UNIVERSITÄT KLAGENFURT

Lakeside Labs
SELF-ORGANIZING NETWORKED SYSTEMS

Drones in Cellular Networks
Some Experimental Results

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Talk at CONNECT and Trinity College Dublin

November 12, 2019

Dronehub K

Research on drone systems in Klagenfurt

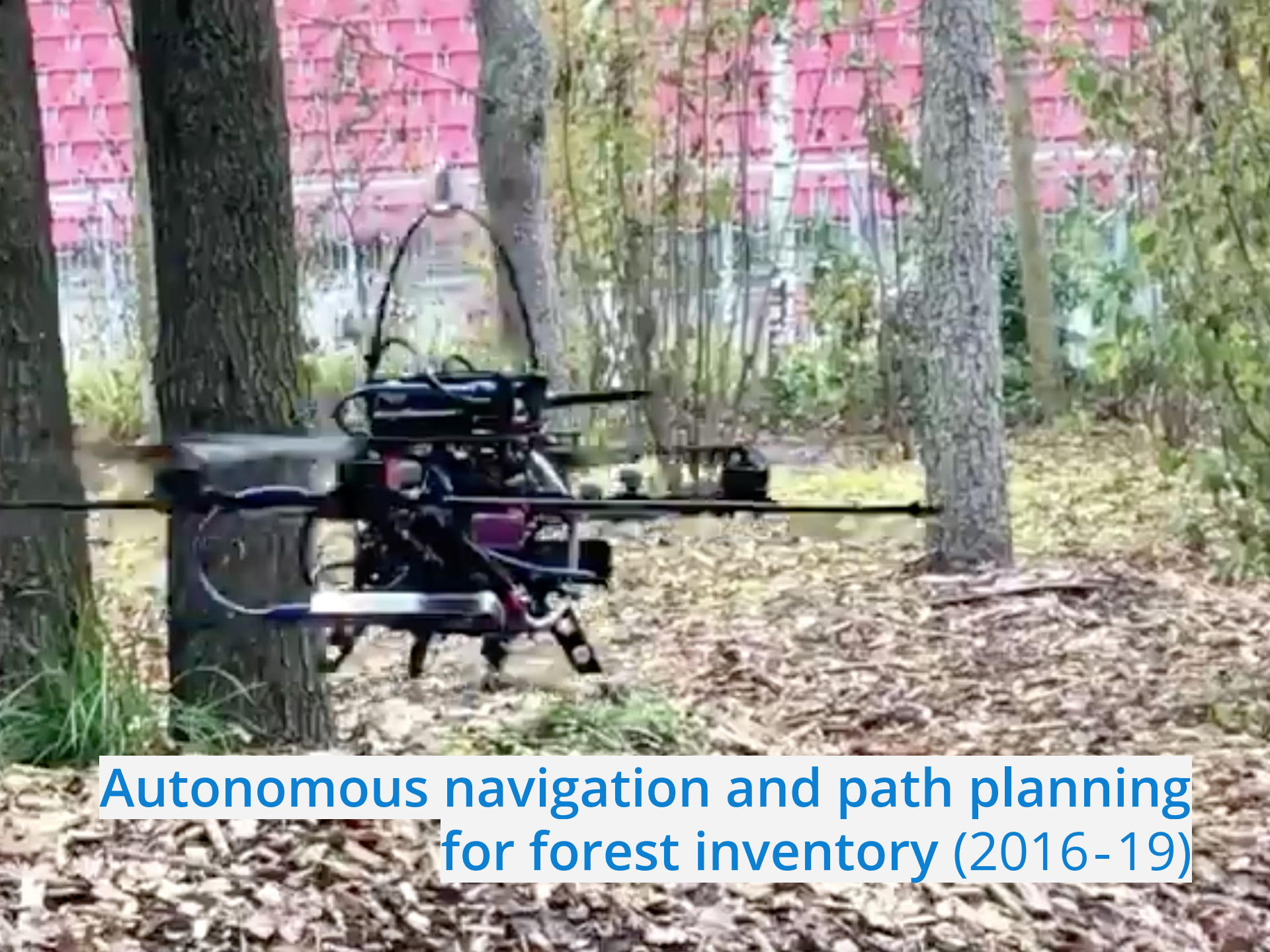
- Autonomous navigation
- Human-drone interaction
- Image processing
- Mission and path planning
- Coordination
- Wireless communications

