

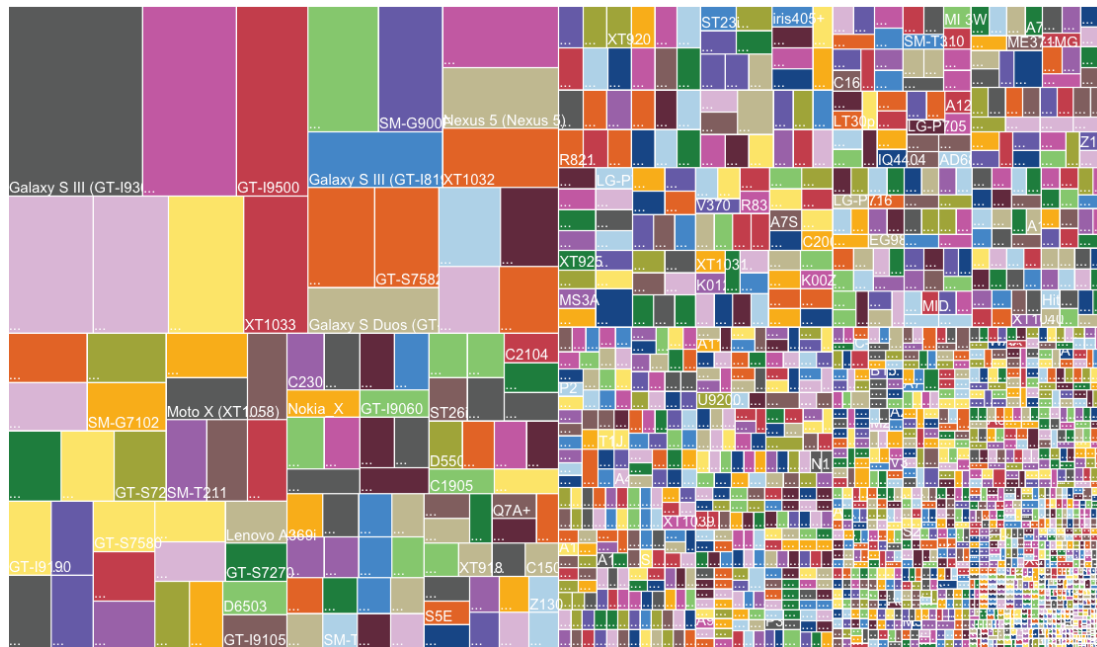
Android Sensing Tutorial

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9/8/2015

Android Device Fragmentation

August 2014 - Over 18,000 Distinct Devices



<https://opensignal.com/reports/2014/android-fragmentation/>

Example Android Device



CPU : Quad-core 2.5 GHz Krait 400
GPU : Adreno 330

Figure 1.1. Samsung Galaxy S5 smartphone. It contains ten different sensors: accelerometer, gyro, proximity, compass, barometer, hall, RGB ambient light, gesture, fingerprint and heart rate [5].

Development - Getting Started

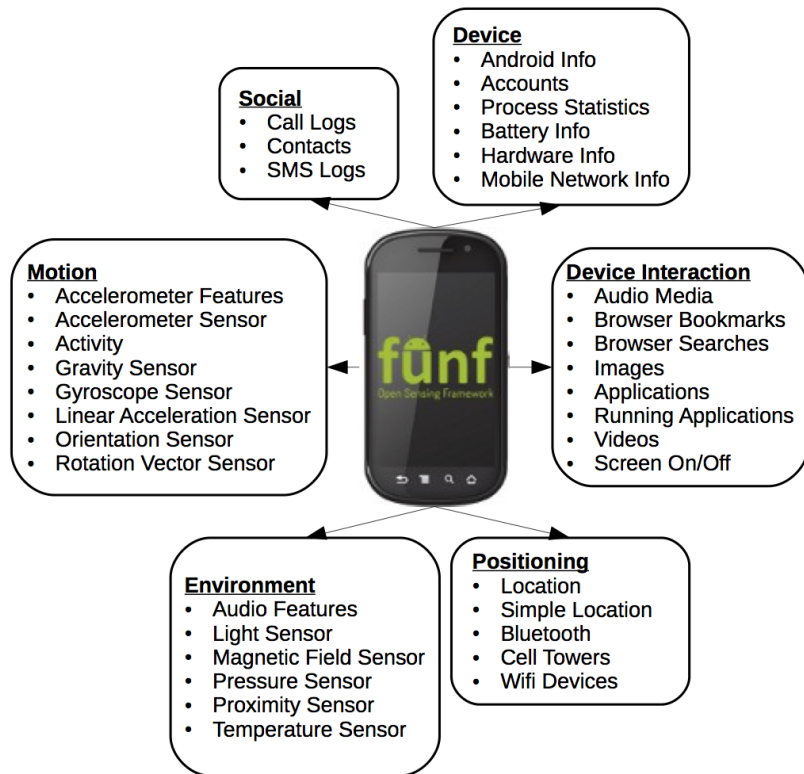
<http://developer.android.com/develop/>

Development - Getting Started

<http://developer.android.com/develop/>

- Download Android SDK
- Create “Hello, World!” application
- Get an Android Device
- Sign up for a developer account

Android Sensing



Funf Journal: Android Data Collection App

<http://www.funf.org/>

- Extensible: can be extended to collect any information that Android OS allows to access
- Collected data are stored in SQLite databases
- Sensitive data (e.g., phone numbers, text messages) are hashed before storing them

Android Sensor API

```
public class SensorActivity extends Activity, implements SensorEventListener {
    private final SensorManager mSensorManager;
    private final Sensor mAccelerometer;

    public SensorActivity() {
        mSensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);
        mAccelerometer = mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
    }

    protected void onResume() {
        super.onResume();
        mSensorManager.registerListener(this, mAccelerometer, SensorManager.SENSOR_DELAY_NORMAL);
    }

    protected void onPause() {
        super.onPause();
        mSensorManager.unregisterListener(this);
    }

    public void onAccuracyChanged(Sensor sensor, int accuracy) {
    }

    public void onSensorChanged(SensorEvent event) {
    }
}
```

<http://developer.android.com/reference/android/hardware/SensorManager.html>

Example Sensor Data

1|**MPU6500 Acceleration Sensor**|[-1.6741456,9.370906,2.6886885]|**1441670212915**

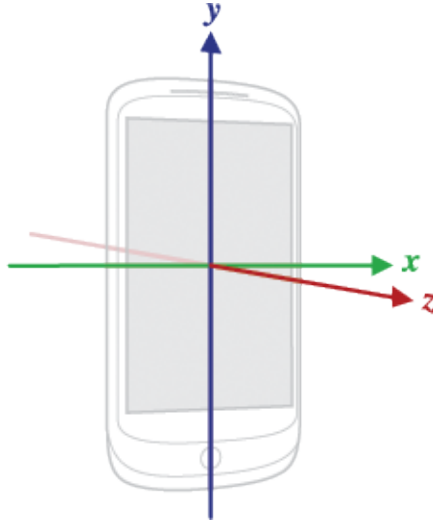
1|**AK09911C Magnetic field Sensor**|[16.86,-64.26,-62.7]|1441670213400

1|**MPU6500 Gyroscope Sensor**|[-0.02263687,-0.016777916,-0.008788432]|1441670213508

1|**GPS**|{"mProvider":"fused","mResults":[0.0,0.0],"mAccuracy":**29.0**,"mAltitude":83.0,"mElapsedRealtimeNanos":98111810945944,"mLat1":0.0,"mLat2":0.0,"mLatitude":**40.748431**,"mLon1":0.0,"mLon2":0.0,"mLongitude":**73.985741**,"mTime":1441575797954,"mBearing":0.0,"mDistance":0.0,"mHasAccuracy":true,"mHasAltitude":true,"mHasBearing":false,"mHasSpeed":true,"mInitialBearing":0.0,"mIsFromMockProvider":false,"mSpeed":**0.0**}|1441573552851

