Indoor Positioning: A Comparison of WiFi and Bluetooth Low Energy for Region Monitoring

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Outline

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1. The Kompass Project

Kompass supports seniors and their caretakers:

1. Appointment reminder,
2. Fall detection with alarm call,
3. monitoring of seniors suffering from dementia with alarm call

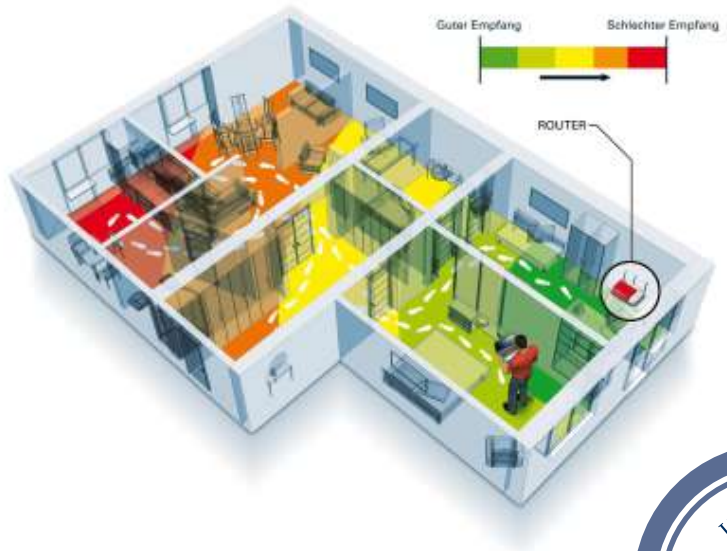
Cooperation with the nursing home Florencehort, LAFIM, in Stahnsdorf

$\Longrightarrow$ Seniors get a smartphone, the *Kompass–Assistent*.