Key facts

- Started 2008
- 9 Professors
- 29 PhDs and Postdocs
- 90 publications

Path planning and aerial imaging for disaster response (2008-12)

Coordination of multiple drones for delivery systems (2013-16)

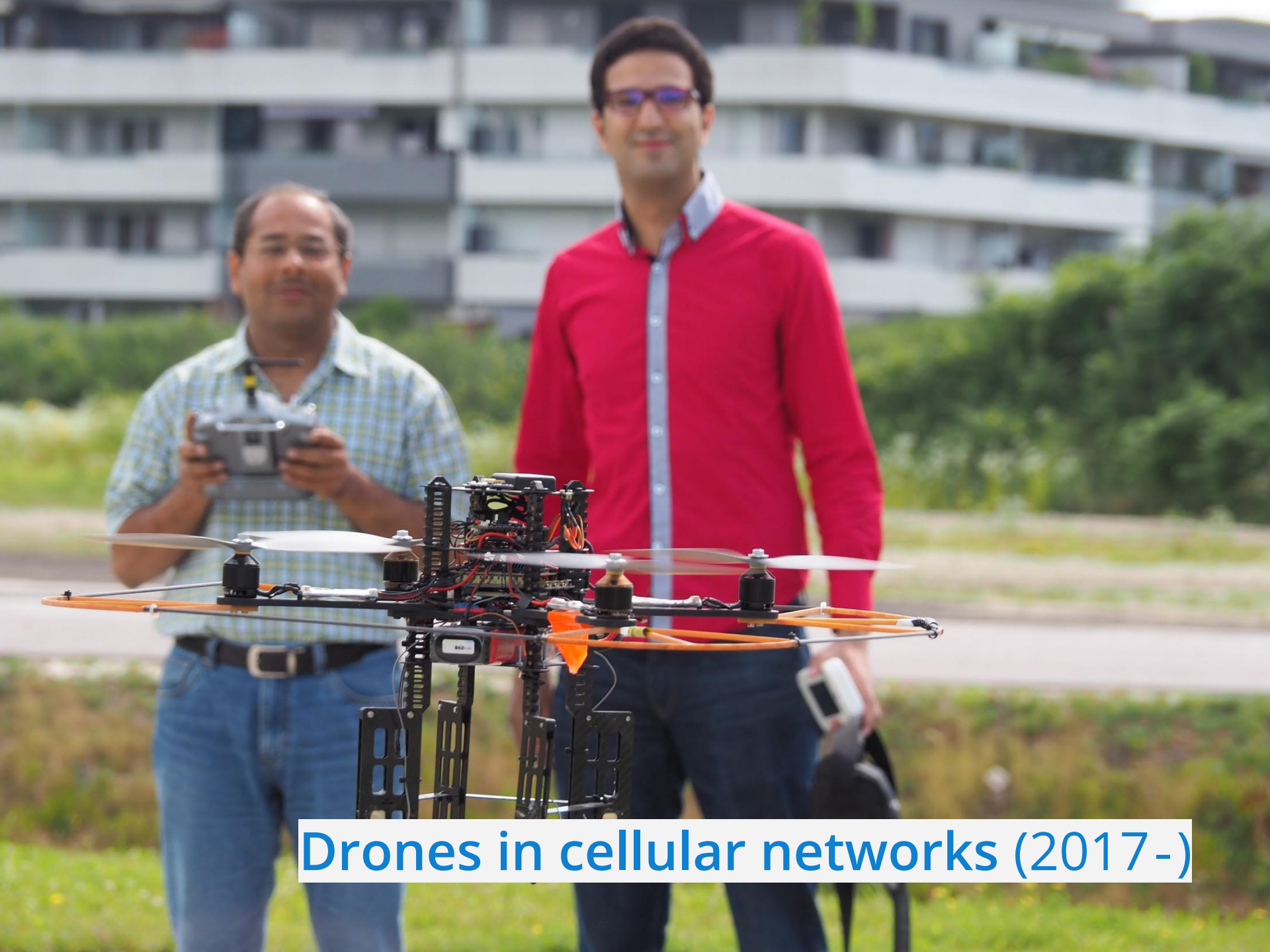


Autonomous navigation and path planning for forest inventory (2016-19)

Wireless LAN communications for search and rescue (2013-15)

Five lessons learnt on drone communications

1. Communication **requirements are manifold** and different from those for ground users and applications.
2. Communications is **highly inter-dependent** on other components of multi-drone systems.
3. Off-the-shelf **IEEE 802.11** can be used with tweaks but is not optimal for 3D communication and agile aerial nodes.
4. There is a need for **specific protocols**, including adaptive multimedia coding schemes.
5. **Experimental research** with multiple drones is very demanding but pays off in the long run.

