Wireless Communications with UAV (Unmanned Aerial Vehicle)

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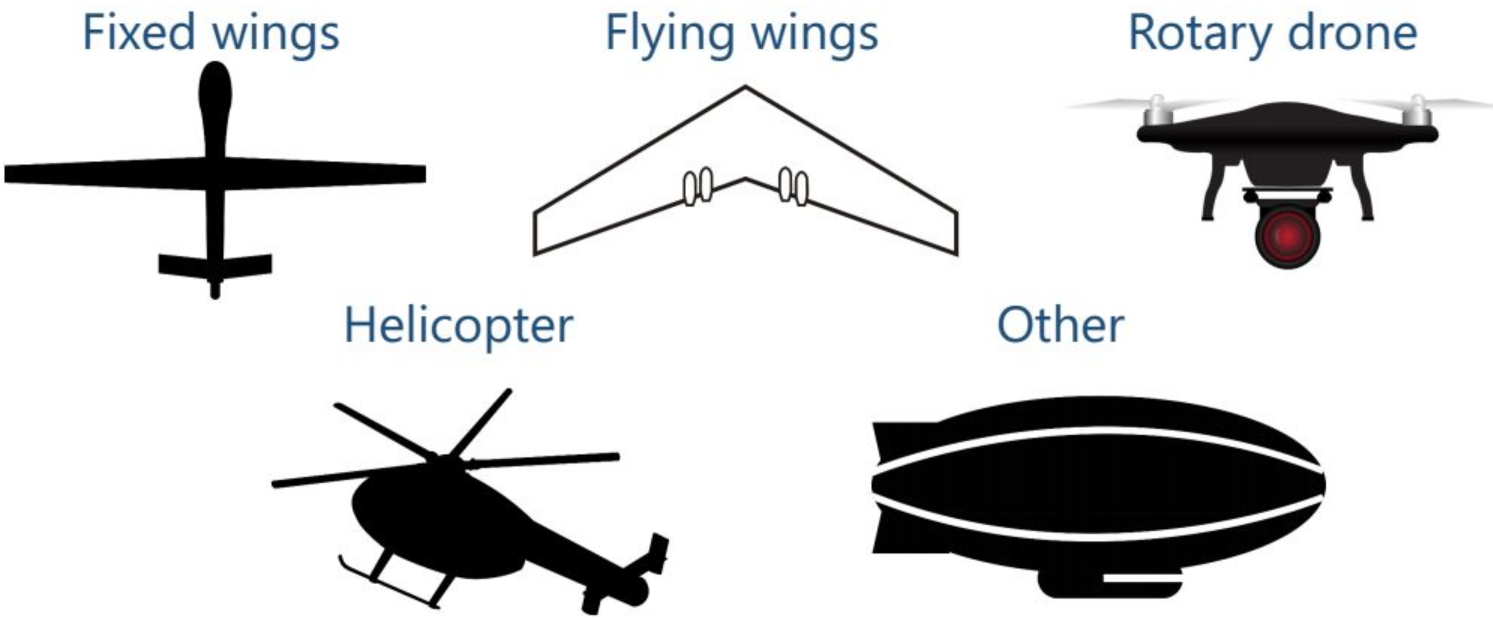
Outlines

- UAV types
- UAV applications
- Advantages
- Challenges
- Channels involved in communications
- Air-to-Ground Channel Model
- Performance Analysis
- Conclusion

