UWB Indoor-Localization in Time-of-Arrival-Configuration

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***Abstract* — During the last years, hardware implementing the IEEE 802.15.4-2011 UWB standard has become increasingly popular for designing high-precision indoor localization systems. A notable example is the decaWave DW1000 IC and corresponding evaluation hardware that will be used in this demonstration. In the standard mode of operation the system has the capability to measure round-trip time of flight (RToF) of data packets between two units. For localizing a mobile tag in a setup with fixed anchors this mode requires excessive communication between the tag and each anchor, thus reducing the possible update rate, and causing large energy consumption. We use a time-of-arrival (ToA) configuration instead, in which for every individual localization, the tag only transmits a single data packet and does not have to use its reception mode. Unlike the RToF-mode, this setup requires the fixed anchors to be synchronized, and the time of transmission of each packet to be estimated along with the tag coordinates. Our system continuously performs wireless anchor synchronization using a dedicated synchronization and localization algorithm to maintain high accuracy while minimizing communication effort in the mobile tag.**

Keywords — ultra-wideband, time of arrival, localization, synchronization

I. APPROACH

In this demonstration we present an infrastructure-based UWB-system based on the time-of-arrival principle capable of localizing a mobile tag using a number of stationary anchor stations mounted at known positions. In contrast to round-trip time-of-flight (RToF) measurement, the communication requirements in the tag are kept to a minimum. Compared to time-difference-of-arrival-systems (TDoA), there is less mathematical redundancy involved in the synchronization process, which allows for faster and more consistent computation at the cost of having to estimate the time of tag packet transmission during localization.

A. Hardware

As shown in Fig. 1, the system's hardware consists of connected off-the-shelf components combined with custom microcontroller and high-level software. Both, the mobile tag and the anchor stations are based on decaWave's EVB1000 evaluation module featuring the DW1000 UWB IC and a microcontroller. In the anchor, custom software for the microcontroller is responsible for the appropriate chip configuration, reading and transmission of timestamps, and communicating with the central processing unit via a Microchip RN171 WLAN module. In the tag, the microcontroller configures the DW1000 and ensures a constant transmission interval in the sub-second-range.

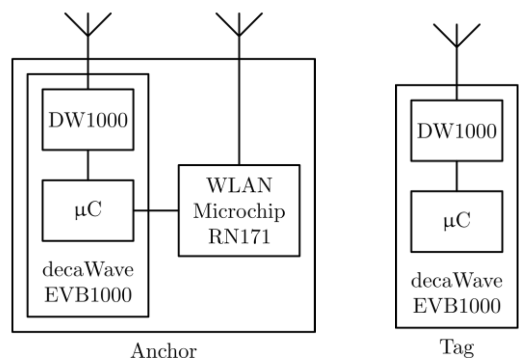

Fig. 1. Anchor and mobile tag building blocks

B. Setup and synchronization

The system is based on time-of-arrival measurements of packets periodically emitted by the mobile tag and received by anchors with a line-of-sight connection. To compute tag location from timing information, the local anchor clocks must be in synchronization, which under changing temperature and environmental conditions cannot be maintained over time. Therefore, as shown in Fig. 2, the anchors also periodically transmit packets that are received by other anchors in the vicinity, where the received packets are timestamped using the local anchor clock. To minimize interference and ensure maximum throughput, a TDMA scheme derived from the tag transmission interval is used.

The information collected by the anchors is periodically transmitted to the central processing unit, which performs a virtual anchor synchronization by continuously computing oscillator offset and skew for all anchors. This is done in a robust fashion to account for non-line-of-sight measurements between anchors. The synchronization procedure is designed for an optimal trade-off between the reaction to dynamic changes in oscillator stability, and localization accuracy.

From synchronized time-of-arrival information of tag packets, the central processing unit computes tag locations and the time of packet transmission. In a 2D configuration it is possible to include information on room geometry such as walls or other structures that cannot be crossed by the tag. In that way, a reliable tag tracking can be implemented [1]. In a 3D configuration an extended Kalman filter is used for tracking purposes. Measures are taken to identify non-line-of-sight measurements and obtain robust position estimates.

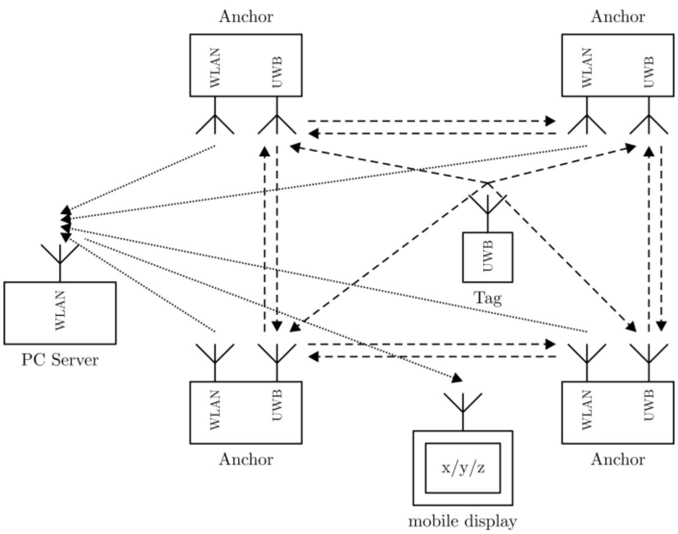

Fig. 2. Setup principle using a number of anchor stations, a mobile tag to be localized, a central location engine and server, and a mobile display device. Dashed lines symbolize UWB-transmissions, dotted lines symbolize WLAN communication.

II. DEPLOYMENT REQUIREMENTS

The system consists of anchors up to the number allowed for deployed infrastructure in the competition. The anchors are battery-powered and therefore do not need additional cabling. The anchors are lightweight and can be tied to structures in the hall or mounted on tripods. For accurate 3D-localization it is required that there is significant difference in elevation between anchors (i.e., it is imperative that not all anchors are mounted in the same plane), and that there is line of sight transmission between the tag and at least four anchors at all times. The anchor’s positions must be determined e.g. by a 3D laser-scan and made available to the estimation algorithms.

There is a WLAN connection from every anchor to the central processing unit which is implemented in a standard PC/Laptop that serves as a WLAN access point, computes position estimates and transmits the results to a mobile display unit. If room geometry (i.e., walls, corners, etc.) should be incorporated into the estimates in a 2D configuration, then a map of the premises must be available or a 3D scan must be performed beforehand.

ACKNOWLEDGMENT

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REFERENCES

[1] M. Pichler, B. Rudic, S. Breitenberger, and W. Auer, “Robust positioning of livestock in harsh agricultural environments,” in *Proc. 14th Mechatronics Forum International Conference*, Karlstad, Sweden, 2014, pp. 527–534.