Proximity Classification for Mobile Devices Using Wi-Fi Environment Similarity

Alessandro Carlotto, Matteo Parodi, Carlo Bonamico, Fabio Lavagetto
DIST – University of Genova
alessandro.carlotto,matteo.parodi}@unige.it
{fabio,charlieb}@dist.unige.it

Massimo Valla
Telecom Italia Lab
massimo.valla@telecomitalia.it

Outline

- Objective
  - Compute distance by analysing signals from existing wireless networks.
- Approach
- Features Selection
- Gaussian Mixture Model Classifier
- Experimental tests and results
  - ‘Single scan’ approach.
  - ‘Best of three scans’ approach.
- Conclusions and future work

Objective

- Devise an algorithm to estimate device distance without any absolute information about locations.
  - Exploiting signals from existing Wi-Fi networks.
- Classify four levels of proximity
  - High - “same room”.
  - Medium - “nearby room / same floor”.
  - Low - “same building”.
  - No Proximity.

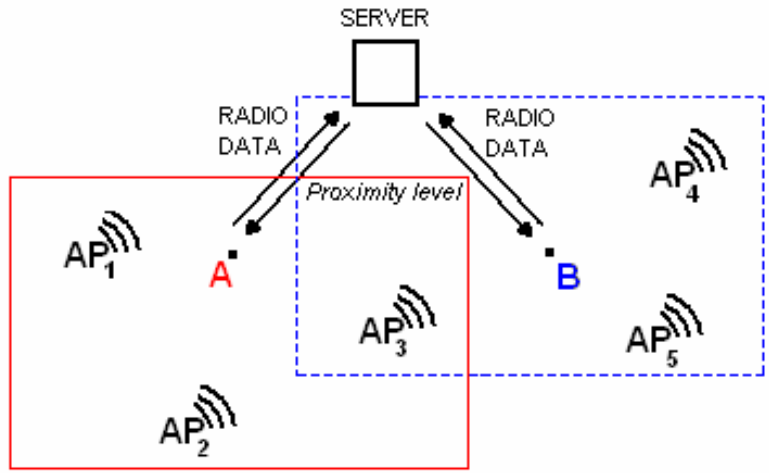
Approach

- Key idea
  - The closer two devices are, the more similar their radio environment will be.
  - Estimate radio environment similarity by comparing a set of signal features.

1. Creation of a database of Wi-Fi scans.
2. Analysis of the collected data.
   - Choice of features useful to discriminate and simple to compute.
3. Choice of Gaussian Mixture Models (GMM) to represent different radio proximity levels.
4. Training of the models with a database of pairs of Wi-Fi scans collected in the corresponding situations.

Operating Scenario

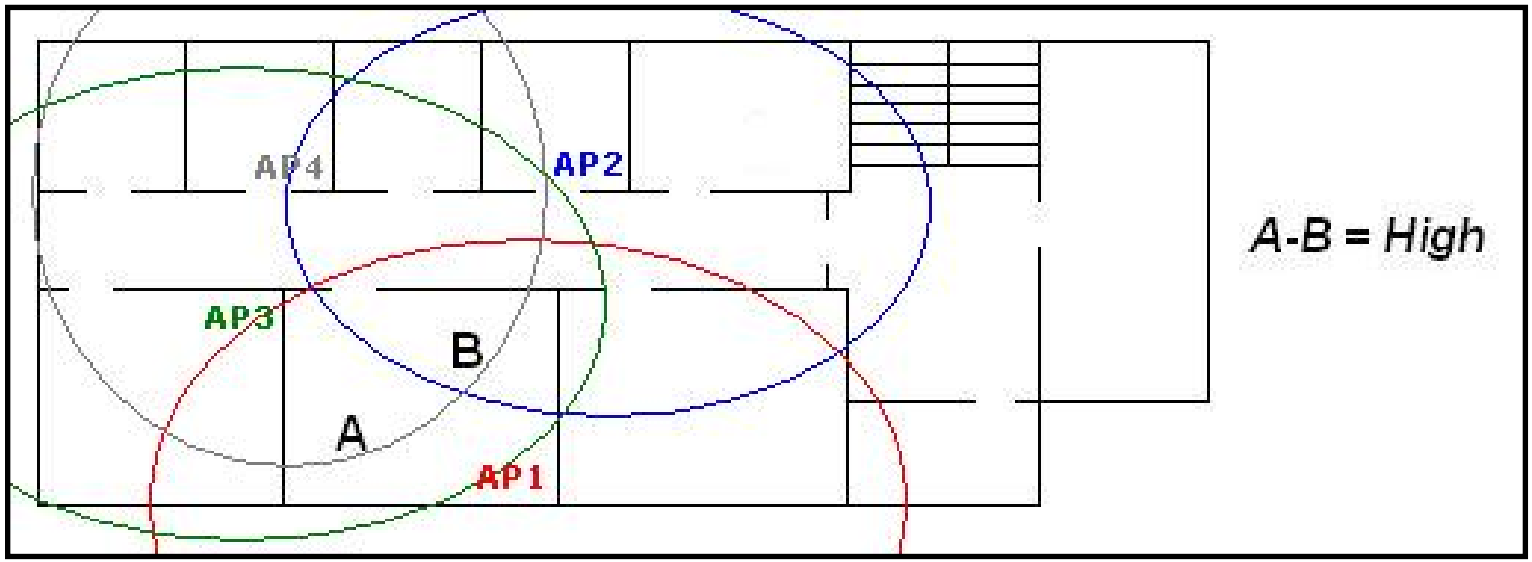
- The algorithm is deployed on a remote Internet server.
- Each device sends MAC address, ID and signal strength of detected APs.
- The server receives scanned Wi-Fi data by devices.
- The server extracts required features from each pair of Wi-Fi data and selects the proximity category.
- The server sends back the proximity estimate.