UAV Types

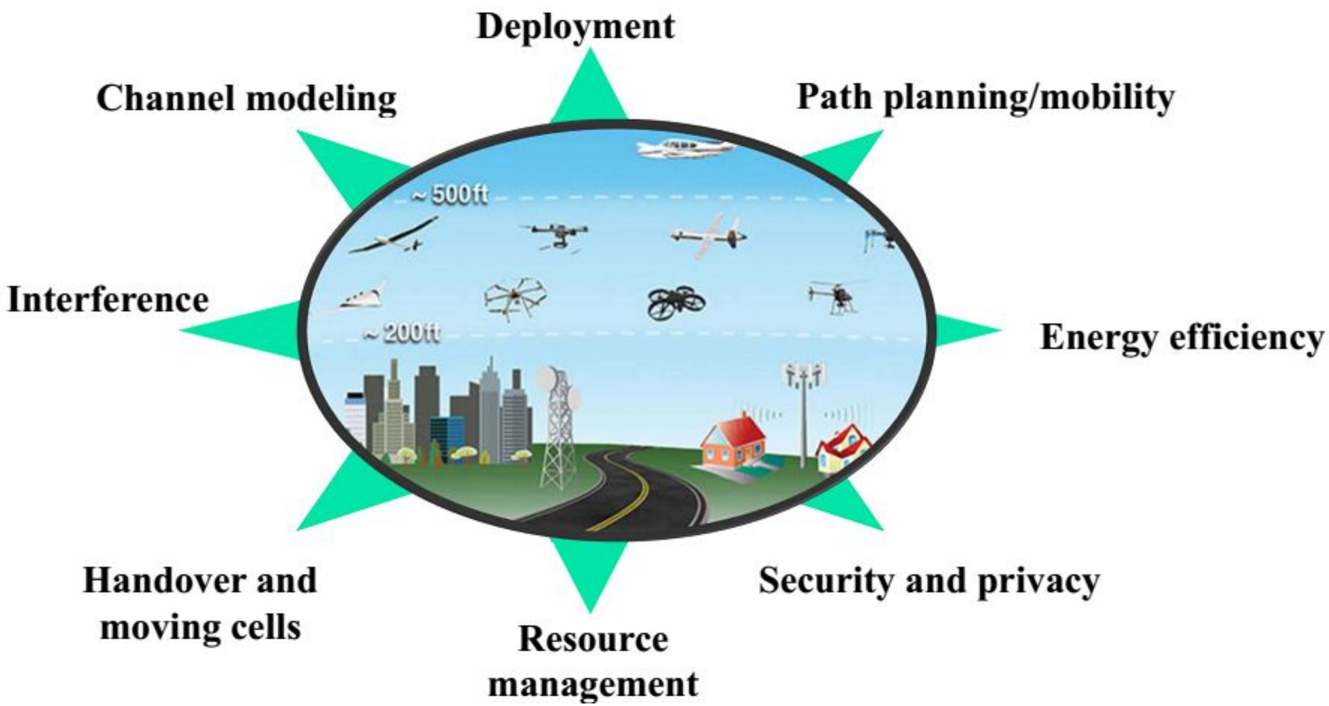


UAV Applications

Advantages

- Adjustable altitude
- Potential Mobility
- Low infrastructure low cost
- On demand deployment,
  fast response
- Low cost
- More flexible in reconfiguratic
  and movement
- Short-distance line of sight
  (LoS) communication

