Investigation of Indoor localization using FM radio

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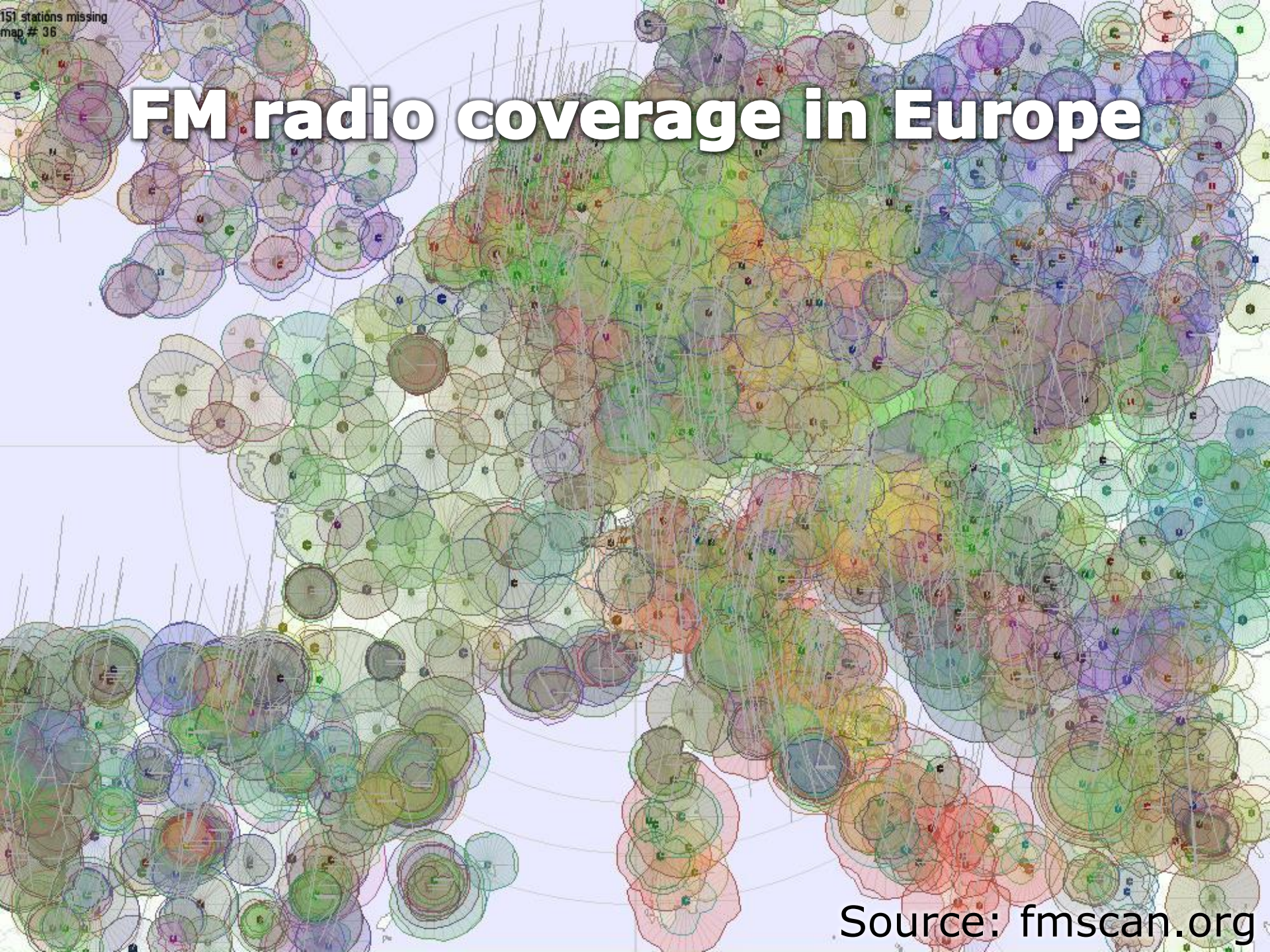
Indoor localization

- Specialized systems are expensive
- Wi-Fi, the de-facto standard
  - Requires infrastructure
  - Limited coverage
  - High power consumption
- Cellular-based systems
  - Good coverage
  - Low accuracy


151 stations missing
map # 36
FM radio coverage in Europe
Source: fmscan.org

FM localization

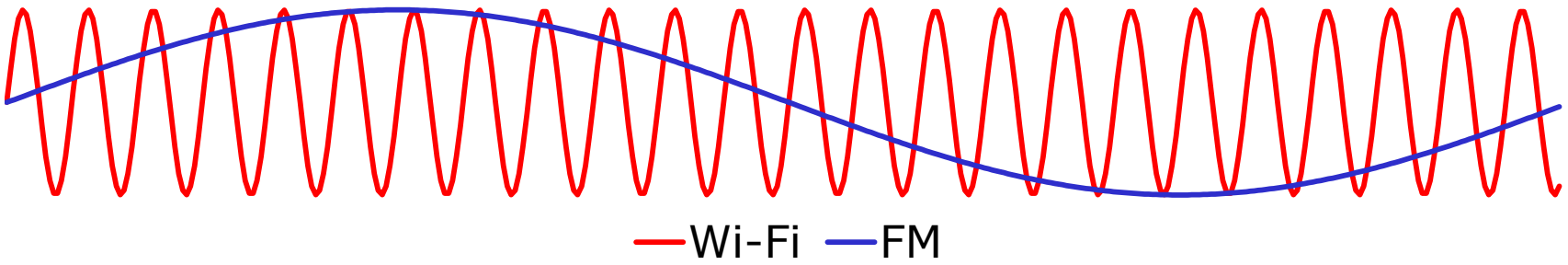
- There are only few works on FM localization
- All of them consider only outdoor scenarios
- Outdoor accuracy:
  - 8 km with 50% probability (Krumm et al., 2005)
  - 20 m with 67% probability (Fang et al., 2009)

