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A Hybrid Peer-to-Peer Recommendation System Architecture Based on Locality-Sensitive Hashing

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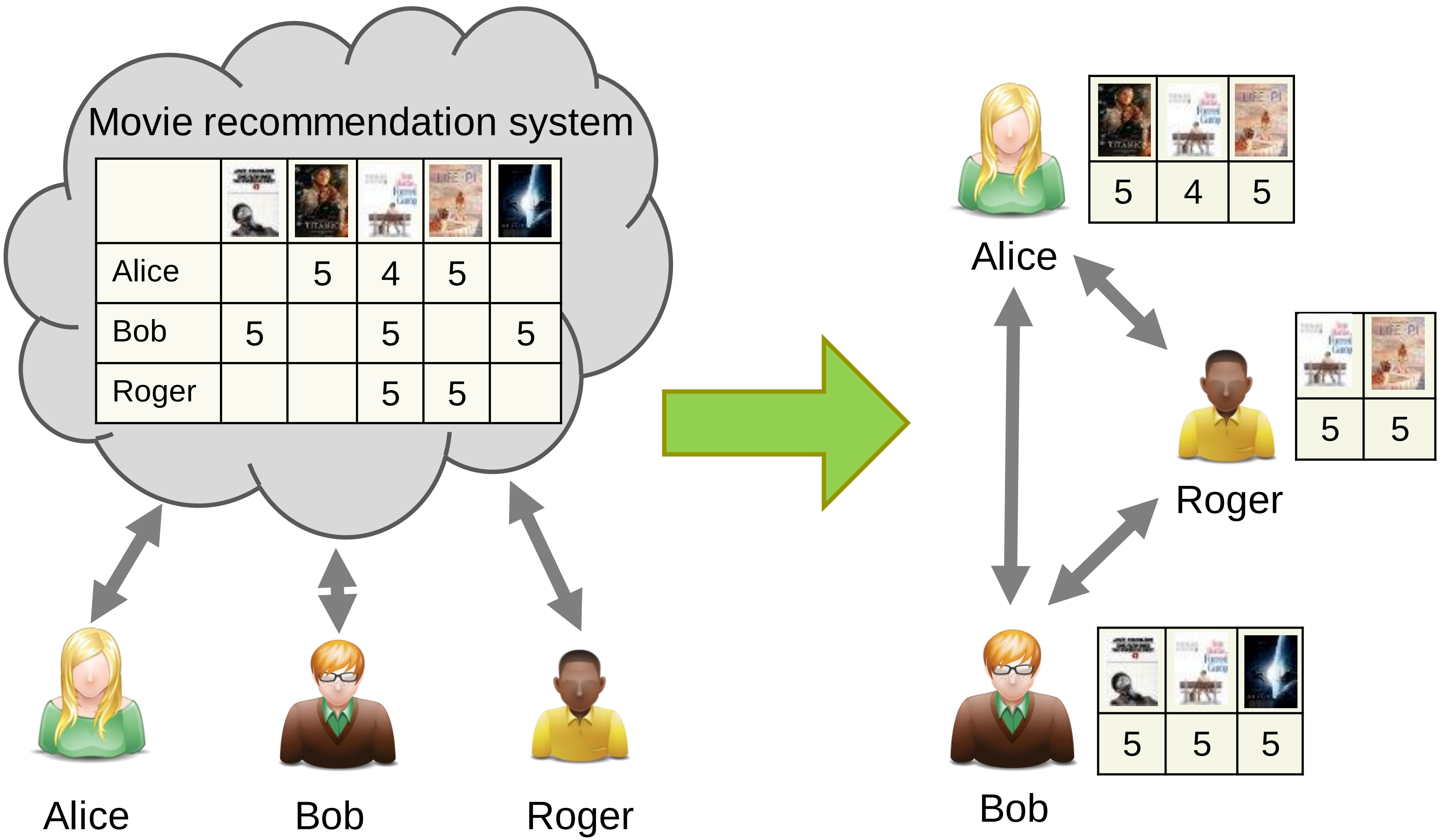
Motivation

- Most of the modern recommendation system designs are centralized. User data are collected and stored at one central point (server machine of server cluster)
- Advantages:
  - Broad spectrum of user preference models
  - Offline analysis by service providers
- Disadvantages:
  - Quandary about rights on preference data
  - Profile slicing
  - Single point of failure

