Computer Communication Laboratory

Research Topic Presentation

Spatial Resource Allocation for ORIS supporting multiple UAVs in FSO-assisted HAP-IoV Networks

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Outline of Presentation

- Research background
  - FSO assisted HAP-IoV network
  - What is the Reconfigurable Intelligence Surface (RIS)?
  - The principle of optical RIS (ORIS)
  - Survey the existing works of ORIS
  - Motivation
- System Proposal
  - Challenging Issues
- Possible approaches
- Our focus: problem statement and my target

The demand for 6G wireless network requires _cost-effective_, _globally connected_ and _high data rate_ solutions. FSO-assisted Non-Terrestrial Network is a promising candidate.

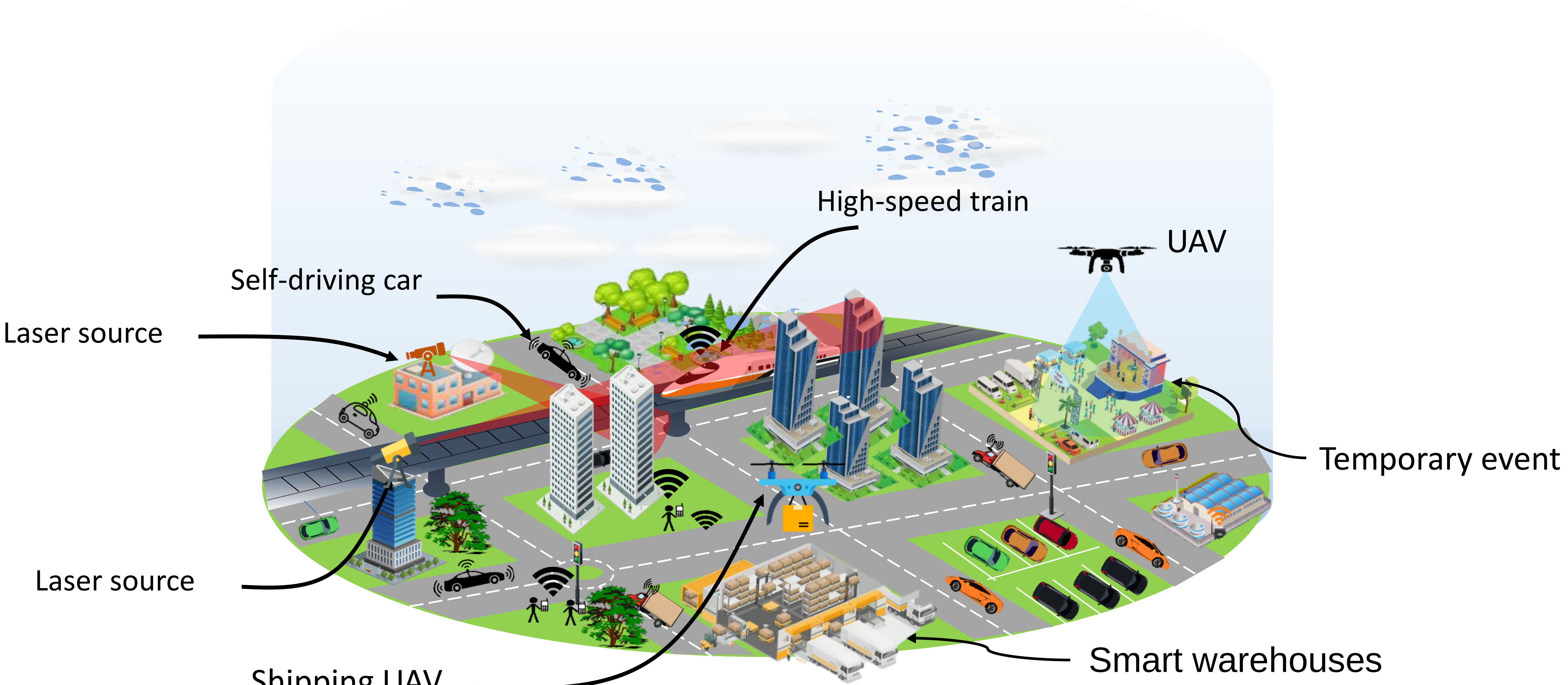
Free Space Optical (FSO) communications

- Using infrared frequency bands to transmit data in free space.
- High-speed connection (Gbps and even Tbps)
- Free-license bandwidth

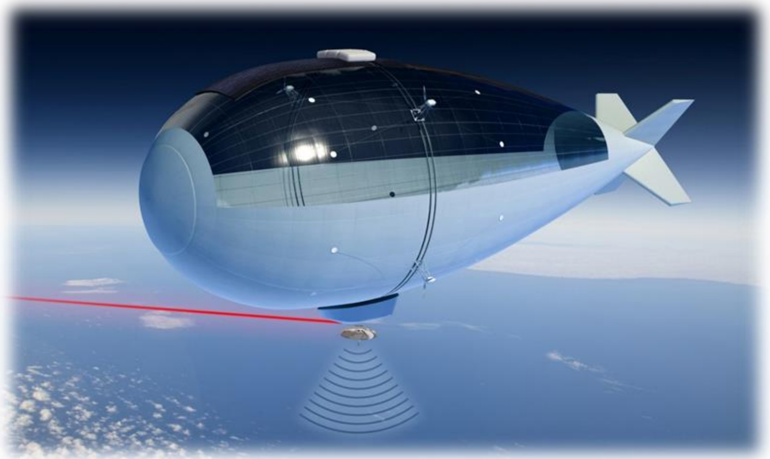
6G applications

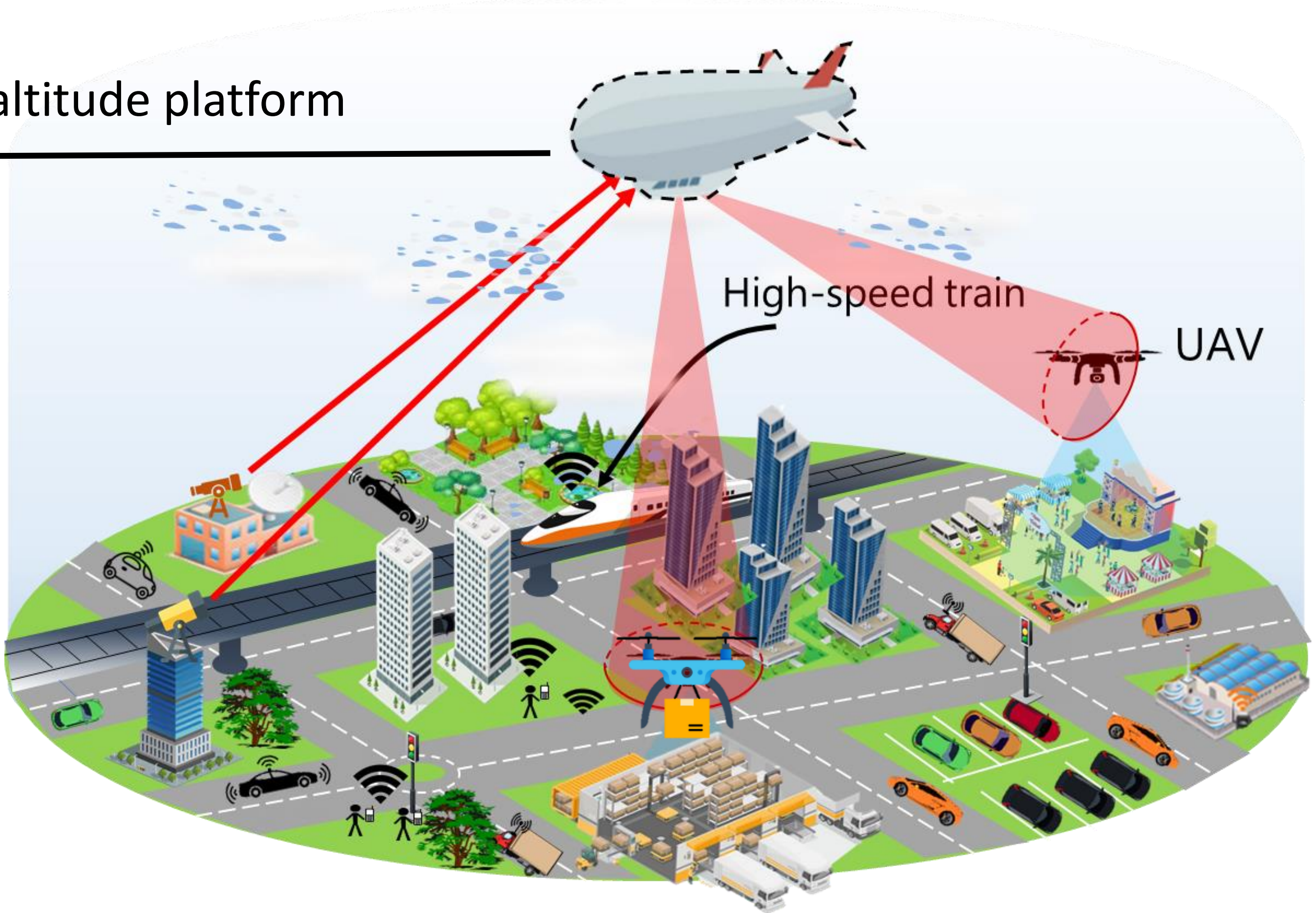
- Internet of Vehicles (IoV)
- Internet of Medical Things (IoMT)
- Internet of Senses (IoS)
- Internet of Remote Things (IoRT)
- Vehicle to Everything (V2X)
- Smart Grid IoT,…

