Application for the Doctoral Contract 2025

Indoor Localization System for Patient Behavior Analysis in the Context of Connected Healthcare

Ph.D. Candidate:

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Dr. Huaqiong LI UCAS

XX / 09 / 2025

Outline

Personal Background

- Academic Background
- Research Experience
- Internship
- Skills

Research Context & Approach

- Research Context
- Research Objectives
- Challenges & Roadmap

Summary & Motivation

- PhD Timeline
- Achievements & Suitability
- Strengths & Motivation

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Academic Background

- **Engineering Diploma in Wireless Communication & IoT Systems** 2022-2025

  ISEP – École d'ingénieurs du numérique, Paris, France

  - Embedded Systems & Sensors, IoT Networks & Protocols, Neural Networks, 4G/5G/6G

- **Bachelor's Degree in Computer Science** 2018-2022

  \- *With Honors (Mention Très Bien)*

  Université Clermont Auvergne, Clermont-Ferrand, France

  - Machine Learning, Path Recognition, Sensor Integration, Signal Processing, Programming

Research Experience

1. Performance Evaluation of Wi-Fi Networks with TDMA Coexisting with CSMA/CA

Wireless Personal Communications, Springer, 2020

- Introduced TDMA into Wi-Fi to enhance real-time performance and reliability.
- Results: Reduced delay, improved reliability with minimal impact on CSMA/CA throughput.

2. Indoor Localization in IoT Networks Based on Graph Neural Networks

Article under preparation, 2025

- Compared DNN vs GNN for Wi-Fi RSSI fingerprint localization.
- Results: GNN achieved lower localization error and shorter runtime, showing higher robustness.

Graduation Internship

Energy Optimization in 5G Core Networks – Orange Innovation (24 Mar – 22 Sep 2025)

- **Objective:**
  - Analyze and optimize the energy consumption of open-source 5G Core (free5GC vs OAI).
- **Method:**
  - Deployed an energy monitoring framework (Kepler + Prometheus + Grafana on Kubernetes).
- **Key Finding:**
  - Theoretically, Free5GC consumes more energy than OAI, but observations show the opposite.
  - Identified frequent heartbeat signaling as the main cause of OAI's higher energy usage.
- **Result:**
  1. Extending heartbeat cycle reduced OAI's energy consumption without affecting stability.
  2. Integrated findings into Orange's internal AI assistant for future deployments.

Skills

Programming: Python, Matlab

AI/ML: DNN, GNN, Computer Vision

Signal Processing: RSSI, feature extraction

IoT Systems: sensors, data collection

Communication: English, French, Chinese

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Research Context

1. **Smart hospitals require indoor localization to:**
    - **Reduce safety risks :** wandering, fall detection
    - **Improve operational efficiency :** equipment & staff management
    - **Support real-time** patient monitoring
    - **Behavior analysis**

2. **System requirements:**
    - High accuracy
    - Low latency
    - Energy efficiency
    - Scalability
    - Integration with hospital IT systems

