High Altitude LoRa Networks for Crisis Communications (HALoN)

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Department of Computer Science and Engineering[2]

Afghans rejoice as internet returns after Tali

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OCT 3, 2025 2:56 AM PT

How the Taliban's Internet Blackout Sowed Fear in Afghanistan

IDEAS GENDER

by Zahra Nader
CONTRIBUTOR

Taliban internet blackout leaves Afghans in limbo while needs surge

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NEWS

Camp Fire Aftermath: 'Technology, the Thing I Trust Most, Failed'

Technology intended to warn Butte County residents about the rampaging Camp Fire failed in several ways, an analysis shows, revealing the fragility of electronic notification systems.





No Signal, No Sirens: How Paradise Was Left to Face the Fire in the Dark

Saropa Contacts News · Follow · 8 min read · Jul 17, 2025

The Problem

Disasters and political interference often disrupt communication, leaving communities unable to:

- reach emergency services
- coordinate rescue efforts
- connect with loved ones







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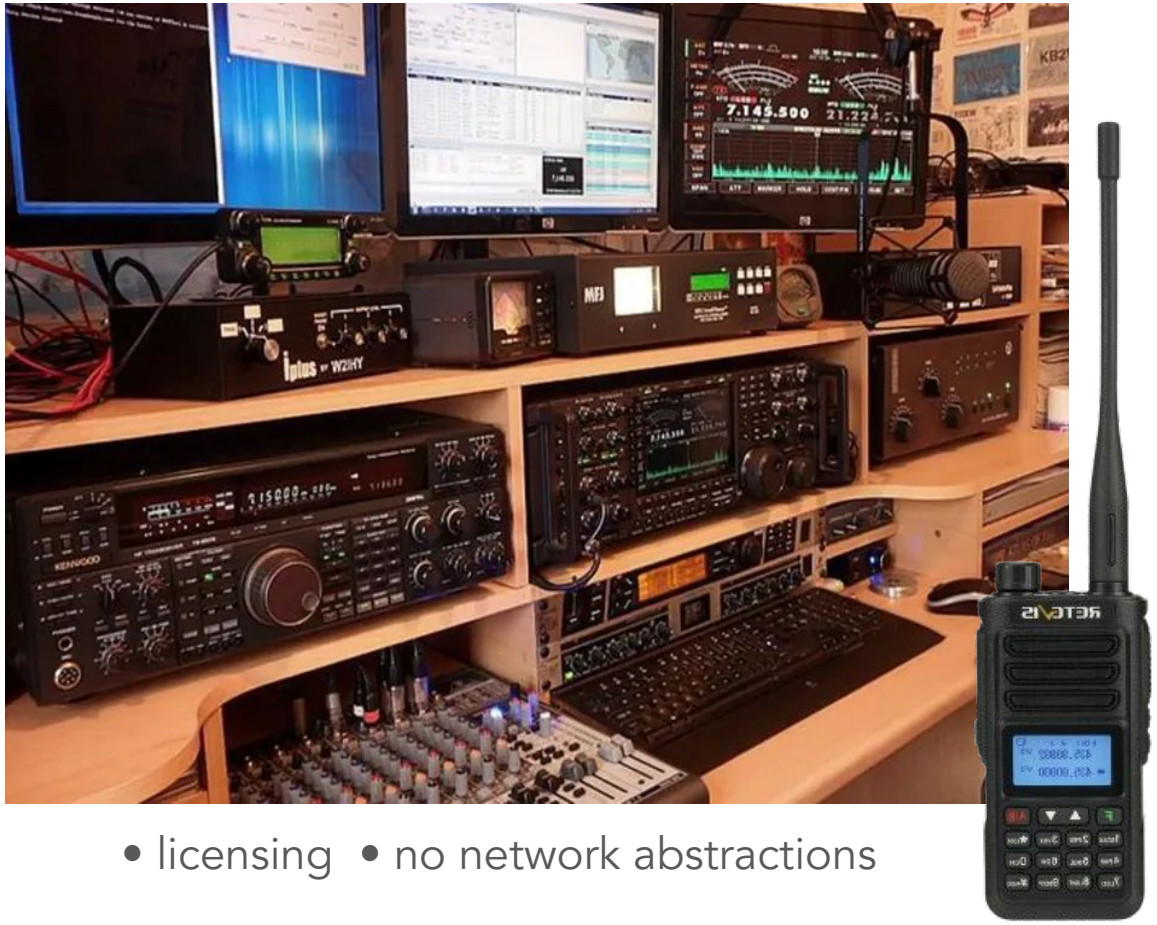
Existing Solutions

SAT Communication



- $500 hardware
- $70/month
- privately owned

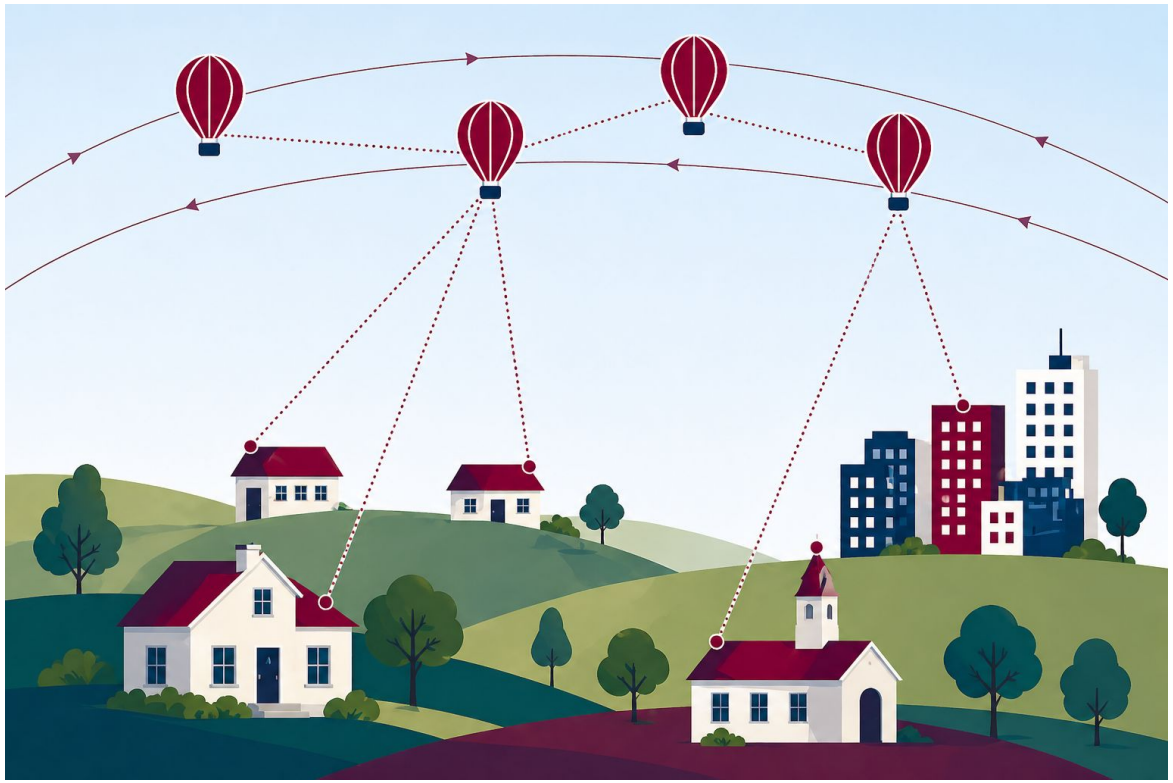
HAM Radio



- licensing
- no network abstractions

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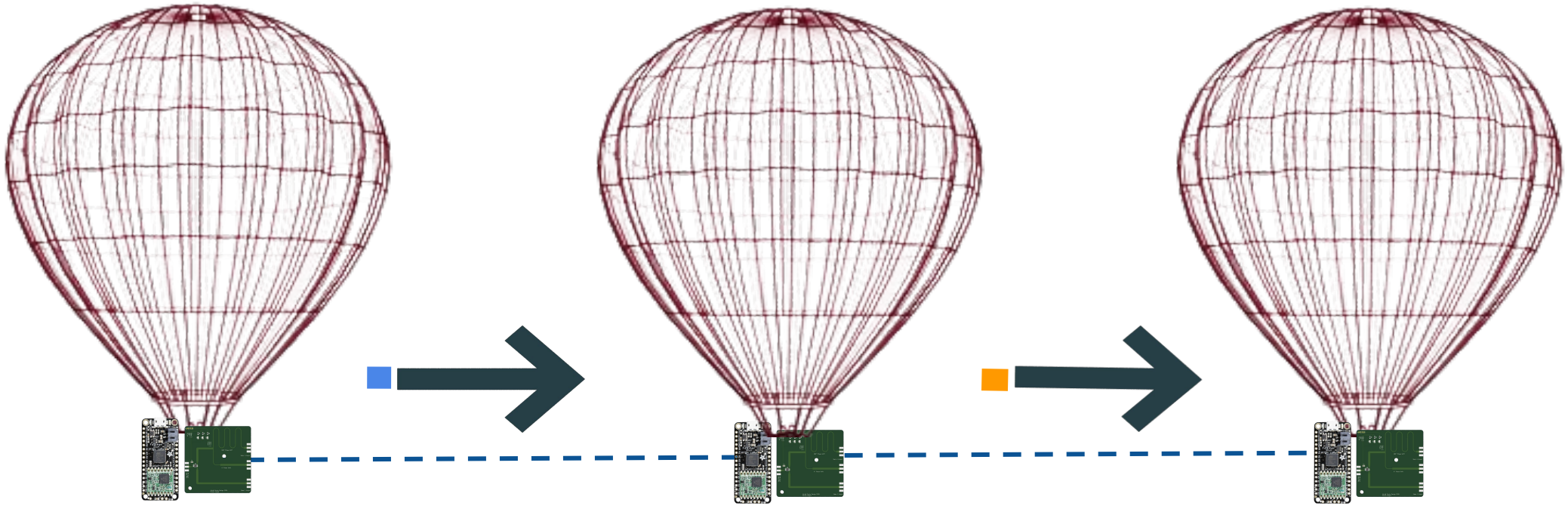
High Altitude Long-Range Networking (HALoN) for Crisis Communications



Build a peer-to-peer mesh network using LoRa-enabled microcontrollers to preserve connectivity when conventional infrastructure fails.