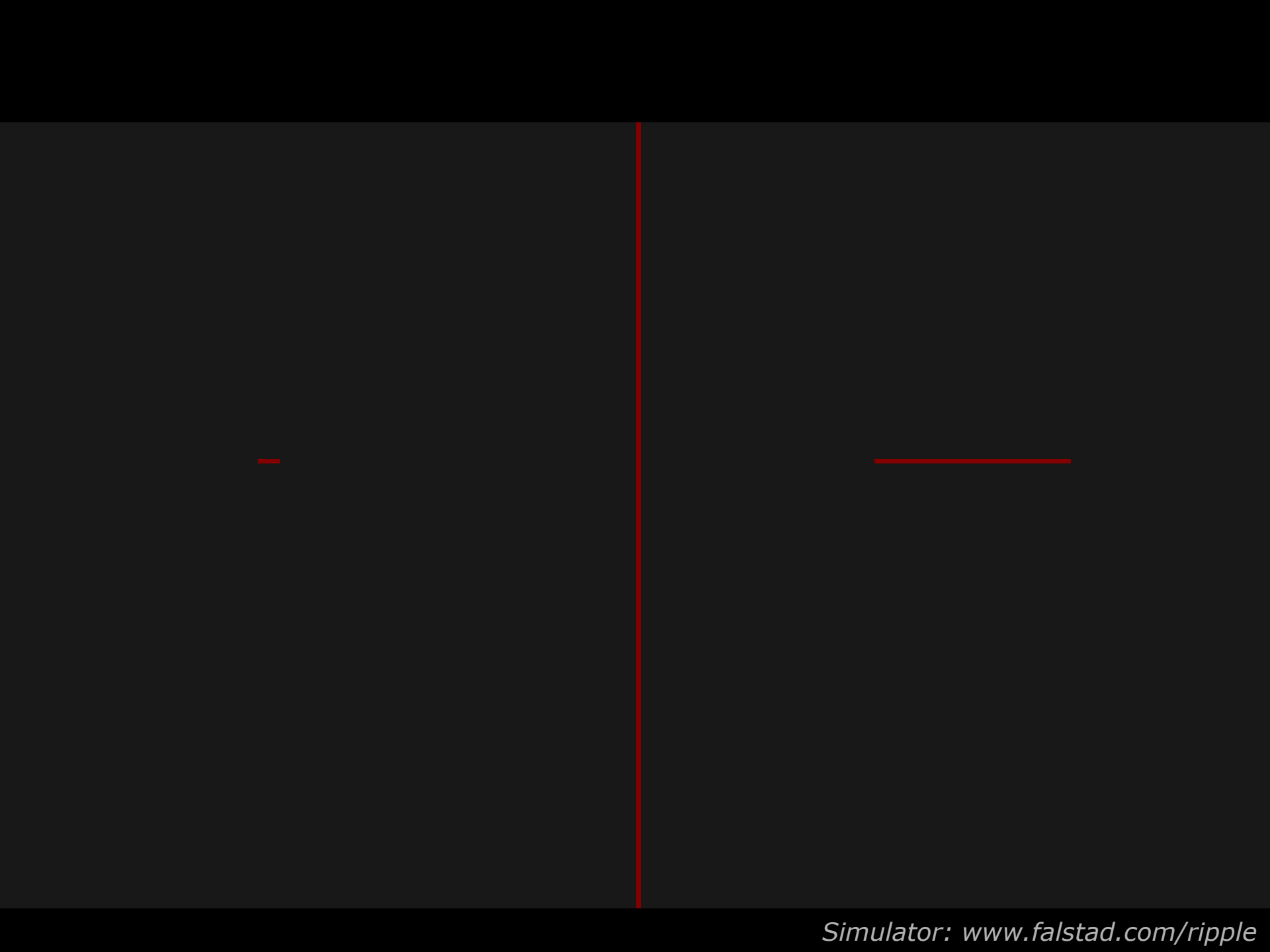
There are no results for *indoor* FM localization performance.

Indoors is different

- Multipath effects
- Propagation depends on wavelength

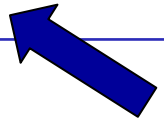
	Frequency	Wavelength
Wi-Fi	2.4 GHz	12 cm
FM radio	~100 MHz	~3 m




Simulator: www.falstad.com/ripple

State of the art: Summary

Technology	Accuracy	Coverage	Battery life	System costs
Wi-Fi	Medium	Low	Low	Low
Cellular	Low	High	Low	Low
Specialized	High	Low	High	High
FM (outdoor)	Low	High	High	Low
FM (indoor)				



The Gap

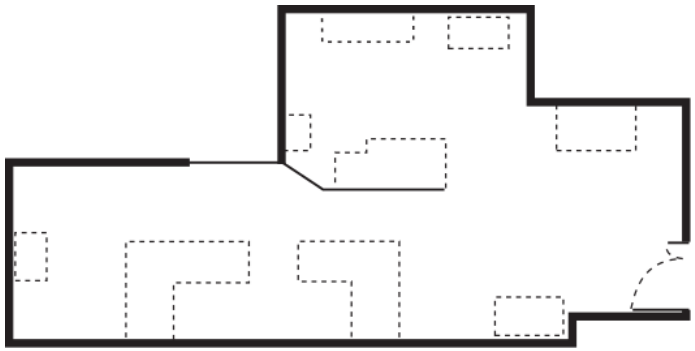
Our approach

- Signal strength fingerprinting
- Different-day datasets

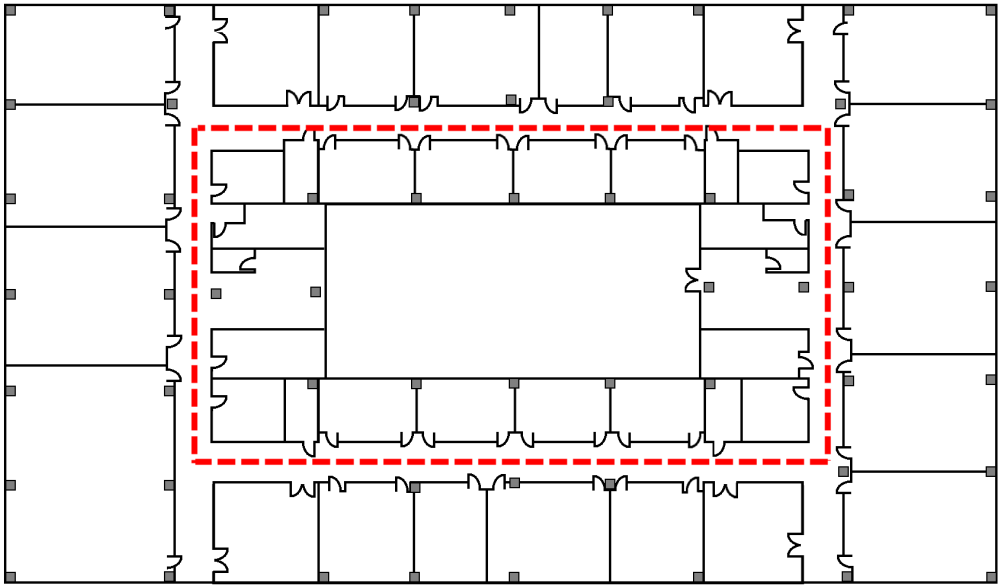
- Off-the-shelf devices
  - 3 smartphones with FM and Wi-Fi modules
  - Wi-Fi access points and FM stations around