Internet of Vehicles (**IoV**) is a network of vehicles equipped with sensors, software, and the technologies that aim to connect and exchange data over the Internet.



Internet of Vehicles (IoV)





Internet of Vehicles (IoV)

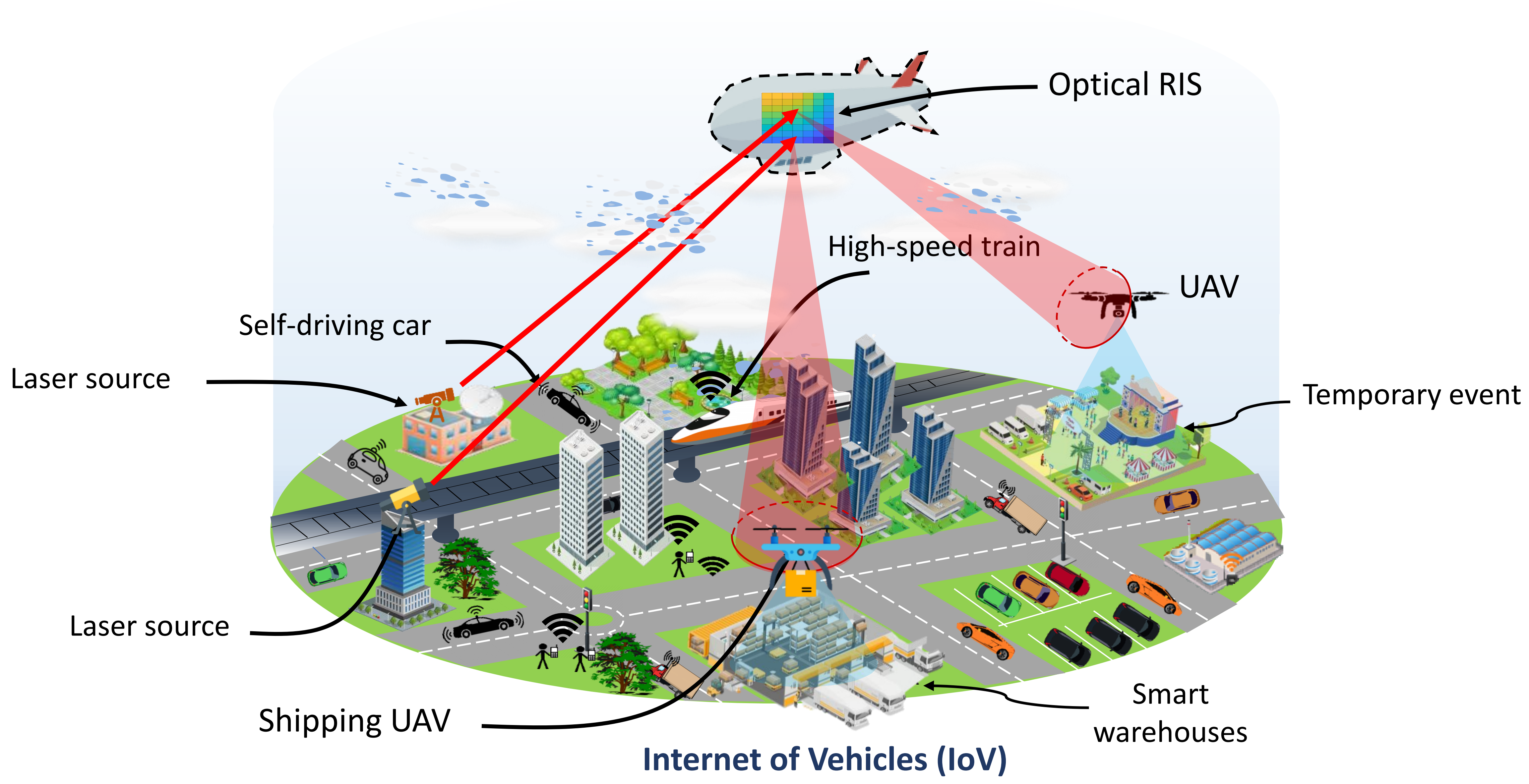
❖ High altitude platform (HAP)

- Airships or balloons
- Altitude: 17-25 km
- Flexible deployment, easy maintenance, cost-effectiveness
- Provide connection to remote areas.

➡ HAPs can serve as relay stations to increase the coverage and avoid blockage.

❖ Challenges

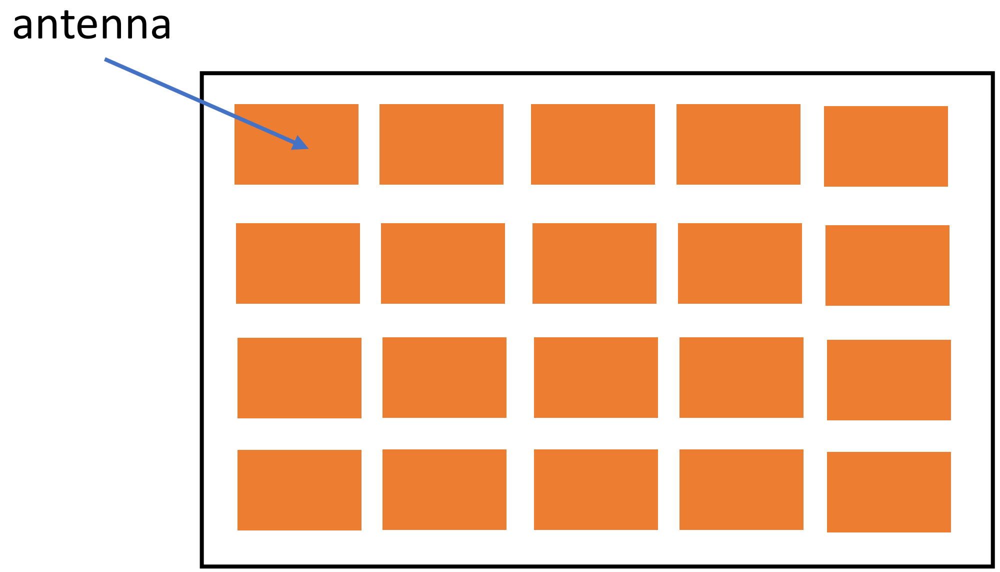
- Power-consuming
- Hardware complexity
- Additive noise


