A Novel Approach for Localizing Non-Equipped Road Users*

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1 Introduction

The protection of so-called Vulnerable Road Users (VRU), i.e. pedestrians, cyclists and other unprotected road users, is getting increasing attention in the Intelligent Transportation Systems (ITS) domain. VRUs equipped with compatible localization and communication devices can report their presence to approaching equipped vehicles by using either direct ad-hoc communication, as for instance ETSI ITS-G5 or DSRC, or mobile-based communication like LTE or 5G [MSJ15]. One approach for protecting non-equipped VRUs in urban settings is to detect and localize them using road infrastructure and forward this information to approaching vehicles. Since camera-based systems have a low performance under bad weather and lighting conditions, radio frequency (RF)-based localization is especially well suited to detect targets, i.e. vehicles and VRUs, in urban environments. In [SPS18], the authors show the potential in localizing these targets by looking at reflected, diffracted and scattered signals using an array of communication units. A different approach for passive localization was introduced in [Wi10], as radio tomographic imaging. This device-free localization (DFL) approach solely relies on variations of the received signal strength (RSS) between individual links of a wireless network. A DFL system employs K transceiving communication nodes, e.g. road-side units, spanning a dense network of bidirectional links in line-of-sight (LoS). In each link, the RSS is mainly influenced by transmit power, distance dependent path loss, fading loss, and a shadowing loss induced by obstacles within the link. In this regard, targets are considered as time-variant obstacles which attenuate the RSS of various links according to their position. In order to localize a target based on RSS-measurements, the network area is initially sectioned in N discrete regions with known location. On the basis of this partitioning, an image vector is

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introduced which describes the attenuation of each respective region. This allows expressing the shadowing loss of any individual link as a weighted sum of the attenuation values. The differences in RSS are measured for every link resulting in a measurement vector, which depends on the position of the target. The measurement equations form a linear system with a weighting matrix and a noise vector incorporating fading and measurement noise. Thus, the image vector can be estimated, e.g., using a least-squares solution with Tikhonov regularization as proposed in [Wi10]. Since the locations of the N regions corresponding to the image vector are known, the position of the attenuating obstacles can be directly inferred from the estimated image vector. As shown in [Wi10], the performance of a DFL system is mainly influenced by the node density. Particularly, an increasing number of nodes leads to an increasing localization accuracy. This can be intuitively explained by the coverage of the network area with LoS-links. The lack of information in areas, where no link-related RSS measurements can be retrieved results in a poor localization performance. Motivated by the resource consuming deployment of communication infrastructure in urban environments required in DFL systems, the approach proposed in this document attempts to downsize the amount of nodes. In comparison to [Wi10], only relying on RSS measurements between LoS-links, our approach bases on an additional exploitation of propagation characteristics [SG08]. To gather this additional information, the measured channel impulse response (CIR) is processed at each node.

Therewith, the proposed localization approach for vehicles and VRUs can be divided in two stages: 1. In an initial calibration phase, the additional information of the propagation channel is precisely estimated from all measured CIRs. 2. The second stage applies commonly known DFL processing, as e.g. described in [Wi10], now including the additional channel characteristics, to determine the position of targets within the network. Due to the usage of additional information of the propagation channel, the proposed passive localization approach improves common DFL methods. Particularly, the approach addresses the problem of link coverage within an observation area. As link coverage correlates to localization quality, the supplemental integration of propagation characteristics results in either an increased localization performance for an unchanged amount of nodes, or allows reducing the amount of required nodes to achieve a targeted localization performance. The algorithm is evaluated in an indoor scenario using five ultrawide-band (UWB) devices. Thereby, one UWB node is acting as transceiver, pinging four relay nodes in a round robin manner. The nodes are stationary mounted, spatially separated at different locations within the observation area. Thus, this setup spans a network of four direct links incorporating additional channel features, which can be used for the positioning of passive targets.

For ground truth, the passive target is tracked with a Vicon high-precision motion tracking system. Using the proposed approach, it is shown for this setup, that the location of a moving person can be estimated and tracked, successfully. A visual comparison of the tracking performance when using solely the LoS links and when using both the LoS and MPC links is shown in Fig.1. The positioning error is shown to be smaller than 1m. Future work will include testing the proposed approach in outdoor road environments, assesing the existance of different propagation paths and analysing the detection and localization performance for different road users.

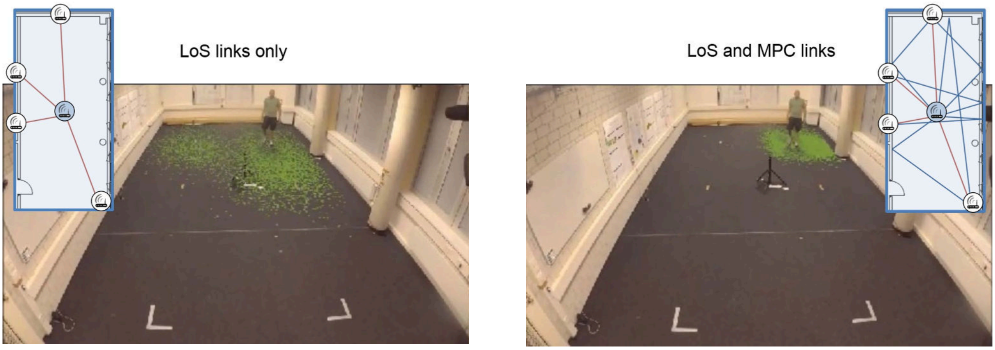

Fig. 1: Tracking performance comparison when using only LoS links (left) and using both, LoS and MPC links (right).

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