Experimental setup

Room
12×6 m

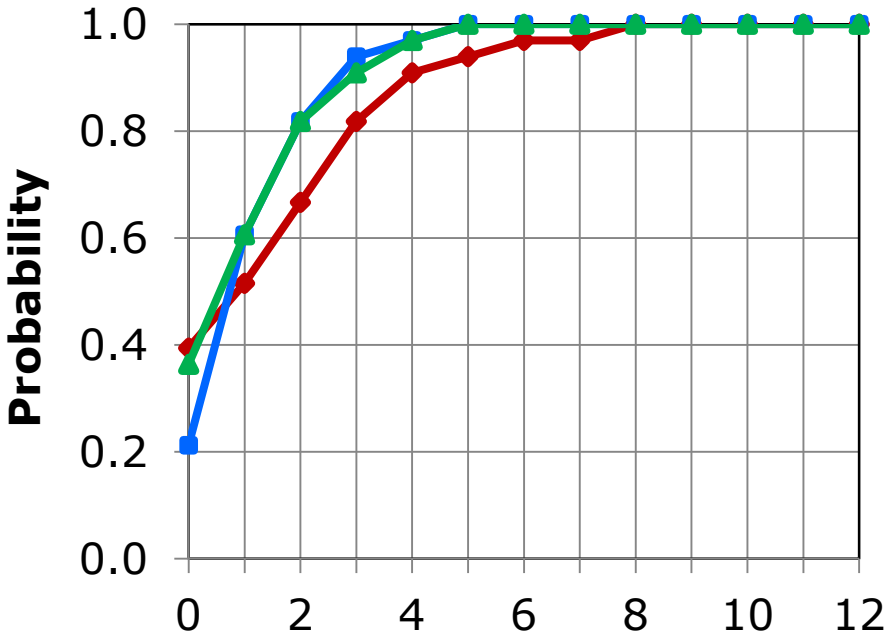


Building floor
50×25 m



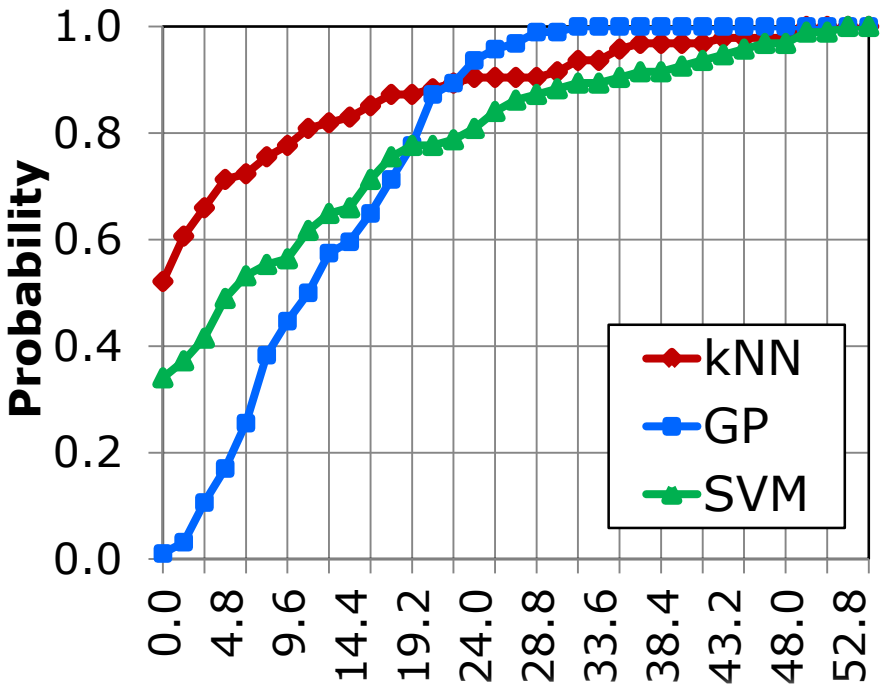
Same device, different day

Room



40% correct
90% within 2.6 m

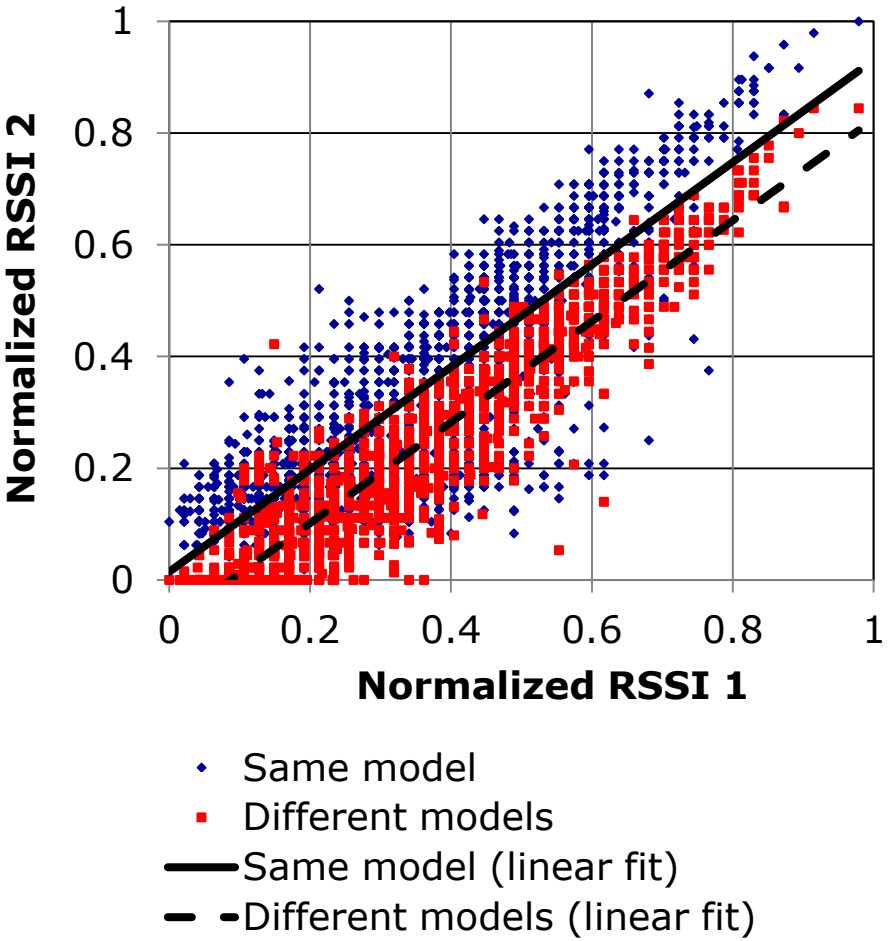
Floor



