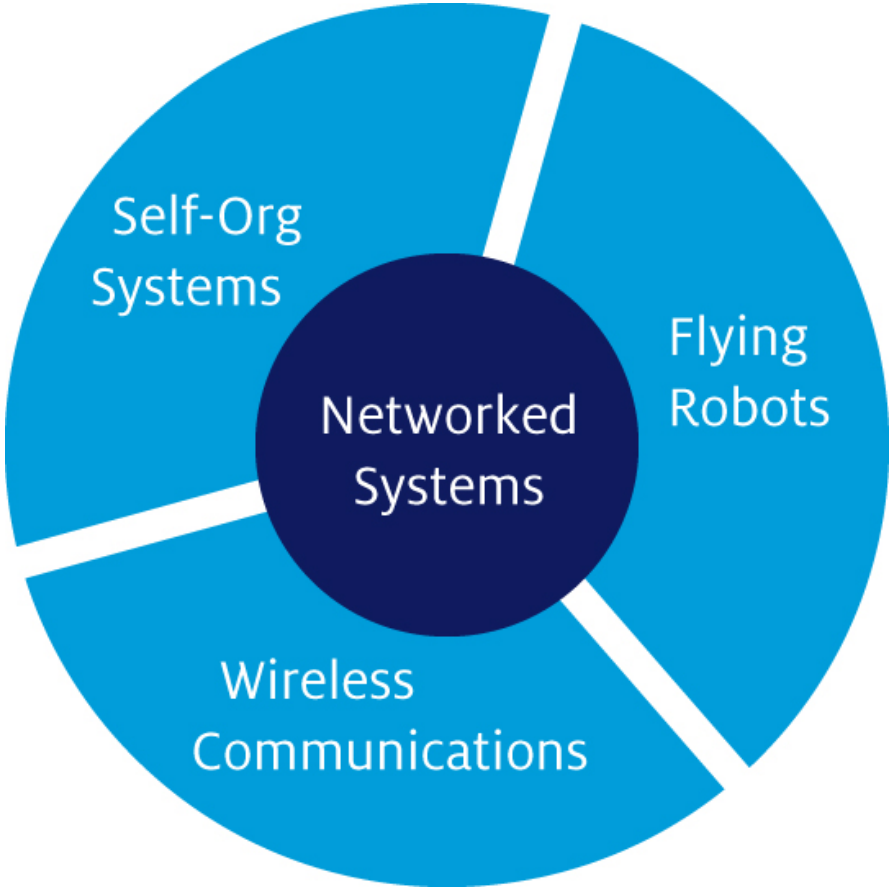
ALPEN-ADRIA UNIVERSITÄT
KLAGENFURT | WIEN GRAZ
Institute of Networked and Embedded Systems

Aerial Imaging and Wireless Communications with Multiple Autonomous UAVs

Univ.-Prof. **Christian Bettstetter** and Dr. **Evsen Yanmaz**
Lakeside Research Days, 9 July 2013

Lakeside Labs

Bettstetter Group



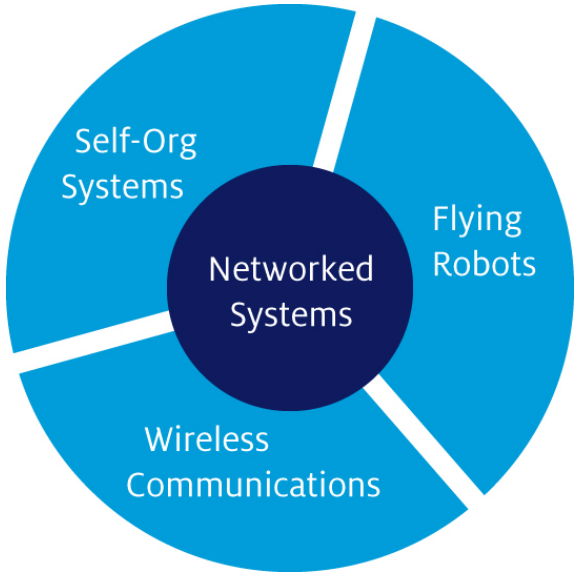
Team

- 1 full professor, 1 secretary
- 4 senior researchers
- 10 PhD students
- Highly international

