TECHNISCHE UNIVERSITÄT WIEN
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A Novel Approach for Wi-Fi Fingerprinting Using Logical Sequences of Intelligent Checkpoints (iCPs)

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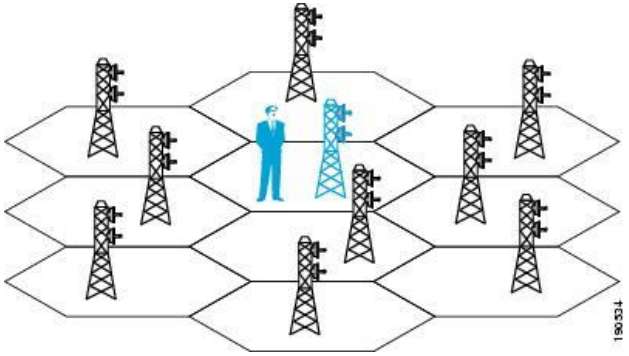
Wi-Fi Positioning Methods

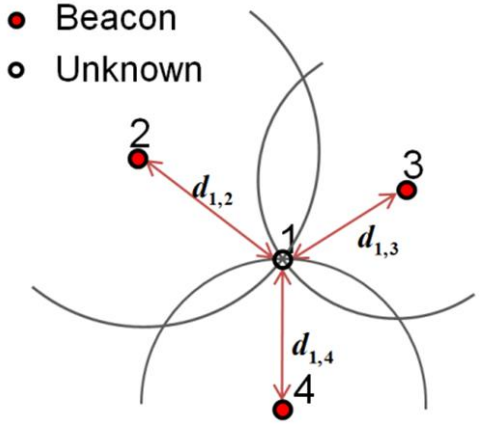
Cell-based positioning – Cell-of Orgin CoO

Simplest and most straight forward technique
Mobile positioning technique for finding the basic geographical coverage unit



