A Hierarchical Semantic Overlay for P2P Search

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Outline

- Motivation
- Our approach
  - Overview
  - Data model
  - Ontology design
  - Semantic clustering
  - Peer identification
  - Top-level overlay
  - Low-level overlay
- Some preliminary results
- Conclusion

Motivation

- *Unstructured* P2P systems
  - Pros: do not impose any structure on the data; easy to handle the dynamic changes of peers and their data; low overlay maintenance cost, etc.
  - Cons: flooding-based routing algorithm generates large amount of redundant messages; not scalable.
- *Structured* P2P systems
  - Pros: efficient routing; good scalability, etc.
  - Cons: data placement and network topology are tightly controlled; high overlay maintenance cost.
- *Hybrid* P2P systems
  - Combine the advantages of both *unstructured* and *structured* P2P systems
  - Our approach - *A Hierarchical Semantic Overlay Network* falls in this category

Overview of Our Approach

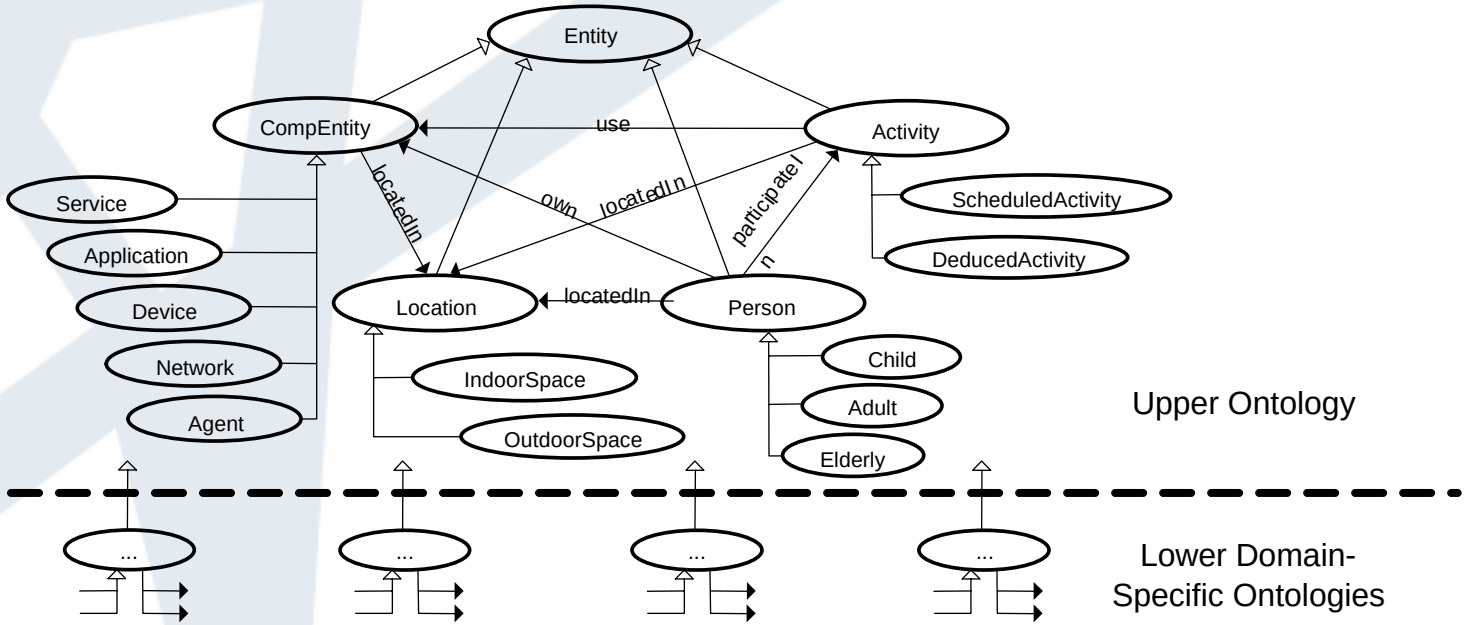
- Ontology-based two-level semantic overlay
  - Top-level overlay: peers are grouped into a semantic cluster based on ontologies; semantic clusters are organized into a one-dimensional ring space.
  - Low-level overlay: semantic clusters can be organized into *unstructured* overlay or *DHT-based* overlay.
- Abstract data semantic based on ontologies
  - Hierarchical design for ontologies
- A DHT-based inter-cluster routing algorithm

