I. Abstract

II. Introduction

- something about importance of IoT and smart cities and fourth industrial revolution

[1]–[3]

- IoT with LoRa [4]
- importance of localization in IoT implementations [5]

LoRa provides excellent communication range at low power consumption but does this by only providing very slow data rates up to a theoretical limit of 11 kbps [3]. Due to this limitation many applications for which LoRa was evaluated in involve a low- or ultra-low-power sensor IoT device which has only small data packets which need to be transferred to a centralized control system or storage server. In [3] a proposal is made for utilizing LoRa and LoRaWAN technology for providing wireless local networks for communication of sensors and actuators in an Industry 4.0 scenario. Other work evaluates LoRa in concrete real-time scenarios. In [6] they evaluate LoRa as a communication technology for vehicle and asset tracking data at the harbor. In [7] they evaluate the achievable coverage in a smart campus setting. And in [8]

III. State of the Art

LoRa and LoRaWAN were released as a radio communication technology to the public in 2015 by Semtech. Very early on it already received coverage in scientific media as it was introduced as a promising long-range radio communication technology for IoT devices [4].

This section presents relevant literature correlating with mobile RSSI-based LoRa Localization.

A. LoRa Localization

Many different applications for LoRa/LoRaWAN were evaluated since its release. Because of the scope of this thesis this section only covers previous work which include some kind of localization with LoRa. The following section should not be regarded as a comprehensive list of all work including LoRa localization concepts but rather be used as a short overview of different applications for which LoRa localization was evaluated prior to this thesis.

Fargas et al. evaluate LoRa for use in an alternative GPS-free geolocation system [9]. This idea is further advanced in [10] where they evaluate LoRa as alternative localization system to GPS for Emergency Services. They found that simple off-the-shelf LoRa hardware could be used for achieving a positioning error between $9 - 20\,\mathrm{m}$ in an area of $200\,\mathrm{m}$ x $120\,\mathrm{m}$. They also estimated the expected battery-life both of the transmitter and the receiver node and found that the transmitter would possibly run up to 200 hours on a 5000 mAh battery but the receiver would only last about 90 hours with one battery charge.

In [11] they evaluate LoRa in carp

- RSSI-based LoRa localization for a low-cost car park localization implementation [11].
- LoRa evaluated for use as communication technology for Emergency Services in off-grid environments [10].
- Evaluation of LoRaHarbor [6]
- lightweight boat tracking using LoRa technology [12]
- LoRa-based mobile emergency management system (LOCATE) [8]
- tracking of patients in elderly care [13]
  - indoor and outdoor

B. Low Power

[14]

C. Deployment

- smart campus [7]
- coverage [3]

D. Challenges for LoRa Localization

[15]

- multiple approaches
  - ToA or TDoA => time-based approach
    - needs specialized hardware
    - insufficient accuracy for range of applications
    - often need pre-trained models
  - RSSI => signal-strength approach
    - multipath effect
    - high fluctuations in RSSI measurements at equal distance

E. Similar work

- RSSI-based LoRaWAN localization + evaluation of accuracy, impairments and prospects with SDR (software-defined radio) [16]
- low power rssi outdoor using 868 MHz ZigBee [14]
  - current consumption: 20mA in active mode, 6.7 uA in sleep-mode all at 3.3V -> receiver periodically wakes up to receive signals
- (indoor RSSI-based LoRa Localization in 2.4 GHz frequency band [17])
- evaluation of using AoA measurement for LoRa Localization in the cloud [18]
- AoA based (indoor?) LoRa Localization [19]
- LoRaWAPS: wide-area positioning system based on LoRa Mesh [20]
- public outdoor LoRa network used for TDoA-based tracking [21]

F. Contribution of this Thesis

- implementation and evaluation of mobile localization tag using RSSI-based LoRa localization with off-the-shelf (OTS) components
  - RSSI measurement is implemented in nearly all receivers -> no dedicated hardware
  - accuracy loss due to multipath effect should not play a huge role in outdoor localization because of higher LOS (line-of-sight) component of the signal
- evaluation of the feasibility of a LoRa based localization system
  - accuracy
  - power consumption
  - frequency band usage

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