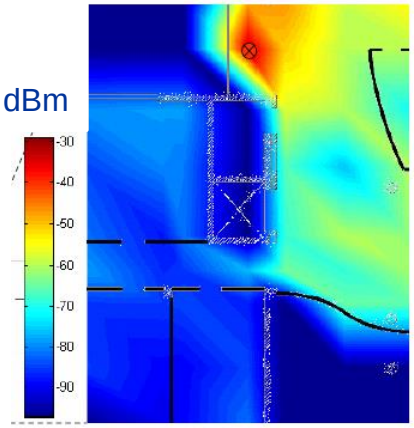
Lateration

RSSI-based techniques employ path loss models for range conversion



Location Fingerprinting

Training and positioning phase very labour consuming

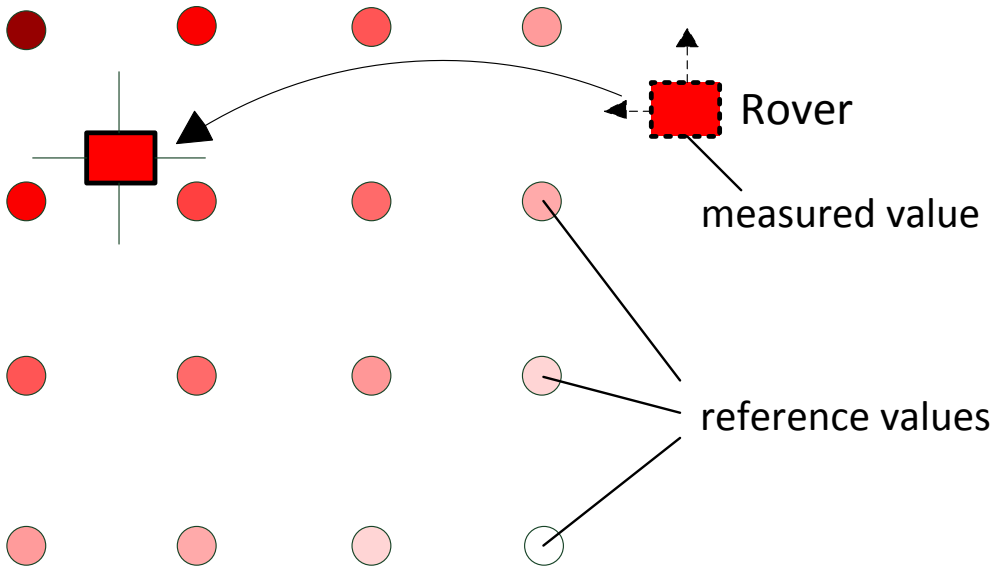


Typical radio map of one AP

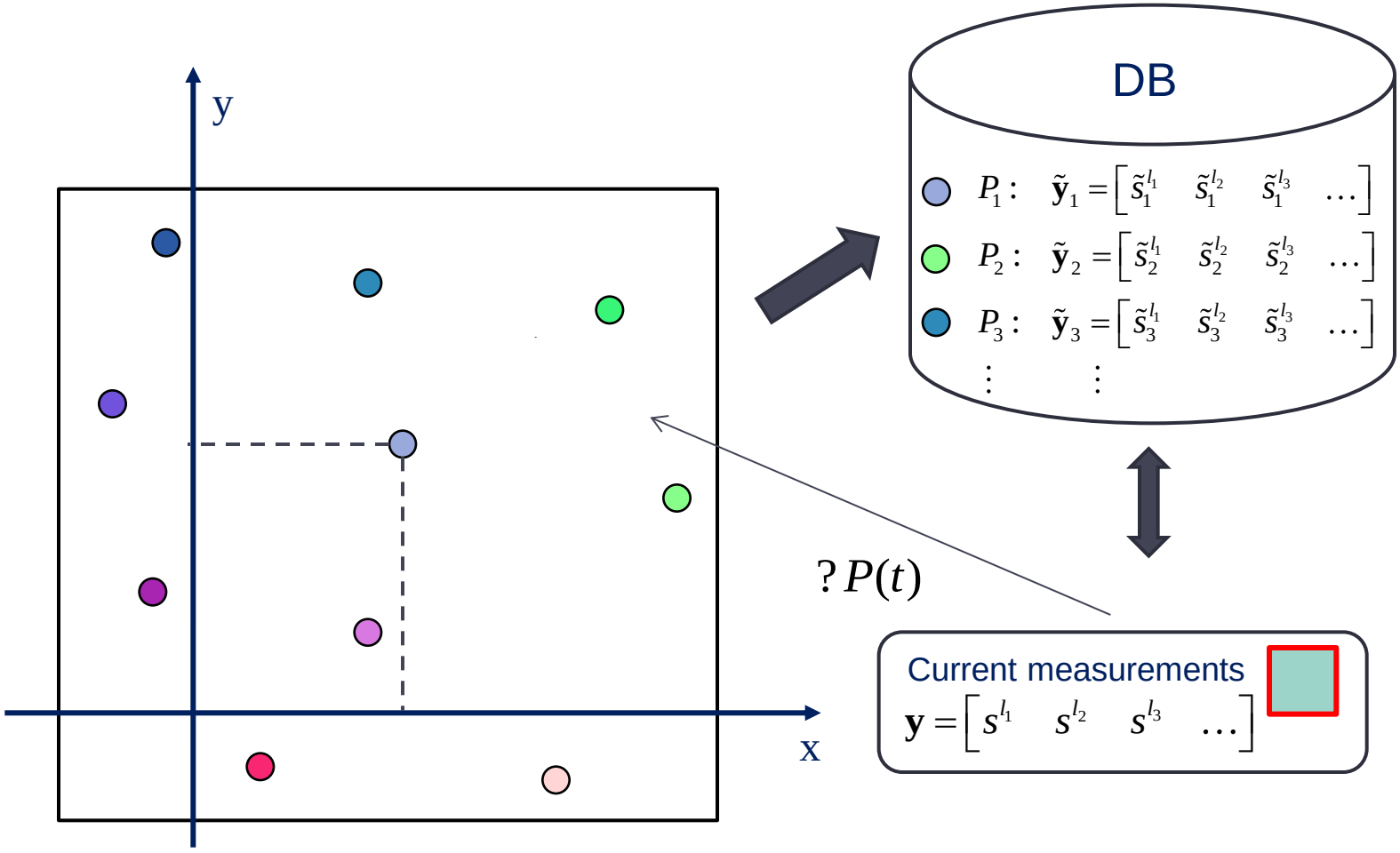
Feature-Based Positioning

Position can also be derived by

- Measuring a spatially varying feature
- Locating the measured value within a database of georeferenced values
  (reference values)



