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RIS-Assisted Visible Light Communication for Outdoor Applications

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Introduction

- Visible Light Communication (VLC) uses the light emitting diode (LED) -based luminaries to provide high-data-rate links while supporting the illumination purposes.
- VLC is becoming an essential utility to support the increasing demand for high-data-rate wireless coverage and to complement the congested Radio Frequency spectrum.
- The *availability of* ***line-of-sight (LoS)*** *link* and the ***alignment*** between VLC transmitters and receivers largely impacts the VLC link performance in outdoor scenarios.
- Reconfigurable Intelligent Surfaces (RISs) can be used to reflect, refract, or focus the incident signals to mitigate ***LoS blockage*** and improve the link quality.

RIS-Based VLC

- **Mirror-based RISs** can be realized using planner mirrors mounted on top of micro-electro-mechanical systems (***MEMSs***).
- The reflected signals are controlled by changing the mirrors ***orientation***, where the angle of reflection can be obtained using Snell's law of reflection.

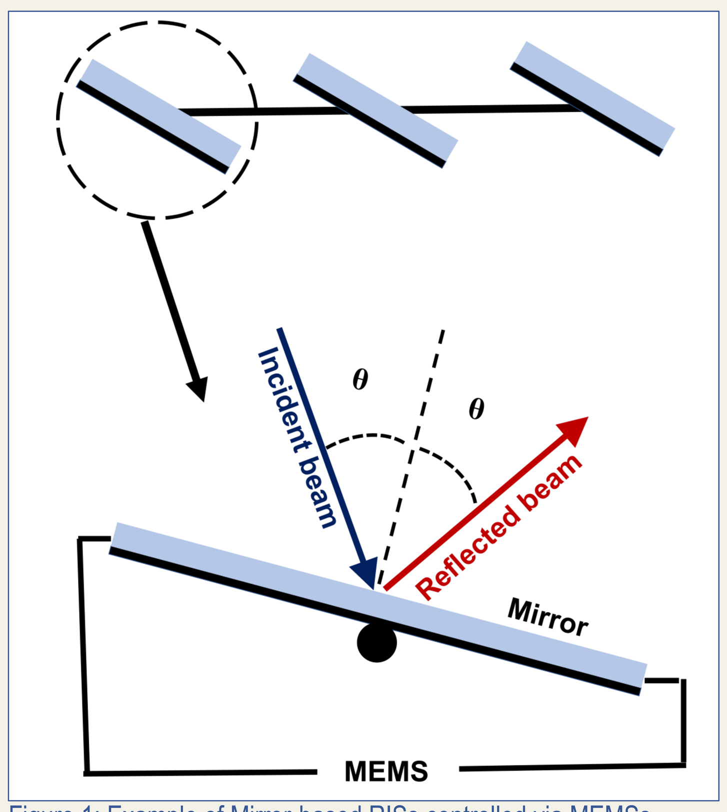

Figure 1: Example of Mirror-based RISs controlled via MEMSs.

- **Metasurface-based RISs** can be realized by using artificial planers to ***reflect*** or ***refract*** the incident beams.
- The metasurface can be controlled via field-programmable gate arrays, which based on their characteristics can be classified as ***non-reconfigurable*** or ***reconfigurable*** metasurfaces.