Optical RIS
High-speed train
UAV
Self-driving car
Laser source
Temporary event
Laser source
Shipping UAV
Smart warehouses
Internet of Vehicles (IoV)

1. What is the Reconfigurable Intelligence Surface (RIS)?

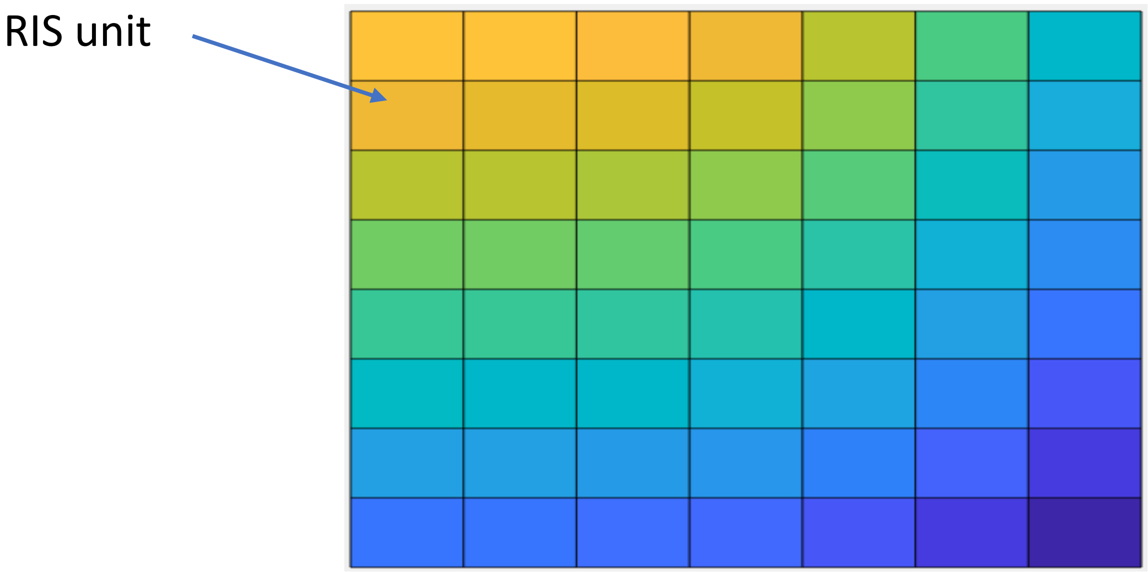
❖ **Reconfigurable intelligent surface (RIS)**

- An artificial surface, made of electromagnetic material or massive inexpensive antenna that controls and manipulates the impinging waves into the expected directions.
- Low cost, low complexity, low power.
- Improve coverage by turning NLoS links into multiple LoS links.



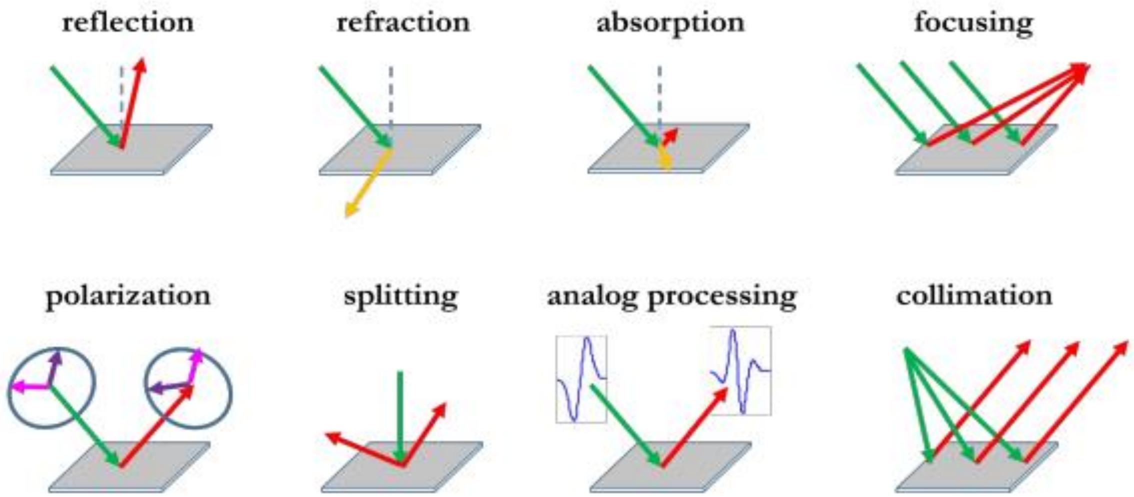
RIS made of massive inexpensive antenna

Meta surface-based RIS



RIS made of metallic or dielectric patches

❖ The function of RIS

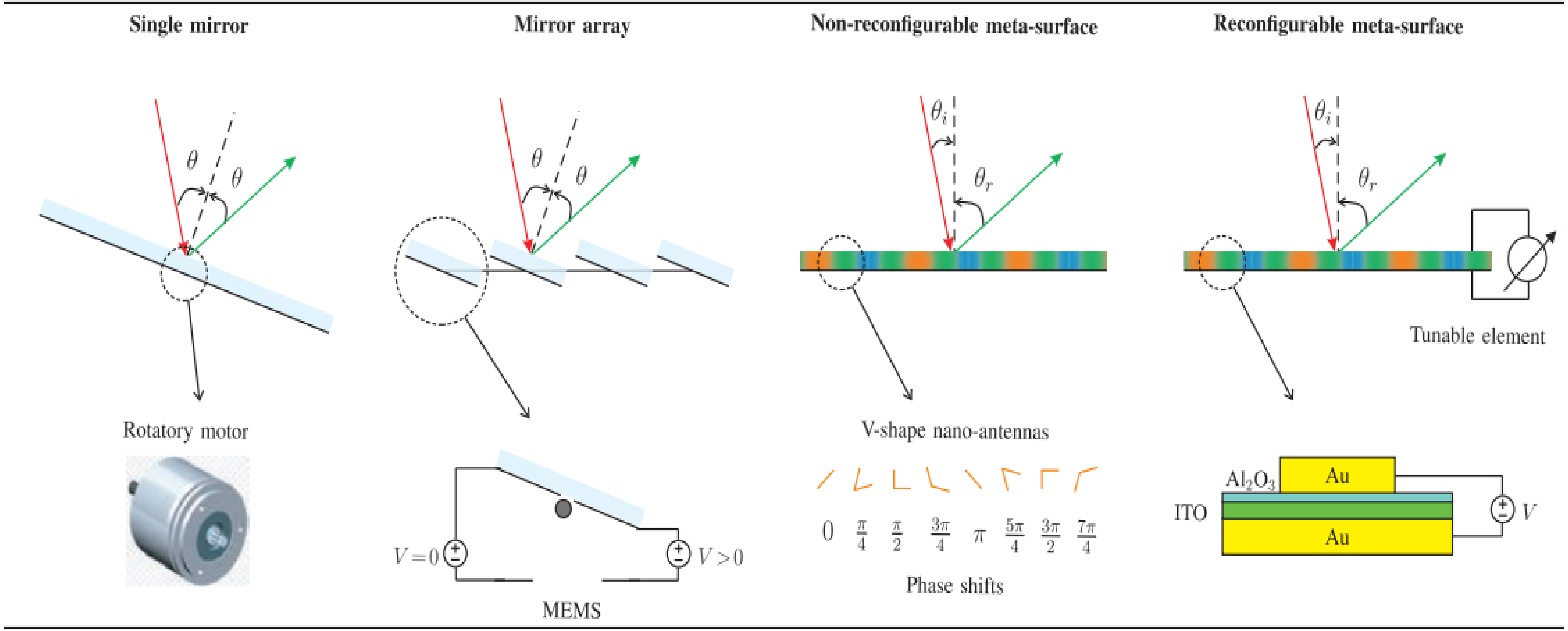


❖ RIS is applied for many technologies

- Radio Frequency (RF)
- Visible Light Communication (VLC)
- TeraHertz (THz)
- mmWave
- QKD
- Hybrid mmWave-THz
- FSO