1. Develop a stack that could be deployed on a high altitude balloon acting as a node in the network.
2. Equip each node with a reconfigurable antenna to optimize propagation and maximize user reach.
3. Implement a low cost scheduling algorithm that prioritizes message coming from regions most impacted by crises.

Ideal Deployment



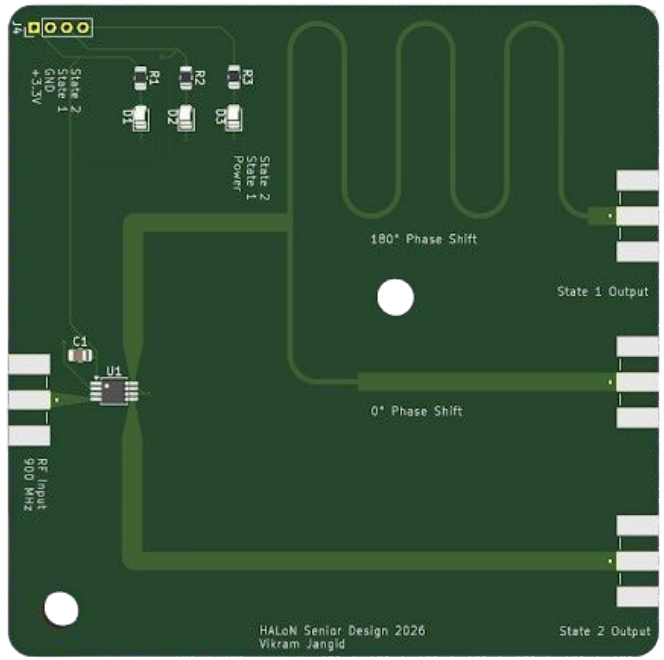
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Node System Diagram

Assesses all packets in queue.
Determines best packet to transmit

Determines the best next hop for selected packet.





Receives packet data from node or ground user.

Transmits packet data to selected node.

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How do we pick which message is sent from a node first?



How do we find the optimal path?

What is the right kind of radio?

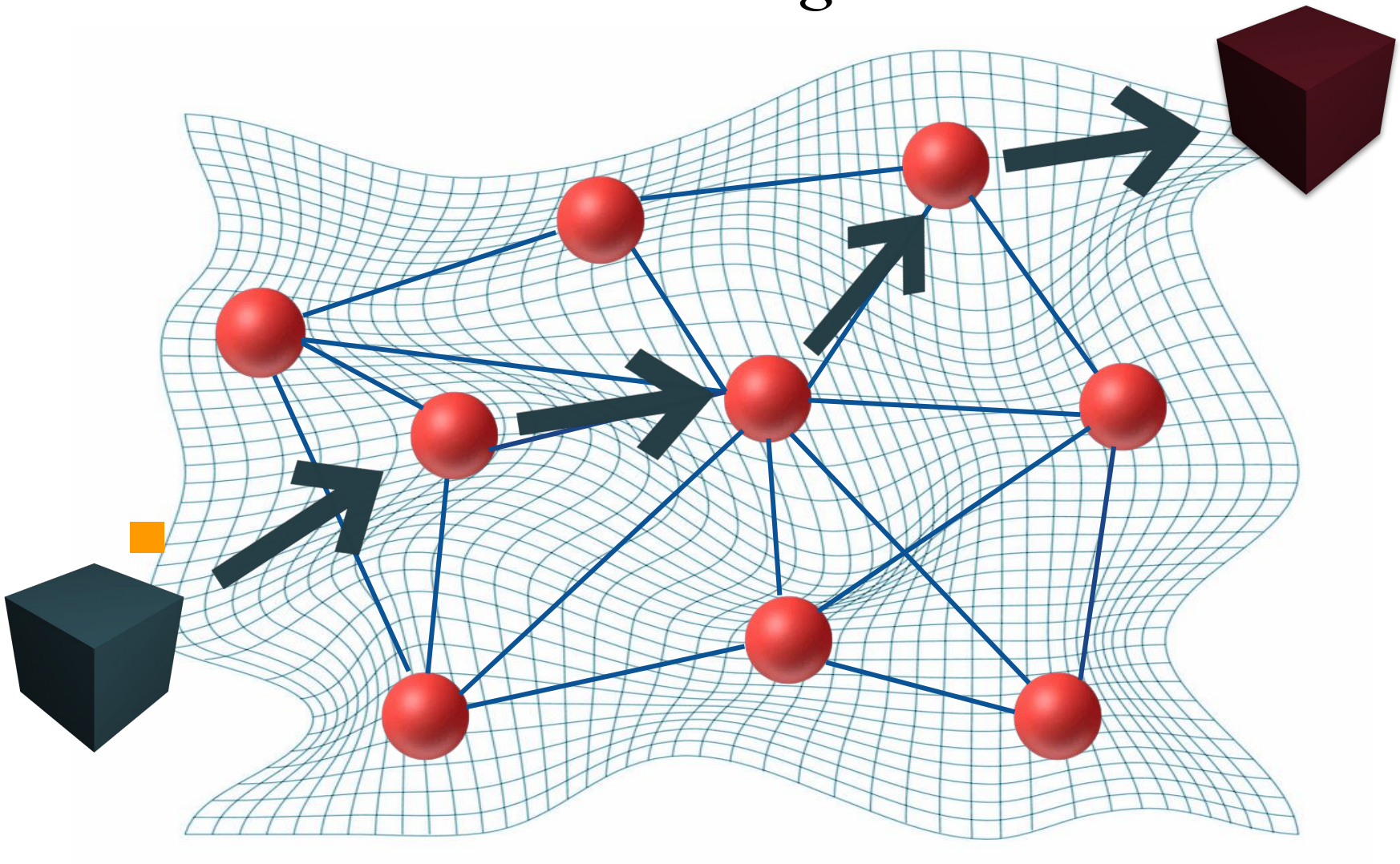
How do we pick the structure of our network?

How can we design an antenna to optimize transmitted power?

