Application for the Doctoral Contract 2025

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

Ph.D. Candidate:

Xiaofan GUO

Supervisors:

Dr. Wafa NJIMA ISEP

Dr. Hedi YAZID ISEP

Dr. Huaqiong LI UCAS

11 / 09 / 2025

Outline

Personal Background

- Academic Background
- Research Experience
- Graduation Internship

Research Context & Approach

- Research Context
- Research Objectives
- Challenges
- Roadmap

Summary & Motivation

- PhD Timeline
- Key Strengths
- Research Fit

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Academic Background

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

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

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

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

  - *With Honors (Mention Très Bien)*

  Université Clermont Auvergne, Clermont-Ferrand, France

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

Research Experience

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

Xiaofan Guo et al. *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.

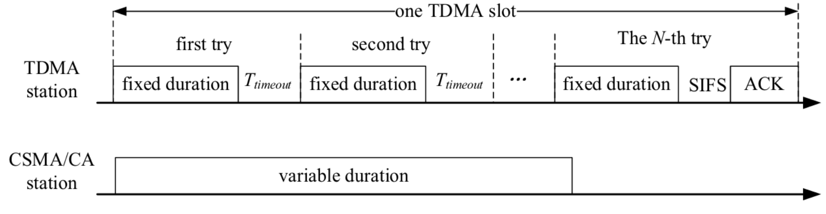


Fig. 2 Preemptive TDMA scheme

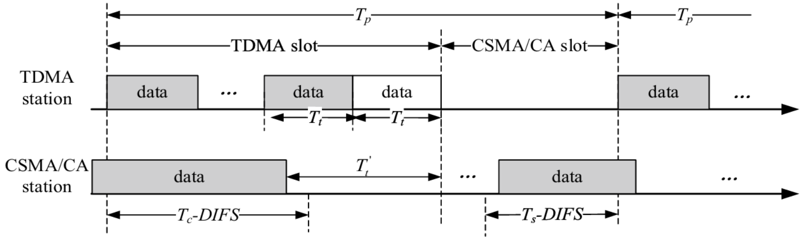


Fig. 4 The interference a CSMA/CA frame suffered from the Wi-Fi TDMA station

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

Xiaofan Guo, Wafa Njima. *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.

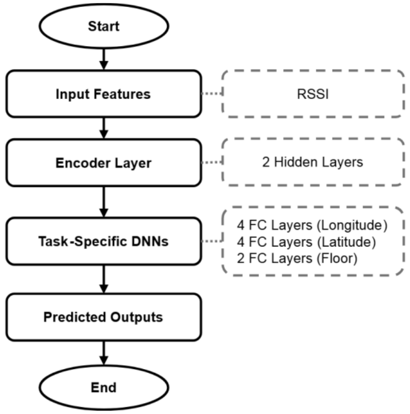


Fig. 1. Overall data preprocessing and prediction workflow of the DNN-based localization model. (FC: Fully Connected).

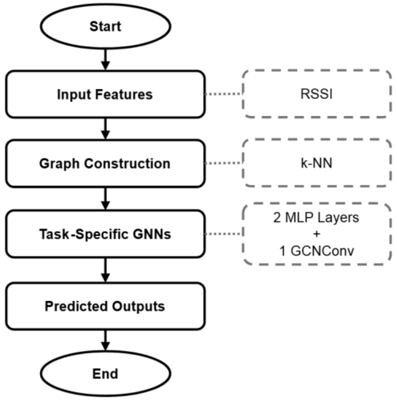
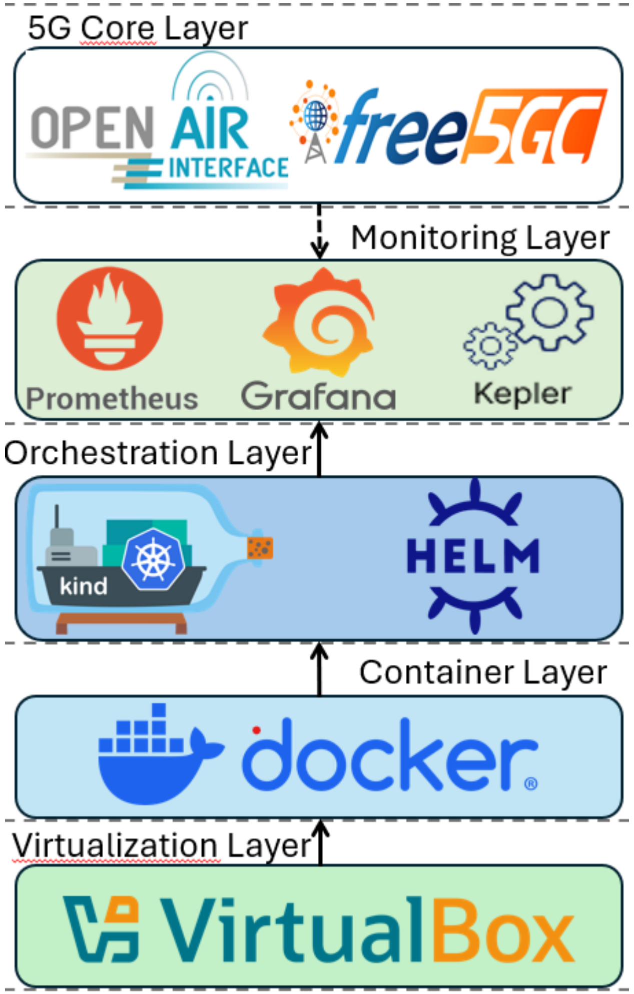


