Indoor positioning using FM radio signals (PhD thesis summary)

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Location based services are becoming an indispensable part of the life. The wide adoption of Global Positioning System in mobile devices, combined with Wi-Fi and cellular networks have practically solved the problem of outdoor localization and opened a new market. This, however, is the case only for outdoors. There are numerous areas of ubiquitous computing, which require the knowledge of user position indoors. Awareness of user's location is important in smart environments, assisted daily living, behavior analysis studies. Over the past years, a significant effort has been dedicated to development of indoor localization systems. The results varied in characteristics, performance, cost and technologies.

Despite the effort, the existing indoor positioning systems are limited: they either require expensive infrastructure (Ubisense, Wi-Fi, ultrasound), have limited coverage (Wi-Fi, Bluetooth, RFID, DECT) or low accuracy (GSM, CDMA). The cost of commercial systems is prohibitive for wide adoption (Ubisense).

The main objective of this thesis is to determine the feasibility of indoor positioning using FM radio signals, generated either locally or by broadcasting stations. The performance of FM localization cannot be simply extrapolated from other technologies, like Wi-Fi or GSM, due to significantly lower frequencies (100 MHz vs. 0.9…2.4 GHz) leading to differences in propagation. Moreover, FM represents a popular and well-established technology; many mobile devices have an embedded FM receiver. Broadcasting FM stations provide almost ubiquitous coverage. Short-range FM transmitters are available license-free from conventional electronics markets.

The contributions of this thesis are:

- identification of FM signal features suitable for localization and discovering their limitations;
- demonstration that indoor positioning using FM signals produced by local short-range transmitters is feasible and its accuracy is comparable to Wi-Fi positioning;
- demonstration that indoor localization using signals transmitted by broadcasting FM stations (without in-building infrastructure) is feasible and in most of the cases outperforms Wi-Fi and GSM systems;
- an approach for maintaining accuracy of a fingerprinting-based positioning system;
- demonstration that FM signal strength is more robust in crowded environments than Wi-Fi.

Two types of FM signal sources have been evaluated: local and external/broadcasting stations (referred as FM_L and FM_B, respectively). The FM_L approach employs local short-range FM transmitters, the consumer-grade devices which do not require licensing. FM_L localization demonstrates the performance similar to Wi-Fi (Figure 1). A combination of FM_L and Wi-Fi fingerprints provides better positioning accuracy than either of the systems used alone.