Motivation

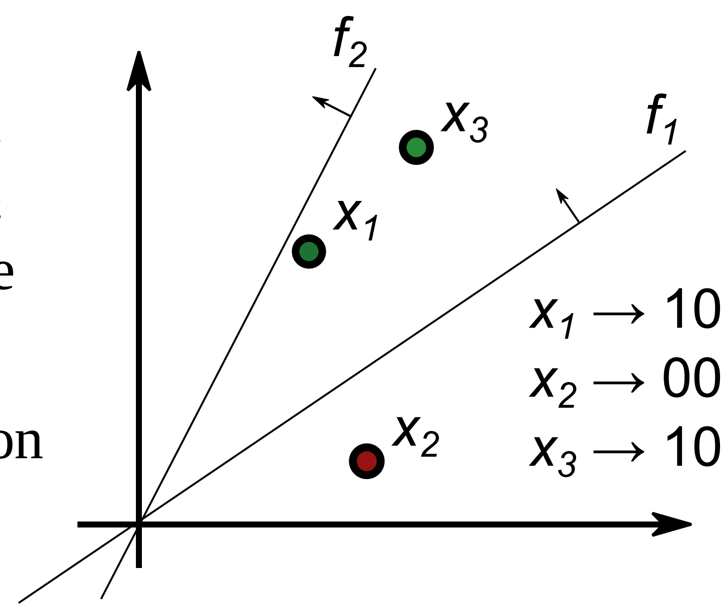
- Decentralized (peer-to-peer) recommendation system: no central database.
- Approach to decentralization: *«Omnia mea mecum porto»*
- Advantages:
  - All user data are on user's device
  - No profile slicing
  - No single point of failure
  - Improved privacy
- Disadvantages:
  - Severe limitations on prediction models
  - Network traffic and resource balancing needed
  - Likely security issues
- **Goal: recommend items without exposing profile details**

User-centric recommendation system



Locality-sensitive hashing: idea

- Locality-sensitive hashing (LSH) – a widely used technique for probabilistic solution of k Nearest Neighbors problem. The idea is to hash multidimensional objects in such a way that similar objects are likely to have the same hash value.
- Formally, let $d_1 < d_2$ be two distances according to some measure d. A family F of functions is said to be (d_1, d_2, p_1, p_2)-sensitive if for every f in F:
  - If $d(a, b) \leq d_1$, then $\mathbf{Pr}[f(a) = f(b)] \geq p_1$
  - If $d(a, b) \geq d_2$, then $\mathbf{Pr}[f(a) = f(b)] \leq p_2$
- Random projections method for cosine distance (d)*
- AND-composition and OR-composition



*) P.Indyk, R. Motwani "Approximate Nearest Neighbors: Towards Removing the Curse of Dimensionality"

Locality-sensitive hashing: recommendations

- Collaborative filtering (CF) system – recommends items based on ratings assigned by other users
- User profile – vector of normalized ratings $r_{uj} \in [-1,1]$, $j \in \{0, M\}$, where M is the number of items
- Algorithm idea:
  - Preparation: Encode each user u profile as L b-dimensional hash values h_i of and put each pair (h_i, u) into corresponding hash table HT_i
  - Recommendations search for user v:
    - Find values of L hash functions of v's profile
    - Look up each hash value in corresponding table
    - Use found user identities to calculate exact similarities
    - Use top-rated items of similar users as recommendations for v