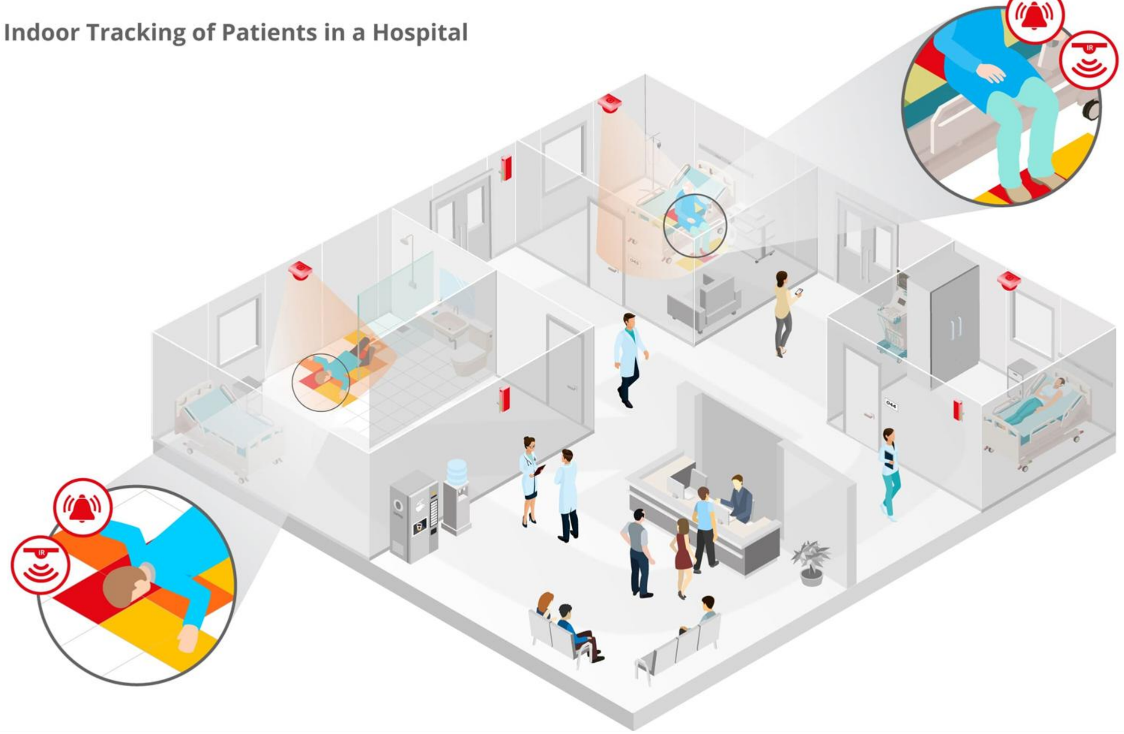
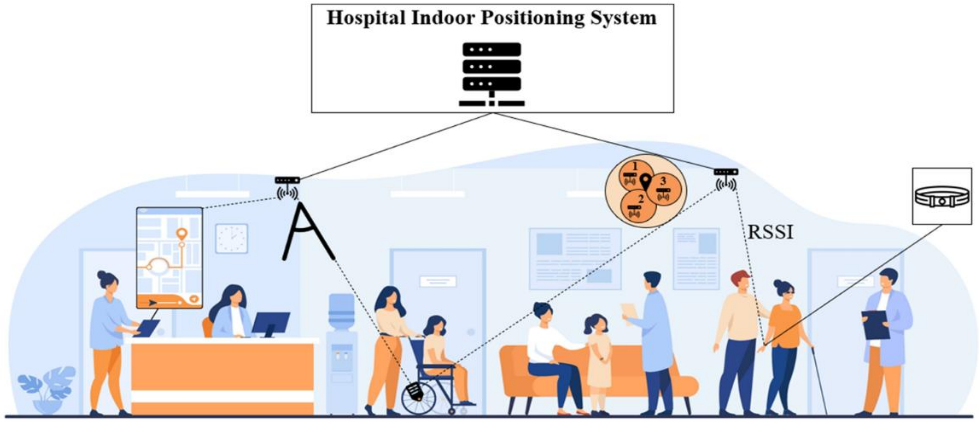


Figure Source: J. Lachmann, *Indoor Tracking of Patients in Hospitals*, July 12, 2018.

Research Objectives



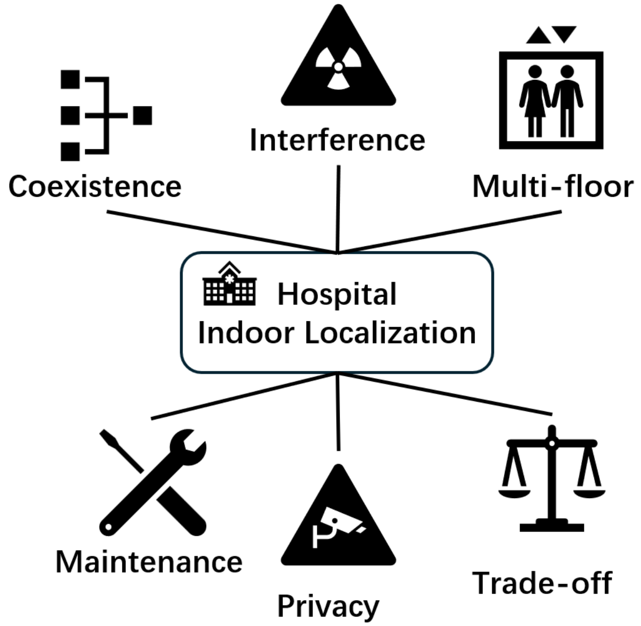
1. Objectives:

- Develop a **multimodal localization system** robust in hospital environments
- Enable **real-time tracking** of patients, staff, and assets
- Achieve a balance between **accuracy – latency – energy efficiency**

2. Proposed Approach:

- **Data acquisition**: Wi-Fi, BLE, infrared, wearables
- **Multimodal fusion**: from baseline methods to advanced AI/ML
- **Real-time edge inference** with lightweight models
- **Evaluation**: accuracy (2D/3D), floor detection, latency, energy

Figure Source: Wichmann J. Indoor positioning systems in hospitals: A scoping review. DIGITAL HEALTH. 2022;8.



Challenges

- **Multi-technology coexistence :** Wi-Fi, BLE, IR, ultrasound, etc.
- **Interference** : medical devices (X-ray, MRI) , moving assets
- **Multi-floor & vertical localization** : stairs, elevators
- **Calibration & maintenance costs** : drift, battery replacement
- **Privacy & IT integration** within hospital infrastructure
- Trade-off between **accuracy – latency – energy efficiency**

Roadmap

1. **Define research scope** : application scenarios & main goals
2. **Data collection** at Wenzhou Hospital : on-site measurements in representative areas
3. **Sensor & technology selection** : identify best combination
4. **System pipeline** : data capture → synchronization → fusion → feature extraction
5. **Model development** : baselines → advanced multimodal AI/ML
6. **On-site validation** : test accuracy, latency, energy, stability
7. **Optimization & deployment** : improve accuracy & efficiency, enable scalable use

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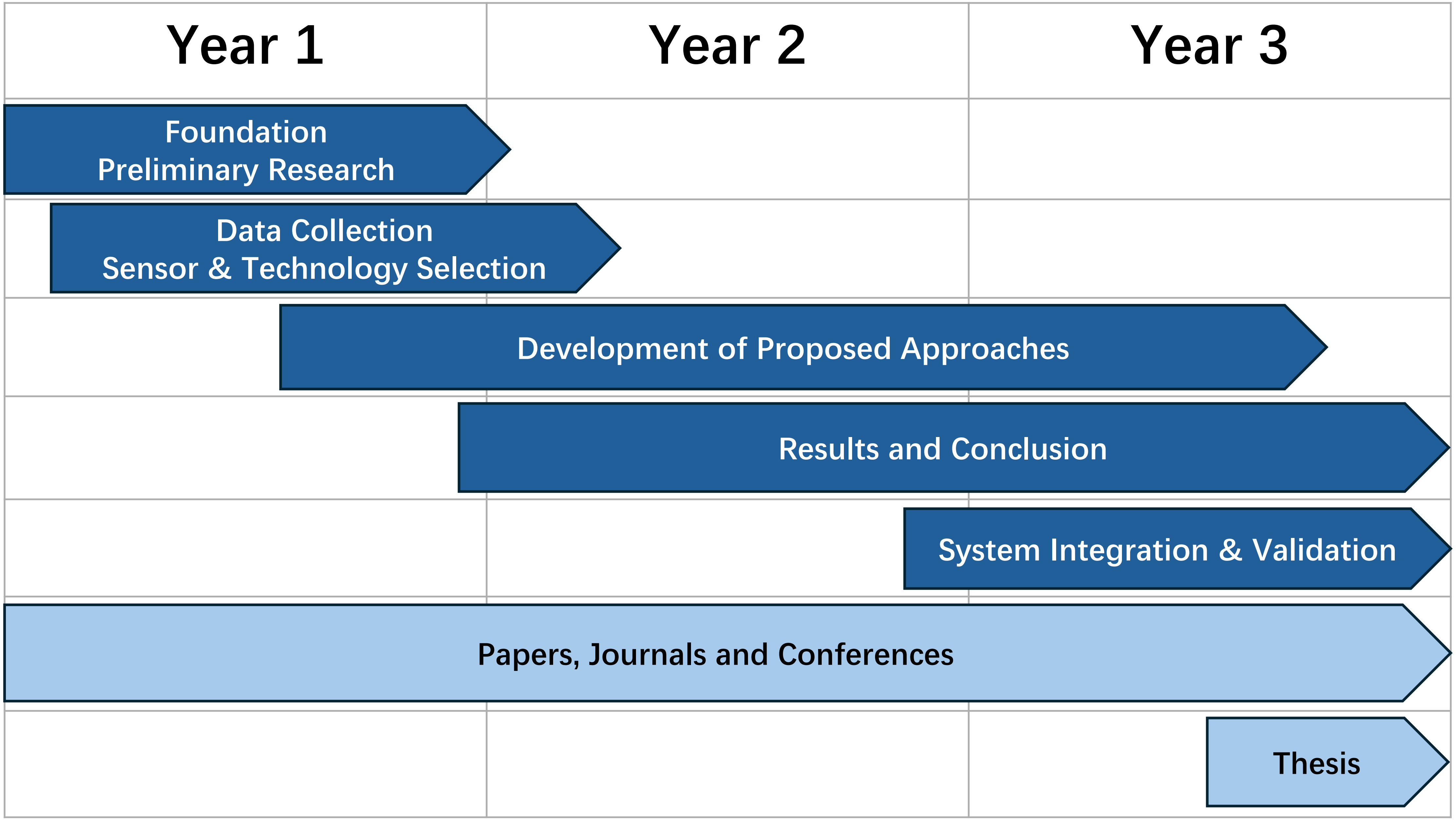
PhD Timeline



