Projektseminar KTS

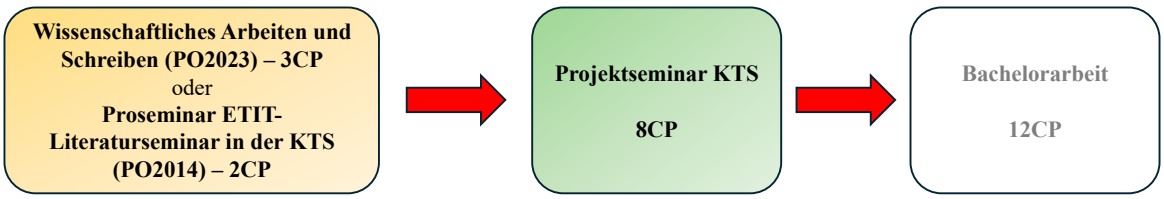
Wissenschafliches Arbeiten und Schreiben (PO2023)
oder
Proseminar etit (Literaturseminar) (PO2014)

Ergänzung zum Projektseminar KTS

TECHNISCHE UNIVERSITÄT DARMSTADT

Fachgebiet Kommunikationstechnik, Prof. Dr.-Ing. Anja Klein
Summer Semester 2026

1 Übersicht



- Im 5. bzw. 6. oder höheren Semester des Bachelor Studiums etit oder WI-etit
- Die Themen werden idealerweise zusammen mit dem Thema für die Bachelorarbeit gewählt
- Ansprechpartner: alle Mitarbeitenden, die eine Bachelorarbeit anbieten
- Startzeitpunkt und Dauer der Projektarbeit (z.B. im Block oder vorlesungsbegleitend) können mit dem/der Projektbetreuer*in individuell vereinbart werden
- Je nach Thema kann Teamarbeit möglich sein
- Wird jedes Semester angeboten
- Ansprechpartner für das Fachgebiet Kommunikationstechnik bei allgemeinen Fragen:
  - Sumedh Dongare, s.dongare@nt.tu-darmstadt.de
  - Prof. Dr.-Ing Anja Klein, a.klein@nt.tu-darmstadt.de

2 Proseminar etit (Literaturseminar) PO(2014) / Wissenschafliches Arbeiten und Schreiben (PO2023)

- Forschungsnahe Erarbeitung eines fachlichen Themas in Zusammenarbeit mit einem/einer wissenschaftlichen Mitarbeiter*in als Betreuer

- Detaillierte Beschäftigung mit technischen Artikeln
- Tiefes Verständnis des darin behandelten fachlichen Themas
- Praktische Erfahrung mit technischer Dokumentation
- Erlernen moderner Präsentationstechniken und deren Anwendung
- Präsentation und Diskussion des fachlichen Themas vor einer Gruppe

3 Projektseminar KTS

- Vorbereitung auf die Bachelorarbeit
- Idealerweise werden das Projektseminar und die Bachelorarbeit am selben Fachgebiet bei dem/derselben Betreuer*in absolviert und die Themen aufeinander abgestimmt
- Tiefes Verständnis eines speziellen, komplexen Forschungsthemas der KTS
- Praktische Erfahrung mit aktueller Literatur
- Praktische Erfahrung mit Algorithmen und/oder Simulation
- Strukturierung einer komplexen Aufgabe
- Präsentation eines komplexen Themas
- Dokumentation eines komplexen Themas

4 Ergänzung zum Projektseminar KTS

- Ergänzt das Modul Projektseminar
- Kann als Ersatz für das Einführungsprojekt belegt werden
- Kann nur zusammen mit dem Projektseminar belegt werden, dessen Aufwand sich dann von 8 CP auf 10 CP erhöht

5 Themen

Im Folgenden sind beispielhaft einige Themen des Fachgebiets Kommunikationstechnik dargestellt. Für weitere Informationen sowie zusätzliche, verwandte Themen kontaktieren Sie bitte den oder die jeweiligen Mitarbeitenden per e-mail. Natürlich können Sie auch ein persönliches Gespräch führen.

5.1 Lightweight No-regret Online Learning in Repeated Stackelberg Security Games

Motivation:

In security games, defenders must protect critical systems against potential adversaries with limited resources, making it impossible to guarantee full coverage at all times. Therefore, it is crucial to find the best strategy for adaptively allocating the available defensive resources. In practice, security games have been used for patrol scheduling at Los Angeles International Airport, wildlife protection against illegal poaching, and cyber-security applications such as jamming and distributed denial-of-service (DDoS) mitigation.

