Development of a Fixed IoT-Based Outdoor Noise Monitoring System

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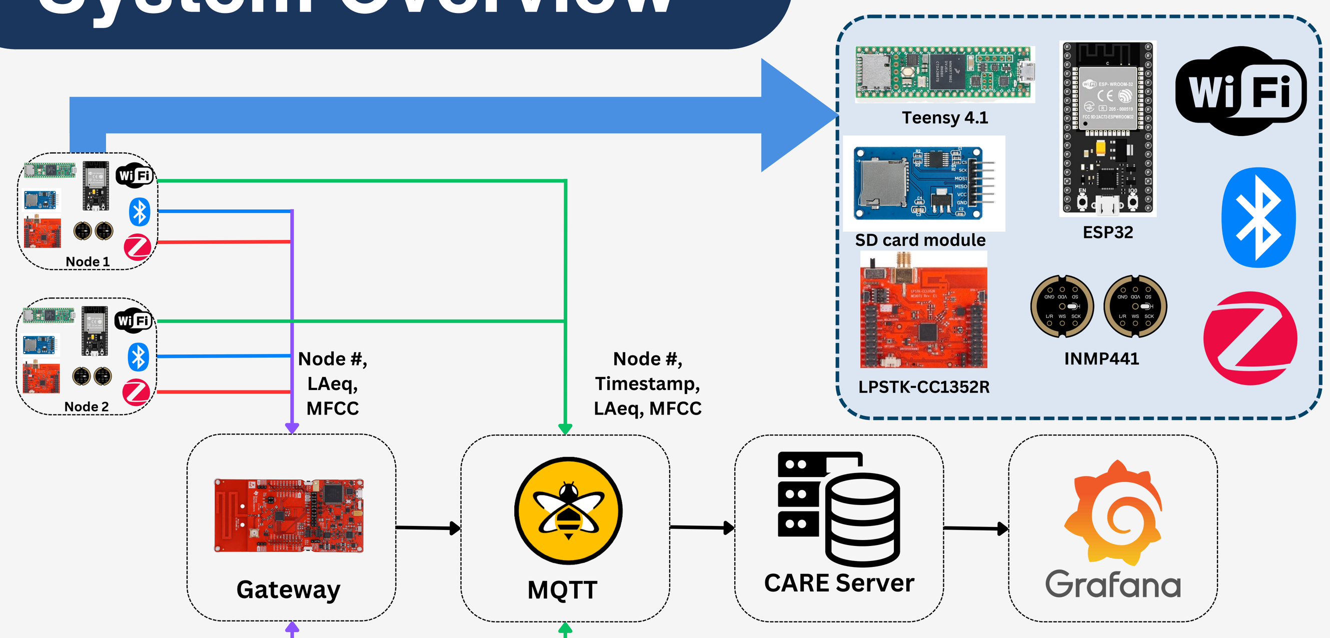
Introduction

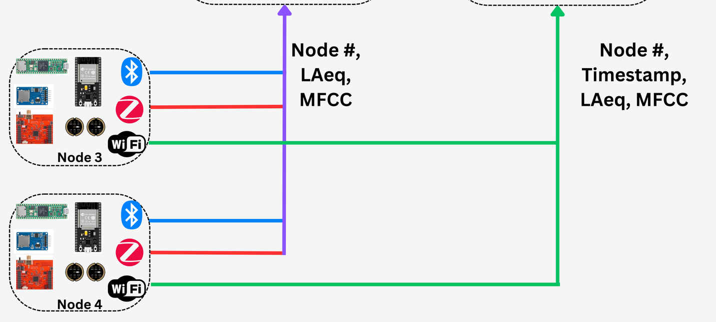
- **Problem**: Noise pollution from daily human activities causes harmful health effects with prolonged exposure
- **Gap**: Current monitoring solutions are limited by data types collected and number of deployed devices
- WHO ranks noise as 2nd largest environmental cause of health problems after air pollution
- Philippines workplace limit: 90 dBA for 80-hour work shifts
- Limited noise pollution studies in Philippines

