CCL Winter Camp 2022

Reconfigurable Intelligent Surface: Challenges and Opportunities

Nguyen Van Thang

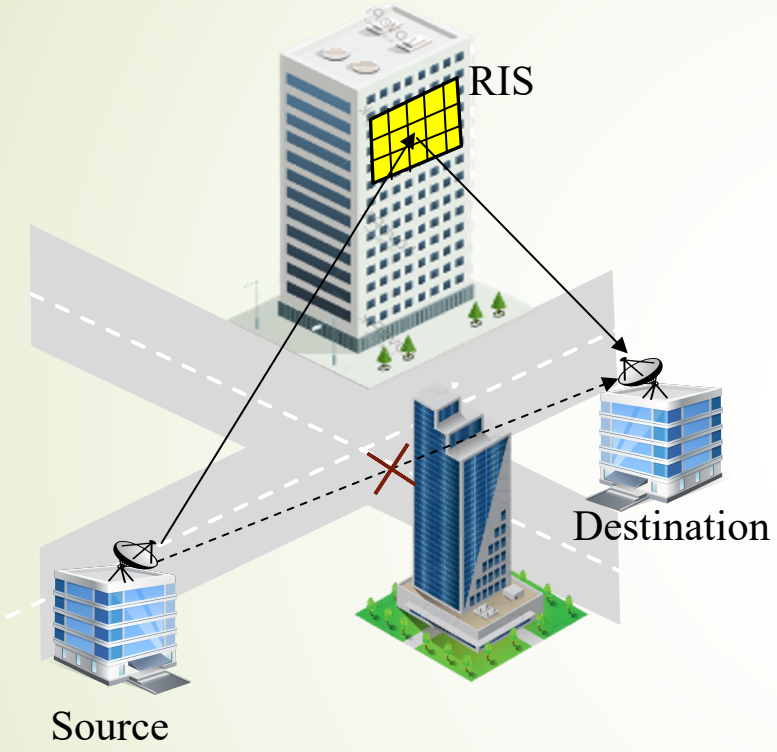
Computer Communications Laboratory, The University of Aizu

March 14, 2022

Outline

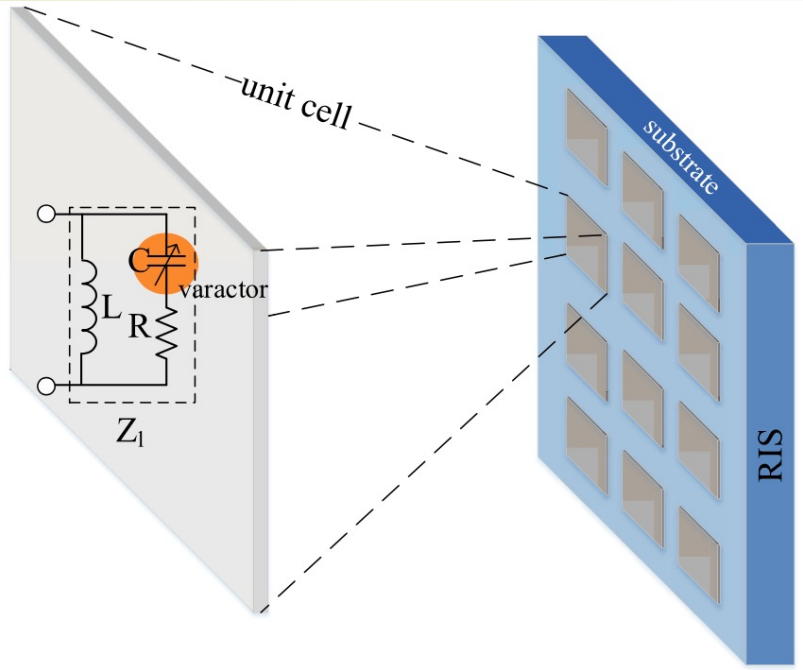
- Research background
- Applications
- Research Directions
  - Existing Issues
  - Opening research Issues
- Conclusions

