Wireless Indoor Positioning: Localization improvements with a Leaky Coaxial Cable Prototype

Mark Weber*§, Ulrich Birkel*, Ralf Collmann‡ and Julia Engelbrecht‡
*TH Mittelhessen
Dep. of Electronic Eng., Giessen, Germany
‡University of Applied Sciences
HTW Dresden, Dep. of Electronic Eng., Dresden, Germany
§mark.weber@ei.fh-giessen.de

***Abstract*—RF (Radio Frequency) Fingerprinting for indoor localization using wireless local area networks attracted significant attention throughout the last decade. A severe drawback of this approach however is the laborious effort to calibrate the radio map. Especially in case of environmental changes recalibration becomes necessary. The main focus of our research project WIPoS (Wireless Indoor Positioning System) is to solve this problem by appropriate RF engineering and optimized methods. This paper compares the performance of a standard leaky feeder cable to a new cable prototype with improved localization properties in a long hallway scenario. We can show that the localization accuracy of the new leaky feeder cable is similar to the performance of localization with standard omni antennas but it has an important advantage: the fingerprints are now more insensitive to environmental changes.**

I. Introduction

RF fingerprinting using wireless local area network [1], like WLAN, has frequently been suggested as an alternative to provide location information for indoor areas. In contrary to other localization techniques like Angle of Arrival (AoA), Time of Arrival (ToA) [2] or Time difference of Arrival (TDoA) [3] our research project WIPoS focuses on rf fingerprinting in combination with leaky feeder cables to solve the problem of radiomap-recalibration in case of environmental changes.

In [4] it has been shown that the application of standard leaky feeder cable is beneficial for localization compared to standard omni directional antennas especially in the presence of obstacles because the local fingerprint stayed more stable whereby the usage of standard access points led to significant degradation in localization accuracy.

Leaky feeder cables are designed to provide homogeneous coverage throughout a building. A low longitudinal attenuation leads to increased coverage ranges compared to standard antennas which makes the application of leaky feeder cables from the coverage point of view interesting. But a lower longitudinal loss obviously results in lower location accuracy (about 8 m at 80% by smoothing), if distance metrics such as Euclidean Distance of RSS vales are used compared to standard antennas (about 5 m at 80% when using 2 AP signals in the same hallway) [5].

Therefore new leaky feeder cable designs were simulated and tested to improve localization accuracy [6], [7]. Finally a prototype with a cascaded attenuation profile [8] has been proposed which is compared to a standard leaky feeder cable and an access point installation by investigating different localization methods in this paper.

II. Experimental setup

For the long hallway test scenario we installed a standard leaky feeder cable (RLKU12) and the new prototype cable (40m, centred) as LF (Leaky Feeder) installation on the ceiling. The AP and LF installations are shown in Figure 1.

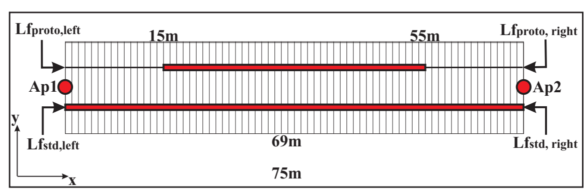
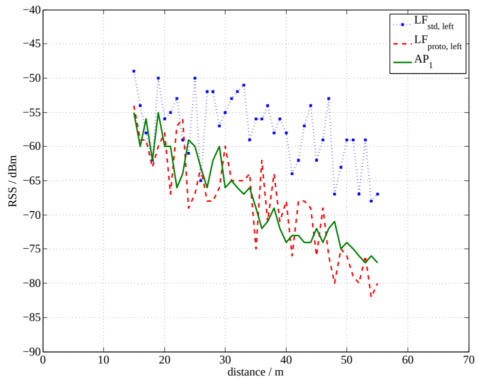
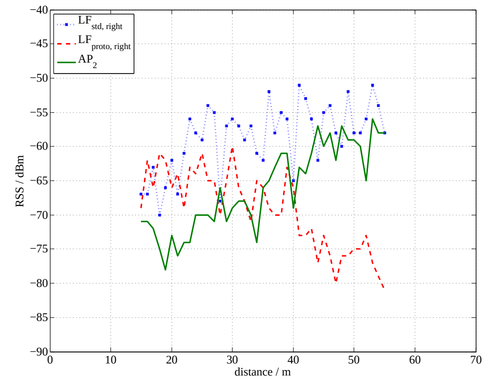


Fig. 1. standard (std) LF, prototype (proto) LF and AP installation

Two independent WLAN signals on different channels were fed from each side into each leaky feeder cable $LF_{std,left}, LF_{std,right}$ and $LF_{proto,left}, LF_{proto,right}$. To compare the LF installation we used as a reference an AP installation with standard omni directional antennas (2 dBi), transmitting on different channels AP_1 and AP_2 from each side. For the position estimates we used the weighted K-Nearest-Neighbor algorithm (WKNN) [9], [10]. The neighbors are computed by finding the K minimum signal distances between the observed RSS (received signal strength) vector $\begin{bmatrix} s_1 & s_2 & \cdots & s_n \end{bmatrix}$ and the RSS vector in the radiomap $\begin{bmatrix} S_1 & S_2 & \cdots & S_n \end{bmatrix}$ with the Euclidean distance. Additionally we used a sliding window of $m = 5$ for smoothing the database and measurements in the online phase.