Features (1)

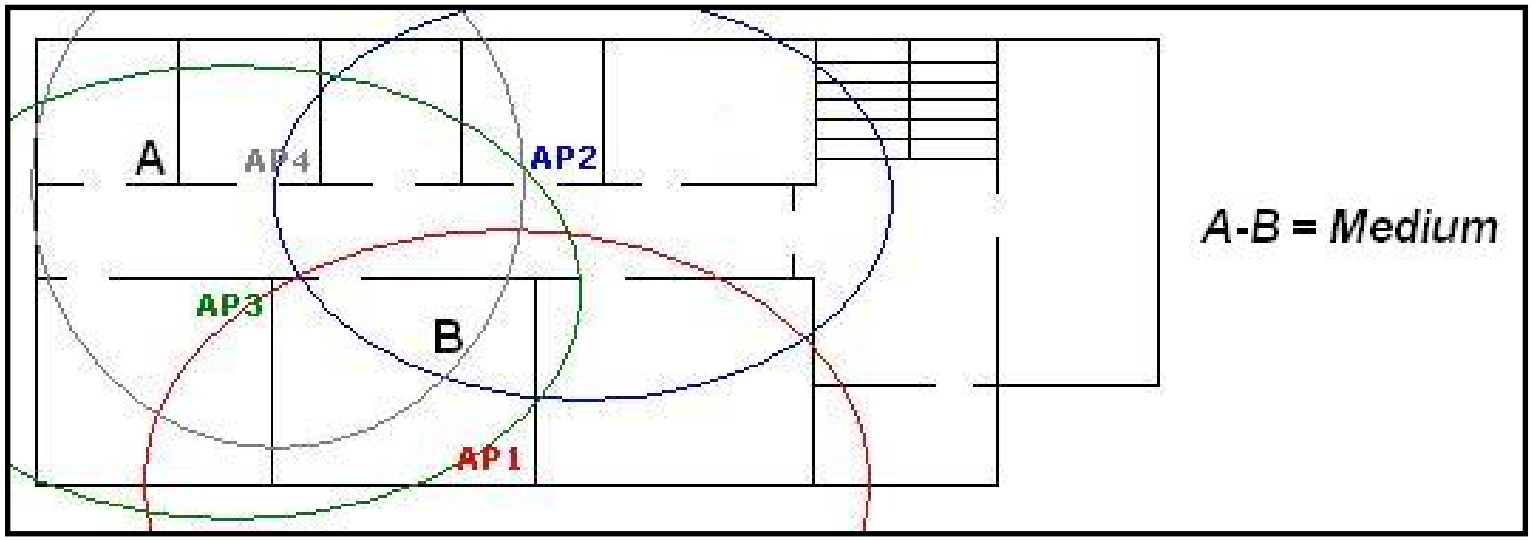
- Number of Common Access Points (NCAP)
  - the number of APs in common between the two clients.
- Number of Not-Common Access Points (NNAP)
  - the number of not in common APs detected by the two clients.
- Not-Common Access Points Difference (NAPD)
  - it is the difference between the number of not in common access points detected by each of the two clients.
- Mean Square Signal Strength Deviation (MSSSD)
  - it represents the difference of signal strength on common access points measured from devices under consideration.
- Wireless Common Power Percentage (WCPP):
  - it's the percentage of common radio power measured in dB by each device.

