Easy-to-use Wireless Sensor Network Simulator for Estimating Power Consumption and Communication Availability

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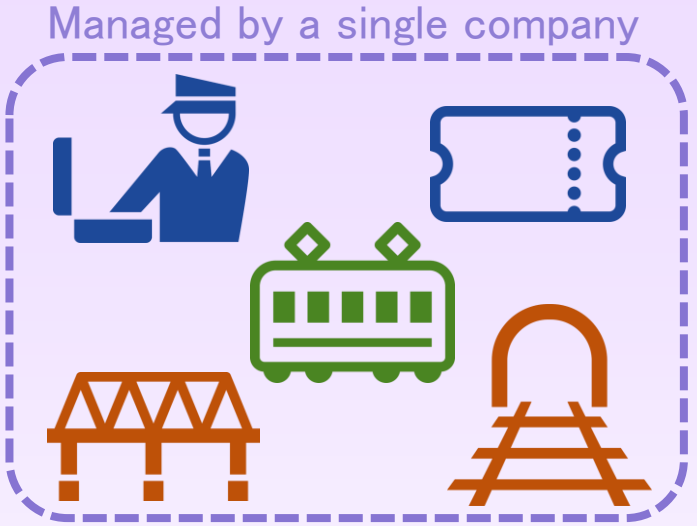
About the Speaker

- Yuta Hosokawa
  - Researcher at Railway Technical Research Institute
    - Research field: telecommunications and networking in railway
- Railway Technical Research Institute (RTRI)
  - Established to take over the research and development activities of Japanese National Railways
  - Conducts research on railway technologies and labor science
  - Promote R&D in cooperation with Japan Railway and other companies

Background

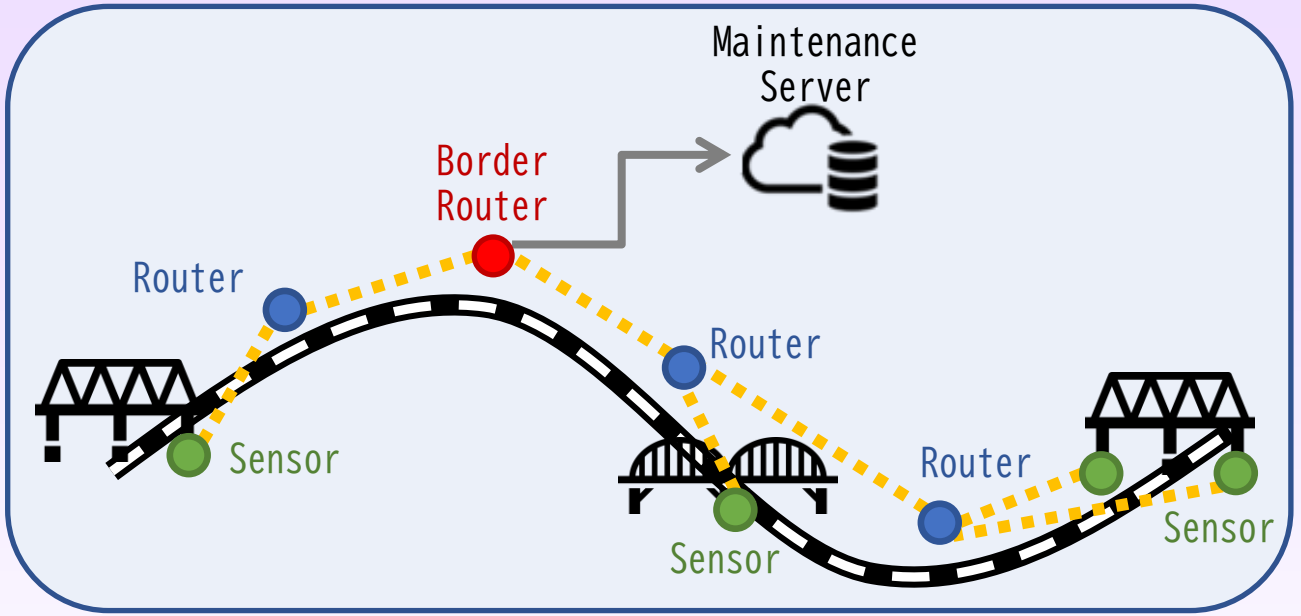


- Railway industry in Japan
  - Single company performs all railway operation, such as transport and equipment maintenance
    - They are often handled by separate companies in EU or USA
- Maintenance of railway equipment
  - Need for frequent on-site inspections over long distances along railways
  - Several tasks must be performed during Non-Operating hours (typically, late at night)