Collaborations and funding

- With Orange, DOCOMO, Max Planck Society, U Porto, Athens UEB, TU Munich
- > 700 T€ third-party funding / year

Bettstetter Group



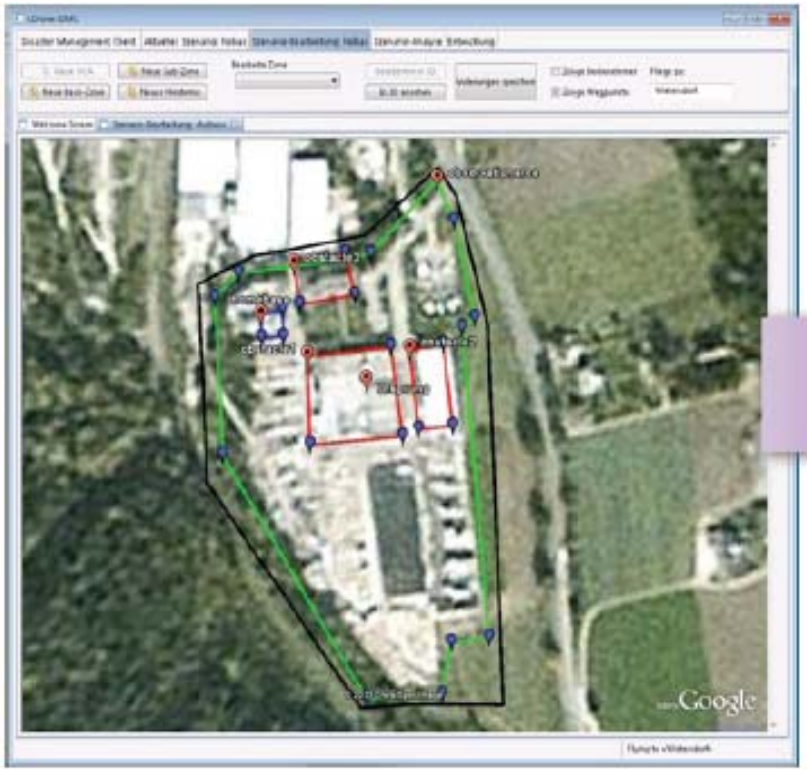
Current Projects

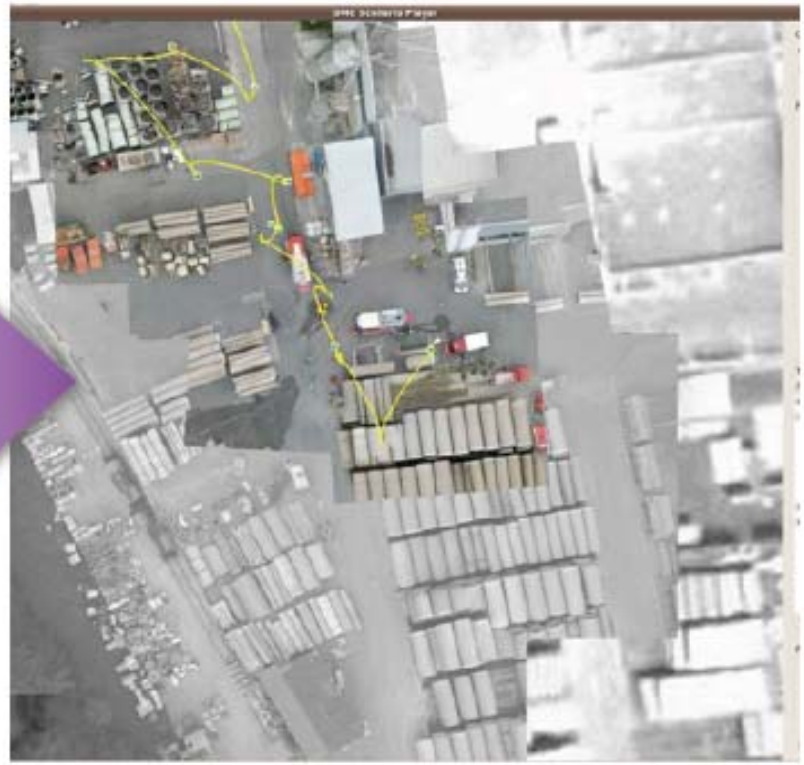
- Cooperative relaying in wireless networks
- Interference dynamics in wireless networks
- Self-organizing synchronization
- Communications and coordination of flying robots

