* $*$ *novelty*

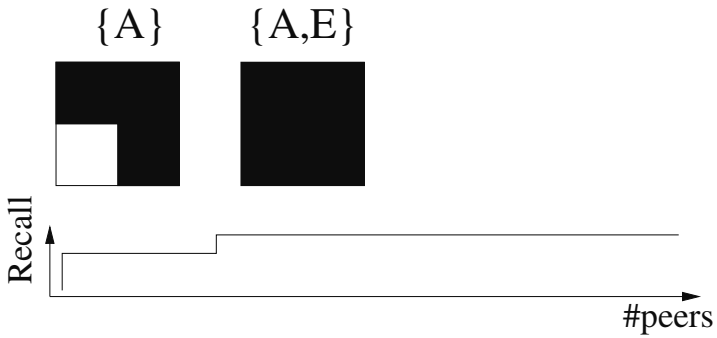
Example



naive routing strategy



overlap aware routing strategy



IQN Algorithm: Integrating Quality and Novelty

Extend per-peer, per-term meta-data with synopses that desribe local collections.

Select all peers to query a-priori

Based on statistics (not their actual query results).

- Choose first Peer X based on quality only $\rightarrow$ use X's per-query descriptor as initial representation of already seen documents.
- Then choose Peer Y with the highest usefulness w.r.t. the already seen docs.
- Merge representations for the peers selected so far and iterate.

Quality Prediction

Find best suitable peers based only on quality measures.

Most popular selection strategies:

- CORI (Callan et al.)
- GlOSS (Gravano et al.)
- Decision-theoretic framework (Fuhr)

Based on:

- document frequency
- maximum term frequency
- total number of distinct terms
- total number of documents

Novelty Prediction

Add statistics that allow novelty estimation.

We are interested in $|S_B - (S_A \cap S_B)|$

Two possible approaches:

- represent whole collection
- use separate representations for (term-specific) index lists

Term-specific representations allow query-specific overlap estimation!

Multi-keyword queries

Combine per-term descriptors of a peer to form per-query descriptor

Data Synopses

Searching for appropriate data synopses ...

Requirements:

- Compact
- Highly accurate
- (.....)

- Bloom Filter
- Hash-Sketches
- Min-wise independent permutations

Bloom Filter

Bit-array of length m. Insert documents by settings bits using k hash functions.

Membership-Queries: A document is contained in a Bloom filter if the corresponding are set. Problem: false positives