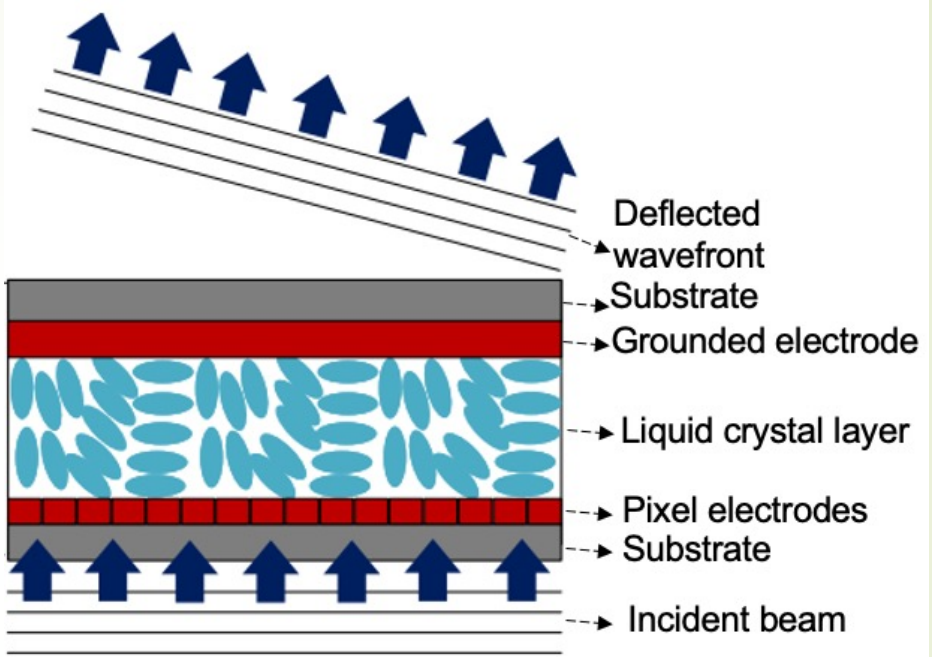
Research Background



- Millimeter-wave (MMW) and free-space optical (FSO) communications are two keys technologies in 5G network due to provide high-speed connections
- MMW and FSO communications require line-of-sight (LoS) connections
- When a LoS link between source and destination is blocked by obstacles, e.g., building, clouds,…etc.
- Virtual LoS links between source and destination can be formed by using reconfigurable intelligent surface (RIS)
- Advantages of RIS:
  - Easy to deloy
  - Spectral efficiency enhancement
  - Environment friendly
  - Compatibility

Research Background





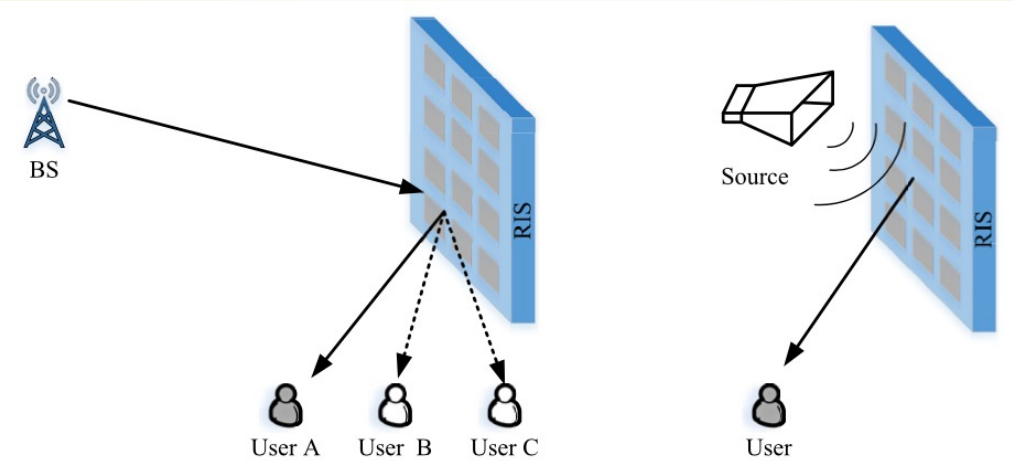
Definition (MMW)

The RIS is man-made surfaces of electromagnetic material that are electronically controlled with integrated electronics and have unique wireless communication capabilities.

Definition (FSO)

RIS consists of one-dimensional array of tens of thousands of long thin electrodes to manipulate a light beam.

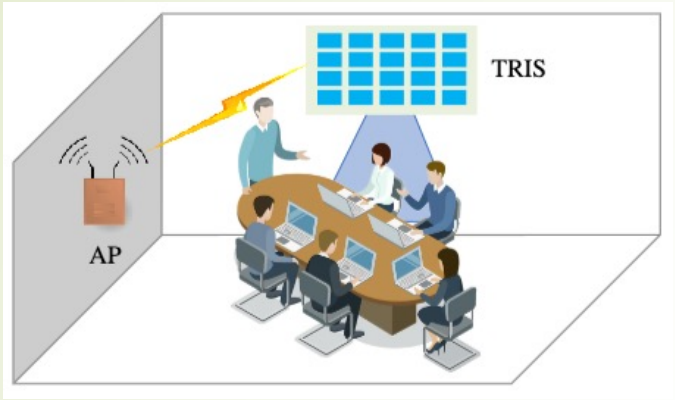
RIS Operating Principles



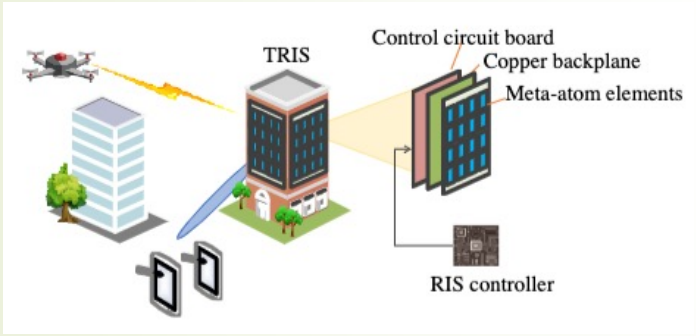
(a) Anomalous reflection (b) Beamforming