Features (2)



- NCAP = 3
  - AP1,AP3,AP4
- NNAP = 1 and NAPD = 1
  - Device A: None, Device B:AP2
- MSSSD = 152
  - Devices are at the same distance from each common AP.
- Wireless Common Power Percentage = 89%

Features (3)

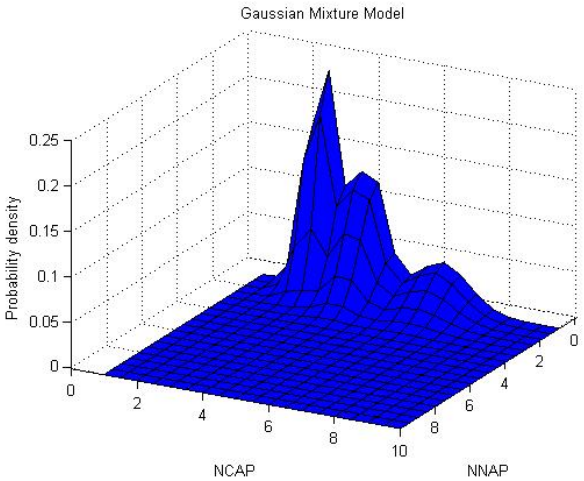


- NCAP = 2
  - AP3,AP4
- NNAP = 2 and NAPD = 2
  - Device A: None, Device B: AP1,AP2
- MSSSD = 483
  - Devices are at different distance from each common AP.
- Wireless Common Power Percentage = 60%

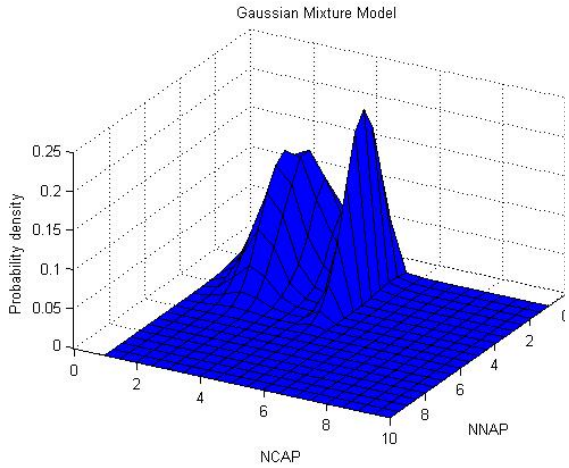
Selection of a statistical model

- Gaussian Mixture Model.
- Density model with a number of K gaussian n-dimentional component functions.
- Each component is represented by the following adjustable parameters:
  - Weight.
  - Mean.
  - Covariance matrix.