Location Fingerprinting



Intelligent Checkpoints iCPs

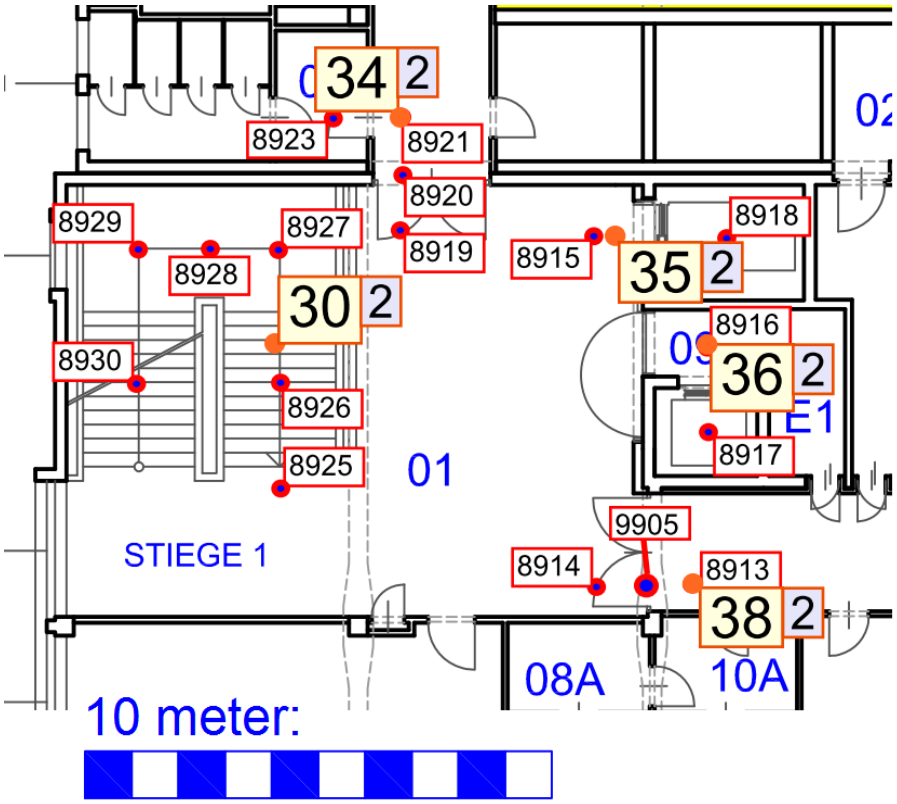
Sparsely distributed reference points in the area of interest

Waypoints along a route have to be passed following a logical sequence

Waypoints are called iCPs

Training measurements on chosen iCPs only

Twofold intelligent because of their intelligent selection and logical sequence along the path



Examples for iCPs in the foyer and staircase of the 3rd floor in a multi-storey office building

Evaluation Definitions

$$\text{matching rate} = \frac{\text{number of correctly assigned RSSI scans to RPs}}{\text{total number of all RSSI scans in positioning phase}}$$

Case 1: - 101 dBm for no scan value available in one epoch

$$\text{Scan1} = [S1_{AP1}, S1_{AP2}, \ldots, S1_{APn}] \quad S1_{APx} \in \{\mathbb{Z}_{<0} \cap \{-100, -99, \ldots, -1\}\}$$

$$S1_{APx} = \begin{cases} \text{RSSI APx in dBm} & \text{if RSSI value to APx is obtained} \\ \text{-101 dBm} & \text{if RSSI value to APx not obtained} \end{cases}$$

Case 2: NaN (Not a Number) for no scan value available in one epoch

$$\text{Scan2} = [S2_{AP1}, S2_{AP2}, \ldots, S2_{APn}] \quad S2_{APx} \in \{\mathbb{Z}_{<0} \cap \{-100, -99, \ldots, -1\} \cup \text{NaN}\}$$

$$S2_{APx} = \begin{cases} \text{RSSI APx in dBm} & \text{if RSSI value to APx is obtained} \\ \text{NaN} & \text{if RSSI value to APx is not obtained} \end{cases}$$

where n is the number of APs given in the vector $AP_x = [AP_1, AP_2, \ldots, AP_n]$