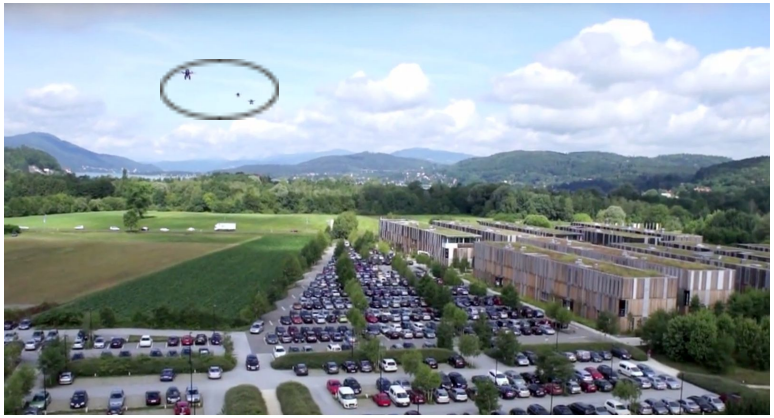


Drones in cellular networks (2017-)

Motivation

Why connect drones to cellular networks?

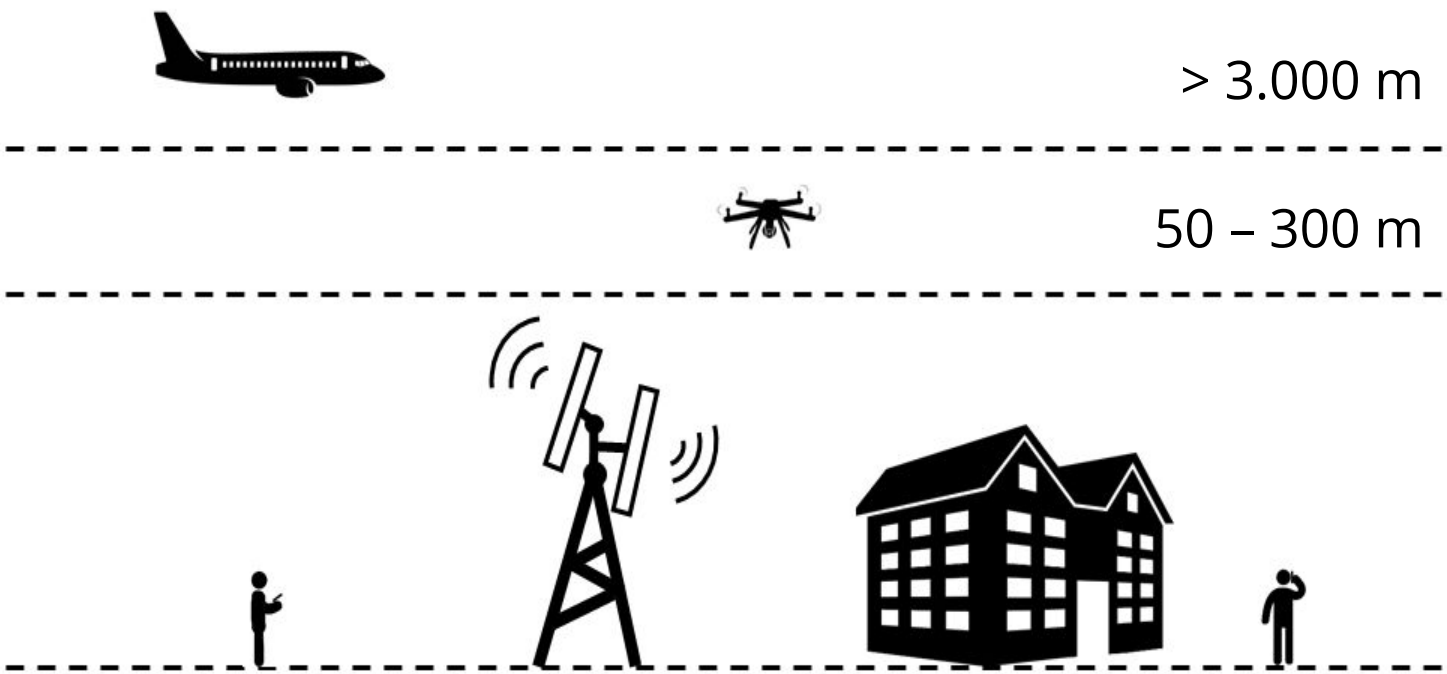
- Wide-area connectivity
- Safety (operator = entity of trust)
- Security and reliability (licensed spectrum)
- Low latency requirements (5G)
- Roles of a drone: base station, relay, or mobile device



