



A HYBRID UAV COMMUNICATION FRAMEWORK FOR NEXT-GENERATION ROBOTIC EXPLORATION MISSIONS



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Introduction

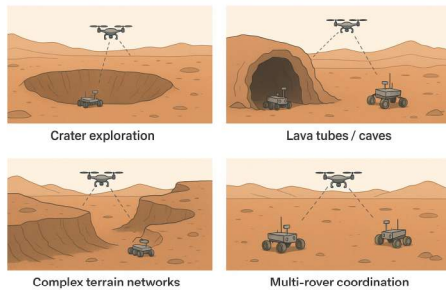
Future planetary exploration increasingly targets subsurface environments on the Moon and Mars such as lava tubes and collapse pits. Current architectures rely on orbital sensing and surface rovers, creating a gap between large-scale observation and local exploration. Terrain often causes loss of line-of-sight communication. UAV-based aerial relays can restore connectivity and support exploration in obstructed environments

Objective

This work investigates the use of UAV-based aerial relays to support rover communication in terrain-induced NLOS environments.

Focus areas:

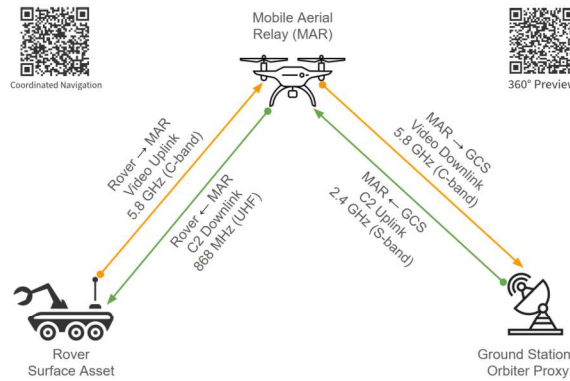
- Restoring line-of-sight communication for rover missions
 - Evaluating relay-assisted multi-hop communication
 - Analysing relay placement and altitude effects on link reliability



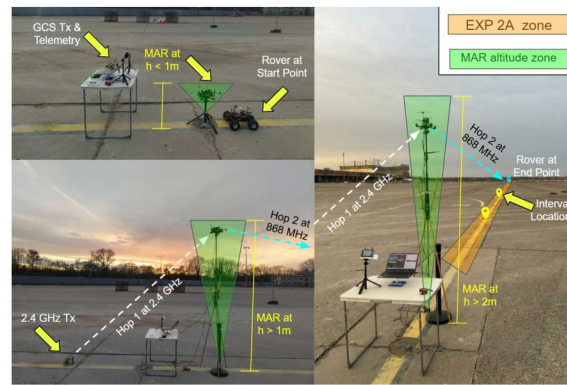
Methodology

- Design and development of a rover-drone communication architecture using a Mobile Aerial Relay (MAR).
- Field experiments conducted in Mars-analog environments to evaluate communication performance under terrain-induced NLOS conditions.
- Comparative evaluation of direct communication vs relay-assisted communication.
- Development of a relay planner and terrain-aware optimizer to analyse relay placement and link margins.
- Experimental validation of relay-assisted communication in mission-scale scenarios.

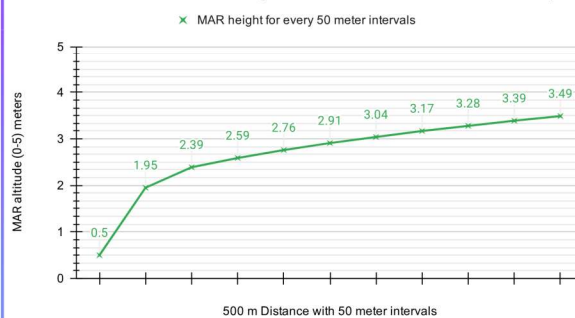
System Architecture



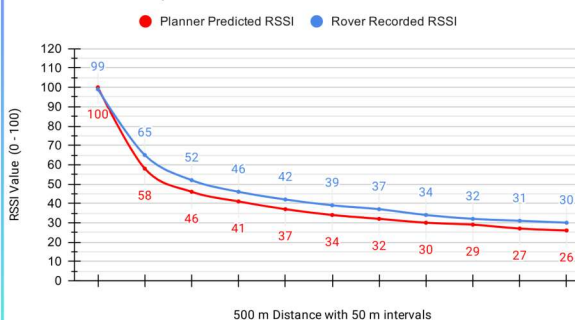
Experimental Setup & Observations



Planner Recommended Height to Position MAR for 500m Sweep



RSSI values predicted vs. recorded over 500m distance



Results & Discussion

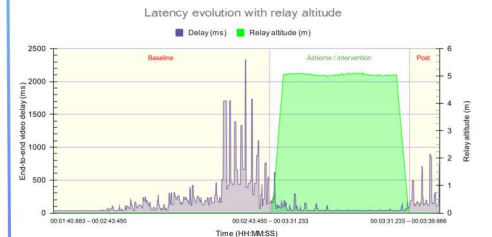
The UAV relay restores line-of-sight communication paths and reduces signal attenuation caused by terrain features.

This architecture provides a scalable solution for robotic exploration missions operating in:

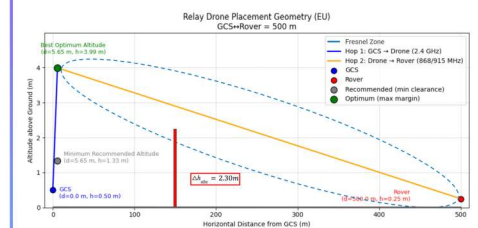
- cratered terrain
- underground structures
- planetary caves and lava tubes
- cluttered terrestrial environments



Experiment Observation



Field experiments show that terrain-induced obstacles significantly degrade direct rover communication. Deploying a UAV-based Mobile Aerial Relay restores line-of-sight and stabilizes the link. Relay-assisted configurations improve signal reliability and reduce data loss, while optimizer-guided relay placement extends operational range under non-line-of-sight conditions.



Conclusion

Terrain-induced line-of-sight loss is a major constraint for rover communication in complex environments. UAV-based mobile aerial relays can effectively restore connectivity and improve communication reliability. Relay planning and terrain-aware optimization enable more robust relay placement, supporting extended operational range and more resilient robotic exploration missions.



Advanced communication and networking technologies for mars exploration. (NASA/TM-2001-210975, 2001).

Continuous Airborne Communication Relay Approach Using Unmanned Aerial Vehicles, volume 65. 01 2012.

Planetary and Space Science, 58 (4):592-598, 2010.

Key Sources & Acknowledgements

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