→ High demands for more efficient and labor-saving technologies

Applying WSNs for Railway Systems

- Monitor the condition of equipment remotely
  - Possible to reduce the need for frequent on-site inspections
- It is challenging for railway operators to design optimal WSNs with consideration of:
  - Communication Availability
  - Suitable communication method
  - Power consumption (≈Frequency of battery replacement)



Existing Network Simulators

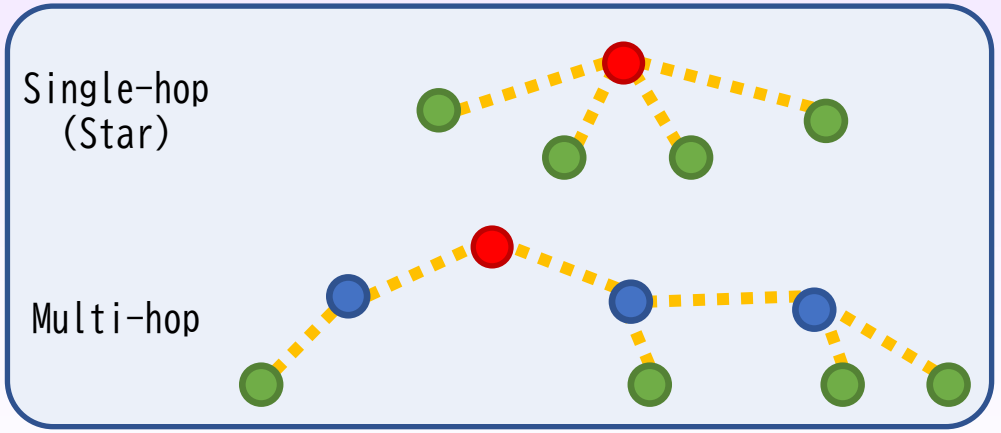
- Common network simulators:
  - NS-2 and NS-3
  - OMNeT++
    - ✓ Detailed network protocol modeling
    - ✓ Power consumption modeling through additional modules

	NW Simulator	
	Existing	Our goal
Detailed modeling	✓	
Additional modules	✓	
Ease of use		✓

- Challenges:
  - Require advanced technical expertise of command-line operations or custom scripting
  - Not suitable for non-technical stakeholders like railway operators

