SenseWaves: Radiowaves for context recognition

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1 Introduction

We are surrounded by a sensor-enriched environment which is able to provide a broad spectrum of features from various sensor classes that can be utilised for situation and activity awareness. However, the probably most common sensor, shipped with nearly every electronic device nowadays such as mobile phones, notebooks, printers as well as keyboards, mouses, watches, shoes, media players – rumour has spread about even media cups – is mostly not utilised for activity recognition: The RF-sensor.

Due to its high penetration, the additional cost for utilising this sensor in an application is considerably low. The application must simply utilise the information available but discarded unused in these devices. Although the wireless channel is frequently utilised for location detection of other active RF devices, it is seldom used to detect other contexts than location from entities that are not actively transmitting.

We demonstrate a system for activity recognition based on features extracted from the RF channel. In particular, we show how static changes in the environment such as moved furniture, activity of a person and an ongoing phone call are detected based on RF channel measurements.

2 Situation detection based on RF channel measurements

Several authors have considered location detection of actively transmitting entities based on measurements from an RF-sensor. In [8], the authors utilise RSSI measurements on MICAz nodes to show that velocity of an entity can be estimated by analysing the RSSI pattern of transmitted packets. The authors of [4]

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study the feasibility of motion sensing by analysing fluctuation in the 8 bit 802.11 RSSI indicator. Also, fluctuations in GSM signal strength have been utilised for activity sensing in [1, 7]. The authors of [1] utilise the signal strength fluctuation from cells in the active set to distinguish between the activities walking, driving and stationary. The authors of [7] describe a system that extracts seven features from GSM signal strength measurements in order to classify six distinct velocity levels with high accuracy. The features are mainly deviations of the variation in signal strength and the frequency of cell-tower changes in the active set. Summarising, for these studies the entity for which the activities are classified must be actively transmitting. Recently, some authors also consider the feasibility of sensing the activity of passive entities. These studies, however, rather focus on the detection of presence than on activity. The authors in [8] show that the RSSI level remains constant in a vacant environment and is fluctuating when an individual enters the proximity of a constantly transmitting node. The authors of [3] extend this work by demonstrating that the RSSI peak is concentrated on a restricted frequency band in a vacant environment and spreaded but less intensive in the presence of an individual. These studies utilise only RSSI measurements and classify between two basic situations. Another work related to our studies was recently presented in [2]. The authors derive context from information about activated electronic devices in a home environment. In particular, their system senses the unique electromagnetic interference created by SMPS oscillators of household electronic equipment.

We demonstrate that activity and not only location can be extracted from the RF-channel by utilising also other features than RSSI. We also consider energy measured on relevant frequency bands, the noise figure or also the fluctuation in signal strength. With these simple features we detect movement, an opened or closed door and an ongoing phone call. Our study expands preliminary work which we conducted in [5, 6] on the feasibility of situation classification based on RF-channel measurements.

3 Evaluation of RF activity recognition with SDRs

We utilise two USRP SDR devices[4] from which one constantly transmits a signal that is read and analysed by the other node. The devices are equipped with 900 MHz transceiver boards (RFX900) and a VERT900 antenna with 3dBi antenna gain. The three context classes of an opened/closed door, a moving person and a phone call are detected with three simple classification schemes. Static alterations in the environment, such as the opening of a door, are detected with the help of a k-NN with the signal amplitude and the number of signal peaks in a defined time frame as input. To detect movement, we utilise an adaptable threshold over the number of large deltas between successive signal peaks in a defined time span. An ongoing phone call is detected by searching the GSM band for strong signal peaks in a defined time span. We placed the two SDR devices to both sides of a door to optimally detect the static signal level changes. Due

[4] http://www.ettus.com

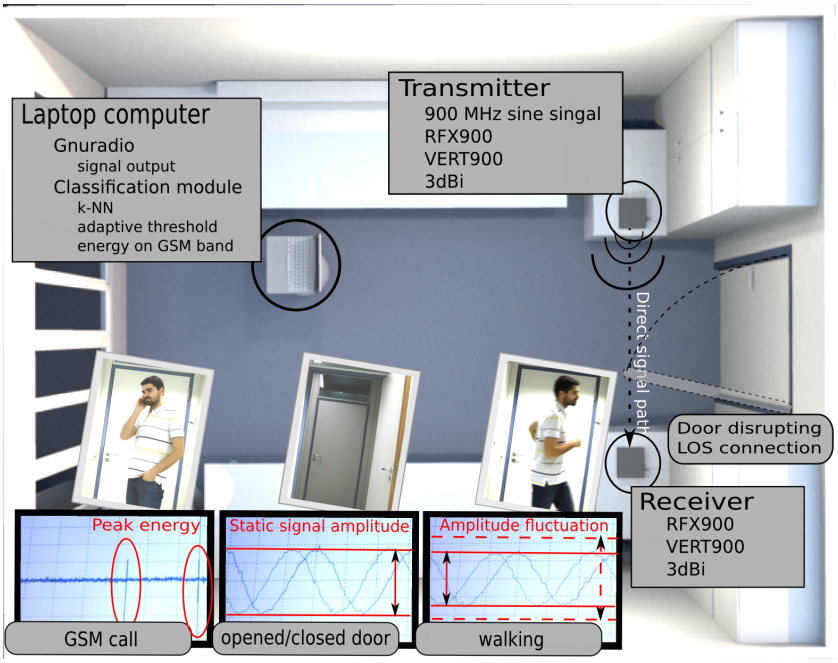

Fig. 1: Schematic illustration of the recognition system

to multipath propagation of signals, the fluctuation of the signal amplitude and the increase in energy on relevant frequency bands is recognised at arbitrary position in the room (cf. Fig 1).

4 Results

We demonstrate the detection of an opened or closed door, a person in a room and an active phone call in an office environment. The results are detailed in table 1. All situations have been trained beforehand and each situation was established 10 times under slightly differing conditions (position of people, differing individuals). The USRP devices were placed so that the door was bridged by a direct link between them. For the idle situations with no persons in the room, detection was perfect regardless of the other condition. The worst detection ac-

Table 1: Accuracy of the implicit situation awareness.

Situation	mean	median	σ
Door state (opened/closed)	0.952	0.9513	0.0099
Presence of individual	0.817	0.8238	0.0455
Phone call (gsm)	0.9	1.0	0.32

curacy was achieved for the detection of the presence of an individual when the door to the room was opened.

5 Conclusion

We have demonstrated the feasibility of activity recognition based on RF-channel measurements. By training the system it can be adapted to various environments. The contribution of this work is a system which can detect activities and not only location and velocity of non-actively transmitting devices. To achieve this we extracted and utilised energy on relevant frequency bands, static amplitude level and amplitude fluctuation from a measured RF signal as features for activity recognition. Situation detection was evaluated at three distinct indoor locations with stable and accurate detection performance.

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