A Stackelberg Security Game (SSG) models one or more defenders and attackers who assign limited resources to either protect or attack a set of targets. In this hierarchical game-theoretic framework, the defender acts as the leader by committing to a strategy first, after which the attacker observes the leader's strategy and reacts accordingly to its best respond in a potentially adversarial way.

As the attacker's behavior may be unknown and change over time, a repeated SSG can be utilized to model the repeated interactions between defender and attacker. Thus, an online learning algorithm can be implemented, allowing the defender to adapt its strategy over time to protect the targets against the adversarial attacker without requiring full knowledge of the attacker's objectives.

Topic:

An online learning algorithm is proposed in [1] to solve a repeated Stackelberg Security Game. A single defender acts as the leader and employs a mixed strategy to protect the targets against an adversarial attacker of unknown type. The attacker acts as the follower by attacking a single target, while the attacker's type is unknown to the defender. The defender's problem in one time slot is formulated as a mixed-integer linear program (MILP), which is incorporated into an online learning algorithm to adaptively determine the best defense strategy against the adversarial attacker.

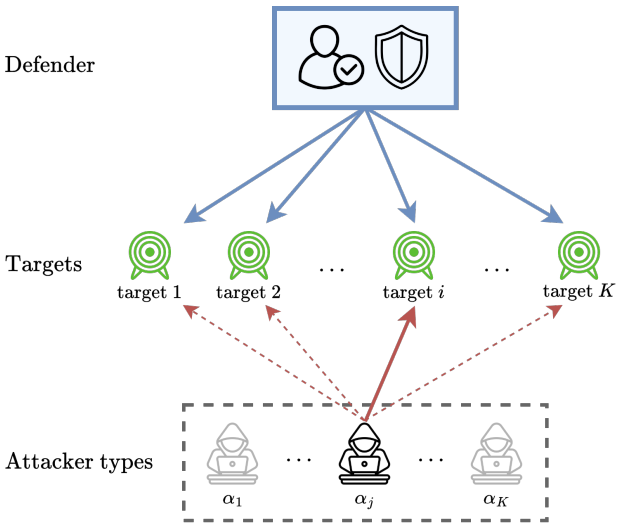


Figure 1: Illustration of the Stackelberg Security Game in [1]

The tasks of this project are:

1. Formulate the repeated Stackelberg Security Game,
2. Implement the online-learning algorithm for finding the best defense strategy, and
3. Evaluate the implemented algorithm in different scenarios.

Requirements: A fundamental knowledge of optimization, MATLAB or Python, and game-theory will be helpful.

Introductory Literature:

[1] Guanda Chen, Yiding Ji, and Shuo Han. "Lightweight No-regret Online Learning in Repeated Stackelberg Security Games". In: *IEEE Control Systems Letters* (2026). DOI: 10.1109/LCSYS.2026.3671784

Contact:

Markus Krantzik, m.krantzik@nt.tu-darmstadt.de

5.2 Risk-Aware Backup Path Allocation for Resilient Wireless Networks

Motivation:

Future sixth-generation (6G) wireless networks are expected to provide ultra-reliable and low-latency communication (URLLC) for a wide range of applications such as autonomous systems, industrial automation, and immersive services. To meet these stringent requirements, network resilience becomes a key design objective, ensuring continuous service despite failures, congestion, or adverse environmental conditions.

A promising approach to enhance reliability is *multi-connectivity (MC)*, where multiple parallel paths are established between the network and the user. However, MC can lead to inefficient resource usage, as redundant resources are allocated even when the primary connection is reliable.

As an alternative, *backup path allocation* can be used to improve resilience more efficiently. Instead of permanently reserving multiple active connections, backup paths are activated only when the primary path fails. A major challenge in this context is that different parts of the network are exposed to different risks, such as base station failures, limited radio resources, or poor channel conditions. Therefore, it is essential to design a *risk-aware* strategy that accounts for these heterogeneous risks when allocating backup paths and resources.

Topics:

In [MOC25], a risk-aware backup path allocation framework for integrated terrestrial and non-terrestrial networks is proposed. The system considers multiple types of radio access technologies, including terrestrial base stations (BSs), high-altitude platforms (HAPs), and low-Earth orbit (LEO) satellites.

The end-to-end (E2E) connectivity is modeled by considering both physical availability and transmission reliability of each path segment. To improve resource efficiency, users are grouped based on disjoint risk factors, and backup resources are shared among users within a group. The backup path for each user is then selected such that the overall availability is maximized, taking into account both the quality of the backup path and the availability of resources.