Fig. 2. Overall data preprocessing and prediction workflow of the GNN-based localization model. (MLP: Multi-Layer Perceptron, GCNConv: Graph Convolution layer).

Graduation Internship

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.

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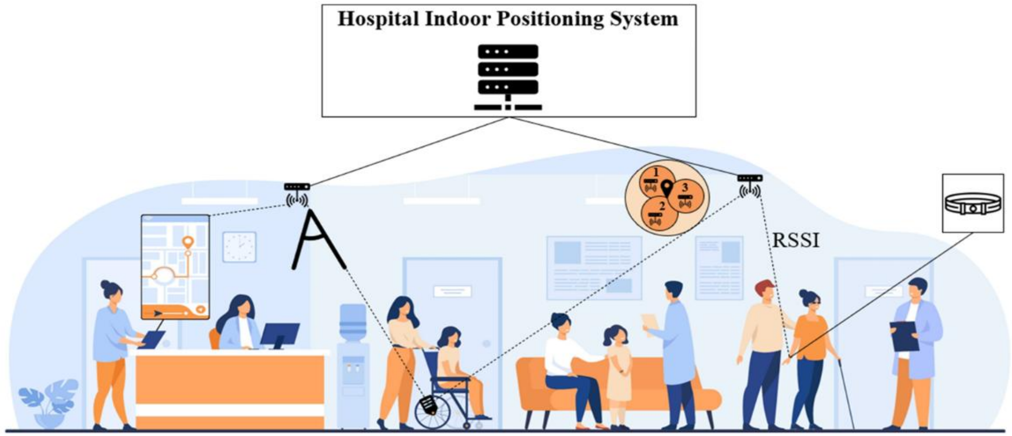
Research Context

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:

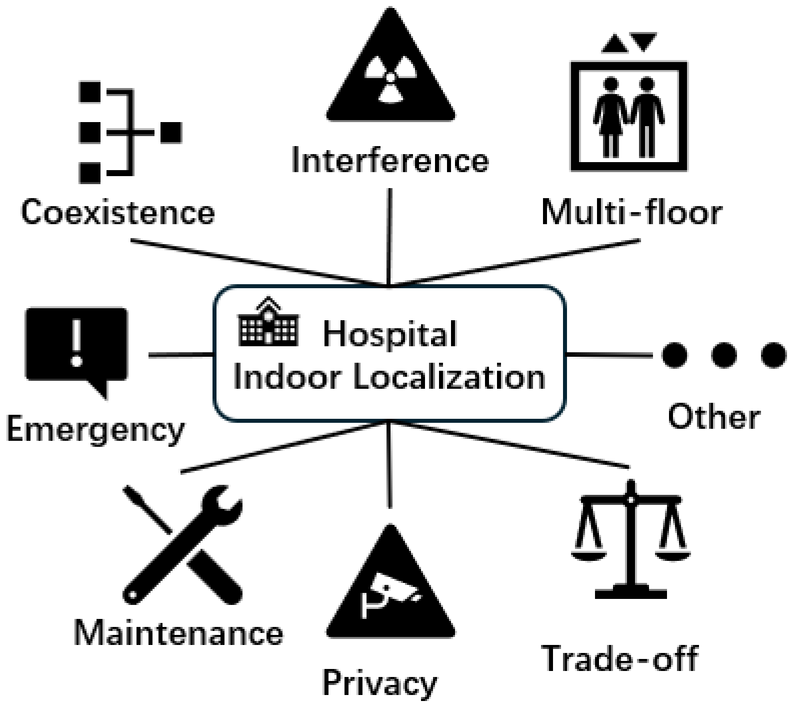
- **Multimodal localization system** in hospital
- **Real-time tracking & monitoring & positioning & behavior analysis**
- **Balance**: accuracy – latency – energy

