Topology Discovery and Coverage Area Approximation with 802.11k

Date: 2008-11-11

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Abstract

Application scenarios—esp. those relying on (seamless) handover or providing location-based services—may profit from an approximation of an AP's coverage area as well as having knowledge on the AP's neighborhood

802.11k-2008 Radio Measurement provides geo-location query/ response and radio measurement operations. It also creates and updates a radio neighborhood map and report.

This talk presents an initial performance evaluation of an 802.11k-based acquisition scheme approximating the AP's coverage and neighborhood

Contributions

- **Analyze the dynamic behavior of the acquisition scheme by quantifying the time needed to reach a certain information level regarding the cell coverage and neighborhood relation of an AP.**
  We refer to this duration as "bootstrapping characteristics"

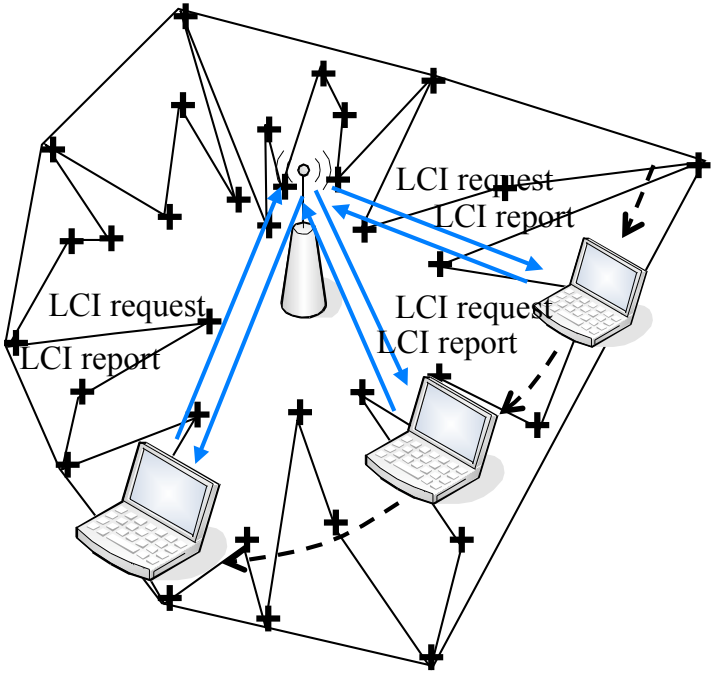
- **Present a novel approach of only partially storing information representing the AP's coverage area; we hereby**
  - analyze the effects on the representation's accuracy and
  - highlight the performance gain.

- **As the overhead of the signaling protocol employed to gather the required information influences the results,**
  we implemented IEEE 802.11k protocol and hence present for the first time an entirely standard compliant approach for Wireless LANs to obtain information on
  - the mobile's position,
  - the AP's coverage area, and
  - the neighborhood relations between APs

Standard Compliant Acquisition Scheme

- **IEEE 802.11k (Radio Resource Management WG)**
  - added a variety of radio resource measurement request / responses
  - which are action fields in the body of standard management frames
  - measurement reports can carry, e.g.,
    - Location Configuration Information (LCI) or
    - Beacon Requests / Reports
- **LCI Requests / Responses**
  - allow to query for and respond with the current position
  - position propagated according to RFC 3825 compliant format, i.e.: latitude, longitude, and altitude
- **Beacon Request / Responses**
  - allow to request information on beacons and the contained information that
    - have been received in the past (history) or
    - are currently received (due to triggered scanning)
  - request / report can be limited to a specific BSSID or a “wildcard” query
- **Additional features**
  - request may indicate that measurements have to be taken in parallel --> obtain relation between LCI and beacon measurements
  - responses are randomly delayed to avoid collision on the wireless media