Many research works and continuously improving

Optical RIS (ORIS) is the RIS that is created to reflect the light waves



A mechanical rotary structure controlled by electrical motors

Use micro-electro-mechanical systems (MEMSs)

Using V-shaped optical nano-antennas

Use oxide material and control electricity to turn the phase of incident waves

❖ ORIS for Terrestrial Networks

Year	Refs	System Model	Channel Modeing	FSO channel	Contributions	Performance Metrics	Multiple users
2021	[1] TvT	Multiple-branch RIS-assisted FSO system	AA, AT, Obstruction Prob	Gaussian beam speading loss	Close-form of channel	OP, BER	yes
2022	[2] JLT	point-to-multipoints FSO system	Experiment	Experiment	Physical models for ORIS, closeform for power density , beam splliting algorithm, power allocation	Power density	yes
2022	[3] TvT	IRS-assisted multilink FSO system	AA, PE, ORIS physical model	Large-scale fading	Space division multiple access	OP, BER	yes
2023	[4] TransCom	Multiple FSO buildings - a single RIS - buildings	AT, PE, AA	Gamma-Gamma	Three allocation protocols	OP, BER	yes
2023	[5] Globecom	Building - RIS/Relay - Building	AA, AT, GML	Gamma-Gamma	Analyze Power Scaling Law	OP	no
2023	[6] TVT	Base Station-ORIS-VLC system	PE, AT, AA, Beam wandering	Log-normal	Proposes an OIRS-assisted cascaded FSO-VLC system	OP, BER	no
2023	[7] LCF	MIMO system, BS is laser source	AA, AT, PE	Log-normal	Mathematical model of Optical MIMO	BER, OP	no
2023	[8] Trans Com	MIMO-FSO system	PE, AT, AA	Malaga distribution	Close-form of FSO channel	Egodic Capacity, BER	no
2023	[9] TVT	One LS-RIS-multiple users	symbolic FSO fading channel	Meijer G-function	Meijer G-based symbolic models	OP	yes
2024	[10] Photonics	Multiple LSs in building - RIS - Multiple PDs	Deeply consider PE	Gamma-gamma	Optimal RIS position under poiting	BER, OP	yes
2024	[11] IoT	RIS-assisted resonant beam SWIPT system	Diffraction	no	Analyze CSI	Transfer efficiency	no
2024	[12] IoT	RIS-assisted hybrid FSO/THz terrestrial system	AT, PE, AA	F-distribution	Close-form PDF, CDF of cascaded channel	OP, SER	no
2024	[13] IoIT	RIS-assisted FSO network for High-Speed Train	AT, Foggy and GML	Gamma-Gamma	Close-form of LCR, AFD	LCR, AFD	no

➡ ORIS for terrestrial network is well investigated.

❖ ORIS for Space Networks

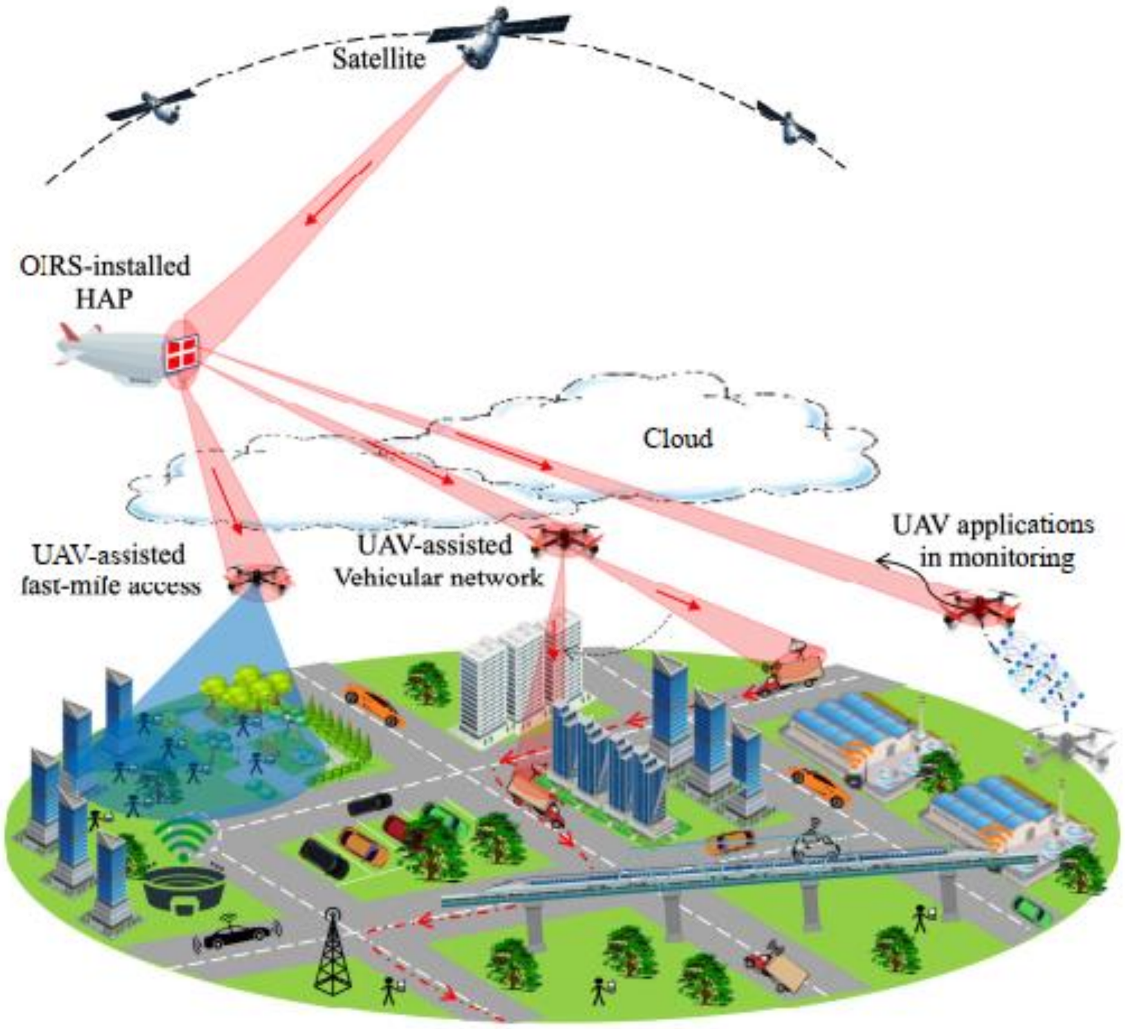
Year	Refs	System Model	Channel Modeing	FSO channel	Contributions	Performance Metrics	Multiple users
2021	[14] ICC	UAV-euipped IRS FSO communication	AT, PE	Gamma-Gamma, Hoyt	Quantify the physical impacts Close form of EC	Ergodic Capacity	no
2022	[15] ICT Exp	IRS-assisted UAV Dual-Hop FSO Com	AT, AoA, GML	Gamma-Gamma	Channel modeling close form of performance	OP, BER	no
2023	[16] TvT	IRS-assisted UAV Dual-Hop FSO Com	AT, AoA, PE	Gamma-Gamma	Considering different locations of the malicious UAV jammer and IRS	BER	no
2023	[17] Photonics	SAT-HAP-UAV assited RIS hybrif FSO/RF	AT, AA, PE	Gamma-Gamma/ Rician	Three different relay schemes in different weather conditions based on HAP	BER	no
2024	[18] Trans NS	RIS-assisted UAV Indoor Optical Networks	Indoor	no	A joint user selection and mirror element assignment problem to maximize the number of users served subject to QoS	Average sumrate	yes
2024	[19] TvT	RIS-assisted UAV multiple-Hop FSO backhaul link	AA, AT, PE	F distribution	Introduce a network architecture suitable for FSO backhaul transmissions	OP, BER	no
2024	[20] TAE	SAT- HAP eqipped RIS - UAVs	AA, AT, Cloud	Gamma-Gamma	Resource allocation algorithm to maximize no.f UAVs	Sumrate	yes

