# Building a Low Cost Mesh Network With LoRA

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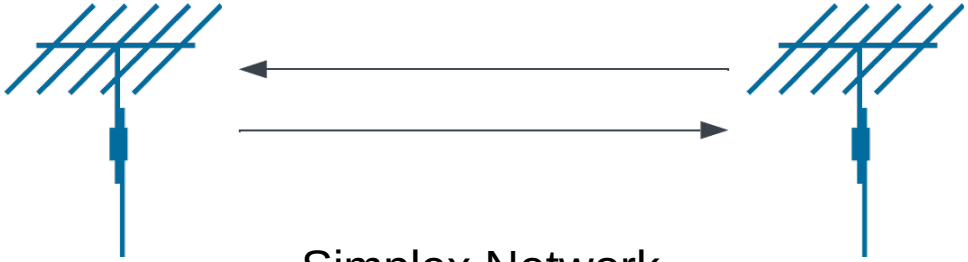
# Introduction

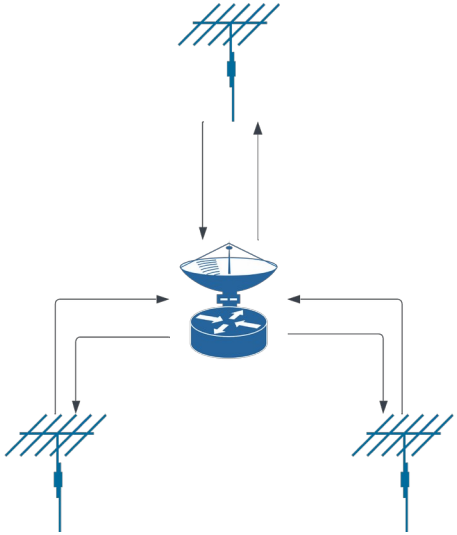
Meshtastic is an innovative open-source project that combines low-cost, long-range radio hardware with GPS capabilities to create a decentralized mesh network for off-grid communication. Primarily leveraging LoRa (Long Range) technology, it allows users to send text messages and GPS locations over vast distances, far beyond traditional cellular networks. Each device in the network, or node, can relay messages, ensuring robust and resilient communication, especially useful in outdoor and emergency scenarios. Meshtastic's unique blend of low power consumption, extended range, and smartphone connectivity makes it an ideal solution for adventurers, emergency responders, and communities in remote areas seeking reliable, alternative communication methods.