Objectives

1. **Deploy** multiple **synchronized sampling nodes** for better coverage of a wider sampling range
2. **Extract** necessary audio signal features through the **Mel- Frequency Cepstrum Coefficient** technique as a form of audio compression
3. **Compare** the performance of **different wireless communication protocols** in a noise monitoring WSN
4. **Transmit** noise level data and the corresponding MFCC Coefficients to the UP-CARE platform

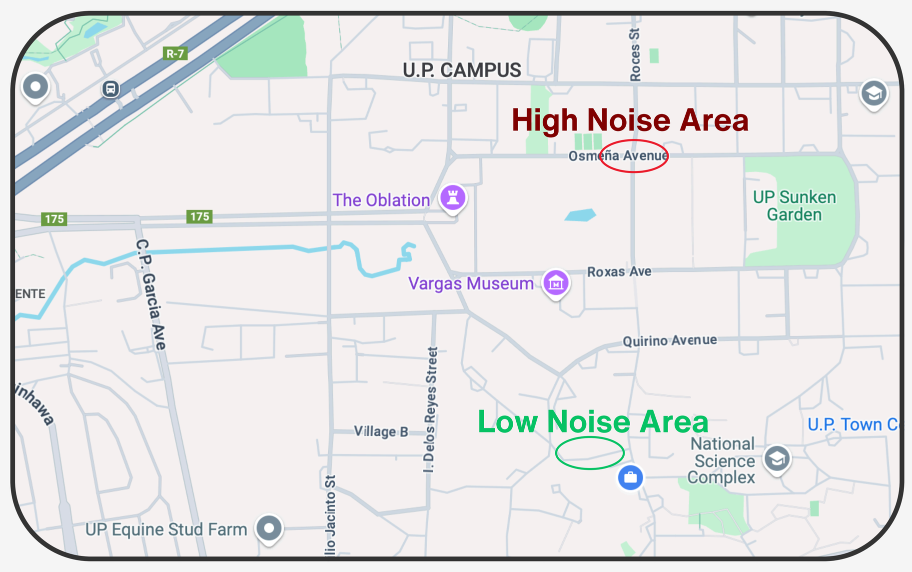
System Overview



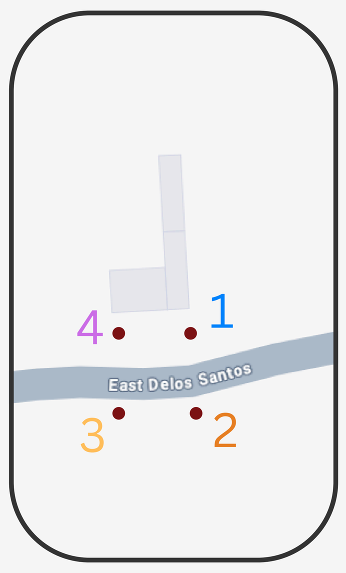


- 4 sensor nodes deployed with each performing:
  - **Audio recording**
  - **MFCC** and **LAeq** computation
- Developed **Wi-Fi**, **BLE**, and **ZigBee** systems

