INTEGRATED PROJECT · PIC 2025/26 · INSTITUTO SUPERIOR TÉCNICO

SkyMesh

Self-healing aerial network for rescue operations

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Project site & demo

100%
link restoration after UAV join

2.3%
voice-grade packet loss (≤5% target)

2.6 km
energy-aware return-to-home radius

1 PROBLEM & MOTIVATION

- Disaster zones & SAR often have **no fixed network** — cellular absent or down.
- Teams lose line-of-sight → **mesh partitions** → voice, telemetry & situational awareness lost.
- Existing solutions are **costly, proprietary or infrastructure-dependent**.

14h30

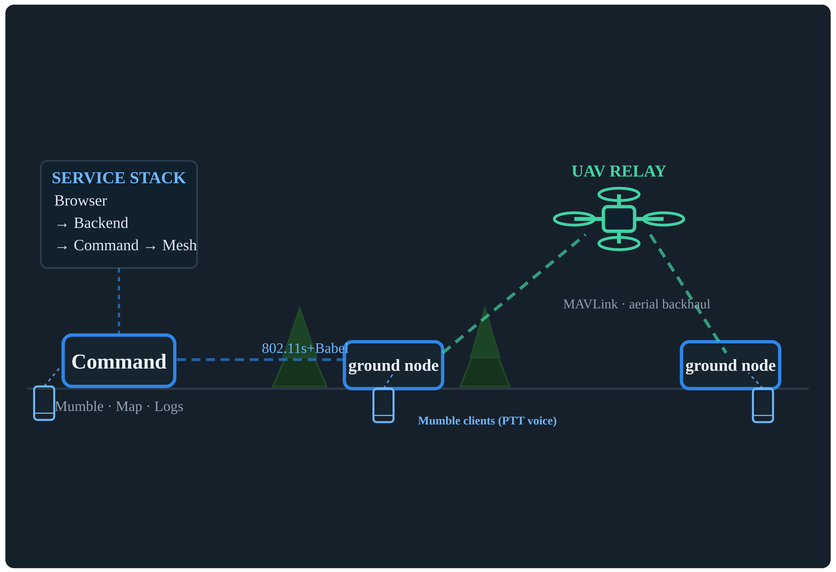
Emergency network (SIRESP) down · 10+ distress calls undelivered

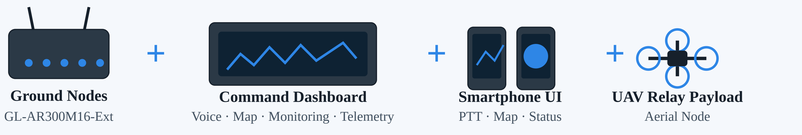
Pedrógão Grande wildfires, Portugal · 2017

Can we keep voice + telemetry using only portable ground nodes and autonomous aerial relays?

2 SYSTEM & ARCHITECTURE

- Three roles: **Command** · **ground node** · **UAV relay**.
- Stack: **browser → backend → Command → Babel mesh**.





SELF-HEALING LOOP

3 METHODS

A · MESH & ROUTING

- **802.11s + Babel**; the **ETX** wireless metric adapts routes to live link quality — traffic always follows the healthiest path.

B · AIR-GROUND RF MODEL

- Link budget = **FSPL + Al-Hourani (2014)** excess path loss; RSSI mapped to usable tiers (Excellent → Blocked).

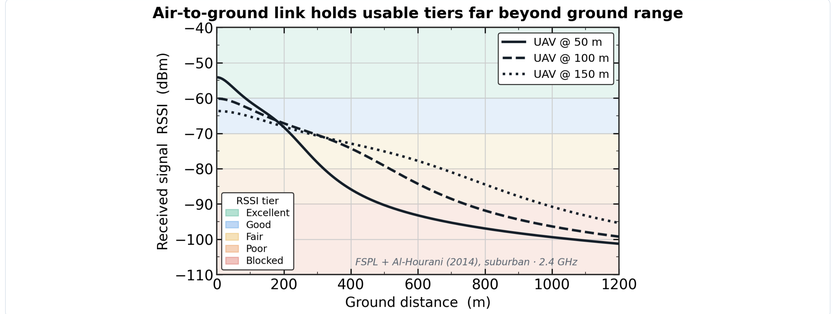
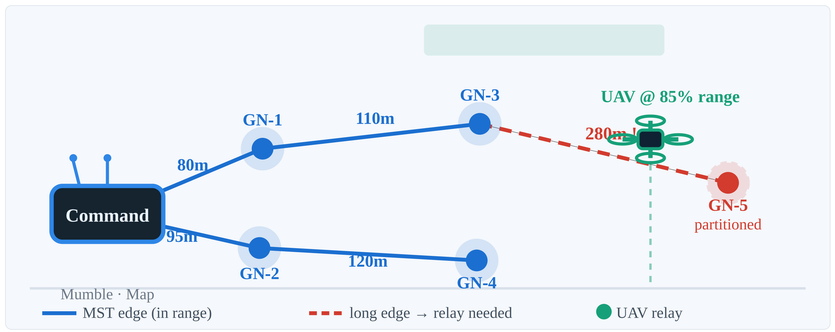


