Overview of MRAV-enabled wireless communication scenarios

Daniel Bonilla Licea[1], Giuseppe Silano[3,2], **Hajar El Hammouti**[1], Martin Saska[2], and Mounir Ghogho[1]

Half-day Tutorial Session at ICUAS 2026 (09:00 – 13:00), 15th June 2026
Room Calypso A – Divani Corfu Palace

[1]Mohammed VI Polytechnic University, Ben Guerir, Morocco,
[2]Czech Technical University in Prague, Prague, Czechia,
[3]Ricerca sul Sistema Energetico, Milan, Italy

hajar.elhammouti@um6p.ma

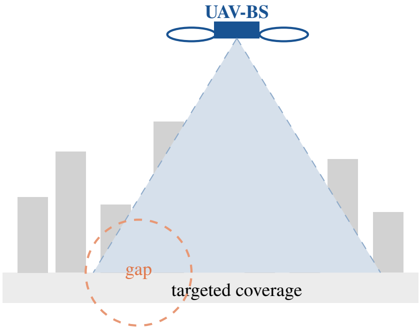
Motivation: why UAVs in wireless communications?

Limitations of terrestrial networks:

- **Coverage holes** in rural/remote areas
- **Infrastructure damage** during disasters
- **Traffic hotspots** at events and stadiums
- **High deployment cost** for sparse areas
- **Static topology** cannot adapt to demand

What UAVs bring:

- **Rapid deployment** in minutes
- **3D mobility** hover over any location
- **High LoS probability** vs ground BSs
- **Flexible, reconfigurable** coverage
- **Cost-effective** for temporary demands



Y. Zeng, et al, "Accessing from the Sky: A Tutorial on UAV Communications for 5G and Beyond," Proceedings of the IEEE, vol. 107, no. 12, pp. 2327–2375, 2019.

Historical evolution

2014–2016 Foundations:

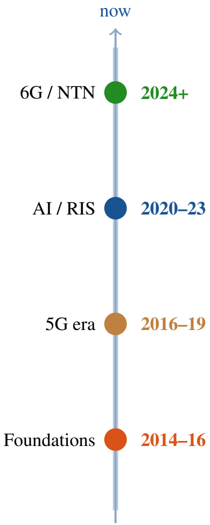
- First UAV-as-BS papers
- Air-to-ground channel modelling
- Optimal altitude for coverage

2016–2019 5G era:

- UAV-assisted 5G deployment
- Energy-efficient trajectory design
- Coverage & capacity optimisation

2020–now Intelligence:

- AI-based UAV networking
- RIS-assisted UAV communications
- Integrated sensing & communication (ISAC)
- Non-Terrestrial Networks (NTN)



Standardisation landscape

3GPP milestones:

Rel. 15	LTE/5G NR baseline
Rel. 16	UAV ID & UTM support
Rel. 17	NTN (satellites, HAPS, UAVs)
Rel. 18	5G-Advanced, enhanced NTN
Rel. 19+	6G-preparatory work

IEEE:

- IEEE 802.11 UAV networking studies
- IEEE 802.15.4 IoT for UAVs
- ComSoc UAV working groups

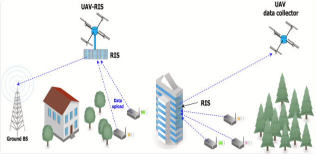
Implication: standardisation is maturing rapidly, moving UAV communications from research to commercial deployment.

Abdalla, Aly Sabri et al. "Communications standards for unmanned aircraft systems: The 3GPP perspective and research drivers," IEEE Communications Standards Magazine vol. 5, no. 1, pp. 70–77, 2021.

UAV wireless applications: the big picture

Main Applications

- **Flying base stations**: on-demand cellular coverage
- **Disaster recovery**: rapid connectivity restoration
- **IoT data collection**: mobile aerial harvesting
- **Relay networks**: extending coverage range



Each application introduces distinct **channel conditions**, **trajectory requirements**, and **optimisation objectives**.

Mozaffari, Mohammad, et al. "A tutorial on UAVs for wireless networks: Applications, challenges, and open problems," IEEE communications surveys & tutorials, vol. 21, no. 3, pp. 2334–2360, 2019.

Use case 1: UAV flying base stations

Concept:

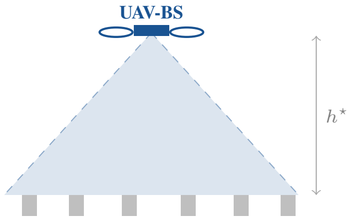
- A UAV deployed as a mobile BS provides **on-demand cellular coverage** at any location within minutes.

Applications:

- Stadiums, festivals, sporting events
- Emergency coverage during infrastructure failure
- Temporary deployment at construction sites

Advantages:

- Rapid deployment, flexible repositioning
- High LoS $\Rightarrow$ better SNR per user
- 3D placement optimisation maximises coverage



Key result: optimal altitude $h^\star$ balances LoS gain with increasing path loss.