Data Model

- The basic model – an RDF triple
  - <*subject predicate object*>
  - E.g., <*socam:TaoGu socam:homeAddress "XYZ"*>, *or* <*socam:TaoGu socam:locatedIn socam:LivingRoom*>
- Machine-understandable, -processable, good interoperability. Limit to representation methods.

Ontology Design

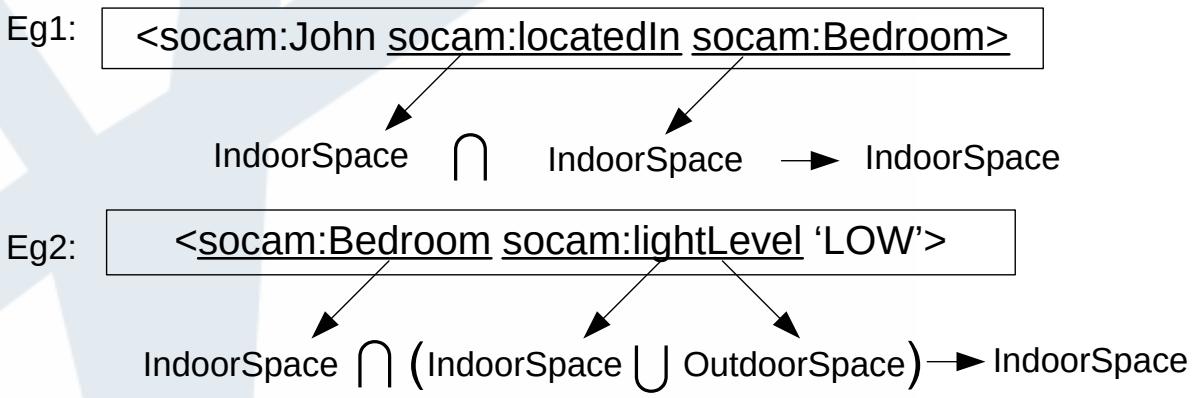
- Two-level hierarchy in the ontology design
  - The upper ontology defines common concepts in a computing/application domain
  - Lower ontologies define details/own concepts.
- Why two-level hierarchy?
  - A peer defines/stores its own lower ontology based on context data, no need to store all – smaller metadata size.
  - It allows the construction of a semantic P2P overlay network.



Ontology-based Semantic Clustering

- The basic principle:
  - The leaf nodes in the upper ontology are used as semantic clusters.
  - If the predicate of a data triple is of type *ObjectProperty*, we use *<pred obj>* pair
  - If the predicate of a data triple is of type *DatatypeProperty*, we use *<sub pred>* pair

Context data triples:



Peer Identification

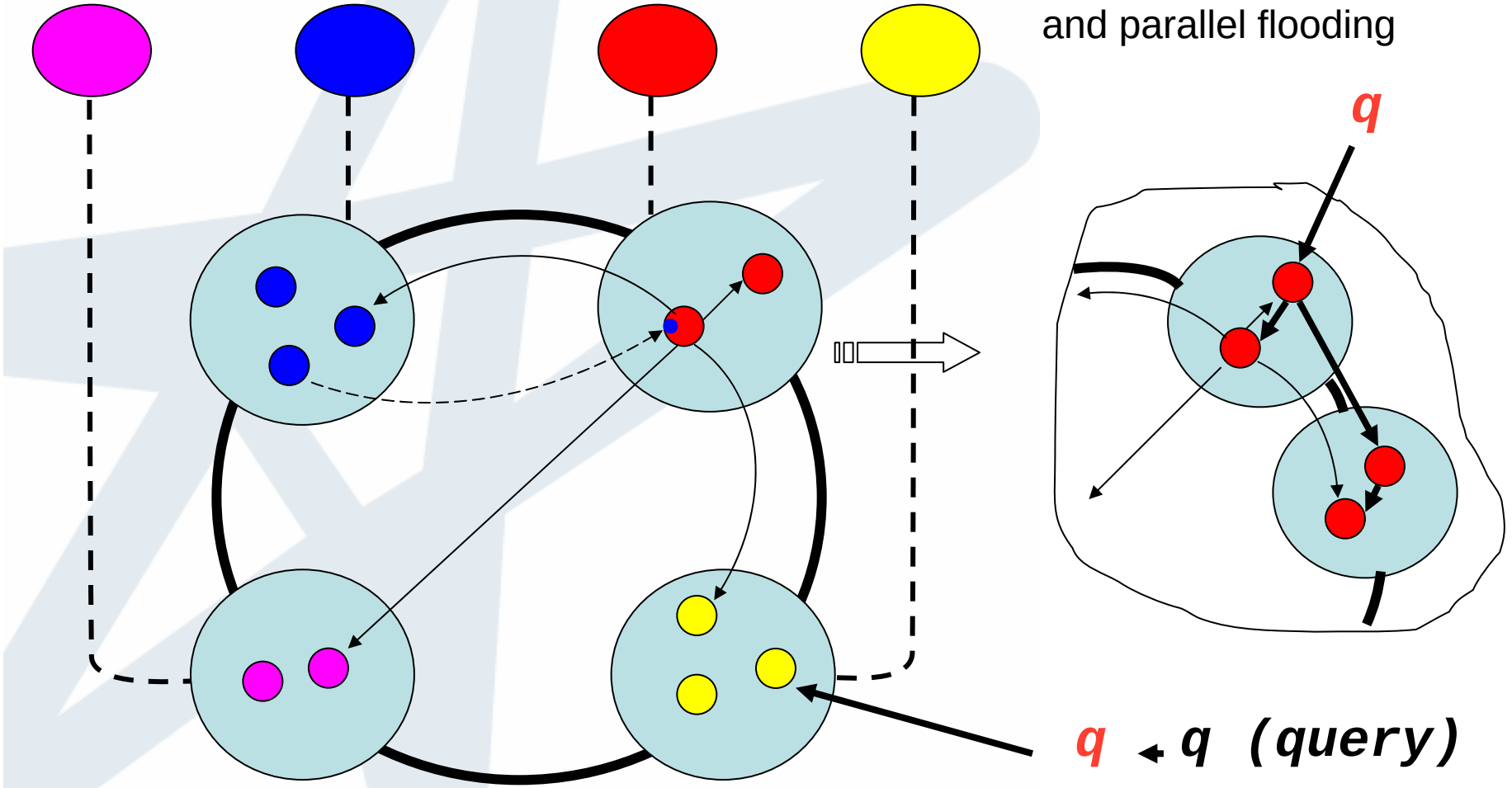
- Semantic Cluster ID
  - *sid = hash("a leaf node in the upper ontology")*
- Peer ID
  - *peer id = [$hash_m$("a leaf node in the upper ontology")][$hash_n$ ("IP address")]*

