LoRa/LoRaWAN Performance at Binghamton University

CS 526 Internet of Things

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BINGHAMTON UNIVERSITY | THOMAS J. WATSON COLLEGE OF ENGINEERING AND APPLIED SCIENCE

Today’s Agenda

- Background / Motivation
- Methodology
- System Architecture Overview
- Key Areas of Interest
    - What is the LoRa signal quality around Binghamton University?
    - How does the campus buildings effect LoRa signal quality?
    - How does motion effect LoRa signal quality?
- Conclusions

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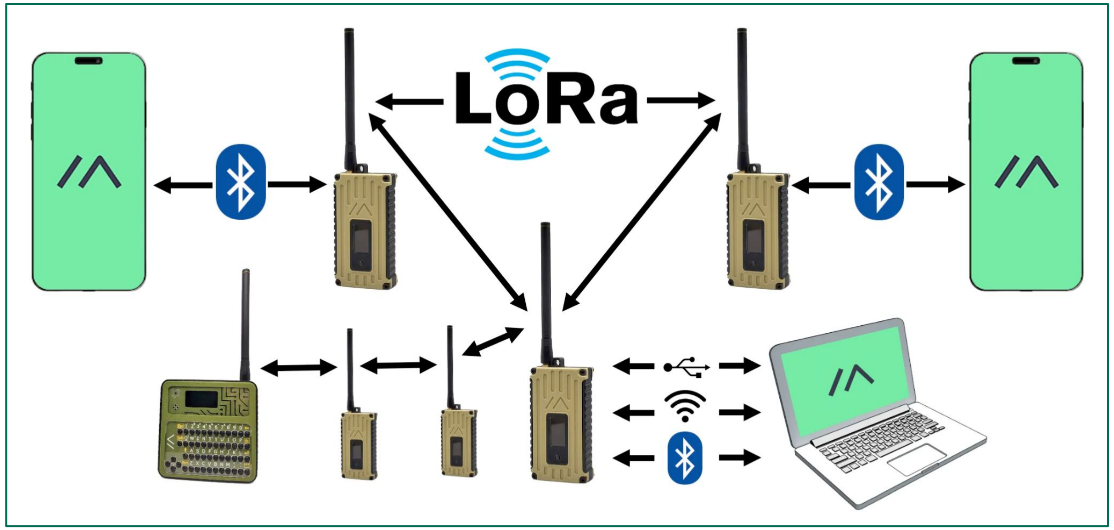
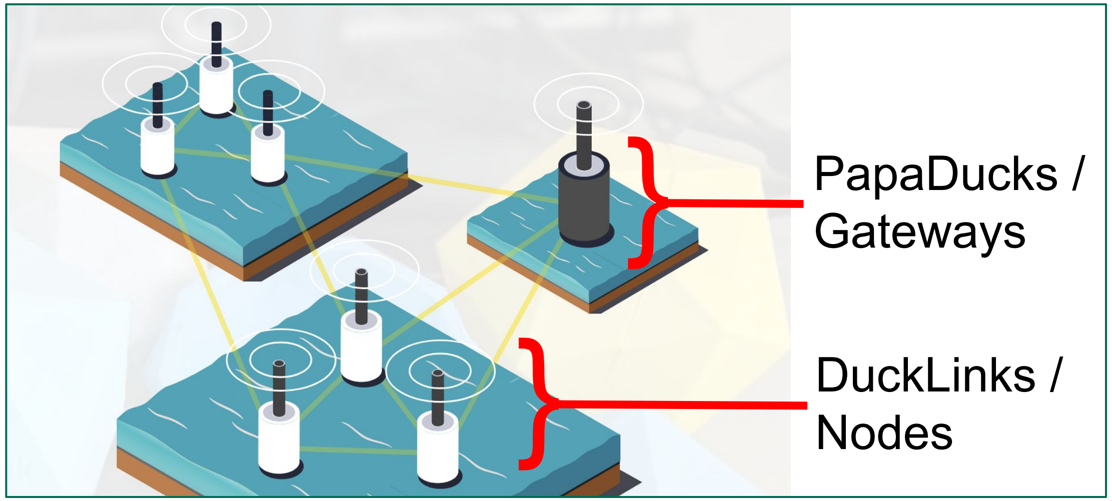
Background

- LoRa characteristics
  - Range (~10 km)
  - Bandwidth (< 27 kbps)
- Use cases
  - Long range sensor networks
  - Smart cities/buildings
  - Resilient “off-grid” networks
    - Meshtastic[10]
    - Clusterduck[11]



Meshtastic system architecture



ClusterDuck system architecture

Motivation

- ➔ Natural disasters
  - Rate of “billion dollar disaster” event occurrence increasing[9]
- ➔ Disaster recovery
  - Search and rescue
  - SoS beaconing
  - Long term supply coordination
- ➔ Low cost
  - Heltec LoRa 32(v3) for $17.90-$19.90
  - Satellite enabled smartphone for $500-$1000


Flooding in Chiva, Spain – AP [7]


Hurricane damage in Asheville, NC – CommonEdge [8]

Related Work

➔ Explores LoRa limitations and application use cases of LoRa/LoRaWAN

[1] F. Adelantado, X. Vilajosana, P. Tuset-Peiro, B. Martinez, J. Melia-Segui and T. Watteyne, "Understanding the Limits of LoRaWAN".

➔ Explores LoRa use cases within urban environments and develops a solution for better performance within urban environments

[2] Rashad Eletreby, Diana Zhang, Swarun Kumar, and Osman Yağan. 2017. Empowering Low-Power Wide Area Networks in Urban Settings.

➔ Explores mobile LPWAN(s) limitations and introduces a solution to mobile nodes using Sensor Network over Whitespace (SNOW)

[3] Dali Ismail, Abusayeed Saifullah. 2021. Mobility in Low-Power Wide-Area Network over White Spaces.

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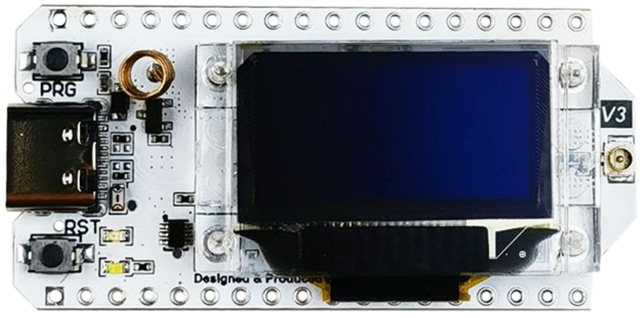
Methodology