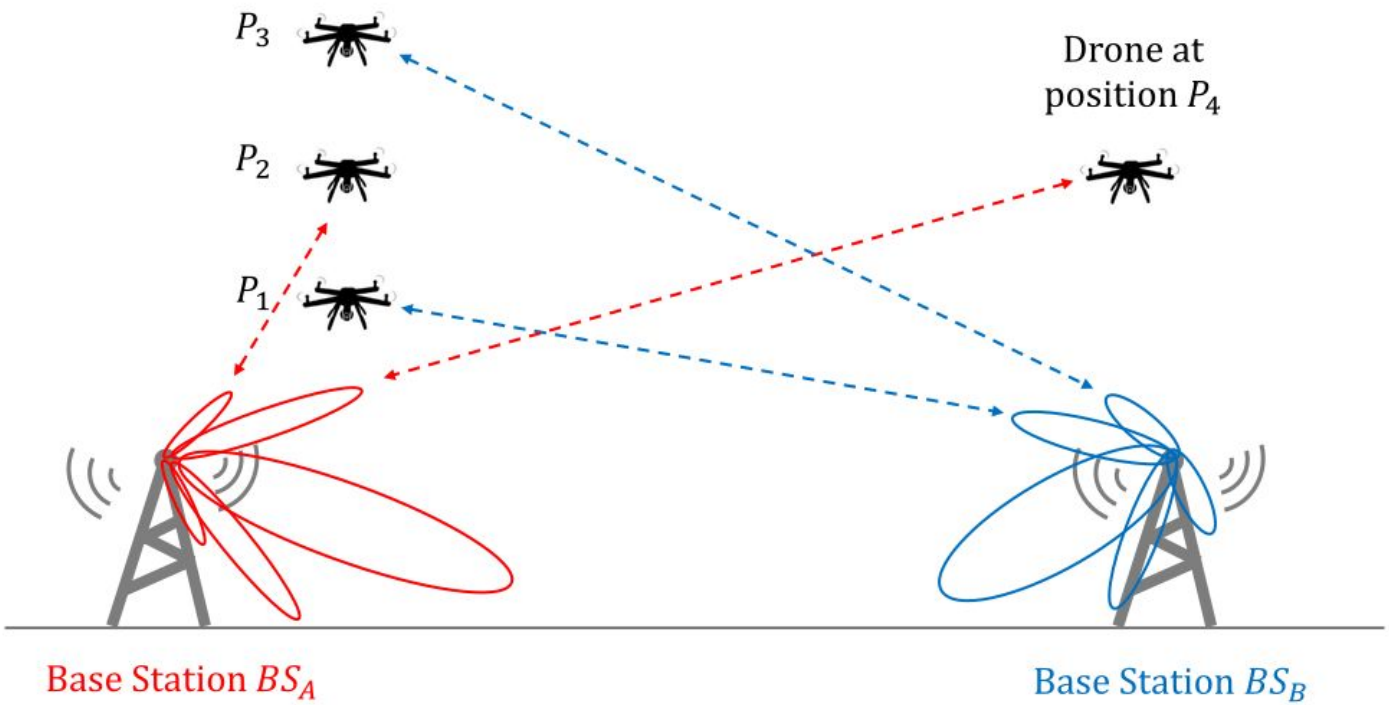
Why multiple drones?