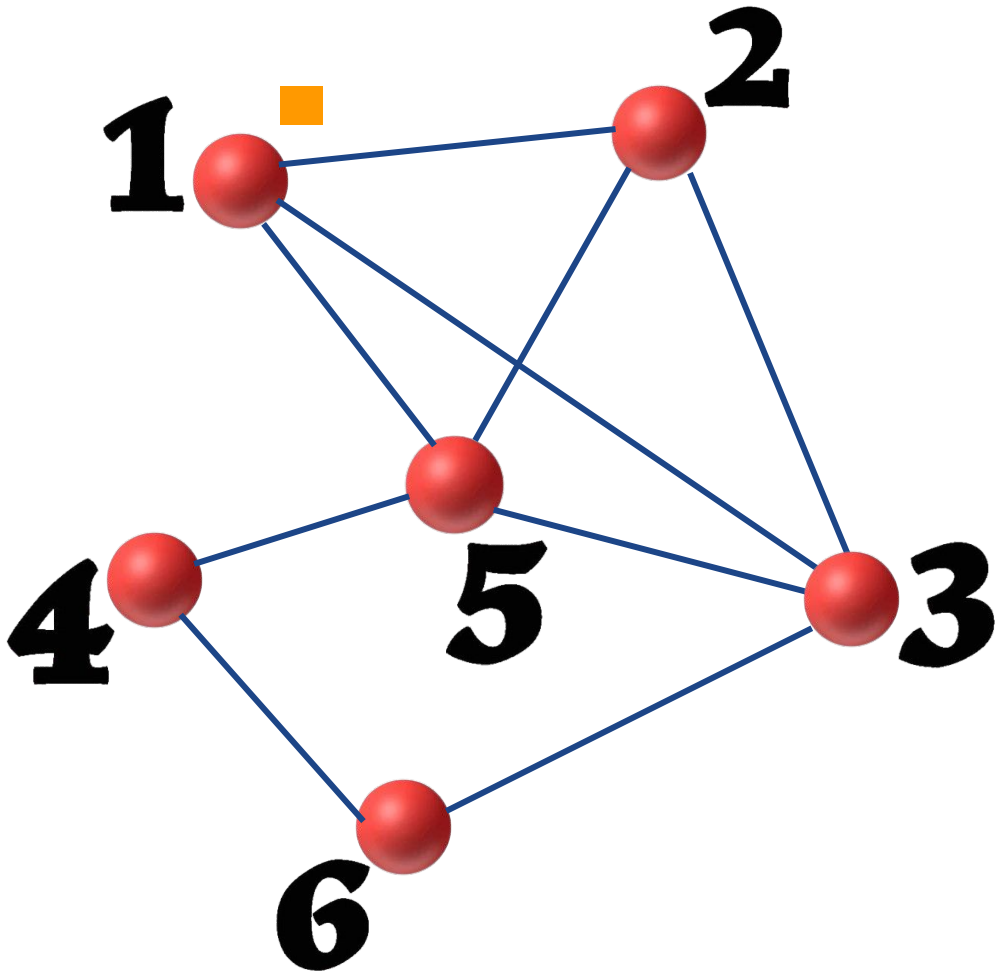


Design Considerations

Routing



Link State Routing



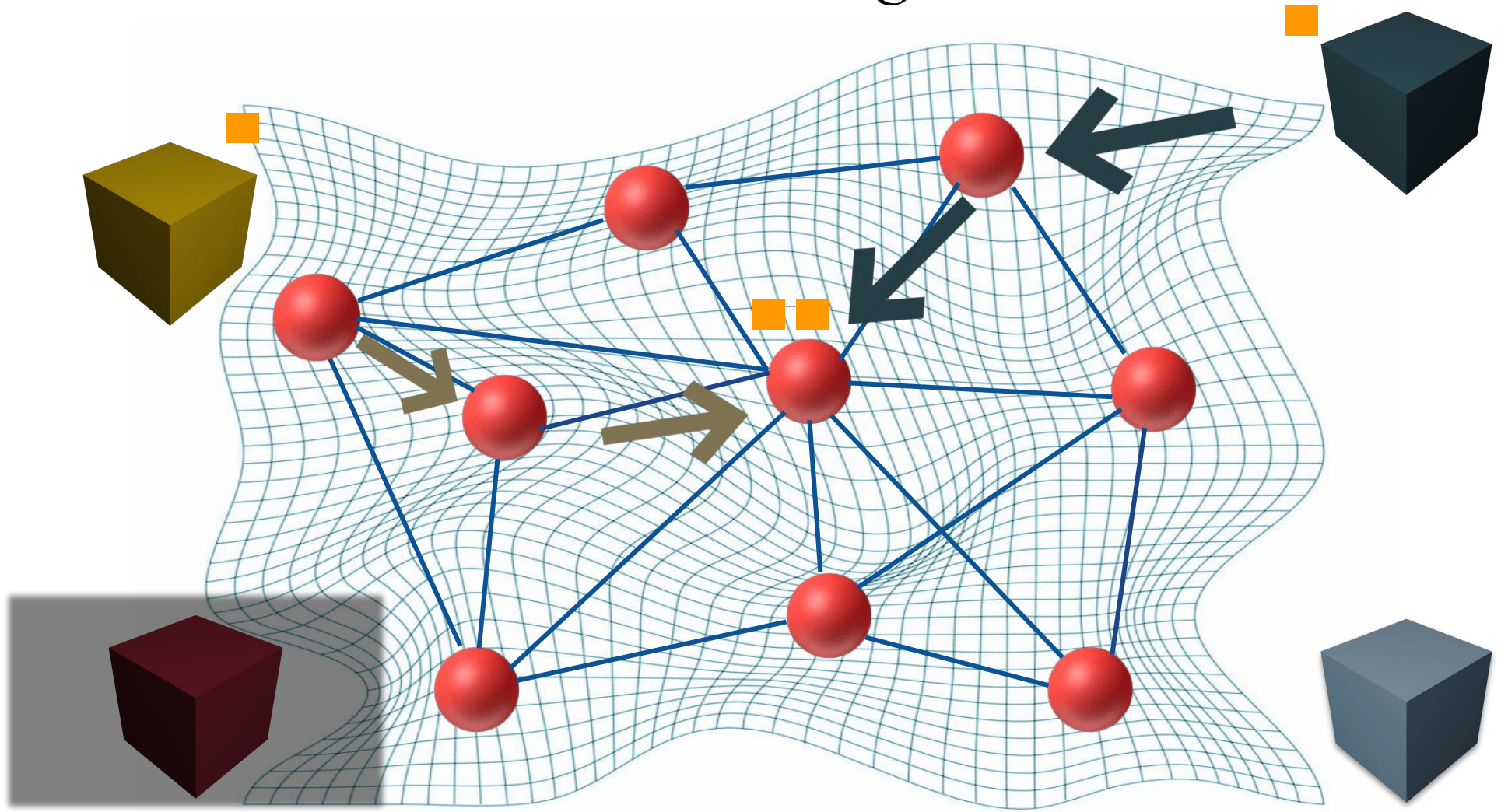
Dijkstra's Algorithm decides the lowest cost hop to the destination.

Hop cost determined by RSSI value

Node 1 Routing Table

Destination Node	Best Hop
2	*2*
3	*3*
4	*5*
5	*5*
6	*3*

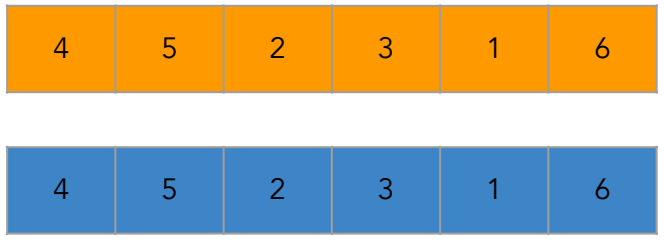
Scheduling



Selecting a Scheduling Algorithm

Nodes share a single channel, so effective scheduling is critical. Algorithms under consideration:

First Come, First Serve (FCFS):

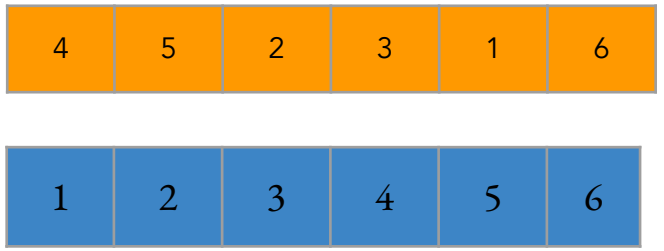


packet length in order received

packet length in order transmitted

fair, simple, may block packets!

Shortest Job First (SJF):



reduces average latency, can cause starvation

Not feasible: Round Robin, Shortest Remaining Time (nodes cannot TX and RX simultaneously).

Queue Learning, Priority Awareness & Scheduling

Each node makes local, per-packet decisions using a learned scoring model to allocate scarce airtime.



$$S_p = (R_p, L_p, Q, P_p, A_p, Z_p)$$

R□ – # of retransmissions	P□ – packet priority
L□ – link quality	A□ – packet age
Q – queue depth	Z□ – packet size

$$reward = (success\ ?\ +100 : -50) - 5 \times age_seconds$$

Developing a Network Simulator



NetworkX
Network Analysis in Python

matplotlib

NumPy

Firmware Development & Integration







RadioHead

Main Page | Classes ▾ | Files ▾ | Examples

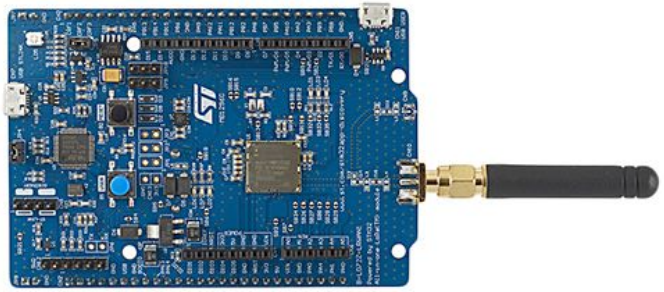
RadioHead Packet Radio library for embedded microprocessors

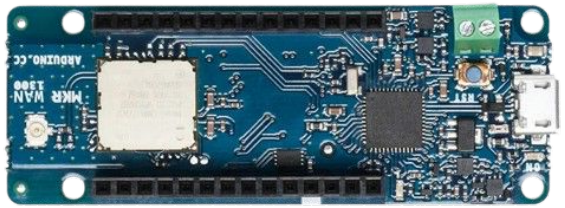
System Demonstration

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Radio Selection







32u4 Feather

- 8-bit AVR
- TX ~120 mA
- Arduino IDE
- $35

ST B-L072Z-LRWAN1

- 32-bit ARM M0+
- TX ~25 mA
- STM32 CubeMX
- $48

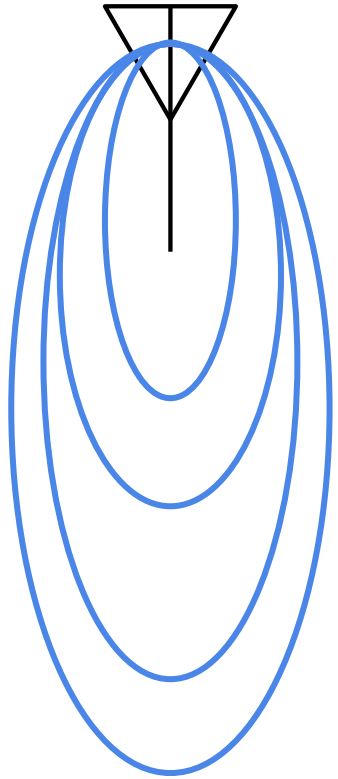
MKR WAN 1300

- 32-bit ARM M0+
- TX ~125 mA
- Arduino IDE
- $46

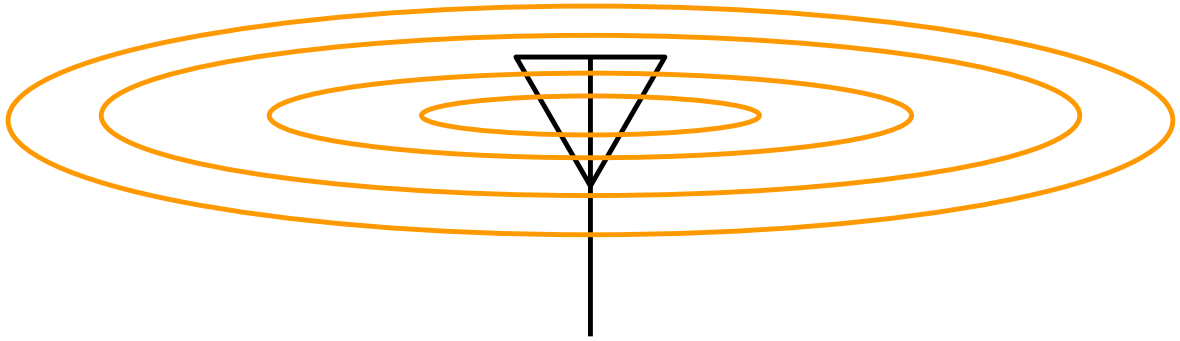
Reconfigurable Antenna System

The built in antenna radiates in all directions → we can optimize where power is directed if we know who we are communicating with…