1. Equipment / LoRaWAN Infrastructure
   - → HELTEC™ AUTOMATION LoRa 32 V3
   - → nuand Tri-Band Antenna
   - → LoRaWAN® gateway on EB roof



https://heltec.org/project/wifi-lora-32-v3/

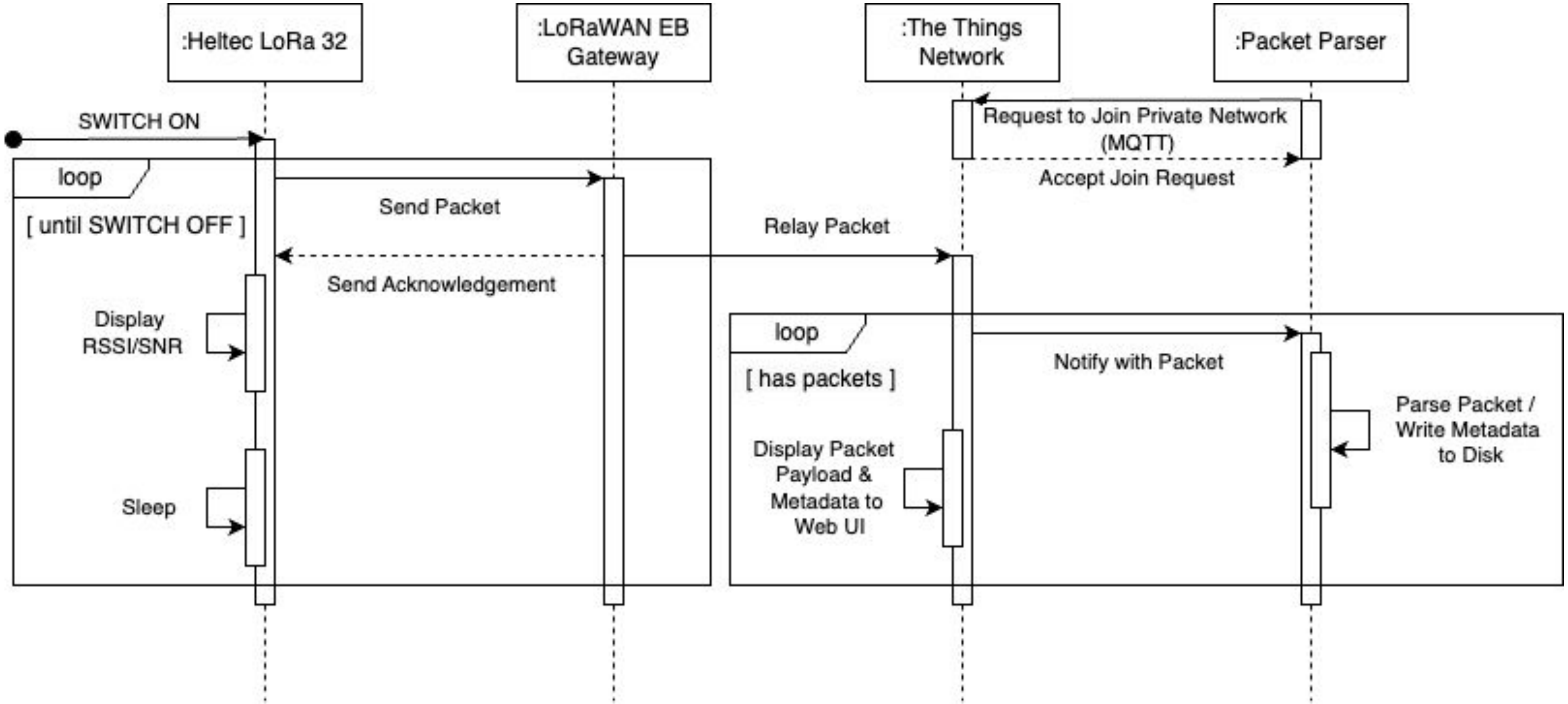
2. Measure parameters that could *potentially* affect signal quality at several locations around the Binghamton University Vestal campus

https://www.nuand.com/product/tri-band-antenna/

Roles

- ➔ Data Collection
  - ➔ Annie Wu, Callisto Hess, Gregory Maldonado
- ➔ Data Analysis
  - ➔ General LoRa Performance - Callisto Hess
  - ➔ LoRa Building Attenuation - Gregory Maldonado
  - ➔ LoRa in Motion - Annie Wu

System Architecture Overview



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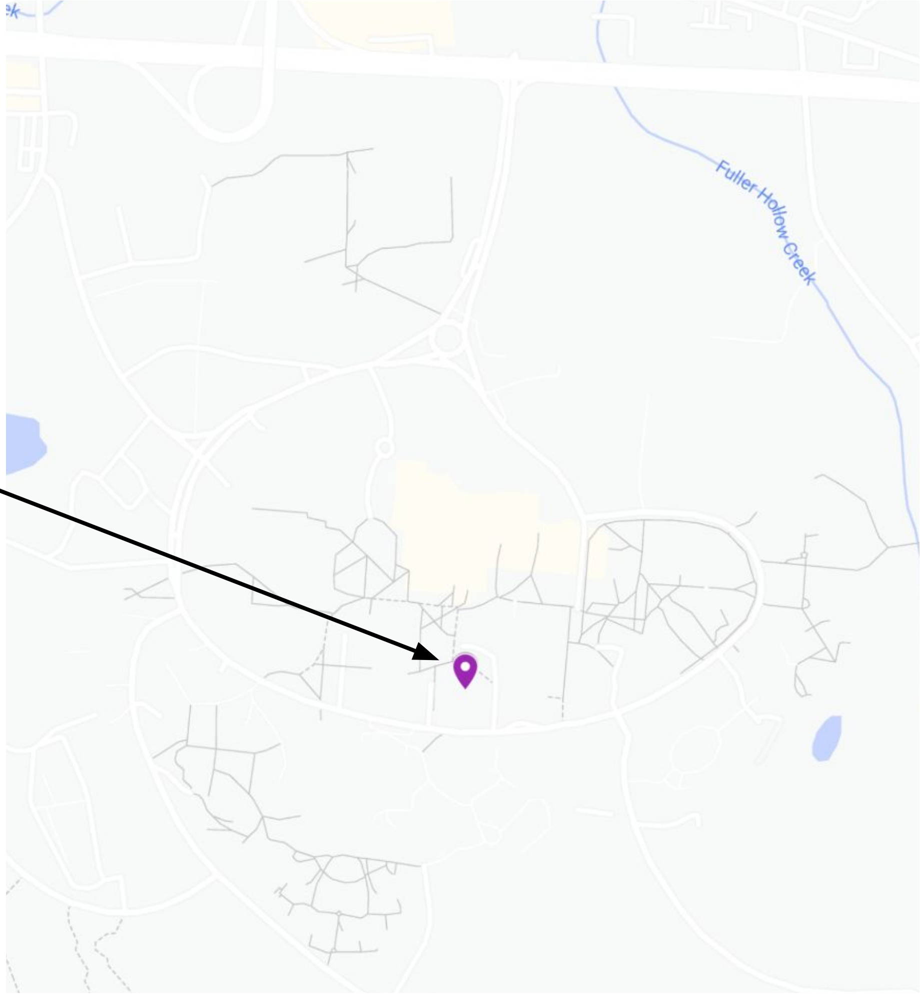
LoRaWAN Gateway on Campus