Achievements

- **Wi-Fi networks**: Introduced TDMA into CSMA/CA, reduced latency, improved reliability
- **Indoor localization**: Applied GNN for fast and accurate predictions
- **Network energy efficiency**: Optimized 5G Core heartbeat, reduced energy & stable operation
- **IoT & health data**: Collected multimodal signals (temperature, fall detection)

Suitability

- Expertise in **indoor localization** & **energy-efficient networking**
- Experience across **data collection**, **AI modeling**, and **system deployment**
- Ability to **integrate AI + wireless + IoT** into healthcare applications
- Strong potential to contribute to **hospital-oriented indoor tracking research**

Strengths

- **Hands-on ability**: from algorithm design to system validation
- **Interdisciplinary profile**: AI, wireless, IoT, healthcare, energy efficiency
- **Communication & collaboration**: familiar with both academic & industrial contexts
- **Multilingual**: Fluent in English, French, Chinese

Motivation

- Strong interest in wireless communications and the Internet of Things
- Committed to advancing wireless communications, AI, and IoT in healthcare applications
- Intend to integrate experience in sensors, network energy efficiency, and indoor localization
- Passionate about research: motivated to identify problems and find solutions

Thank you for your attention.

I would be happy to answer any questions.

Appendix

Research Experience-Published Article

Performance Evaluation of the Networks with Wi-Fi based TDMA Coexisting with CSMA/CA

Wireless Personal Communications, Springer, 2020

- **Objective**:
  - Introduce TDMA into Wi-Fi to improve real-time performance and reliability when coexisting with CSMA/CA.
- **Method**:
  1. **Canceling Carrier Sensing**: TDMA devices transmit directly in allocated slots without checking channel availability.
  2. **Priority Mechanism**: TDMA devices gain priority over CSMA/CA devices on the shared channel.
  3. **Collision Handling**: TDMA devices immediately retransmit data until an ACK is received, ensuring reliability.
- **Result**:
  - The TDMA mechanism significantly reduced delay for real-time applications and improved reliability through retransmissions.
  - As frame length and duty cycle increased, CSMA/CA throughput slightly decreased but the impact remained manageable.