52% correct
90% within 24 m

Hardware diversity

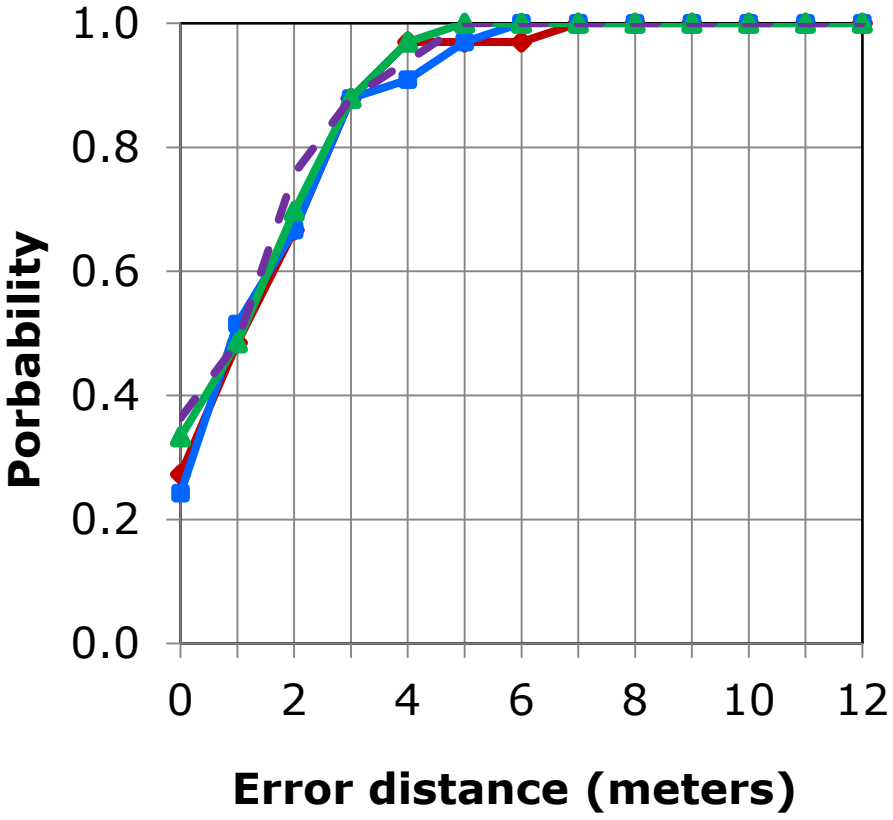
Hardware diversity



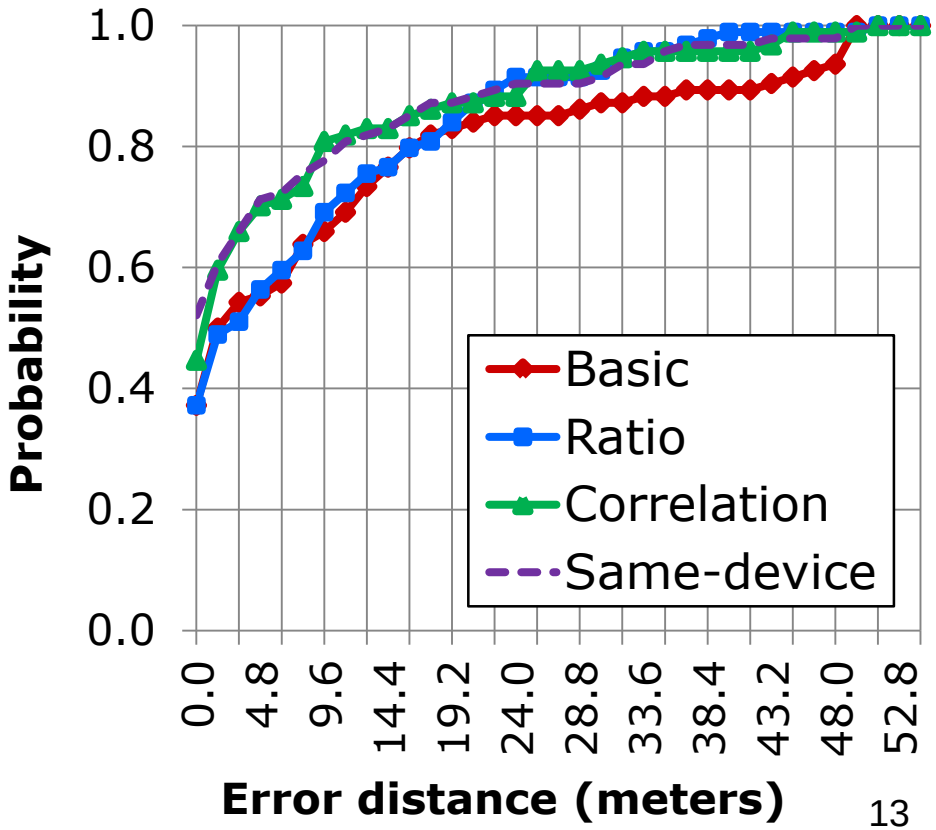
- Three approaches to handle the diversity:
  - Basic (raw RSSI)
  - Ratio (hyperbolic)
  - Correlation