Engineering Building



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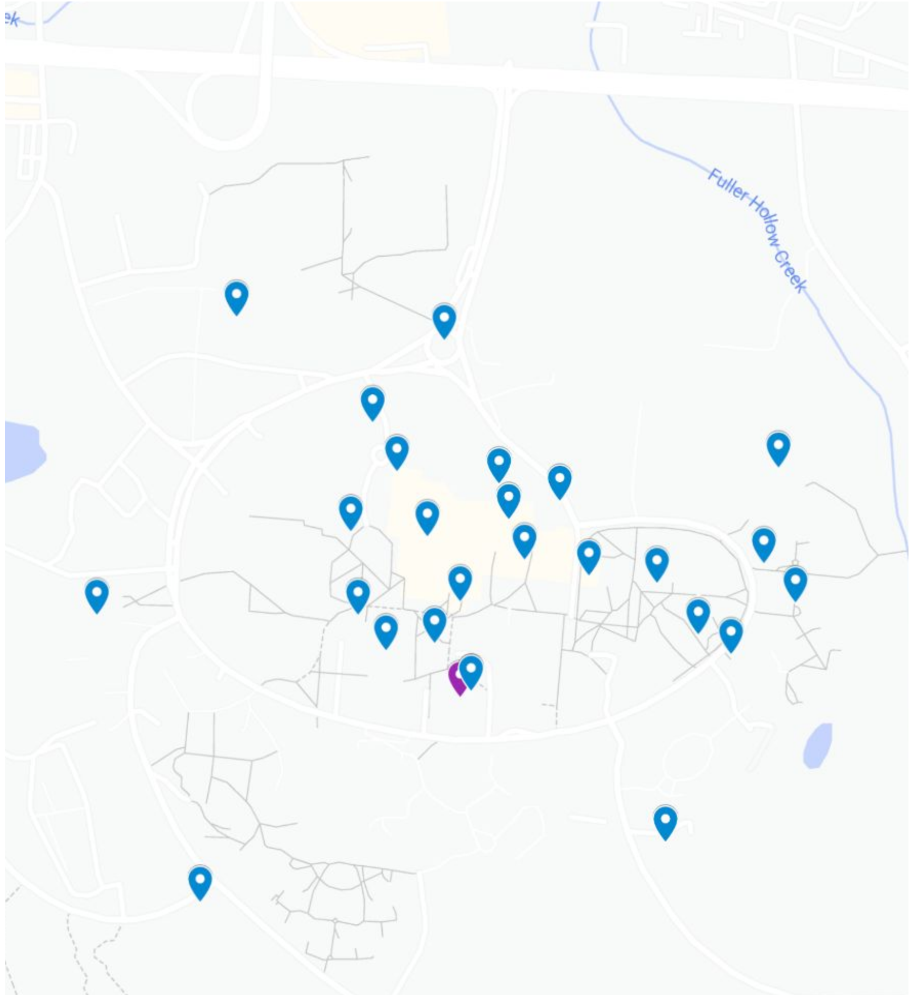
Sampled Locations on Campus

26 total sampled locations ranging in:

- ➔ Elevation
- ➔ Distance (from gateway)
- ➔ Line of Sight
- ➔ {In, Out}door



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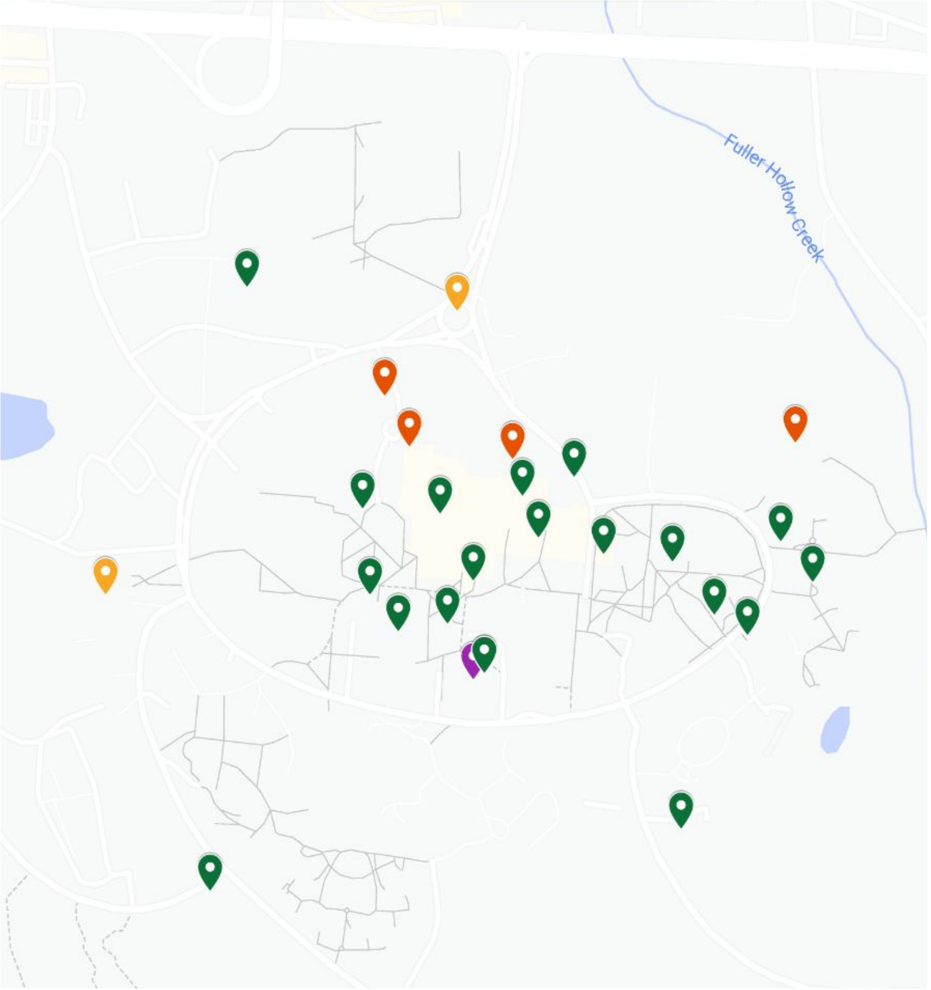
Approximate Transmission Reliability on Campus