1. Node to User: radiate downwards → endfire
2. Node to Node: radiate outwards in the plane → broadside

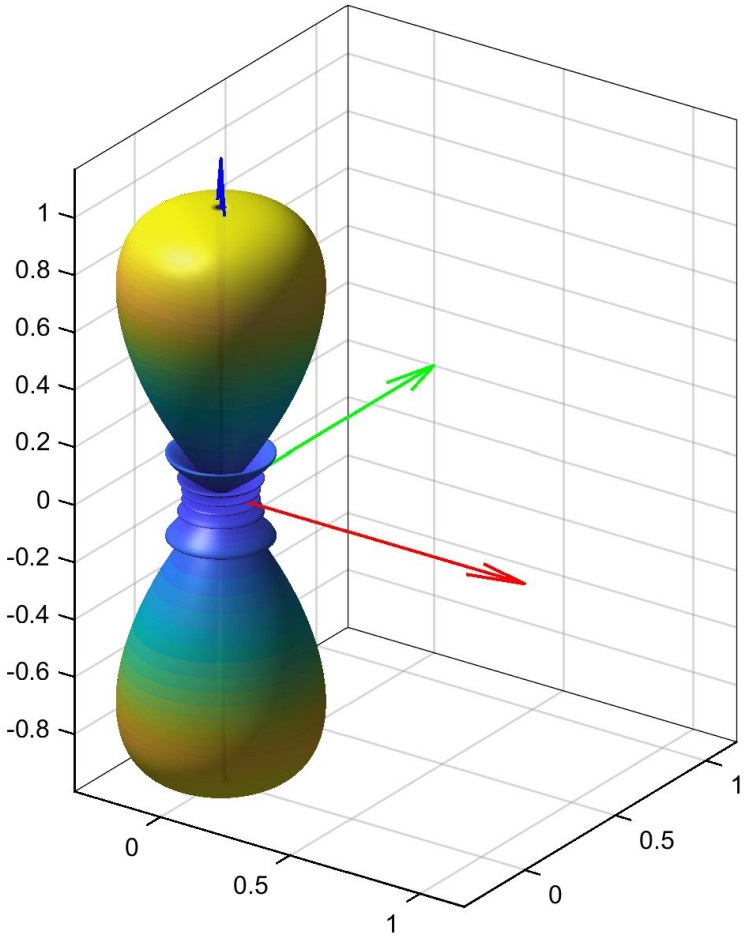


Endfire

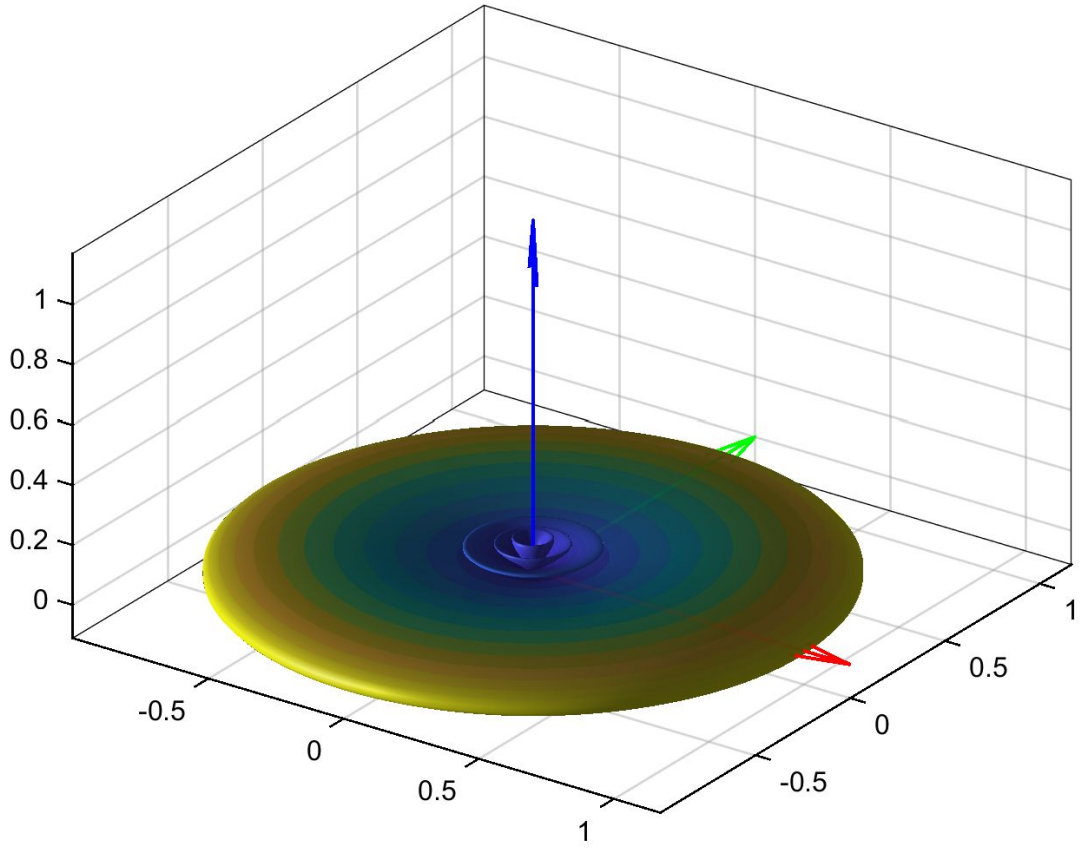


Broadside

Radiation Patterns

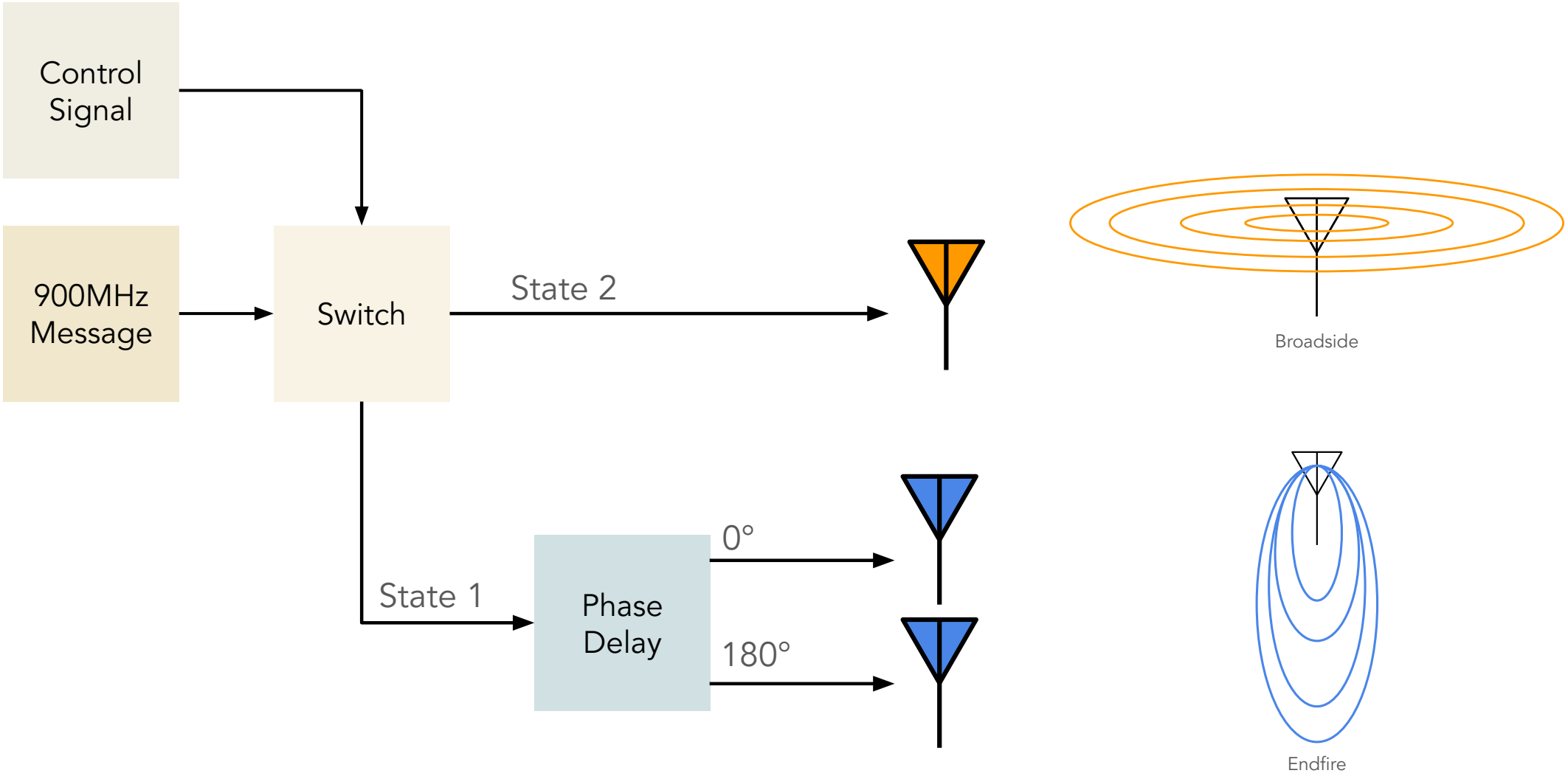


Endfire



Broadside

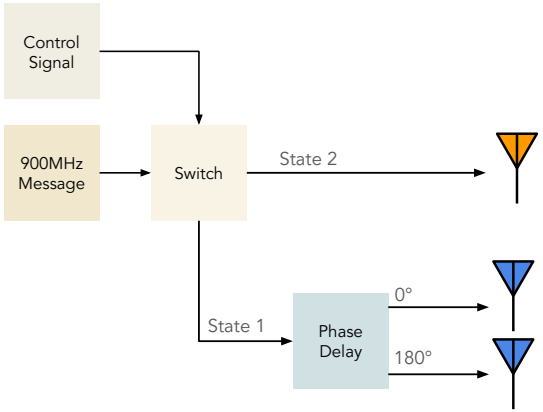
Overview of Reconfigurable System



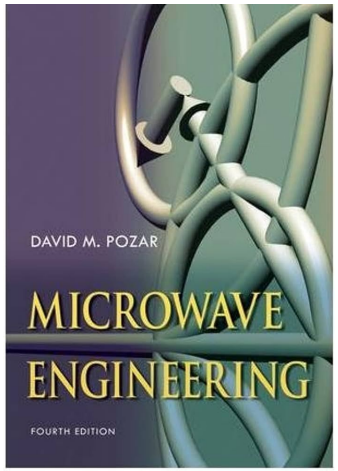
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Design Flow