Consideration of all 4 Orientations

		Results of test using all four orientations							
		DB1 (-101dBm)				DB2 (NaN)			
		mean DB		median DB		mean DB		median DB	
		-101dbm	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*
all AP RSSI values	**SM1 DB**	66.2 %	46.9 %	38.3 %	35.3 %	20.4 %	20.7 %	**72.5 %**	72.0 %
	SM2 SB	56.9 %	49.4 %	50.6 %	44.4 %	34.8 %	33.6 %	67.9 %	**69.4 %**
	joint DB	42.6 %	30.2 %	41.8 %	34.4 %	17.0 %	16.1 %	**55.5 %**	53.8 %
	mean matching rate	**55.2 %**	**42.1 %**	**43.6 %**	**38.0 %**	**24.1 %**	**23.4 %**	***65.3 %***	**65.1 %**
unique AP RSSI values	**SM1 DB**	61.0 %	48.9 %	52.1 %	39.3 %	24.2 %	23.7 %	**62.7 %**	61.0 %
	SM2 SB	68.7 %	66.2 %	56.4 %	55.4 %	53.6 %	53.9 %	64.9 %	**68.9 %**
	joint DB	**63.8 %**	55.4 %	55.8 %	45.0 %	33.0 %	33.2 %	51.4 %	51.6 %
	mean matching rate	***64.5 %***	**56.8 %**	**54.8 %**	**46.6 %**	**37.0 %**	**36.9 %**	**59.7 %**	**60.5 %**

Best matching rates are achived if
- own DBs are used for each smartphone
- DB mean (-101 dBm) and test DB1 (-101dBm) for arithmetric mean
- DB median (-101 dBm) and median (NaN) with test DB2 (Nan) for median
- APs of multiple networks are reduced to unique AP if a joint DB is used

Consideration of Heading

		Results of test with known orientation							
		DB1 (-101dBm)				DB2 (NaN)			
		mean DB		median DB		mean DB		median DB	
		-101dbm	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*
all AP RSSI values	SM1 DB	62.5 %	46.3 %	39.5 %	36.0 %	40.8 %	46.3 %	**70.5 %**	69.8 %
	SM2 SB	52.6 %	46.4 %	49.6 %	49.1 %	43.4 %	46.4 %	**66.4 %**	66.2 %
	joint DB	46.2 %	34.9 %	44.8 %	41.5 %	27.8 %	34.9 %	**56.9 %**	55.8 %
	mean matching rate	**53.8 %**	**42.5 %**	**44.7 %**	**42.2 %**	**37.3 %**	**42.5 %**	***64.6 %***	**63.9 %**
unique AP RSSI values	SM1 DB	**65.2 %**	55.9 %	50.6 %	46.6 %	44.6 %	55.9 %	58.7 %	57.4 %
	SM2 SB	**75.2 %**	65.7 %	63.4 %	48.4 %	58.9 %	65.7 %	64.7 %	63.7 %
	joint DB	**66.8 %**	62.1 %	56.4 %	53.1 %	45.4 %	62.1 %	55.2 %	50.8 %
	mean matching rate	***69.1 %***	**61.2 %**	**56.8 %**	**49.4 %**	**49.6 %**	**61.2 %**	**59.5 %**	**57.3 %**

Improvement compared to the case where all orientations are tested:
- in average 3.0 % for arithmetric mean
- 5.3 % for median

Main advantage: only one orientation in direction of movement (heading) has to tested which results in only one quarter of RSSI scans need to be tested and thus significant reduction of processing time

Consid. of Logical iCP Sequence (1)