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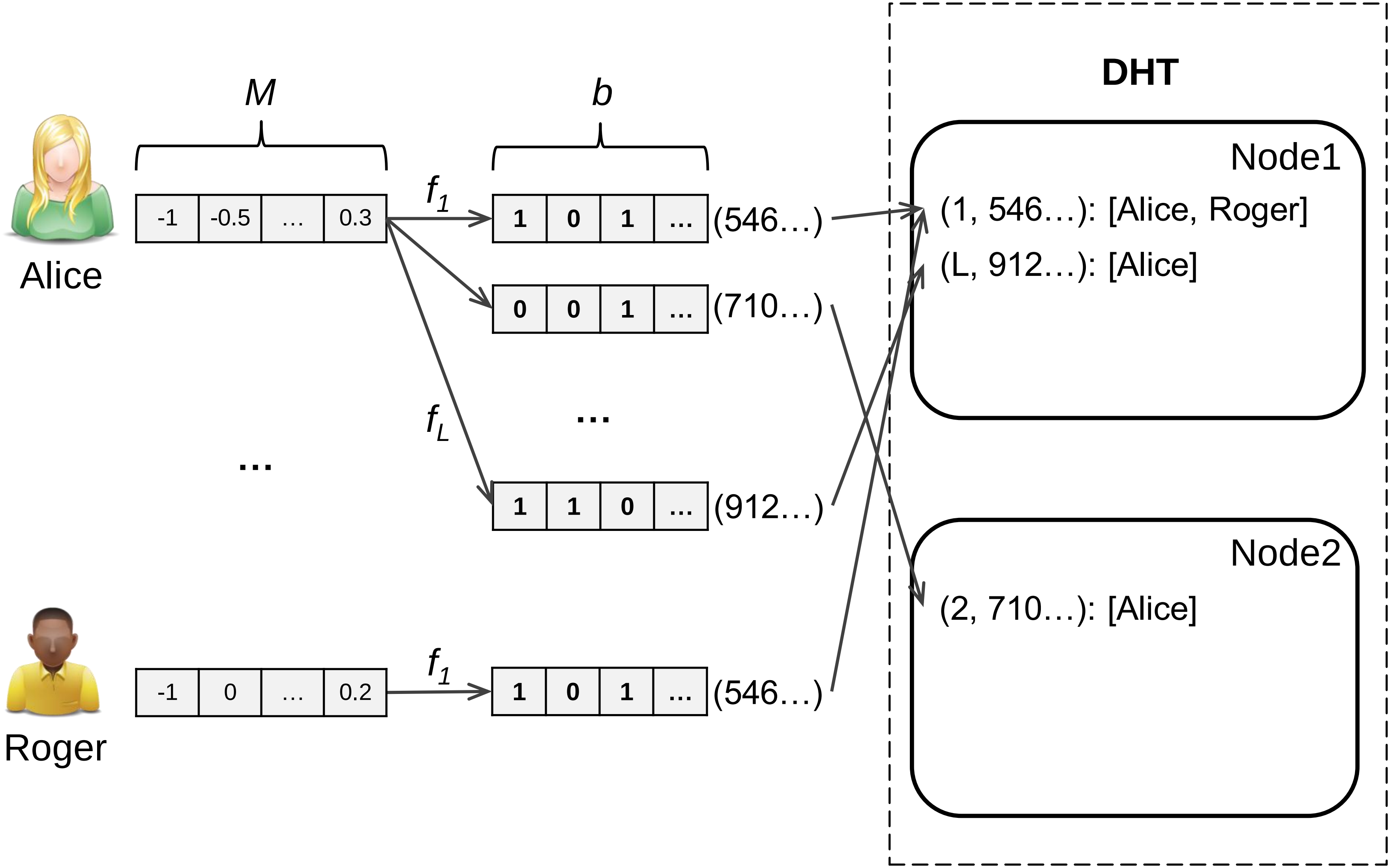
Distributed locality-sensitive hashing

- Distributed Hash Table (DHT) – a structured Peer-to-Peer architecture allowing to maintain a distributed hash table with fast lookups
  - e.g., Chord: O(log n)

