Empowered by Innovation NEC

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Location Cognition for Wireless Systems: Classification with Confidence

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To be a leading global company leveraging the power of innovation to realize an information society friendly to humans and the earth

NEC Group Vision 2017

Outline

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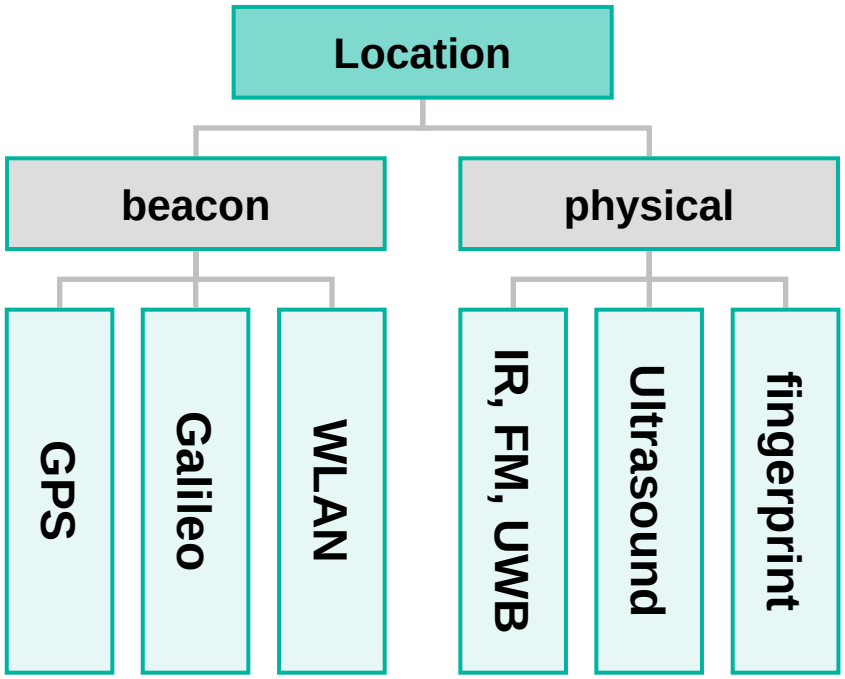
Motivation

Problem description of terminal localization in wireless systems

Indoor Sensing	**Indoor spectrum sensing (cognitive radio) is missing location information (no GPS information available)**
Location method	**Selection of appropriate and simple way of terminal location cognition (fingerprint, beacon, UWB, etc.)**
Proposal	**Monitoring of transmission characteristics and statistical analysis**

Location Methods

Available/proposed location methods



There are several proposals regarding terminal location

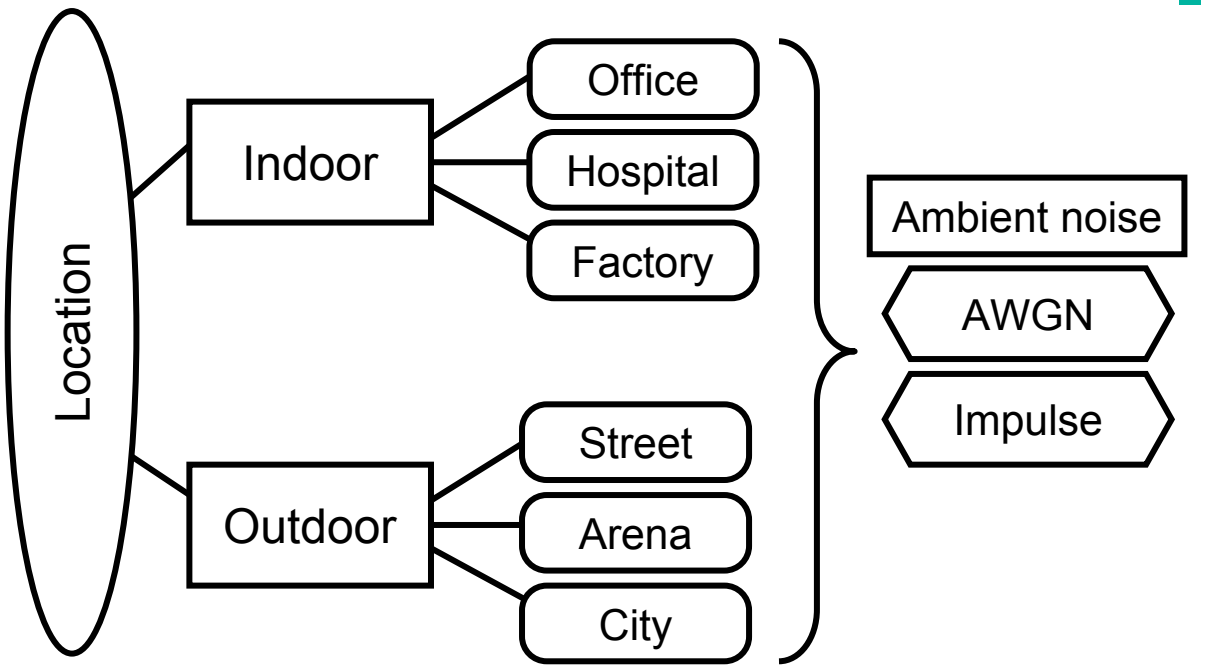
Combination can improve the location cognition performance