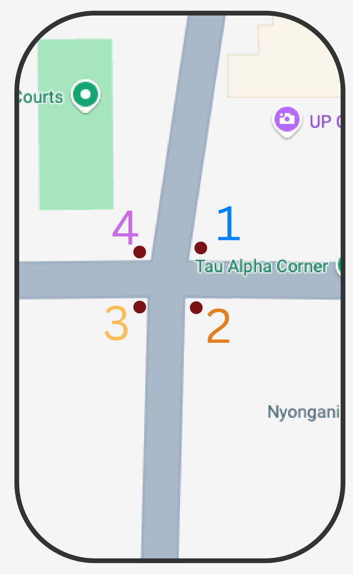
Two Deployment Sites



UP Diliman Map



Low Noise Area

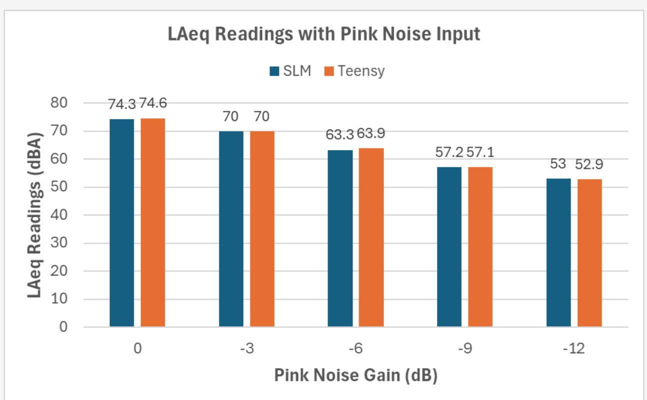


High Noise Area

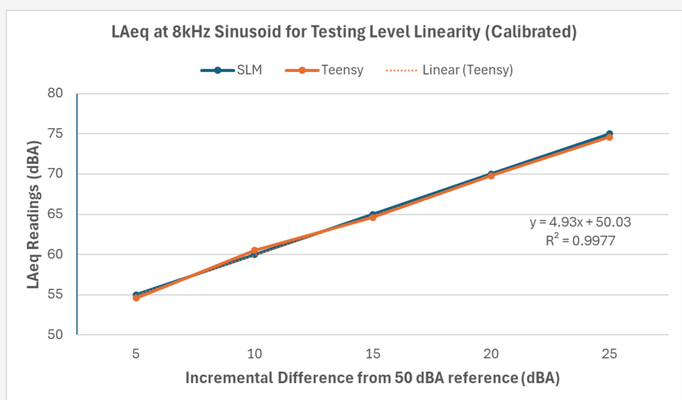
- Low Noise Area: **East Delos Santos Street**
- High Noise Area: **Roces- Osmeña Intersection**

System Validation

LAeq Accuracy and Linearity

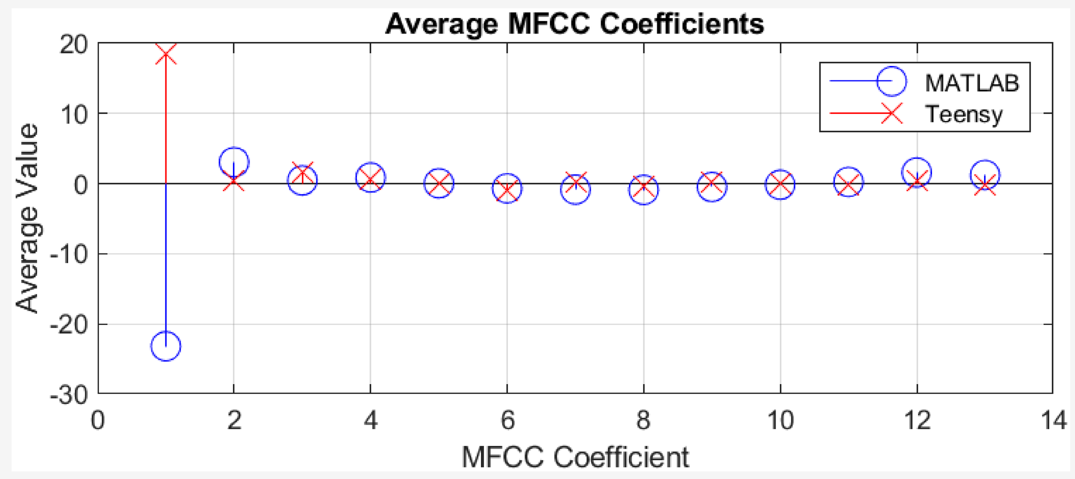


System showed high accuracy with reference to a PAA3x audio analyzer across different gains, achieving an average error of only 0.22 dBA.



Strong linear response (R^2 = 0.9977) observed with 5 dBA incremental increases from 50 dBA reference level.