# What Is A Mesh Network

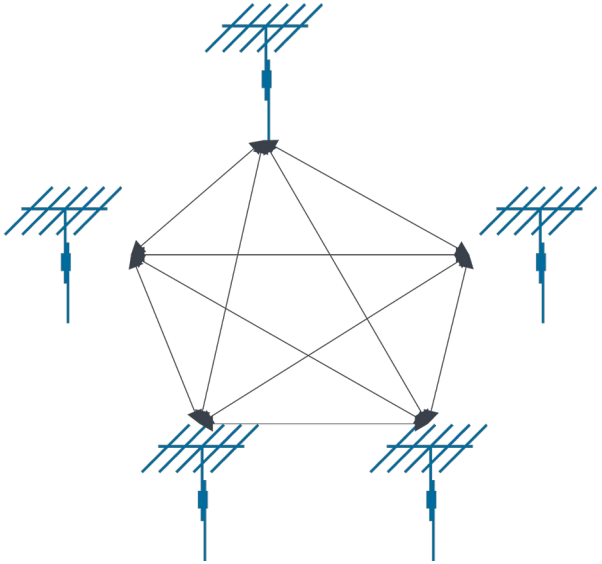


Simplex Network

Star Network

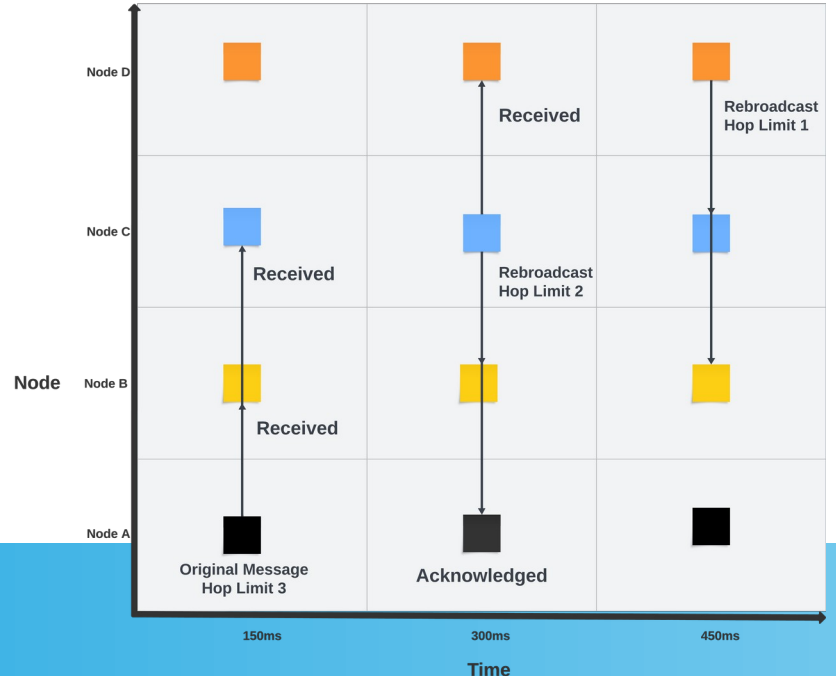


Mesh Network



# Meshtastic Theory of Operation

- NodeA broadcasts a message to the mesh
- NodeB receives the message
  - Node1 checks the message SNR and delays rebroadcasting
- NodeC receives the message
  - Node2 rebroadcasts the message sooner that node1 due to the lower SNR, this acts as an ack for node0, and prevents node1 from rebroadcasting.
- NodeD receives the message
  - Node3 decrements the hoplimit number
  - if its more than 0 it rebrodcasts and decrements
  - If hoplimit is 0 it does nothing.



# Encryption and Security

- Encryption is implemented in devices/nodes with network-wide encryption keys. Stream cipher is AES256-CTR. Our AES key is 128 or 256 bits, shared as part of the 'Channel' specification.
- Encryption is optional and is turned off when devices are in 'Ham mode'.
- There is no encryption supported in the clients (iOS, Android) to facilitate distribution as mass market software.
- Pairing from client-to-device is by:
  - direct USB cable
  - BT pairing
  - Ethernet / wireless network
- Devices are 'promiscuous' and will pair with any near-by client. Network confidentiality requires physical protection of all nodes.

# Use Cases

- Off grid communication
  - Long range communication in remote areas
  - Send location data in case of emergency
  - Easily deployable remote self contained router nodes
- Remote sensors / actuators
  - Farm water level monitoring
  - Remote sensors send data to a central MQTT server for logging
- Encrypted local messaging
  - Communicate in Cellular / internet denied areas
  - Secure messaging / PSK can be rotated
  - MQTT can be used to securely connect meshes over long distances

# Technical Details

- Max message size
  - 256 bytes total
    - Low Level Header: 16 bytes
    - Node UUID: 3 bytes
    - Available Message size: 237 bytes
- App / API
  - Android and iOS apps
  - Python API
  - MQTT
- Max range
  - Maximum tested range is 254km (158 miles)
  - Max of 50 – 100 nodes depending on available RAM
- Power
  - Varies by hardware, TBEAM 3v 180ma max (GPS, Transmit, and display on)
  - Most include battery charging circuit
  - Often include input for solar panels

# Bandwidth

| Channel setting | Alt Channel Name | Data-Rate | SF / Symbols | Coding Rate | Bandwidth | Link Budget |
|---|---|---|---|---|---|---|
| Short Range / Fast | Short Fast | 10.94 kbps | 7 / 128 | 4/5 | 250 | 137dB |
| Short Range / Slow | Short Slow | 6.25 kbps | 8 / 256 | 4/5 | 250 | 140dB |
| Medium Range / Fast | Medium Fast | 3.52 kbps | 9 / 512 | 4/5 | 250 | 143dB |
| Medium Range / Slow | Medium Slow | 2.95 kbps | 10 / 1024 | 4/5 | 250 | 146dB |
| Long Range / Fast | Long Fast | 1.07 kbps (default) | 11 / 2048 | 4/5 | 250 | 148.5dB |
| Long Range / Moderate | Long Moderate | 0.335 kbps | 11 / 2048 | 4/8 | 125 | 151dB |
| Long Range / Slow | Long Slow | 0.18 kbps | 12 / 4096 | 4/8 | 125 | 154dB |
| Very Long Range / Slow | Very Long Slow | 0.09 kbps | 12 / 4096 | 4/8 | 62.5 | 157dB |