1|**WiFi**|{"BSSID":"00:21:6c:87:02:d1","SSID":"eduroam","capabilities":"[WPA2-EAP-CCMP]","frequency":2462,"level":**-82**}|1392465248466

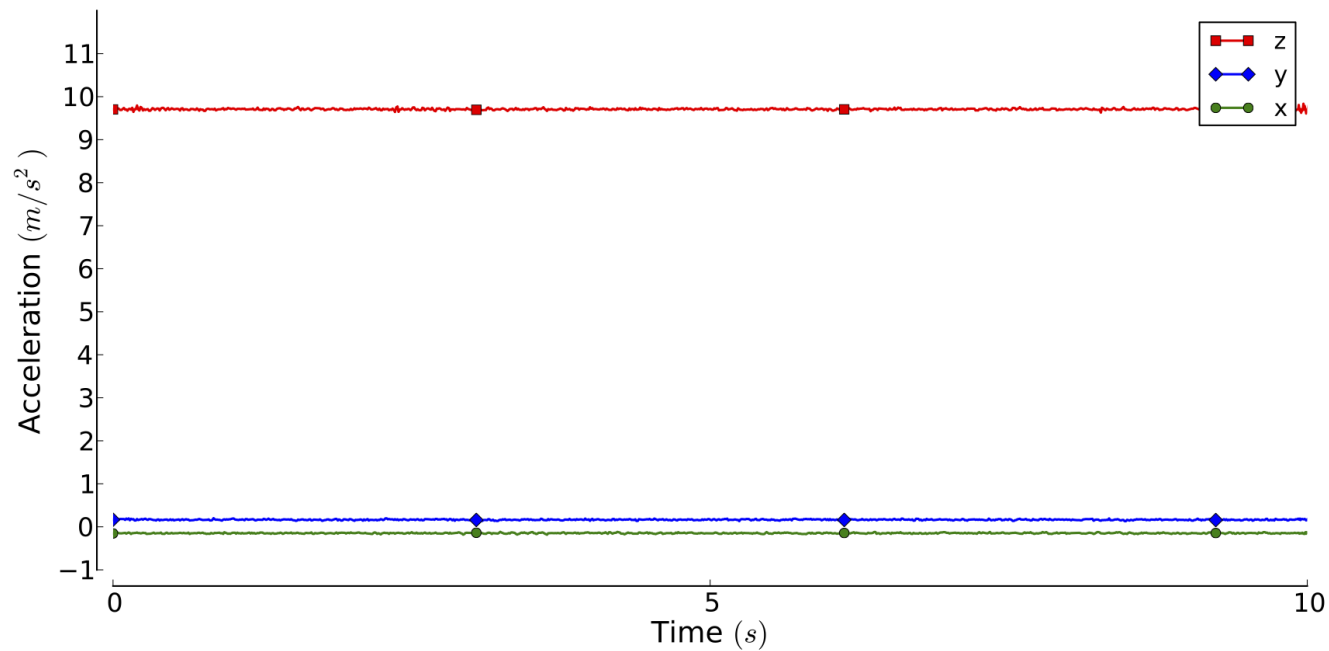
Sensor Coordinate System



http://developer.android.com/guide/topics/sensors/sensors_overview.html#sensors-coords

