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Northeastern University

Commercial Aircraft as Sustainable Relays for Satellite Direct-to-Device Access

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Motivation

- An **unmodified handset** can close a satellite link only at **low frequency**.
- Measurements of Starlink's direct-to-cell: about **3Mbps per beam** on a 5MHz channel.

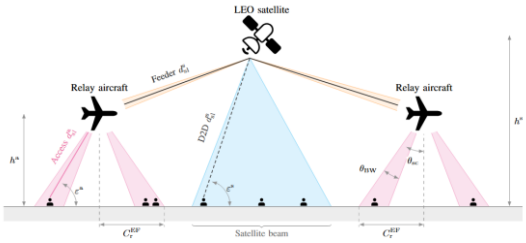
→ **Limited to messaging**

Relaying splits the strongly attenuated link into two hops, moving the complexity away from the handset.

However, common relays (such as UAVs, HAPs):
- Must be **built**, **launched and kept in service** for this purpose.
- Work only where they are deployed, limiting scalability and sustainability.

Proposal

Commercial aircraft act as **regenerative** decode-and-forward **relays, steering the beam** towards the users below.



Sustainable as:
- **Aicraft already fly:** no new launch and deployment.
- **Fewer satellite needed** for the same delivered service.
- **Limited hardware complexity,** negligible added mass and power consumption.

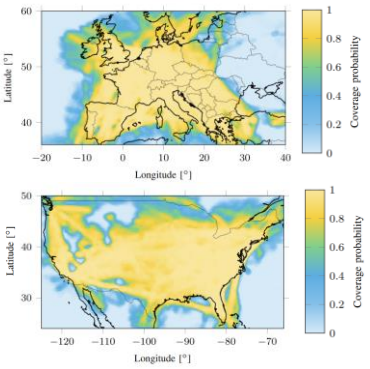
Evaluation

Real coverage measurement

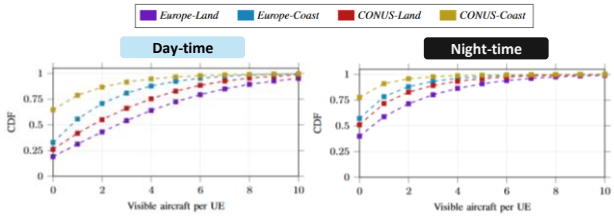
STARLINK | OPENSKY

3 Days of OpenSky ADS-B flight traces and **Starlink orbital data** over Europe and the United States, day and night.

Most of both continents are covered, including **remote areas with no network today**. Coverage reduces over coasts.

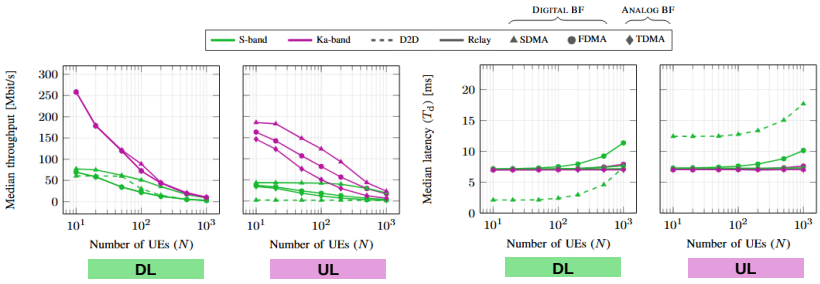


In Europe, by day,more than half of the see at least 3 aircraft at once**, relay diversity**.



End-to-end network performance

NTN channel model of the access and feeder links, in S- and Ka-band, with analog and digital beamforming and different beam multiplexing schemes (**TDMA**, **FDMA**, **SDMA**).



- Aircraft relay provides a much larger data rate and a more **stable latency**,
- SDMA gives the highest rate, at the cost of **one RF chain per beam** (up to 100 under high load).
- Analog **TDMA** approaches SDMA performance but **with a single RF chain**, still enabling broadband connectivity, but with a lower complexity and cost.

Conclusions

- Aircraft can bring Ka-band broadband connectivity to unmodified handset: **84%** coverage on Europe by day, **120Mbit/s** UL, and **7ms** latency.
- Sustainable as: **no new platforms** and launches needed, and **a single RF chain** can still enable broadband services.

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