# Hardware Options

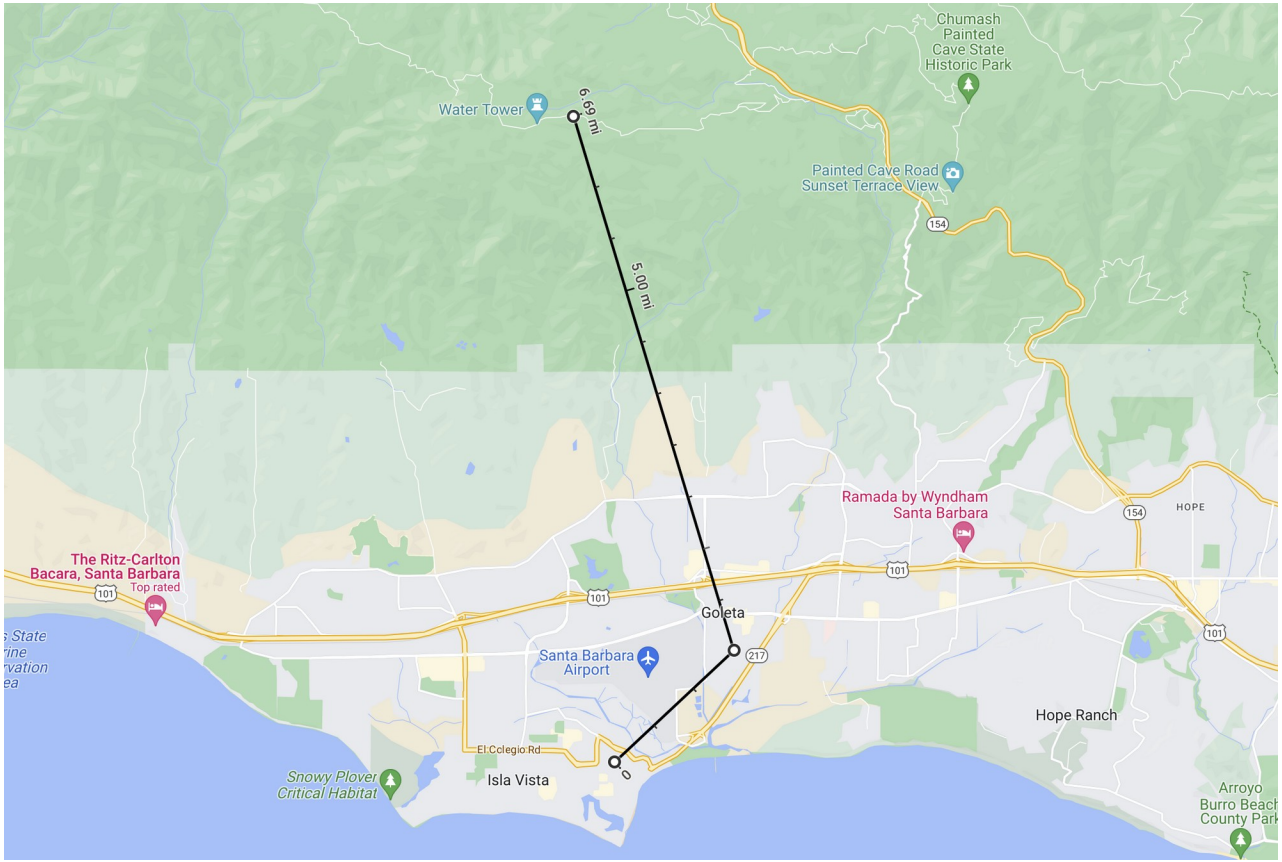
- Lilygo
  - T-Beam (ESP32)
  - T-echo (nRF52840)
  - LoRA (ESP32)
  - T-Deck (ESP32, AIO)
  - T-Watch (nRF54280, wearable)
- Station
  - G1 (ESP32, for licensed HAMs)
  - Nano G2 / Explorer (mobile)
- RAKwireless
  - RAK4631 (nRF52840)
  - RAK11200 (ESP32)
  - RAK11310 (RP2040)
- Radios
  - All use SX12xx LoRA radios
  - ISM 915mhz, 858mhz bands
- Cost
  - Prices vary, most nodes between $30 and $100