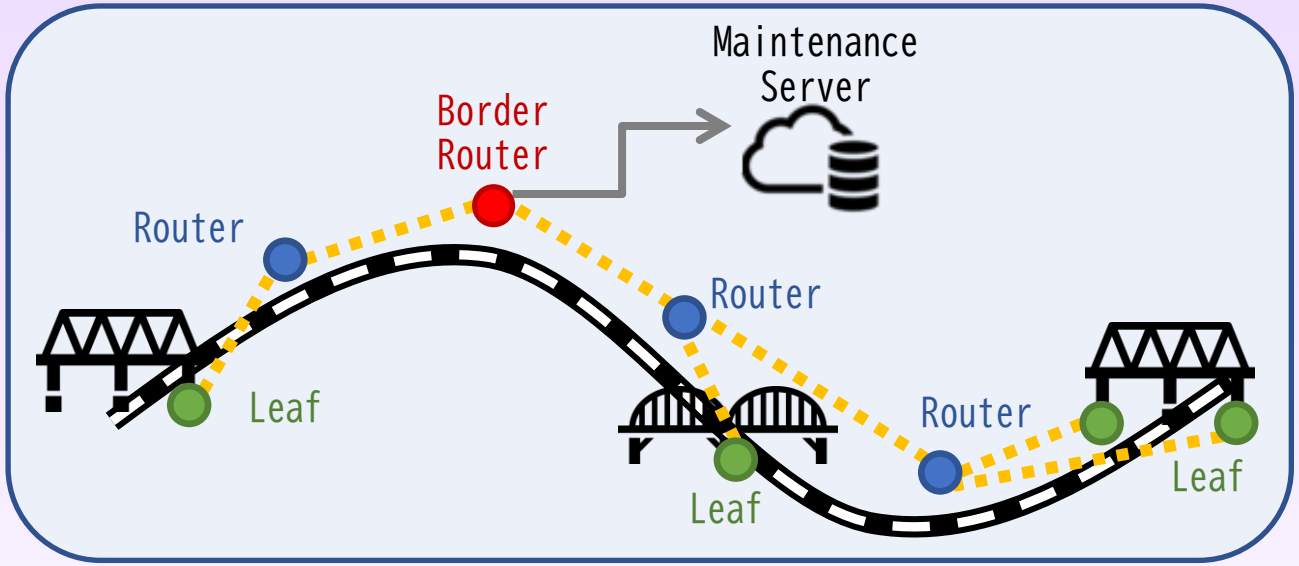
Objective of Our Study

- Support railway operators in deploying WSNs efficiently
- Develop a user-friendly WSN simulator which estimates:
  - Communication range and path in WSN
  - Power consumption for each node
  - Battery life
- Key features:
  - Supports multi-hop communication
  - No requirement for specialized software or coding knowledge
  - Instant graphical feedback on simulation results



Simulation model: **Node Types in WSN**

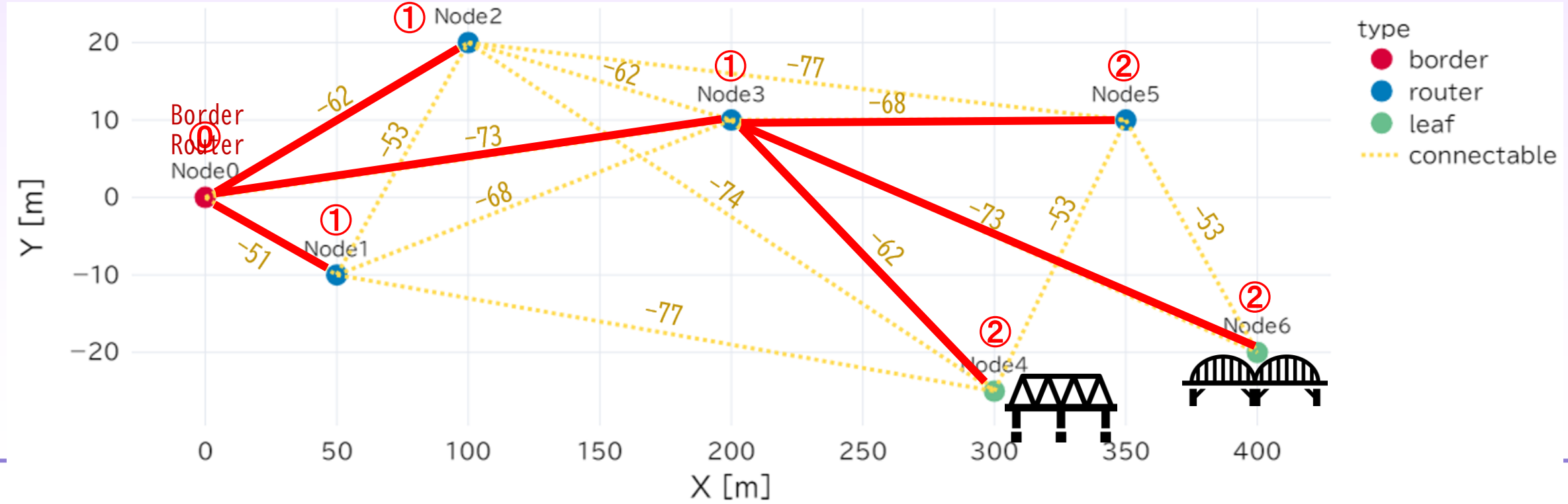
- Nodes are classified into three roles
  - Based on Wi-SUN FAN (Field Area Network) model



- Border Router
  - Collects all sensor data and send them to the server
- Router node
  - Capable of relaying data from distant nodes
- Leaf node
  - Terminal node that sends sensor data (no relay functionality)