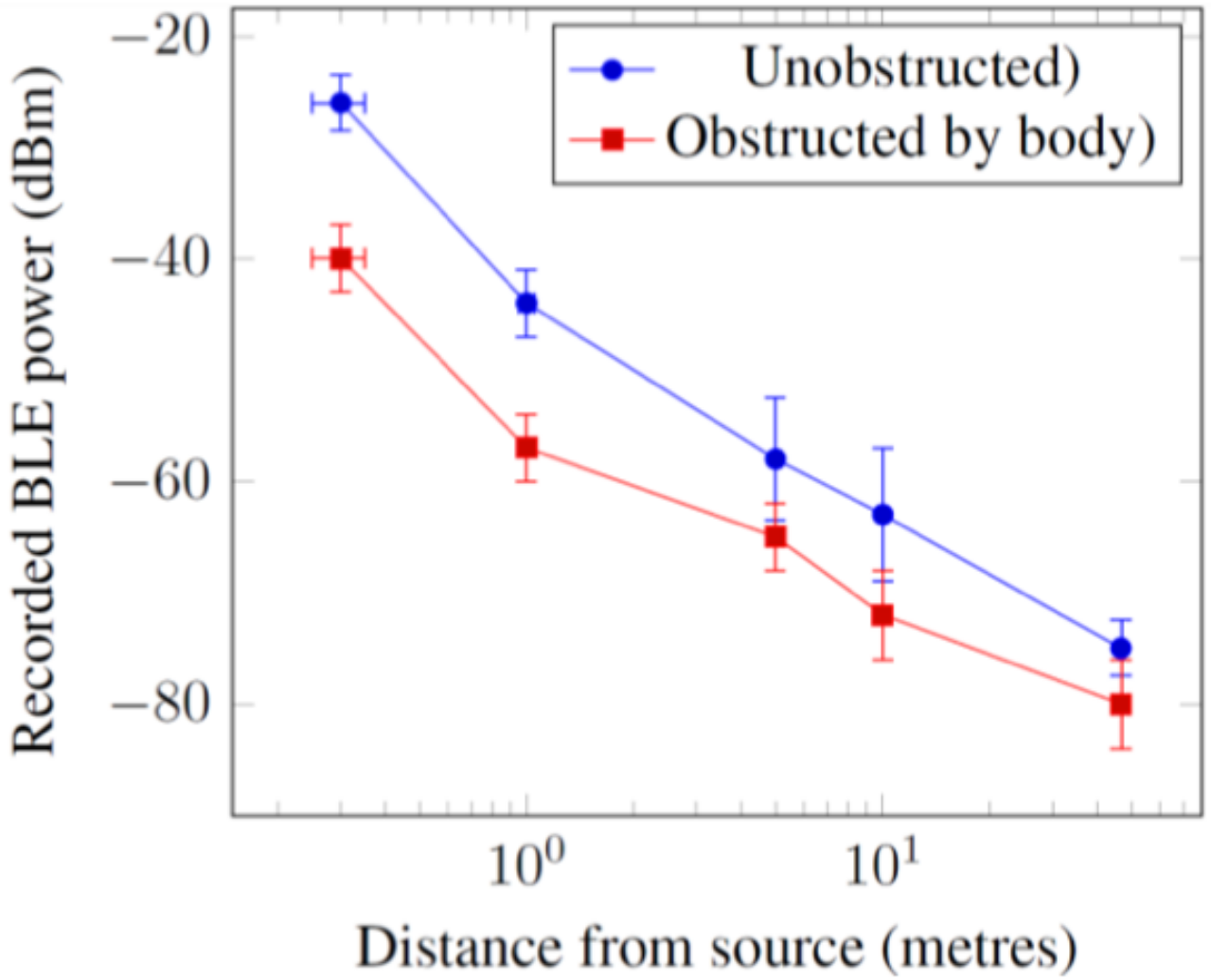
Wireless Indoor Positioning

- Environment is equipped with **beacons/WiFI-Router** which send advertisement messages
- Lokalization based on the Received Signal Strength (RSS)
- The received RSS values of the beacons are compared with the *expected* values from the **Radio-Propagation Map** at each grid position $\Longrightarrow$ position with least error is calculated

Fingerprinting or **model-based** approach



Reference: [Seemann, 2015]