Methodology

- Methods from maths (stochastics, graph theory) over simulation and protocol engineering to prototyping on hardware
- Striving for a good mix of fundamental and applied research, more and more also interdisciplinary research

Starting Point: Disaster Management





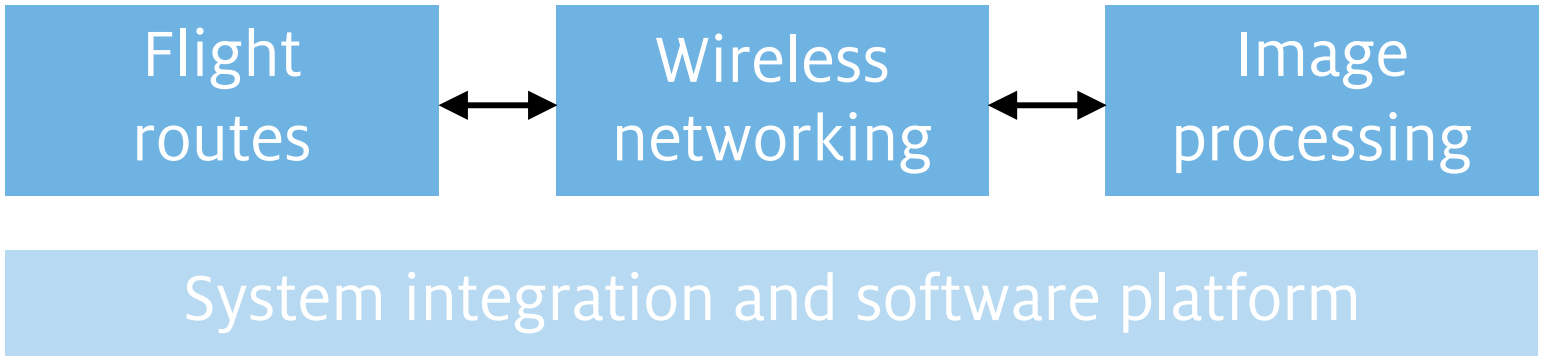
User defines high-level tasks (e.g. observation area)

User obtains real-time high-quality overview image

Goals and Research Issues

- Develop autonomous system for aerial reconnaissance
- Support first responders in disaster management
- Use off-the-shelf, small-scale, low-altitude multicopters equipped with high-quality cameras and GPS
- Deploy multiple drones to achieve fast area coverage

Research Issues



Flying High: Multi-UAV Aerial Imaging

Lakeside Labs

Challenges

- Strong resource limitations:
  Flight time, payload, computation
- Coordination of multiple drones:
  Centralized vs. distributed approach
- Multimedia network with dynamic, three-dimensional mobility
- Non-trivial user interface with prompt response
- Aspects of experimental research:
  Safety, legal issues
- Application partners, project funding

Image Processing: Stitching

Using position data
(GPS)

Using position and orientation
(GPS and IMU)

Exploiting feature detection
(Image data)

Apparatus and method for generating an overview image of a plurality of images using an accuracy information. European patent pending, EP2423871 (A1), 2012

3D Landscape Models in Disaster Areas



- Covering 45 km² in Haiti in six days
- System that local people can use
- E.g.: Understand flow of water

DRONE ADVENTURES

Switzerland

Photos with kind permission from Emanuele Lubrano

Applications Beyond Disaster Response

3D mapping

Person and object tracking

Industrial site monitoring, police support, accident documentation, and many others

Left photo with kind permission from C. Strecha, Pix4D.