To my best knowledge, the research works in ORIS for space networks is not well investigated

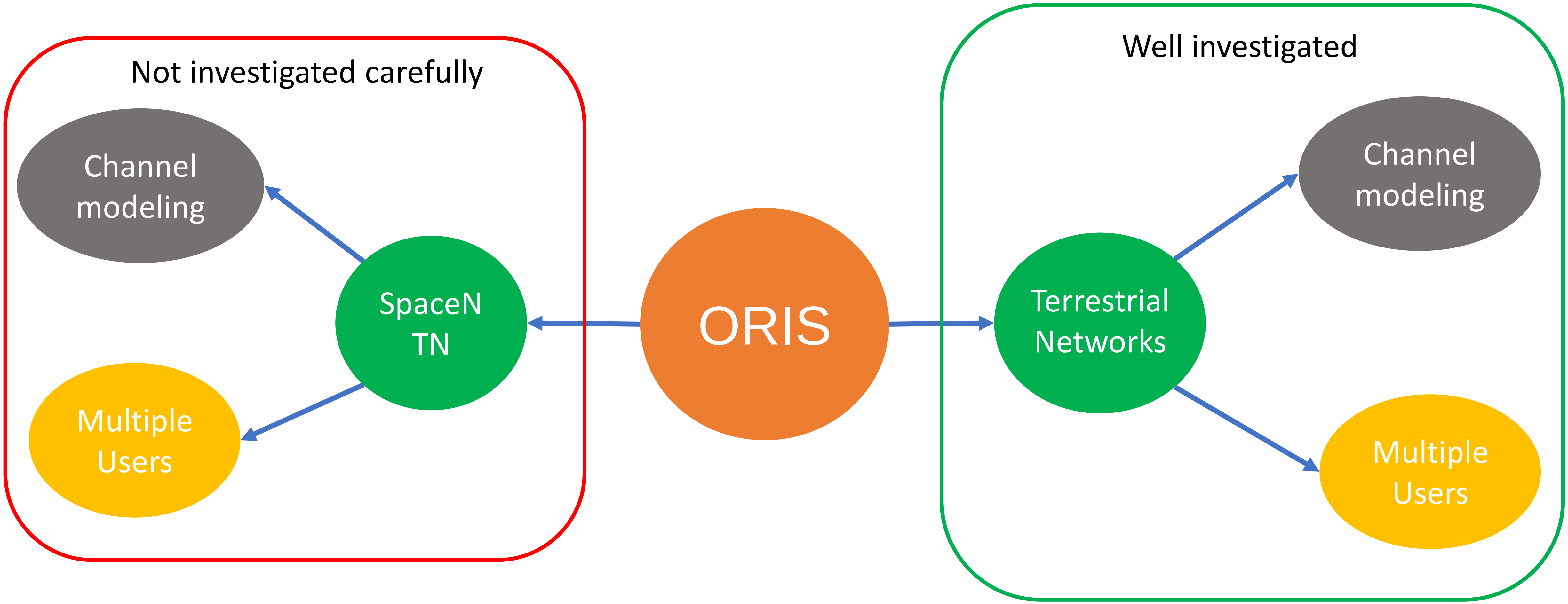
❖ ORIS for Space

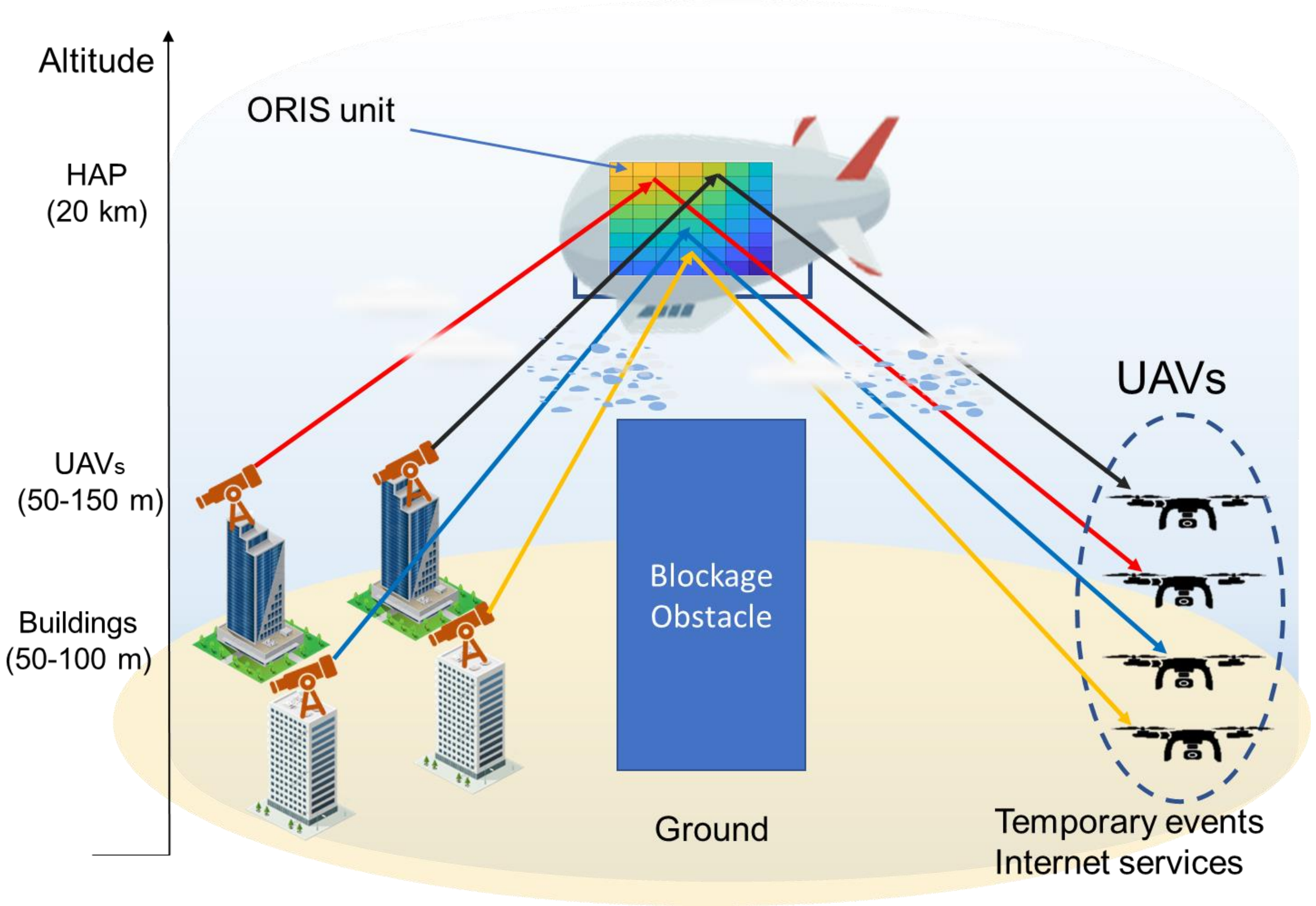
- **Contribution:** Propose RIS's resources allocation to maximize number of UAVs

- **Weakness :**
  - Not consider pointing error
  - The channel is not investigated carefully
  - Not maximize the total sum rate