2. Proposed Approach:

- **Data acquisition**: Wi-Fi, BLE, infrared, wearables
- **Multimodal fusion**: baseline → AI/ML
- **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
- **Interference** : medical devices, dense wireless traffic
- **Multi-floor & Vertical localization** : complex layouts
- **Calibration & Maintenance** : battery, re-deployment
- **Privacy & IT Integration** : compliance, interoperability
- **Scalability & Reliability** : large-scale deployment
- **Emergency** : high traffic, power outage

Roadmap

1. Define Scope & Goals
- Define application scenarios & key metrics

2. Technology & Sensor Selection
- Evaluate combinations, enhance robustness

3. Data Acquisition (Wenzhou Hospital)
- Multimodal: Wi-Fi, BLE, IR, wearables

4. System Pipeline Design
- Data - synchronization - preprocessing - fusion - features

5. Model Development
- Baselines → multimodal AI/ML

6. Validation & Evaluation
- Accuracy, latency, energy, stability

7. Optimization & Deployment
- Trade-off tuning, scalable integration

Proposed Methods

⭐2 Adaptive Sensor

⭐3 Multimodal Fusion

⭐4 Cross-modal Alignment
⭐4 Drift Compensation

⭐5 Transformer Fusion
⭐5 Edge Lightweight Inference

⭐6 Interference/Stress Testing

⭐7 Behavior Analysis
⭐7 Resource Management

Build an efficient and intelligent healthcare indoor localization system with behavior analysis

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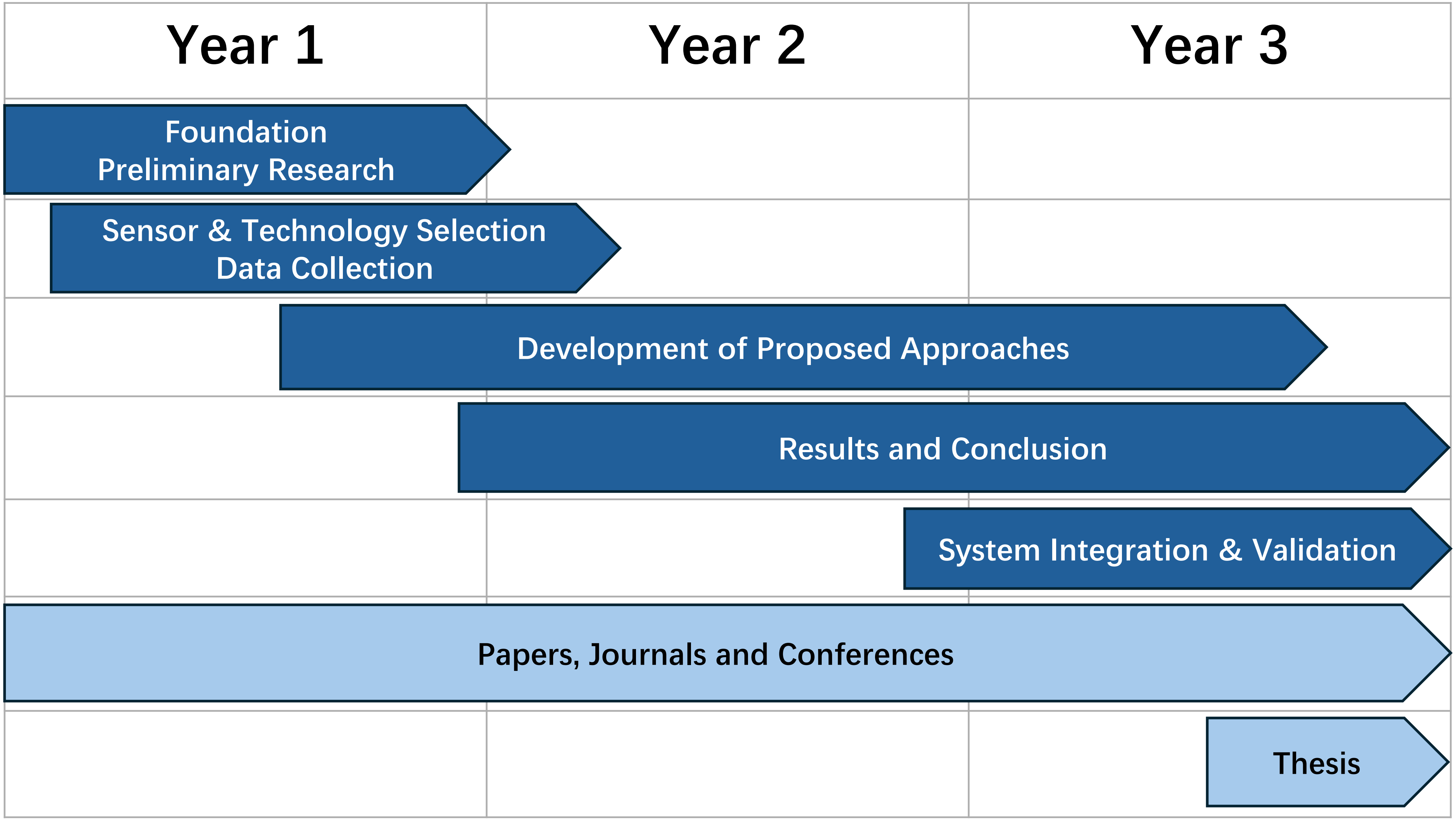
PhD Timeline