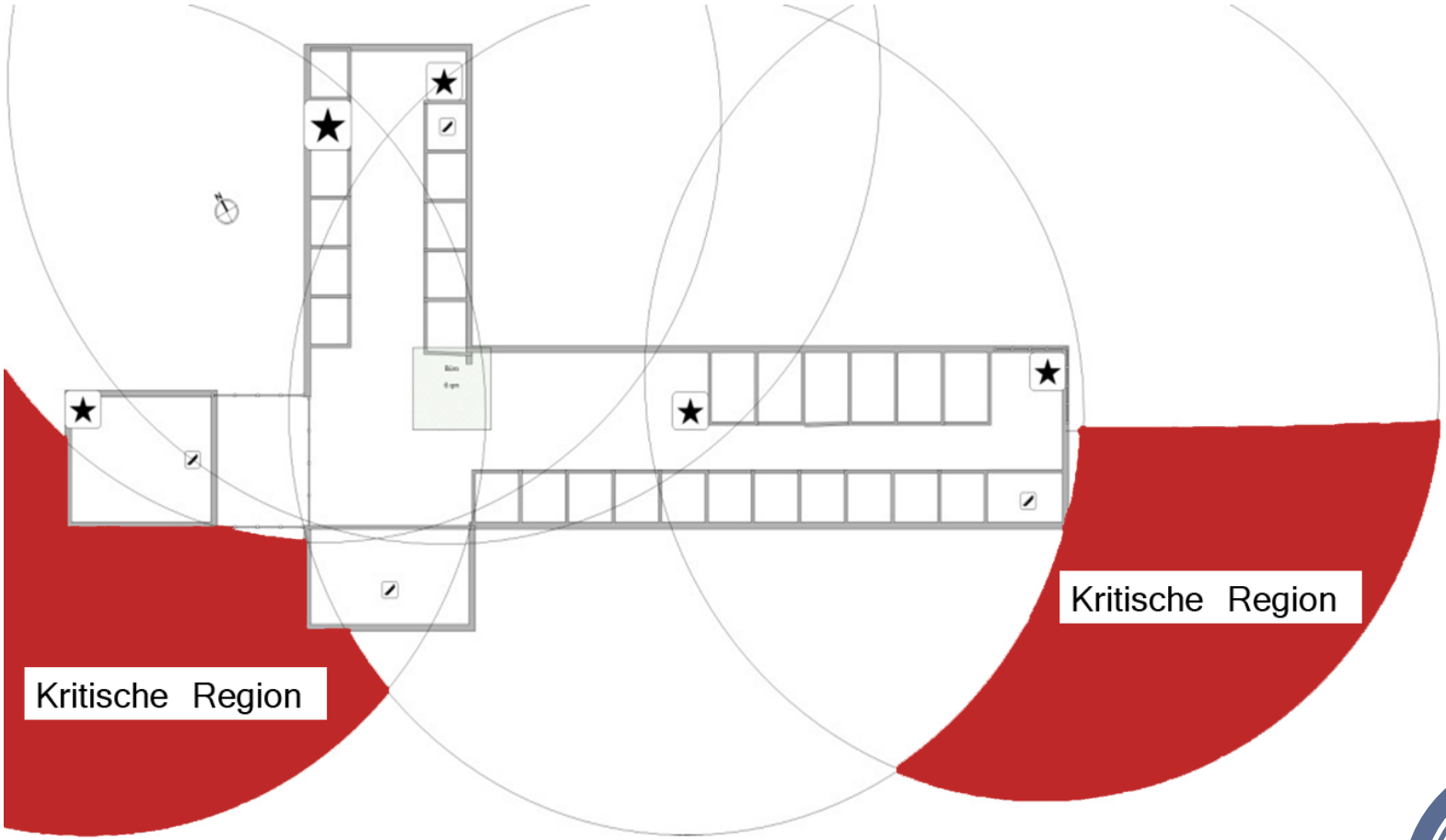


Reference: Ramsey Faragher and Robert Harle: *An Analysis of the Accuracy of Bluetooth Low Energy for Indoor Positioning Appli*

[Faragher and Harle, 2014]

2. Region-Monitoring Approach

- 6 Wi-Fi Router



Definition of Region:

A region is defined by a list of beacons which have to be received (**positive list**) or which may **not** be seen (**negative list**).

All regions are stored in the so-called **region map**.

$\Longrightarrow$ Just the reception of a beacon advertisement message is important, not its RSS value.

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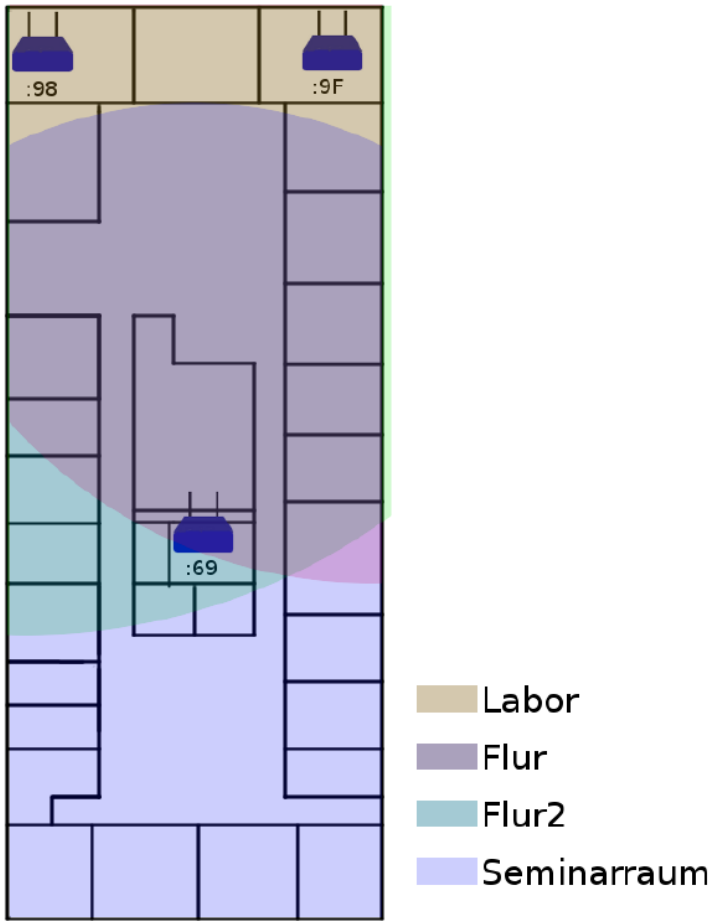
Experiences with WiFi



Regions with WLAN access points [Kappel, 2014].

Region	Pos. List	Neg. List
Lab	:9f; :98	:69
Floor	:69; :9f; :98	
Floor 2	:98; :69	:9f
Classroom	:69	:98; :9f

Correct localizations: 98.4 % during a walk with 65 measurements.

Device Runtime: 37 hours for 10 s positioning interval

Observation: The disabling of the WiFi-Interface for energy savings did not work reliable on Android.

Question: This was very coarse grain localization: Any improvement possible?