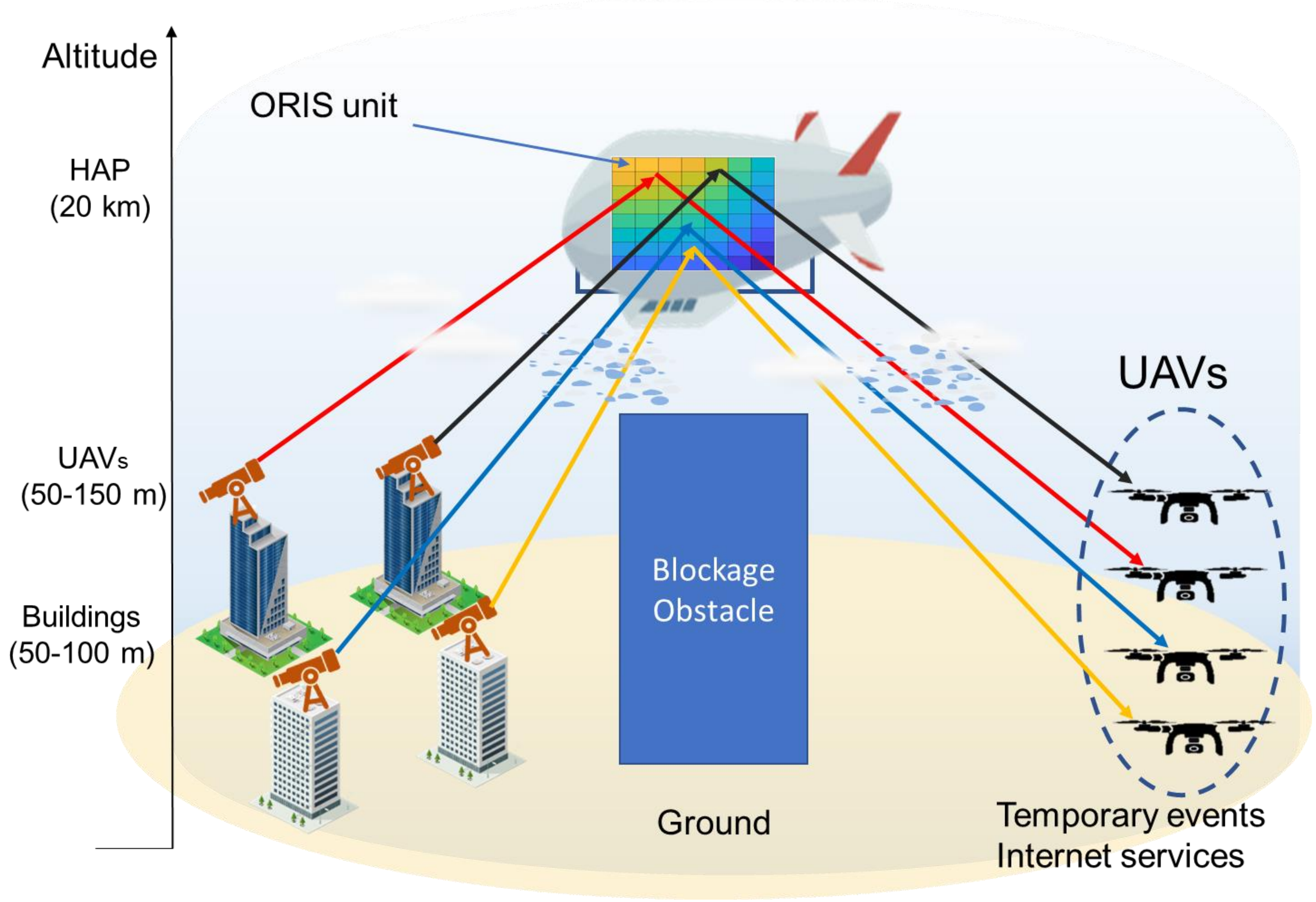
[20] Transaction on Aerospace and Electronic Systems


Not investigated carefully
Channel modeling
SpaceN TN
Multiple Users
ORIS
Well investigated
Terrestrial Networks
Channel modeling
Multiple Users



❖ **System description:**

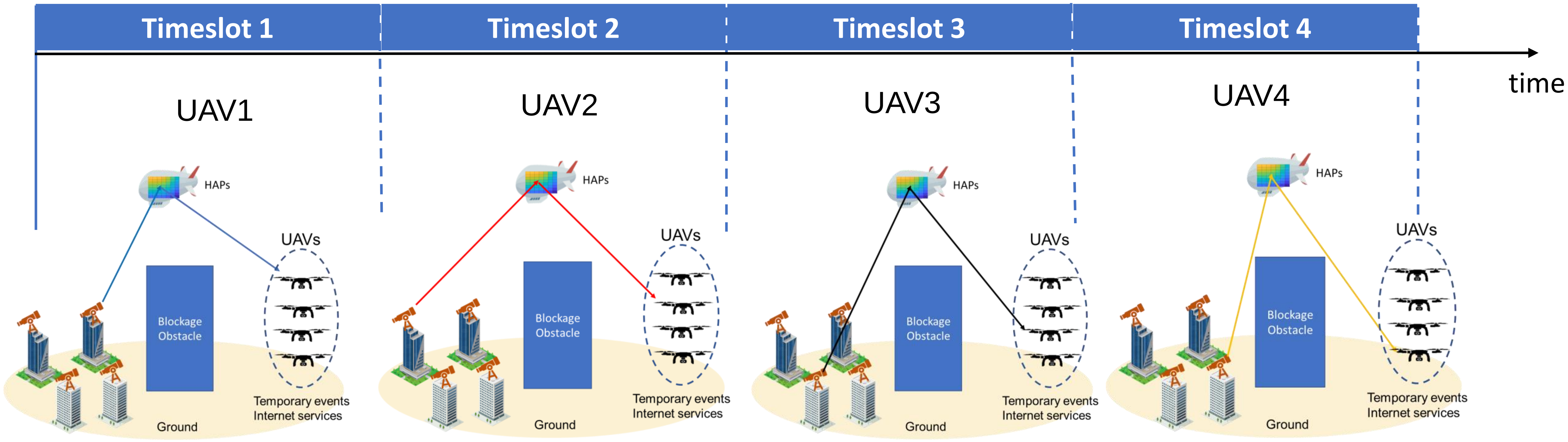
- **Source:** multiple laser sources putting in the top of buildings
- **Relay:** HAP carries one ORIS
- **Destination:** multiple UAVs for temporary event, shipping, rescue, data collection service.



❖ **Challenge:**
- The limited ORIS's unit, size
- Large beam footprint
- Time varying channel
- Pointing error

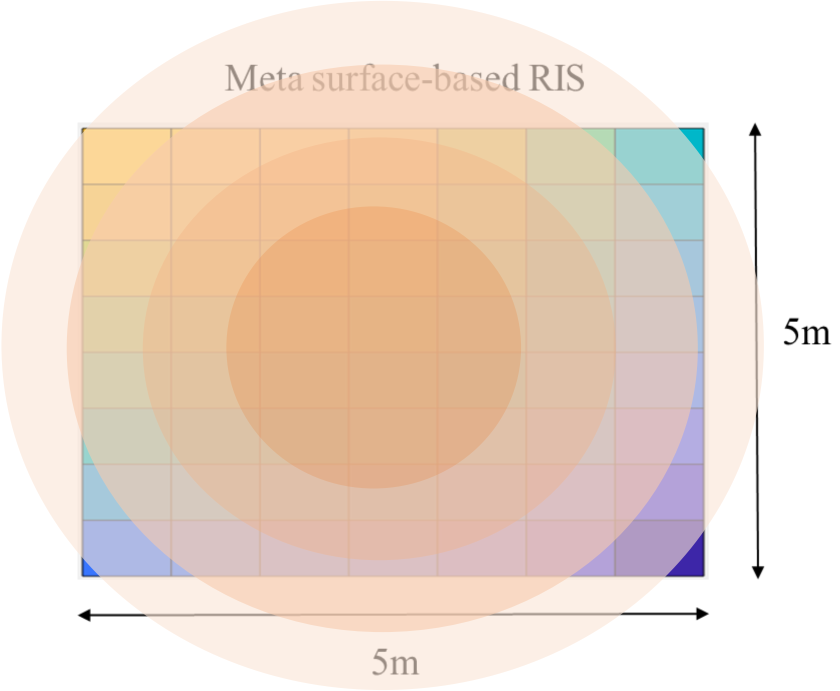
❖ In the context of *multiple laser sources-multiple UAVs (LS-UAV)*, how to allocate units of RIS effectively to multiple LS-UAVs?

