LoRa Mesh Network for IoT Applications

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Introduction

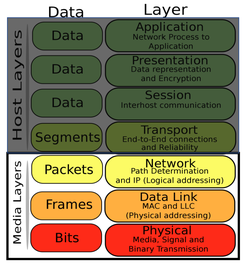
- **Problem** – *Large-scale monitoring of various agricultural parameters: temperature, humidity, barometric pressure, etc.*

- **How do you collect sensor data from dozens of sensors across a large area?**
- Dozens of square kilometers
- No existing infrastructure
- Low power – indefinite lifespan with solar panels
- Not a lot of data – a few bytes per sensor per hour

Background

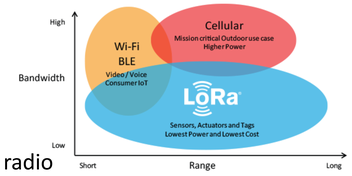
Networking Model:

- To get data from the nodes to a server, the data needs to go across a network
- Packet-switched networks are built in layers
- We are concerned with layers 1, 2, and 3 – Physical, Data Link, and Network



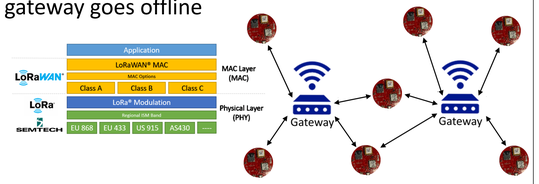
LoRaPHY:

- Long range
- Low cost
- Low power
- Low bandwidth
- Uses unlicensed radio frequency bands (which differ by region)



Current Solution: LoRaWAN Protocol

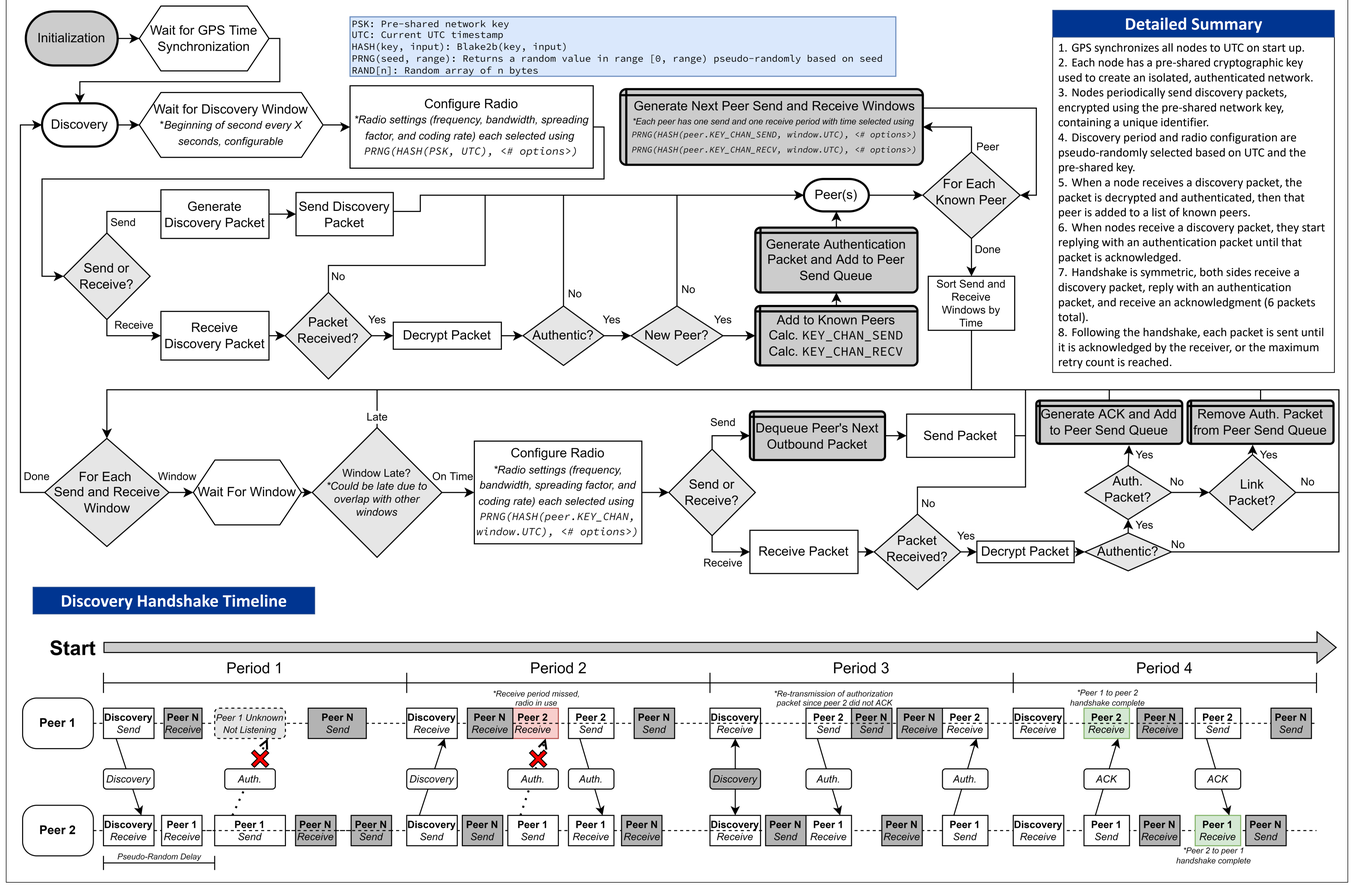
- Built on top of LoRaPHY
- Uses a star network topology
- Limited expandability/scalability since each node must connect directly to a gateway
- Requires hands-on setup and maintenance
- Gateways are relatively expensive
- No peer-to-peer communication, no failover if gateway goes offline



Why Use a Mesh Network Instead?