Approximation of Coverage Area



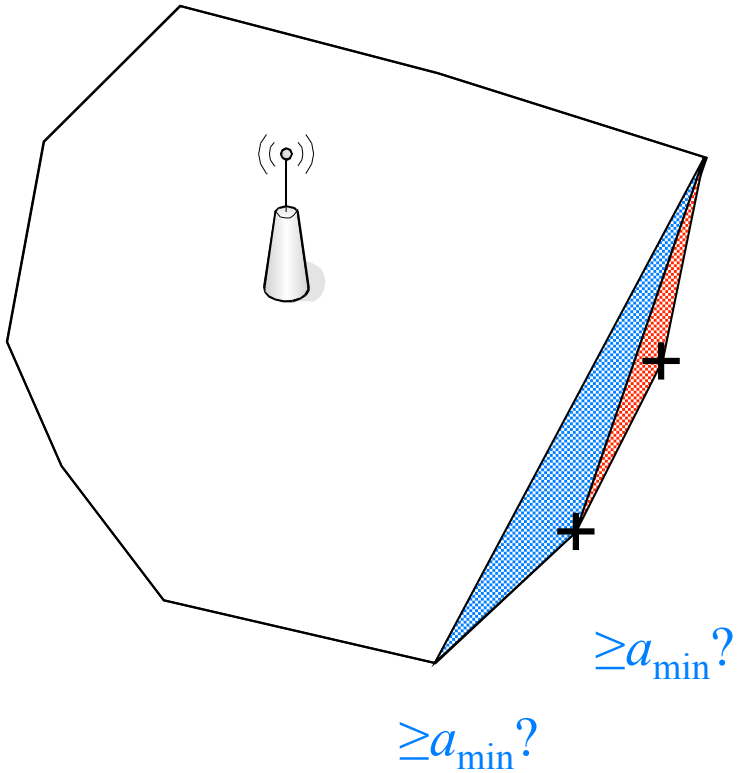
- **LCI requests are sent by the AP to the mobile devices**
- **Devices report their locations**
- **AP learns the positions being covered**

- Polygonal description can be derived by connecting the points via straight lines

- **Drawback: steadily growing number of vertices of the polygon**
- **Use convex hull (smallest convex polygon enclosing all points of the actual coverage area)**

Reducing Number of Vertices

- **Newly reported positions become vertices, if these are not laying within existing convex hull**
- **Nevertheless, problem of a steadily growing number of vertices still exists**
- **Add vertices only to the convex hull if the area of the new polygon is increased by a_{min}**



- Deviation between the original and approximated areas increase
- Requires investigation

Simulation Parameters

- **Omnet++ based simulation**
- **30 IEEE 802.11 APs regularly placed on a**
- **1km x 1km territory**

