NETWORKING RESEARCH CHALLENGES IN MULTI-UAV SYSTEMS

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Where Do We Come From?

Pertinent Research:
8 years of research on technology and deployment of networks of multiple unmanned aerial vehicles (multi-UAV systems), in particular for emergency response operations.

Representative Projects and Objectives:
- **Collaborative Microdrones (cDrones)**
  - Flight formation and networked control
  - Cooperative aerial imaging to create overview pictures (mosaics) of disaster-affected areas
- **Self-organizing Intelligent Networks of UAVs (SINUS)**
  - Distributed coordination of UAV movements and task execution
  - Reliable aerial networking for robust multimedia streaming
PORTFOLIO IN AERIAL ROBOTICS

Research Topics:
- Autonomous navigation and coordination
- Mission and path planning
- Image processing
- Wireless (multimedia) comm.
- Human-UAV interaction

Application Areas:
- Search and rescue
- Aerial surveillance
- Precision agriculture
- Delivery of goods
1. Communication requirements are manifold
COMM. REQUIREMENTS / TRAFFIC TYPES

Scenario:

3D mobility
Infrastructure and mesh networking
Reliability and robustness against interference
Mix of traffic types, payload and control, incl. low latency, high data rates
Precise time sync and localization

Traffic Type
- UAV control
- Vision-based navigation
- Multimedia applications

Requirements
- Low latency & high reliability
- High data rate & low latency
- High data rate & QoS support
1. Communication requirements are manifold

2. Communication network of a multi-UAV system and their other components are highly interdependent
INTERDEPENDENCE OF (MULTI-)UAV COMPONENTS
FINDINGS w.r.t. NETWORKING AND COMMUNICATION (III)

1. Communication requirements are manifold

2. Communication networks of a multi-UAV system and their other components are highly interdependent

3. Off-the-shelf IEEE 802.11 WLAN is not well suited for 3D communication and agile network nodes (UAVs)
SAMPLE THROUGHPUT PERFORMANCE RESULT

IEEE 802.11n and 11ac over outdoor drone-to-ground link

Special antenna setup

Transmit power 10 dBm = 10 mW
UDP (User Datagram Protocol) traffic

Throughput in Mbit/s

Distance in m
Findings w.r.t. Networking and Communication (IV)

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4. Cooperative relaying or/and specific protocols are needed to support the multi-UAV mission
**Wireless Multi-Hop Communications**

- UAVs may serve as *relays* for traffic from other UAVs
- UAVs may form a *mesh* network using IEEE 802.11s
- UAVs may exploit *cooperative diversity* to make links more robust
- Large drone network may use *ad-hoc routing* protocols
- Large drone network may use concepts from *delay-tolerant networking* for certain applications

Different approaches for each traffic type possible
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5. Adaptation of payload data (e.g., pictures) in terms of quality/data rate, to network conditions at hand, helps
**EXPERIMENT: ADAPTIVE VIDEO STREAMING**

Video packets' queueing delays and video quality …

… *without* video adaptation

… *with* video adaptation

(Current heuristic:
- Downgrade if delay > 0.3 s
- Upgrade if delay < 0.1 s for 250 p.)
WHERE TO GO FROM HERE?

Research Objective:
To make multi-UAV systems fully autonomous

Doctoral Programme:
- *Networked Autonomous Aerial Vehicles (NAV)*
- Faculty: Bettstetter, Hellwagner, Rinner, Weiss
- Funding: ~0.5 M€ granted by AAU, 3 years

Networking Research Challenges …
… partially addressed
NETWORKING RESEARCH CHALLENGES

1. Autonomous, collaborative 3D environment reconstruction and navigation of the UAVs will have to be supported
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2. Fine-granular temporal synchronization between aerial vehicles will have to be established

3. Ad-hoc multipoint-to-multipoint communication and coordination will be needed
NETWORKING RESEARCH CHALLENGES

1. Autonomous, collaborative 3D environment reconstruction and navigation of the UAVs will have to be supported
2. Fine-granular temporal synchronization between aerial vehicles will have to be established
3. Ad-hoc multipoint-to-multipoint communication and coordination will be needed
4. Security and safety of an autonomous multi-UAV system will become of utmost importance
5. Availability of dedicated spectrum for mission-critical UAV networks will have to be discussed
Why TNC‘17?

Challenging networking research topics

Multi-UAV systems increasingly used for creative businesses, e.g.:
- Picture and movie productions
- Arts performances, e.g., AE Linz, “Drone 100” (Intel)
- Entertainment, e.g., Arrowonics

What if creative persons and artists could easily interact with a massive UAV swarm, e.g., by gestures?
→ New types of aerial shows, fireworks, entertainment
→ New networking research challenges
**SELECTED PUBLICATIONS**


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