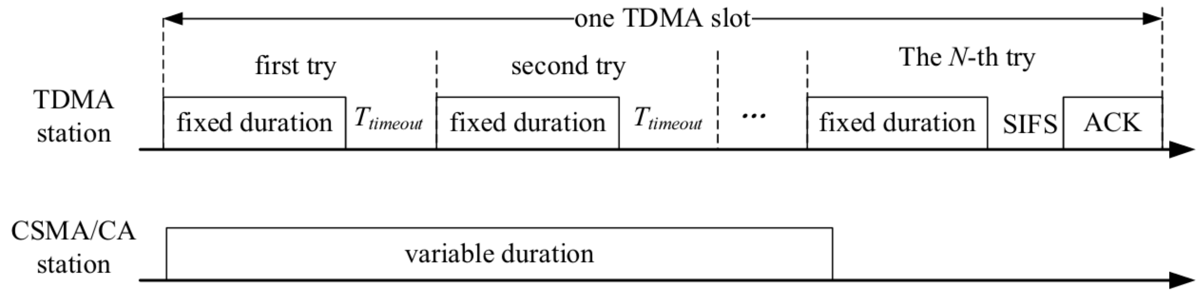


Fig. 2 Preemptive TDMA scheme

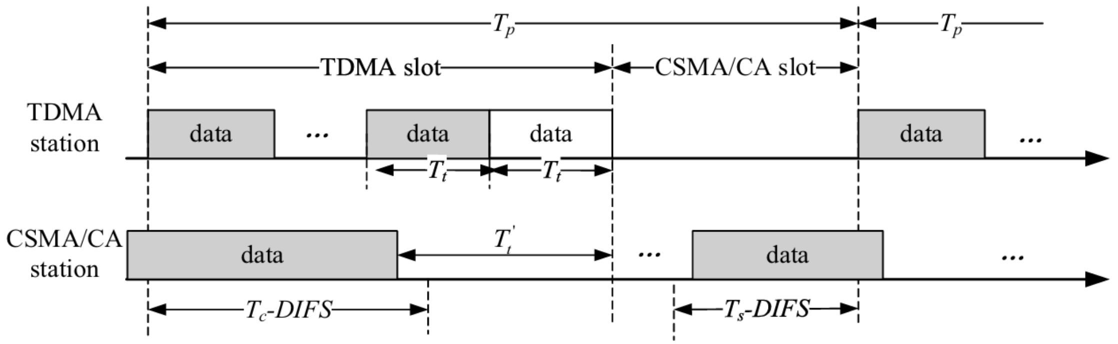


Fig. 4 The interference a CSMA/CA frame suffered from the Wi-Fi TDMA station

Research Experience-Article Under Preparation

Indoor Localization in IoT Networks Based on Graph Neural Networks

2025

- **Objective**:
  - Compare the performance of DNN and GNN in Wi-Fi RSSI fingerprint-based localization, Including predictions for longitude, latitude, floor and predicted time.
- **Method**:
  1. **DNN Encoder–Decoder**: Built an encoder–decoder baseline model with multi-task regression to jointly predict.
  2. **GNN with k-NN Graphs**: Constructed graphs using k-NN and applied GCN layers with message passing to capture spatial topology.
  3. **Evaluation Metrics**: valuated models by comparing hidden layer configurations, localization error, and runtime performance.
- **Result**:
  - GNN achieved lower localization error and shorter runtime with fewer hidden layers, improving accuracy and robustness.

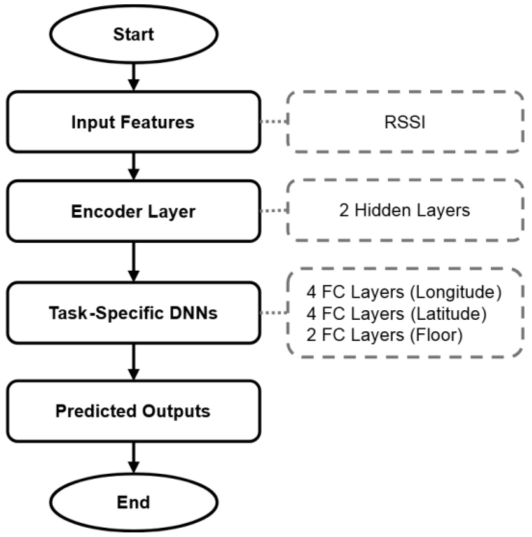


Fig. 1. Overall data preprocessing and prediction workflow of the DNN-based localization model. (FC: Fully Connected).