Functionality



Design Equations



Simulation

Ansys HFSS

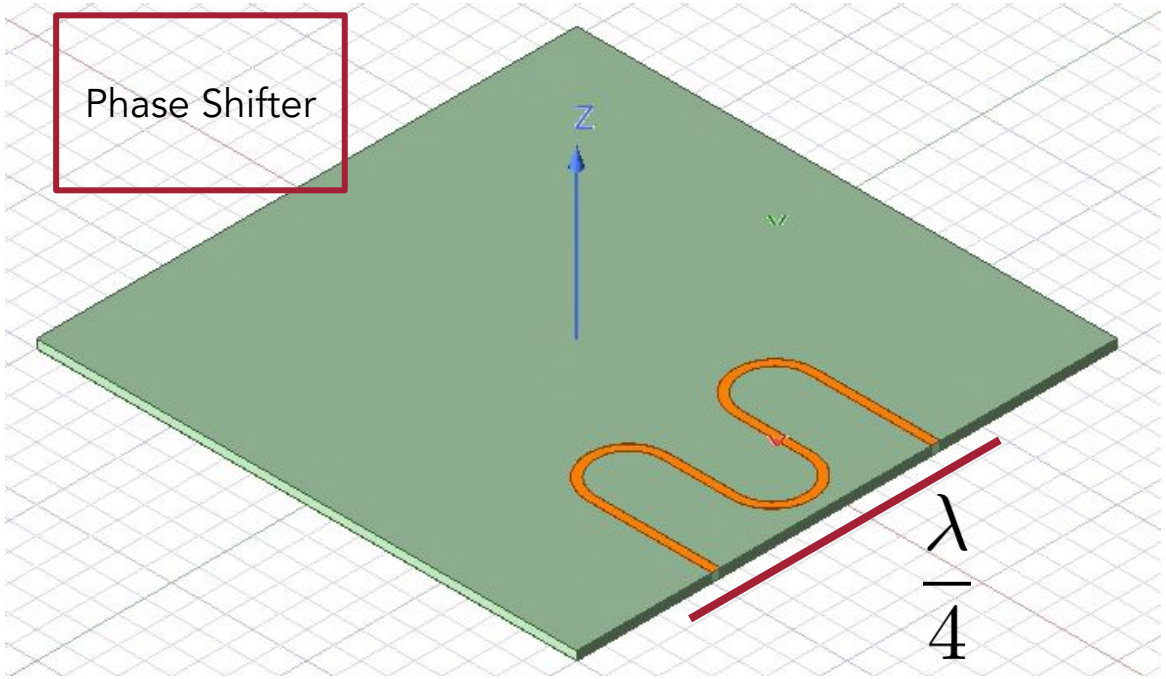
PCB Design

KiCad

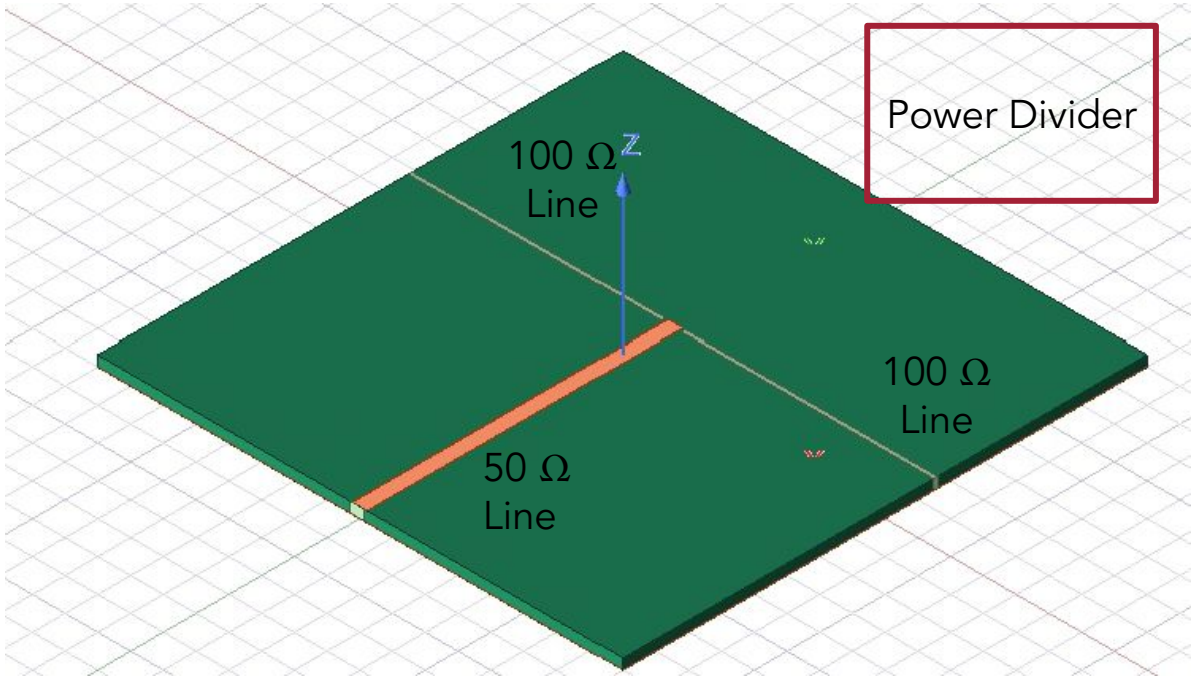
Characterization



Simulation of System

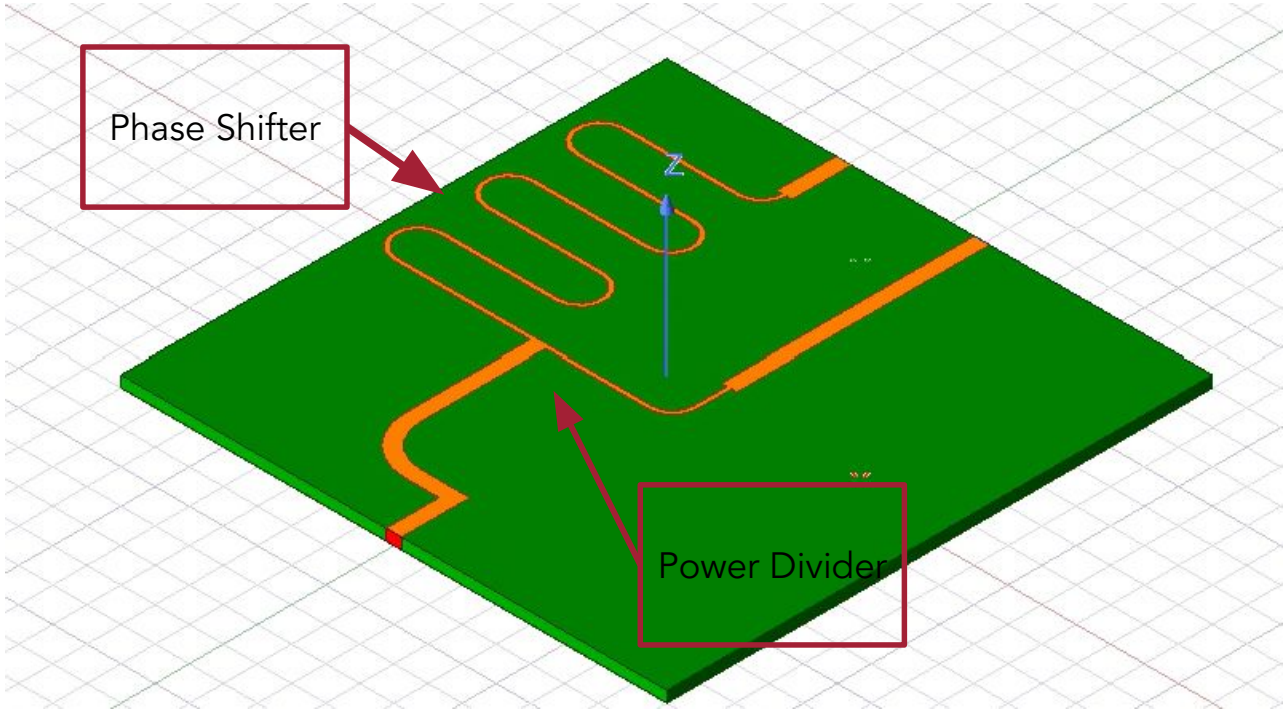


Path to Induce 180° Shift

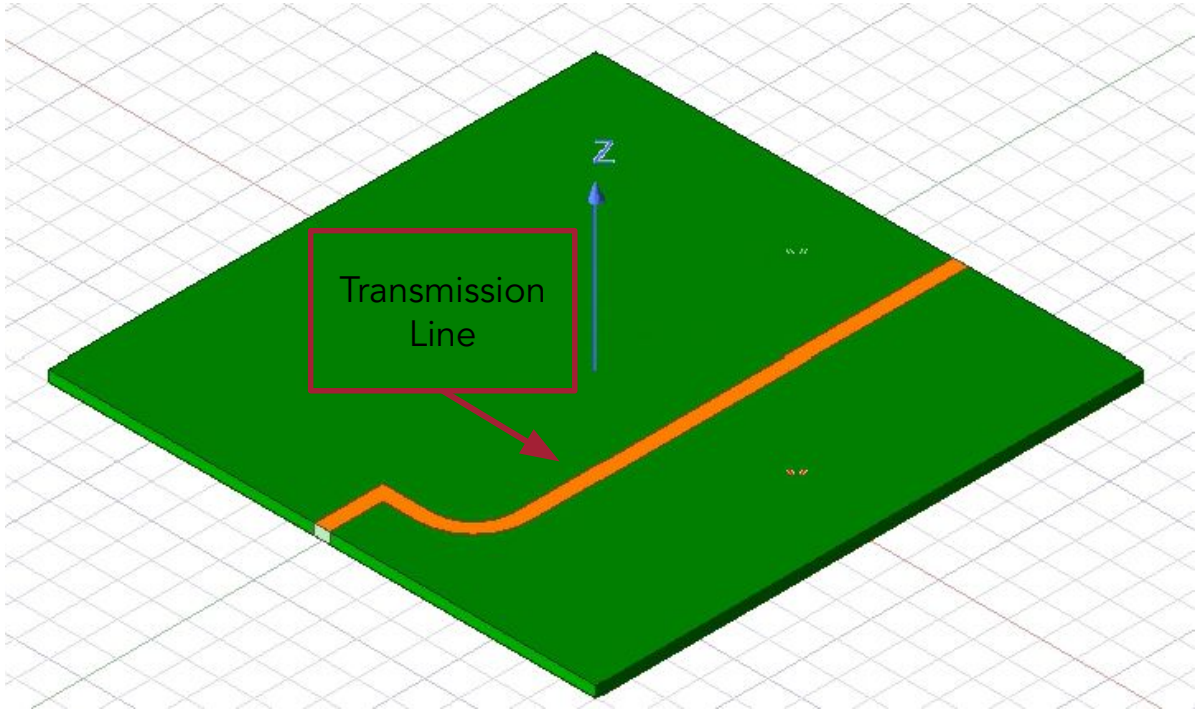