Wireless Communications

Issues to consider

- Which technology? Which antennas?
- Which UAV?
  - 3D motion, tilting
  - Hardware limitations (payload, placement)

Basic question

- How far can we deliver data at which data rate?

Experiments Conducted

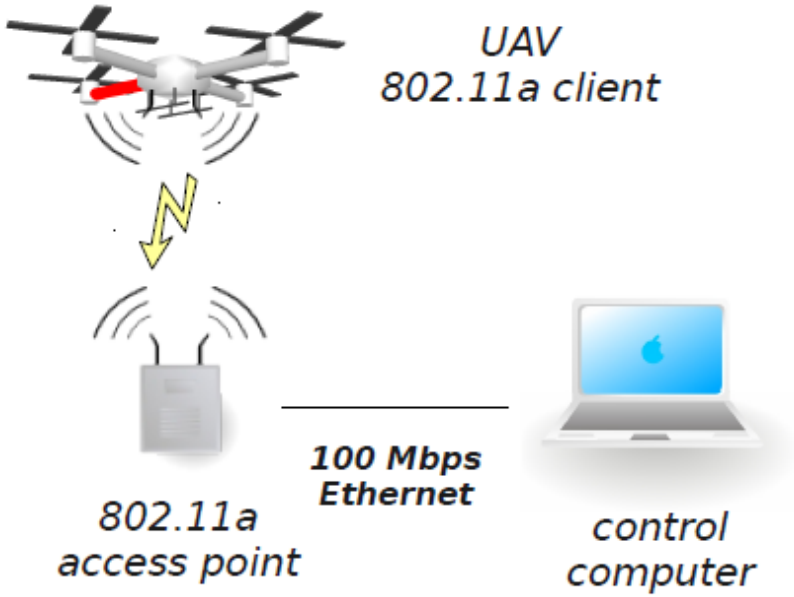
- Flew quadrotor with waypoint navigation
- Generated UDP traffic (uplink and downlink) over WLAN

