Trajectory Optimization for UAV-Assisted Hybrid FSO/THZ IoV Network

Master's research plan seminar

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Outline

1. Terrestrial-Assisted RF IoV Network
2. Challenging Issues
3. Possible Solutions
4. Research goal & plan

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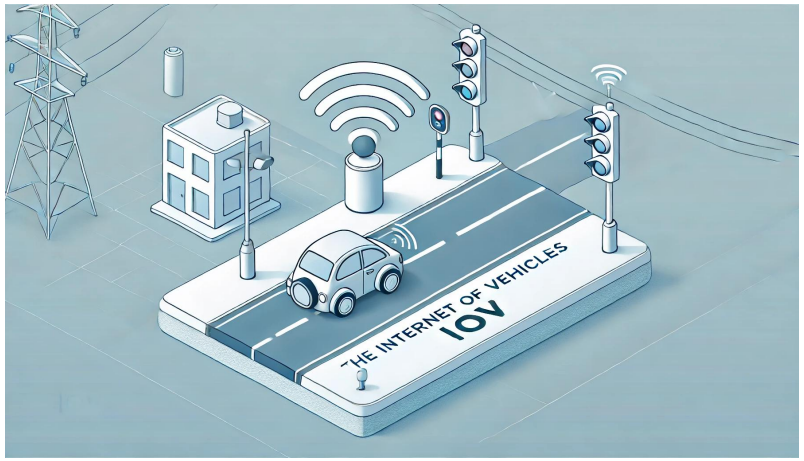
Introduction to IoTs and IoVs

The Internet of Things(IoTs)

- **The Internet of Things (IoTs)** refers to the network of physical objects—“things”—that are embedded with sensors, software, and other technologies with the aim of connecting and exchanging data with other devices and systems over the internet.
- These objects can range from ordinary household items to sophisticated industrial tools. IoT has a significant impact on various aspects of life and industry, driving the evolution of smarter environments.

The Internet of Vehicles(IoVs)

- **The Internet of Vehicles (IoVs)** is an extension of the Internet of Things (IoTs), focusing specifically on the interconnection of vehicles.
- IoV aims to improve road safety, enhance driving experiences, and optimize traffic management through advanced communication technologies.



Existing system

Terrestrial Communication Systems

- The Internet of Vehicles (IoVs) involves connecting vehicles to each other, infrastructure, and networks to create a smarter transportation system.
- Terrestrial communication systems are crucial in IoV, providing the necessary ground-based infrastructure for data exchange and vehicle communication.

Radio Frequency communications

- Current terrestrial communication systems widely utilize Radio Frequency (RF) technology, particularly in the context of the Internet of Vehicles (IoV) and other Internet of Things (IoT) applications.
- RF involves the use of electromagnetic waves to transmit data over the air, enabling wireless communication between devices.Radio Frequency (RF) ranges from 3 kHz to 300 GHz.

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Disadvantages of existing approaches

1.Terrestrial Communication Systems: blocked by obstructions

- Issue: Terrestrial communication systems rely on ground-based infrastructure to transmit and receive signals. In urban environments, these signals often have to travel through or around buildings because of the mobility of vehicles.

You can see that the signal is easy to be blocked by buildings.

Disadvantages of existing approachs

2. RF Communication Systems: Transmission Speed

- Issue: For future applications,we need higher data rate which RF can not achieve.
- The data rate in existing Terrestrial system
  - 4G LTE (Long-Term Evolution): Typically offers download speeds of up to 100 Mbps and upload speeds of up to 50 Mbps.
  - 5G NR (New Radio): Offers significantly higher speeds, with typical download speeds ranging from 100 Mbps to several Gbps, and upload speeds from 50 Mbps to several hundred Mbps.

➡ Why it is not enough for IoVs?

- Ultra-HD and 4K/8K Video Streaming
- V2X Communication(Real-Time Applications)
- Network Congestion:With increasing data traffic, existing systems may face congestion, leading to degraded QoS(Reliability and Quality of Service).

➡ So we need to improve the data rate.

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Possible Solution 1:Unmanned Aerial Vehicles

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are aircraft systems that can operate without a human pilot on board. They are controlled remotely or autonomously via onboard computers.

Why UAVs?

- 1: UAVs can fly above buildings and other physical obstructions, ensuring a clear line of sight for communication signals. This ability allows them to bypass obstacles that ground-based systems cannot.
- 2: UAVs can be moved as needed to provide coverage in areas where buildings and other obstructions would otherwise block signals. This is particularly useful in urban environments with many tall structures.

Possible solution 2: hybrid FSO/THZ

Why FSO/THZ,not RF?

- In an autonomous vehicle collision detection system, real-time capture and upload of high-definition images of accident scenes are crucial for quick analysis and response. Due to the large file size and the need for high-speed transmission, RF communication may be insufficient.

➡ We use FSO/THZ to guarantee the speed.