Wang, Haijun, et al. "Deployment algorithms of flying base stations: 5G and beyond with UAVs," IEEE IoT Journal, 2019.

Use case 2: Disaster recovery communications

Concept:

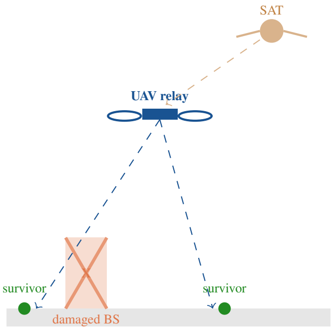
- A UAV deployed as a mobile BS to provide **intermittent connectivity** for damaged infrastructure.

Applications:

- Earthquake, flood, wildfire or hurricane destroys terrestrial infrastructure.
- UAVs restore connectivity in **hours**.

Advantages:

- Immediate coverage over disaster zone
- Supports search & rescue coordination
- Relays emergency calls to surviving network



Real examples: Hurricane Maria (2017), Turkey/Syria earthquake (2023) – UAVs deployed within hours.

Wang, Yuntao, et al. "Task offloading for post-disaster rescue in unmanned aerial vehicles networks," IEEE/ACM Transactions On Networking, 2022.

Use case 3: UAV-assisted IoT data collection

Concept:

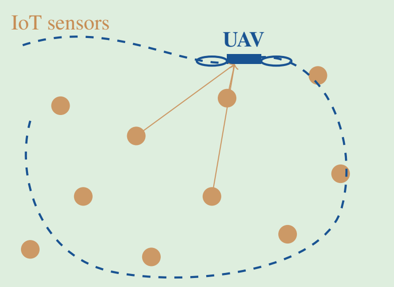
- A UAV flies over distributed IoT/sensor nodes, harvesting data.

Applications:

- **Smart agriculture:** soil moisture, pest detection
- **Environmental monitoring:** air quality, wildfire sensors
- **Smart cities:** distributed infrastructure sensors
- **Industrial IoT:** remote pipeline inspection

Advantages:

- Short communications ranges
- Less IoT transmission energy



Trajectory design jointly minimises mission time and energy subject to per-sensor data volume constraints.

Poorvi, Joshi, et al, "Reliable and efficient data collection in UAV based IoT networks," IEEE Communications Surveys & Tutorials, 2025.

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Use case 4: UAV relay networks

Concept:

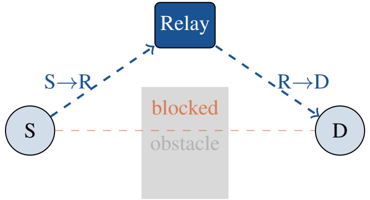
- A UAV acts as an aerial relay between two nodes whose **direct link is blocked or too weak**.

Applications:

- A communication with a faraway base station
- A communication with satellites and HAPs.

Advantages:

- Line-of-Sight availability.
- Mobility and flexibility



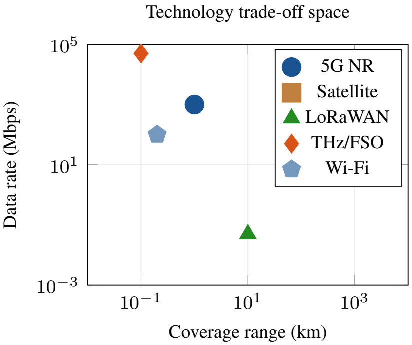
Relay 3D placement to improve End-to-end latency and reduce interference.

Su, Yuhan, et al. "Toward optimal deployment of UAV relays in UAV-assisted Internet of Vehicles," IEEE Transactions on Vehicular Technology, 2023.

Communication technologies: overview

Which wireless technologies connect UAVs to the network?

Technology	Primary Use Case
Cellular 4G/5G/6G	Flying base station, relay node, command-and-control (C2) link
Satellite / NTN	Rural and remote area coverage, disaster recovery
Wi-Fi (802.11)	Short-range data offload, last-hop connectivity
LPWAN (LoRa, NB-IoT)	Low-power IoT sensor data collection
mmWave / THz	High-capacity backhaul, ultra-dense links
FSO	Inter-UAV free-space optical links



Different technologies address different trade-offs between **range**, **throughput**, **energy**, and **reliability**.

Vegni, Anna Maria, et al. "Communication technologies enabling effective UAV networks: A standards perspective." IEEE Communications Standards Magazine 2022.

Key takeaways

1) **UAVs add mobility** to wireless networks, enabling on-demand, adaptive coverage impossible with fixed infrastructure.
2) **Several applications:** flying BSs, disaster recovery, IoT collection, and relaying; each with distinct optimisation challenges.
3) **Cellular (5G/6G), NTN, LPWAN, mmWave/THz, FSO** are the key enablers, chosen by trade-offs between range, rate, energy, and reliability.
4) **UAVs are evolving** from single-purpose tools to fundamental nodes in future **6G aerial networks** integrated with NTN, edge computing, and AI-driven autonomy.

Thank you

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