Performance metrics

- Received signal strength (RSS)
- Throughput and delay
- Packet loss

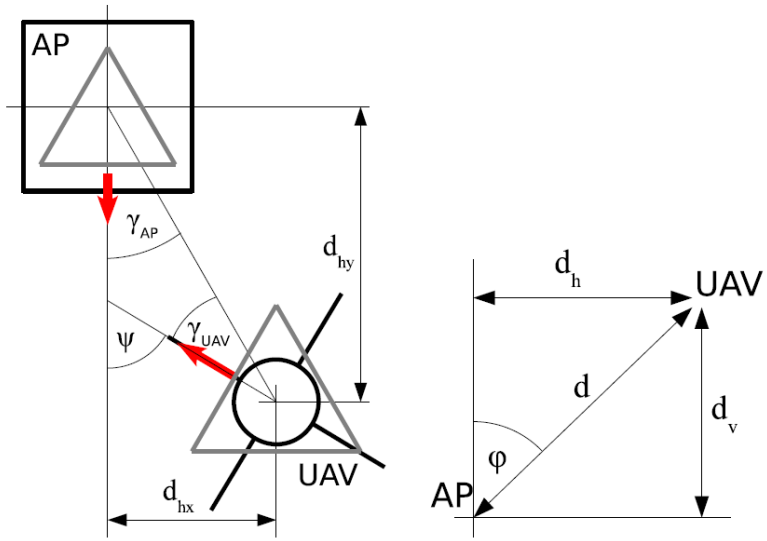
Test influence of

- Height and distance
- Orientation UAV-base station
- Antenna setup



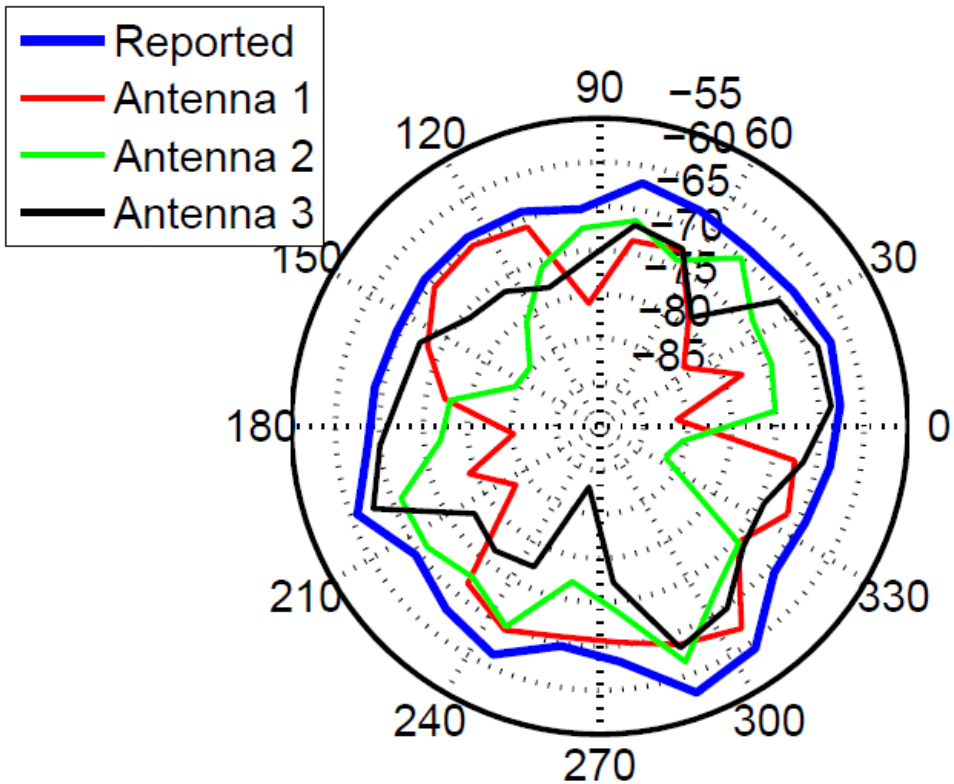
A Simple Extension to IEEE 802.11a

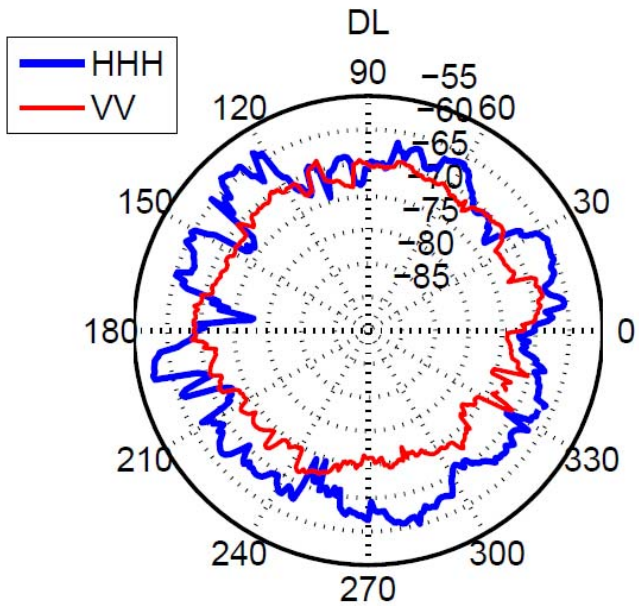
HHH

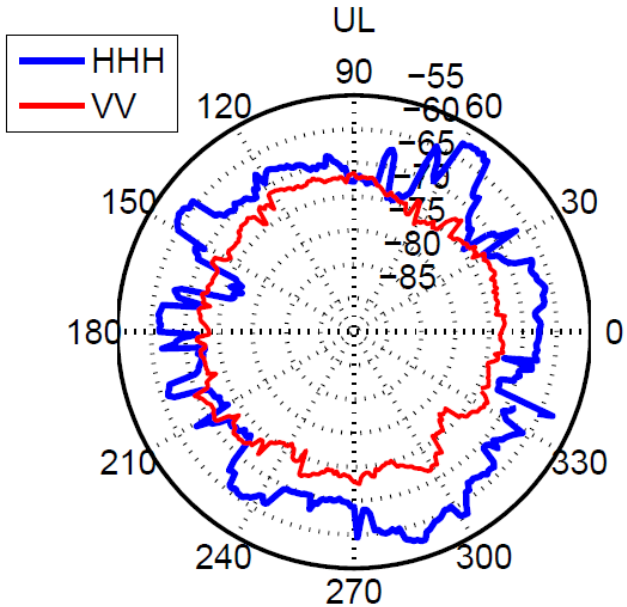


Radiation Pattern (HHH setup)