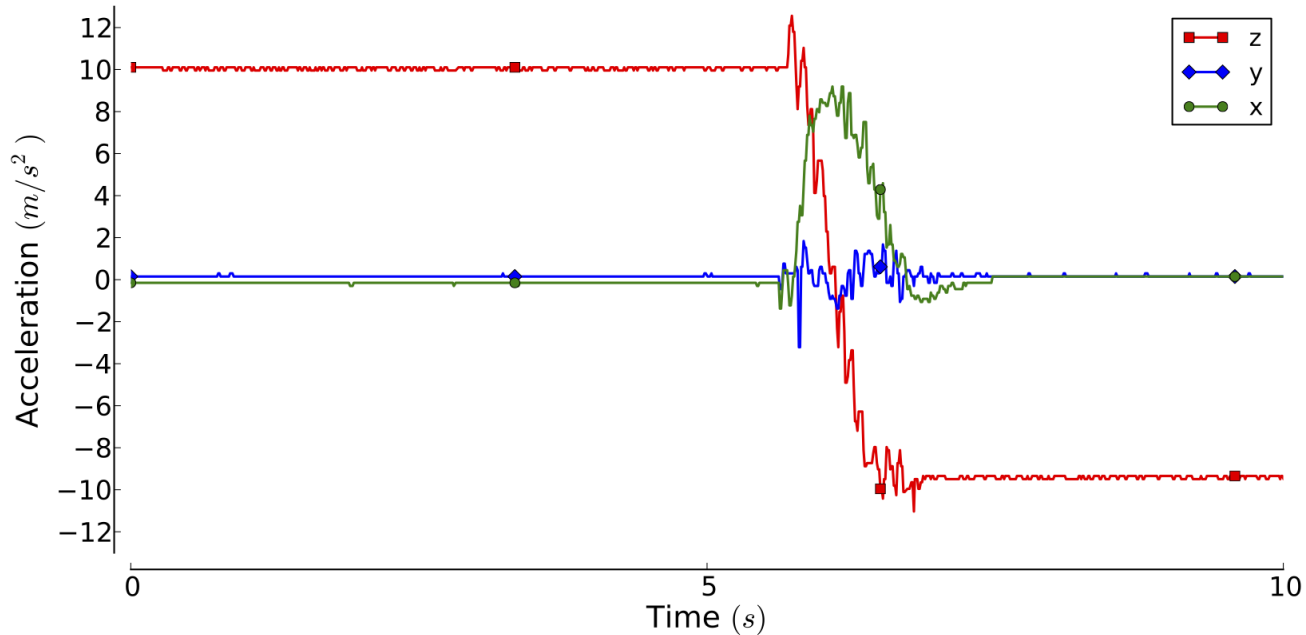
Accelerometer

At rest



Accelerometer

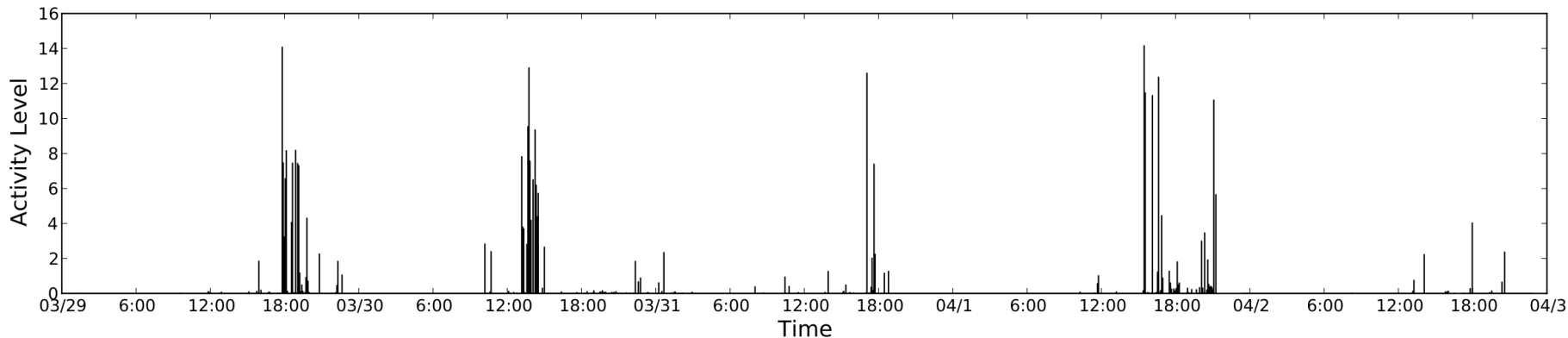
Rotation around y axis



Accelerometer

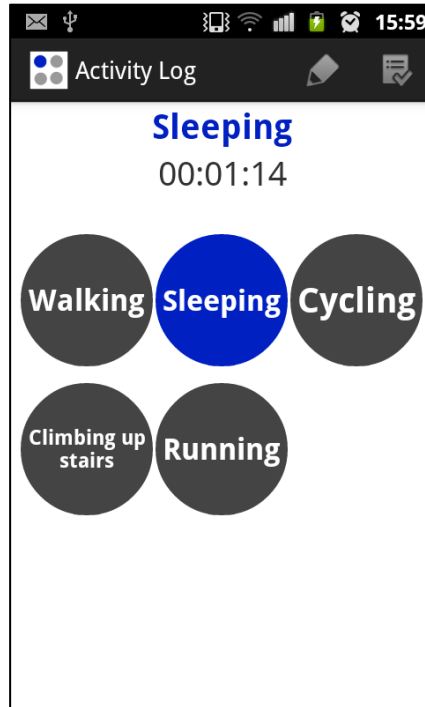
Physical Activity Level Inference

$$m = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

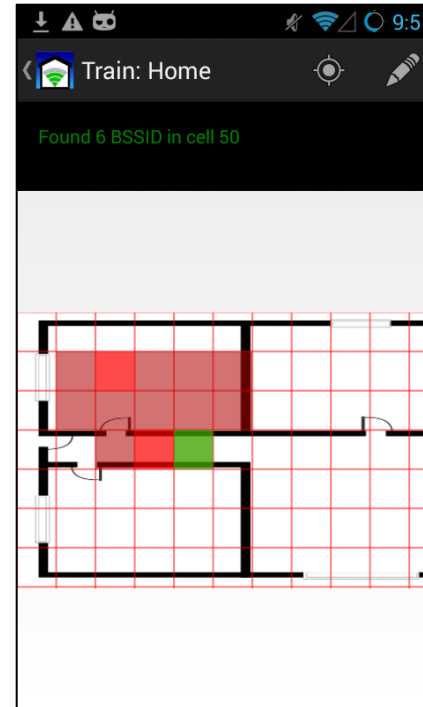


Example Applications

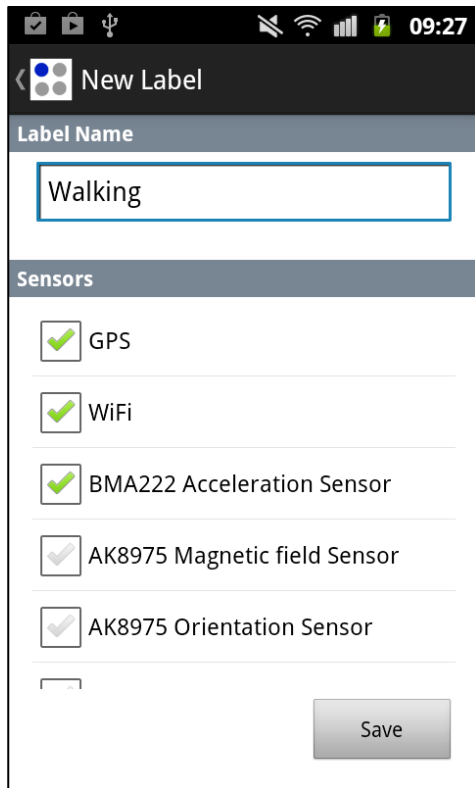
[Sensor Log](#)



[WiFi Indoor Localization](#)



Activity Recognition Study



This screenshot shows the 'New Label' interface of a mobile application. At the top, the status bar displays various icons and the time 09:27. The app's header bar is dark with a back arrow, a four-dot menu icon, and the title 'New Label'. Below the header, there is a section titled 'Label Name' with a text input field containing the word 'Walking'. Underneath this is a section titled 'Sensors' which lists five sensors with checkboxes: GPS (checked), WiFi (checked), BMA222 Acceleration Sensor (checked), AK8975 Magnetic field Sensor (unchecked), and AK8975 Orientation Sensor (unchecked). A 'Save' button is located at the bottom right of the screen.

09:27

New Label

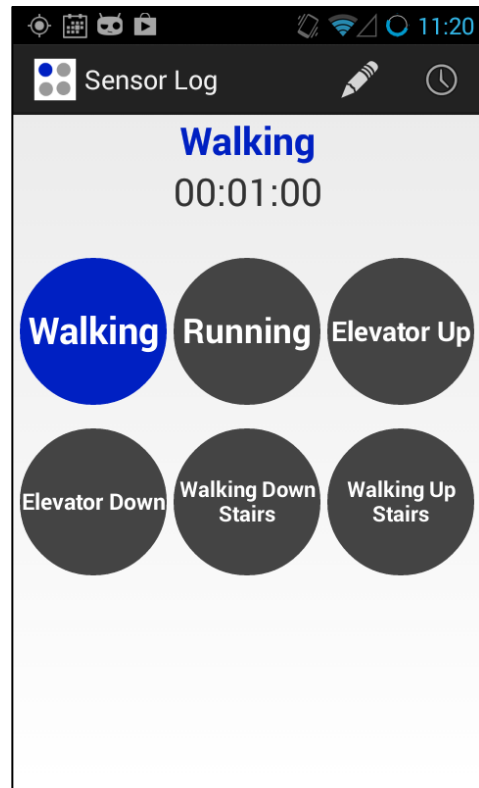
Label Name

Walking

Sensors

- ☒ GPS
- ☒ WiFi
- ☒ BMA222 Acceleration Sensor
- ☐ AK8975 Magnetic field Sensor
- ☐ AK8975 Orientation Sensor

Save



This screenshot shows the 'Sensor Log' interface of the same mobile application. The status bar at the top shows the time 11:20. The app's header bar is dark with a four-dot menu icon, the title 'Sensor Log', and icons for a pencil and a clock. The main content area has a light gray background. At the top, the word 'Walking' is displayed in blue, followed by a timer showing '00:01:00'. Below this, there are six circular buttons arranged in a 2x3 grid. The top-left button is blue with the word 'Walking' in white. The other five buttons are dark gray with white text: 'Running', 'Elevator Up', 'Elevator Down', 'Walking Down Stairs', and 'Walking Up Stairs'.

11:20

Sensor Log

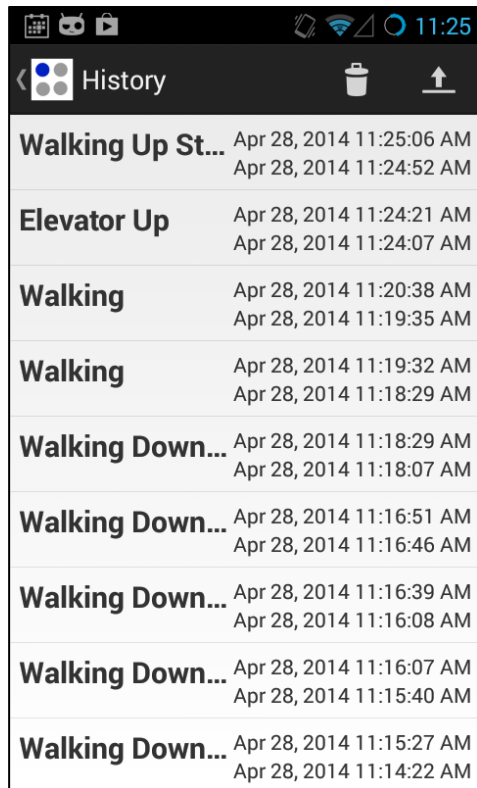
Walking

00:01:00

Walking Running Elevator Up

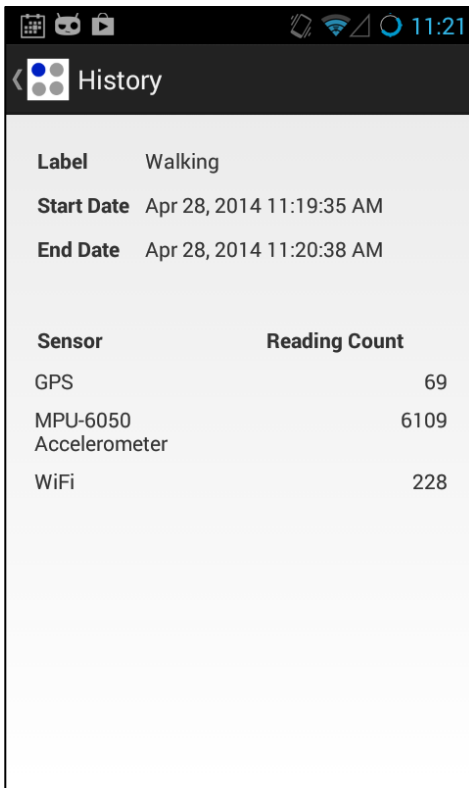
Elevator Down Walking Down Stairs Walking Up Stairs