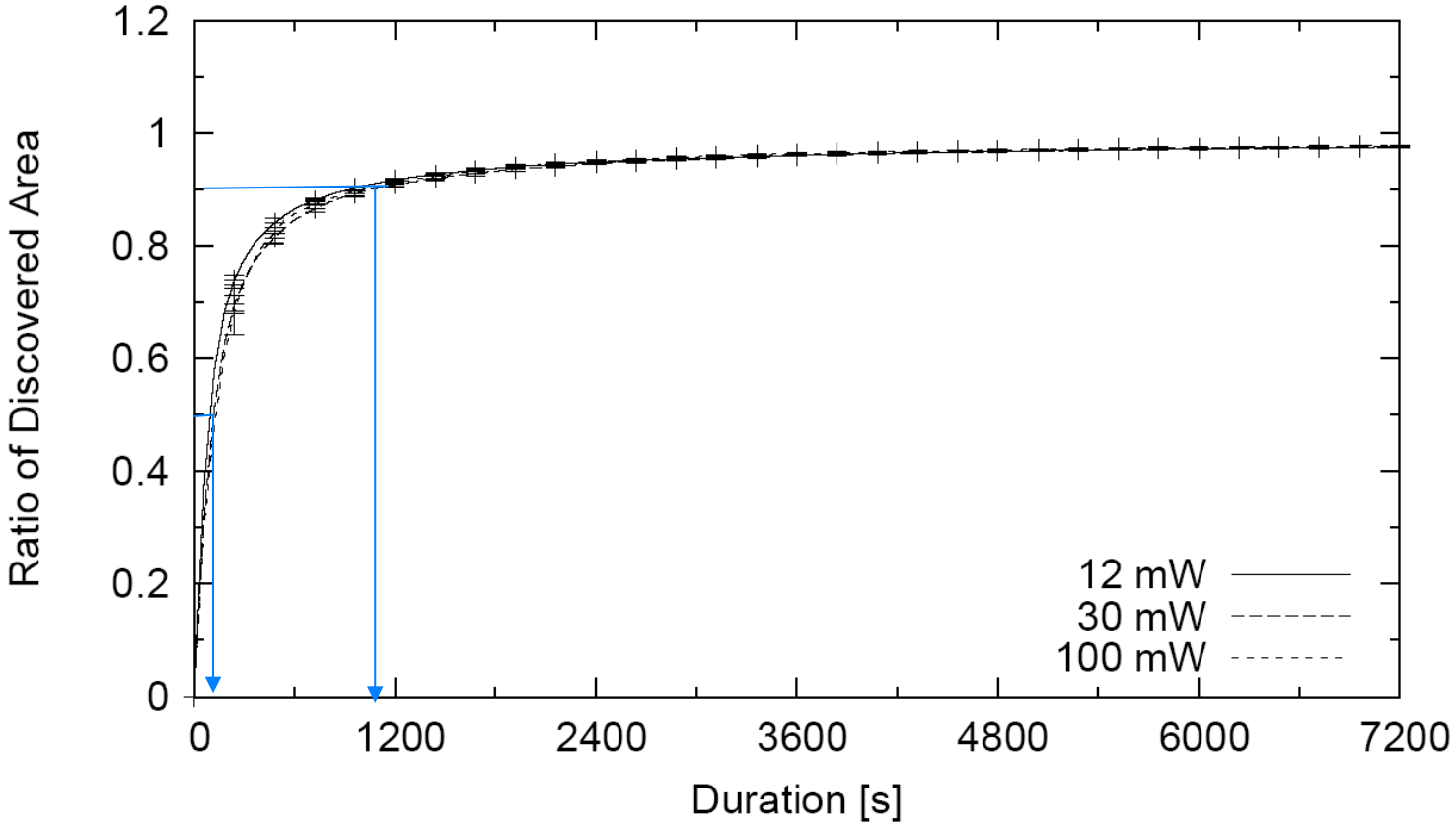
- **50 mobile users traveling at**
- **user speeds of**
  - 1.5 m/s (50%)
  - 5.5 m/s (20%) and
  - 15 m/s (30%)

- Results obtained for both,
  - Gauss-Markov and
  - Random Waypoint

  mobility models

- Free-Space path loss model
- Different sizes of overlap realized by varying the TX power