- None of them provide a multi-type location information
- Additional devices/hardware needed
- No seamless location (indoor/outdoor) cognition

Idea: Location method which is independent of additional beaconing or hardware

Location Types

Classification of wireless propagation environments



- Different locations and environments have different physical characteristics:
  - Indoor: high multipath fading, low delay.
  - Outdoor: low multipath fading, high delay.
  - Different sources of ambient noise.

Simple location classification as
binary location type (indoor/outdoor) is helpful

Proposal

Location Cognition Engine

Supervised location type classification based on entropy estimation by using off-line classification of wireless link fluctuations in typical locations and on-line monitoring and comparing of statistical distributions of wireless link characteristics.

Proposal

Location Cognition Engine

Off-line phase

- Obtaining statistical distributions (templates) of link fluctuations indoor and outdoor.
- Select reference distributions (false rate).
- Storing reference distributions in data base.

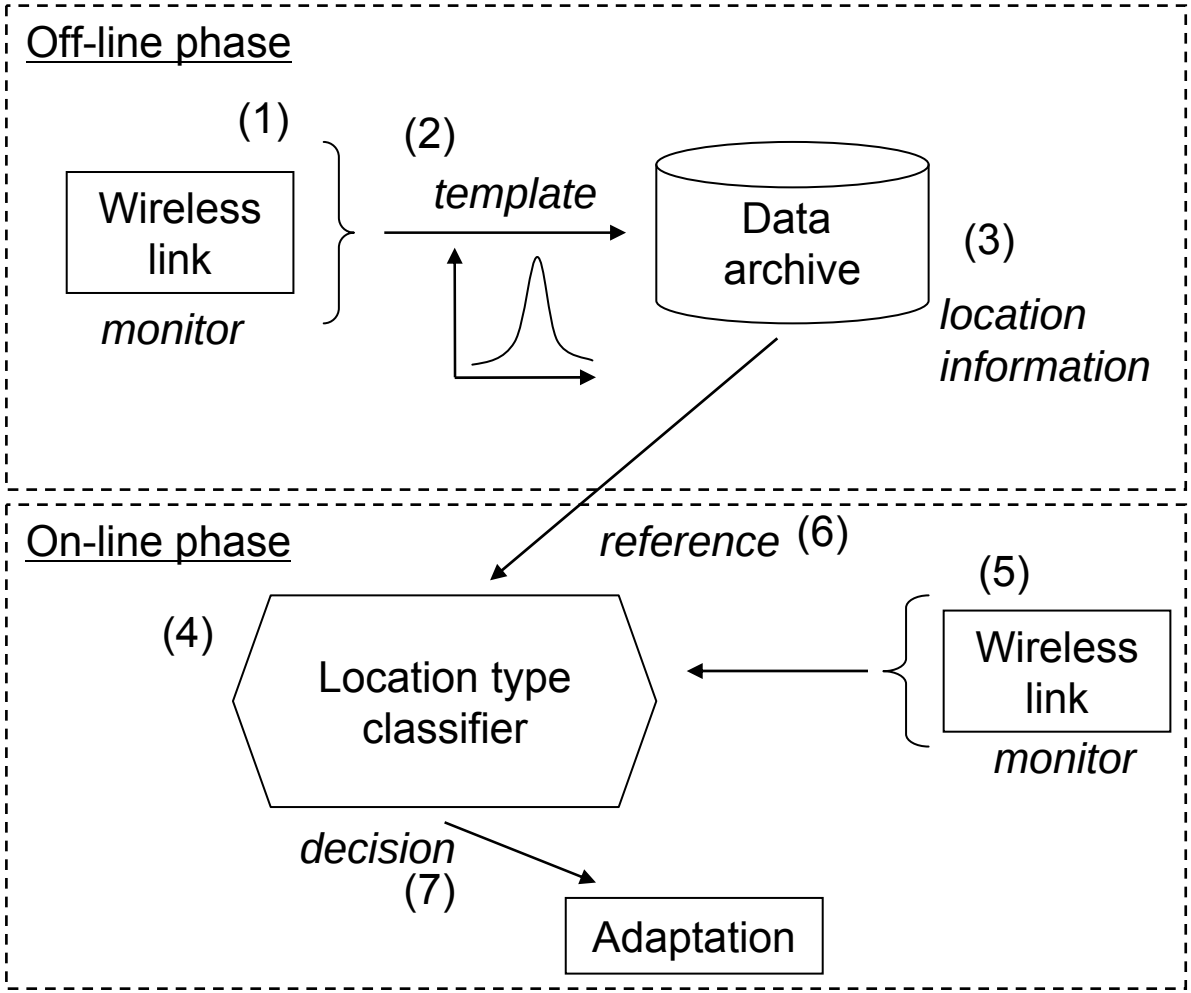
On-line phase

- Location cognition algorithm using:
- Using reference distributions from the data base.
- Monitoring data in the current location.
- Indication of location type.

Location type detected

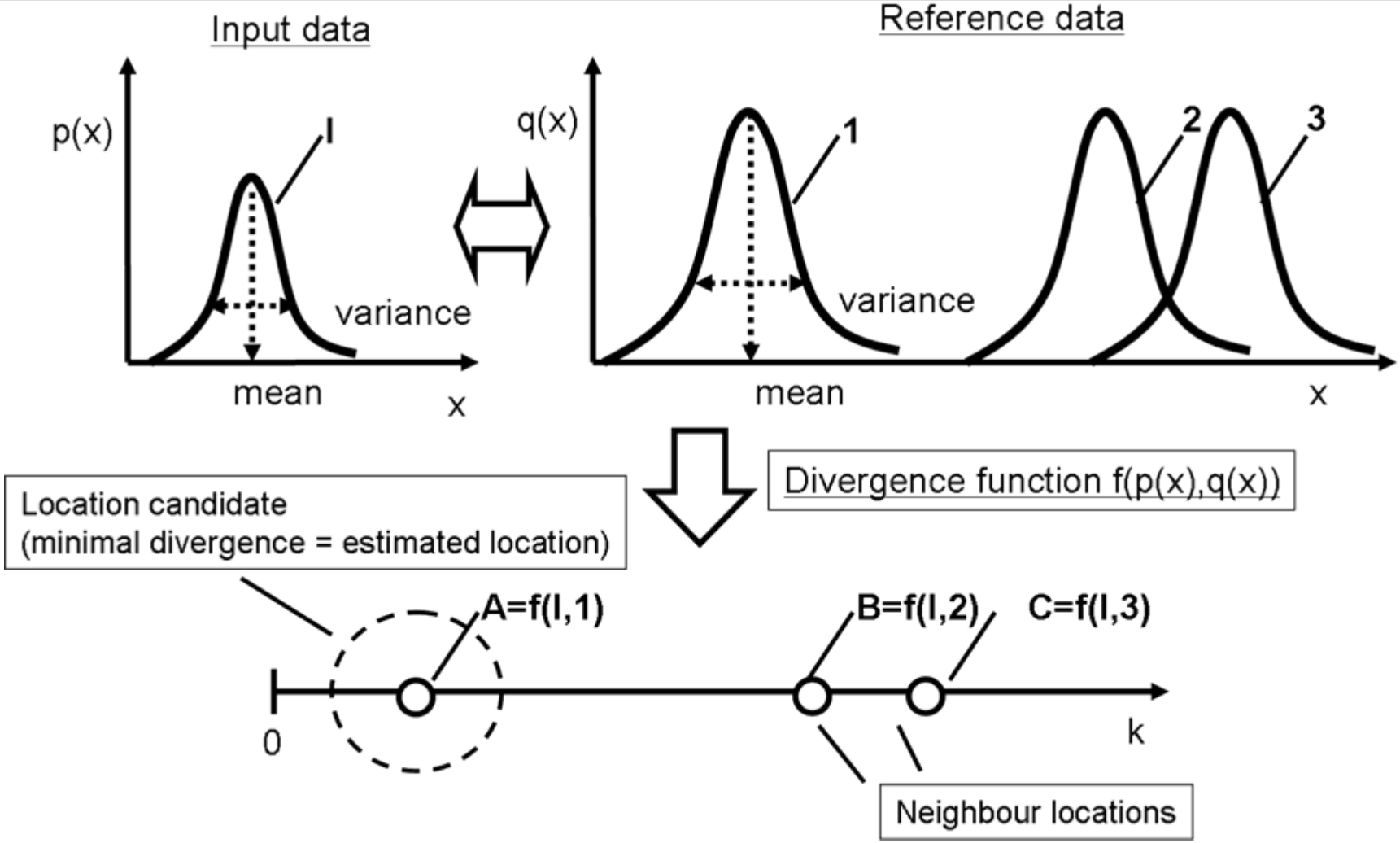
Location Cognition Engine

System architecture



Location Cognition Engine

Proposed entropy-based location cognition



Location Cognition Engine

Jeffrey-Divergence (entropy estimation)