MFCC Accuracy vs. MATLAB



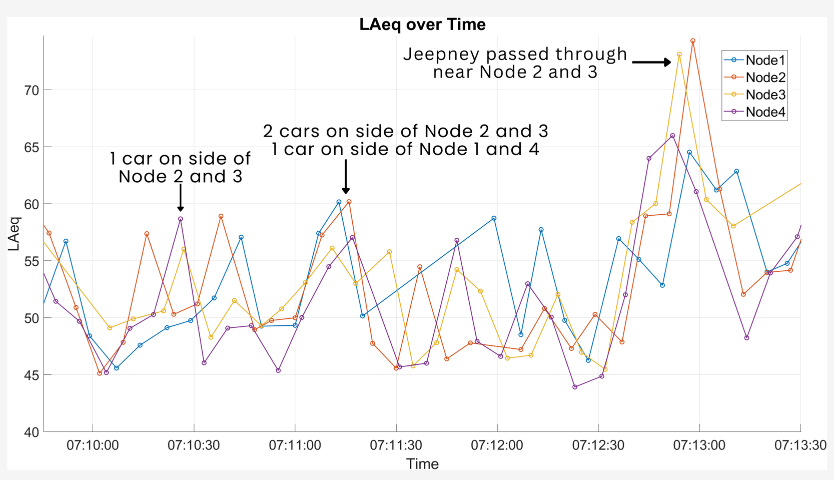
Despite the 1st coefficient displaying the largest deviation, it does not contain any spectral information and is often discarded. This indicates that the use of MFCC as a means of data compression remains feasible.

Network Performance

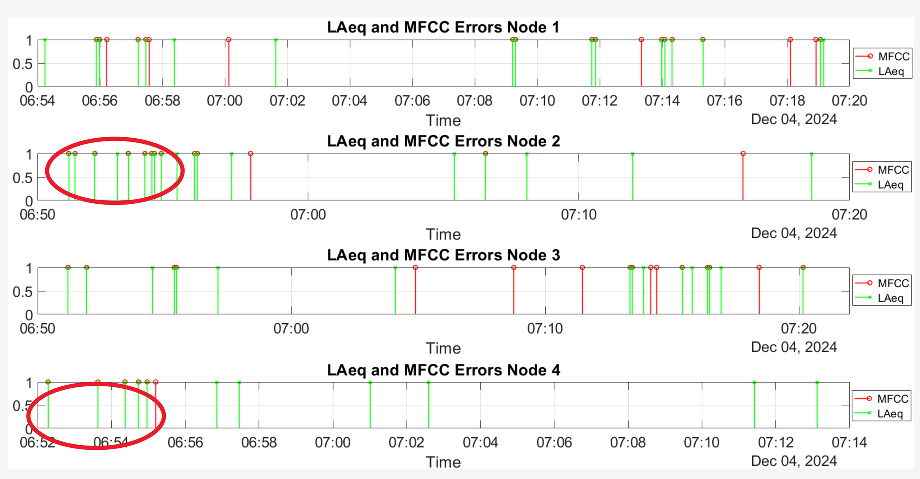
Metric	Wi-Fi	BLE
LAeq Latency	49.67ms	1000.02±180ms
MFCC Latency	2924.68ms	7.299s
Power Consumption	0.8687W	0.483W (Non-simultaneous LAeq/MFCC tasks)
Transmission Success Rate	90-94%	100% (tested at 4m range)
Test Deployment	Full outdoor deployment	Initial indoor testing*

*BLE capability not limited to indoor use; further outdoor testing for future works

Deployment Results



The spikes and dips in the plot closely align to various noise events across all four nodes.



A correlation between the MFCC and LAeq error was observed wherein delays in MFCC transmissions led to the failure of LAeq transmissions

Measured Noise Levels

- **Quiet areas**
  - Mean: 52.397 dBA
  - Range: 41.78 - 74.31 dBA
- **High-traffic**:
  - Mean: 61.714 dBA
  - Range: 52.55 - 82.30 dBA

Transmission success rates:

- **Quiet areas**: MFCC 94.1%, LAeq 93.2%
- **High-traffic**: MFCC 92.5%, LAeq 90.8%

Conclusion

- The development of this IoT-based noise monitoring system demonstrates the feasibility of implementing cost-effective urban noise monitoring systems, with Wi-Fi implementation proving successful while BLE showed promise despite limitations.
- Although ZigBee implementation faced technical challenges that prevented full functionality, the successful integration of LAeq measurement and MFCC computation on a single hardware platform opens possibilities for advanced noise analysis applications.
- Areas with low and high traffic inside UP Diliman showed a significant gap in terms of noise levels, approximately 10 dBA.
- This work provides a technical foundation that can support evidence-based environmental policy-making and urban noise management in the Philippines.

References

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