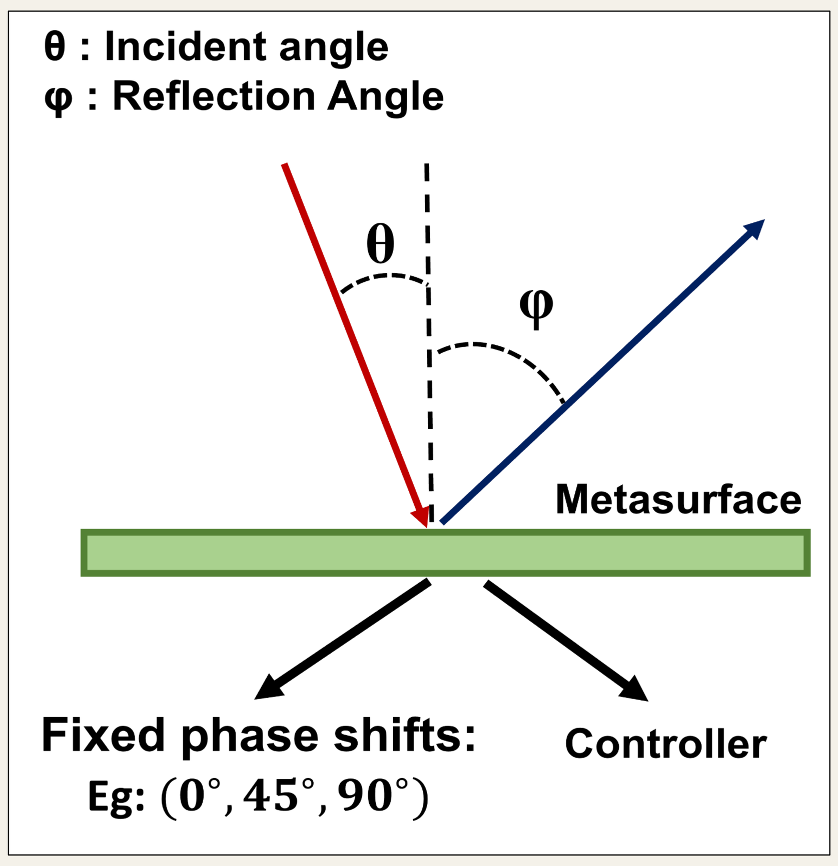

Figure 2: Example of Metasurface-based RISs.

- By using Simultaneous Transmission And Reflection (STAR) RISs, the ***reflection*** and ***refraction*** of the incident beams can be controlled.