UAV rotating around its z-axis at 100 m distance from the AP

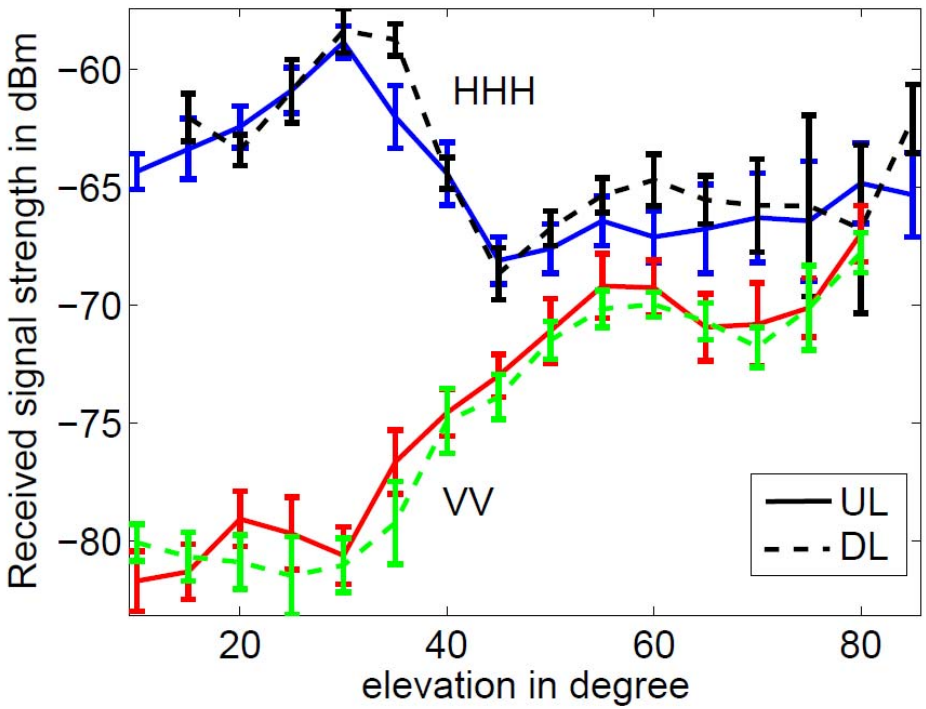




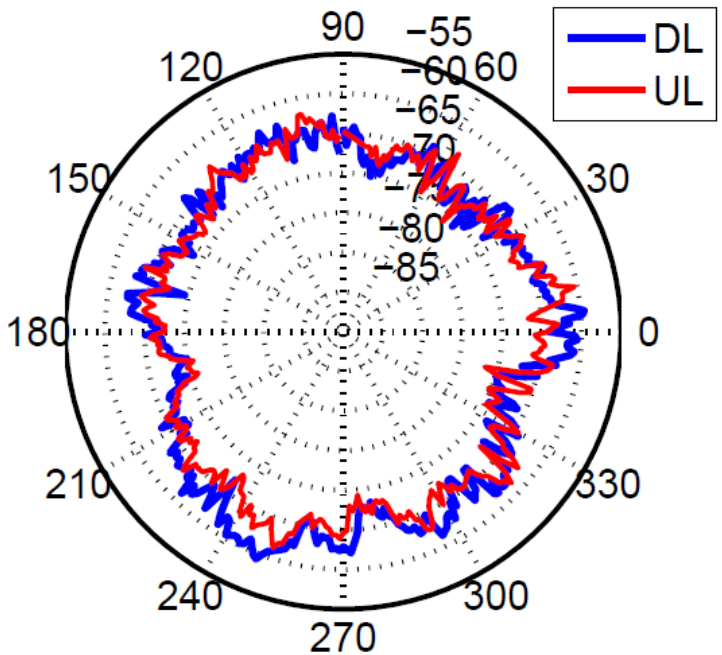


Radiation Pattern (HHH setup)