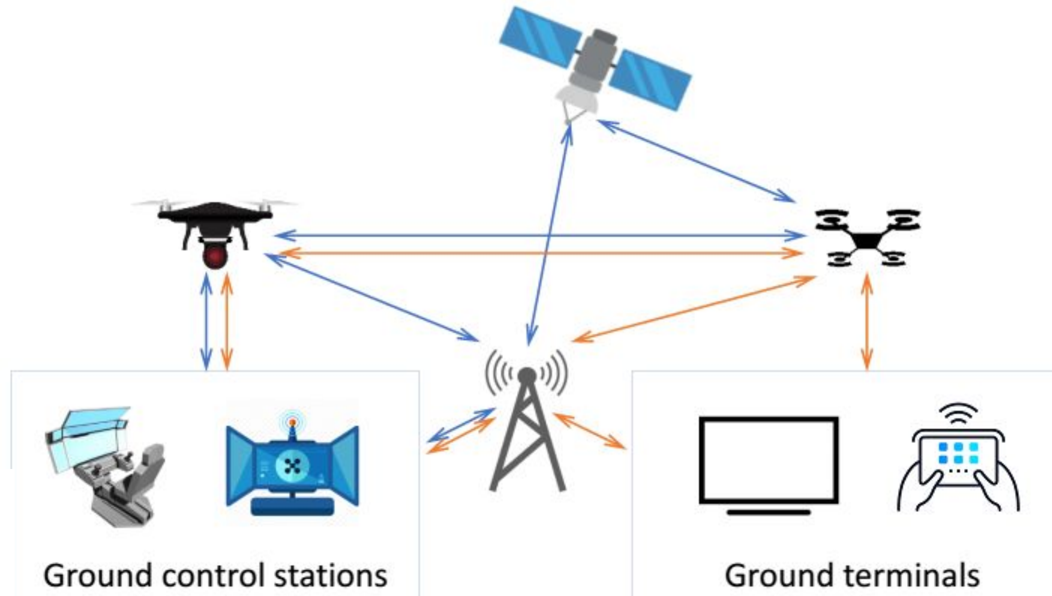
Challenges

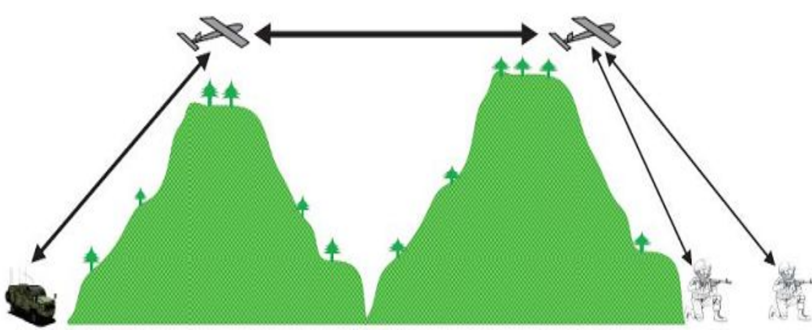


Deployment
Channel modeling
Path planning/mobility
~ 500ft
Interference
~ 200ft
Energy efficiency
Handover and moving cells
Resource management
Security and privacy

Channels involved in communications

- Air-to-Air
- Ground-to-Air
- Air-to-Ground
- UAV-aided relaying

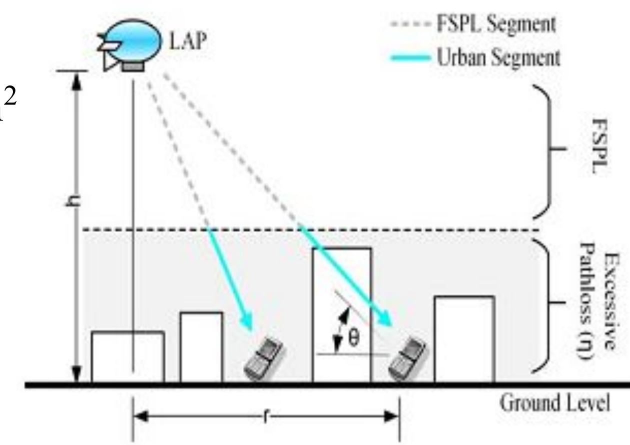




UAV-aided relaying

Air-to-Ground AtG Channel Model

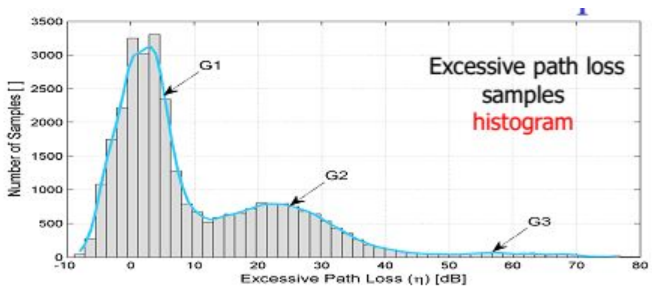
- Radio propagation in AtG channel differs from terrestrial propagation models
- Typically radio waves in AtG channel travel freely without obstacles for large distances before reaching the urban layer of man-made structures.
- Common models define a LOS probability between UAV and ground user that depends on:
  - Environment (suburban, urban, dense urban)
  - Height (h) and density of the buildings (building/km^2)

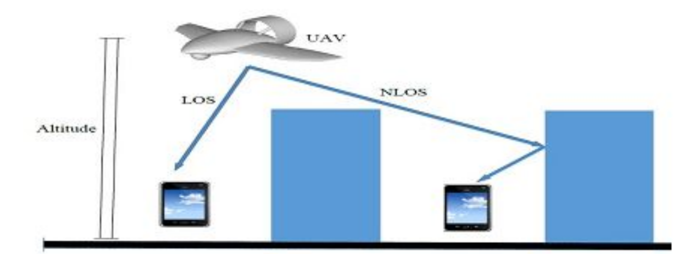


AtG (cont.)