- Gateways are expensive
- Less user maintenance
- Redundancy against individual node failures

Mesh Protocol – Peer-to-Peer Data Link



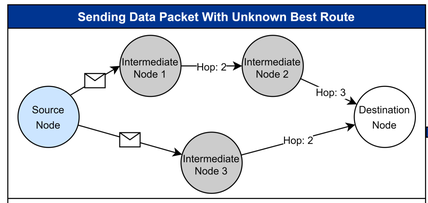
Detailed Summary

1. GPS synchronizes all nodes to UTC on start up.
2. Each node has a pre-shared cryptographic key used to create an isolated, authenticated network.
3. Nodes periodically send discovery packets, encrypted using the pre-shared network key, containing a unique identifier.
4. Discovery period and radio configuration are pseudo-randomly selected based on UTC and the pre-shared key.
5. When a node receives a discovery packet, the packet is decrypted and authenticated, then that peer is added to a list of known peers.
6. When nodes receive a discovery packet, they start replying with an authentication packet until that packet is acknowledged.
7. Handshake is symmetric, both sides receive a discovery packet, reply with an authentication packet, and receive an acknowledgment (6 packets total).
8. Following the handshake, each packet is sent until it is acknowledged by the receiver, or the maximum retry count is reached.

Discovery Handshake Timeline

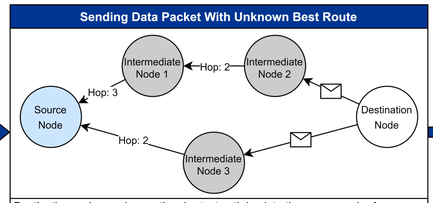
Mesh Protocol – Network Packet Routing

Sending Data Packet With Unknown Best Route



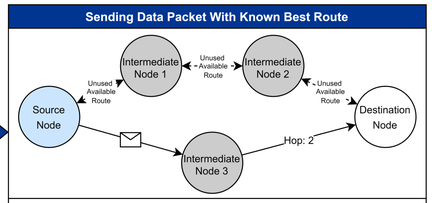
Source node initially floods all connected peers with data packet to count how many hops the packet takes through each peer to get to the destination node.

Sending Data Packet With Unknown Best Route



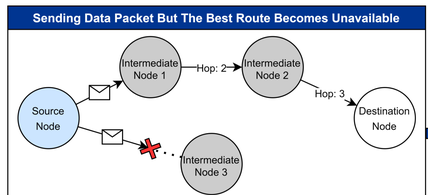
Destination node now knows the shortest path back to the source node. An acknowledgement packet is sent via each available return path so that the source node also knows the shortest path to the destination node. Each node sorts and stores the discovered routes by their length, with the shortest routes having the highest priority.

Sending Data Packet With Known Best Route



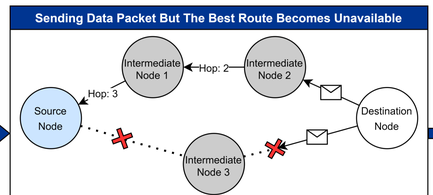
The next time the source node has to transmit a packet to the destination node it will prioritize the shortest available route. The other possible routes are stored, but unused.

Sending Data Packet But The Best Route Becomes Unavailable



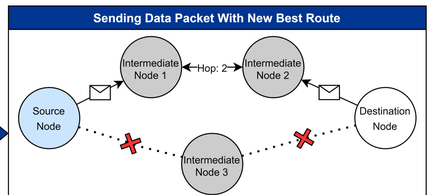
The source node will attempt to send a message via the shortest available route several times. If the packet is still not acknowledged, it will lower the priority of the original route and try a different stored route, even if that route is longer.

Sending Data Packet But The Best Route Becomes Unavailable



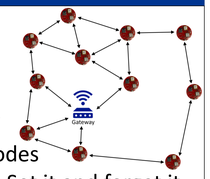
The destination node will attempt to reply via the best available route, which is still via node 3. When that node fails to acknowledge the packet, the destination node will lower the priority of that route and send the packet via node 2.

Sending Data Packet With New Best Route



Both the source and destination nodes have determined that node 3 is no longer the best path and have updated their routing tables accordingly. Further communication will be via nodes 1 and 2. This demonstrates the self-configuration capabilities of the mesh.

Solution



- Also built on top of LoRaPHY
- Alternative to LoRaWAN
- Very expandable/scalable
- Low maintenance and hands-off
- Traffic is load-balanced across nodes
- Self-configuring and correcting – Set it and forget it
- Peer-to-peer packet routing, only one gateway is needed, multiple can be added
- Capable of simultaneous overlapping networks

Future Work

- Improved response time for changes to the network, such as nodes being added/removed or physically moving
- Dynamic duty cycle adjustment to reduce wasted processing time during periods of low network utilization
- Better sleep state management for lower overall power consumption
- Better routing decisions and radio configuration selection based on signal integrity and proximity to peer
- Large scale testing over long time periods

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Library GitHub Link

https://github.com/arc968/LoRaMeshCapstone