Top-level Overlay

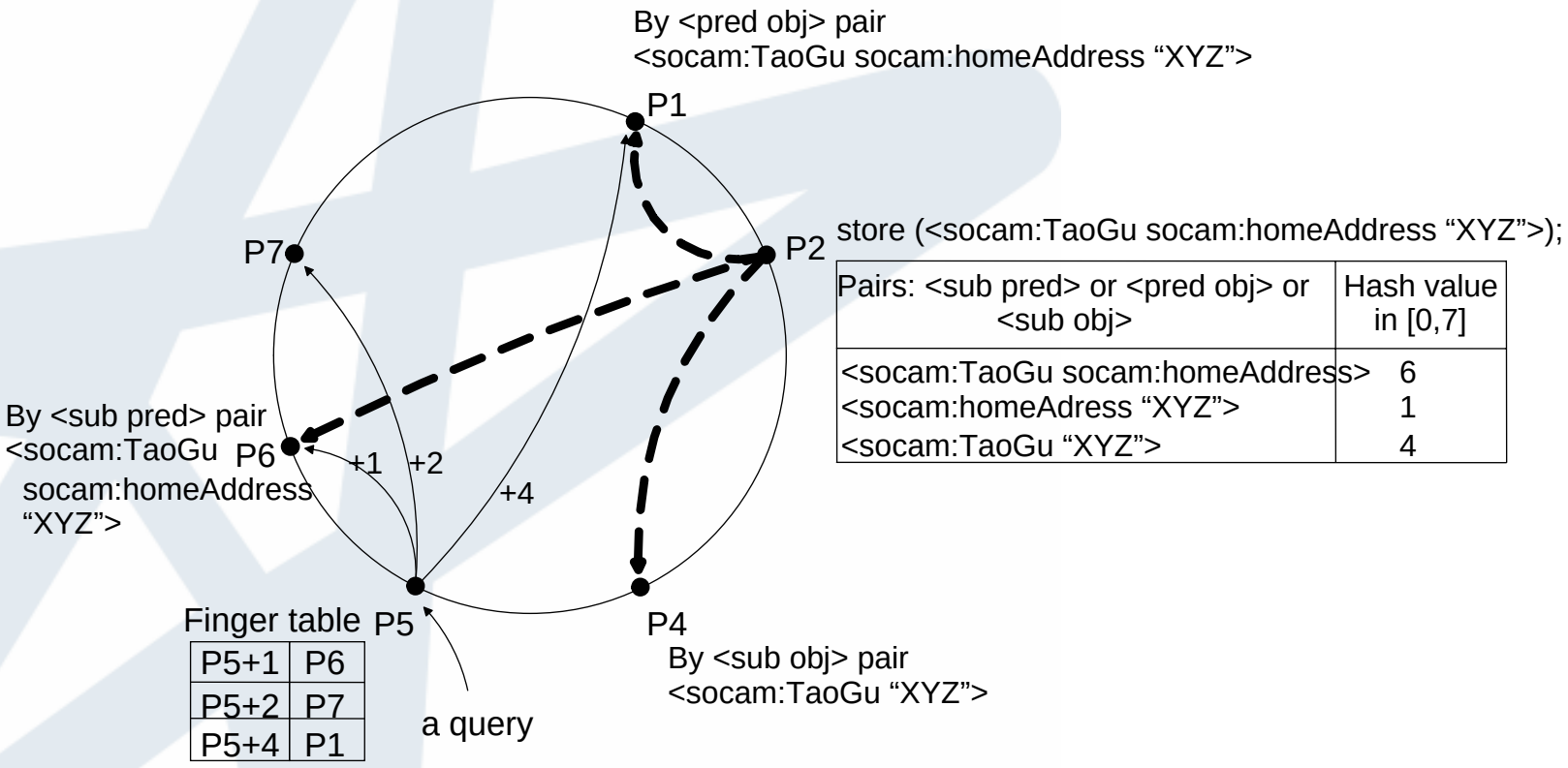
semantic clusters

(leaf nodes in the upper ontology)

A *unstructured* low-level overlay with cluster splitting/merging and parallel flooding



A Chord-based Low-level Overlay



store (<socam:TaoGu socam:homeAddress “XYZ”>);