Activity Recognition Study



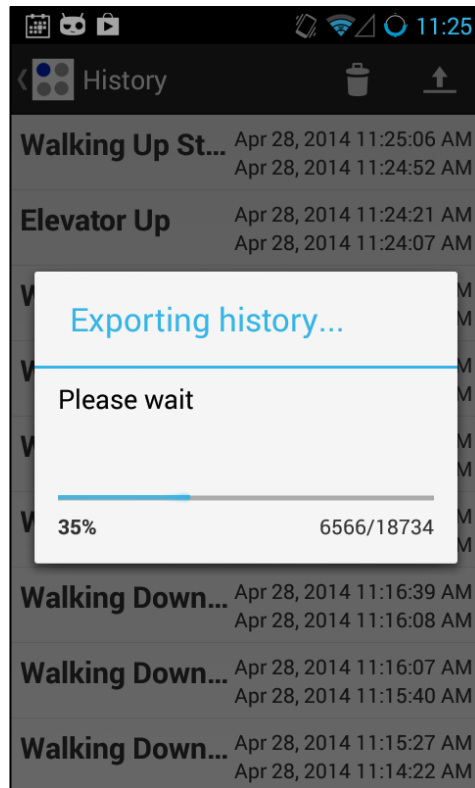
History

Walking Up St...	Apr 28, 2014 11:25:06 AM Apr 28, 2014 11:24:52 AM
Elevator Up	Apr 28, 2014 11:24:21 AM Apr 28, 2014 11:24:07 AM
Walking	Apr 28, 2014 11:20:38 AM Apr 28, 2014 11:19:35 AM
Walking	Apr 28, 2014 11:19:32 AM Apr 28, 2014 11:18:29 AM
Walking Down...	Apr 28, 2014 11:18:29 AM Apr 28, 2014 11:18:07 AM
Walking Down...	Apr 28, 2014 11:16:51 AM Apr 28, 2014 11:16:46 AM
Walking Down...	Apr 28, 2014 11:16:39 AM Apr 28, 2014 11:16:08 AM
Walking Down...	Apr 28, 2014 11:16:07 AM Apr 28, 2014 11:15:40 AM
Walking Down...	Apr 28, 2014 11:15:27 AM Apr 28, 2014 11:14:22 AM



History

Label	Walking
Start Date	Apr 28, 2014 11:19:35 AM
End Date	Apr 28, 2014 11:20:38 AM
Sensor	Reading Count
GPS	69
MPU-6050 Accelerometer	6109
WiFi	228



History

Walking Up St...	Apr 28, 2014 11:25:06 AM Apr 28, 2014 11:24:52 AM
Elevator Up	Apr 28, 2014 11:24:21 AM Apr 28, 2014 11:24:07 AM
Walking	Apr 28, 2014 11:20:38 AM Apr 28, 2014 11:19:35 AM
Walking	Apr 28, 2014 11:19:32 AM Apr 28, 2014 11:18:29 AM
Walking Down...	Apr 28, 2014 11:18:29 AM Apr 28, 2014 11:18:07 AM
Walking Down...	Apr 28, 2014 11:16:51 AM Apr 28, 2014 11:16:46 AM
Walking Down...	Apr 28, 2014 11:16:39 AM Apr 28, 2014 11:16:08 AM
Walking Down...	Apr 28, 2014 11:16:07 AM Apr 28, 2014 11:15:40 AM
Walking Down...	Apr 28, 2014 11:15:27 AM Apr 28, 2014 11:14:22 AM

Exporting history...

Please wait

35% 6566/18734

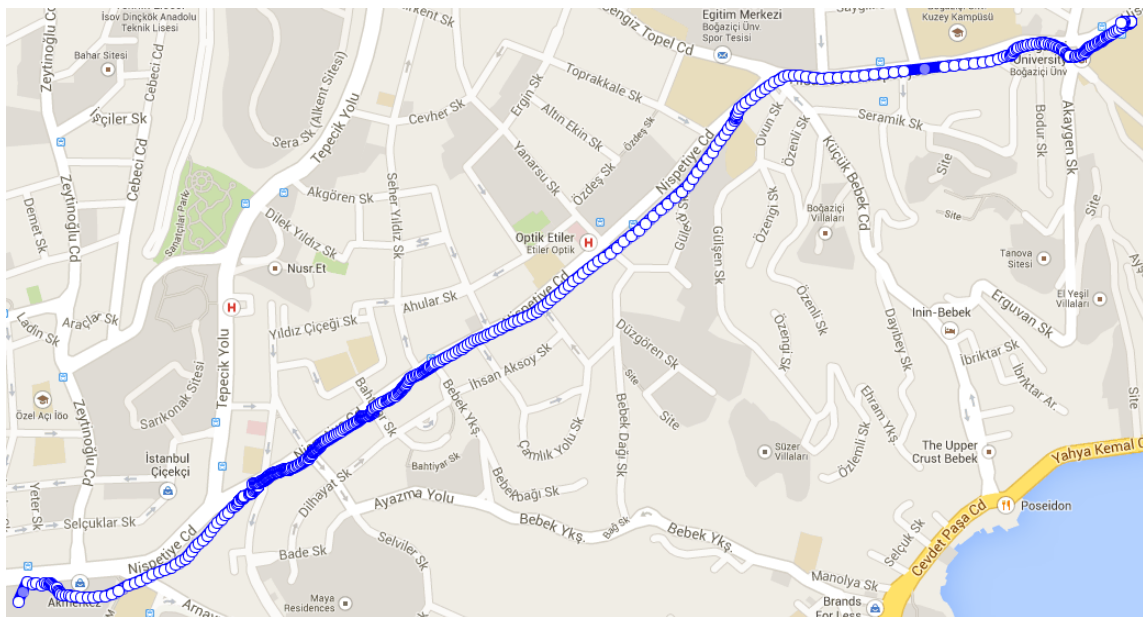
Activity Recognition Study

Running



Activity Recognition Study

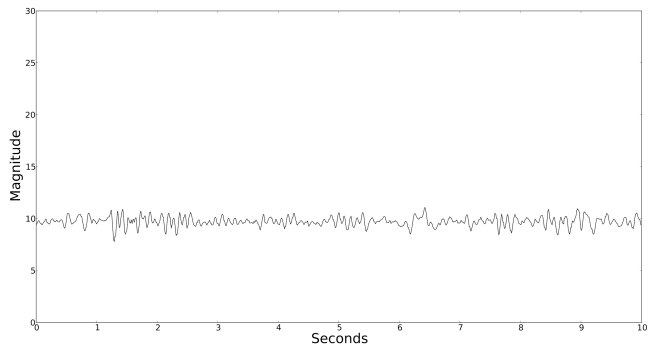
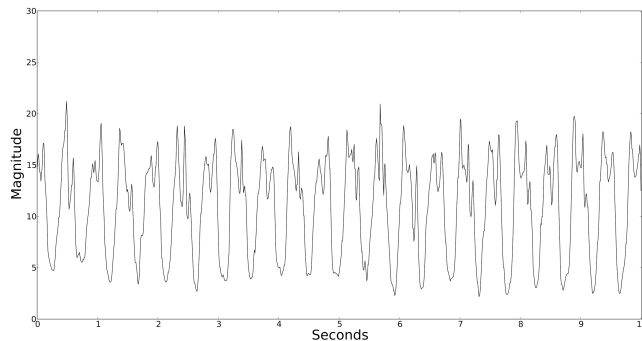
In Vehicle