Why hybrid FSO/THZ

- Free-Space Optical (FSO) communication is a technology that uses light propagating in free space to transmit data wirelessly.Its frequency range from 187THz to 400THz
- FSO systems can achieve data rates up to few Gbps or higher, making them suitable for high-bandwidth applications.
- But FSO can be affected by adverse issues such as fog,rain,snow and strong winds.
- To fulfill the high data-rate demand of IoV applictions,THZ,can be expoited for such backup links.Terahertz (THz) refers to the frequency range of electromagnetic waves that lies between the microwave and infrared regions of the electromagnetic spectrum. The range of THZ frequncy is from 0.1THz to 10 THz.

➡ Hybrid FSO/THZ is a promising solution.

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Our focus:UAV-Assisted hybrid FSO/THZ IoV

- We consider UAV-Assisted hybrid FSO/THZ for the internet of vehicles.
  - UAV serves as a base station.
  - Hybrid FSO/THZ is used to optimize the achievable rate

Primary Link	FSO
Backup Link	THZ
Outage	No Transmission

Basically we use FSO as a primray link,but if FSO is not avaliable because of weather conditions like fog,we can use THZ as a backup link because THZ will not be affected by fog.

When the quality of THZ link becomes unacceptable and FSO link is also unavailable,the system outage occurs.

The right figure shows the system illustration,where the UAV uses FSO/THZ links to communicate with self-driving cars in an urban environment.

Problem Statement

- **Issues with UAVs in IoVs (Internet of Vehicles) Applications**

1. **Vehicle Mobility**:

   Problem: Constant vehicle movement in IoV requires UAVs to continuously follow them, necessitating advanced tracking and coordination to maintain communication links.

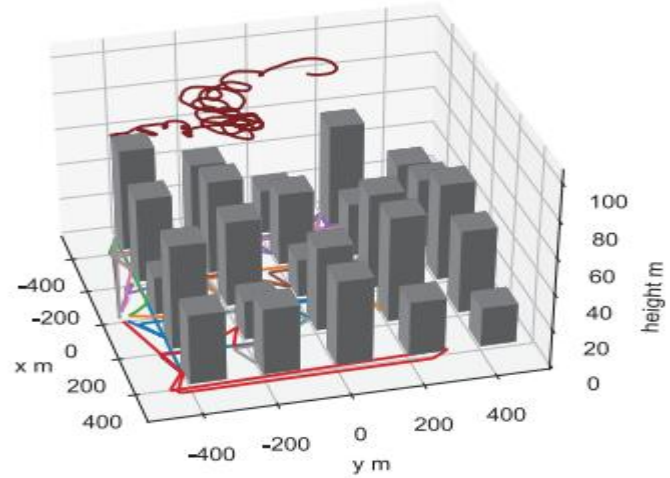
2. **Blocked by obstructions in some situations:**

   Problem: The signal can be obstructed by tall buildings and structures in some situations, causing signal loss or degradation, so we should find good path.

   ☐ **Why we can not just let the UAVs fly high enough to be not blocked by obstrsutions?**

   - **Flying high=consume more power**
   - **The lower battery power will**
     - ① **limit the flight range**
     - ② **increase the cost**

   The right figure shows the simulation environment. Dark red curve:The flight trajectory of UAVs Colored curves:IoVs



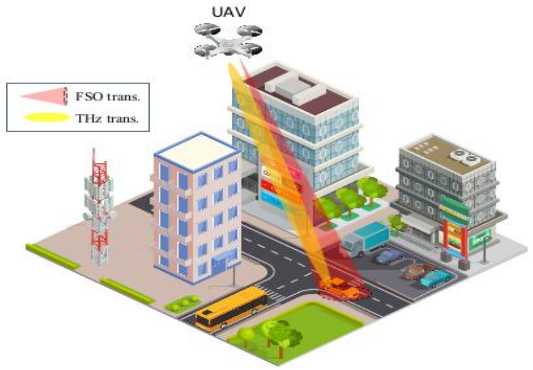
3. **Weather Conditions:**

   Problem: Adverse weather conditions such as rain, snow, fog, and strong winds can impair UAV stability and signal transmission, causing potential communication interruptions in IoV services.

Our goal

- To choose the optimal path for UAVs to maximize the achievable data transmission rate, taking into account weather conditions and obstructions, **We plan to apply ML/DRL to solve the problem,so why DRL?**
  - 1: RL algorithms optimize UAV paths to minimize energy consumption, mission time, and improve efficiency.
  - 2: Ensuring UAVs can adapt to dynamic environments and varying mission requirements through intelligent trajectory planning.

Moreover, the FSO link is used primarily to achieve the high target rate. When the FSO link is insufficient, the THZ link is supplemented at a lower rate.



- This involves switching between Free-Space Optical (FSO) and Terahertz (THZ) communication systems to ensure the fastest and most reliable transmission.
- Reliable transmission means?
  - It means that we should set a standard transmission speed for the link.If FSO can not reach that speed because of the weather condition,we should change it to THZ to guarantee the speed.