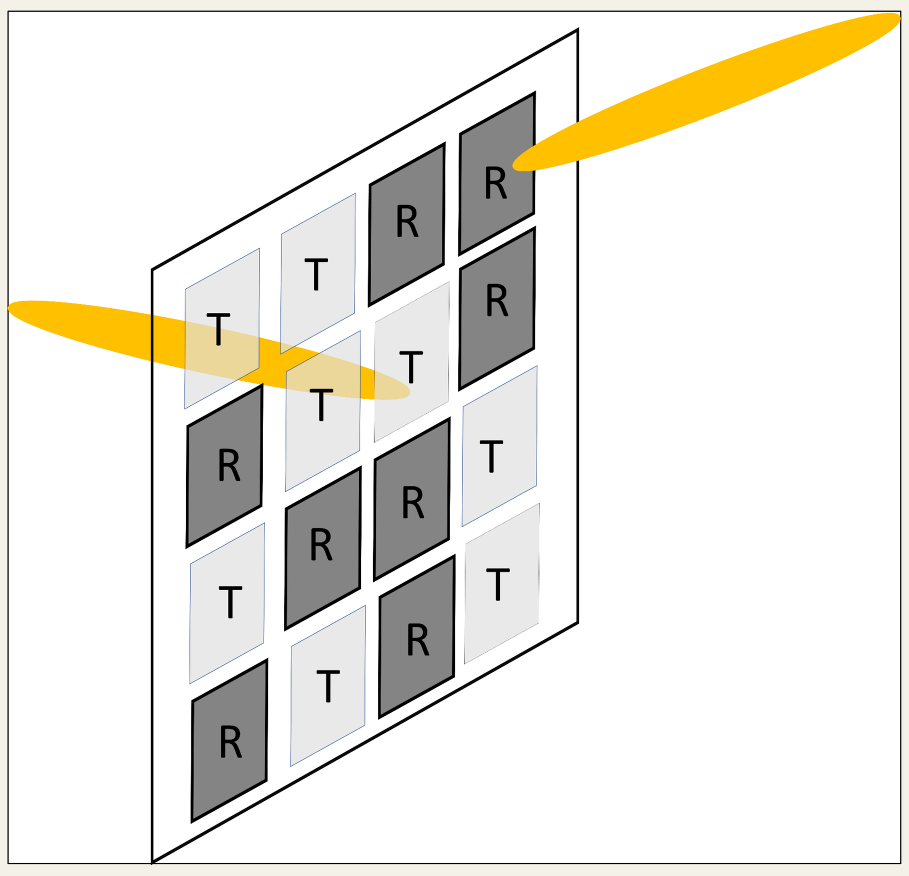

Figure 3: STAR RIS array, where elements labeled with **T** and **R** refract and reflect the incident beams, respectively.

RIS-Assisted UAV-Based VLC

- As UAVs hover at relatively high altitudes, UAV-based VLC systems may suffer from *LoS link blockage*. Also, the *coverage is limited* by the transmitter's beam-width.
- IRSs can be used to mitigate the *LoS blockage*, *extend the coverage, and improve the channel quality.*

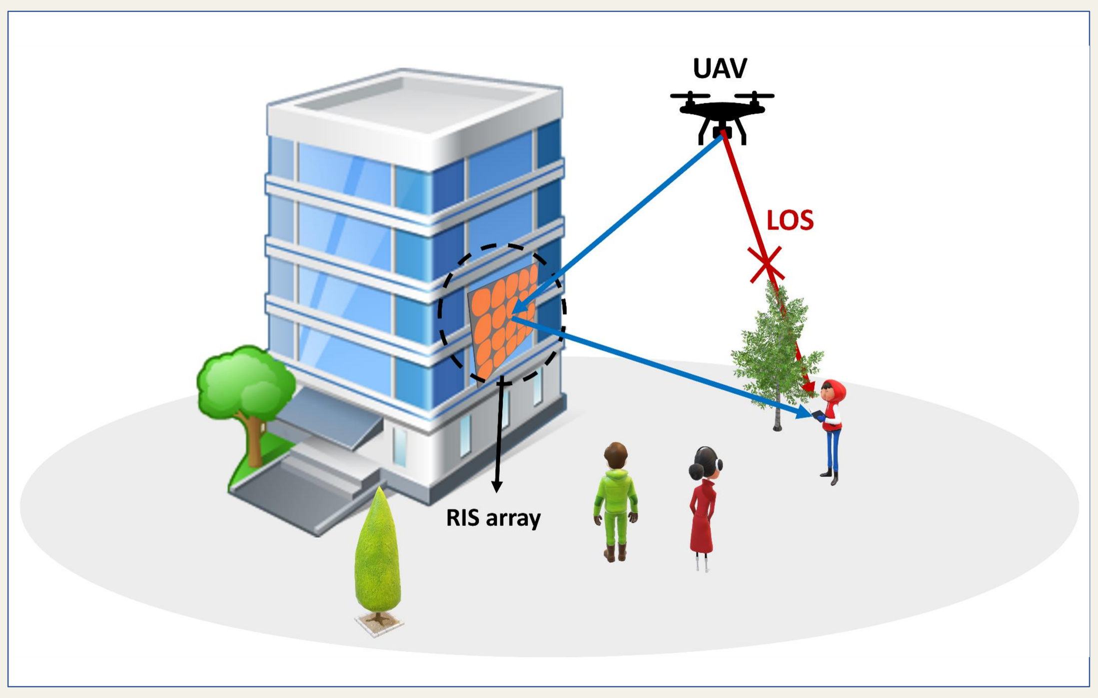

Figure 4: VLC-enabled RIS-assisted UAV network, where the users are served by the LoS links from UAVs and the reflected components by the RISs.