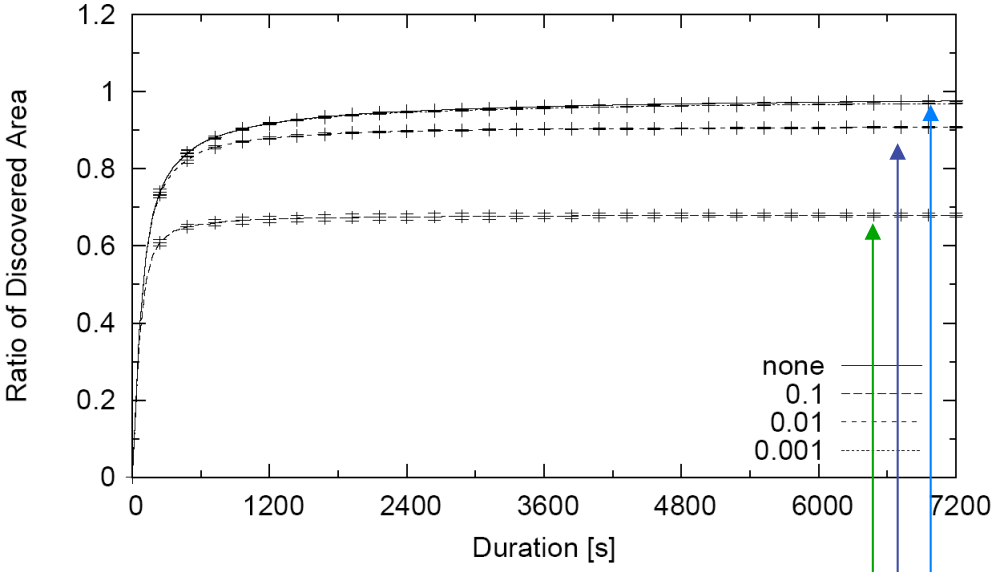
Duration of Coverage Area Discovery



- **50% of the coverage area already discovered after 2 minutes**
- **90% after 18 minutes**
- **Results independent of the coverage area's size (90% confidence intervals shown)**

Gauß-Markov mobility model

Effects of reducing the number of vertices

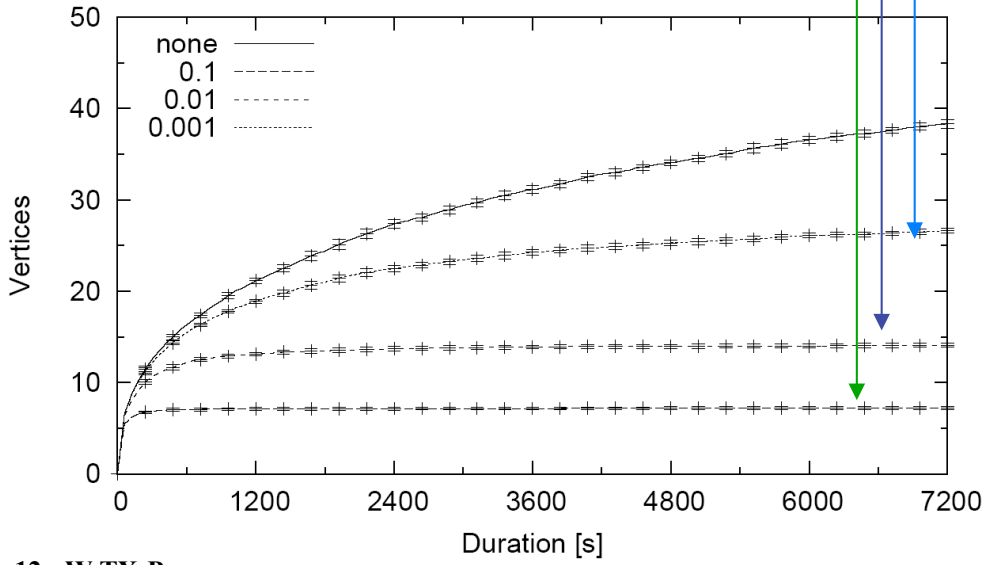


Discovered Area:

0.1% Threshold: No statistical significant difference

1% Threshold: 7 % degregation

10% Threshold: 30 % degregation



Number of Vertices:

0.1% Threshold: 30 % less vertices

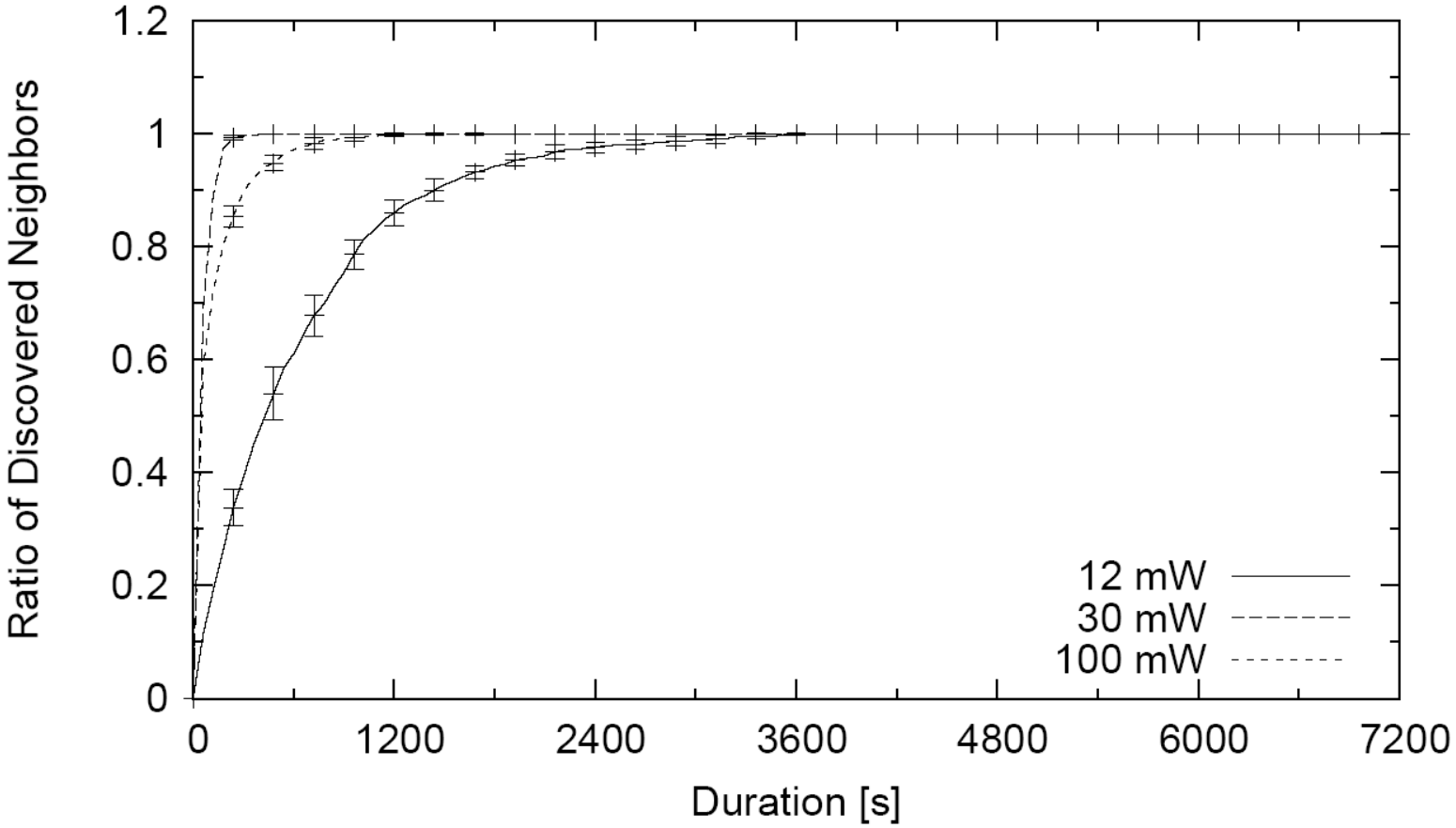
1% Threshold: 63 % less vertices

10% Threshold: 81 % less vertices

Results for 12mW TX-Power

Comparison results for t=7200s

Duration of Neighborhood Discovery



- **Size of overlapping regions influences the duration of the bootstrapping phase**
- **The larger the overlap, the longer is the dwell time of a mobile in this region and hence the time to hear more than one AP at a time is higher**

Summary

- **Evaluation of the bootstrapping phase of the presented approach shows that a dynamic acquisition of coverage and neighborhood information is feasible even for a moderate population density of mobiles (1 mobile per 20.000 m^2 --- 4000 users would be enough for former West-Berlin with 3 million inhabitants)**
- **Presented a simple algorithm to reduce the number of vertices needed to describe the AP's coverage area without reducing the description's accuracy**
- **Presented an entirely standard compliant way to determine the coverage area and neighborhood of access points using the upcoming IEEE 802.11k amendment**
- **Next steps:**
  - Empirical Evaluation
  - Cooperation with industry for measurements

References

S. D. Hermann, M. Emmelmann, O. Belaifa, and A. Wolisz. Investigation of IEEE 802.11k-based Access Point Coverage Area and Neighbor Discovery. In Proc. of IEEE International Workshop on Wireless Local Networks (WLN), Dublin, Ireland, October 2007. (pdf)