Legend

- Reliable
- Okay
- No Transmission



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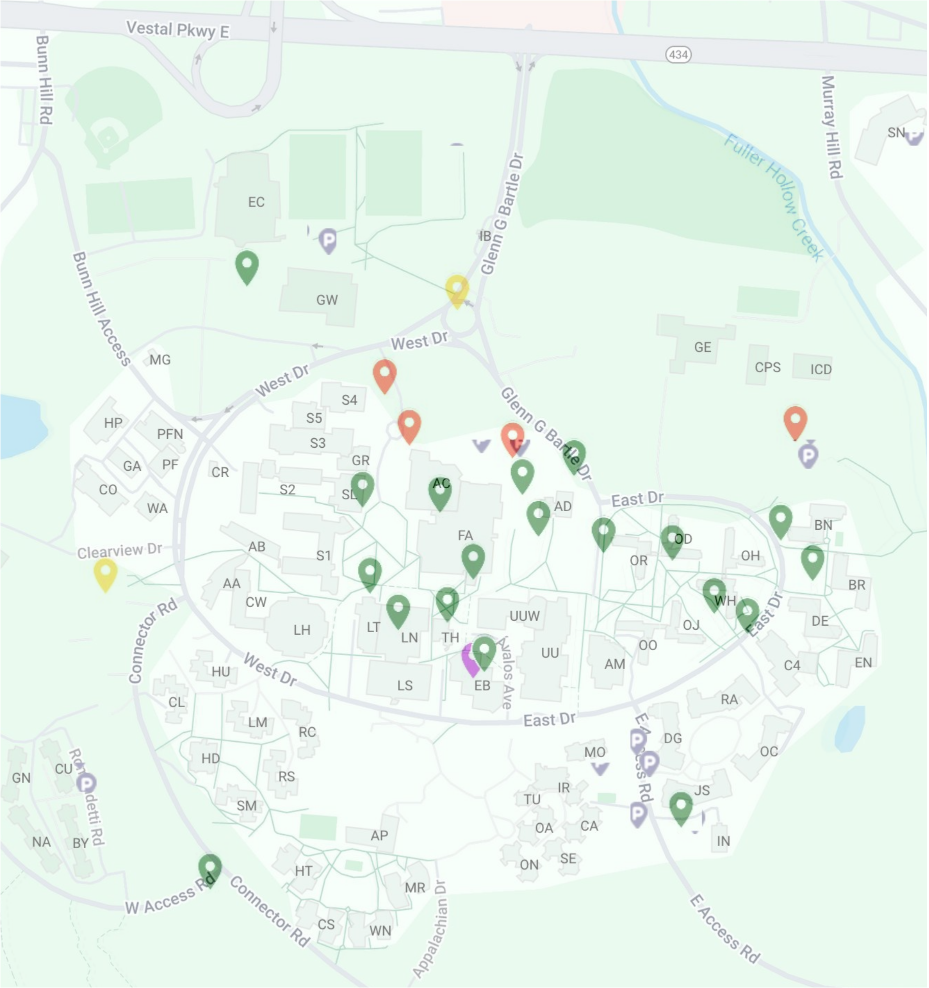

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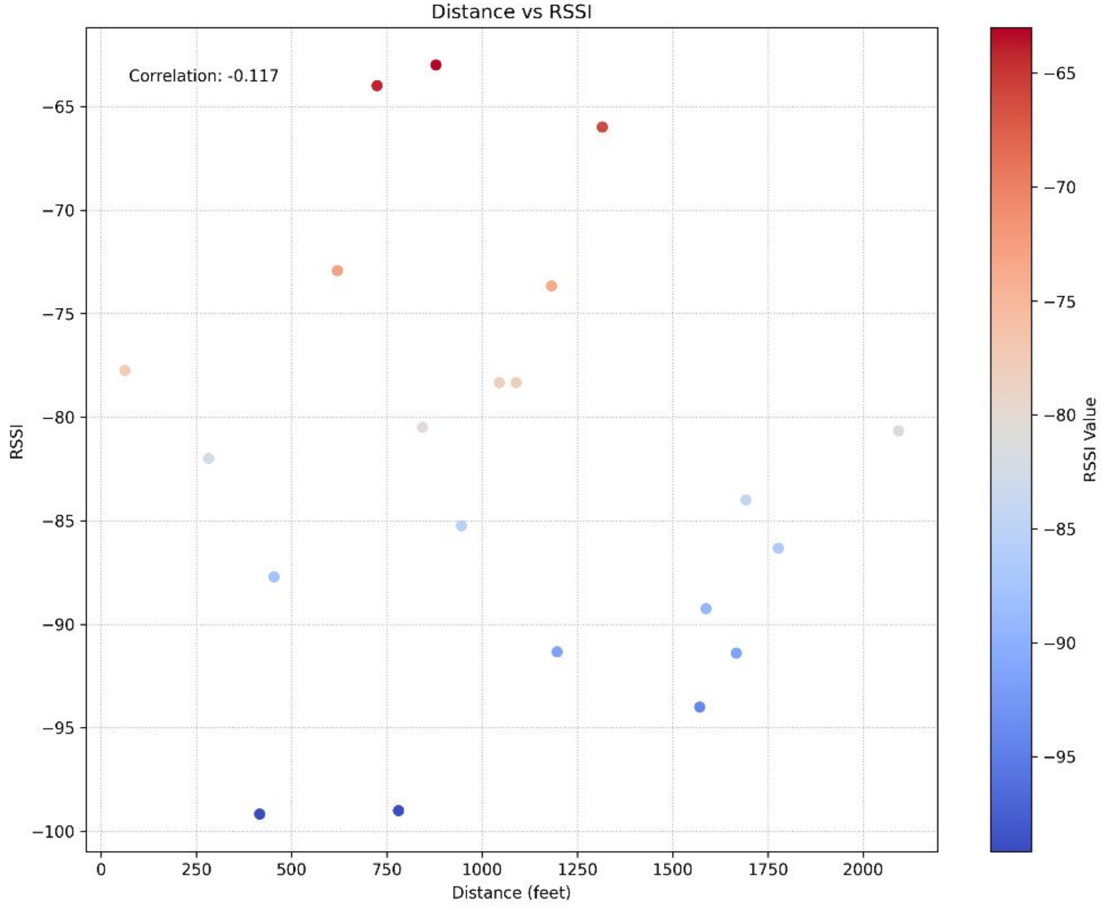
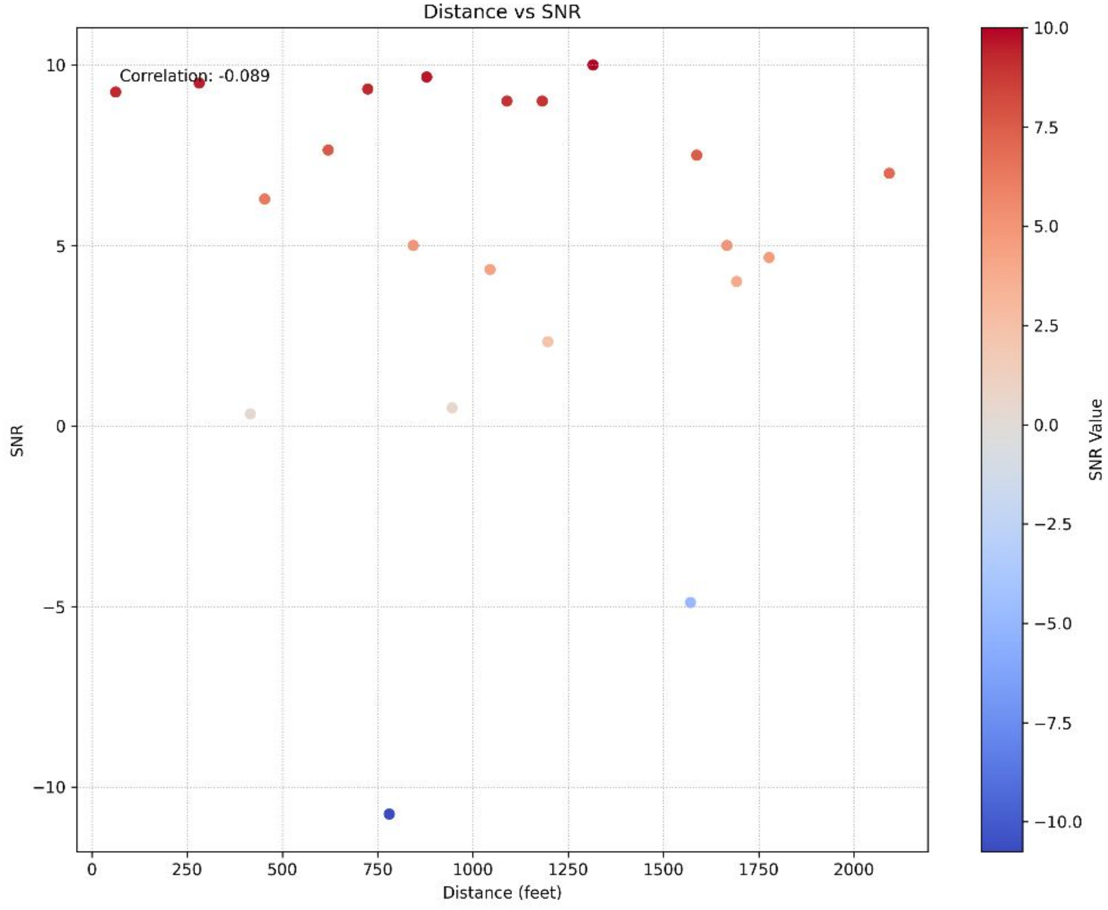
LoRaWAN Data Visualization Demonstration