UAV ascending on the surface of a sphere



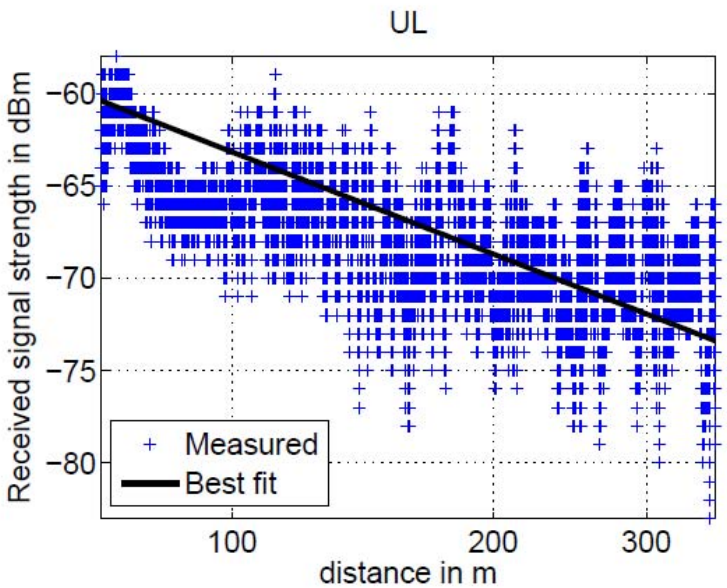
UAV flying around the access point at fixed altitude



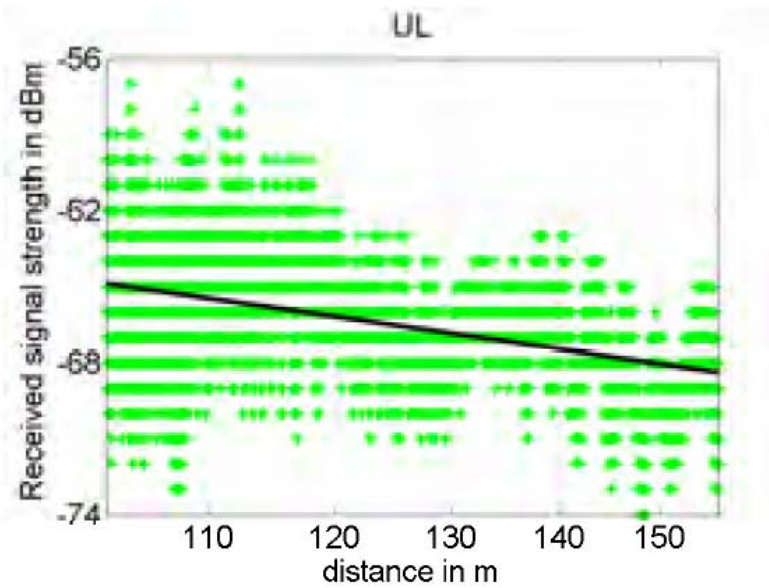
Path Loss Between UAV and Access Point

Path loss coefficient is ~2; consistent with free-space path loss

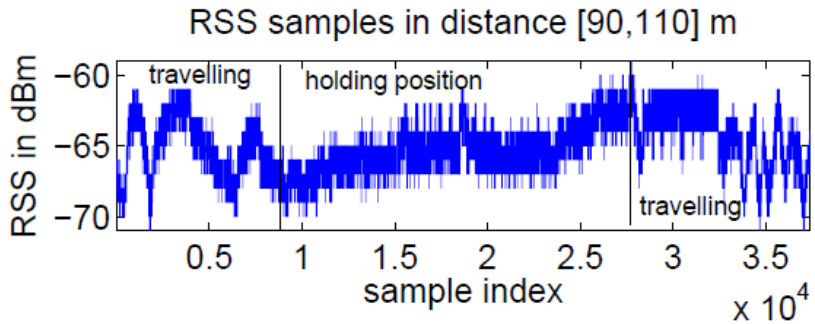
$$\mathrm{PL}(d) = \mathrm{PL}(d_0) + 10\alpha \log_{10}\left(\frac{d}{d_0}\right)$$