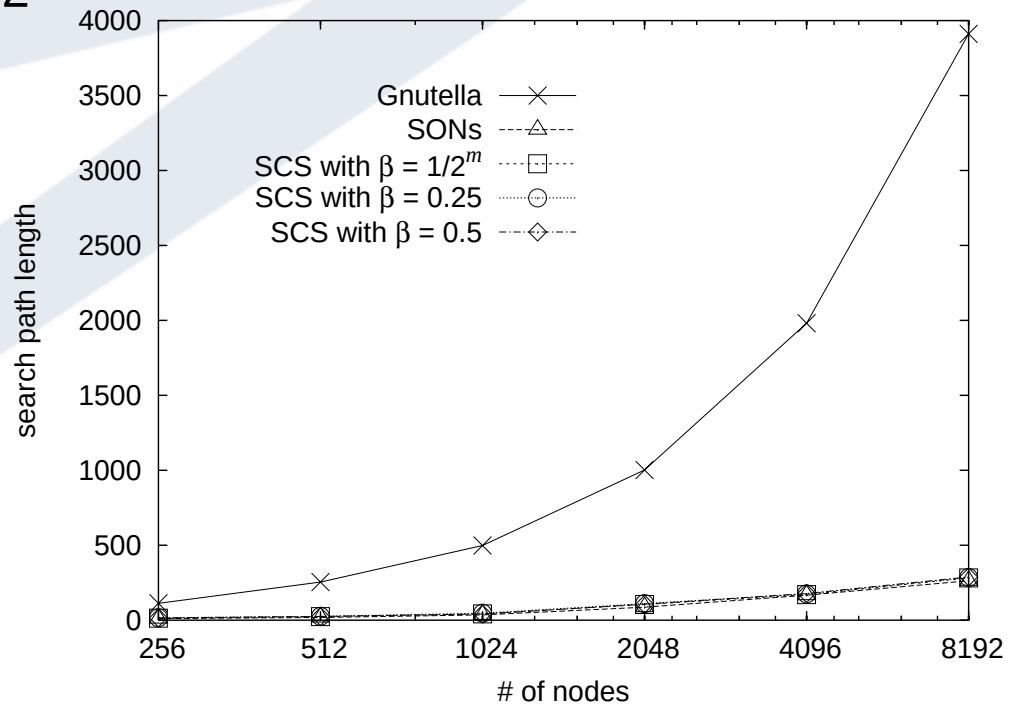
Pairs: <sub pred> or <pred obj> or <sub obj>	Hash value in [0,7]
<socam:TaoGu socam:homeAddress>	6
<socam:homeAdress “XYZ”>	1
<socam:TaoGu “XYZ”>	4

Some Preliminary Results

- Simulation Setup
  - Two types of network topologies in our model: physical topology and P2P overlay topology.
  - Parameters: *m – number of bits to represent semantic cluster, n – number of bits to represent sub-cluster, M – cluster size, N – network size*
- Performance metrics
  - *Fraction of nodes contacted per query*
  - *Search path length*
  - *Search cost*
  - *Maintenance cost*