Same receiver model

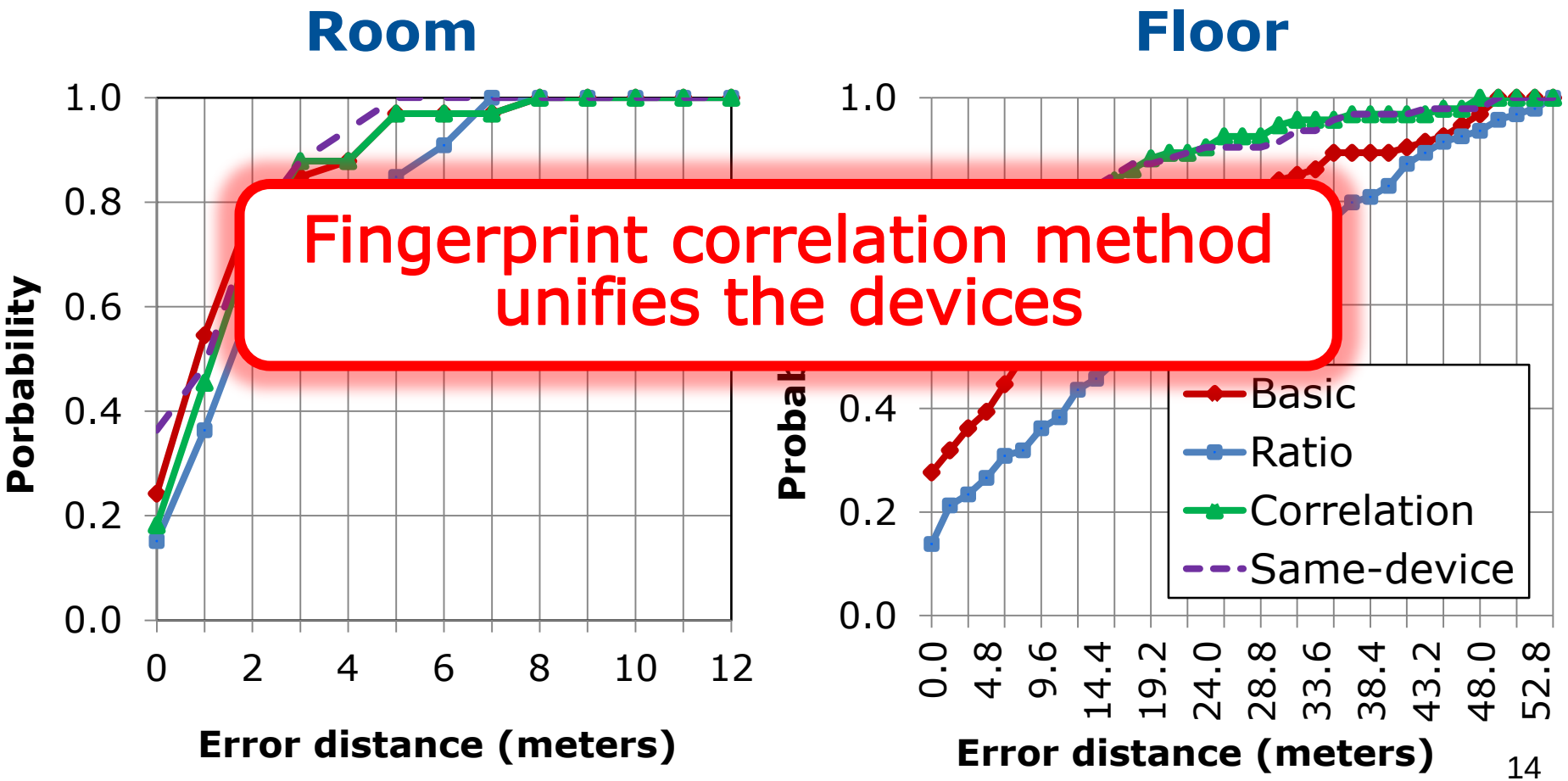
Room



Floor



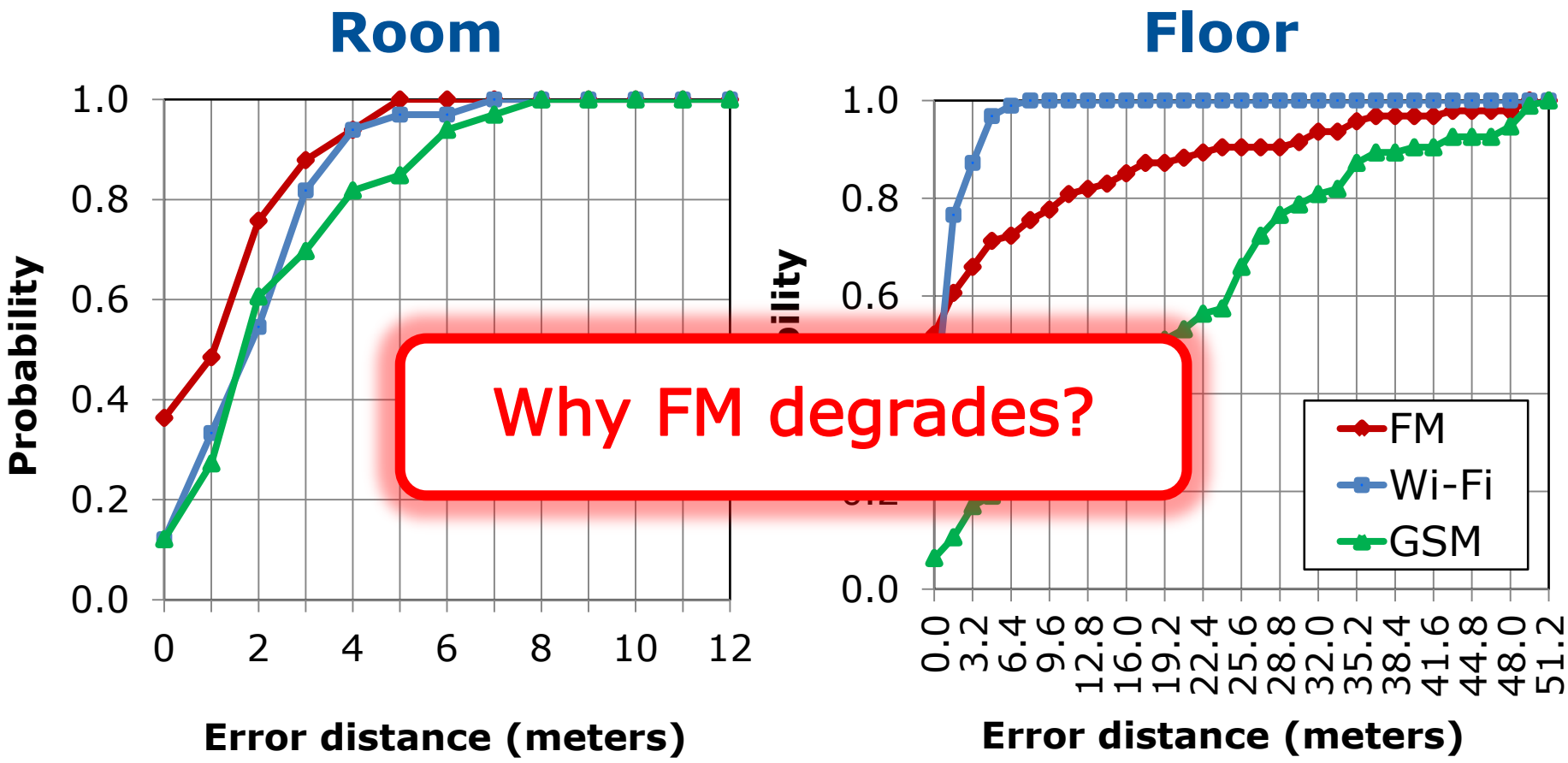
Different receiver models



Different technologies

- Comparison is fair only in the same conditions.
- We collected FM, Wi-Fi and 7-cell GSM fingerprints in both test environments.

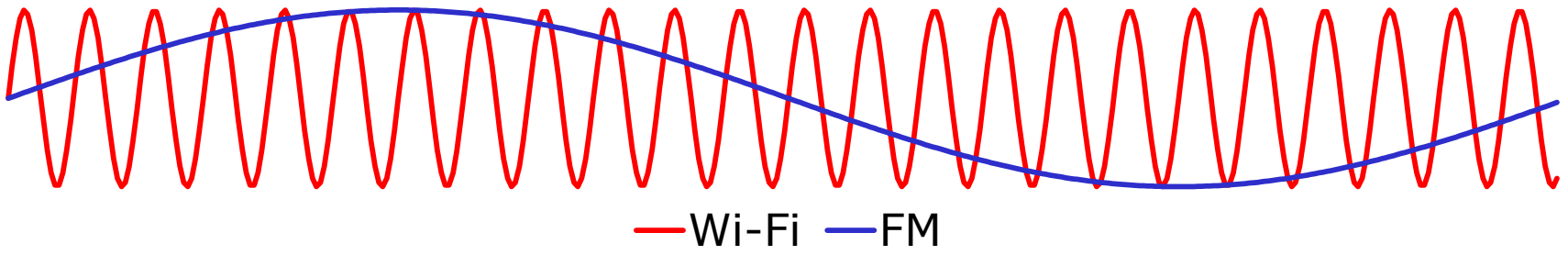
Different technologies



Analysis

- There are two components of signal variation
  - Large-scale variation (path loss)
  - Small-scale variation (interference, reflection, diffraction)