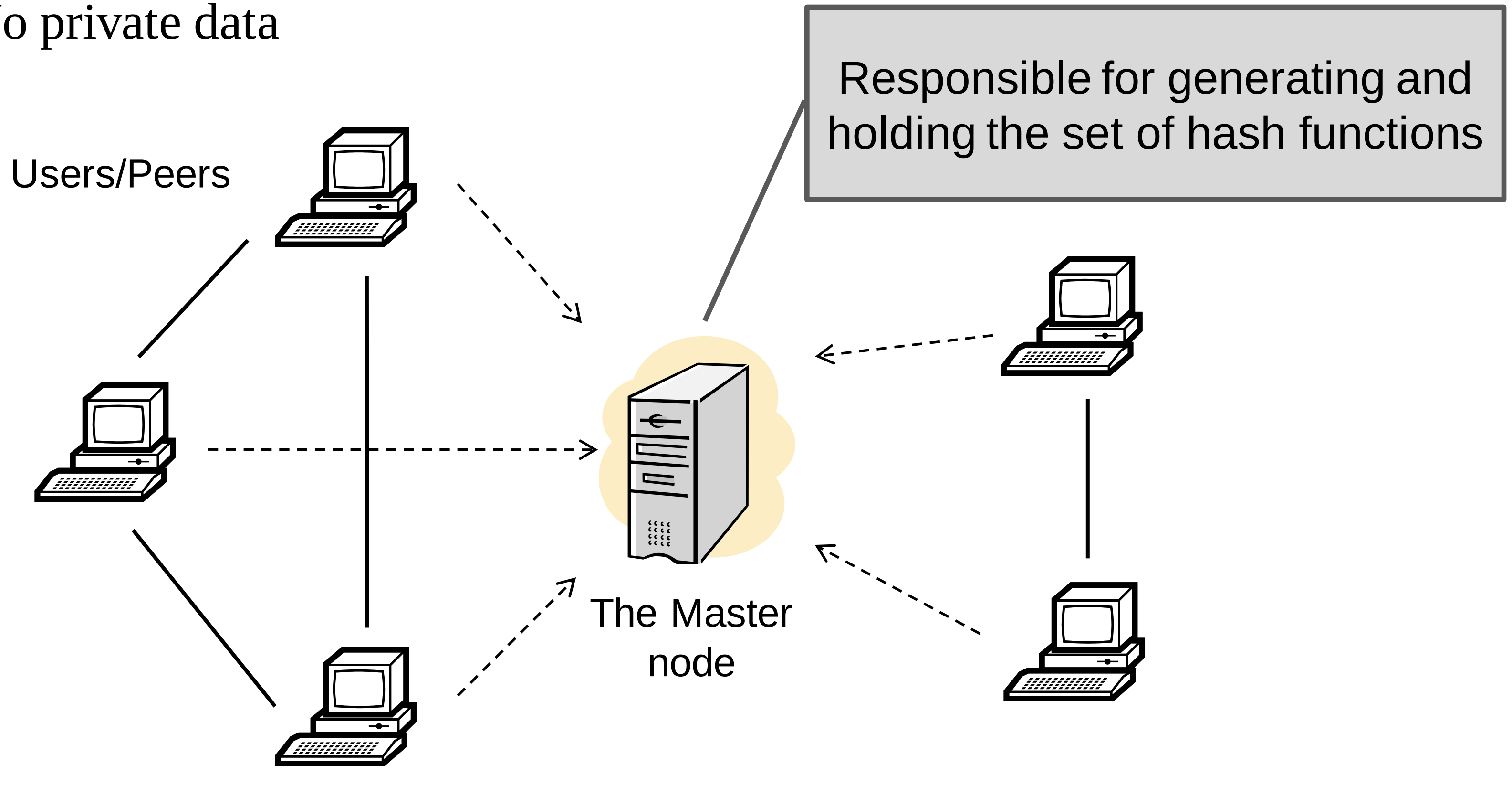
- L hash tables used in LSH nearest neighbor search are transformed into one distributed hash table where key is a tuple (i, h_i)
- Search for nearest neighbors is transformed into lookup in DHT of all keys (i, h_i), where $h_i = f_i(Profile_v), i \in \{1..L\}$

Distributed locality-sensitive hashing



Shared state

- Problem! Need to share hash functions between nodes.
- Solution: breaking Peer-to-Peer design by the Master node
  - Not used in recommendation scenarios
  - No private data