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Bluetooth Low Energy Use Cases

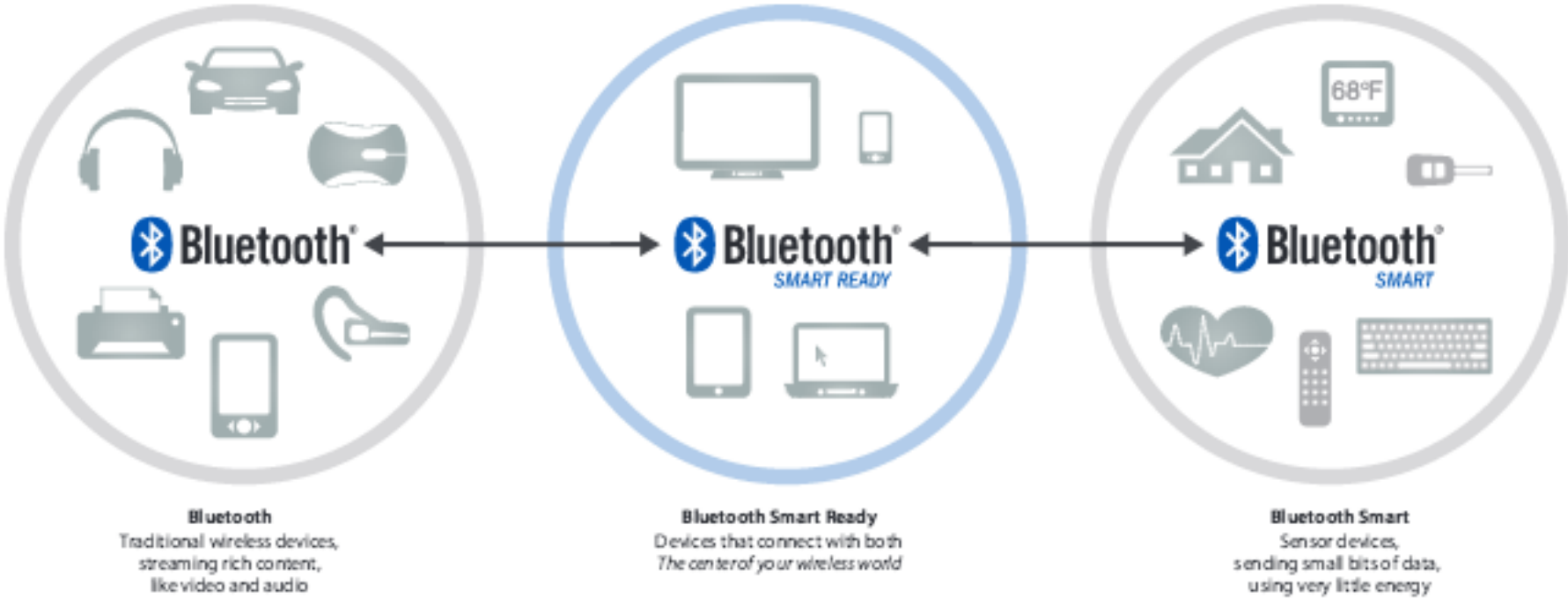


Figure 1. The relationship between Bluetooth Smart and Bluetooth Smart Ready devices (Source: Bluetooth SIG)

Quelle: Karl Torvmark: *Three flavors of Bluetooth: Which one to choose?*, EDN Magazine, March 2014

3. WiFi versus Bluetooth Low Energy (BLE)

	WiFi	**BLE**
frequency band	2.4 GHz (license-free)	
distance	up to 100 m	up to 10 m
transmit power	up to 100 mW	up to 10 mW