		Results of test with known orientation							
		DB1(-101dBm)				DB2(NaN)			
		mean DB		median DB		mean DB		median DB	
		-101dbm	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*	*-101dbm*	*NaN*
all AP RSSI values	**whole iCP DB**	**74.3 %**	60.1 %	62.2 %	54.9 %	25.1 %	60.1 %	70.8 %	70.7 %
	section 0 joint DB	**92.9 %**	67.5 %	76.2 %	57.1 %	69.8 %	67.5 %	89.7 %	86.5 %
	section 1 joint DB	58.8 %	48.2 %	56.1 %	53.5 %	32.5 %	48.2 %	**69.3 %**	65.8 %
	section 2joint DB	**82.7 %**	73.3 %	64.3 %	60.4 %	57.9 %	73.3 %	74.9 %	75.2 %
	section 3 joint DB	46.6 %	34.2 %	46.6 %	41.1 %	42.5 %	34.2 %	**64.4 %**	**64.4 %**
	section mean matching rate	**70.2 %**	**55.8 %**	**60.8 %**	**53.0 %**	**50.7 %**	**55.8 %**	***74.6 %***	**73.0 %**
unique AP RSSI values	**whole iCP DB**	**87.1 %**	83.6 %	75.7 %	69.8 %	58.5 %	83.6 %	68.5 %	66.1 %
	section 0 joint DB	**97.6 %**	96.0 %	83.3 %	61.9 %	85.7 %	96.0 %	83.3 %	81.7 %
	section 1 joint DB	**84.2 %**	78.9 %	70.2 %	58.8 %	63.2 %	78.9 %	64.0 %	52.6 %
	section 2 joint DB	88.0 %	**89.4 %**	78.8 %	79.7 %	74.1 %	**89.4 %**	71.6 %	69.6 %
	section 3 joint DB	72.6 %	74.0 %	69.9 %	60.3 %	**75.3 %**	74.0 %	69.9 %	63.0 %
	section mean matching rate	***85.6 %***	**84.6 %**	**75.6 %**	**65.2 %**	**74.6 %**	**84.6 %**	**72.2 %**	**66.8 %**

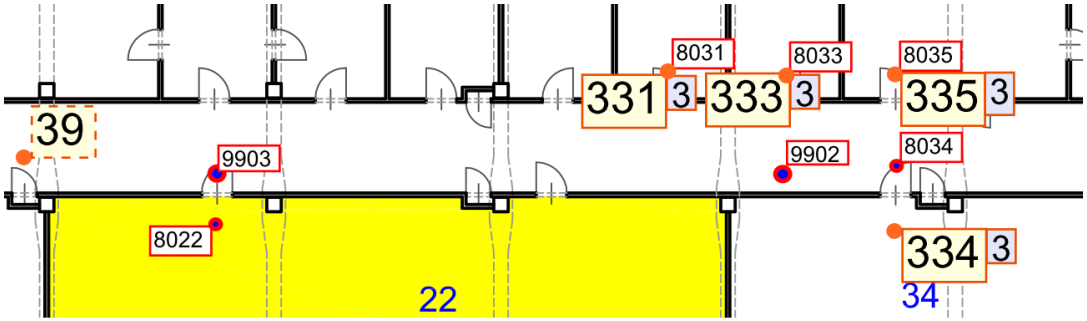
Sections: 0 = building entrance; 1 = staircase or elevator; 2 =staircase with points function as a junction; 3 = entrances to 4 destination rooms

Mean matching rate is significantly higher

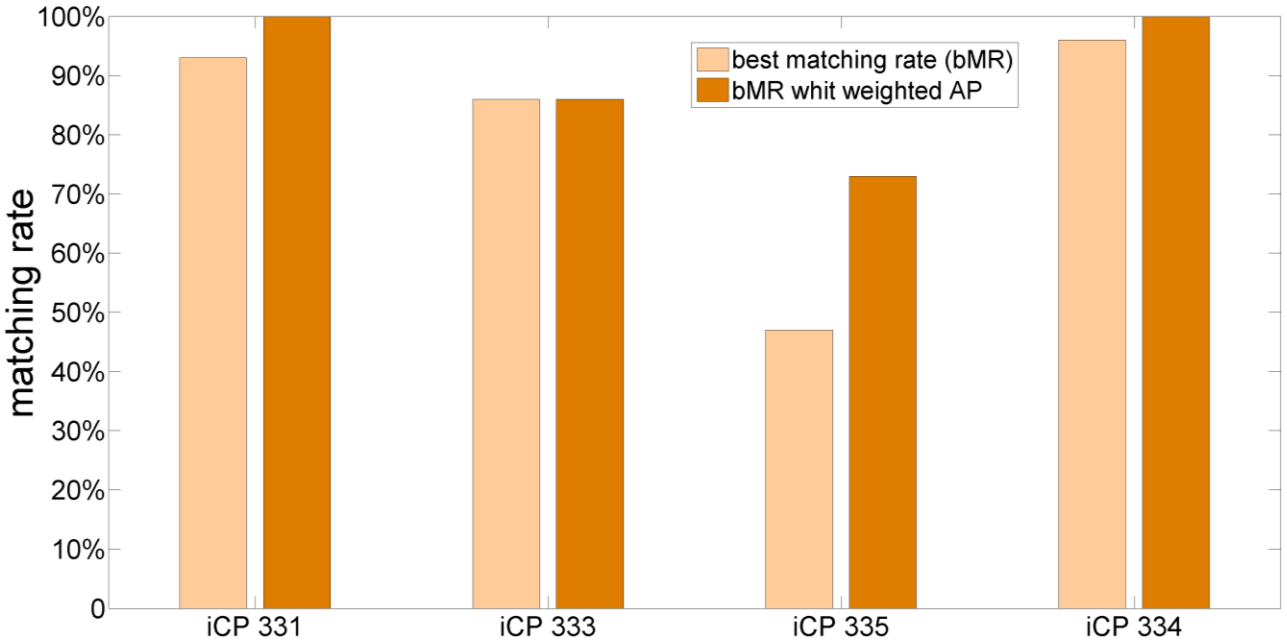
Consid. of Logical iCP Sequence (2)