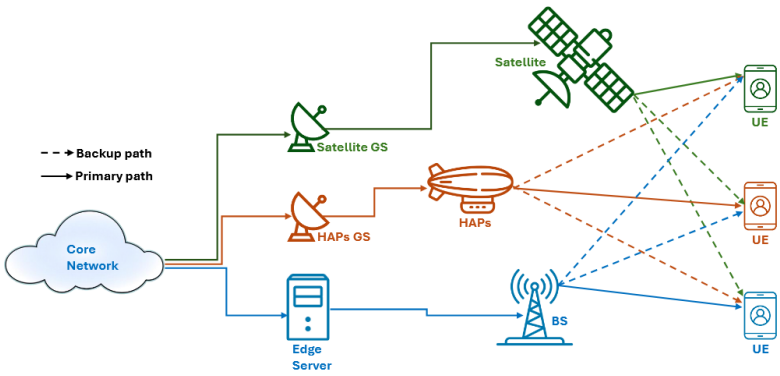


Figure 2: System model of integrated terrestrial and non-terrestrial network with primary and backup paths [MOC25]

The tasks of this project are:

- Understand the system model, including the modeling of SINR, data rate, and transmission reliability
- Derive and implement the end-to-end path availability based on segment-wise reliability and physical availability
- Implement the risk-aware backup path allocation algorithm
- Evaluate the performance for different metrics

Introductory Literature:

[1] Aunas Manzoor, Mustafa Ozger, and Cicek Cavdar. “Risk-Aware Backup Path Allocation in O-Ran Based Integrated Terrestrial and Non-Terrestrial Networks”. In: 2025

Contact:

Leonhard Wahl, l.wahl@nt.tu-darmstadt.de, S3|10 316

5.3 Digital Twin Placement in Mobile Edge Computing

Motivation:

Digital twins (DTs) are regarded as one of the cornerstones of future sixth-generation (6G) wireless communication networks. A DT is a virtual software-based representation of a real physical system (PS), e.g., an autonomous vehicle or Internet of Things (IoT) device. By simulating the status of the PS in real-time, a DT replicates its PS's behavior in the virtual space. Since the real-time simulation of the PS requires large amounts of computation resources, DTs are usually hosted on computation servers.

DTs can provide additional functionalities like analysis of the PS's current state or prediction of future PS behavior, which can be used to gain insights into the PS's dynamics. Moreover, DTs can interact on behalf of the PSs with third parties, e.g., applications. In the context of 6G IoT networks, these functionalities can be used to optimize wireless communication systems to meet strict requirements regarding latency, data rate and reliability.

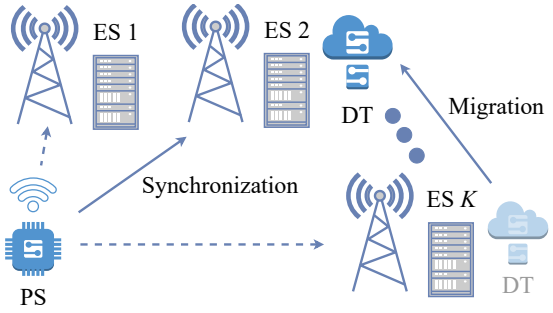
In order to accurately represent its PS, the DT needs to synchronize with its PS. This synchronization process entails two steps. Firstly, the PS transmits data regarding its current state to the host server of the DT. Secondly, the received data is being processed on the host server in order to update the DT model of the PS. For a seamless synchronization of PS and DT, the latency associated with the synchronization should be minimized.

Mobile Edge Computing (MEC) has shown to be a suitable technology for that purpose. By hosting the DTs on edge servers (ESs), which offer large computation resources at the network edge, the synchronization latency can be reduced compared to a deployment on remote cloud servers. However, the DT placement problem, i.e., the selection of a host ES for the DT, is challenging, as available communication and computation resources at the ESs are heterogeneous and shared with other users. Furthermore, real MEC systems evolve dynamically, which requires the DT placement to be adaptive.

Topic: DT Placement in Dynamic MEC Systems Using Reinforcement Learning

In [1], DT placement in an uncertain and dynamic environment, with the objective of jointly minimizing synchronization latency and energy consumption, is investigated. Specifically, a PS aims for selecting the optimal ESs without having any prior knowledge of the environment and MEC system characteristics, i.e., wireless channel qualities and the ESs' computation capabilities and loads. Furthermore, it is assumed that the environment changes dynamically in a statistically non-stationary manner. This requires a flexible and adaptive solution for the DT placement, which is able to identify the optimal ES in an unknown environment and migrate the DT between ESs to adjust to changes. Moreover, since the migration of the DT between ESs incurs an additional overhead, the DT placement strategy should also account for this.