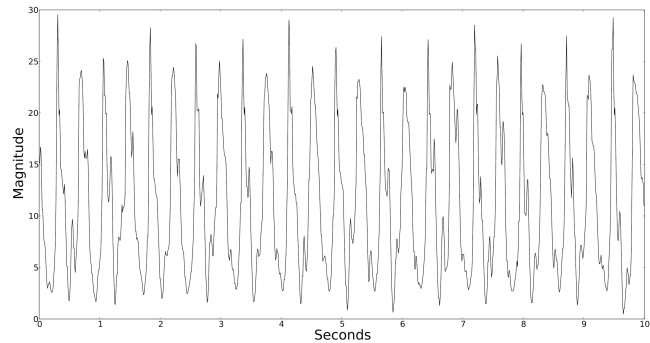
Activity Recognition Study

Talk about road
condition monitoring
acce & gps

Walking



In Vehicle



Running

Activity Recognition Study

Table B.1. Details of the collected data for different transportation modes.

	Duration	GPS	Accelerometer
Walking	4 minutes 25 seconds	258	25246
Running	2 minutes 38 seconds	151	15200
In Vehicle	9 minutes 6 seconds	570	56382

Table B.2. Confusion table of the transportation mode discovery study.

	<i>Walking</i>	<i>Running</i>	<i>In Vehicle</i>
Walking	50	0	0
Running	16	34	0
In Vehicle	0	6	44

Android “DetectedActivity” API

int	IN_VEHICLE	The device is in a vehicle, such as a car.
int	ON_BICYCLE	The device is on a bicycle.
int	ON_FOOT	The device is on a user who is walking or running.
int	RUNNING	The device is on a user who is running.
int	STILL	The device is still (not moving).
int	TILTING	The device angle relative to gravity changed significantly.
int	UNKNOWN	Unable to detect the current activity.
int	WALKING	The device is on a user who is walking.

<https://developers.google.com/android/reference/com/google/android/gms/location/DetectedActivity>

WiFi Localization Study

Table B.3. Number of Wi-Fi scans performed for six different places.

Place Names	Wi-Fi Scan Count
Office Room 1 (P1)	236
Office Room 2 (P2)	72
Office Kitchen (P3)	71
Home Kitchen (P4)	71
Home Living Room (P5)	81
Supermarket (P6)	73

Example WiFi Scan Data

```
{  
  "BSSID": "00:21:6c:87:02:d1",  
  "SSID": "eduroam",  
  "capabilities": "[WPA2-EAP-CCMP]",  
  "frequency": 2462,  
  "level": -82  
}
```

WiFi Localization Study

WiFi Fingerprint

Table 4.3. Wi-Fi fingerprint generation. A 1 denotes the existence and 0 denotes the absence of the corresponding BSSID in the fingerprint of a place. For example, only

BSSID₃ exists in the Wi-Fi fingerprint of Place B.

	BSSID ₁	BSSID ₂	BSSID ₃	BSSID ₄
Wi-Fi scan result	1	1	1	0
Place A	1	1	0	1
Place B	0	0	1	0

Tanimoto Similarity (Jaccard Similarity)

$$T_b(X, Y) = \frac{\sum_i (X_i \wedge Y_i)}{\sum_i (X_i \vee Y_i)} \quad (4.1)$$