- Received signals include:
  - Line of sight (LOS): strong signal (G1)
  - Non-line of sight (NLOS): strong reflection (G2) or fading (G3)
- Each group with a specific probability and excessive loss
- Dominant components:

- LOS links exist with probability P and NLOS links exist with probability 1-P
- Consider LOS/NLOS separately with different path

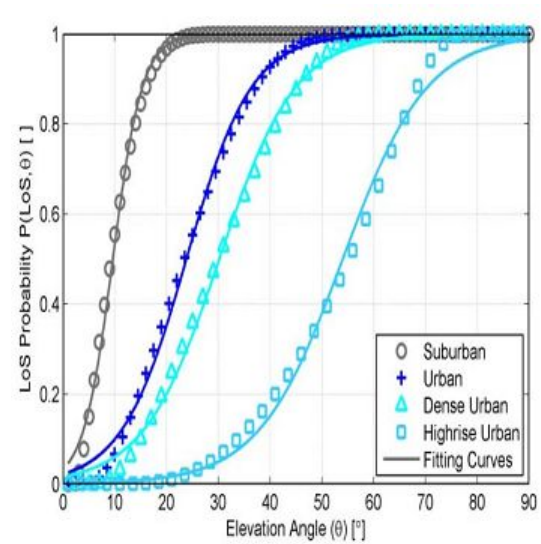




LOS Probability approximation

- Probability of having LOS link:
  - Trend approximated to a simple modified Sigmoid function (S-curve)
  - Increasing LOS probability by increasing elevation angle or UAV's altitude

$$P_{\text{LOS}} = \frac{1}{1 + C\exp(-B\,[\theta - C])}$$



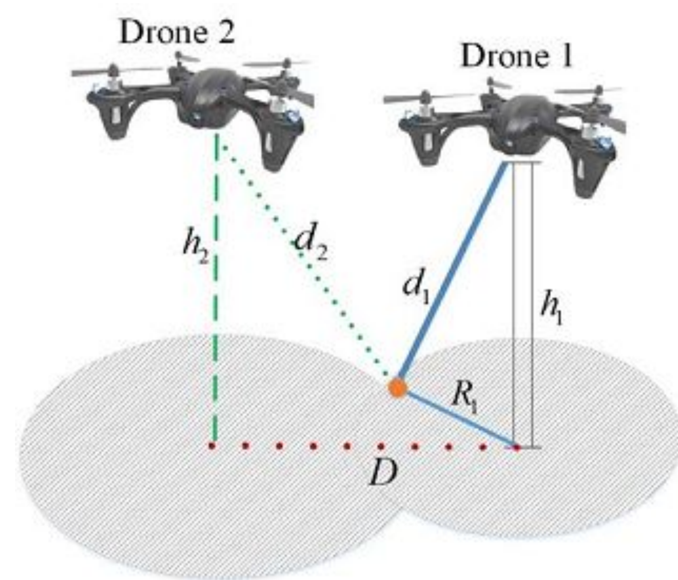
- B and C: constants that depend on the environment
  Θ: Elevation angle

Performance Analysis

System Model

- Downlink scenario
- Drones provide coverage for a target area
- Scenarios:
  - Single drone
  - 2 drones without interference
  - 2 drones with intercell interference

  Target: Meeting the minimum SINR requirement on the ground

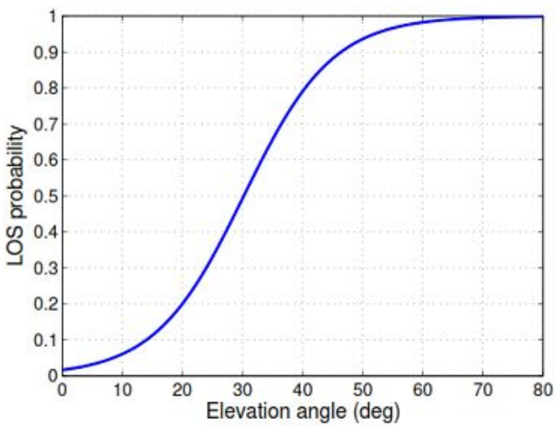


Performance Analysis (cont.)