		best matching rate	*best matching rate with AP weighting*
all AP RSSI values	**whole iCP DB**	76.9 %	76.9 %
	section 0 joint DB	92.9 %	95.2 %
	section 1 joint DB	69.3 %	72.8 %
	section 2 joint DB	90.3 %	90.3 %
	section 3 joint DB	64.4 %	71.2 %
	mean matching rate	**79.2 %**	**82.4 %**
unique AP RSSI values	**whole iCP DB**	87.1 %	88.1 %
	section 0 joint DB	99.2 %	99.2 %
	section 1 joint DB	84.2 %	84.2 %
	section 2 joint DB	94.4 %	95.0 %
	section 3 joint DB	83.6 %	93.2 %
	mean matching rate	**90.4 %**	**92.9 %**

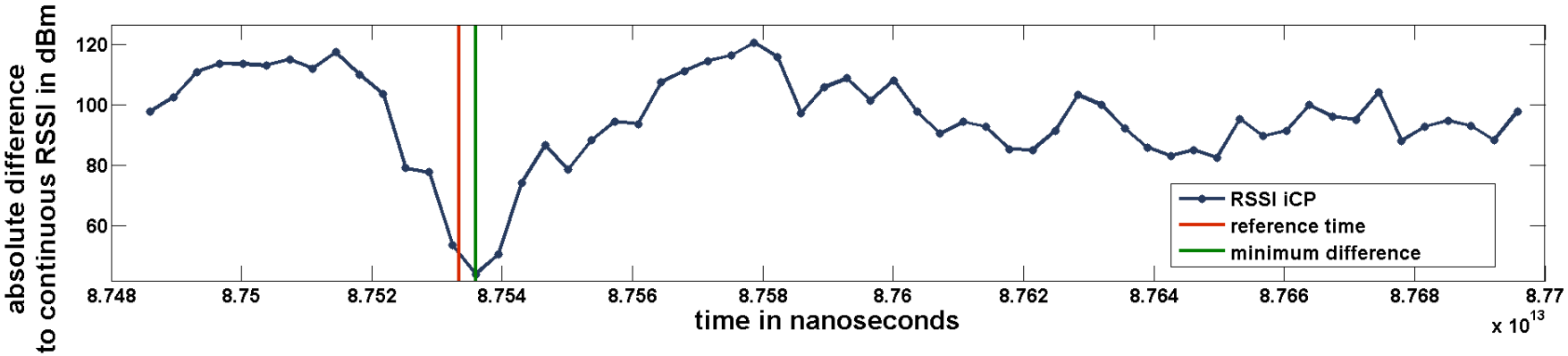
Results Section 3: Destination Rooms



10 meter:



Integration of Smartphone Motion Sensors



Eucledian distances of a certain iCP calculated from continuous RSSI scans while walking along a trajectory

Journal of Applied Geodesy (JAG)

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Special Issue Vol. 9, No. 4
Publication Date: December 2015

http://www.degruyter.com/view/j/jag

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