Power Consumption

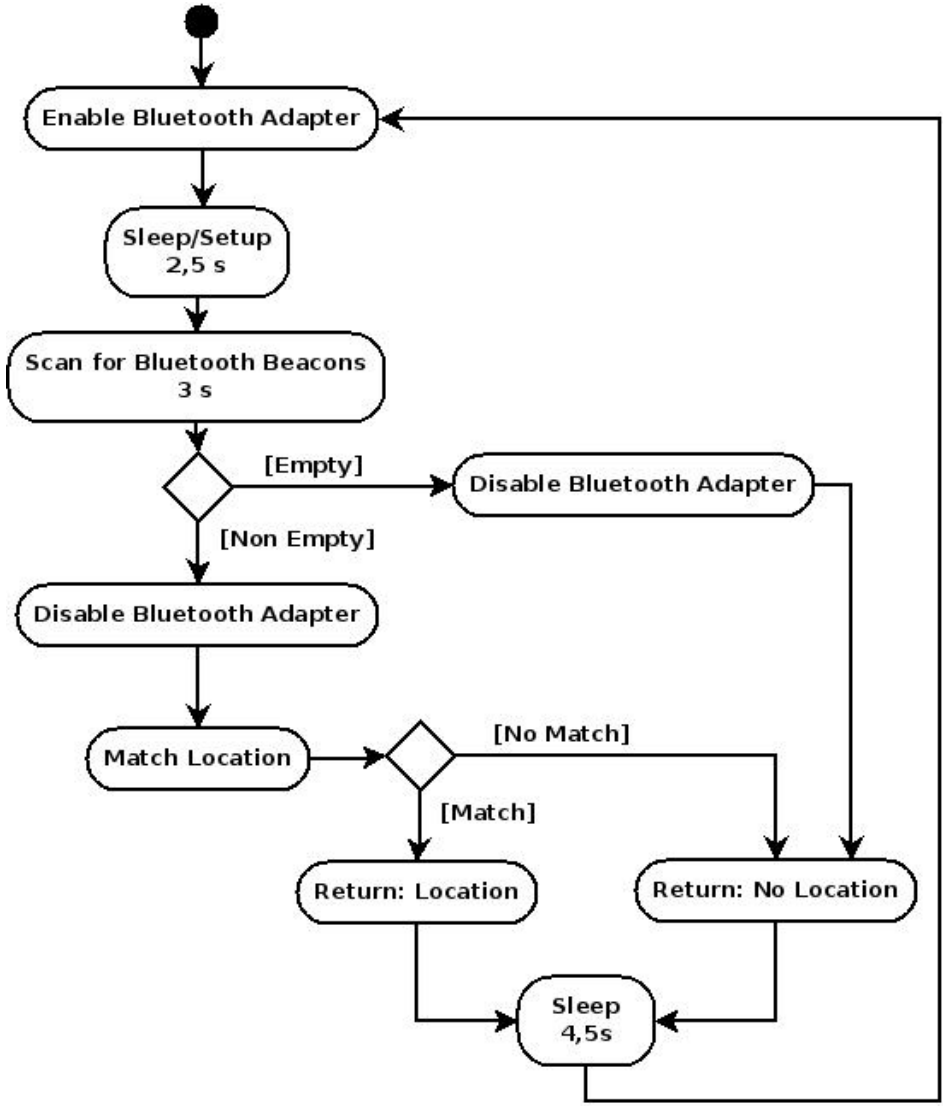
Localization	device runtime	
	HTC Evo 3D WiFi	HTC ONE mini2 BLE
Without	358 hours[1)]	500 hours
every 10 s	**37 hours**	**70 hours**
every 30 s	50 hours	151 hours

1) manufacturer specifications, own measurement: about 185 hours

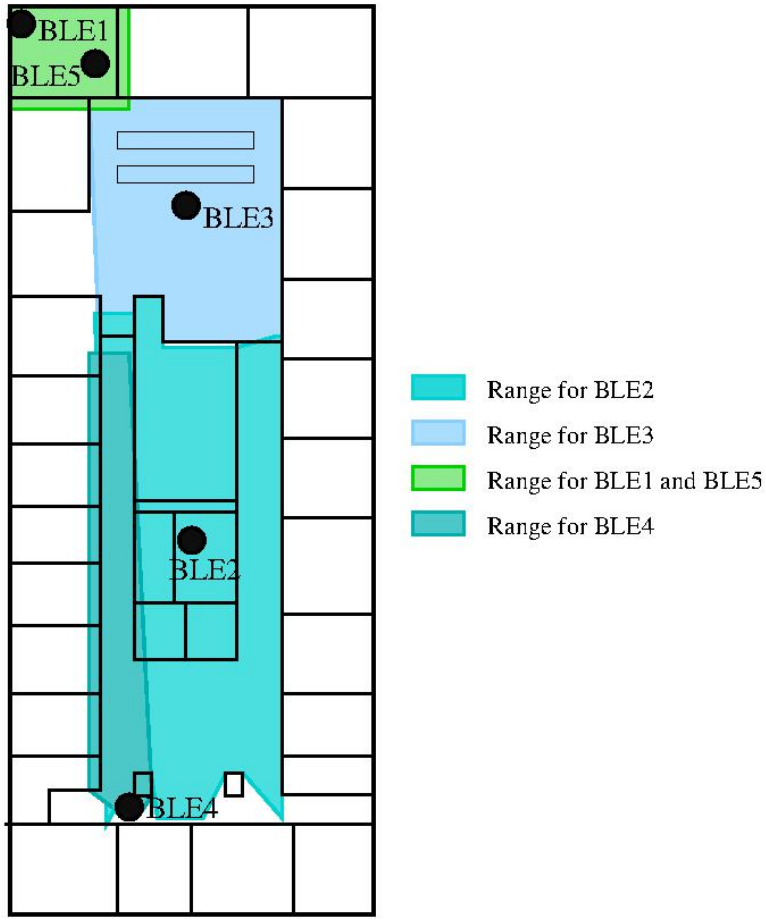
Beacon Parameter	Value	description
Advertising Interval	200 ms	Time between two advertisements
Beacon transmit power	-23/-6/0 dBm	