(a) Horizontal: moving away

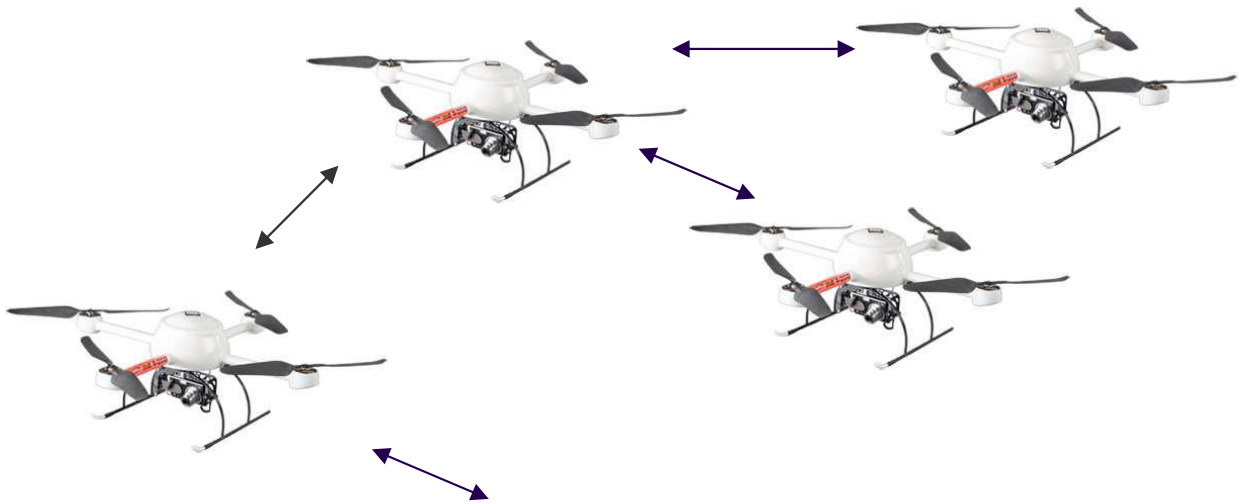


(b) Vertical: ascending



From Communications to Networking

- Wireless UAV mesh network based on WLAN 802.11s
- Use of cooperative relaying
- Interaction between UAV coordination and networking



Concluding Remarks

- Work on routing, image stitching, and wireless communications
- Challenges due to multidisciplinary and experimental character
- Various applications, several startup companies
- Various legal and privacy issues
- Attractive for students and PhD researchers

Selected Publications

- E. Yanmaz, R. Kuschnig, C. Bettstetter: Channel measurements over 802.11a-based UAV-to-ground links. In *Proc. IEEE GLOBECOM-WiUAV Workshop*, 2011.
- V. Mersheeva, G. Friedrich: Routing for continuous monitoring by multiple micro UAVs in disaster scenarios. In *Proc. Europ. Conf. Artificial Intellig.*, 2012.
- Evsen Yanmaz: Connectivity versus Area Coverage in Unmanned Aerial Vehicle Networks. In *Proc. IEEE Intern. Conf. Communications (ICC),* 2012.
- E. Yanmaz, R. Kuschnig, C. Bettstetter: Achieving air-ground communications in 802.11 networks with three-dimensional aerial mobility. In *Proc. IEEE INFOCOM*, 2013.
- T. Andre, C. Bettstetter: Assessing the value of coordination in mobile robot exploration using a discrete-time Markov process. Accepted for *IEEE/RSJ Intern. Conf. on Intelligent Robots and Systems (IROS),* 2013.

Acknowledgements