# Example Fixed Node

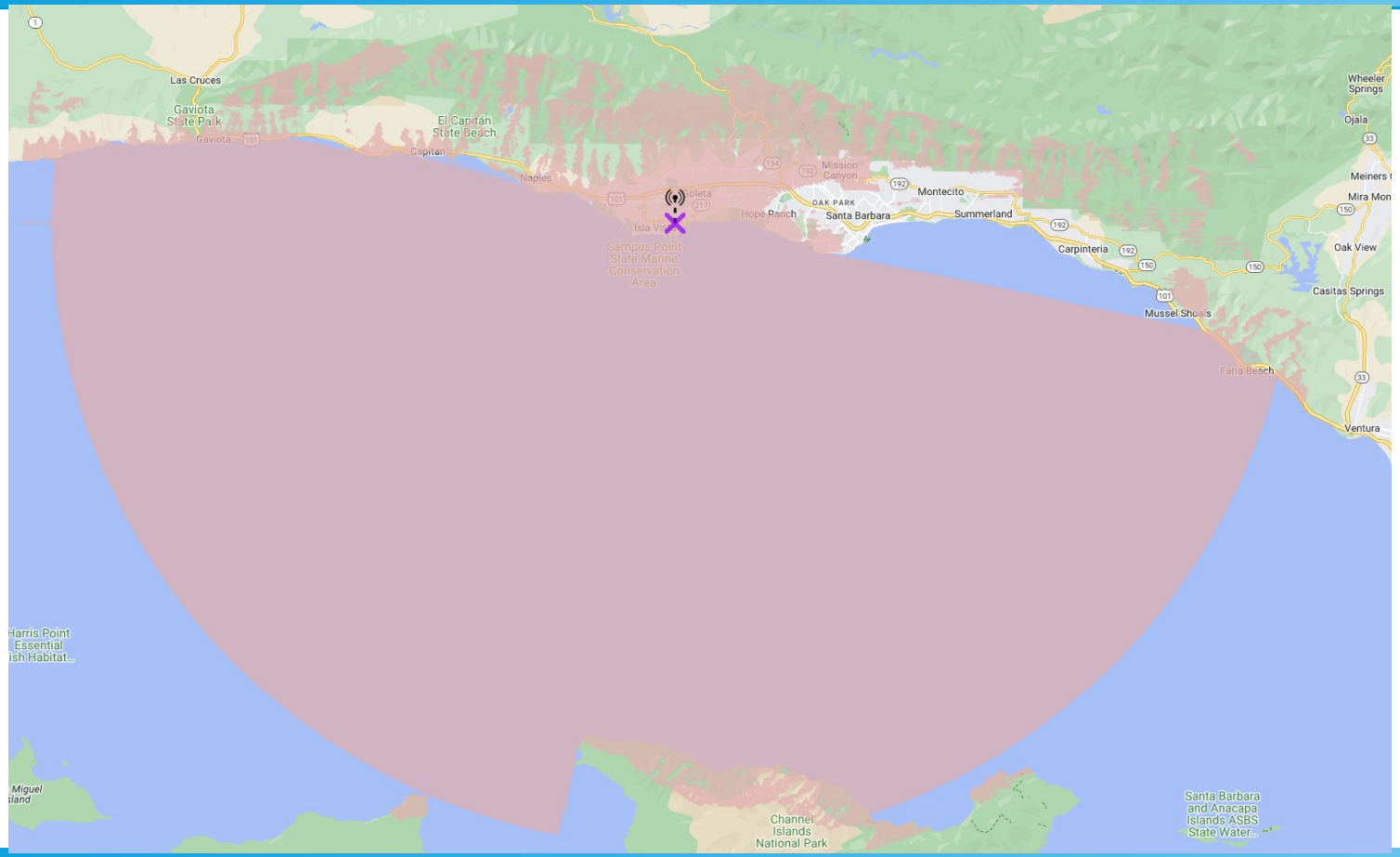
- IP65 Waterproof Enclosure 156 x 90 x 60 mm - $10
  - https://www.amazon.com/gp/product/B07H5GS8VY/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&psc=1
- 10 Ah Lithium Ion Battery - $27
  - https://www.amazon.com/gp/product/B07S75HC2H/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&psc=1
- Bulkhead SMA Connector - $8
  - https://www.amazon.com/gp/product/B07BXZ2NDV/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&psc=1
- 5v 1A Solar Panel with Regulator - $14
  - https://www.amazon.com/gp/product/B099RSLNZ4/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&th=1
- Bulkhead Gland - $10 (20x)
  - https://www.amazon.com/gp/product/B085NVDC3K/ref=ppx_yo_dt_b_asin_title_o06_s00?ie=UTF8&psc=1
- 5.8dbi 915mhz Omni antenna - $53 (1x)
  - https://www.amazon.com/gp/product/B09TZVQ4F7/ref=ppx_yo_dt_b_asin_title_o07_s00?ie=UTF8&psc=1
- Ulkhead IP65 momentary pushbutton - $10 (6x)
  - https://www.amazon.com/gp/product/B08R9P3RKM/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1
- Lilygo LoRA32 - $32
  - https://www.amazon.com/gp/product/B09SHRWVNB/ref=ppx_yo_dt_b_asin_title_o08_s00?ie=UTF8&psc=1
- 6” SMA male to male extender - $9
  - https://www.amazon.com/gp/product/B0C34KL463/ref=ppx_yo_dt_b_asin_title_o02_s01?ie=UTF8&psc=1

