Using Kademlia for the Configuration of B3G Radio Access Nodes

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Content

- Introduction and Problem description
- The ECAP architecture
- Simulation results
- Conclusion
Introduction: Network Management

First level of management hierarchy

Polling and distribution of information, e.g.,
SSID
Cryptographic key handover policies
Network IDs

Element manager

Attachment points
Problem formulation

- Configuration information has to be distributed to suitable nodes (i.e., cells that overlap the local cell)
- These neighboring cells/nodes have to be identified
- Large effort in heterogeneous networks with many small cells
- System must be flexible to react on changes in the network topology
Distribution of configuration functions

- Exchange of configuration information (e.g. network IDs)
- Neighborhood relationship (overlay connection)
Why P2P?

- Scalability
  - Access network is expected to grow

- Self-organization: new nodes/attachment points are easily adapted into the system without manual interference
  - Allows for easy expansion of the system

- Heterogeneous nodes are supported
  - Future technologies can be added

- Failure of some nodes do not impair the whole system (no central point of failure)
The ECAP architecture

- ECAP: easy configuration of attachment points

- Each attachment point (nodeB, WLAN AP, etc.) is a node in a peer-to-peer (P2P) overlay network

- The overlay is used by each peer to determine its physical neighbors and to enable communication

- With this infrastructure, configuration tasks like the establishment of handover connections can be automated

- Additionally, the network can be used to store network management information in a distributed fashion
Architectural details

- Kademlia is used as a basic algorithm

- To achieve adaptation in the required sense (automatic detection of close nodes), a spatial metric is used

- Coordinates (known e.g. via GPS) are used as node IDs

- Distance in the overlay is the Euclidean distance

- Symmetry of the metric is conserved
Attachment point/peer $p$

bucket $N$

location of an attachment point

bucket $N-1$

bucket $N-2$

bucket $i$ of peer $p$ consists of peers $q$ with distance

$$d(p, q) \in \left[2^{N-i}, 2^{N-i+1}\right]$$
Finding neighbors

Upon join, the k closest nodes are known. These nodes are also the best candidates for neighbors.

After a longer time in the network, more distant nodes are put into the buckets. More nodes are known in closer areas than in distant ones.
Routing

destination

source

destination

message routing
Range queries

- **Aim:** get all nodes in a certain area

**Step 1:** All nodes in buckets that lie in the specified area are asked.

**Step 2:** All new nodes are asked until no new nodes are found.
Document storage

- Additional to the establishment of neighbor relationships, network management documents can be stored in the network
  - P2P allows for redundant storing

- Each document also gets a two-dimensional ID, with each dimension carrying different types of information
  - e.g., IP of the responsible node and type of information

- Search for documents also accelerates information dissemination
  - Kademlia uses information contained in queries to update its buckets
Results

- Network organizes itself

- A high number of known nodes implies a high number of known neighbors

- The exact time needed for stabilization depends on a number of parameters (e.g., network size)

- Different methods for neighborhood detection have been tested

![Graph showing probability distribution over the number of known nodes after join and stabilization.](image)
Impact of search radius

- Manual filling of routing tables by periodic search
- Search radius below 10km and above 200km has no significant effect
- Smaller search radius leads to better knowledge, due to symmetry of the metric and a larger portion of the routing table that is reserved for closer nodes
Conclusions

- Solution for heterogeneous network management
  - It reduces configuration efforts
  - Information about the network is stored in a redundant fashion

- Highest reduction is achieved for heavily heterogeneous networks
  - Usage of P2P technology allows for incorporation of different access technologies

- Flexibility and adaptivity for changing network structures

- Outlook: churn studies, search methods, …
Thank You

Q&A