WiFi Localization Study

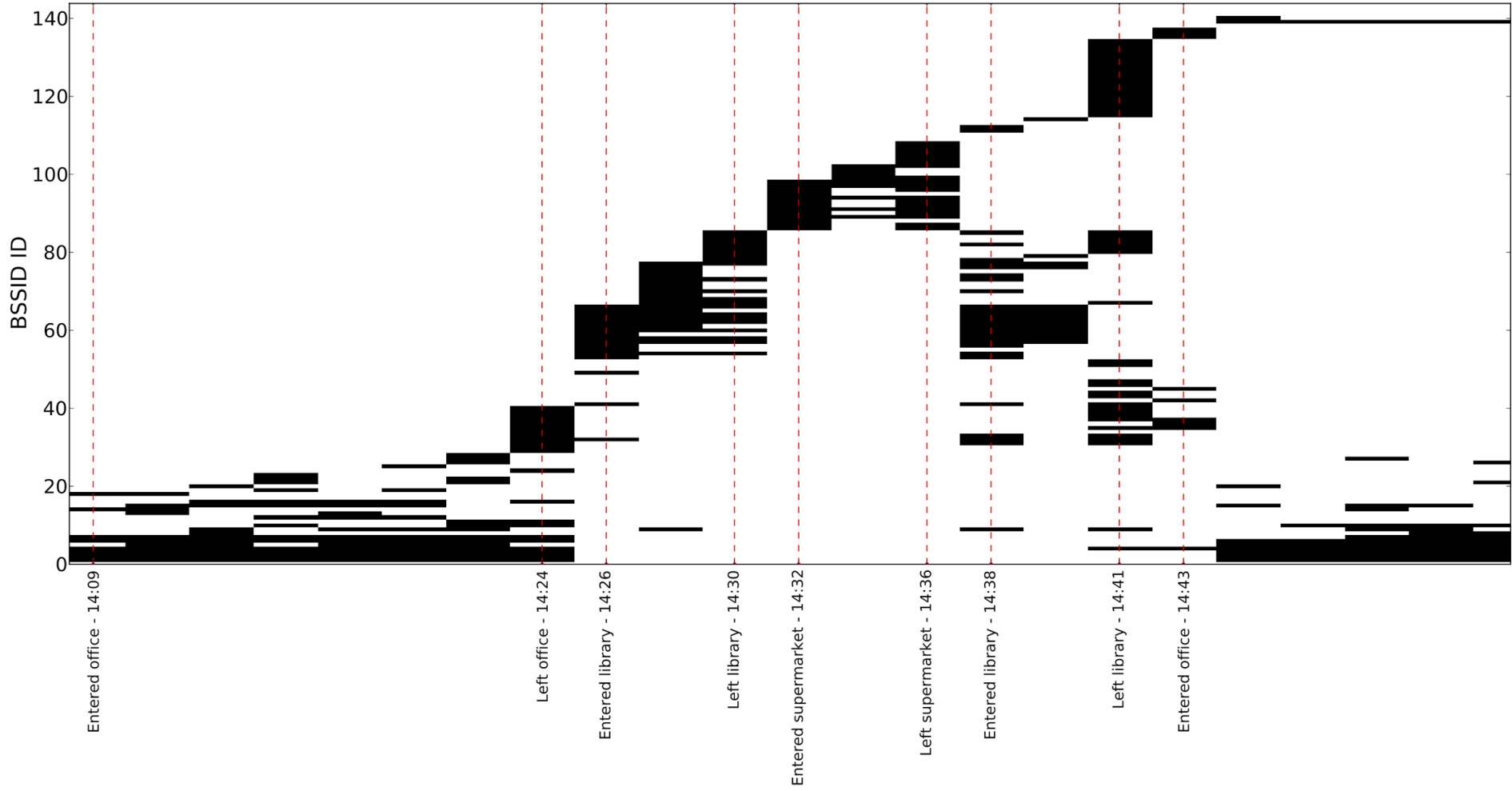
WiFi Fingerprints

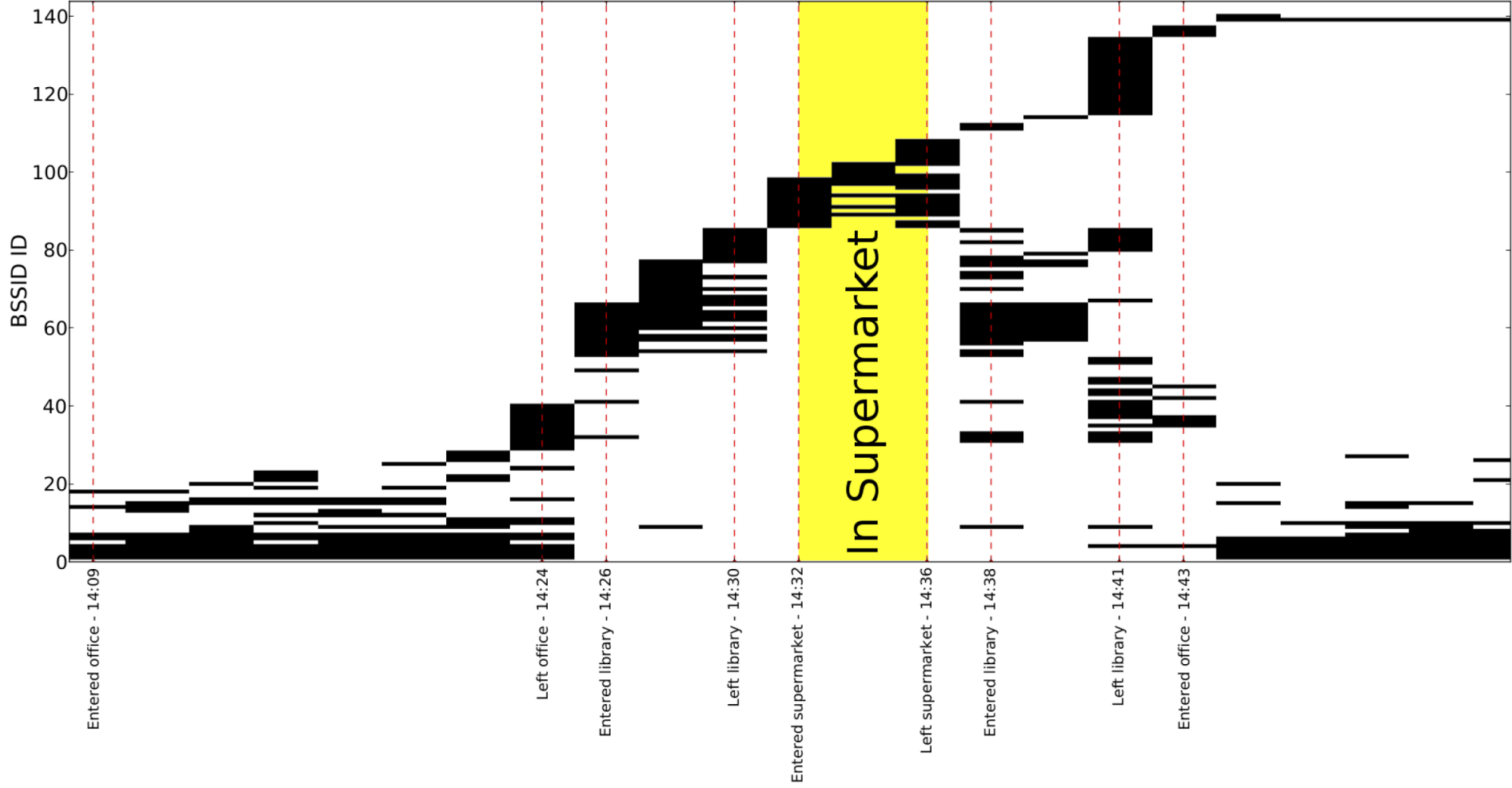
1 Office Room 1	[0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1, 0, 0, 0, 0, 0, ...,0]
2 Office Room 2	[1, 1, 0, 0, 0, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, ...,1]
3 Office Kitchen	[1, 1, 1, 1, 0, 0, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, ...,0]
4 Home Kitchen	[0, 0, 0, 0, 1, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, ...,0]
5 Home Living Room	[0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, ...,0]
6 Supermarket	[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, ...,0]

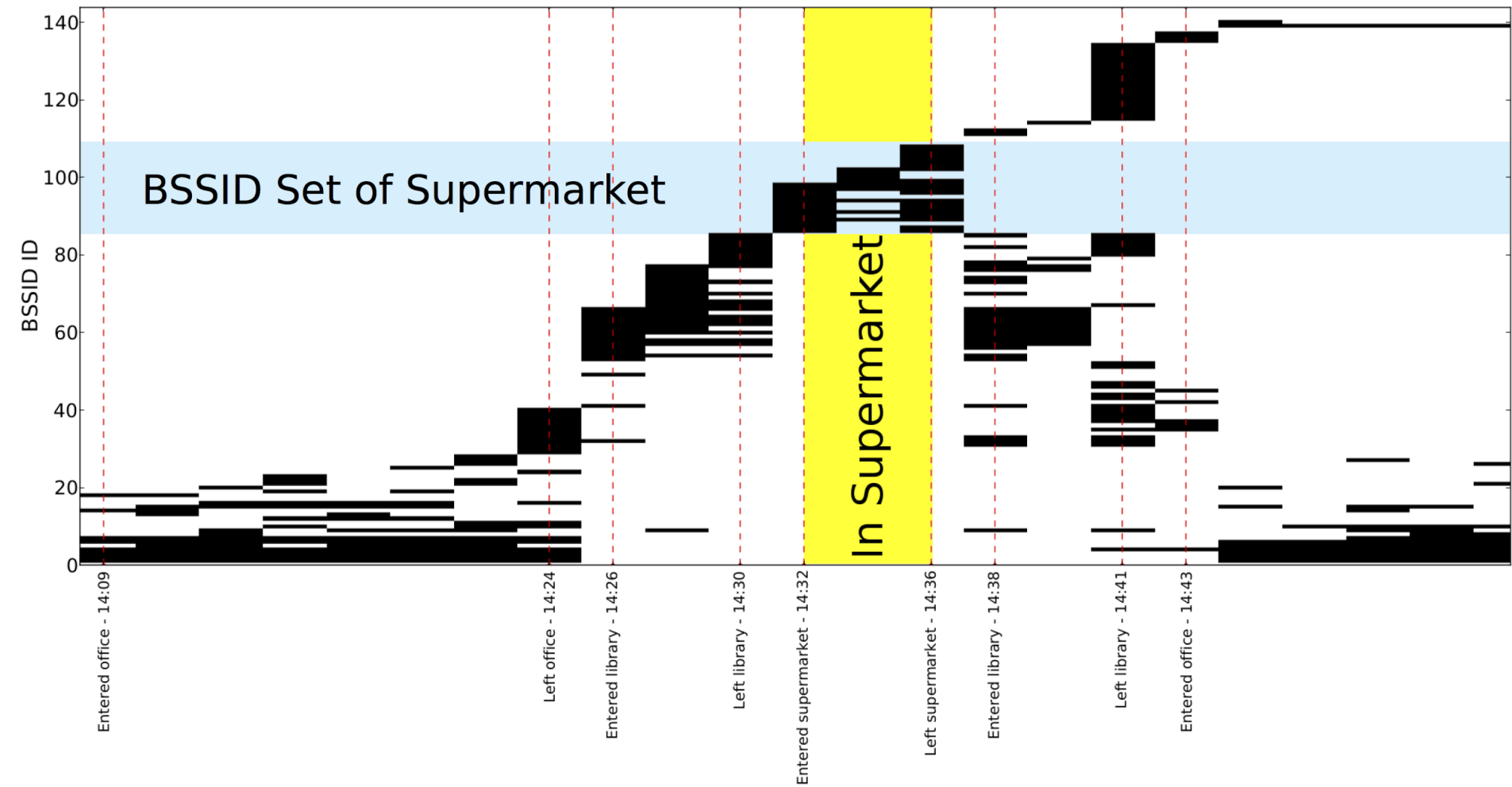
WiFi Localization Study

Table B.4. Confusion table of the indoor localization study.