Total: $146.70

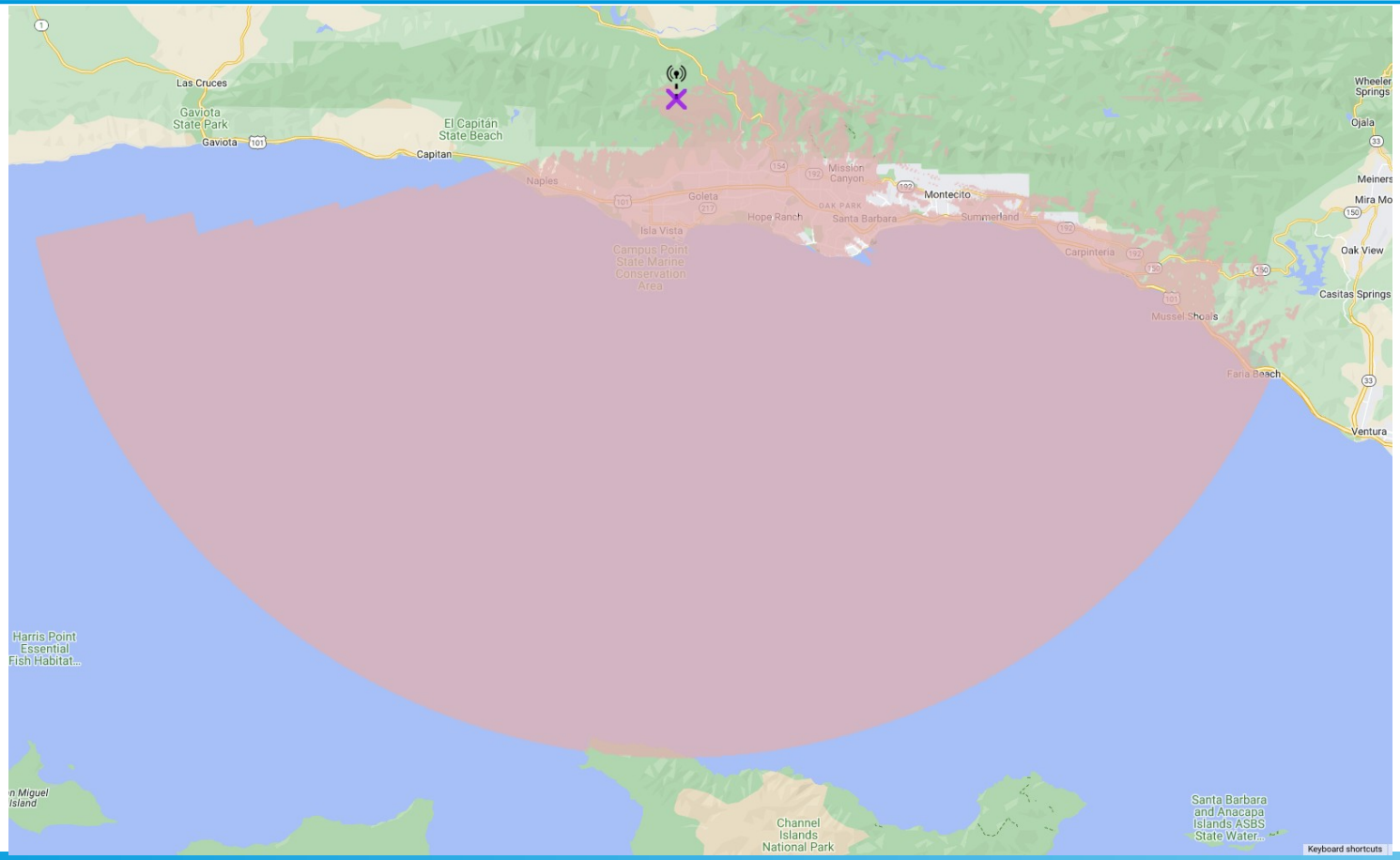
# Existing Network



# Approximate Coverage From UCSB



# Approximate Coverage From E. Camino Cielo



# References


- https://meshtastic.org/docs/introduction
- https://github.com/meshtastic
- https://github.com/GUVWAF/Meshtasticator
- https://meshtastic.org/docs/overview/range-tests
- https://en.wikipedia.org/wiki/LoRa