- There are two operating functions are widely used in the context of wireless communication including: **anomalous reflection** and **beamforming**
  - **Anomalous reflection** is a wavefront transformation from a plan wave to another plane wave. The RIS is designed to reflect an incident beam to a far-field terminal by enhancing the signal strength at targeted angles.
  - **Beamforming** is a wavefront transformation from a plane wave to a desired wavefront. The RIS is designed to reflect an incident beam to a near-field terminal by enhancing the signal strength at a target locations.

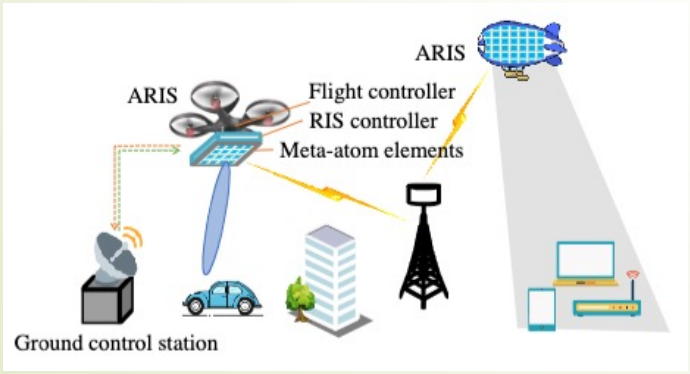
Applications



(a) Terrestrial RIS-assisted indoor system
- Guarantee no blind spots in the coverage area of some block-sensitive scenarios, e.g., VLC



(b) Terrestrial RIS-assisted outdoor system
- Bypassing the obstacles between source and destination
- Support massive connectivity



(c) Aerial RIS-assisted system
- Adjust the phase shifts of RISs instead of controlling the movements of the UAVs in order to form LoS links between source and destination

Research Directions

1) Channel Modeling
   - Existing issues:
     a. The current models adopted in most existing works are inaccurate due to consider ideal rural, suburban, and open field environment which are not suitable to model dense environment characterized by dense buildings, streets, trees, and various weather conditions.
     b. Rarely considered to model the channel in high frequency bands which suffer from severe attenuation, and high probability to be blocked
     c. Doppler frequency shift effect is in general ignored
   - Opening research issues:
     a. Propose accurate channel models to account for wave propagation at high frequencies, doppler spread and mobility of users.
     b. Need to consider the different distance between end terminal and all reflecting elements
     c. There is a necessity to investigate new aerial models that consider RIS capabilities together with aerial platforms properties

Research Directions

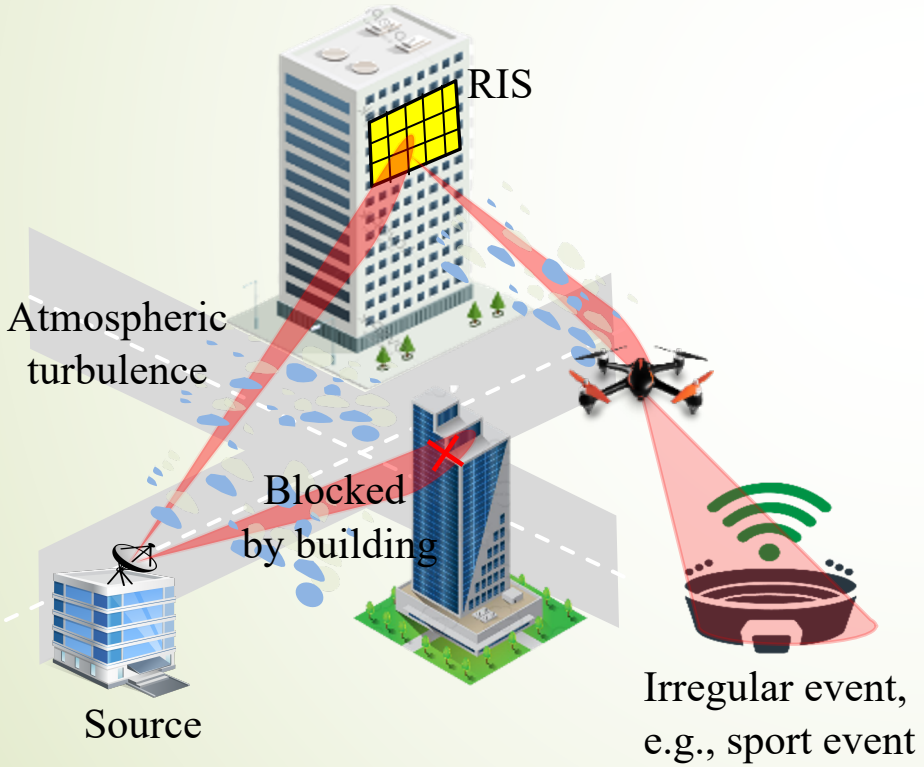
2) Channel Estimation
   - Existing issues
     a. Difficult to estimate the channel, since RIS is sensitive to the arrival angle of the impinging wave. As this arrival angle in the uplink differs from that in the downlink, reciprocity of channels could not be met
     b. Channel estimation is more challenging due to mobile aerial platforms and becomes even more difficult when aerial RISs instead of terrestrial RIS are considered.
   - Opening research issues
     a. It is important that the energy cost and the long delay it entails be taken into consideration.
     b. Machine-learning techniques might be a promising way to facilitate the estimation process