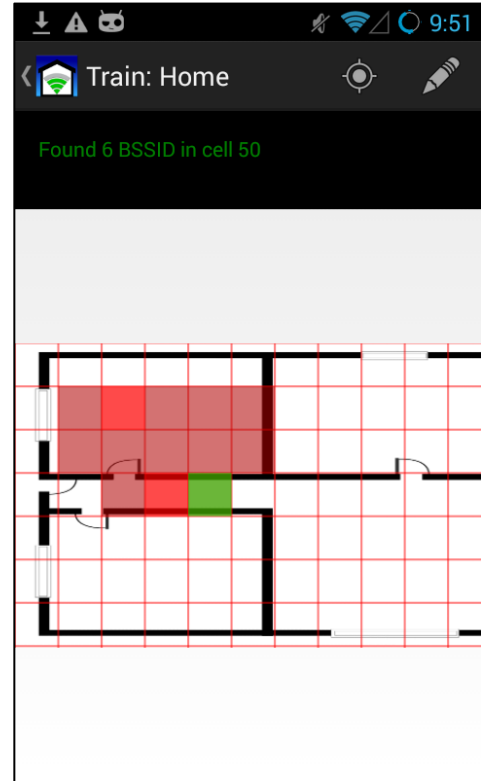
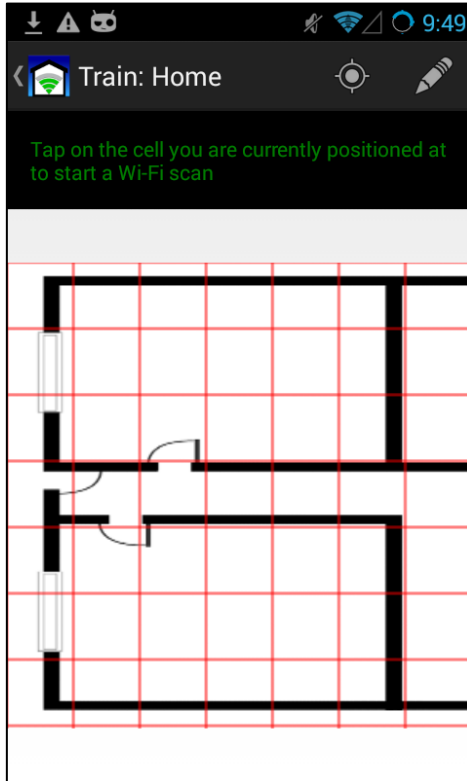
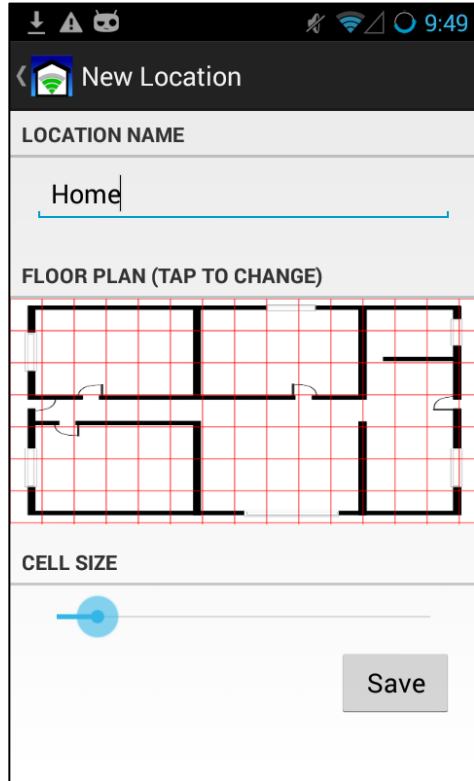
	P1	P2	P3	P4	P5	P6
Office Room 1 (P1)	60	0	0	0	0	0
Office Room 2 (P2)	0	60	0	0	0	0
Office Kitchen (P3)	0	0	60	0	0	0
Home Kitchen (P4)	0	0	0	59	1	0
Home Living Room (P5)	0	0	0	6	54	0
Supermarket (P6)	0	0	0	0	0	60