- The Jeffrey-Divergence is derived from the KL-Divergence.
- The Jeffrey-Divergence is symmetric, numerically stable.
- The Jeffrey-Divergence is robust against noise and data bin size.
- The Jeffrey-Divergence is defined as follows (discrete values).

$$JD(P \| Q) = \sum_i \left[p_i \log\left(\frac{p_i}{m_i}\right) + q_i \log\left(\frac{q_i}{m_i}\right) \right]$$

with

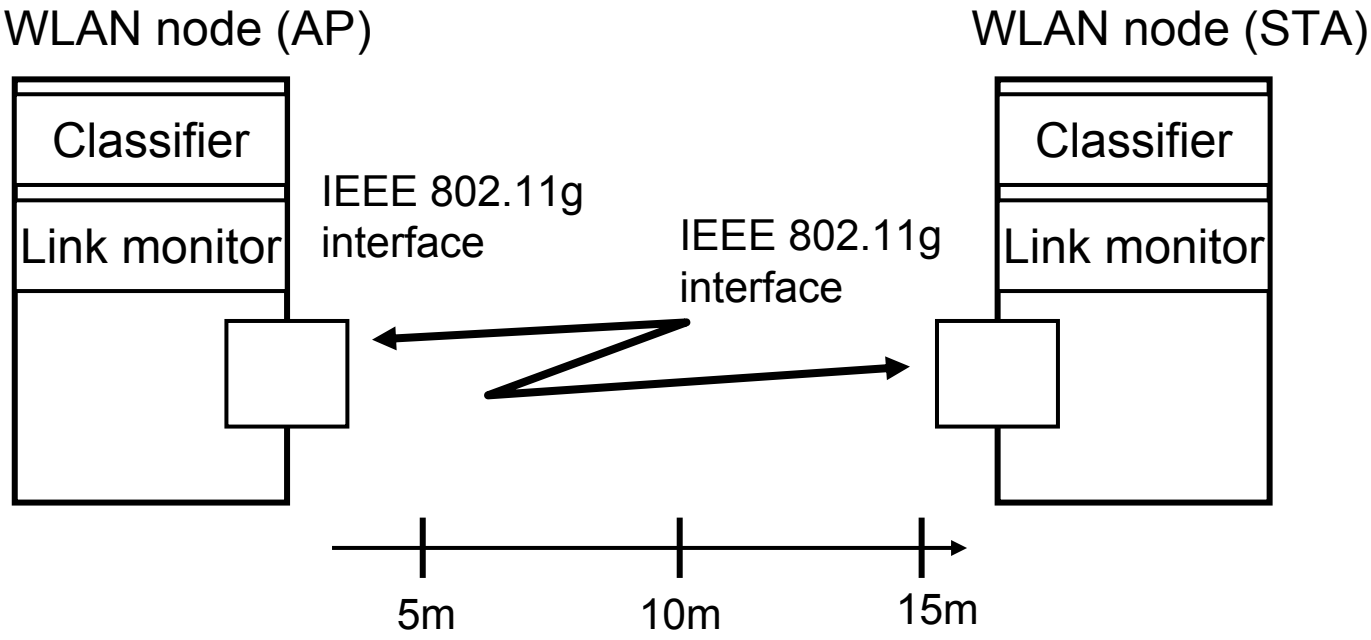
$$m_i = \frac{p_i + q_i}{2}$$

We use a version of Jeffrey-Divergence where the mean and standard deviation can be used (Gaussian approximation).