- Given that the transmissions of the UAVs are directed towards the *ground users*, they cannot be used directly for ***inter-UAV communications.***
- IRSs are proposed to *enable **UAV-to-UAV** communication* by reflecting the beam coming from one UAV towards another UAV.

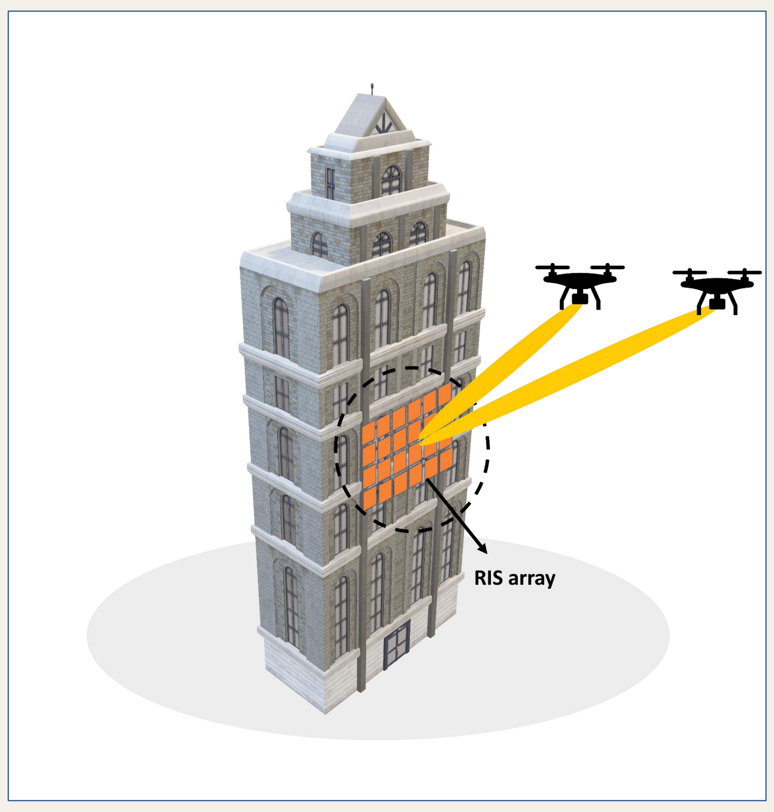

Figure 5: VLC-enabled RIS-assisted UAV-to-UAV Communication system.

RIS-Assisted Vehicular VLC

- Due to the physical properties of light, communication between vehicles *approaching road intersections is not possible.*
- IRSs installed at building facades can create a communication link between vehicles approaching road intersections.