Smartphone Parameter	Value	description
Setup time	2.5 s	Time until the Bluetooth radio is ready
Sleep Interval	4.5 s	Time between localizations
Scan Time	3 s	Time the Bluetooth radio is listening

Region-Monitoring Algorithm with BLE Parameters



Repetition of WiFi Experiment

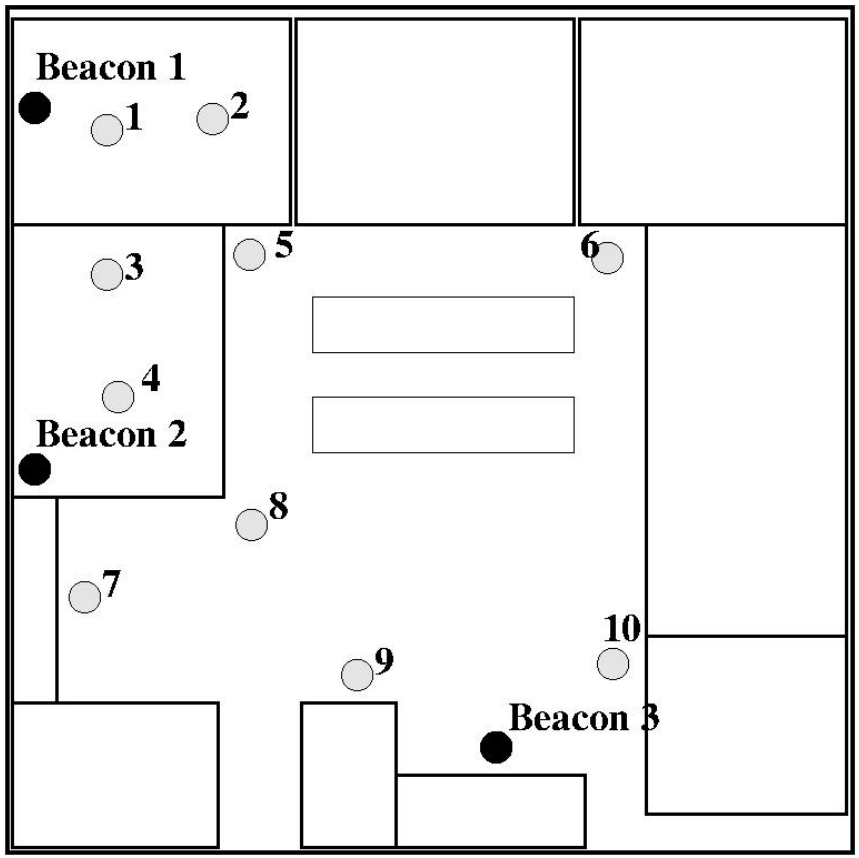


Regions with **5 BLE** beacons.

	transmit power
BLE1, BLE5	low
BLE3	medium
BLE2, BLE4	high

Correct localizations: 96.6 % during a walk with 88 measurements. (98.4 % for WiFi).