Key Strengths

Rich Research Background	· Publications & multiple research projects · Passionate about problem-solving in **wireless & IoT**
Wireless & IoT Expertise	· **Wi-Fi networks**: TDMA into CSMA/CA → reduced latency, improved reliability · Expertise in **indoor localization** & **energy-efficient networking**
AI & Data Analysis Skills	· Applied **GNN** for fast, accurate indoor predictions · Experience across **data collection**, **AI modeling**, **Matlab signal processing**
Hardware & Sensor Experience	· **IoT** & health data: multimodal signals (temperature, fall detection) · Hands-on ability: from **algorithm design** to system validation
Communication & Collaboration	· **Multilingual**: English, French, Chinese · Experienced in academic & industrial teamwork

Research Fit

Final Year Engineering Project
- Focused on **indoor localization**
- Aligned with PhD topic

Orange Innovation Internship
- Optimized 5G Core heartbeat → reduced energy & stable operation
- Experience directly relevant to **energy-efficient** and reliable system design.

Wearable sensors experience
- Health monitoring with temperature, fall detection, etc.
- Consistent with **smart healthcare** goals

Undergraduate projects
- Path & image recognition, intelligent vehicle navigation
- **Computer vision** foundation for healthcare **behavior analysis**

Interdisciplinary profile
- AI + wireless + IoT + healthcare + energy efficiency
- Foundation for **stable, intelligent, and energy-efficient systems** in hospitals

Research motivation
- Strong interest in **wireless communications & IoT**
- Committed to advancing AI & networking for medical impact

Thank you for your attention.

I would be happy to answer any questions.

Appendix

1. Research Experience-Published Article
2. Research Experience-Article Under Preparation
3. Graduation Internship
4. Methods & Contributions
5. Future Goals

Research Experience-Published Article

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

Wireless Personal Communications, Springer, 2020

➢ **Objective**:

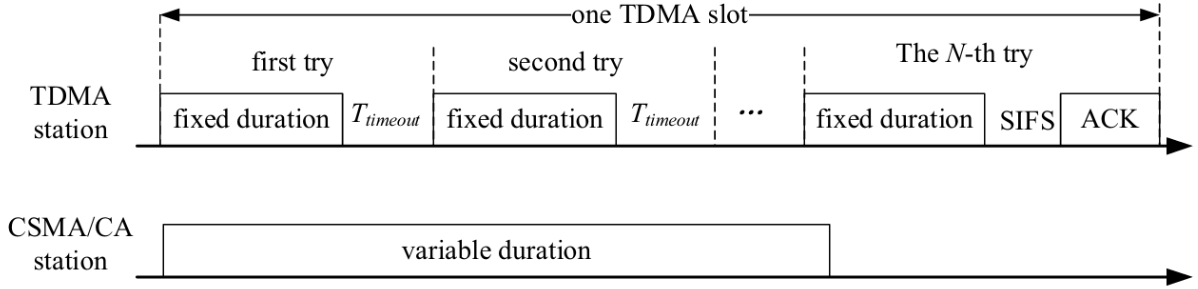
- Introduce TDMA (Time Division Multiple Access) into Wi-Fi to improve real-time performance and reliability when coexisting with CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)

➢ **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.