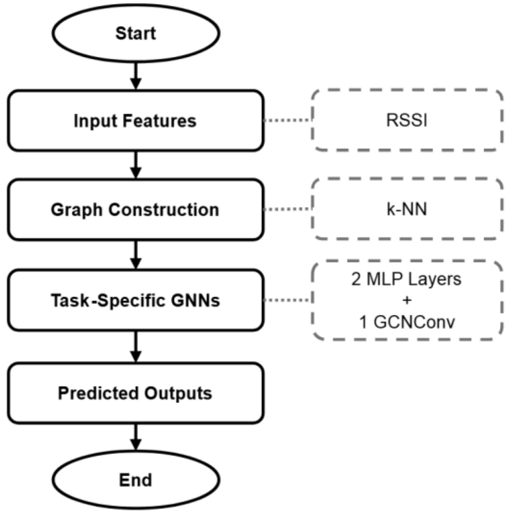


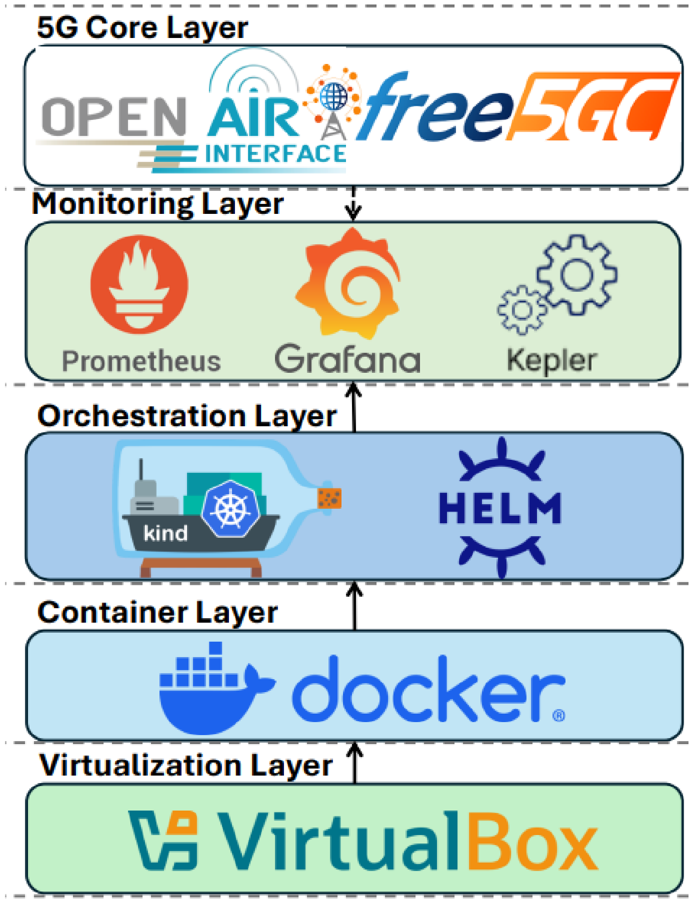
Fig. 2. Overall data preprocessing and prediction workflow of the GNN-based localization model. (MLP: Multi-Layer Perceptron, GCNConv: Graph Convolution layer).

Graduation Internship (24 Mar – 22 Sep 2025)

Energy Optimization in 5G Core Networks – Orange Innovation

orange™

- **Objective:**
  - Analyze the energy consumption of open-source 5G Core (free5GC and OAI) and explore methods to reduce it.
- **Method:**
  1. **Deployed** an energy monitoring framework (Kepler + Prometheus + Grafana on Kubernetes).
  2. **Installed and compared** free5GC and OAI; experiments revealed OAI consumed significantly more energy.
  3. **Proposed three hypotheses**: database implementation differences, residual container processes, and frequent inter-Pod signaling.
  4. Identified **frequent AMF heartbeat** signaling as the main cause, **modified** the source code, and extended the cycle from 10s to 100s.
- **Result:**
  1. Extending the heartbeat cycle significantly reduced OAI's energy consumption while maintaining system stability.
  2. The achievements were integrated into an AI assistant at Orange to support rapid future deployment.



Methods & Contributions

Multi-floor

Fixed

Mobile

Single-floor

Multi-floor · Fixed Localization

Possible Approaches

- Multimodal input: combine Wi-Fi, BLE, UWB.
- Add a floor classification module in DNN.