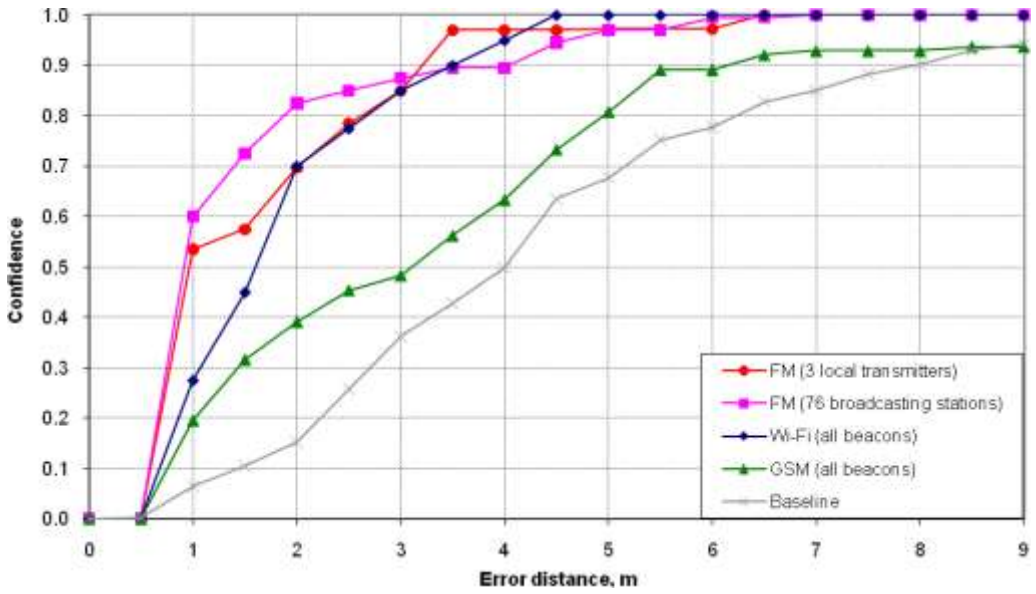

Figure 1. Accuracy of FM, Wi-Fi and GSM positioning systems in lab measurements.

The second approach, FM_B, leverages radio signals from broadcasting FM stations. FM_B localization does not require any in-building infrastructure and thus has zero hardware costs. Moreover, the coverage of FM broadcasts is much wider than that of Wi-Fi networks. Finally, due to the high number of available stations the FM_B indoor positioning system provides better accuracy than Wi-Fi in 90% of the cases (Figure 1). The performance of GSM positioning, which also employs external beacons, is notably inferior to FM_B or Wi-Fi.

To counter the degradation of accuracy with time, inherent to all fingerprinting–based positioning systems (including FM), this thesis has proposed the spontaneous recalibration approach, which utilizes periods when device's location is known, to update calibration data of the positioning system. Unlike other recalibration methods, spontaneous recalibration does not require additional hardware or special efforts from the user.

A considerable part of the thesis has been dedicated to the study of influence of human presence on FM and Wi-Fi signal strength. Both FM_B and Wi-Fi signals were found to be sensitive to the presence of people and exhibited increased variations in such cases; the deviation of FM, however, was lower than that of Wi-Fi, except for the medium-density crowd where they were equal. It has also been found, that the FM_L signal strength depends on user orientation, however, the dependence has minor effect on positioning accuracy and cannot be utilized to recognize user direction from signal fingerprints.

The main advantage of the presented concepts is that they can be readily deployed: FM tuners are available in many mobile devices. The client-side FM radio is a passive receiver – thus, FM positioning may be used in sensitive areas where radio transmission, such as Wi-Fi or GSM, is prohibited for safety or security reasons. Finally, an FM receiver has lower power consumption than Wi-Fi module and provides 2.6 to 5.5 times longer battery life in localization mode.

Relevant publications

1. Andrei Papliatseyeu, Venet Osmani and Oscar Mayora-Ibarra. FINDR: A Novel Approach for Indoor Positioning Using FM Radio Signals. International Journal of Handheld Computing Research (IJHCR), Volume 1, Issue 3, 2010. Pages 19—31.

2. Aleksandar Matic, Andrei Popleteev, Venet Osmani, Oscar Mayora-Ibarra. FM Radio for Indoor Localisation with Spontaneous Recalibration. Journal of Pervasive and Mobile Computing (PMC), Volume 6, Issue 6, 2010. Pages 642—656. **(17% of papers invited)**

3. Andrei Papliatseyeu, Aleksandar Matic, Venet Osmani, Oscar Mayora-Ibarra. Indoor Positioning Using off-the-shelf FM Radio Devices. Abstact volume of IPIN-2010. Zurich, Switzerland, September 2010. Pages 41—42.

4. Aleksandar Matic, Andrei Papliatseyeu, Venet Osmani and Oscar Mayora-Ibarra. Tuning to Your Position: FM-radio based Indoor Localization with Spontaneous Recalibration. Proceedings of PerCom-2010. Mannheim, Germany, April 2010. Pages 153—161. **(Acceptance rate 12%)**

5. Andrei Papliatseyeu, Niko Kotilainen, Oscar Mayora-Ibarra, and Venet Osmani. FINDR: Low-cost indoor positioning using FM radio. Proceedings of MobilWare-2009, Berlin, Germany, April 2009. Pages 15—26.