- "Small-scale" is the scale of wavelength



Small-scale variations (Wi-Fi)

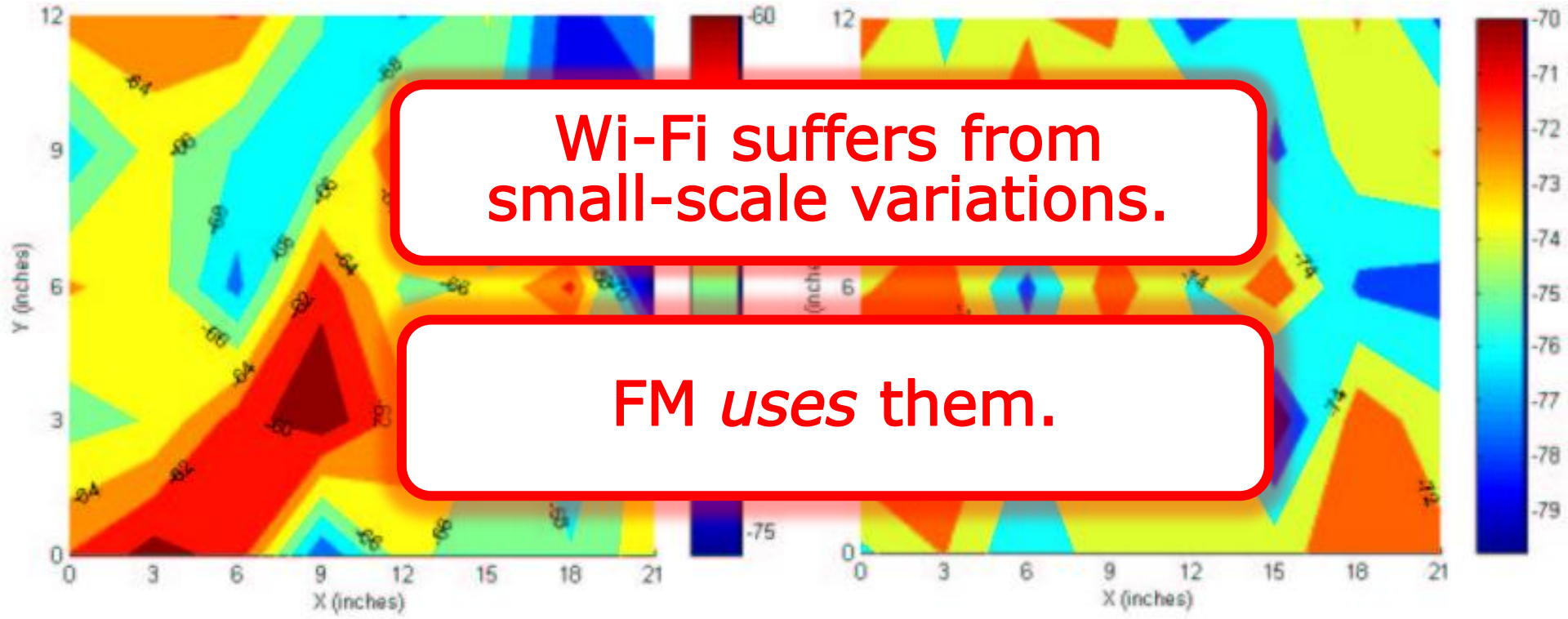


Image courtesy of M. Youssef and A. Agrawala, "Small-scale compensation for WLAN location determination systems". WCNC 2003.

Summary

- Indoor FM localization is feasible
  - It *exploits* multipath effects
  - Accuracy comparable to Wi-Fi in small areas
  - Always better than GSM
  - Low power consumption
- Future work
  - Evaluate the influence of user orientation
  - Evaluate robustness to the weather

Thank you!

Need a postdoc?

contact@popleteev.com

Frequently asked question

- Don’t you need an antenna?