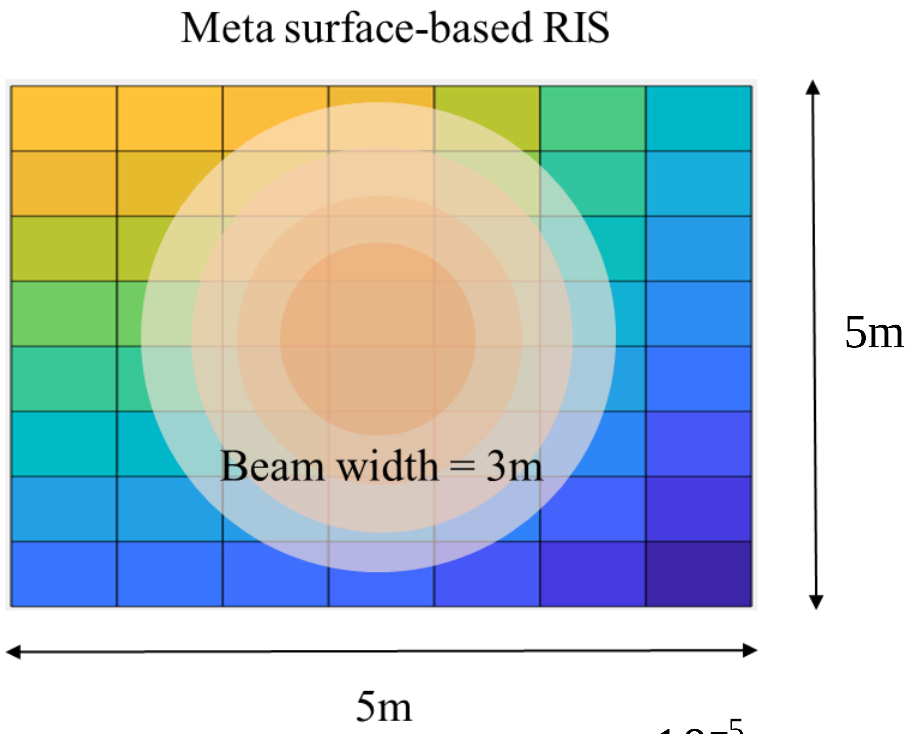
❖ **Time Division Protocol (TD):** each time slot, one LS-UAV pair transmits, while the others are inactive.



Assume that there are 4 pair LS-UAVs, the maximum transmission rate for each link is 1Gbps

- **Advantage:**
  The active user receives maximum power as the RIS serves only one LS-UAV pair at a time





Given : Divergence angle = 0.1 mrad
Zenith angle = 45

Given : Divergence angle = 10^{-5} rad
Zenith angle = 45

- **Disadvantage:** the time sharing among LSs degrades the total achievable throughput, waste of RIS's units.

$$\text{Total system's throughput} = \frac{1+1+1+1}{4} = 1 \text{ Gbps}$$

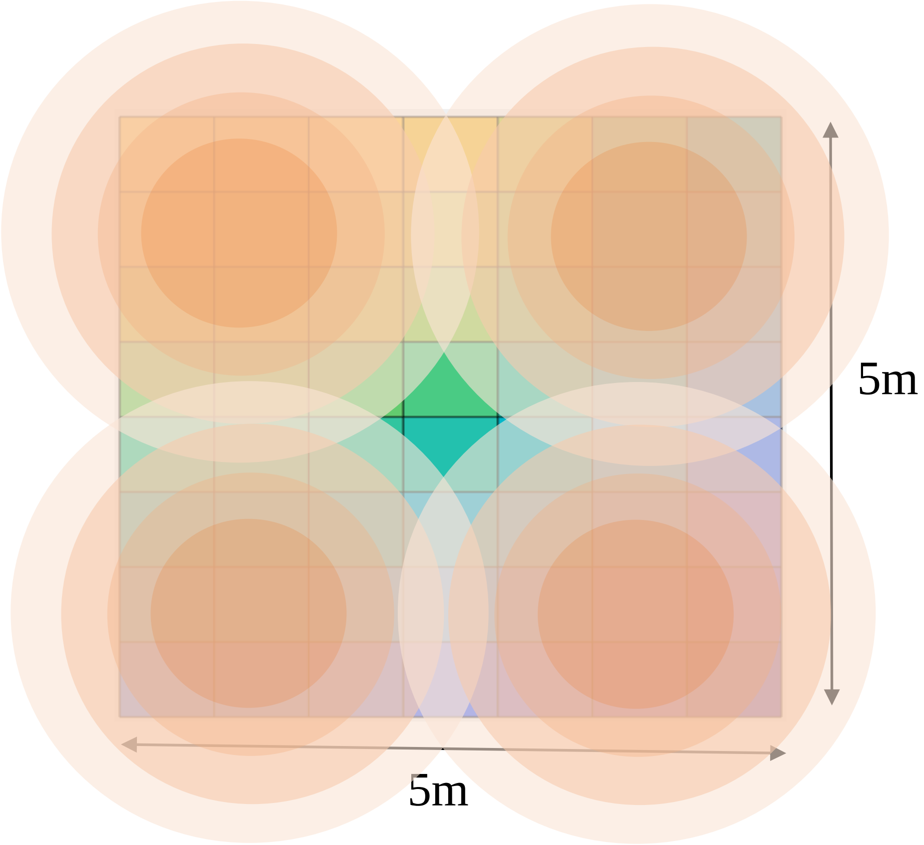
❖ **Space Division Protocol (SD):** divide RIS's unit to all LS-UAVs equally.

❖ **Advantages**
- All LS-UAVs simultaneously illuminate the RIS.
- Data rate may be increased compared to the TD protocol.

❖ **Disadvantage:**
- Large Beam width, so can't reach the maximum transmission rate for each LS-UAV.
- When pointing error occurred, the system's throughput is dramatically decreased.

Total system's throughput = $\frac{0.7\times4\times4}{4}$ = 2.8 Gbps > Time Division