- Time-critical missions
- Wide-area coverage

Vertical coverage of cellular networks

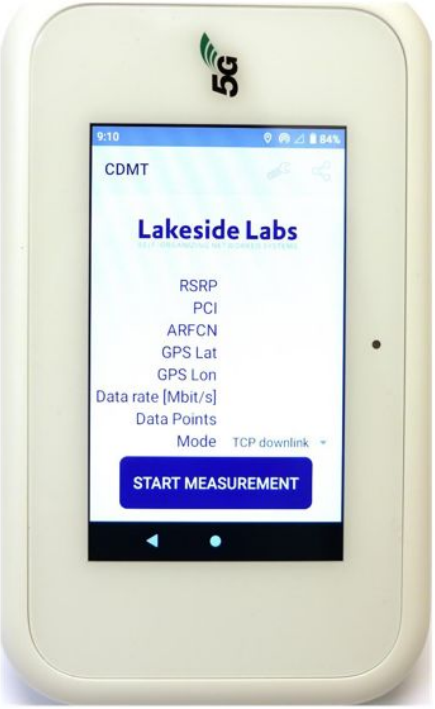


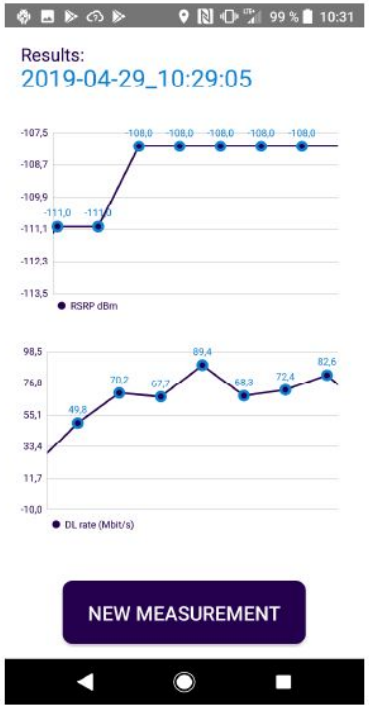
Antenna tilting and cell association



Cellular drone measurement tool (CDMT)

- Received power (RSRP)
- Received quality (RSRQ)
- Signal-to-noise ratio (RSSNR)
- Channel number (EARFCN)
- Cell identifier and neighboring cell information
- Throughput
- GPS





Available for academic use: *www.lakeside-labs.com/cdmt*

Experimental setup

LTE-A (3GPP Rel 13)