(a) LF and AP signals from left side



(b) LF and AP signals from right side

Fig. 3. Mean RSSI over distance for LF (std: blue dotted line; proto: red dashed line) and AP (green solid line) installation

III. Evaluation and Results

To create the radio map 41 reference points have been selected in the center of the corridor with a distance of 1 m, namely P15 to P55 as shown in Figure 2. In order to generate the radio map 1000 RSS samples have been recorded at each reference point. In the radio map the mean RSS of the signals received from the six APs, via the leaky feeder installation ($LF_{std,left}, LF_{std,right}$ and $LF_{proto,left}, LF_{proto,right}$) and the omnidirectional AP installation (AP_1 and AP_2) have been stored. Figure 3 shows the mean RSS along the hallway for the LF and AP installations.

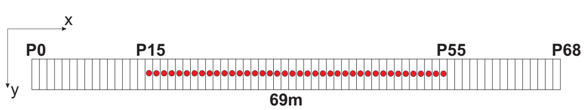


Fig. 2. Reference points in radio map

We can see that the new leaky feeder cable has a higher longitudinal loss than the standard cable. This leads to less ambiguities in localization estimations even if the signal of the new cable shows a Rayleigh fading characteristic again. But the small-scale fading effect is improved compared the the standard leaky feeder design. The faded signal of the AP can rather be described as being Rician faded with a higher k-factor, due to the presence of a stronger dominant LOS component along the hallway [11]. In Figure 4 we can see that the improvement of the overall accuracy using the prototype cable is 4 meters compared to the standard leaky feeder cable by smoothing the database and measurements in the online phase and using the weighted K-Nearest-Neighbor algorithm (WKNN). Other distance metrics such as Mahalanobis have been investigated but they did not lead to any further improvements.

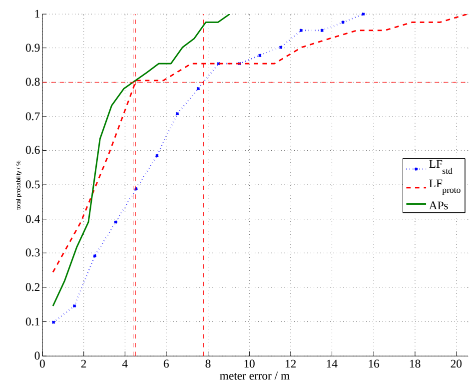


Fig. 4. Comparison of CDF of AP (green solid line) and the standard LF (blue dotted line) and prototype LF (red dashed line) installation

IV. Conclusion and Future Work

We showed that the overall positioning accuracy using the new prototype cable with higher longitudinal loss and improved fading characteristics increased to an overall accuracy of 4 m at 80% and is similar to the AP installation. The additional advantage of using this leaky feeder cable is that the fingerprints are less sensitive to environmental changes. The new leaky feeder design is therefore a promising approach to improve the localization accuracy with leaky feeder cables using rf fingerprinting. Our next steps will be to evaluate the localization accuracy with UMTS using the new cable.

Acknowledgment

This project was supported by the German Federal Ministry of Education and Research under contract No. 1739B08. This work was also supported by our project partners RFS GmbH, Alcatel-Lucent Germany AG and AWE Communications GmbH.

References

[1] P. Bahl and V. N. Padmanabhan, “Radar: an in-building rf-based user location and tracking system,” in *Proc. IEEE Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies INFOCOM 2000*, vol. 2, 2000, pp. 775–784 vol.2.

[2] M. Vossiek, L. Wiebking, P. Gulden, J. Wieghardt, C. Hoffmann, and P. Heide, “Wireless local positioning,” vol. 4, no. 4, pp. 77–86, 2003.

[3] K.-i. Nishikawa, T. Higashino, K. Tsukamoto, and S. Komaki, “Two dimensional position detection method using bi-directional leaky coaxial cable based on tdoa,” in *Proc. IEEE 20th Int Personal, Indoor and Mobile Radio Communications Symp*, 2009, pp. 2167–2170.

[4] M. Weber, U. Birkel, and R. Collmann, “Indoor rf fingerprinting using leaky feeder cable considering environmental changes,” in *Proceedings of the 6th International Conference on Mobile Technology, Application & Systems*, ser. Mobility ’09. New York, NY, USA: ACM, 2009, pp. 18:1–18:6. [Online]. Available: http://doi.acm.org/10.1145/1710035.1710053

[5] M. Weber, U. Birkel, R. Collmann, and J. Engelbrecht, “Comparison of various methods for indoor rf fingerprinting using leaky feeder cable,” in *Proc. 7th Workshop Positioning Navigation and Communication (WPNC)*, 2010, pp. 291–298.

[6] J. Engelbrecht, R. Collmann, U. Birkel, and M. Weber, “Methodical leaky feeder design for indoor positioning considering multipath environments,” in *Proc. IEEE Radio and Wireless Symp. (RWS)*, 2010, pp. 164–167.

[7] ——, “Suppression of power level fluctuations at leaky coaxial cable ends using ferrite cores,” in *Proc. German Microwave Conf. (GeMIC)*, 2011, pp. 1–4.

[8] ——, “First results of a leaky coaxial cable prototype for indoor positioning,” in *Wireless Telecommunications Symposium (WTS)*, 2011.

[9] N. Swangmuang and P. Krishnamurthy, “Location fingerprint analyses toward efficient indoor positioning,” in *Proc. Sixth Annual IEEE International Conference on Pervasive Computing and Communications PerCom 2008*, 2008, pp. 100–109.

[10] V. Honkavirta, T. Perala, S. Ali-Loytty, and R. Piche, “A comparative survey of wlan location fingerprinting methods,” in *Proc. 6th Workshop on Positioning, Navigation and Communication WPNC 2009*, 2009, pp. 243–251.

[11] T. S. Rappaport, *Wireless Communications: Principles and Practice (2nd Edition)*, 2nd ed. Prentice Hall, Jan. 2002. [Online]. Available: http://www.amazon.com/exec/obidos/redirect?tag=citeulike07-20&path=ASIN/0130422320