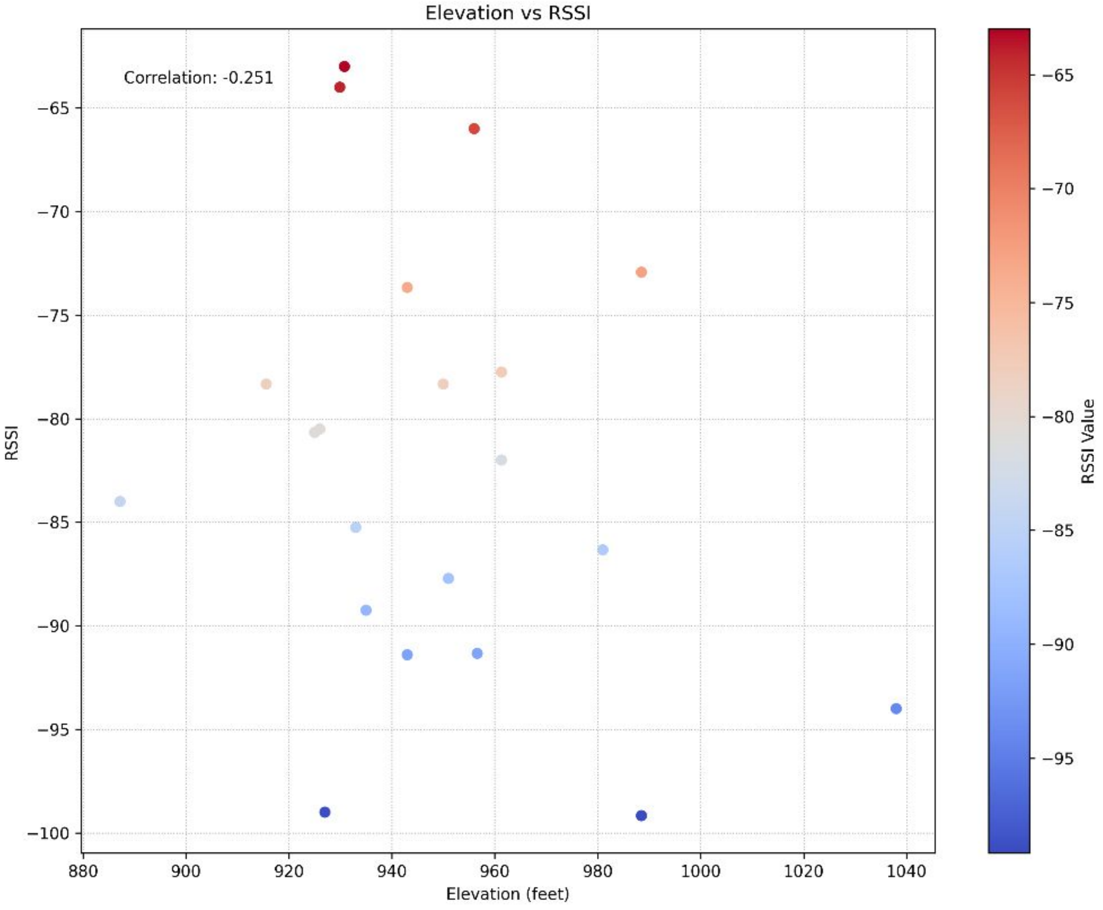
https://www.google.com/maps/d/u/0/viewer?mid=1WuD7BzSU43TnNg1SiYuitD-MUiLMppE&ll=42.09004663033867%2C-75.96827357672119&z=16