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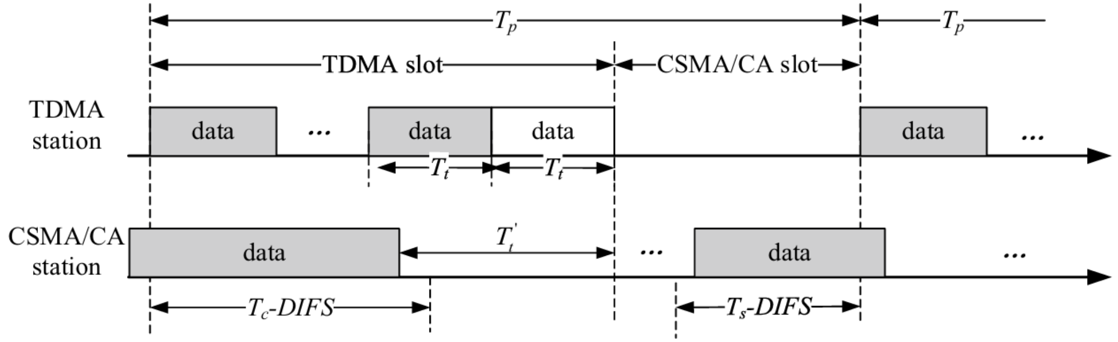


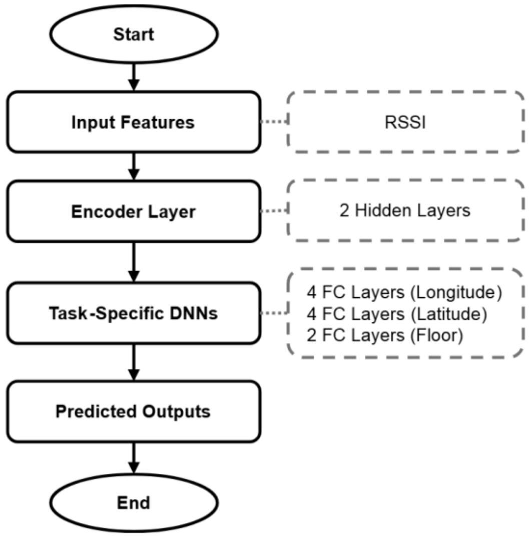
Fig. 4 The interference a CSMA/CA frame suffered from the Wi-Fi TDMA station

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.



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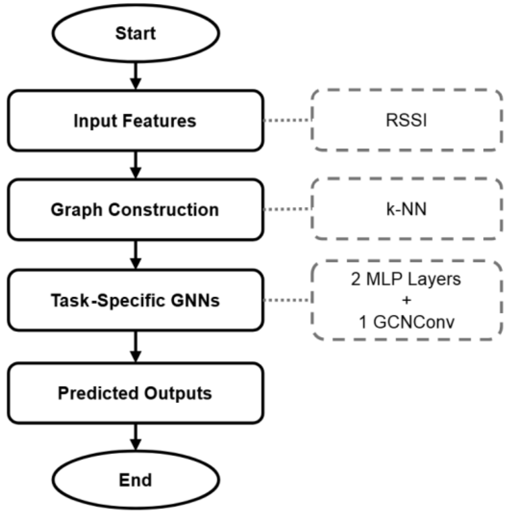


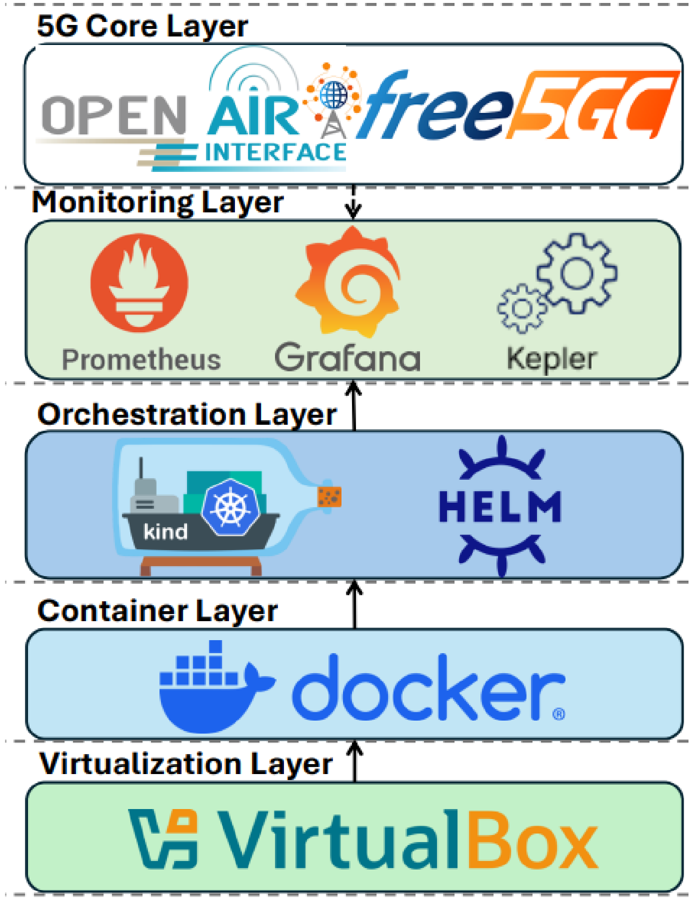
Fig. 2. Overall data preprocessing and prediction workflow of the GNN-based localization model. (MLP: Multi-Layer Perceptron, GCNConv: Graph Convolution layer).