Topology to Divide Power

Simulation of System



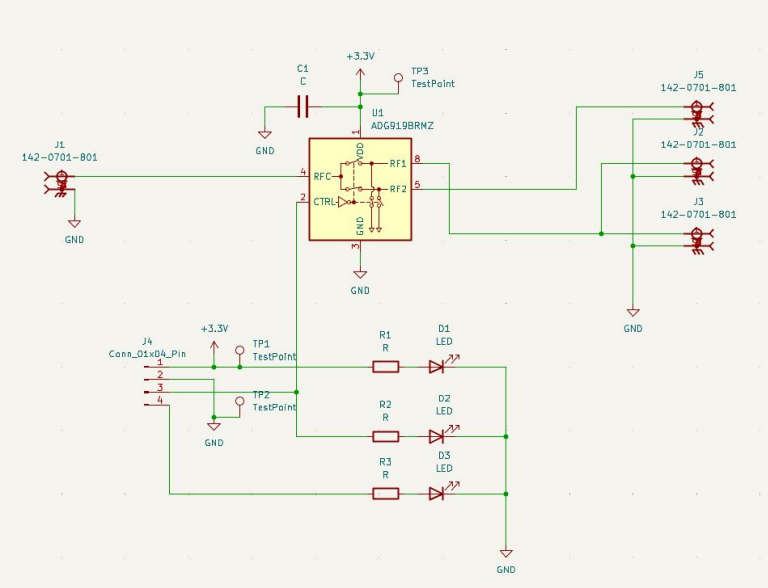
State 1: Endfire



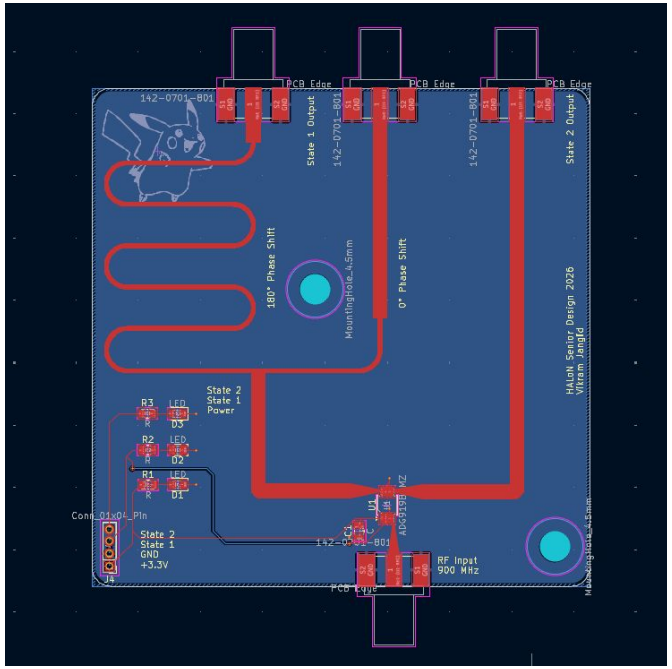
State 2: Broadside

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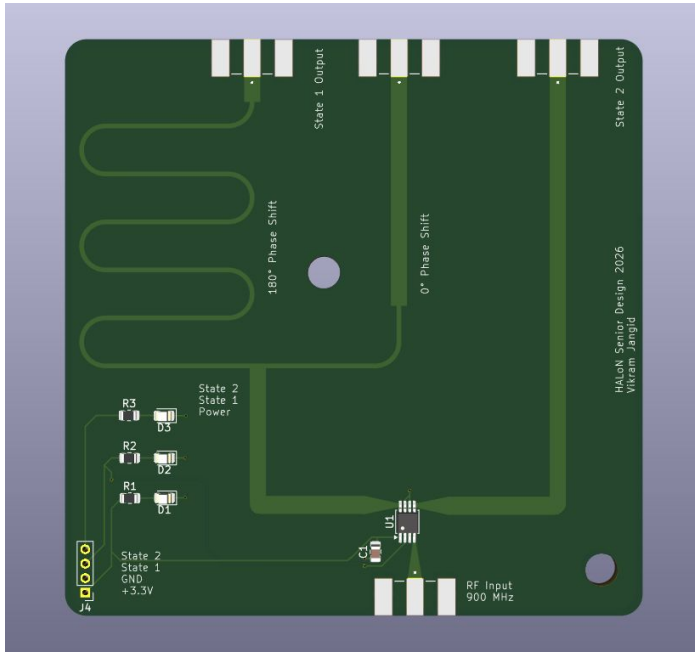
PCB Design