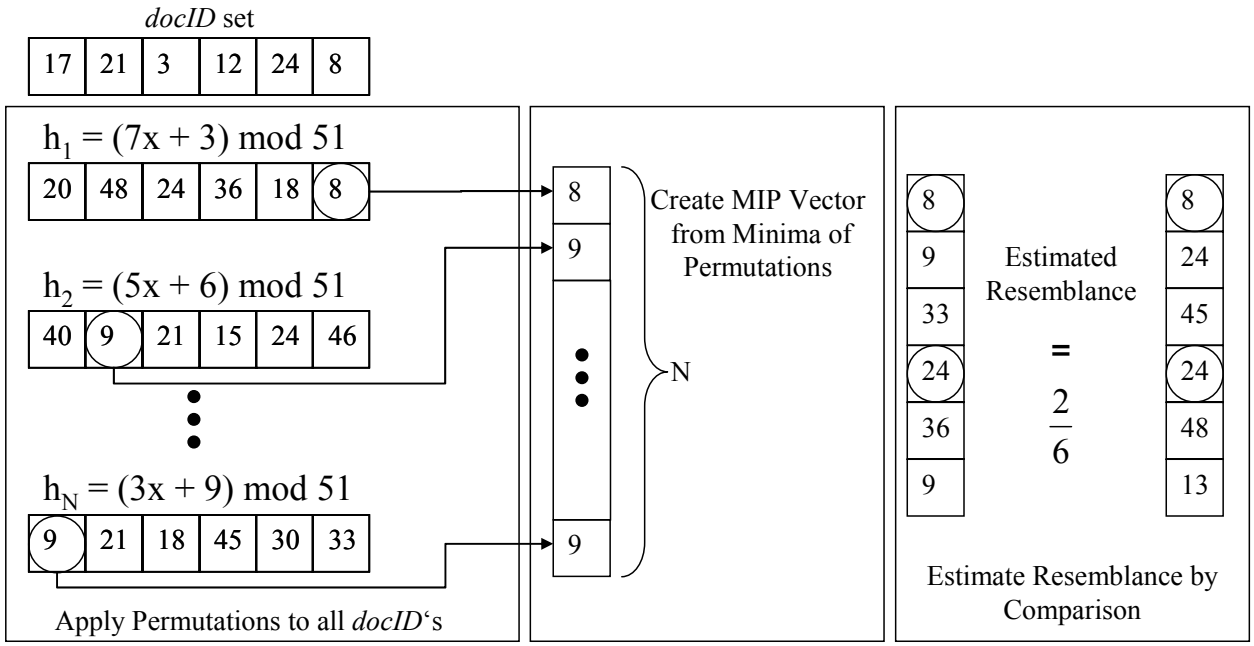
$$pfp \approx (1 - e^{-kn/m})^k$$

Hash Sketches

- Pseudo-uniform hash function h
- Apply h to all documents and record the position of the least significant (leftmost) 1-bit in the binary representation in a bitmap vector $B[0 \ldots L-1]$.
- Idea: $B[0]$ will be set approximately $\frac{n}{2}$ times, $B[1]$ approximately $\frac{n}{4}$ times, ...
- More formally: The leftmost 1 bit at position k provides an estimation of $log(n)$.

Min-wise independent Permutations (MIPS)

N independent permutations



Given $|S_A|$, $|S_B|$, and the resemblance $R = \frac{|S_A \cap S_B|}{|S_A \cup S_B|}$, we estimate the overlap between S_A and S_B as $|S_A \cap S_B| = \frac{R*(|S_A|+|S_B|)}{(R+1)}$.

Aggregate Synopses

Remember: After having selected the best peer in an iteration of the IQN method, we need to update the reference synopsis.

MIPs

Given $MIPs_A[]$ and $MIPs_B[]$, one can form $MIPs_{A \cup B}[]$ as follows $MIPs_{A \cup B}[i] = min\{MIPs_A[i], MIPs_B[i]\}\ \forall i : 1 \leq i \leq n$.

Hash Sketches

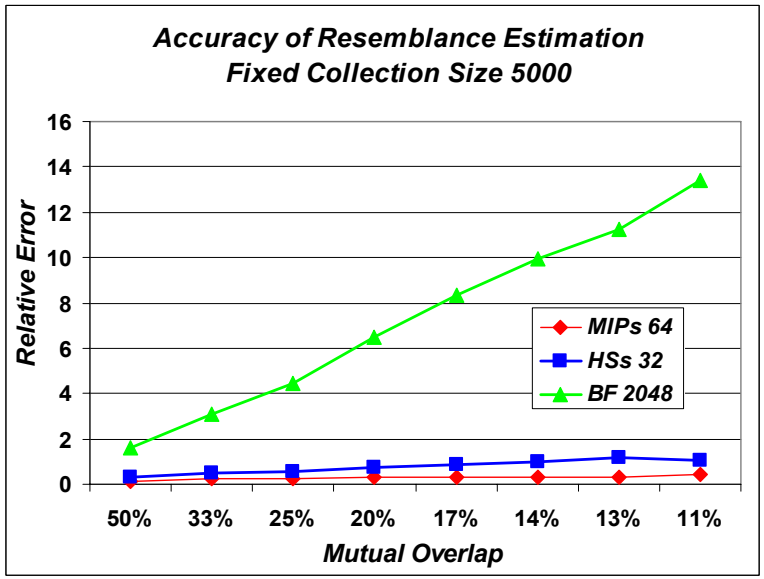
straight forward: use the bit-wise OR operation

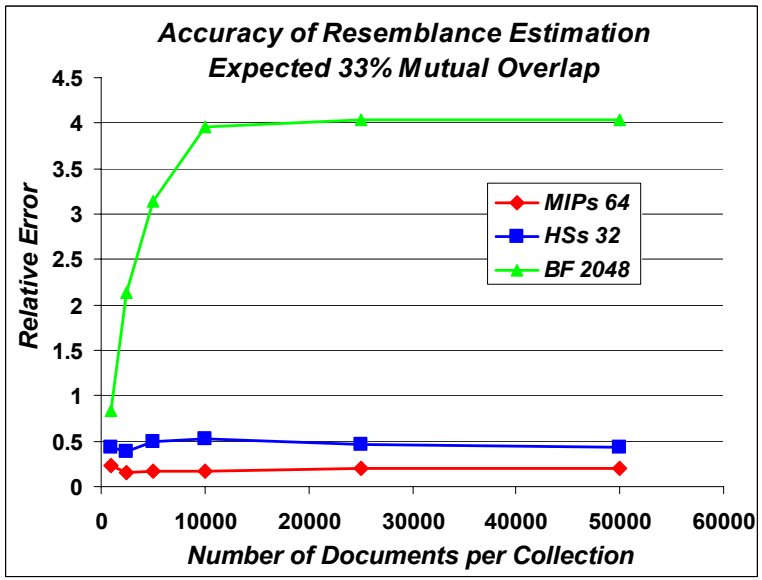
Bloom Filter

Again, bit-wise OR: $BF_{A \cup B}[i] = BF_A[i]\ OR\ BF_B[i]\ \forall i : 1 \leq i \leq n$.