Anonymization technique

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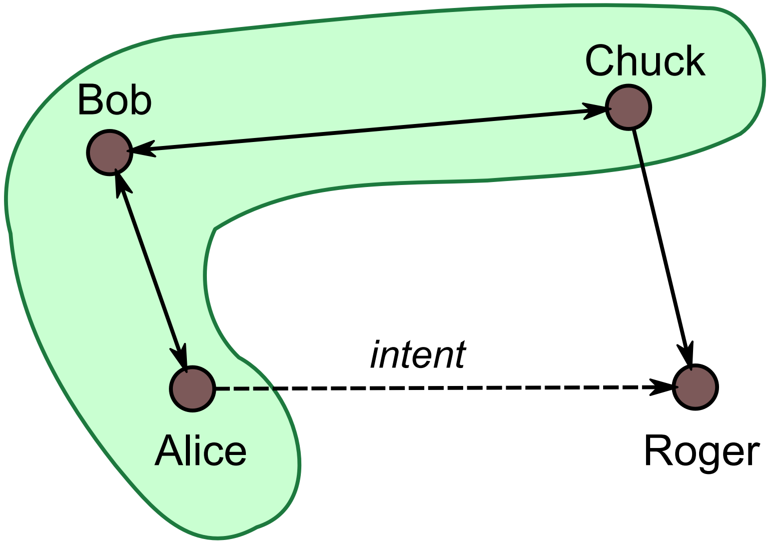
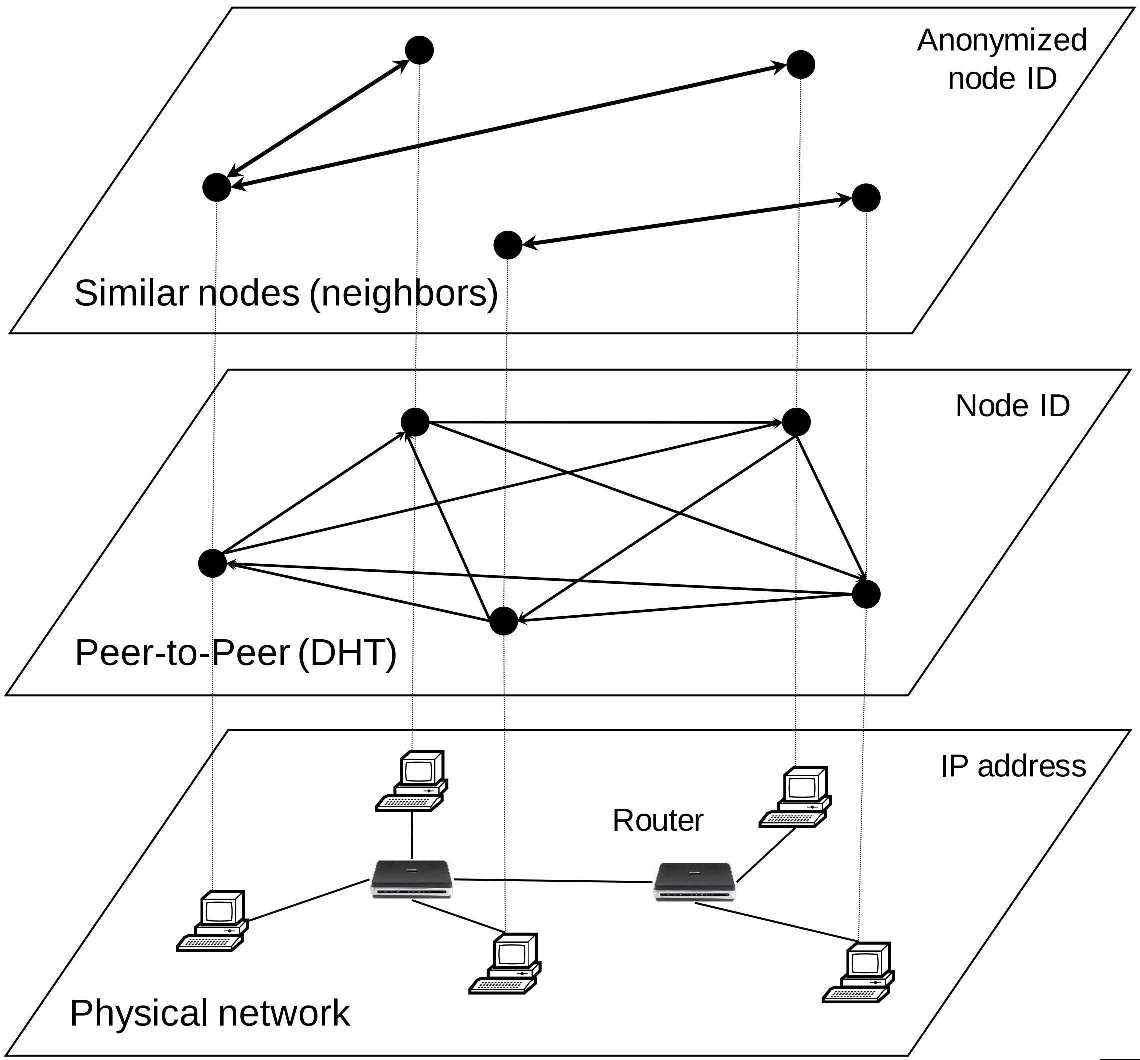
- Original DHTs have security vulnerabilities:
  - Look up interception
  - Routing corruption
- Secure DHTs:
  - e.g. Octopus*