Carrier aggregation up to 60 MHz

Antennas at 30 m height with 20 W max. TX power

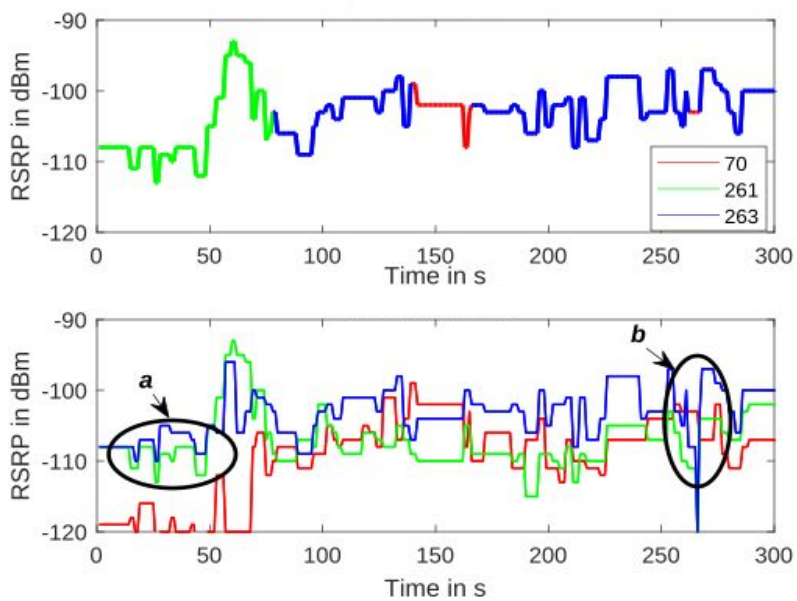
Modulation:
DL: 256 QAM
UL: 64 QAM

AscTec Pelican with Sony Xperia H8216

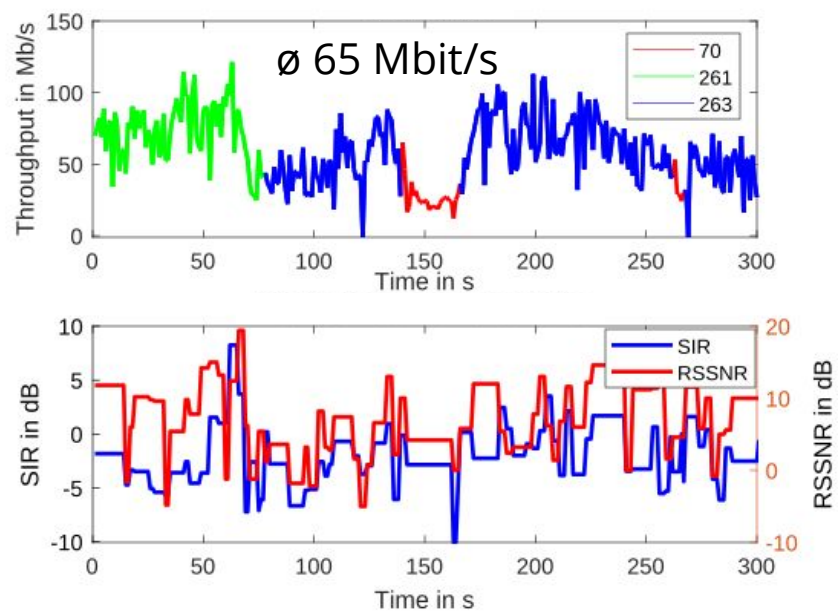
Performance results

Ground scenario in downlink

Drone flying
at 10 m height



Received signal power
and handovers



Throughput, SIR, SNR

a: No hand-over

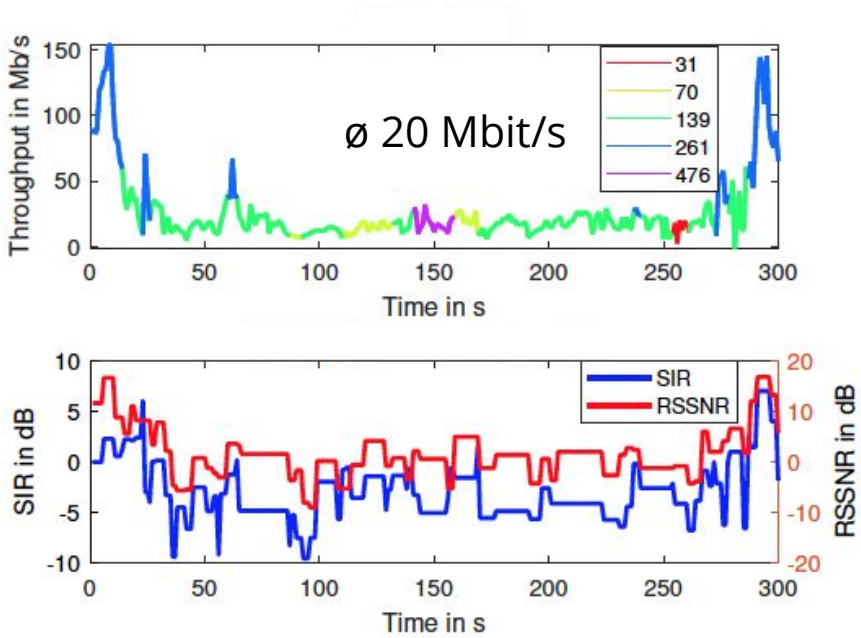
b: Ping-pong handover

Performance results

Aerial scenario

Drone flying
at 150 m height

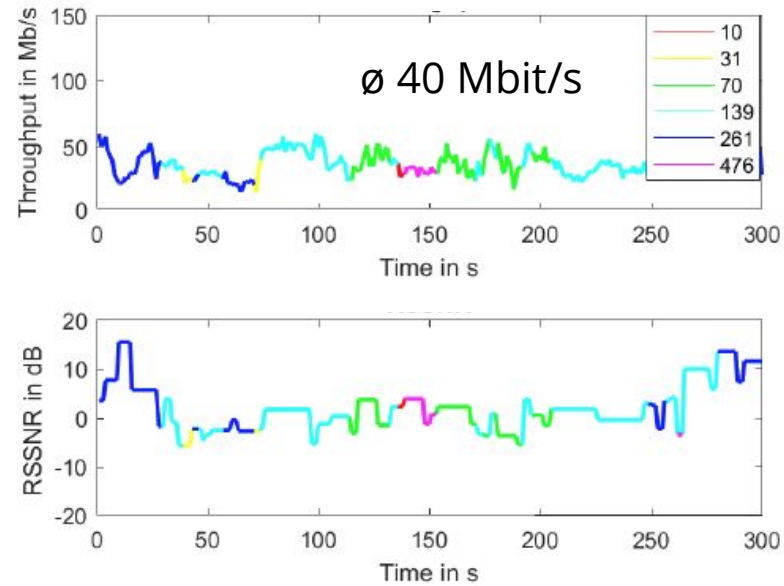
Downlink



Takeoff → Landing

Throughput drops with height

Uplink



Takeoff → Landing

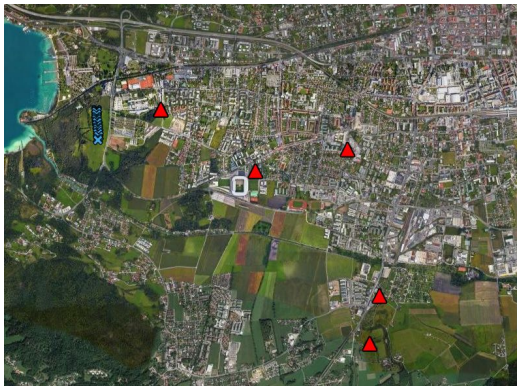
Throughput is more stable

Cell association

1. Ground scenario

2. Flying at 50 m

3. Flying at 100 m



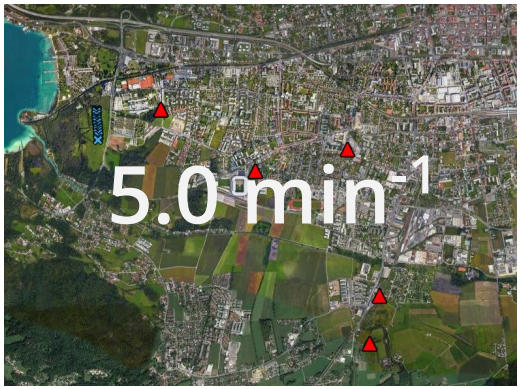
4. Flying at 150 m

Handovers

1. Ground scenario

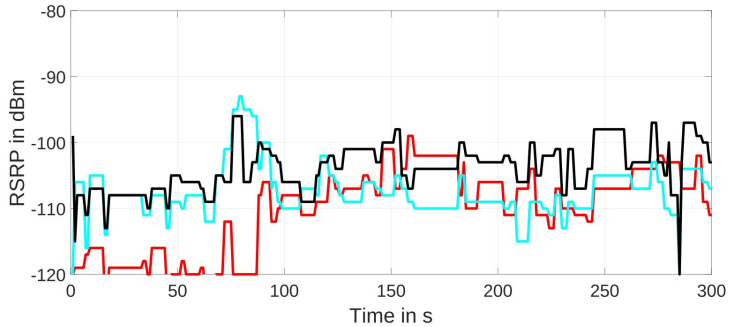
2. Flying at 50 m

3. Flying at 100 m

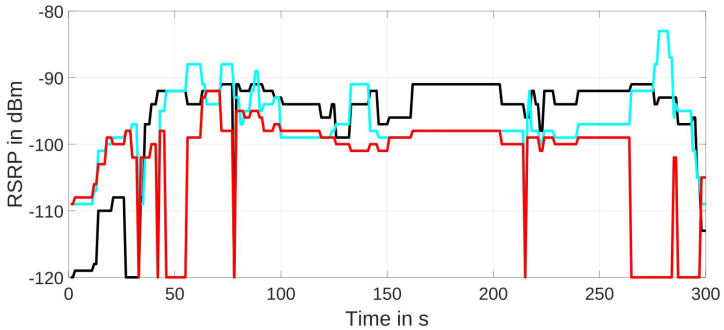


4. Flying at 150 m

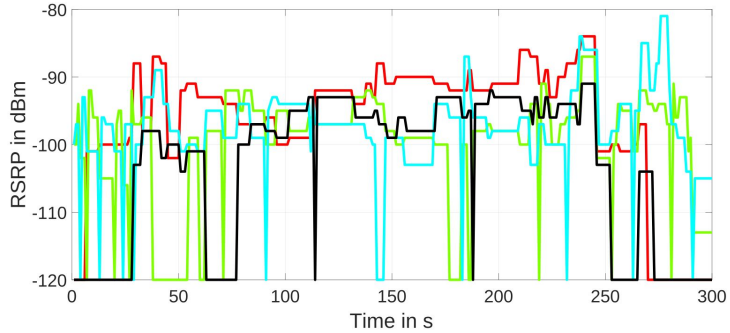
Handovers and signal strength



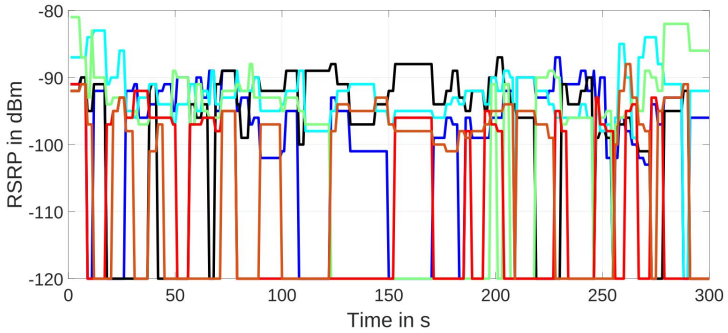
1. Ground scenario



2. Flying at 50 m



3. Flying at 100 m



