SURF-2025-0217 Project Overview: GPS-Free Geolocation Based on LoRa

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Outline

- Localization
- Related Work
- Plan for This Year

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Localization

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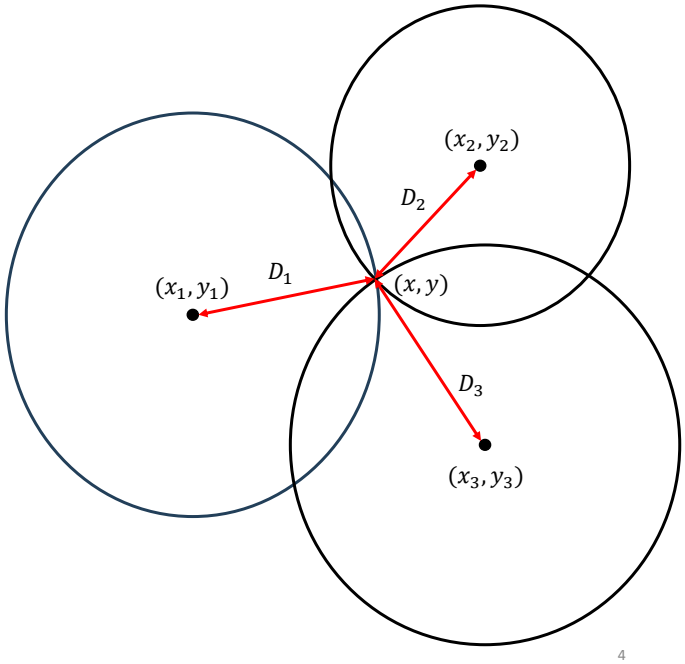
Tri/Multilateration

- The estimation of the distances D_i is a key to the estimation of the unknown location (x, y), i.e.,

$$D_i = \sqrt{(x - x_i)^2 + (y - y_i)^2},$$

through
  - Time of arrival (ToA)
  - Time difference of arrival (TDoA)
  - Angle of arrival (AoA)



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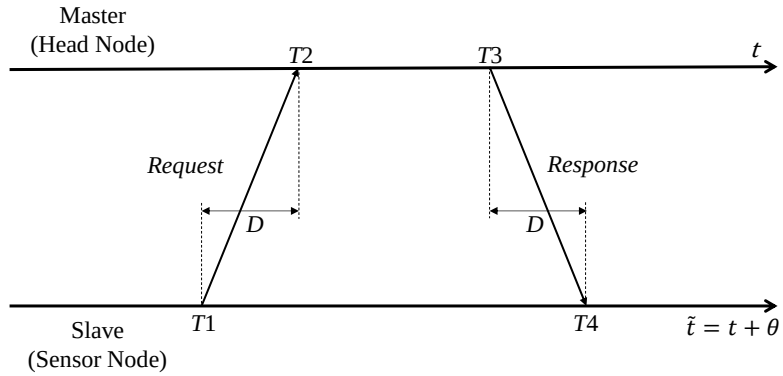
Two-Way Message Exchanges

- Propagation delay:
  - $D = \frac{(T4-T3)+(T2-T1)}{2}$.
- Clock offset:
  - $\theta = \frac{(T4-T3)-(T2-T1)}{2}$.



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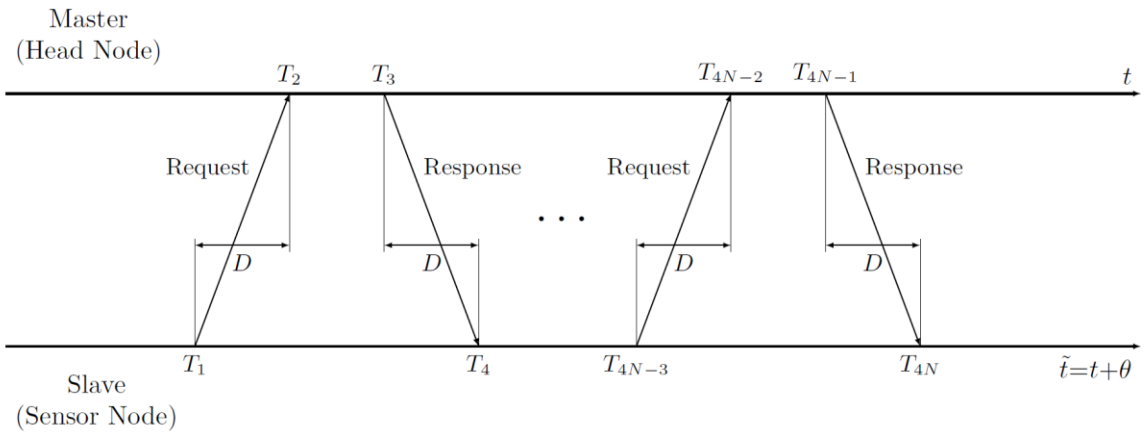
Multiple Two-Way Message Exchanges