Schematic Diagram

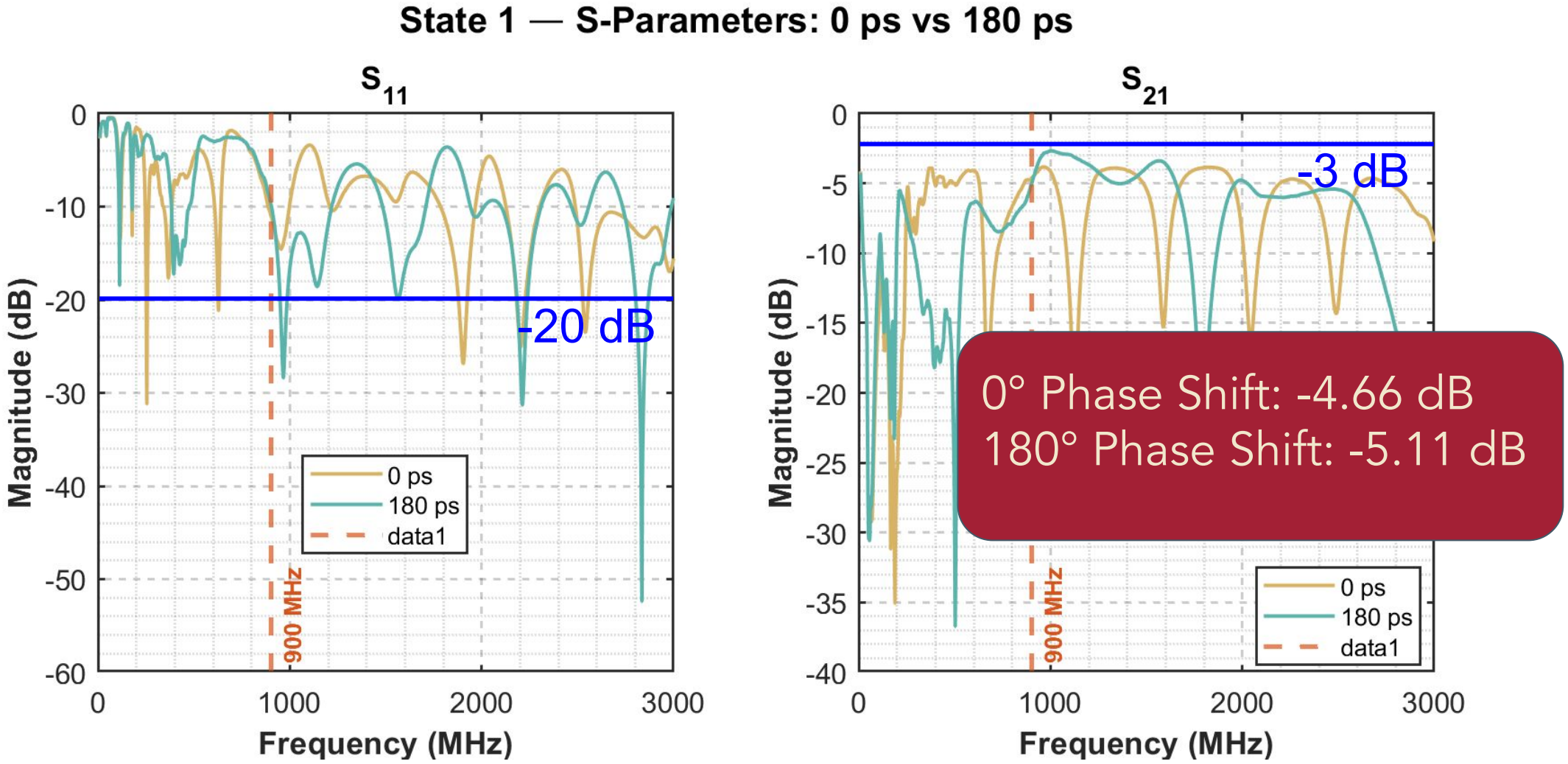


Component Layout



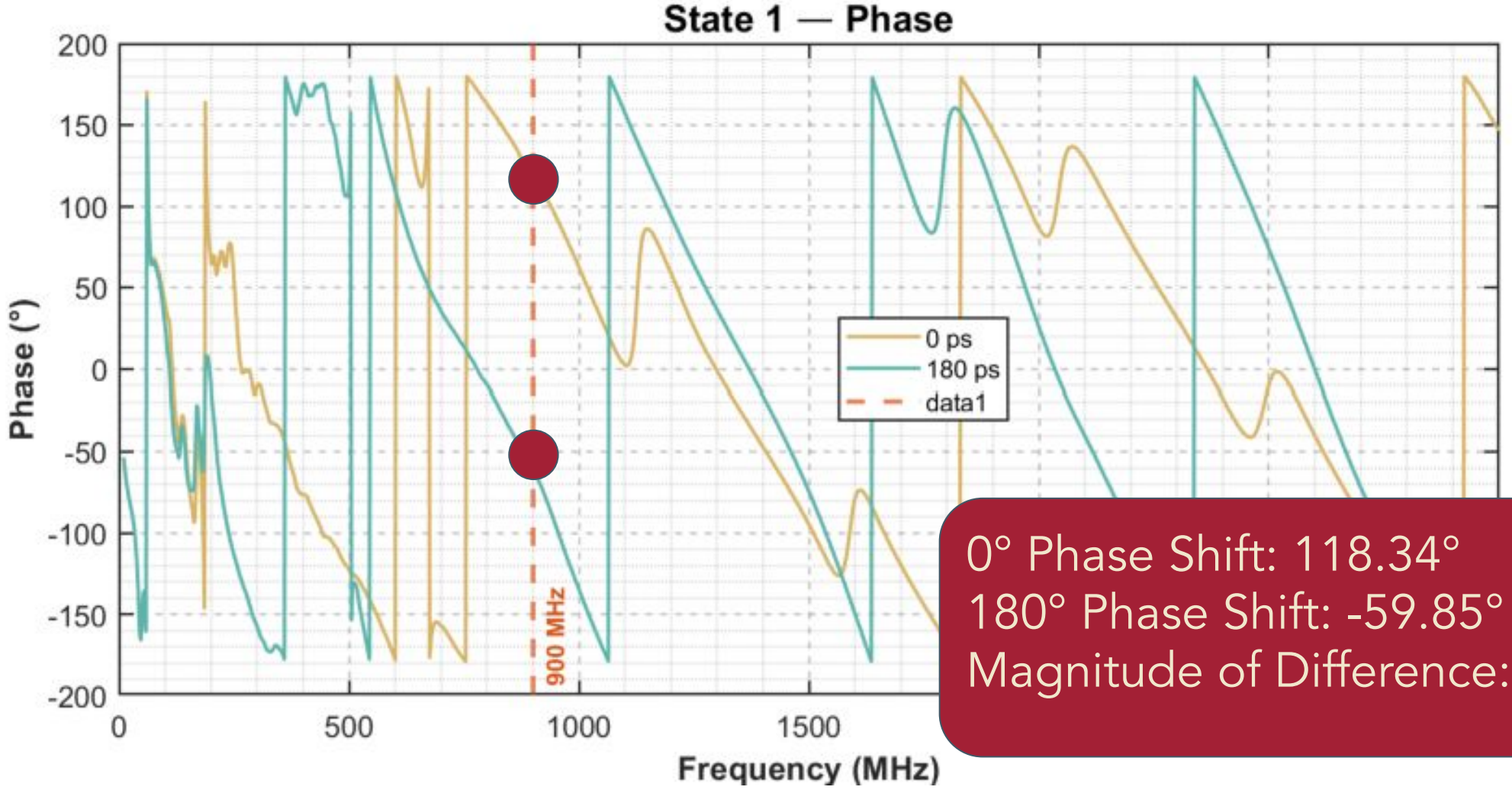
3D Model

Results


State 1 — S-Parameters: 0 ps vs 180 ps
S11
Magnitude (dB)
Frequency (MHz)
-20 dB
900 MHz
0 ps
180 ps
data1
S21
-3 dB
0° Phase Shift: -4.66 dB
180° Phase Shift: -5.11 dB

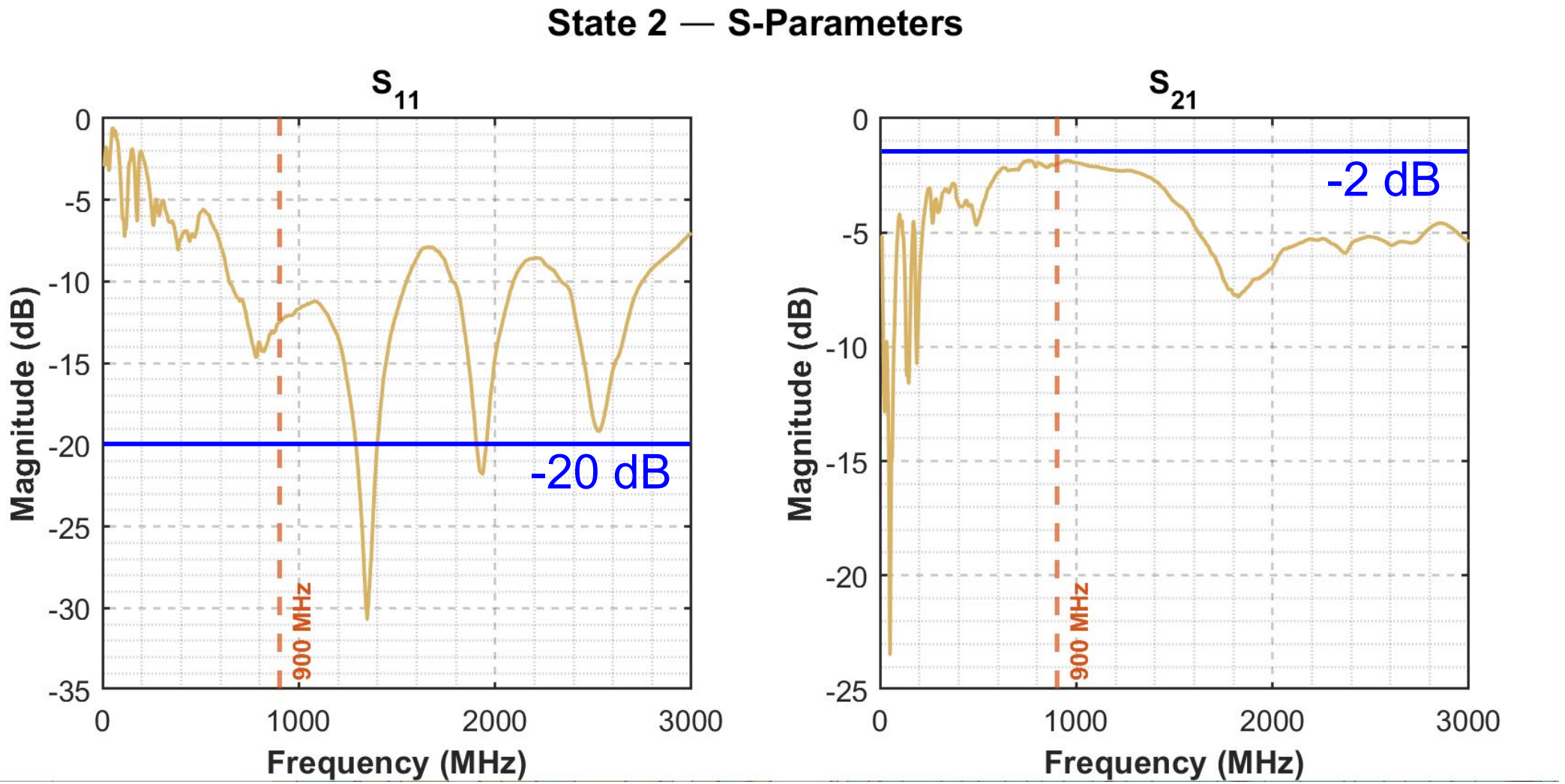
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Results