- **Determining the optimal altitude of drones**
  - Leading to maximum coverage
  - Full coverage using minimum transmit power for the drones
- **Optimal deployment of two interfering drones**
  - Distance between the drones?
  - Altitudes?
- **Highlighting tradeoffs while deploying drones**
  - Interference, coverage, transmit power

Impact of Drone’s Altitude

- Higher altitude: Higher path loss vs. higher LOS proba.
- Lower altitude: Lower path loss vs. more NLOS
- Altitude and flight constraints
  - Higher and lower altitudes are bounded



Single Drone

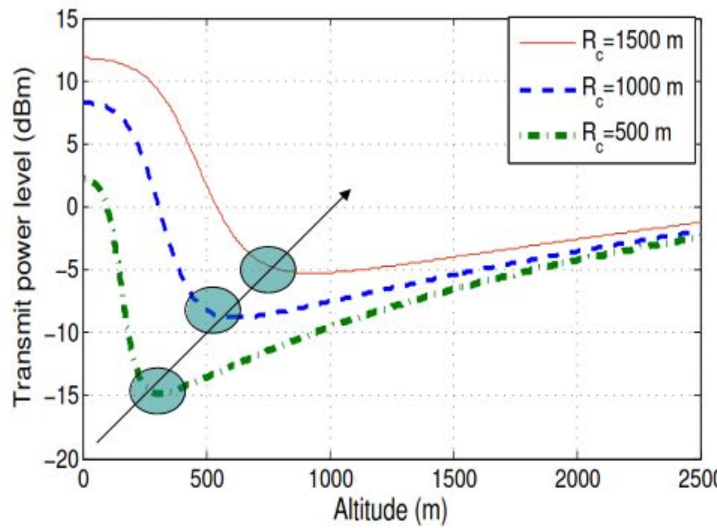
- **Optimal altitude depends on the area size (Rc)**
  Increasing drone's altitude to service larger areas

@Low-altitude: high shadowing
+ low LOS probability →coverage radius decreases

@ **high-altitude**: high LOS probability but PL
Increases –> Coverage decreases

E.g.; optimal altitude for providing 500m coverage
radius while consuming min. tx power is 310 meters

Altitude increases w/ coverage radius



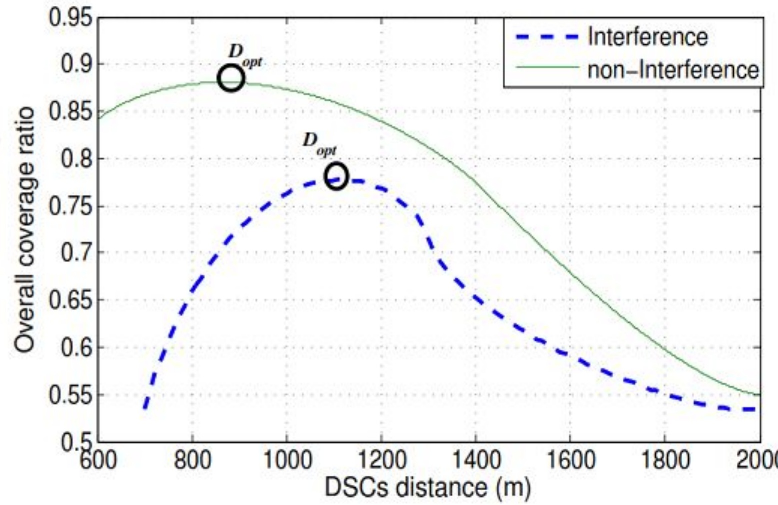
Two Drones

- **Bounded target geographical area**
  Existence of optimal drones' separation distance for maximum coverage

At high drone distance, although separated, coverage ratio is low (undesired)

Likewise, if too close interference increases.

→optimal separation distance exists!



Conclusion

- UAVs provide with many new opportunities to improve wireless communications
- The Internet of Flying Things will be upcoming and we must be “analytically” ready.
- Fundamental results on performance are needed
- Self-organization in terms of resources, network topology, access modes, security, etc.
  Machine learning, game theory and related techniques
- Human-in-the-loop: bounded rationality
  Ubiquitous wireless connectivity from the sky!