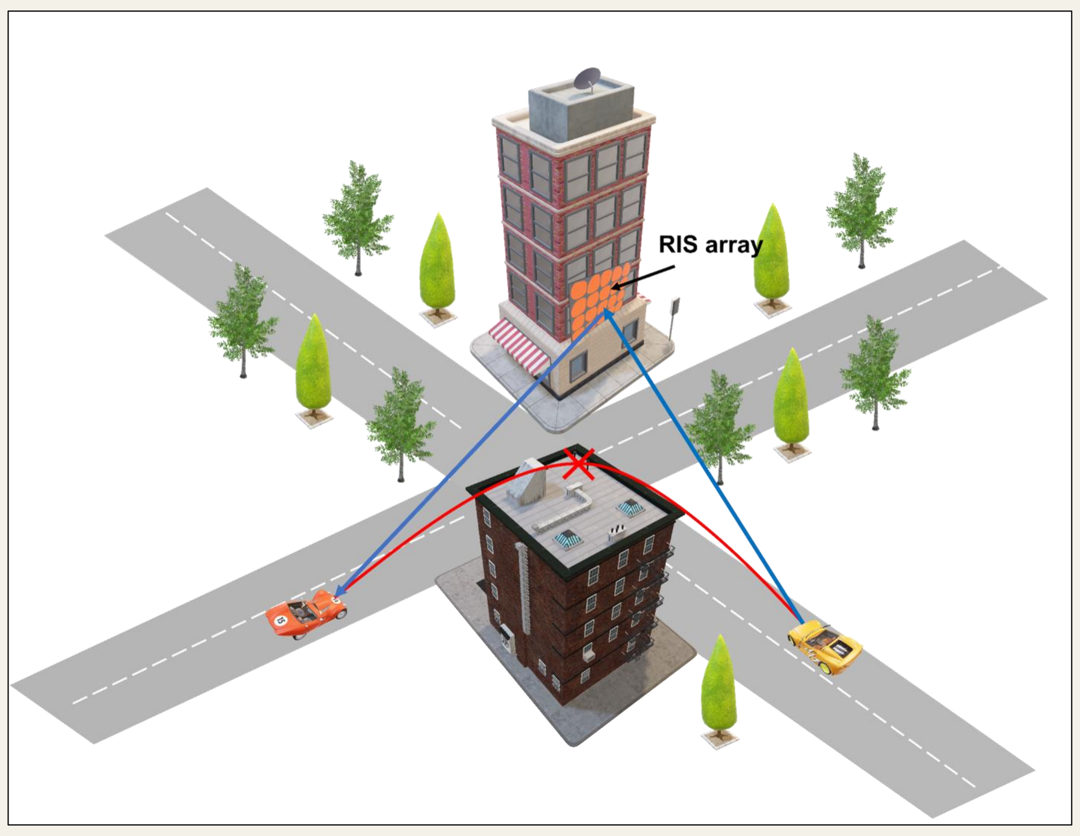

Figure 6: RIS-Assisted VLC system at road intersections, where RISs act as a gateway between two perpendicular roads.

- Due to the ***limited FOV*** of the VLC transmitters and receivers, vehicles moving parallel to each other cannot communicate.
- IRSs can be used to overcome such problem by ***reflecting*** the incoming beams from one vehicle towards another vehicle.

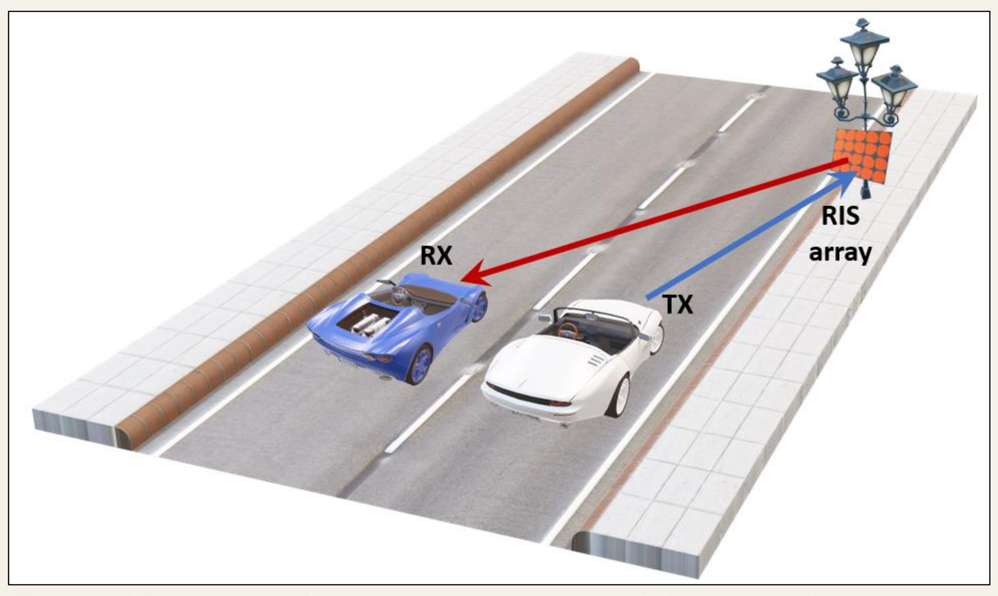

Figure 7: RIS arrays to enable communication between parallel moving vehicles.