4. Flying at 150 m

Papers on drone communications

Most recent papers (ACM DroNet Workshop 2019)

Handover challenges for cellular-connected drones.

An experimental evaluation of LTE-A throughput for drones.

Selected papers

Achieving air-ground communications in 802.11 networks with three-dimensional aerial mobility. *IEEE INFOCOM*, 2013.

Application-driven design of aerial communication networks. *IEEE Communications Magazine*, 2014.

Drone networks: communications, coordination, and sensing. *Ad Hoc Networks*, 2018.

Live multicast video streaming from drones: an experimental study. *Autonomous Robots*, 2019.

Conclusions

Drones connected to today's cellular networks ...

- achieve an average throughput of a few tens of Mbit/s,
- establish radio links to distant base stations,
- cause interference issues,
- cause a high handover rate, which increases with height.

... leave room for industry-relevant research issues.

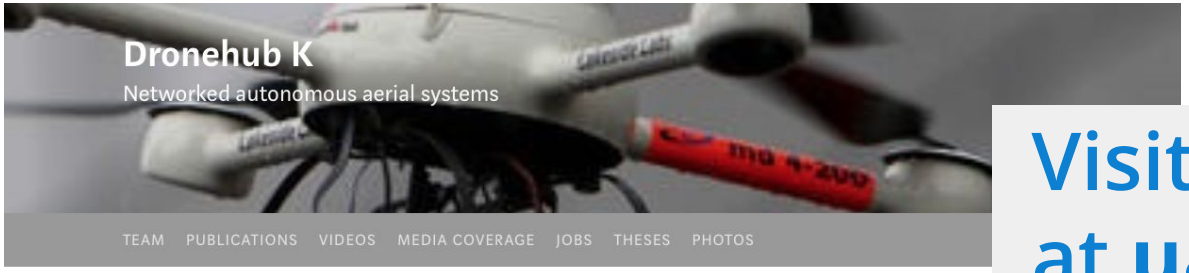
Outlook

The integration of drones into cellular networks requires ...

- novel handover techniques,
- novel interference management approaches,
- additional standardization and regulation solutions.

Our ongoing work includes ...