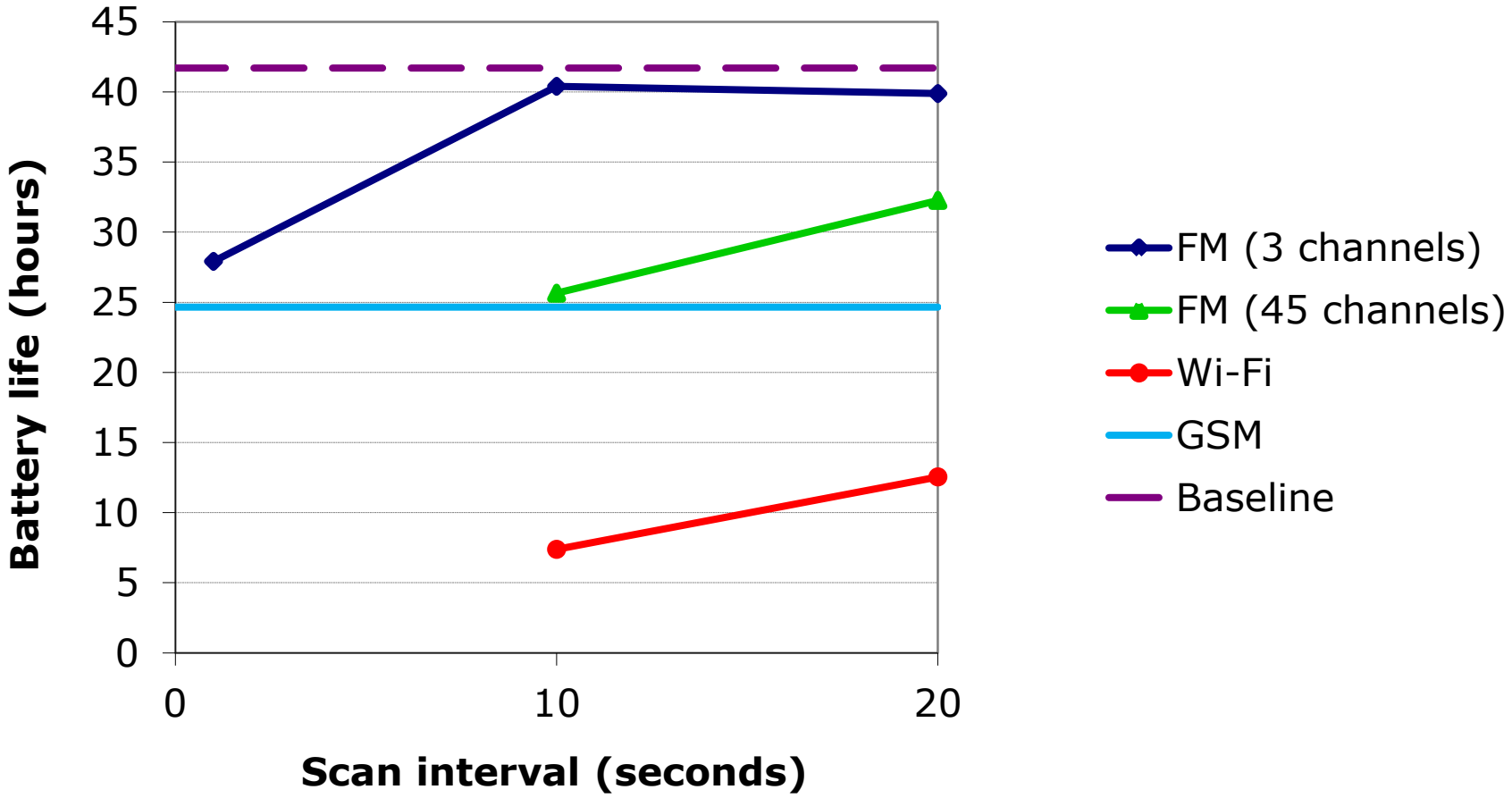
Nokia X3

Nokia 5030

iPod

Radio clock

Battery life



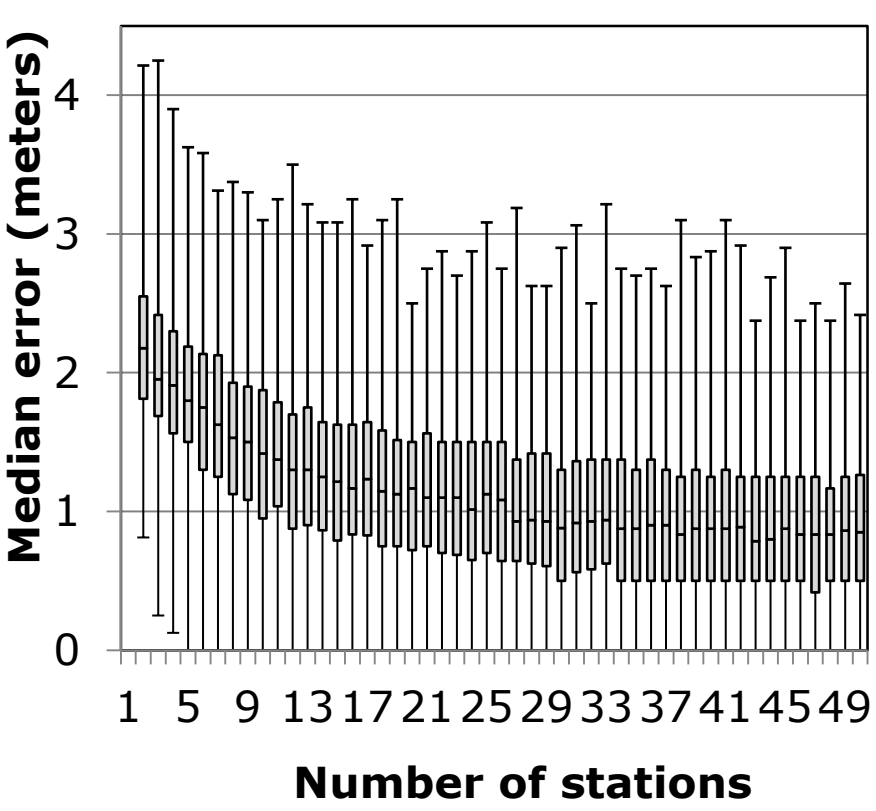
Fingerprint size

- More stations in fingerprint result in:
  - Better localization accuracy
  - Higher computational load
  - Longer scanning times
    - 50 stations take 10 seconds

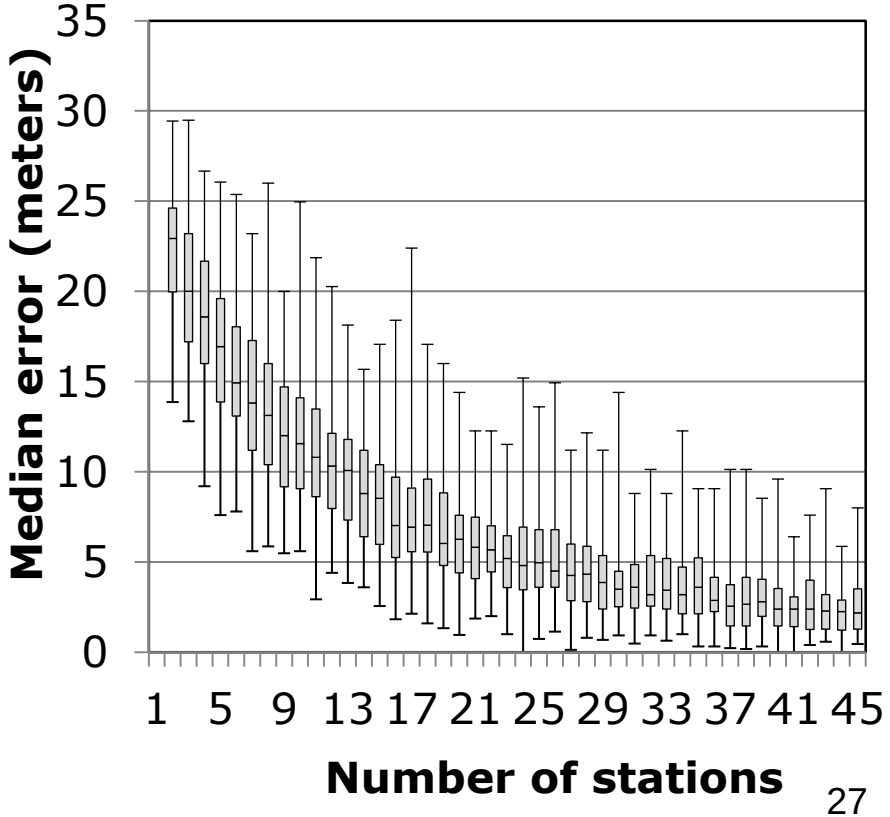
Do we need all the stations?