Research Directions

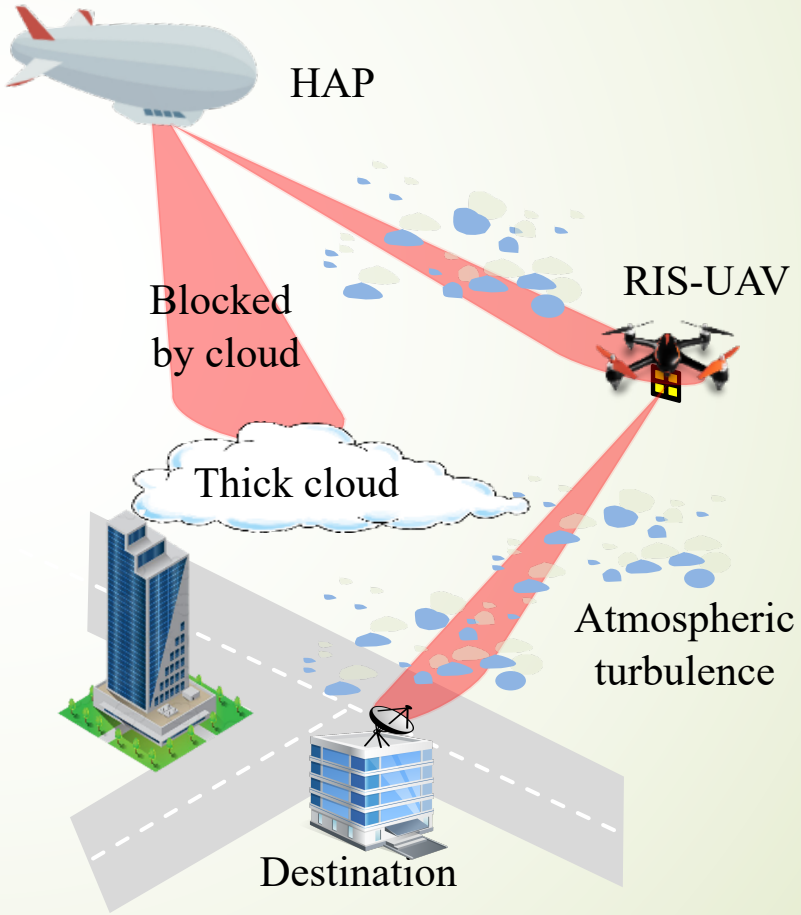
3) Tracking
   - Existing issues:
     a. RISs cannot send pilot signals to enable tracking of their movement, especially when the direct links between the end devices are blocked.
   - Opening research issues:
     a. Develop near-field sensing and localization models that exploit the information in the wavefront curvature
4) Hardware limitations
   - Existing issues:
     a. The unrealistic assumption is that RIS can perfectly manipulate the impinging electromagnetic waves and reflect them with the optimized ideal phase shift.
   - Opening research issues:
     a. Build practical models accounting for properties of the used physical materials, the manufacturing processes, and the RIS's reliability and configuration capabilities for different communication frequencies and diverse numbers and sizes of RIS units.

Approaches to RIS-based FSO

RIS-assisted optical terrestrial system



RIS-assisted optical aerial system



Conclusions

- RISs are considered a promising technology for the future communication network due to smartly reconfiguring the wireless propagation environment
- Describing the basic principles of RISs
- Give major existing issues and research opportunities associated with the integration of RISs

Thank you for your listening!