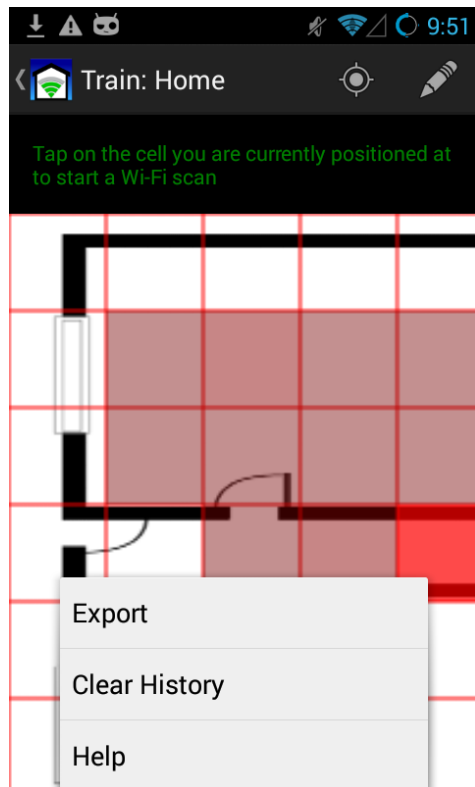




WiFi Indoor Localization



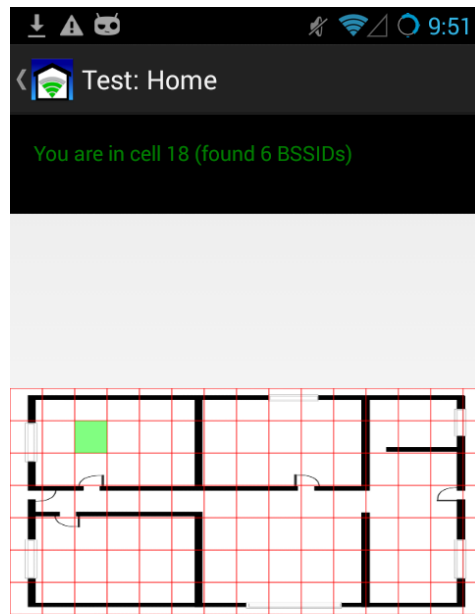
WiFi Indoor Localization



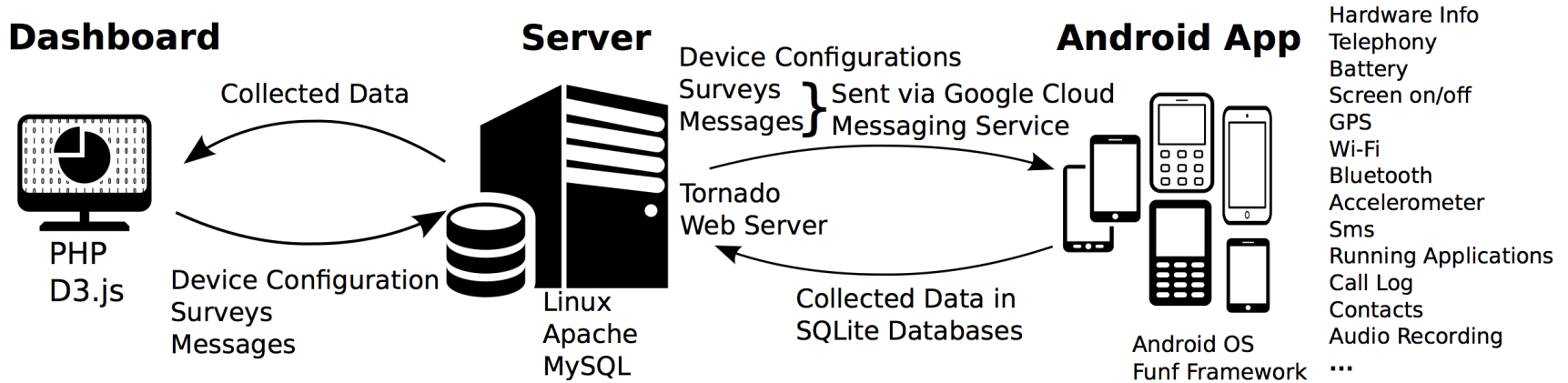
Home.txt

cellId|bssid|ssid|level|timestamp

```
17|00:24:6c:f6:35:f1|eduroam|-50|1392666615259
17|00:24:6c:96:f4:61|eduroam|-76|1392666615259
17|00:24:6c:97:87:31|eduroam|-73|1392666615259
17|00:24:6c:f6:35:f0|eduroam-guest|-50|1392666615259
17|00:24:6c:96:f4:60|eduroam-guest|-75|1392666615259
17|00:24:6c:97:87:30|eduroam-guest|-73|1392666615259
18|00:24:6c:f6:35:f1|eduroam|-50|1392666619359
18|00:24:6c:96:f4:61|eduroam|-77|1392666619359
18|00:24:6c:97:87:31|eduroam|-68|1392666619359
18|00:24:6c:f6:35:f0|eduroam-guest|-49|1392666619359
18|00:24:6c:96:f4:60|eduroam-guest|-77|1392666619359
18|00:24:6c:97:87:30|eduroam-guest|-68|1392666619359
18|00:24:6c:f6:35:f1|eduroam|-50|1392666623418
18|00:24:6c:96:f4:61|eduroam|-78|1392666623418
18|00:24:6c:97:87:31|eduroam|-73|1392666623418
18|00:24:6c:f6:35:f0|eduroam-guest|-50|1392666623418
18|00:24:6c:96:f4:60|eduroam-guest|-79|1392666623418
18|00:24:6c:97:87:30|eduroam-guest|-76|1392666623418
19|00:24:6c:f6:35:f1|eduroam|-50|1392666627507
19|00:24:6c:96:f4:61|eduroam|-77|1392666627507
19|00:24:6c:97:87:31|eduroam|-72|1392666627507
19|00:24:6c:f6:35:f0|eduroam-guest|-50|1392666627507
19|00:24:6c:96:f4:60|eduroam-guest|-79|1392666627507
19|00:24:6c:97:87:30|eduroam-guest|-74|1392666627507
20|00:24:6c:f6:35:f1|eduroam|-54|1392666631573
20|00:24:6c:96:f4:61|eduroam|-80|1392666631573
20|00:24:6c:97:87:31|eduroam|-77|1392666631573
20|00:24:6c:f6:35:f0|eduroam-guest|-53|1392666631573
20|00:24:6c:96:f4:60|eduroam-guest|-79|1392666631573
20|00:24:6c:97:87:30|eduroam-guest|-75|1392666631573
21|00:24:6c:f6:35:f1|eduroam|-50|1392666635648
21|00:24:6c:96:f4:61|eduroam|-80|1392666635648
21|00:24:6c:97:87:31|eduroam|-78|1392666635648
.....
```



Moving Data to the Cloud



Moving Data to the Cloud

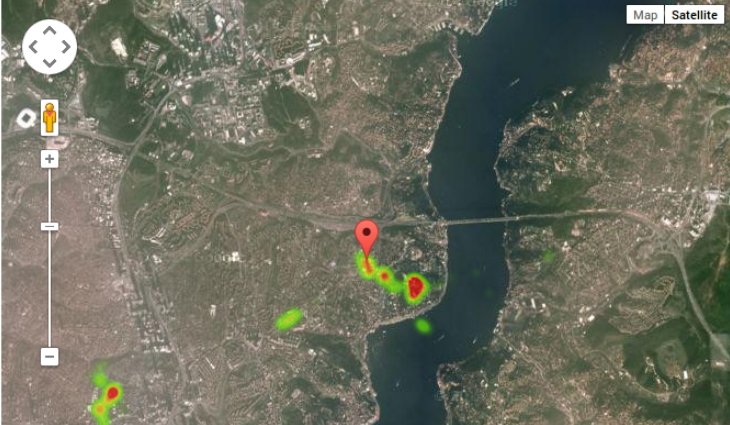
[Smartphone Tracker](#) [Dashboard](#) [Devices ▾](#) [Surveys](#) [test@boun.edu.tr ▾](#)

Samsung GT-I8150

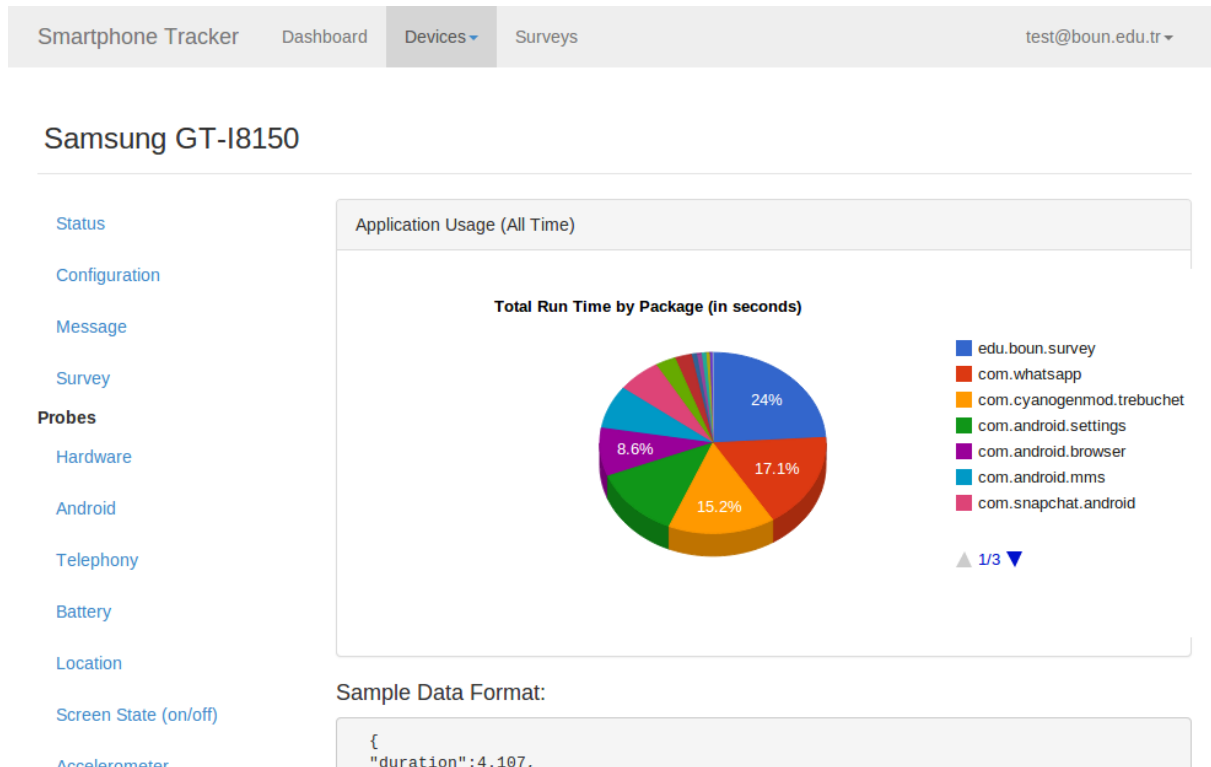
[Status](#)
[Configuration](#)
[Message](#)
[Survey](#)
Probes
[Hardware](#)
[Android](#)
[Telephony](#)
[Battery](#)
[Location](#)
[Screen State \(on/off\)](#)
[Accelerometer](#)

Location

- Latest known location of the device is shown with a marker.



Moving Data to the Cloud



Crowdsourced WiFi/GSM Databases

- <http://opencellid.org/>
- <http://opensignal.com/>

Questions?

Thank you.