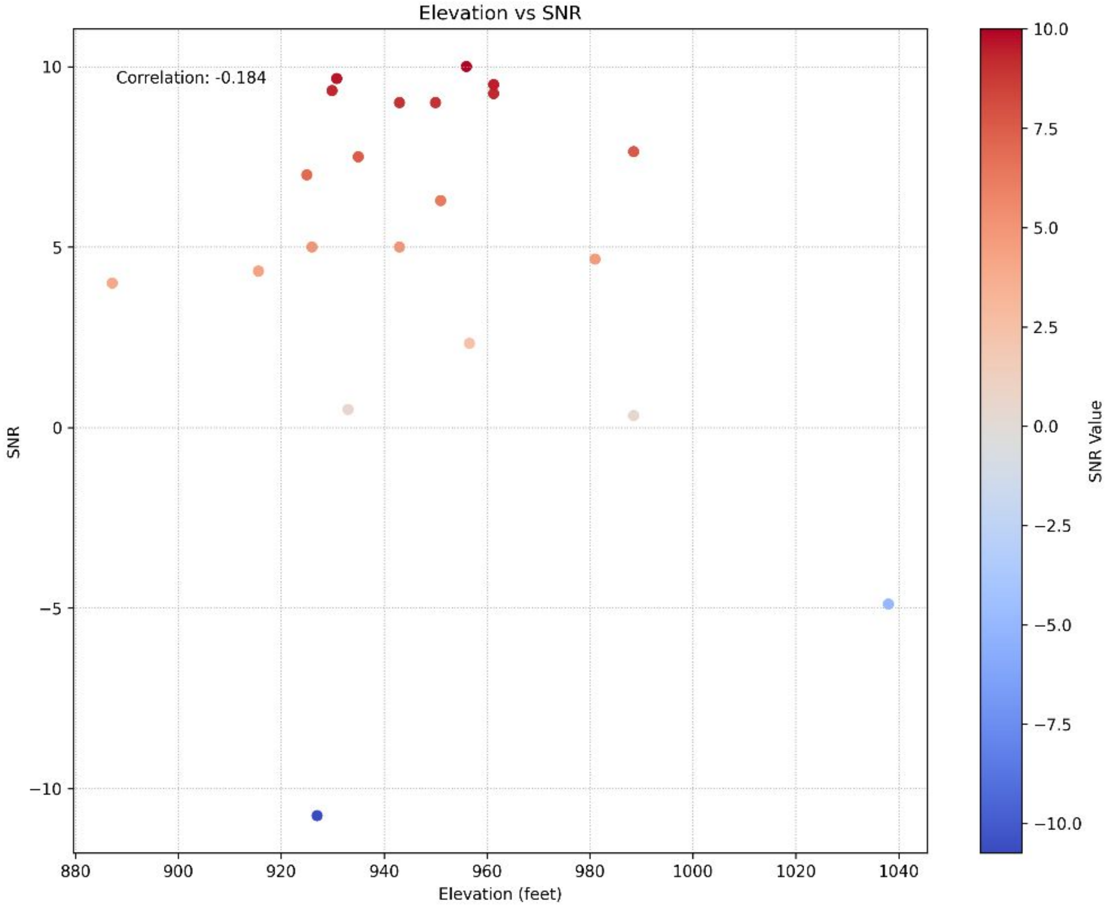
Signal Quality vs Distance





LoRa Signal Quality vs Elevation





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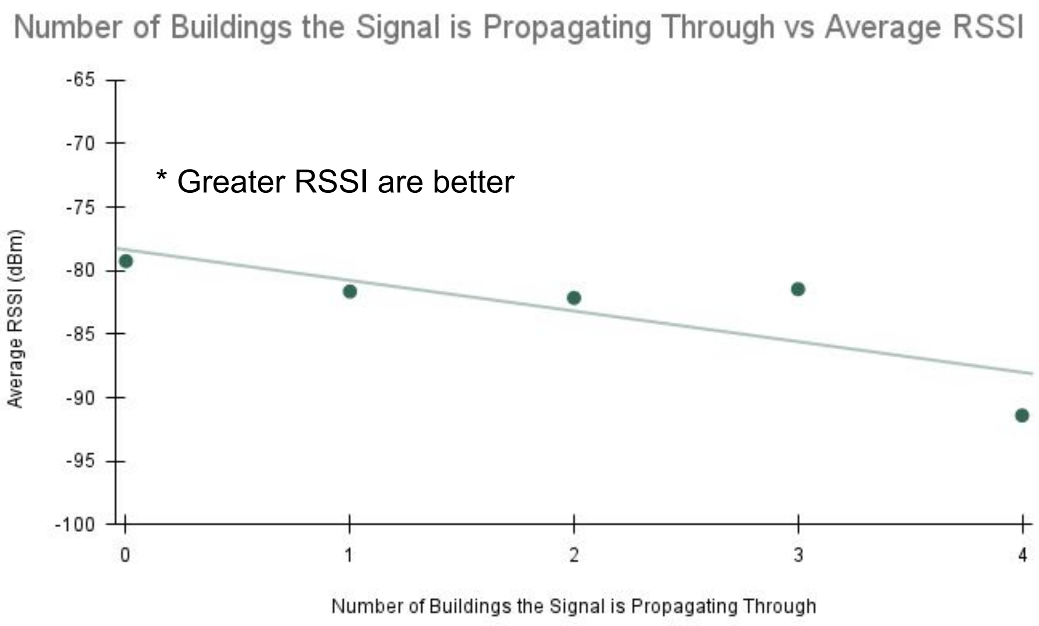
Signal Attenuation

Attenuation is the reduction in the amplitude of a signal as it travels through a medium due to transmission loss, reflection, or absorption. [5]

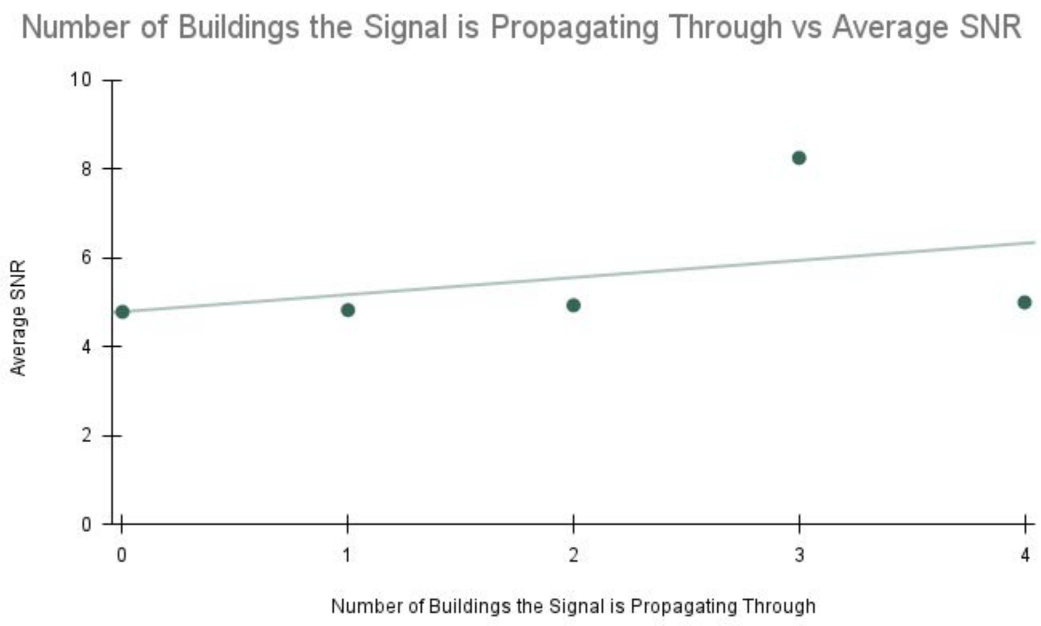
Clear Glass Window	2 dB
Window, Brick Wall	2 dB
Marble	5 dB
Brick Wall	2 to 8 dB
Concrete Wall	10 to 15 dB
Metal door in brick wall	12 to 13 dB

Table 1: Path Loss for Common Materials [6]

LoRa Signal Path loss due to Campus Buildings



* Greater RSSI are better



* **Note:** With the limited project scope and time constraints, this is a major oversimplification of what could be affecting signal quality. These measurements assume **all** buildings are the same dimensions, made out the same materials, at the same elevation, etc. which is **NOT** true but gives a general idea of LoRa signal path loss.