Location Cognition Engine

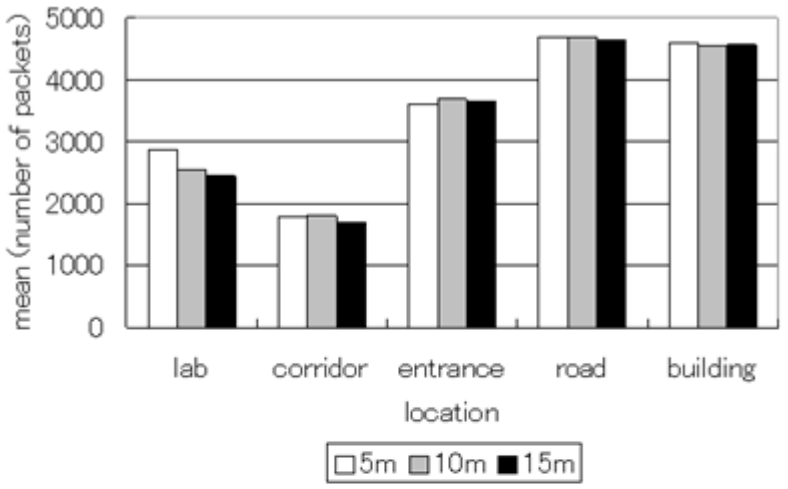
Setup

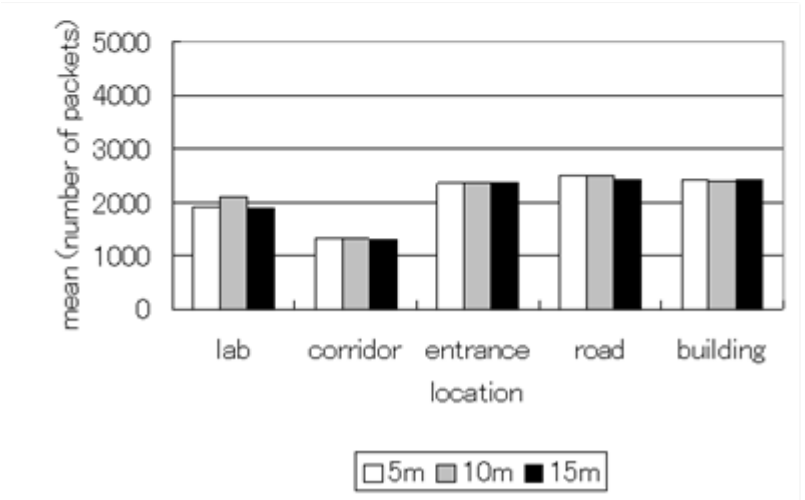
- 2 WiFi terminals, 802.11g, AP, STA.
- Indoor and outdoor measurements (UDP traffic, iperf).
- Distances (5, 10, 15m), sending rates (1, 16,18,20,22 Mbps).
- 100ms monitoring interval.



Location Cognition Engine

Results - mean





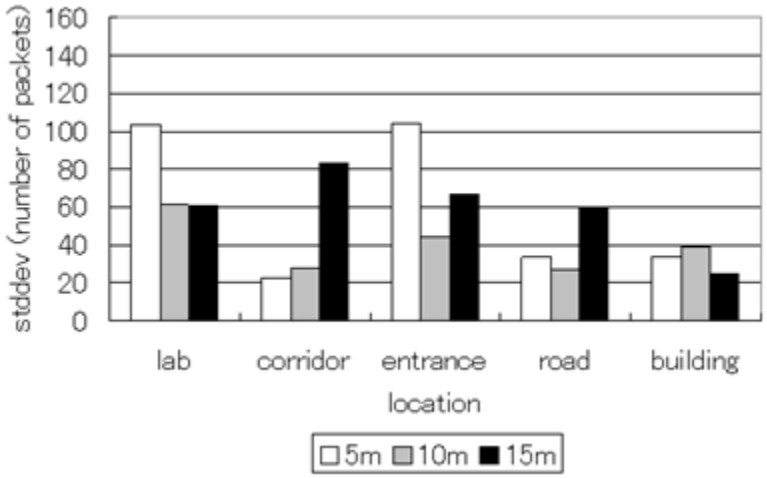
Short packet length

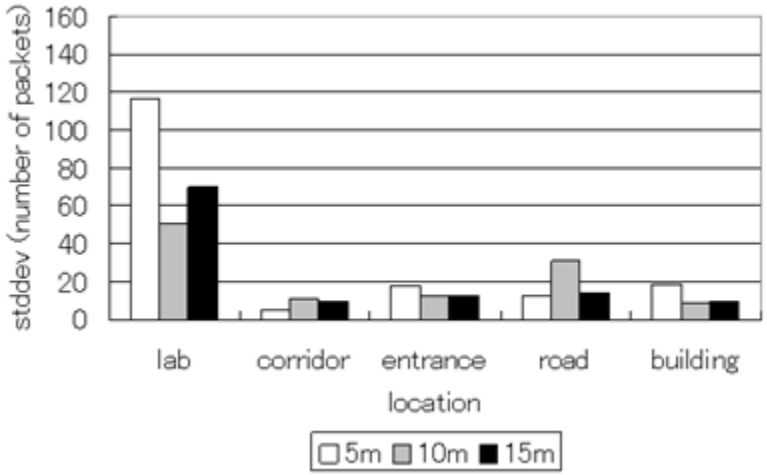
Mean (number of packets) for short (top graph) and long packets (bottom graph) at five different locations and three different distances.