4. BLE Accuracy Tests: 19 x 19 m Test Environment



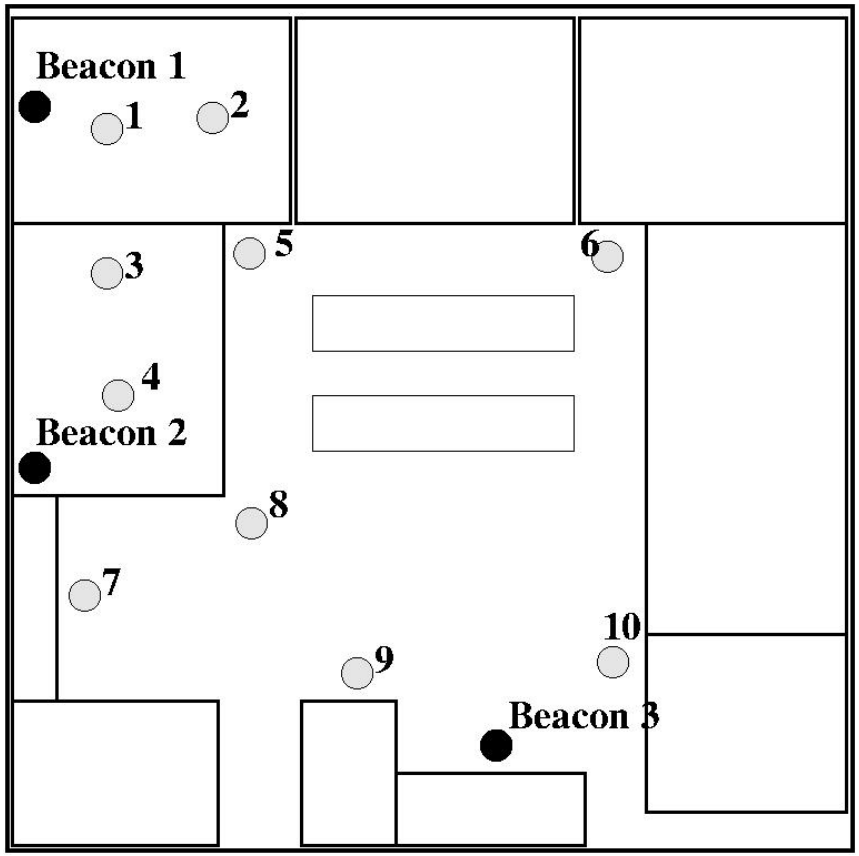
Region	Pos. List	Neg. List
Lab 1	Beacon 1	empty
Lab 2	Beacon 2	empty
crit. region	Beacon 3	empty
safe corridor	empty	empty

Correct localizations: 78 %

Problems at position 1,2 and 9,10.

Three beacons with **low** Transmit Power.

4. BLE Accuracy Tests: 19 x 19 m Test Environment



Test place	correct	false
1	5	4
2	7	2
3	9	0
4	9	0
5	7	2
6	9	0
7	7	2
8	8	1
9	4	5
10	5	4
Total	70	20
Percent	77.8	22.2

Three beacons with **low** Transmit Power.

Correct localizations: 78 %

Problems at position 1,2 and 9,

Reason for bad result:

1. Beacon signal was obstructed by human body of test person.
2. Beacon signal was shielded by elevator.
3. Interference with WiFi-router

2. Experiment: Increasing the transmit power of the BLE beacons:
Results get worse due to overlapping beacon cells.

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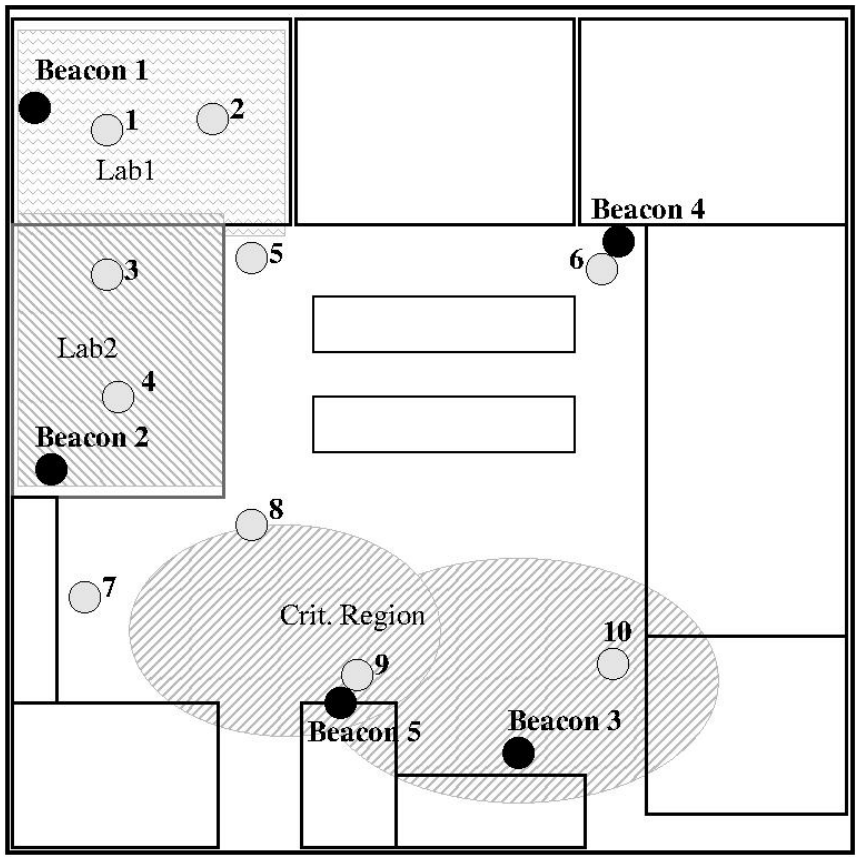
3. Experiment: Higher Beacon Density