- link measurements in 5G networks,
- aspects of communications in drone swarms,
- offloading of computations from drones to edge computing.



Visit **Dronehub K** at **uav.aau.at.**

News

Using existing cellular networks for drones

It might soon become common for drones to transport goods and people, monitor disaster zones, and bring various forms of relief to areas...

Romy Müller
Sep 10 · 3 min read

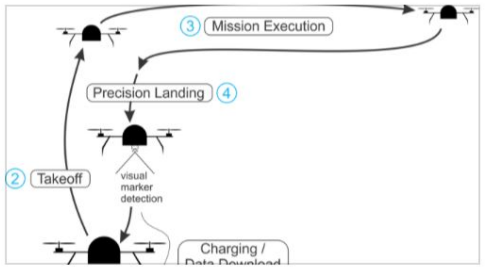
Unmanned aerial vehicle communications: Opportunities and challenges

Wireless communications is essential for many applications with commercial drones. Omid Semiari interviewed Christian Bettstetter about...

Christian Bettstetter
Dec 18, 2018 · 6 min read

"Drones are here to stay. Get used to it."

This statement was the title of a TIME article, which was included in the magazine's special report on "The Drone Age". We asked Christian...



Long-Duration Autonomy for Small Rotorcraft UAS including Recharging

Reliable Unmanned Aerial Vehicle (UAV) that are capable of performing long-duration missions autonomously received a lot of attention...

Or come by Klagenfurt (again).

Funding

European Union
European Regional
Development Fund

KWF

BABEG
Invest
in Carinthia

Magenta

FFG