Long packet length

Location Cognition Engine

Results – standard deviation





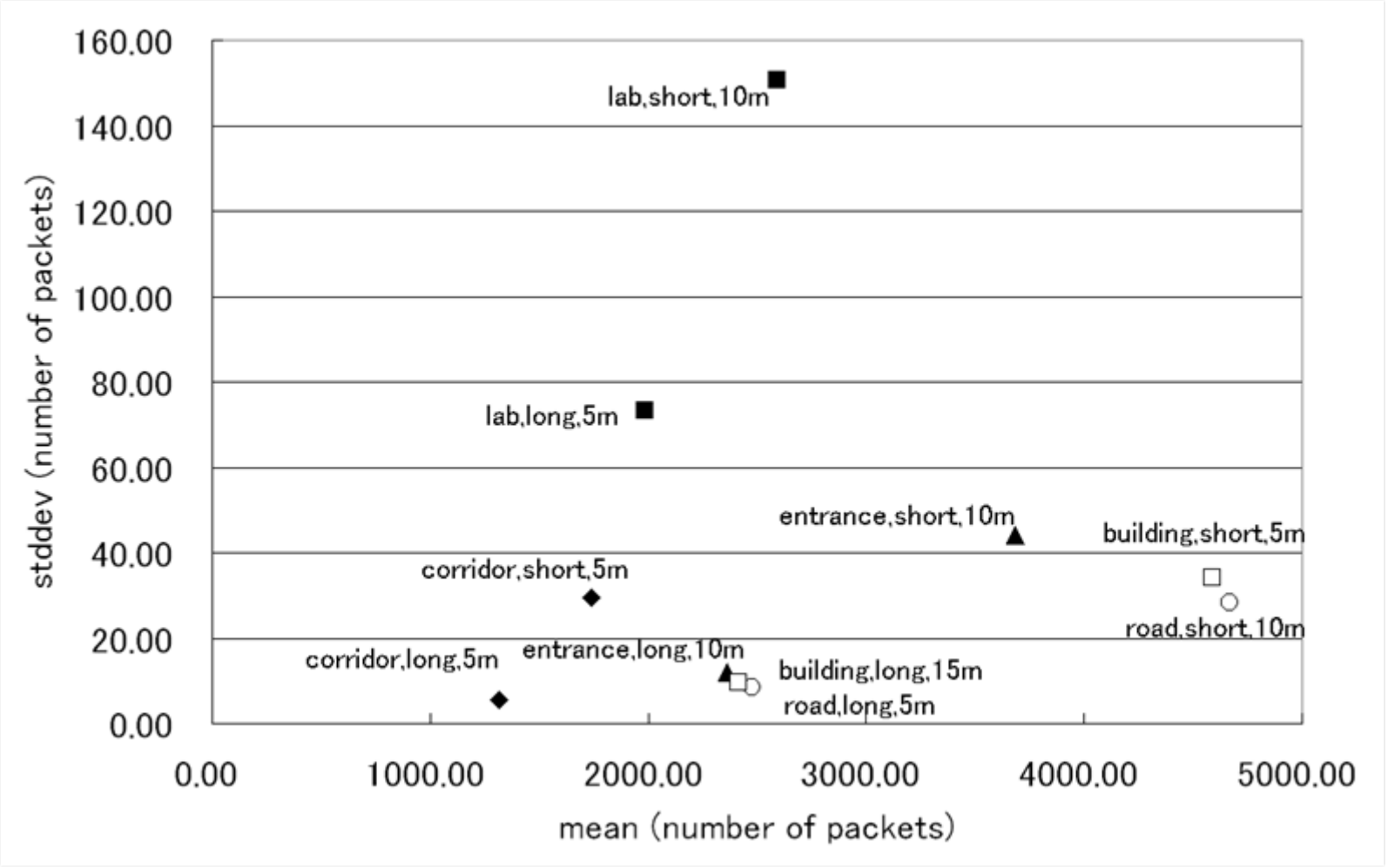
Short packet length

Standard deviation (number of packets) for short packet length (top graph) and long packets (bottom graph) at five different locations and three different distances.