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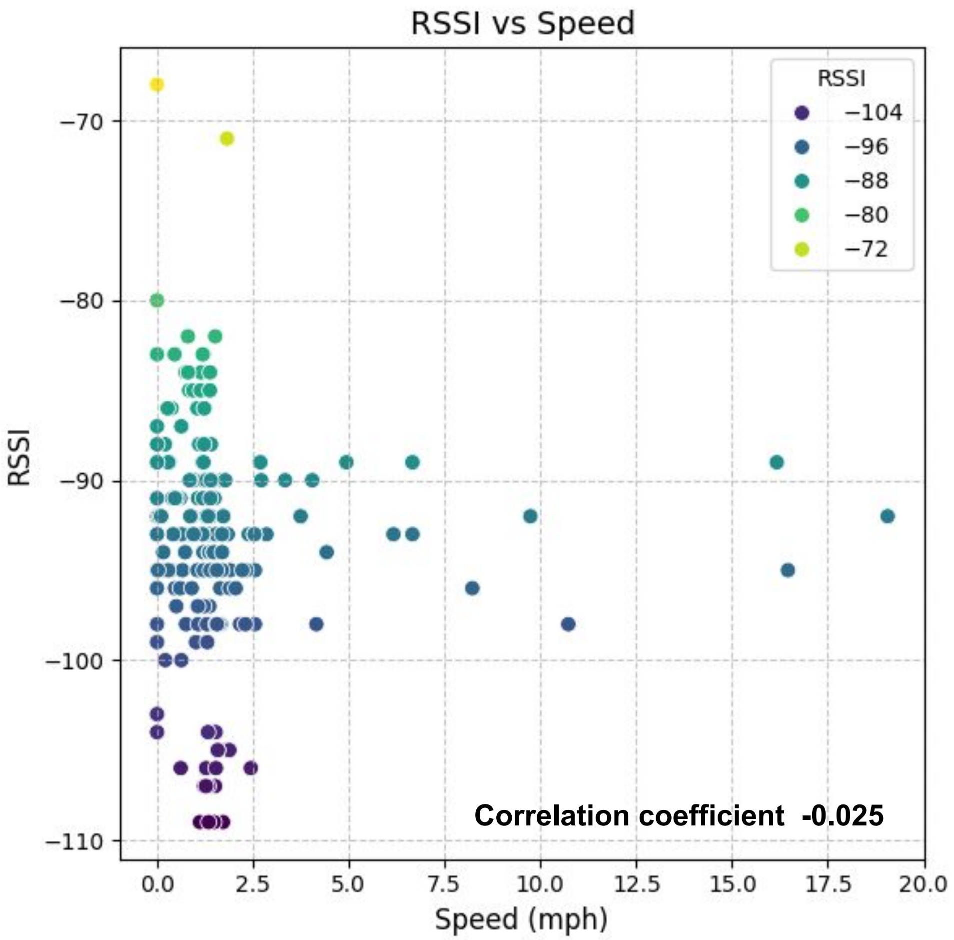
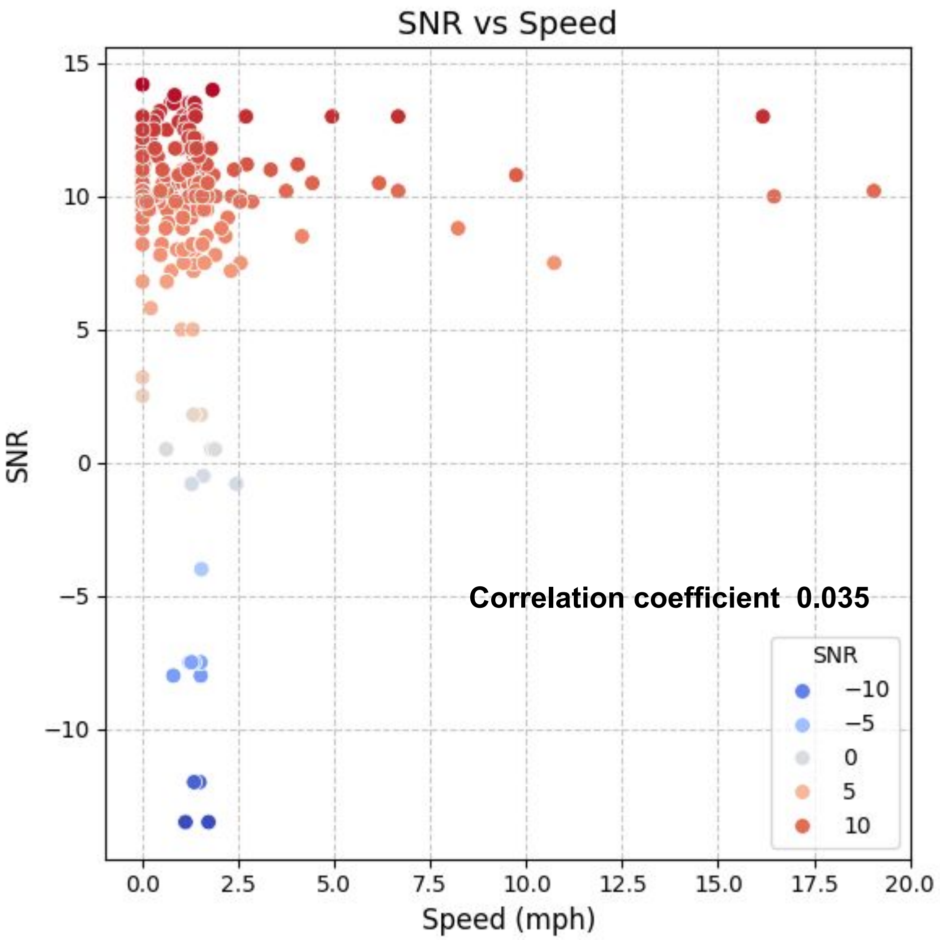
LoRa Signal Quality vs Speed