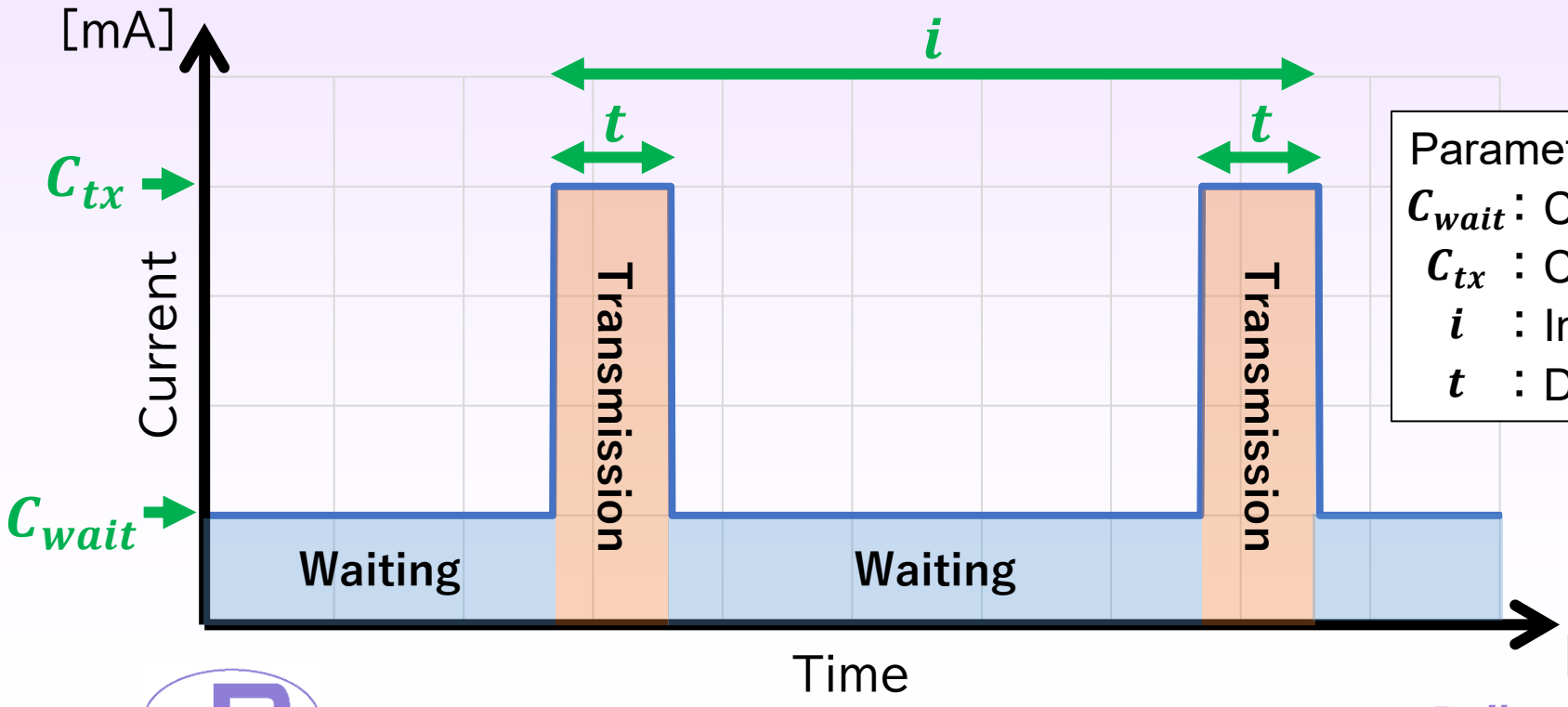
Simulation Model: **Communication Availability and Path**

- RSSI is calculated using the two-ray ground-reflection model
  - Communication is deemed possible when the RSSI exceeds a threshold
- Transmission paths to the Border Router are determined using Routing Protocol for Low-Power and Lossy Networks (RPL), as in Wi-SUN



Simulation Model: **Power Consumption and Battery Life**

- Model of fixed-cycle transmission of sensor data
- Sum up the current consumption over time
  - Assuming a constant voltage output