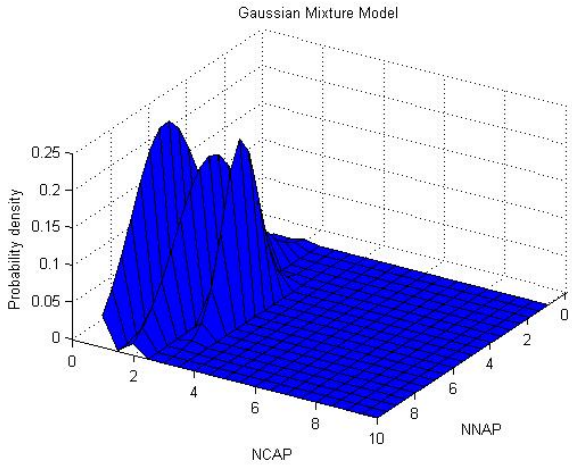
GMM



High



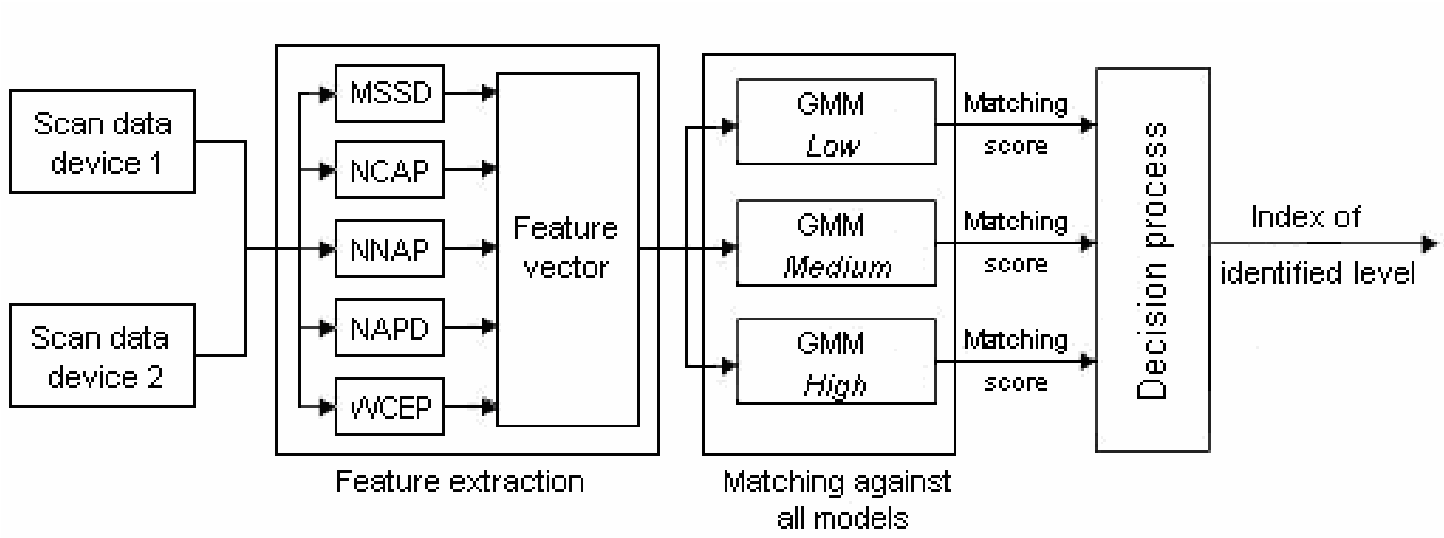
Medium



Low

- Probability Densities of Wi-Fi environments' GMMs.
- Each GMM is composed by 3 bidimentional gaussian functions.

Classification algorithm



- When there are not AP in common between the two devices the classifier reports “No proximity”

Test setup

- Device used to test the system
  - Nokia N95
  - 802.11 b/g
- Test performed in a campus like environment

Building characteristics	**Building 1**	**Building 2**
Total number APs	*24*	*16*
Area	*4050 m^2*	*2400 m^2*
Avg. Area /APs	*168.7 m^2*	*150 m^2*

“Single Scan” Approach Results

- Correct level classification percentage: 68.7%

Proximity Level	Low	Medium	High
Low	68.6%	25.7%	5.7%
Medium	14.8%	64%	21.2%
High	3.9%	21.9%	74.2%

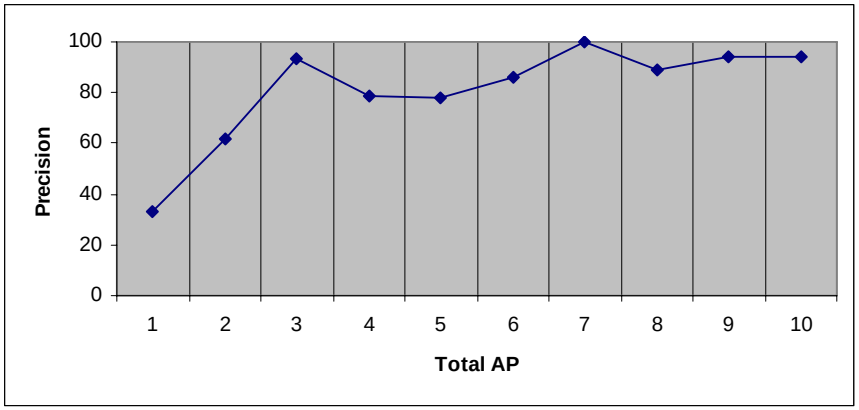
Confusion Matrix

Improving the results

- We observed that the number of received APs strongly affects the classification performance
- The phone sometime scans fewer Wi-Fi networks than those actually present, because of
  - limited sensitivity of the smartphone's Wi-Fi hardware
  - long beacon interval of some APs.

“Best of Three Scans” Approach Results

- Groups of three scans collected in the same place and within thirty seconds.
- Algorithm fed with the scan that has the highest number of APs detected.
- Correct level classification percentage: 88.2%



Percentage of correct decision as function of the total number of APs.

Proximity Level	Low	Medium	High
Low	**96.5%**	2.9%	0.6%
Medium	13.6%	**77.8%**	8.6%
High	1.7%	8.1%	**90.2%**

Confusion Matrix

Example Application

- Proximity aware buddy list for Symbian smartphones.
- The application uses the proximity classifier system to detect nearby users.
- Integrated in Telecom Italia's Context Awareness Platform.

- The building's icon on the left of the names indicates that the technology used to obtain proximity is Wi-Fi.
- The black bars on the right represent the three proximity levels.

Conclusions

- The classification system discriminates among three different proximity levels between two devices.
  - Classifier chooses the correct level using simple features extracted by devices' Wi-Fi AP scans.
- One-time training is required to create the statistical classification models.
  - The training is not environment-dependent.
- The algorithm reaches a percentage of correct classification near to 90%, achieving the best results where at least 3-4 APs are detected.

Future Work

- The algorithm will be extended to classify proximity using information derived from other technologies.
  - Bluetooth, GSM Cell-Ids, etc.
- The application will be extended including user proximity alerts and integration with APIs offered by popular social networks.
  - LinkedIn, Facebook, etc.