Accuracy Evaluation

Experiments on synthetic data-sets:

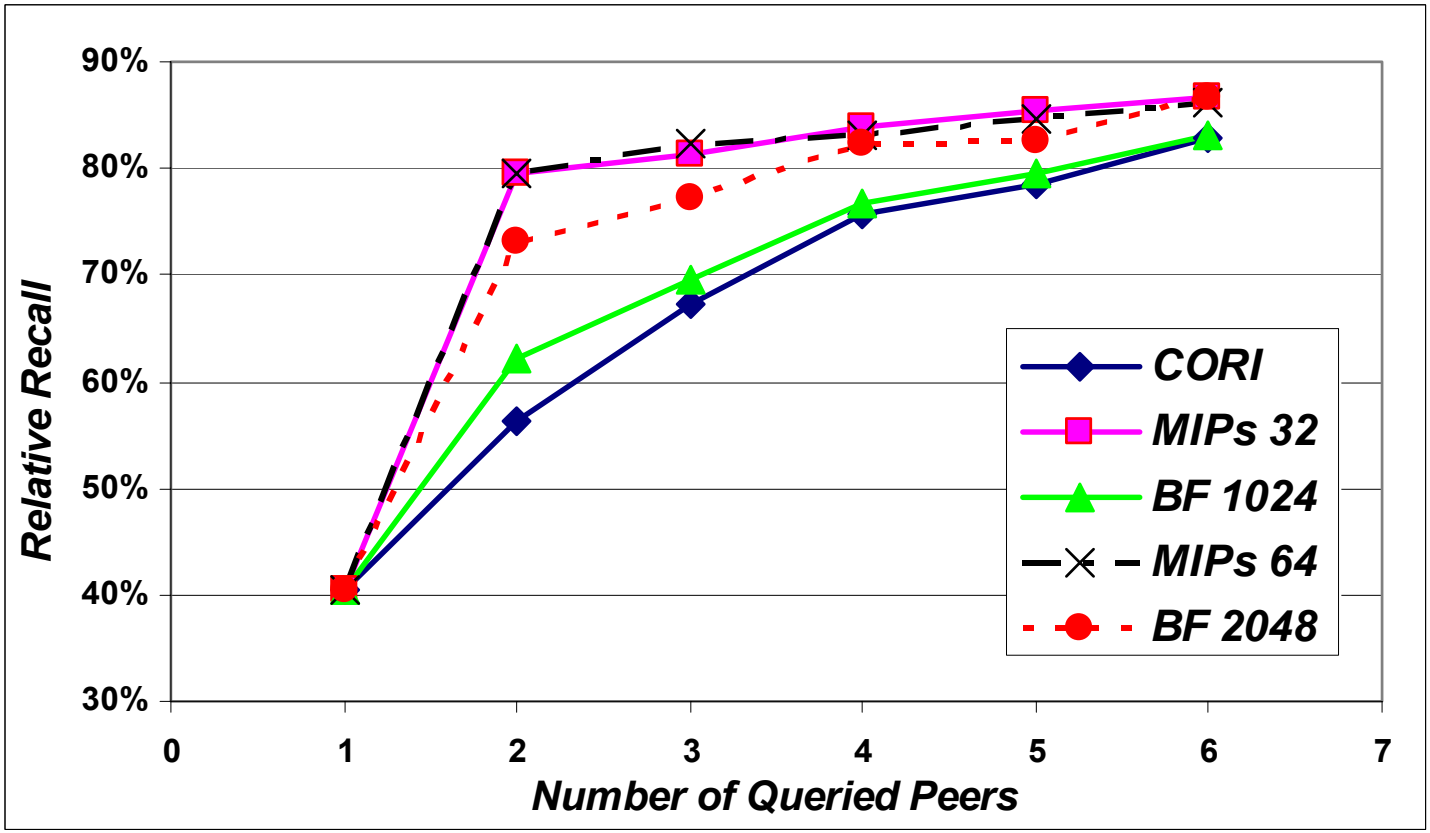




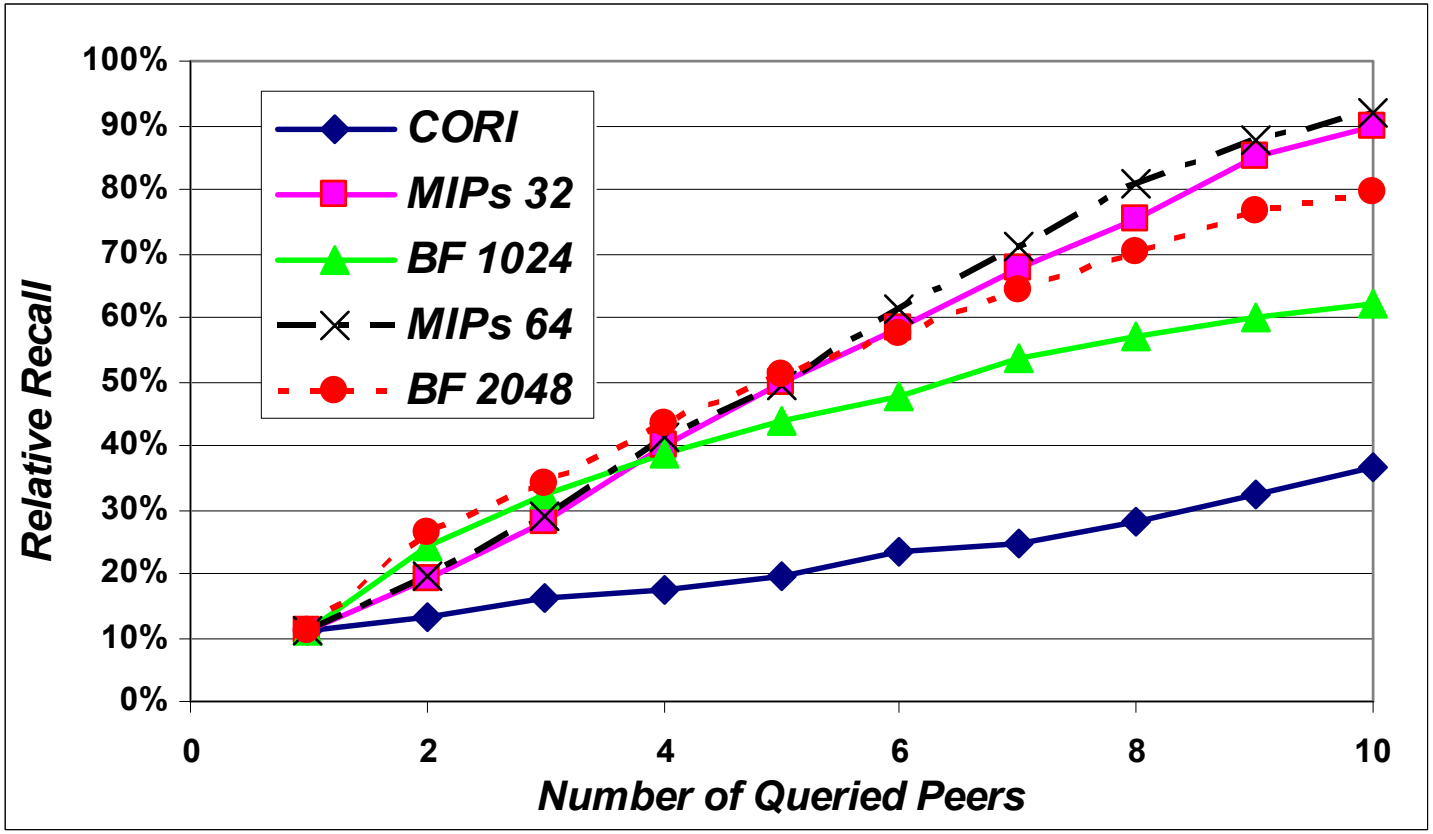
Experimental Setup (2)

- Routing Strategies
  - pure CORI
  - overlap aware CORI using MIP based overlap prediction
  - overlap aware CORI using Bloom Filter based overlap prediction
- Datasets:
  - Subset of the official TREC .GOV collection split into disjoint fragments. Building peers using
    - sliding window over these fragments
    - mirrored collections
    - ...
  - Queries: 50 TREC-2003 Web queries, e.g. juvenile delinquency
  - Measure the recall w.r.t. the query results of the whole document set (relative recall)

Experimental Results: $\binom{6}{3}$ Benchmark



Experimental Results: Sliding Window Benchmark



Conclusion and Outlook

Conclusion

- Comprehensive performance evaluation of MIPs, Bloom Filter, and Hash-Sketches
- Experiments on real-web data showing the impact of overlap aware query routing

Future Work

- Evaluation of the usage of histogram enhanced synopses
- Adaptive synopses lengths
- System behavior under churn