Parameters

C_{wait} : Current consumption while waiting

C_{tx} : Current consumption while transmitting

i : Interval of transmission

t : Data transmission time

Development of the Simulator

- Programming language and library
  - Python 3.11
  - Streamlit library
    - Enable web-based GUI
    - Real-time parameter configuration and result visualization
- Execution environment
  - A Linux server connected to the network
  - Users can access via a web browser on any PC

サインイン

WSN Simulator

localhost:8505/battery_simulator

Deploy

Battery Simulation Setting

Elapsed Time [day]

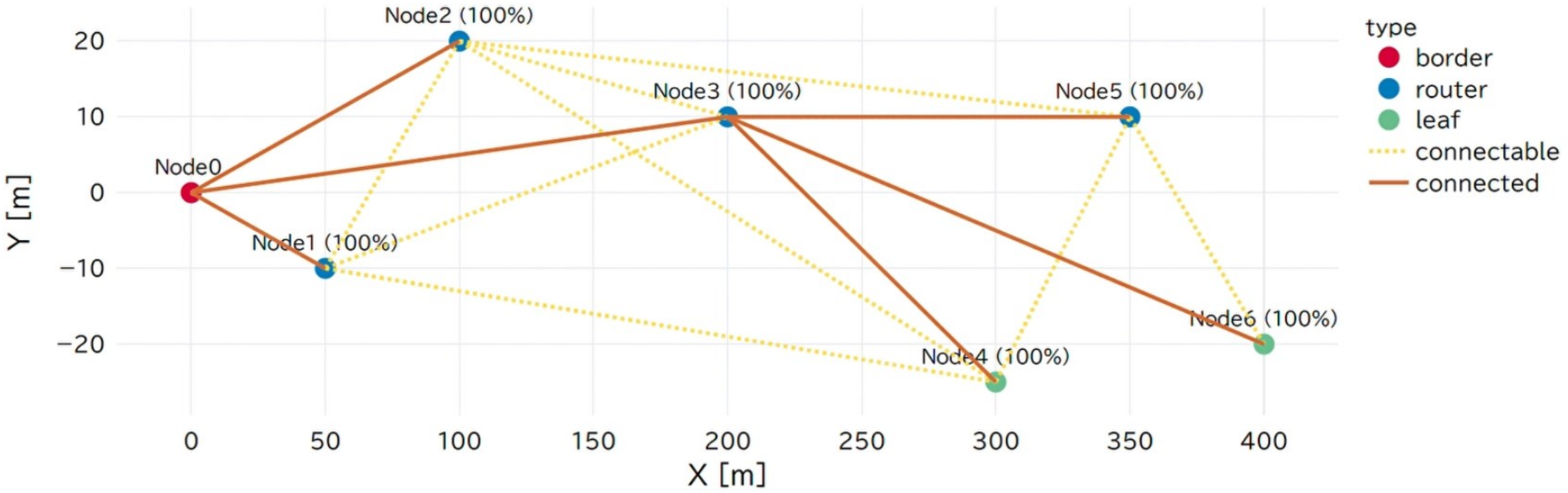
0

70

Show node name

Show battery capacity

Show RSSI



Advantages of Our Simulator

- Optimized for use in railway settings
  - Supports multi-hop and mesh networking over long distances
  - Provides instant estimates for communication quality and battery life
- User-friendly
  - Web-based interface, no need for specialized software or coding skills
- Real-time visualization
  - Instantly shows results when a user configures parameters
  - Allows rapid comparison of node placements and communication methods

Future Work and Improvements

- This work is in progress, with further improvements planned
- Enhance simulation accuracy
  - Power consumption model uses a threshold to determine communication feasibility
  - To apply message arrival rate estimation and coverage modeling
  - Further refine power consumption modeling
- Real-world deployment
  - Consider the effects of terrain and railway facilities on communication quality
  - Support other routing protocols and more communication methods

Conclusion

- Developed a user-friendly WSN simulator
  - Designed and optimized for use in railway settings
  - Provides real-time results for communication quality and battery consumption
  - Offers advantages over existing simulators, especially for non-technical users
- Future work includes enhancing features and real-world validation

Thank you