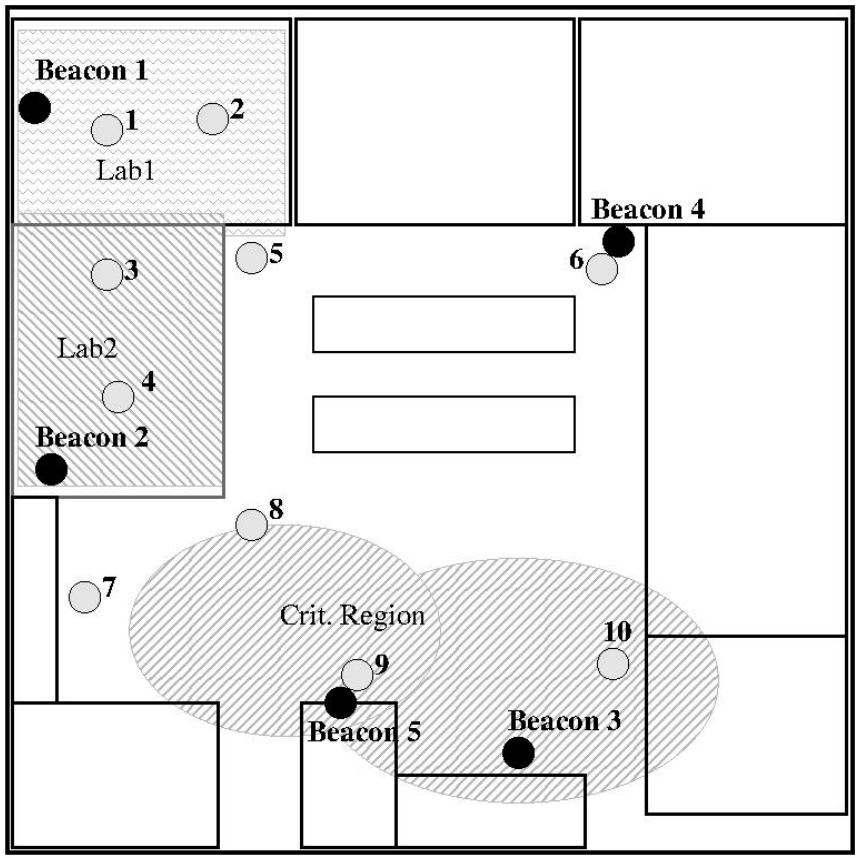


Five beacons with **low** Transmit Power.

Region	Pos. List	Neg. List
Lab 1	BLE 1	BLE 4
Lab 2	BLE 2	BLE 4
Crit. Reg.	BLE 3	BLE 1, 2, 4
	or BLE 5	
Safe Corridor	-	BLE 1, 2

Correct localizations: 68 % (78 % with 3 beacons)
Problems at position 1 (Lab1), 3 (Lab2) and 7 (safe corridor).

3. Experiment: Higher Beacon Density



Test place	correct	false
1	5	4
2	6	3
3	4	5
4	7	2
5	8	1
6	9	0
7	1	8
8	6	3
9	8	1
10	7	2
Total	61	29
Percent	67.8	32.3

Five beacons with **low** Transmit Power.

Correct localizations: 68 %
Problems at position 1 (Lab1), 3 and 7 (safe corridor).

5. Conclusion

+ BLE: easy installation, beacon battery running for months
+ **Device runtime:** 70 hours when the device tries to localize its position every 10 seconds with BLE.
  (compared to 37 hours with WiFI on an older device).
+ **Region-Monitoring (coarse grain):** 96.6 % correct localizations with BLE.

- **Region-Monitoring (fine grain):** 78 % correct localizations with BLE.

  Further experiments with thresholds for the RSS values show no improvements.
- all BLE experiments done on Android 4.4.2 (KitKat)
- BLE infrastructure is not suited for sending alarm messages, instead the WiFi infrastructure of the building or SMS messages have to be use

Faragher, R. and Harle, R. (2014).

An analysis of the accuracy of bluetooth low energy for indoor positioning applications.

pages 201–210, Tampa, Florida, USA.

Kappel, M. (2014).

Indoor-Lokalisierung mit Android basierten Smartphones.

Bachelor thesis, University of Potsdam.

Seemann, M. (2015).

So erhöhen Sie die WLAN-Reichweite.

PC Magazin.