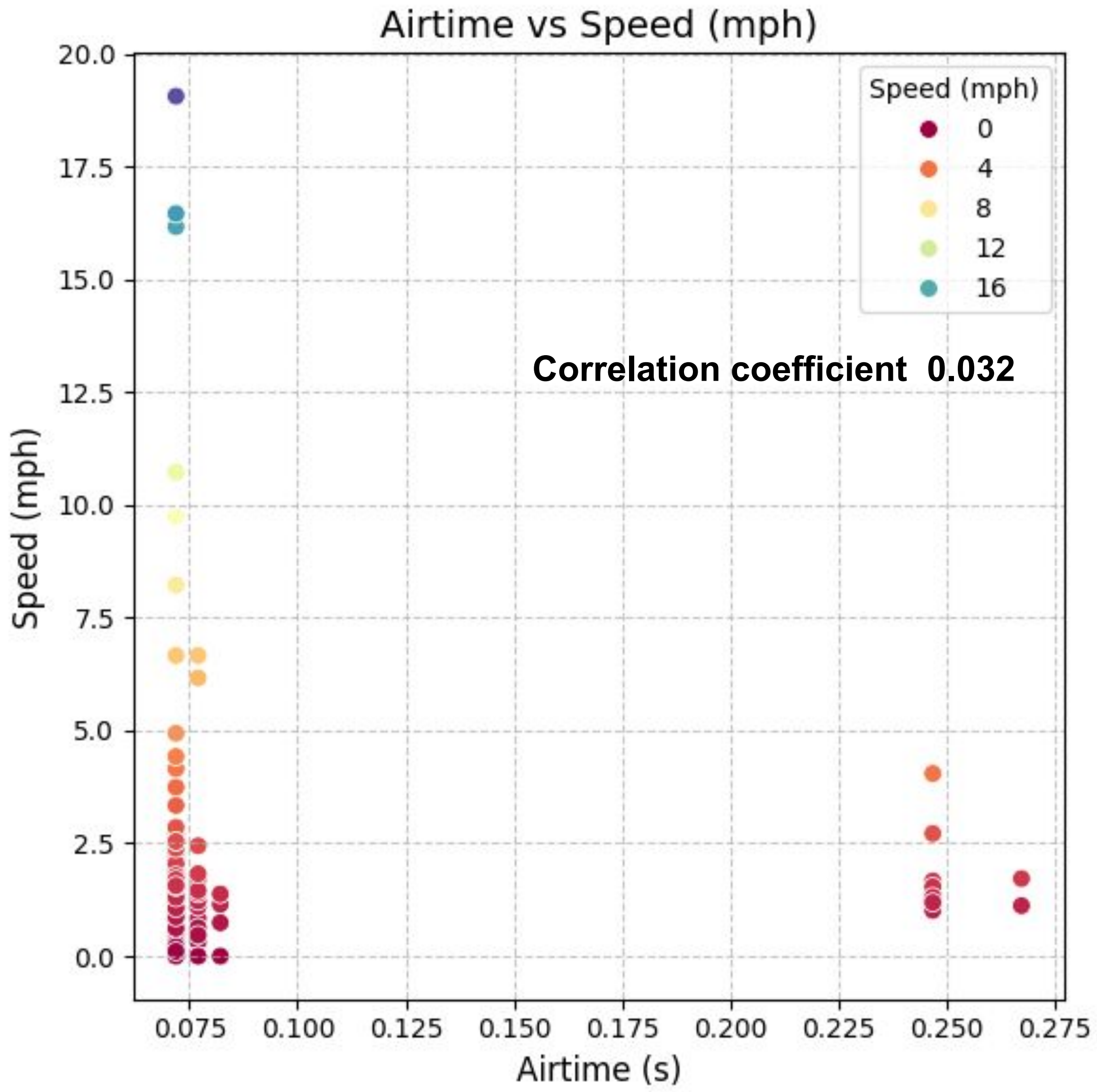




Motion Impact with Airtime

The airtime shows a very weak correlation (0.032) with speed.

At lower speeds, packet transmission rates more reliably

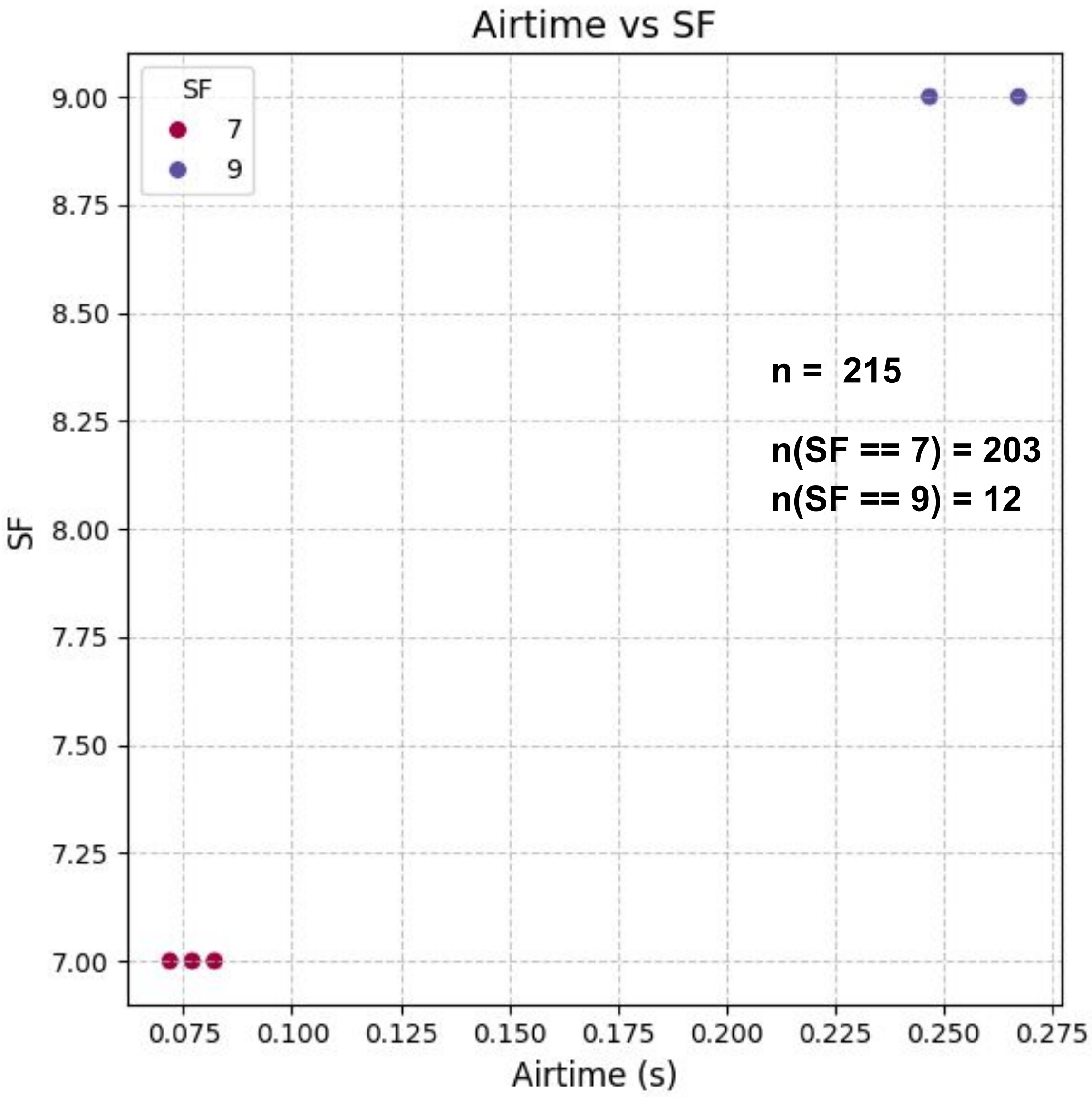


Speed Impacts Packet Success

1. SF=7 dominates at all speeds

2. SF=9 is only used in certain cases

→ Higher SF leads to longer airtime but ensures reliability in challenging conditions.



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Conclusions

How does the campus buildings effect LoRa signal quality?

- ➔ There exists an approximately linear relationship between path obstacles and signal quality but …
- ➔ Number of buildings is not the only factor of signal quality. Buildings can be made out of different materials that absorb / reflect radio signals.

How does motion effect LoRa signal quality?

- ➔ LoRa is NOT a technology designed for mobile systems.
- ➔ There exists PHY layer solutions that take into account the doppler effect like "Mobility in Low-Power Wide-Area Network over White Spaces" [3].
- ➔ "Studies on LoRa show that its performance is susceptible even to minor human mobility" [12] [13]

Feature	Semtech LoRa chips	HELTEC LoRa 32
Modulation Technology	SX1276/SX1272	SX1262
Interference Tolerance	More sensitive to Doppler shifts and carrier frequency offsets	±30 kHz of Doppler shift

Future Work

- ➔ How does LoRa perform in noisy environments such as densely populated cities?
- ➔ How does LoRa perform in remote environments?
- ➔ How we make LoRa/LoRaWAN adaptable for mobile systems?

References

[1] F. Adelantado, X. Vilajosana, P. Tuset-Peiro, B. Martinez, J. Melia-Segui and T. Watteyne, "Understanding the Limits of LoRaWAN," in IEEE Communications Magazine, vol. 55, no. 9, pp. 34-40, Sept. 2017, doi: 10.1109/MCOM.2017.1600613.

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[13] Petajajarvi, Juha & Mikhaylov, Konstantin & Pettissalo, Marko & Janhunen, Janne & Iinatti, Jari. (2017). Performance of a low-power wide-area network based on LoRa technology: Doppler robustness, scalability, and coverage. International Journal of Distributed Sensor Networks. Vol. 13. 1-16. 10.1177/1550147717699412.

Questions?