$$\tilde{D}=\frac{(T_{4N}-T_1)-\sum_{i=1}^{N}(T_{4i-1}-T_{4i-2})-\sum_{i=1}^{N-1}(T_{4i+1}-T_{4i})}{2N}$$

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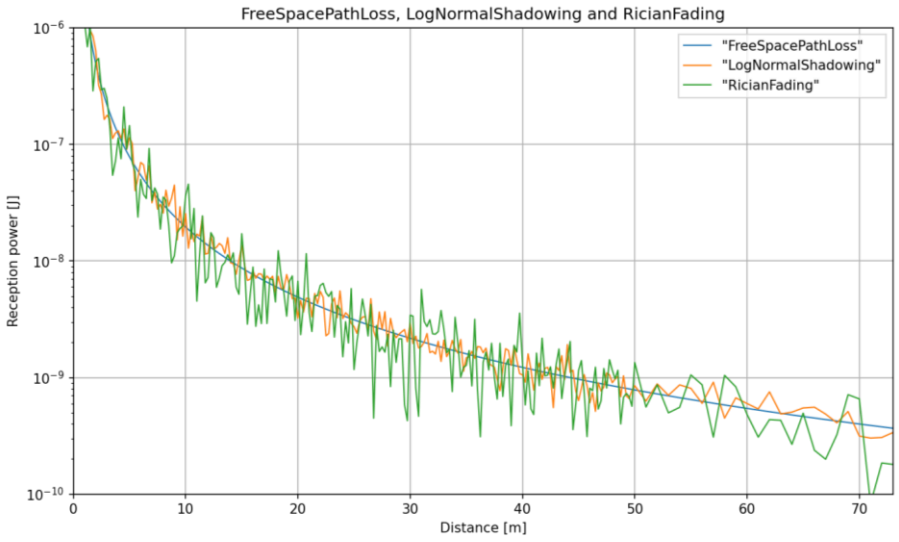
Path Loss Models: RSS vs. Distance*



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* https://inet.omnetpp.org/docs/showcases/wireless/pathloss/doc/index.html

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Related Work

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Joint RSS and Ranging Fingerprint for LoRa Indoor Localization*

- This is one of the most closely related to our project but in a slightly different context of indoor localization.
  - Both distances to and RSSIs from LoRa gateways (GWs) are jointly used as location fingerprints.
- In our case, on the other hand, there is only one GW.
  - We need to exploit the time variation of distance and RSSI for a single GW, instead of those for multiple GWs.

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* https://ieeexplore.ieee.org/document/10570742/

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Plans for This Year

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Research Questions

- What kinds (e.g., RSSIs, distances, or raw timestamps) and types (e.g., static vectors or dynamic time series) of location fingerprints are the best for LoRa-based geolocation?
- What DNN architectures and training frameworks are the best for LoRa-based geolocation?

Project Plans

- WP1: Construction of location fingerprint database
  - To investigate what, where, and how to collect fingerprint data.
    - Include as many **raw data (e.g., timestamps)** as possible in the database.
    - The extraction of actual fingerprints from the raw data (e.g., distances from timestamps) is to be done during the pre-processing (e.g., prefiltering for excluding outliers and smoothing, clock adjustment, and battery level compensation).
  - To implement HW and SW for LoRa development boards.
- WP2: Development of DNN models for multi-modal fingerprint data.
  - To implement and evaluate the localization performance of DNN models based on various architectures for the proposed fingerprint datasets from WP1.
    - Consider the use of LLMs, too.