Future plan

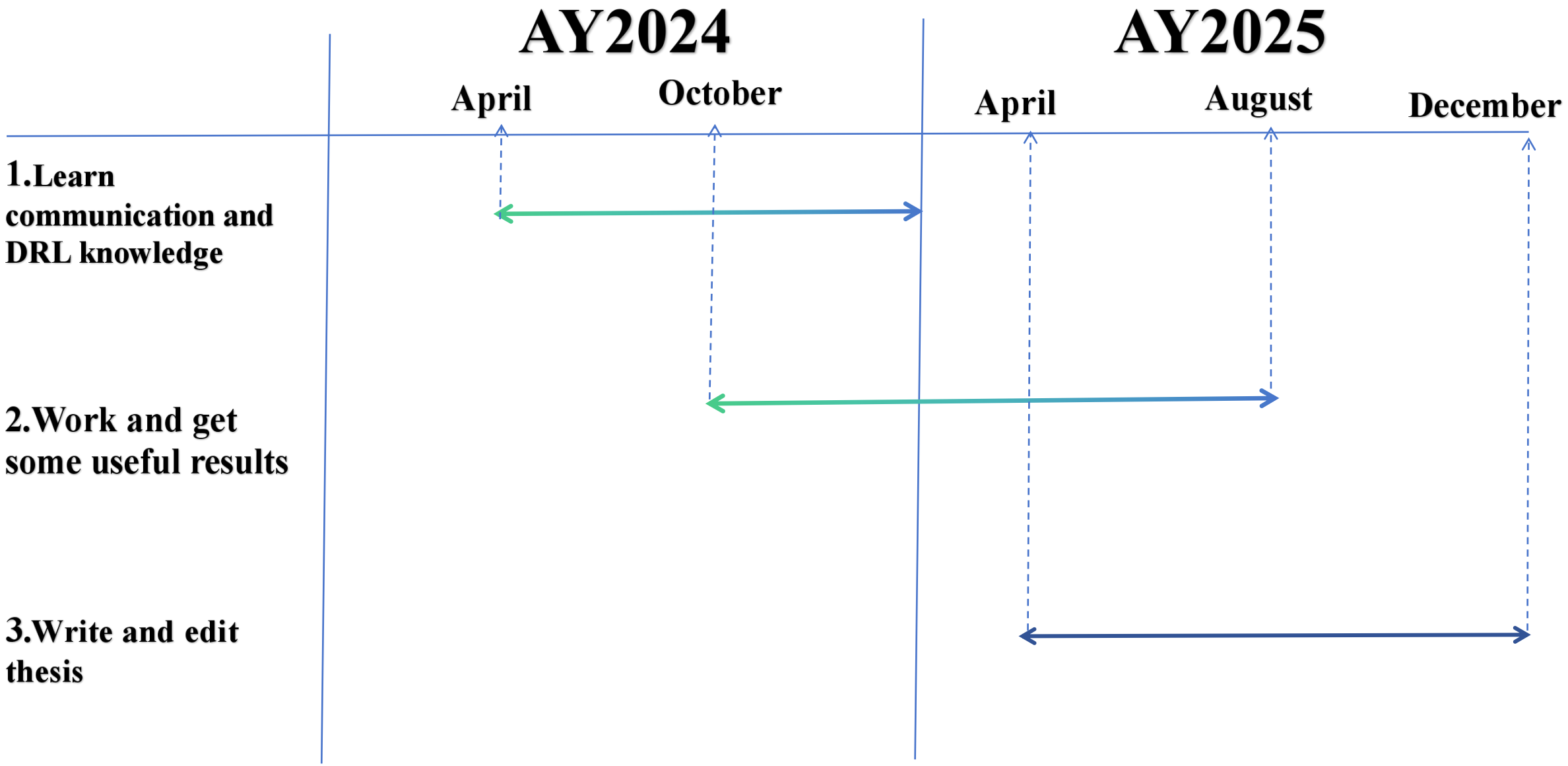
- **Stage1:Because I am new to this field,so i need to gain some background knowledge first.**
- **Stage2:For this peroid,i will work for the research,find how to choose the good path to optimize the achievable rate of communication and how to switch one communication link to another.**
- **Stage3:I will start writing and edit thesis.**

Improve the knowledge by taking courses

- Wireless network
  - ① Optical course(by Prof Le,Q2)
  - ② Computer networking(Prof Le,Q3)
  - ③ Wireless course(Prof Pham,Q4)

- Machine Learning
  - ① Online courses on coursera
  - ② ML course(by Prof Zhao,Q2)

Future plan


AY2024
AY2025
April
October
April
August
December
1.Learn communication and DRL knowledge
2.Work and get some useful results
3.Write and edit thesis

Thanks for your attetion