To solve the aforementioned challenges, a reinforcement learning approach, based on Multi-Armed Bandits (MABs), is proposed as a DT placement approach.



The tasks of this project are:

- Familiarize yourself with the system model and DT placement problem formulation in [1].
- Understand the proposed DT placement algorithm based on a MAB reinforcement learning approach.
- Implement the proposed DT placement algorithm as well as the compared benchmark schemes in order to verify the results obtained in [1] with your own simulations.

Introductory Literature:

[1] Maximilian Wirth, Andrea Ortiz, and Anja Klein. "Risk-Aware Bandits for Digital Twin Placement in Non-Stationary Mobile Edge Computing". In: *2024 IEEE International Conference on Communications Workshops (ICC Workshops)*. IEEE. 2024, pp. 13–18

Contact:

Maximilian Wirth, m.wirth@nt.tu-darmstadt.de, S3|10 318

5.4 UAV-aided Integrated Sensing and Communication

Motivation:

Unmanned aerial vehicles (UAVs) are increasingly used in sensing and communication applications due to their agile mobility and flexible, low-cost deployment. Recently, UAV-aided integrated sensing and communication (ISAC) has been proposed as a promising approach to realize efficient simultaneous wireless sensing and communication onboard UAVs. ISAC enables a light-weight design ideal for UAVs constrained by size, weight, and power (SWAP), as it allows for onboard sensing and communication using shared spectrum, signal processing algorithms, and transmitter hardware. Moreover, by employing a common signal for sensing and communication, rather than separate, potentially interfering signals, ISAC enhances the utilization of limited radio resources. Further, mobile UAVs can also improve the ISAC performance by e.g. proactively seeking strong line-of-sight (LoS) channels and avoiding obstacles between the UAV and sensing targets or communication users, especially in emergency scenarios or complex environments.

Topic:

The goal of this project is to jointly consider the 3D radiation patterns of practical antennas, the orientation of the antenna array, and beamforming in UAV-aided ISAC systems. We focus on a UAV-aided ISAC system, as illustrated in Fig. 3, where a rotary-wing UAV serves as a dual-functional aerial access point (AP) to simultaneously perform downlink communication with multiple ground/aerial users and radar sensing towards multiple targets. The UAV is equipped with a novel, rotatable uniform linear array (ULA) comprising practical antenna elements, such as half-wavelength dipoles. Consequently, both beamforming and array steering can be optimized to enhance communication and sensing performance. References [1] and [2] have introduced a low-complexity iterative algorithm based on convex and manifold optimization to address this highly non-convex, multi-variate, joint optimization problem. However, this algorithm relies on several hyperparameters that significantly impact convergence and optimization outcomes. The aim is to refine the algorithm and determine the patterns of influence caused by different hyperparameters.

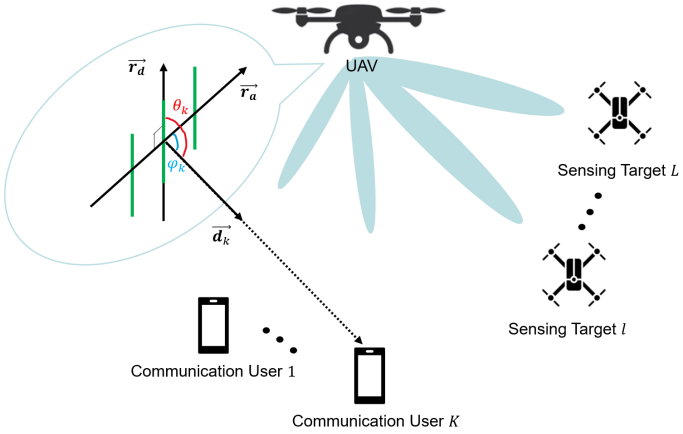


Figure 3: System model of UAV-aided ISAC using rotatable ULA

The tasks of this project are:

1. Investigate the UAV-aided communication and sensing systems using the rotatable antenna array.
2. Exploit various practical metrics for ISAC.
3. Explore efficient optimization algorithms for array orientation optimization.

Introductory Literature:

[1] Fengcheng Pei Lin Xiang and Anja Klein. “Joint Optimization of Beamforming and 3D Array Steering for Multi-antenna UAV Communications”. In: ()

[2] Lin Xiang Fengcheng Pei and Anja Klein. “Joint Optimization of Beamforming and 3D Array-Steering for UAV-Aided ISAC”. in: ()

Contact:

Fengcheng Pei, f.pei@nt.tu-darmstadt.de