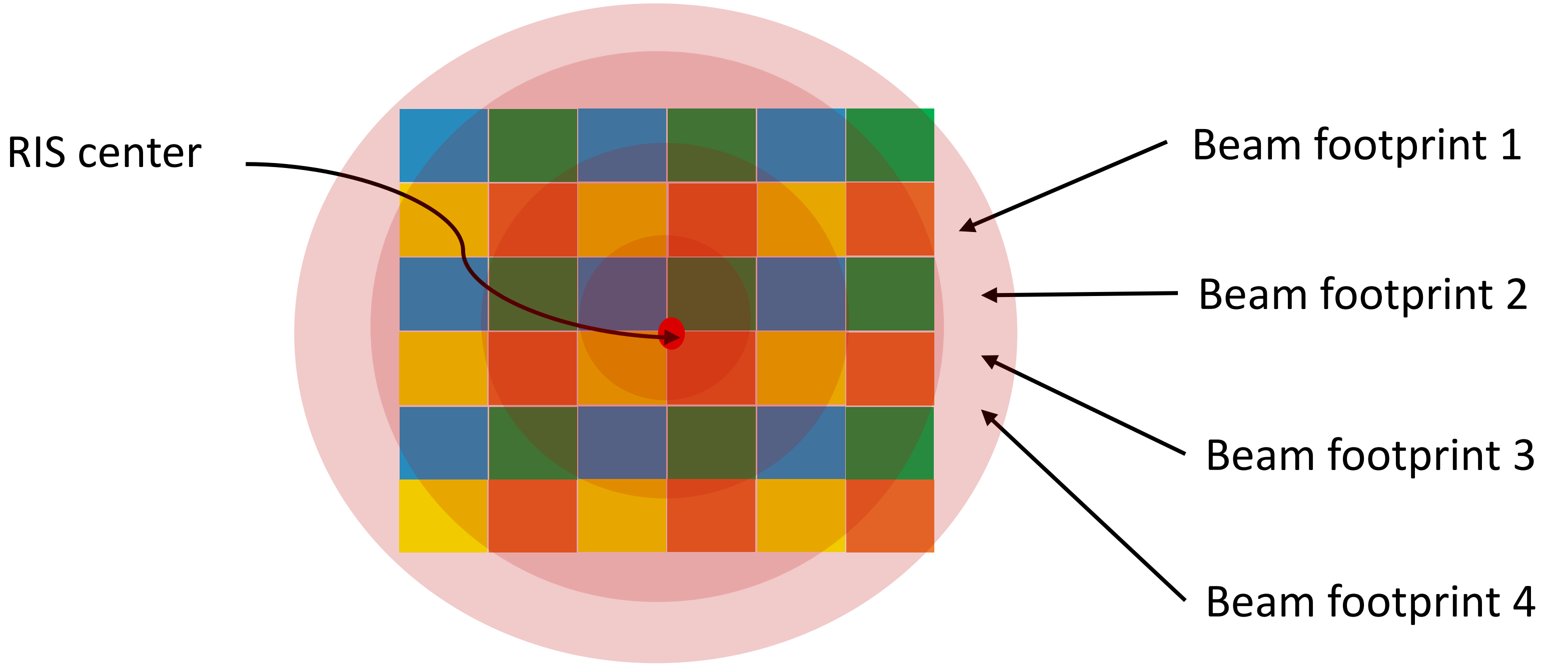
Meta surface-based RIS



❖ **IRS homogenization (IRSH):** divide the RIS's unit in interlaced arrangement

❖ **Advantages**
- Degrade the effect of pointing error.

❖ **Disadvantages**
- In case of no pointing error, performance is smaller than ID,SD



UAV1 UAV2 UAV3 UAV4

❖ Problems

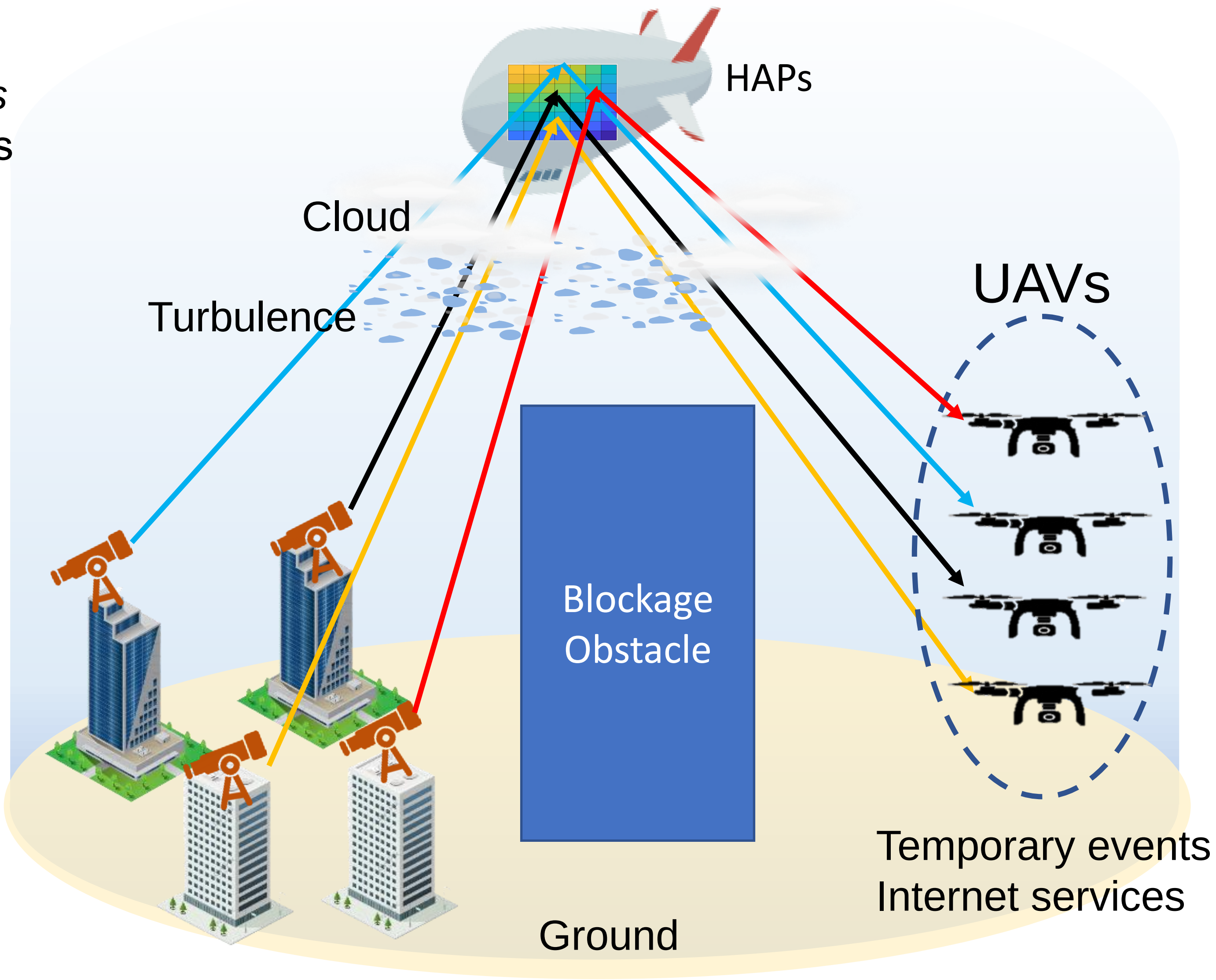
- ***Firstly,*** due to the mobility of UAVs, *the channel is dynamic* (the time varying channel) while the RIS's units *are divided equally*.
- If channel is ***good***, it needs ***few RIS's units***
- If channel is ***bad***, it needs ***more RIS's units.***

For example:

- UAV1 is in *good channel condition*, waste of RIS's unit
- UAV2 is in *very bad channel condition*, outage occurred.

- ***Secondly,*** TD, SD, IRSH *don't maximize* the total throughput.

- ***Thirdly,*** in case of PE, how to *arrange* the RIS's units to *reduce the effects of pointing error* and provide higher throughput than IRSH?



Contributions

- ***Firstly,*** I propose a ***novel resource allocation mechanism*** *considering the different channel condition* of each UAVs. This mechanism will ***allocate*** the number of RIS's unit for each user that *maximize the total throughput* while *guarantee the outage probability level* and *Quality of Services (QoS) of each UAVs.*

$$\text{Number of RIS's units for UAV}_i$$

$$\max\left(Total\_Throughput\right) = \sum_{i=1}^{N} Throughput(i), \text{ where N is number of UAVs}$$

$$\text{s.t } OP \geq OP_{\text{target}}, QoS$$

- ***Secondly,*** considering the *pointing error* when *HAP is hovering* and *UAV is moving,* propose ***a new RIS's units arrangement*** to reduce the impact of pointing errors and provide higher total throughput.

THANK YOU FOR LISTENING!