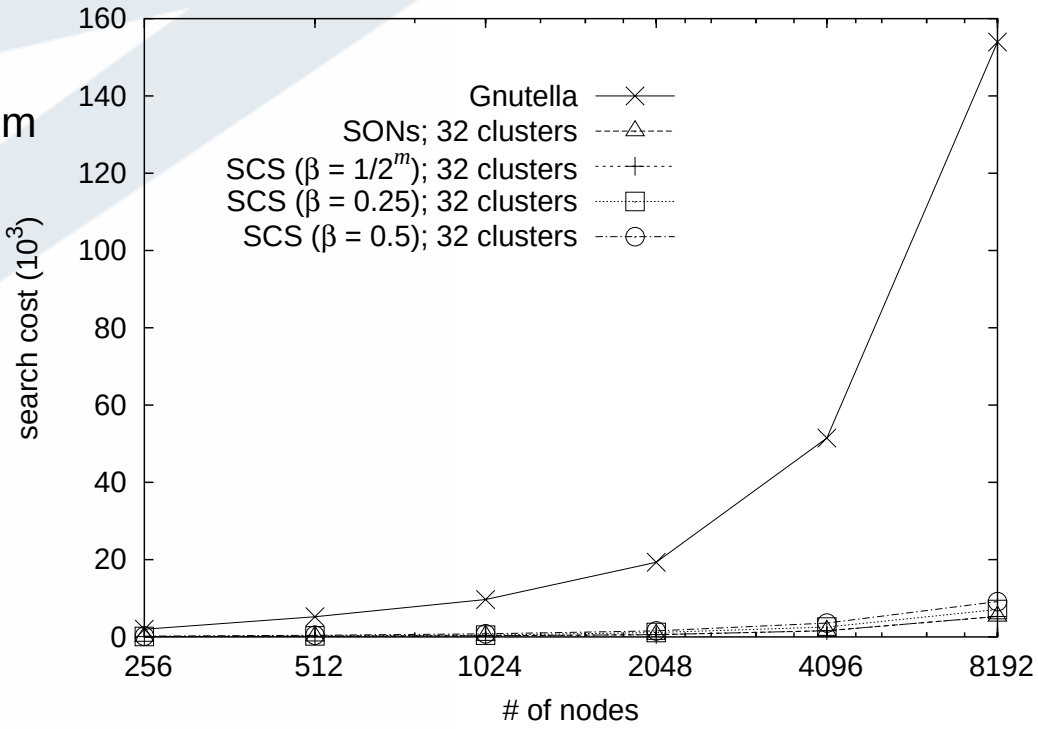
Search Path Length

- The average number of hops traversed by a query to the destination.
- $N = 2^8 \sim 2^{13}$
- $M = 1$ (disable clustering effect)
- $n = 0$ (disable parallel search)
- $\beta = 1/4$ or $1/2$ or $1/2^m$



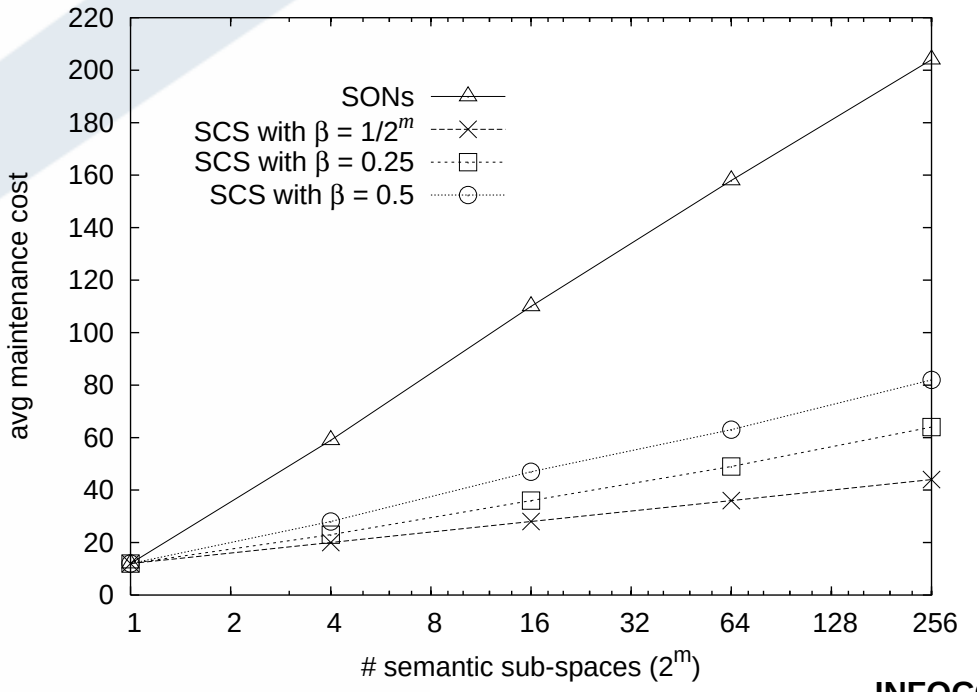
Search Cost

- The average number of query messages incurred during a search operation in the network.
- N from 2^8 to 2^{13}
- $m = 5$
- $n = 0$ or 2, 3
- $\beta = 1/4$ or $1/2$ or $1/2^m$



Maintenance Cost

- The average number of messages incurred when a node joins or leaves the network. It consists of the costs of node joining and leaving, cluster splitting and merging, and index publishing.
- $M = 32$
- $n = 2$
- $m = 1 \sim 8$
- β = 1/4 or 1/2 or $1/2^m$



Conclusion

- Conclusion
  - A hybrid approach to P2P search
  - Preliminary results shows efficiency
- On-going work
  - Building the simulator for the chord-based low-level overlay
  - Further evaluate the performance