1 Introduction

Networked systems consist of several physically non-coupled subsystems, called agents. The agents are controlled by local controllers and act autonomously. The local controllers exchange information over a communication network in order to reach a common control goal. The combination of multiple agents with a communication network is called multi-agent system.

Figure 1 shows the structure of the system to be investigated. A controlled agent consists of an agent $P_i$ ($i = 1, 2, \ldots, N$) and its local controller $C_i$. As the dynamics of the control system are sensitive to time delays and interruptions of the feedback loop the communication network $K$ has to provide communication links among the local controllers with acceptable transmission reliability and latency.

2 Project aim

The aim of this project is to elaborate complementary methods for the design of the communication and networked control system of mobile agents. The systems should be able to adapt the structure of the distributed controller and of the communication system to the current control aims under real-time conditions by varying the communication links among the agents. The controlled agents should act based on their local information only, without a central coordinator. Hence, the structure of the resulting system is a result of self-organisation of the subsystems. In this project two kinds of control problems will be considered:

- **Formation Control**: The agents have to assume and keep their defined relative positions to each other. The control aim is to attenuate disturbances.
- **Collision Avoidance**: The agents have distinct destinations reachable by individual routes. The control aim is to find non-conflicting trajectories and ensure safety requirements, as to ensure safety margins.

In this project an event-based control approach will be used.

3 Event-based networked control of mobile objects

Event-based control aims at reducing the communication effort using a control loop by closing the feedback loop only after an event generator indicates a control error exceeding a given bound [2]. If the control error is inside given bounds there is no need to close the control loop and the system acts in a feedforward structure without using the communication network. The information exchange should be reduced to a minimum communication is necessary to ensure the control goal and avoid an overload of the communication network. In Figure 2 the event-based control loop is depicted. It consists of the following parts:

- plant with input vector $u(t)$, output vector $y(t)$, state vector $x(t)$, disturbance vector $d(t)$
- control input generator
- event generator
- communication network $K$
- controller.

The solid arrows in the figure describe information links, that are continuously used, while the information links used only after an event occurred are shown by dashed arrows.

**Event-based formation control.** In event-based formation control the agents have to assume and keep their defined relative positions to each other. Figure 3 shows a formation of five agents (e.g. quadrocopters) flying in the formation. The main control aim is to attenuate disturbances [1]. To this end the local controllers have a dynamical model representing the state of neighbouring agents.
together with the disturbance of this state. If the disturbance becomes too large the controller needs additional information provided by other controllers via communication. Therefore, it is necessary to communicate not only the current state of the agents but also an estimate of the current disturbances. The control system has also to cope with a communication network, which might transmit the required information with delay or transmission failures. Note that the agents do not have a coordinator at a higher level that decides to what time which information has to be communicated among the agents. These decision rules have to refer only to local information that is available at an individual agent. Hence the control and communication is a result of self-organisation of the controllers.

### 4 Example

An application example is the formation control of unmanned aerial vehicles (UAV). Such a vehicle (e.g. a quadrocopter) has six degrees of freedom along the three cartesian coordinates and around the three axis in the three-dimensional space. Such crafts consist of four individual controllable rotors with which the quadrocopter is able to change its position in every possible direction. In Figure 5 a quadrotor in a cartesian coordinate system is shown. The torque $M$ around the three axis resulting by the rotors leads to a change of position. The goal is to bring several quadrocopters in a predefined formation and move the whole formation through the spatial room. A second goal is to move the quadrocopters to a new position without colliding with other quadrocopters underway.

### References