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)

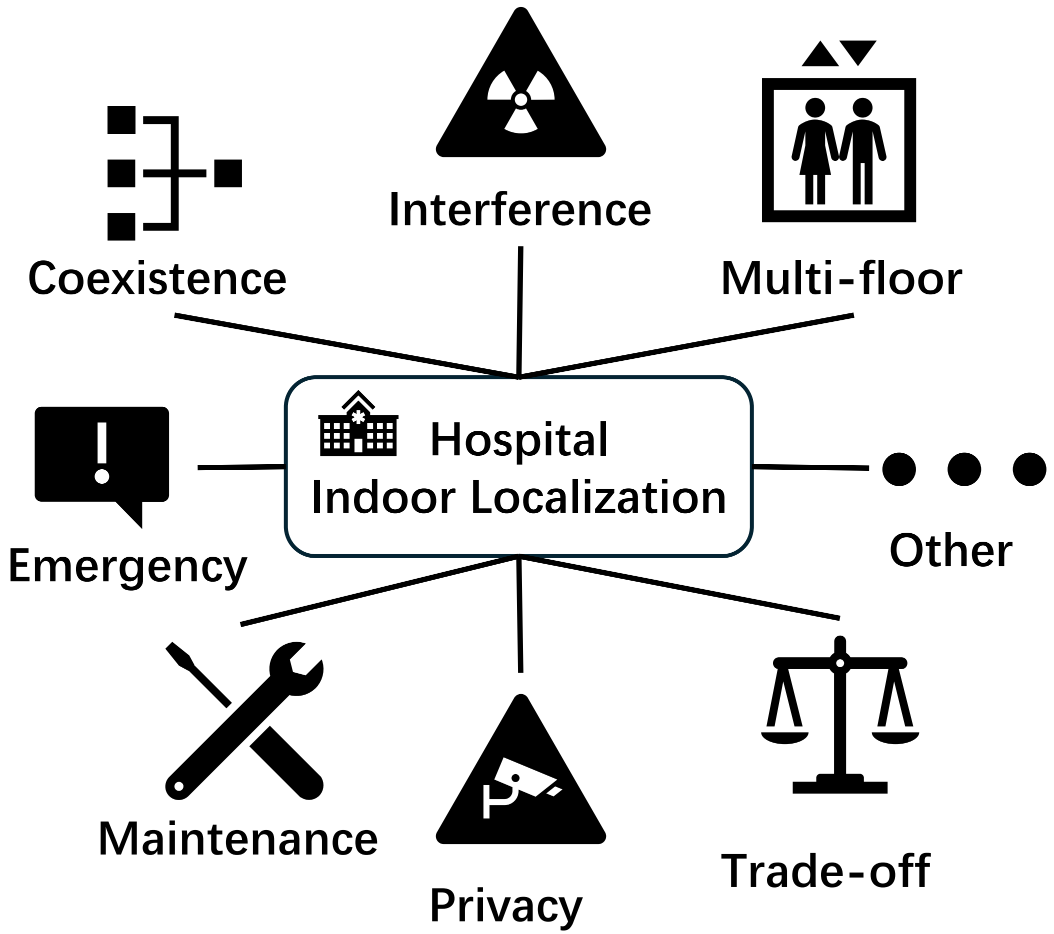
Develop a multimodal AI indoor localization system with high accuracy, low energy cost, and scalability in smart hospitals.

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
Emergency
Other
Maintenance
Privacy
Trade-off