Fig 1. An aerial relay holds the link in usable tiers well beyond ground range.

C · RELAY PLACEMENT (MST)

- **Minimum spanning tree** over anchors; UAV placed on long edges at **85% of usable range** (safety margin).



D · ENERGY-AWARE RTH (ZENG 2019)

- Return-to-home triggers on the **energy needed to fly back** — not a naïve fixed 10% reserve.

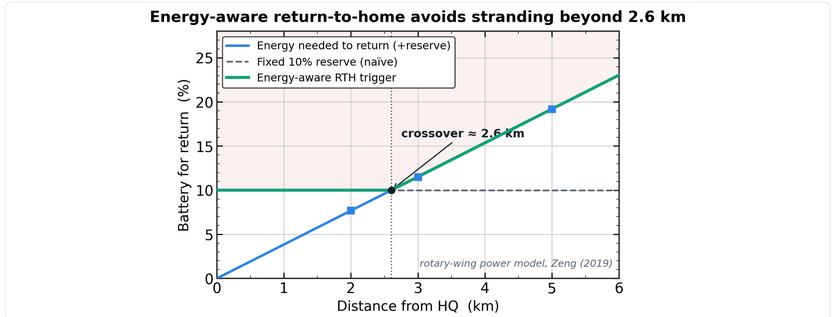


Fig 2. Beyond 2.6 km a fixed reserve is unsafe — the drone computes return energy from distance flown.

4 IMPLEMENTATION

- **Reproducible lab:** OpenWrt on **QEMU / Docker** — iterate with no hardware.
- **pic-nav** (relay/navigation logic) + **pic-gossip** (state sharing) onboard.
- **Command dashboard** (React / TanStack): live map, voice, monitoring, telemetry.
- UAV control & telemetry via **MAVLink**.

OpenWrt · 802.11s · Babel · QEMU · Mumble (PTT) · MAVLink · React

5 RESULTS & EVALUATION

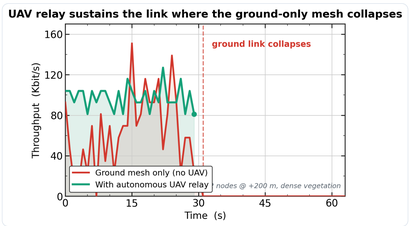


Fig 3. UAV relay sustains throughput where the ground mesh collapses at 31 s.

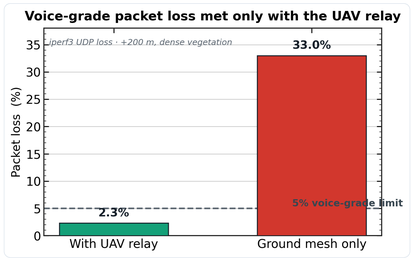


Fig 4. Voice-grade packet loss (≤5%) met only with the relay (2.3% vs 33%).

Dist. to Command	Return energy	RTH triggers
2 km	**7.7%**	**10% (floor)**
3 km	**11.5%**	**11.5%**
5 km	**19.2%**	**19.2%**

100% link restoration *after the relay joins; Babel reconverges in seconds.*

6 CONCLUSION & FUTURE WORK

Portable nodes plus an **autonomous aerial relay** keep voice and telemetry online across partitions — with **energy-safe** UAV operation.

- **Next:** multi-UAV scaling & relay hand-off
- Real-hardware field trials
- Link security & encryption

§ REFERENCES

1 Al-Hourani et al., *Optimal LAP Altitude for Maximum Coverage*, IEEE WCL, 2014.

2 Zeng et al., *Energy Minimization for Rotary-Wing UAV Communication*, IEEE TWC, 2019.

3 Chroboczek, *The Babel Routing Protocol*, RFC 8966, 2021.

4 IEEE 802.11s — Mesh Networking; Mumble/Murmur — low-latency voice (PTT).