Long packet length

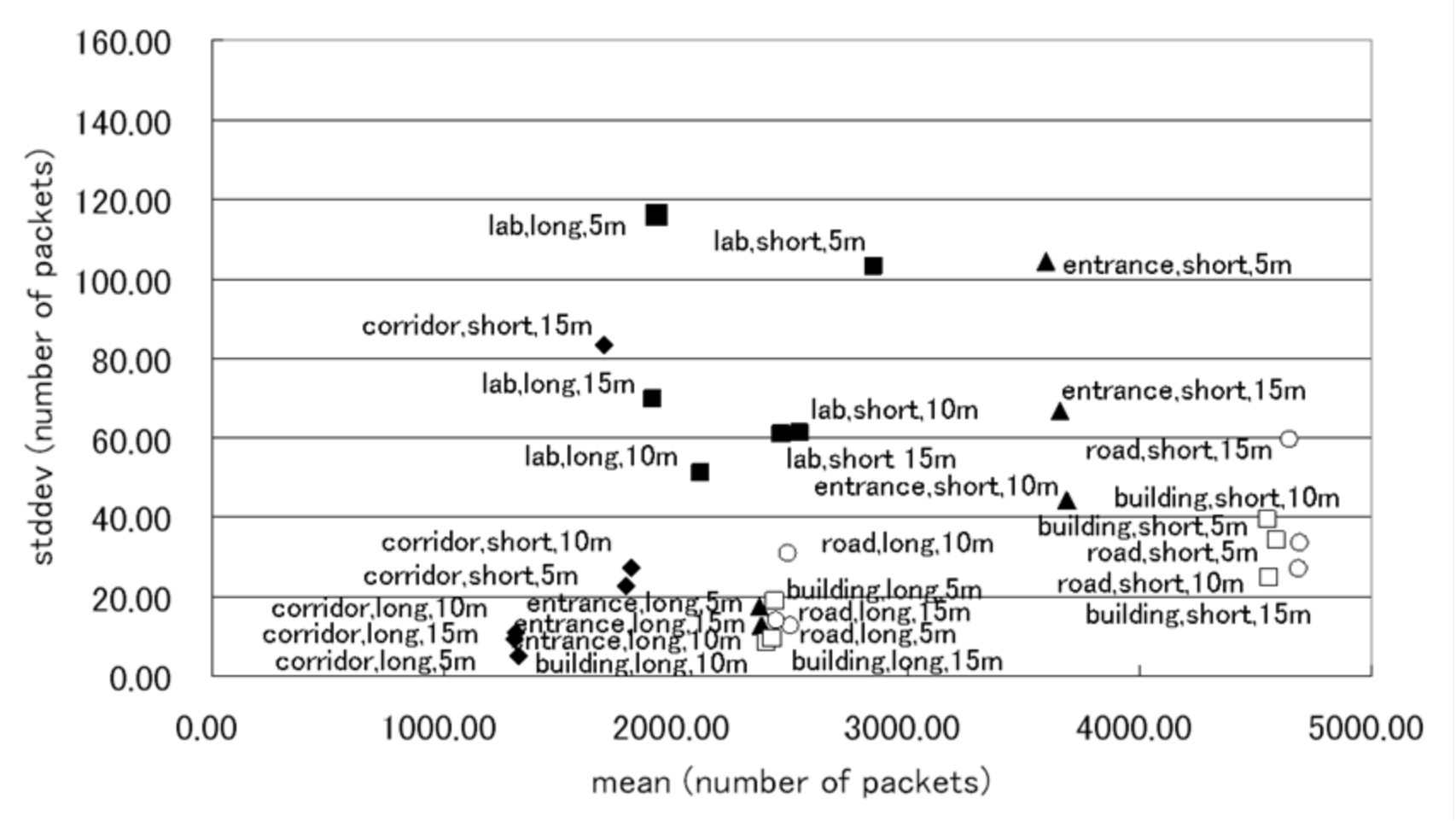
Location Cognition Engine

Results – location



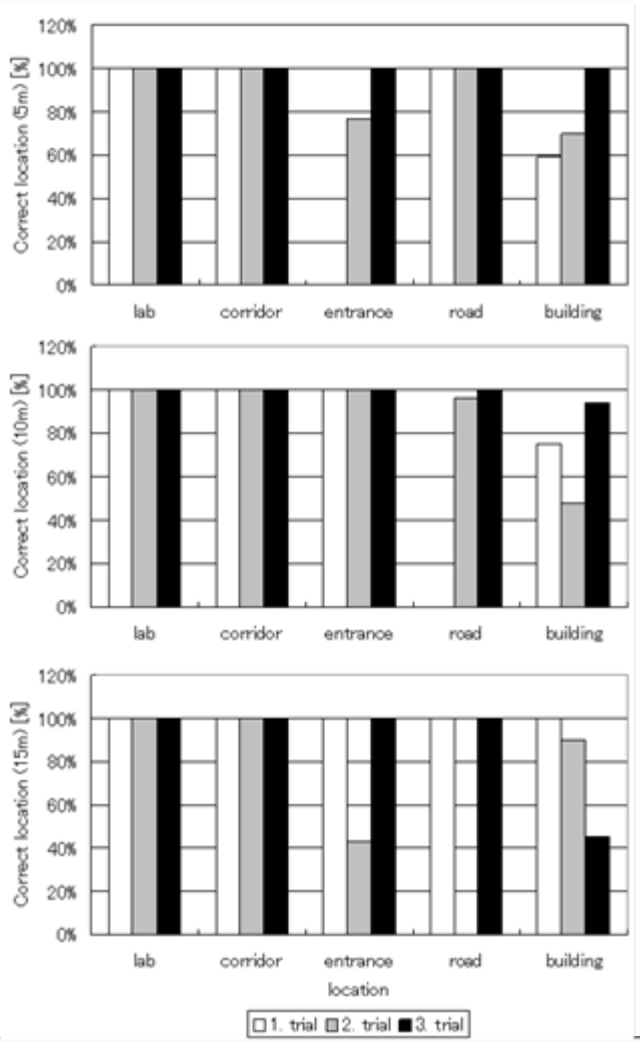
Location Cognition Engine

Results – location & distance



Location Cognition Engine

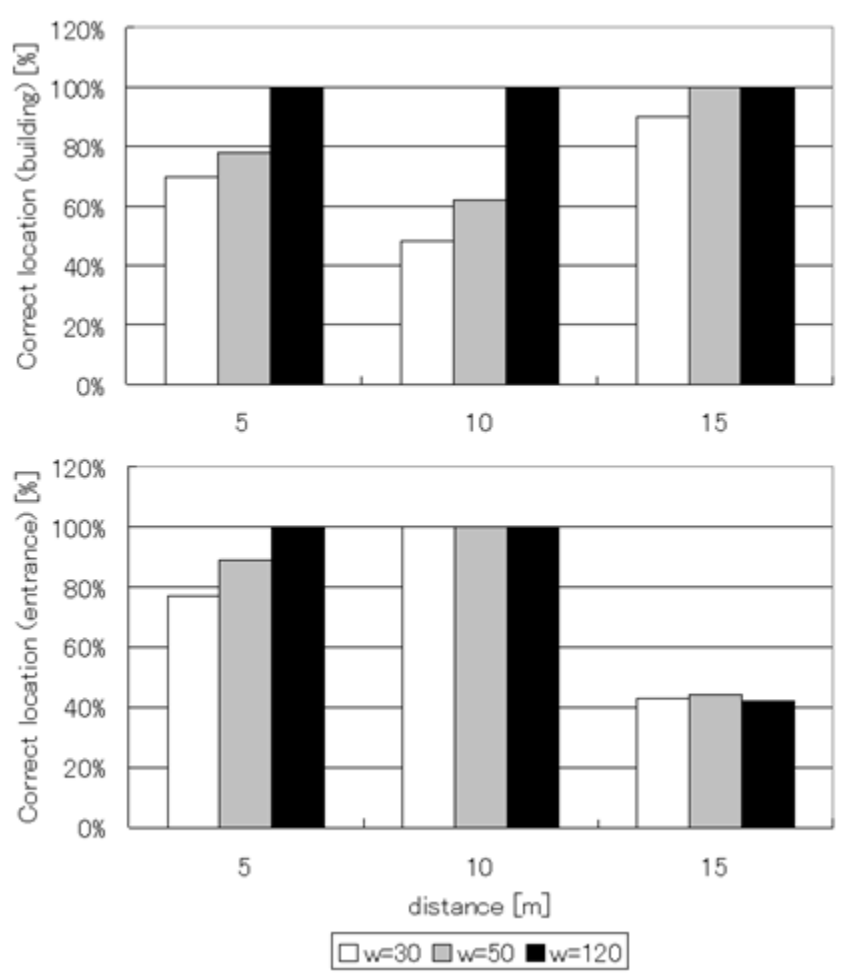
Results – location cognition



Result of correct location cognition for all locations at each distance and for 3 trials (1500 byte packet size)

Location Cognition Engine

Results – distance cognition



Results of increased window size to improve combined location and distance (2. trial)

Conclusion

Summary

Proposal – Location Cognition Engine

Fingerprint-type location method is an efficient way of location cognition when GPS is not available

Using link statistics as finger prints (data base) and comparing them with on-line monitored data

Prototype - Results

High accuracy for location type identification
Sufficient accuracy for distance cognition which can be further improved

Next steps

Using signal strength information to increase the accuracy of distance cognition

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