Possible Challenges

- Complex data synchronization.
- Strong floor-to-floor signal variation.

Multi-floor · Mobile Localization

Possible Approaches

- Fuse Wi-Fi, BLE, UWB, and sensor data.
- Use GNN combined with temporal models for cross-floor trajectory modeling.

Possible Challenges

- Cross-floor attenuation & dynamic interference.
- High computational and scalability requirements.

Single-floor · Fixed Localization

Possible Approaches

- Use Wi-Fi or BLE RSSI fingerprinting.
- DNN regression model for (x, y) prediction.

Possible Challenges

- Signal interference from walls and devices.

Single-floor · Mobile Localization

Possible Approaches

- Use BLE/UWB with IMU sensors.
- GNN (k-NN graph) for trajectory modeling.

Possible Challenges

- Dynamic interference sources.
- High real-time computational cost.

Future Goals

Short-term (3 years)

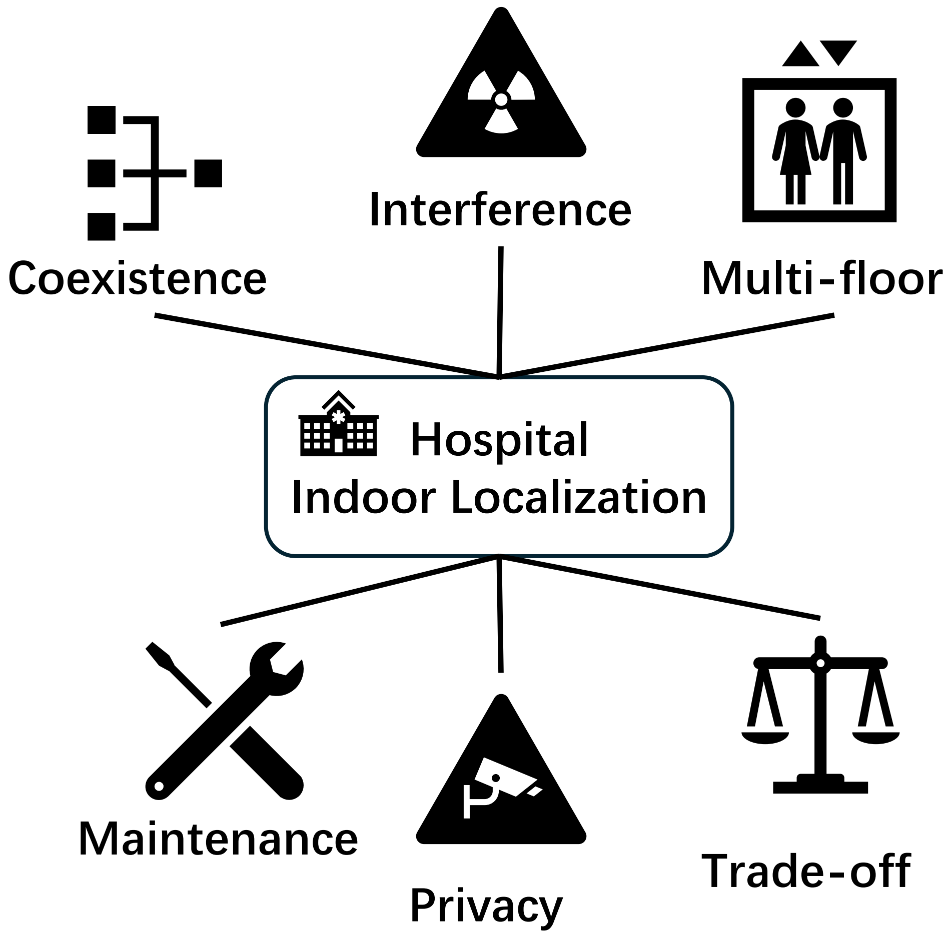
Develop a multimodal AI indoor localization system with high accuracy, low energy cost, and scalability in smart hospitals.

Mid-term (5 years)

Promote the deployment and standardization of AI-based indoor localization and behavior analysis in healthcare.

Long-term (10 years)

Explore the integration of 6G networks and smart healthcare.



Interference
Coexistence
Multi-floor
Hospital
Indoor Localization
Maintenance
Privacy
Trade-off