Anonymization path



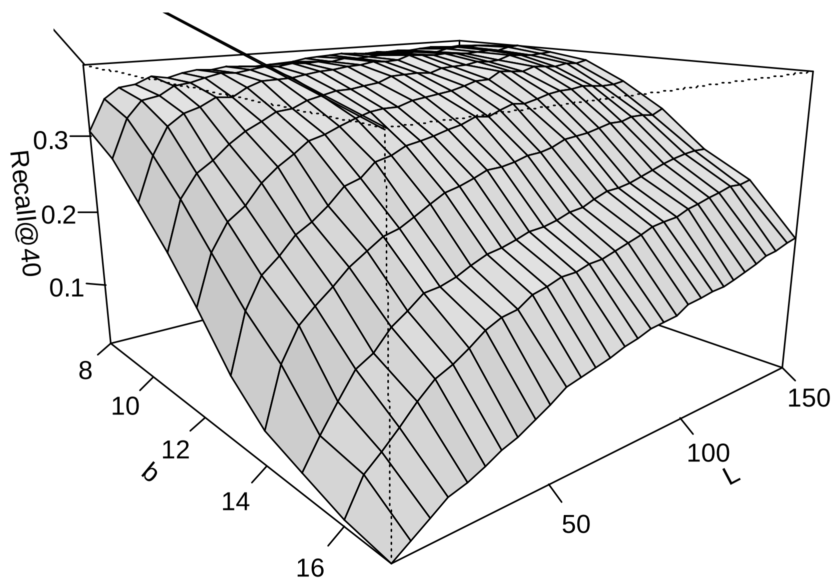
*) Q. Wang, N. Borisov “Octopus: A Secure and Anonymous DHT Lookup”

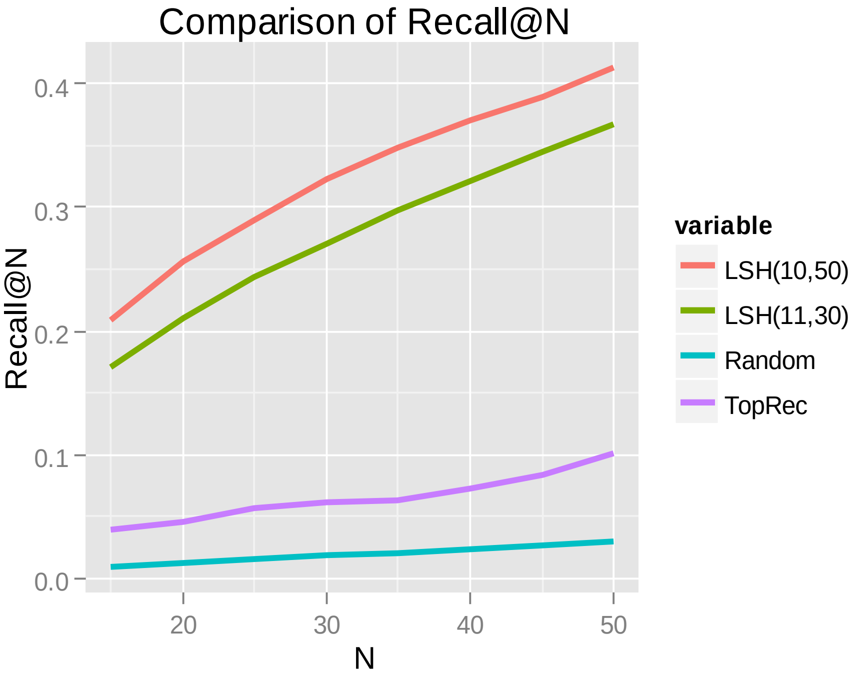
Architecture overview



Experiments

- Dataset: MovieLens 100k (943 users on 1682 items)
- Technique: 80/20 split
- Quality indicator: recall at fixed recommendations count





Conclusion

- Main objectives
  - ✓ User-centric distributed recommendation system
  - ✓ Limited ratings disclosure

- Open questions
  - Shared state in pure peer-to-peer design (epidemic protocols?)
  - Automatic parameters tuning
  - Context-awareness
  - High churn networks

and finally…

Thank you!

Questions are welcome!

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