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SMI doctoral school (ED432)
Ph.D. thesis proposal
2024 call

Title: RIS-aided indoor localization for next 6G networks

Context:

In our increasingly interconnected world, accurately determining the location of devices and individuals is becoming increasingly critical, particularly in indoor environments where various applications such as asset tracking, indoor navigation, location-based services, and context-aware computing are prevalent. Consequently, indoor localization plays a pivotal role in environments such as shopping malls, airports, hospitals, warehouses, and smart homes. On the other hand, Machine Learning (ML) algorithms have been extensively utilized to develop robust localization algorithms [1-2]. These algorithms can extract patterns from signal attributes measurements collected from communication technologies within indoor environments. ML models can then predict device locations based on these learned patterns [3].

For future communication standards, Reconfigurable Intelligent Surfaces (RIS) are being investigated as innovative technologies that could revolutionize wireless communication systems, particularly in indoor environments where traditional methods encounter challenges [4]. Consisting of passive elements capable of reflecting and manipulating electromagnetic waves, strategically deploying RIS elements can enhance signal coverage and overcome obstacles or signal blockages common in indoor spaces. Indeed, RIS can manipulate reflected signals to create constructive interference and mitigate multipath effects, thereby improving signal quality and reliability. These enhancements benefit localization techniques by providing additional information about signal propagation characteristics [5]. Analyzing reflections from RIS elements can yield valuable data for localization algorithms, enhancing accuracy and reliability, especially in complex and dynamic environments. Furthermore, RIS can facilitate collaborative localization schemes where multiple devices share information about observed signals and estimated locations. RIS elements can amplify or redirect signals to improve localization accuracy and consistency across different parts of indoor spaces.

By integrating ML-based localization algorithms with RIS technology, indoor localization systems stand to achieve higher accuracy, opening new opportunities for applications in indoor environments. However, such a solution still faces several challenges, including the complexity of indoor environments, sparse and noisy data, labor-intensive training data collection, generalization to new environments, real-time adaptation, integration complexity, and cost and deployment scalability.

Addressing these challenges will be the focus of this thesis and will require interdisciplinary research efforts involving expertise in machine learning, signal processing, wireless communications, sensor networks, and indoor environment modeling. Innovative approaches leveraging advances in ML, RIS technology, and data-driven localization techniques will be crucial for overcoming these challenges and unlocking the full potential of indoor localization systems.

Objectives and proposed approaches:

Addressing the previously enumerated challenges will be the focus of this thesis and will require interdisciplinary research efforts involving expertise in machine learning, signal processing, wireless communications, sensor networks, and indoor environment modeling. Innovative approaches leveraging advances in ML, RIS technology, and data-driven localization techniques will be crucial for overcoming these challenges and unlocking the full potential of indoor localization systems.

The objective of this thesis is threefold:

1. **Model-based indoor localization techniques**: The first contribution of this thesis will be on the study and proposal of model-based indoor localization techniques integrating RIS technology

and which's are suited for one of the scheduled 6G use cases. The proposed technique will be compared to classical ones to evaluate the gain brought by the RIS system.

2. **ML-based localization algorithms with RIS technology:** A second contribution of this thesis will be related to the use of ML approaches to improve the performance of the previously proposed indoor localization techniques. Many challenges will be faced and considered to reach this objective among which we can cite the choice of the network topology, the construction of the training sets, the reduced latency allowed to adapt the RIS unit cell phases for mobile users.

Timeline:

In the following, we summarize the main working steps of this thesis:

1. First step [1 to 3 months]. This step will be dedicated to a bibliographic study phase. During this stage the candidate will study the principles of indoor localization techniques, RIS systems and ML approaches. She/he will make a synthesis of the main contributions published in the literature and related to the concepts of indoor localization techniques integrating or not RIS technology. During this stage, the candidate must also, if she/he doesn't have a sufficient level in MATLAB and Python programming, follow a learning phase to master these software tools which will be very important for the rest of the thesis.
2. Second step [~30 months]. This is the useful part of the work which will be dedicated for proposing and evaluate the performance of the proposed solutions. This step will be punctuated by regular meetings with the supervising team, to develop ideas and discuss contributions that could be published through conference or journal papers.
3. Third step [3 to 6 months]. This stage will be dedicated to the writing of the dissertation and the preparation of the defense.

Ph.D. thesis supervisors:

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Bibliography:

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[4] C. Beldi, A. Dziri, F. Abdelkefi and H. Shaiek, "PARAFAC Decomposition based Channel Estimation for RIS-aided Multi-User MISO Wireless Communications," 2023 International Wireless Communications and Mobile Computing (IWCMC), Marrakesh, Morocco, 2023, pp. 1537-1542, doi: 10.1109/IWCMC58020.2023.10182441.
[5] C. Huang, G. C. Alexandropoulos, C. Yuen and M. Debbah, "Indoor Signal Focusing with Deep Learning Designed Reconfigurable Intelligent Surfaces," 2019 IEEE 20th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), Cannes, France, 2019, pp. 1-5, doi: 10.1109/SPAWC.2019.8815412.