Number of stations vs. Localization error

Room



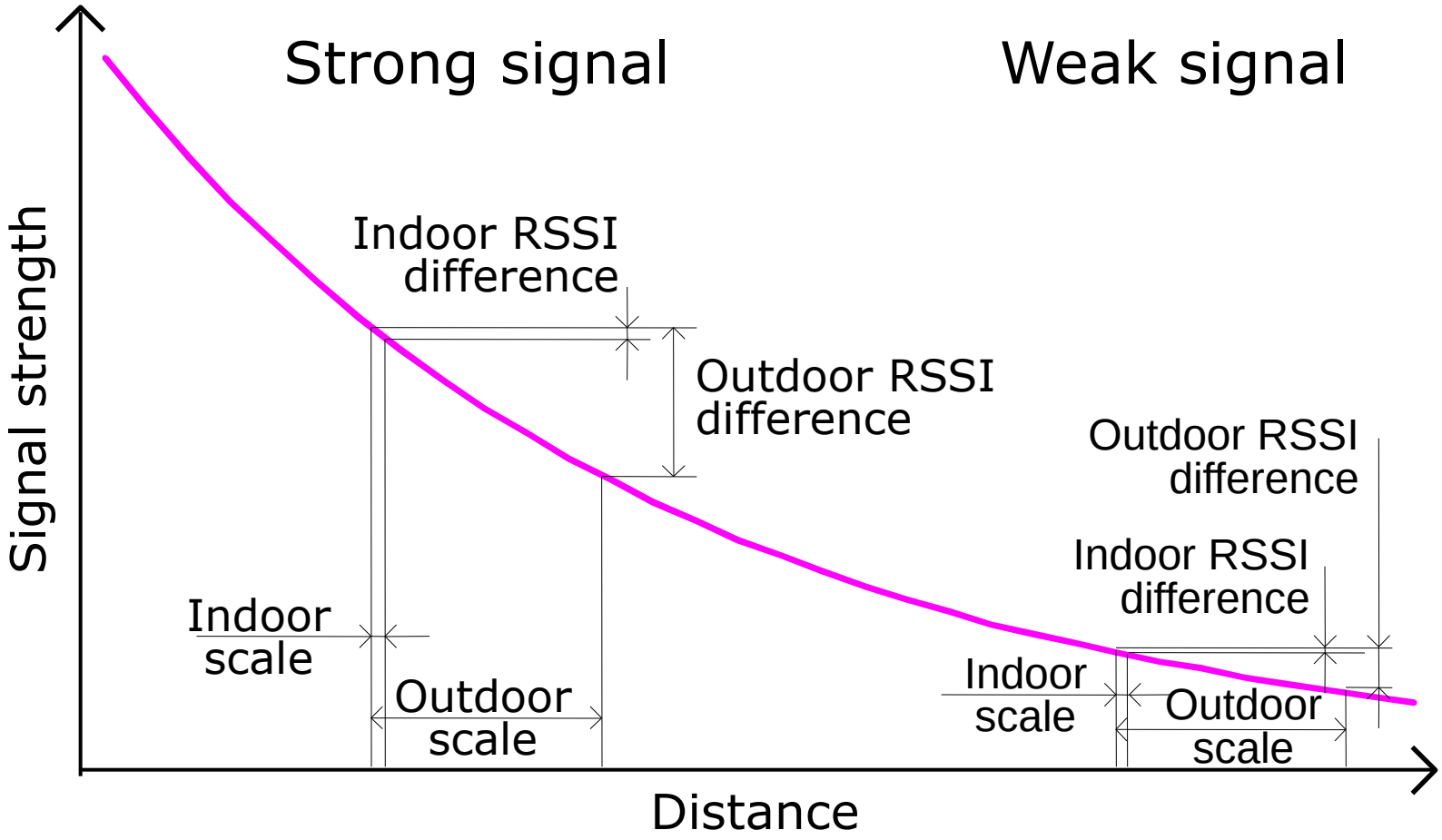
Floor



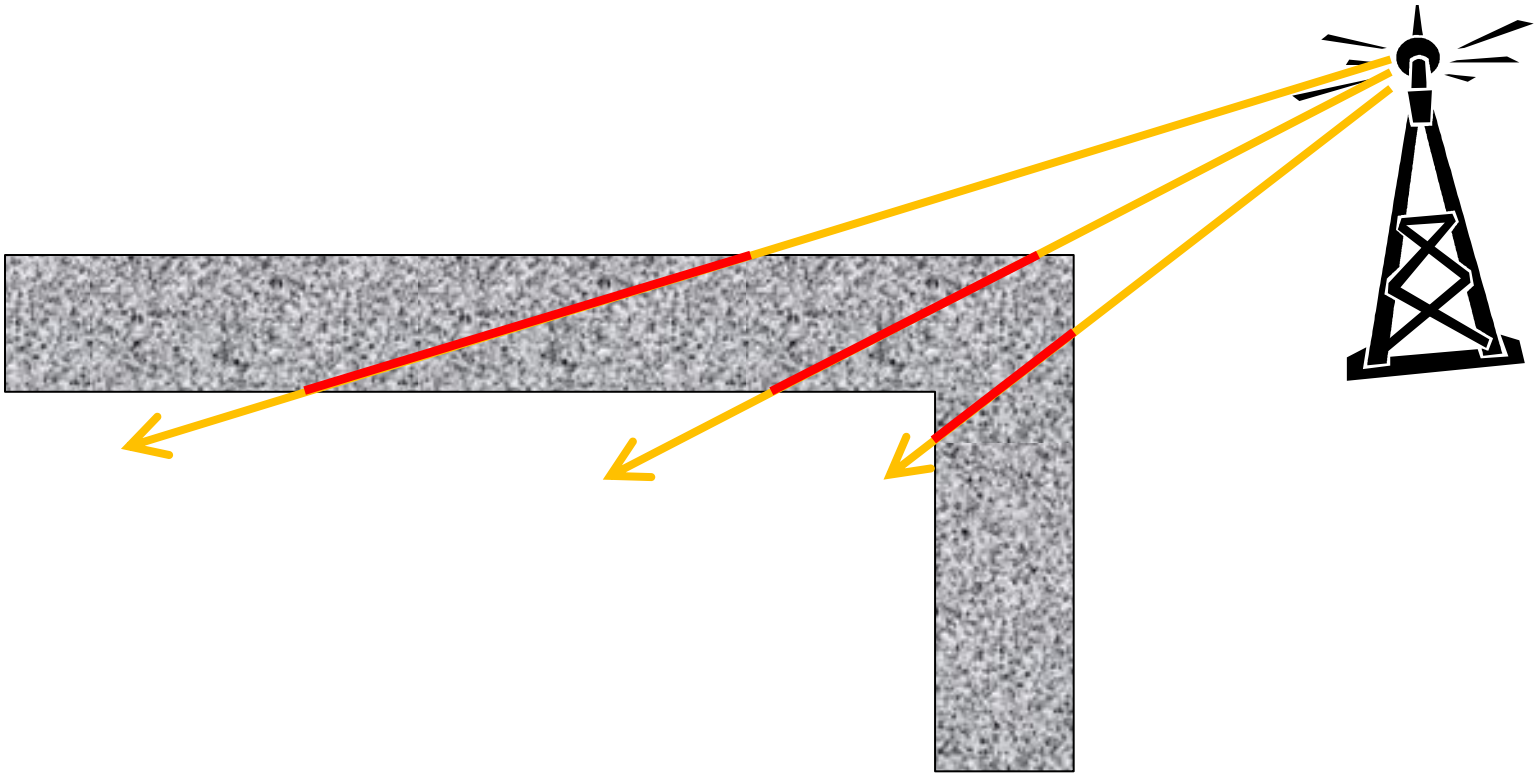
How to choose the stations?

- For outdoor FM positioning, strongest stations provided best performance.
- Not the case for indoors!

Outdoor vs. indoor scale



Indoor obstacles



Fingerprint correlation