0° Phase Shift: 118.34°
180° Phase Shift: -59.85°
Magnitude of Difference: 178.19°

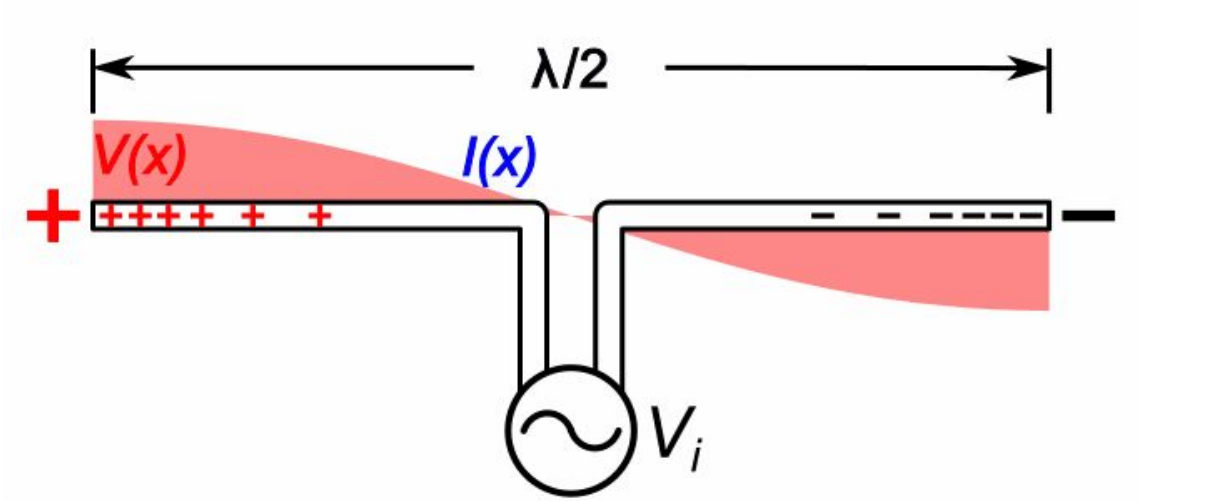
Results


State 2 — S-Parameters
S11
Magnitude (dB)
0
-5
-10
-15
-20
-25
-30
-35
-20 dB
900 MHz
0
1000
2000
3000
Frequency (MHz)
S21
Magnitude (dB)
0
-5
-10
-15
-20
-25
-2 dB
900 MHz
0
1000
2000
3000
Frequency (MHz)

Future Work

This system can still be improved through…

1. Design of the antennas that the PCB connects to
2. Integration of reconfigurable antenna system with firmware



Conclusion

Designed and developed a low cost, low power & affordable communication system to support communities in crisis.

In order to do so, we built:

- Network Simulator
- Priority Aware, Q-learning Scheduling Algorithm
- RSSI-Informed LSA Routing algorithm
- Reconfigurable Antenna Feed Network
- Scaled Testbench
- Great memories!

ACK Packets



Amma, Appa and Aran
Dr. Ramamoorthy, Dr. Schab & Dr. Schimpf
Vikram! (I suppose)
- Sahana Chandramohan

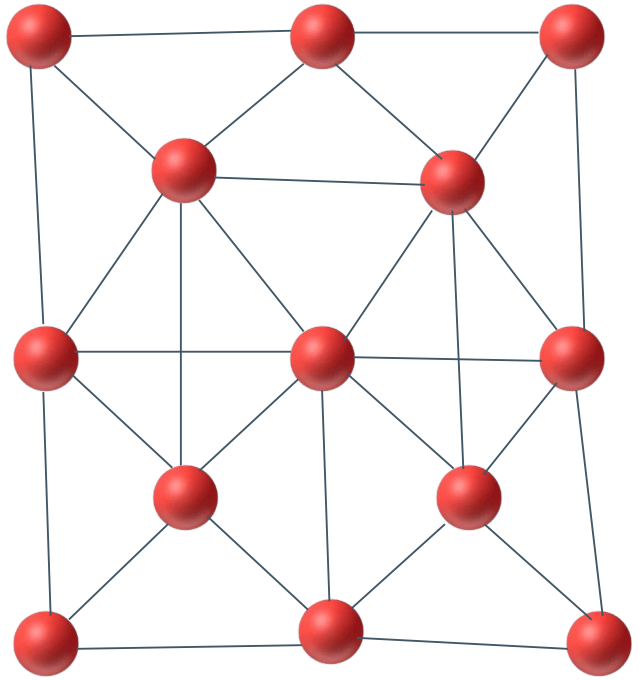
Siddhi, Rakesh, and Aditya
Dr. Schab, Dr. Ramamoorthy
RF Lab
The Sailing Team
Sahana! (I guess)
- Vikram Jangid

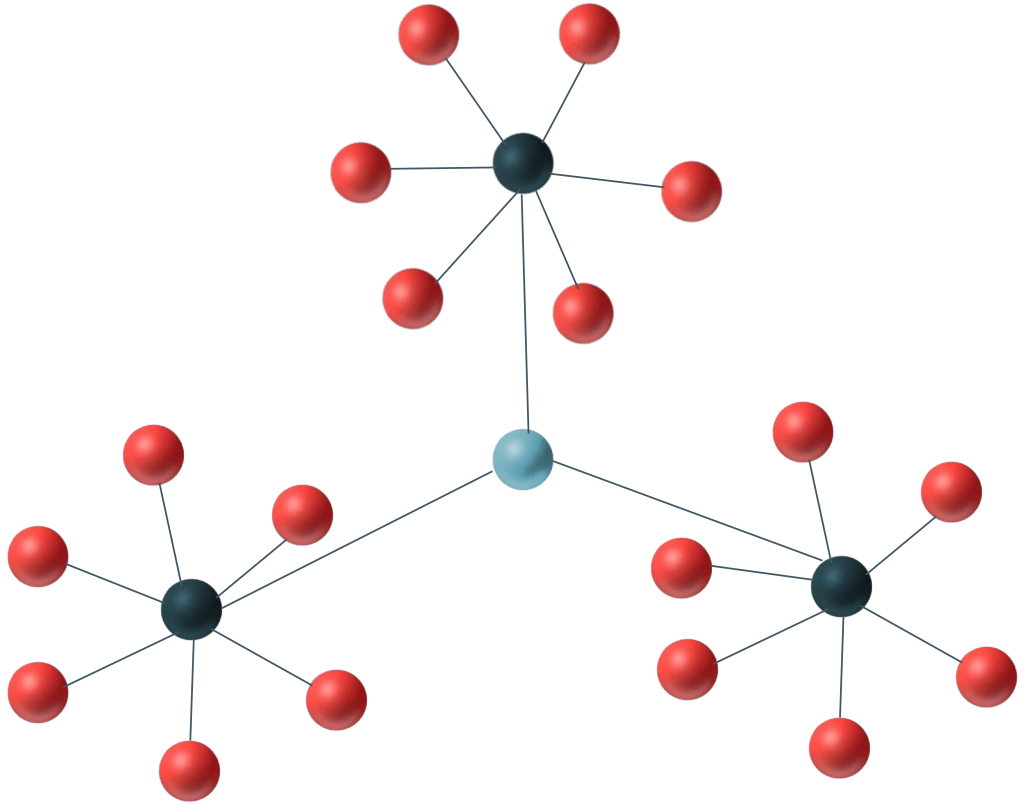


Auxiliary Slides

LoRa Mesh vs. LoRaWAN

endpoint server gateway





Radio Selection

- LoRa = Long Range
- Adafruit Feather 32u4 - RFM95 LoRa Radio
  - TX Power: 20mW ~ 13dBm
  - Industrial, Scientific and Medical (ISM) Radio Band: 900-928 MHz
  - Chirp Spread Spectrum Modulation
  - Typical Link Distance (urban): 2-5 km
- RadioHead software library → many built in functions



Part Number: 3078

Firmware Integration Challenges

- memory consumption issues
- broken acknowledgement scheme
- bricked some boards
- soldering (+ some cheeky burns)



Conclusion

future extension of the work
reiteration of the initial expectations
emphasize frugality of the project
optimal deployment of nodes