RIS-Assisted Outdoor-to-Indoor Communication

- Due to the physical properties of light, VLC users in indoor scenarios cannot directly receive signals from VLC access points in outdoor scenarios.
- By installing ***STAR RISs*** at building windows, Outdoor-to-Indoor communications could be realized.

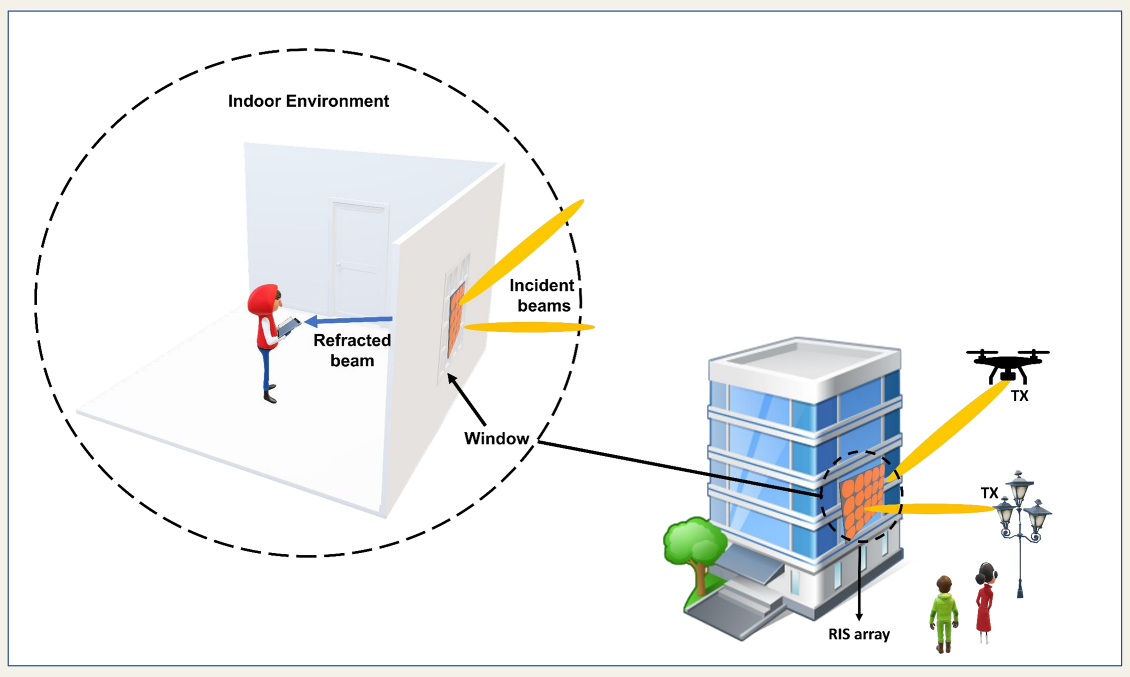

Figure 8: RIS-Assisted Outdoor-to-Indoor VLC system.

Impact of RISs on Outdoor VLC - Simulations

- To highlight the merits of considering RISs in outdoor VLC systems, we carried out ***simulations*** for ***Walkway scenario*** in an urban area.
- Random users' ***locations*** and random device ***orientations*** were assumed. The random orientation is defined in spherical coordinates as the orientation of a unit vector normal to the devices surface. The Azimuthal angle for the normal vector follows *Uniform distribution*, $\omega \sim U[-\pi, \pi]$, while the Polar angle follows truncated Laplace distribution:

$$f_\theta(\theta) = \frac{\exp\left(-\frac{|\theta-\mu_\theta|}{b_\theta}\right)}{2b_\theta}, \quad 0 \le \theta \le \frac{\pi}{2}$$

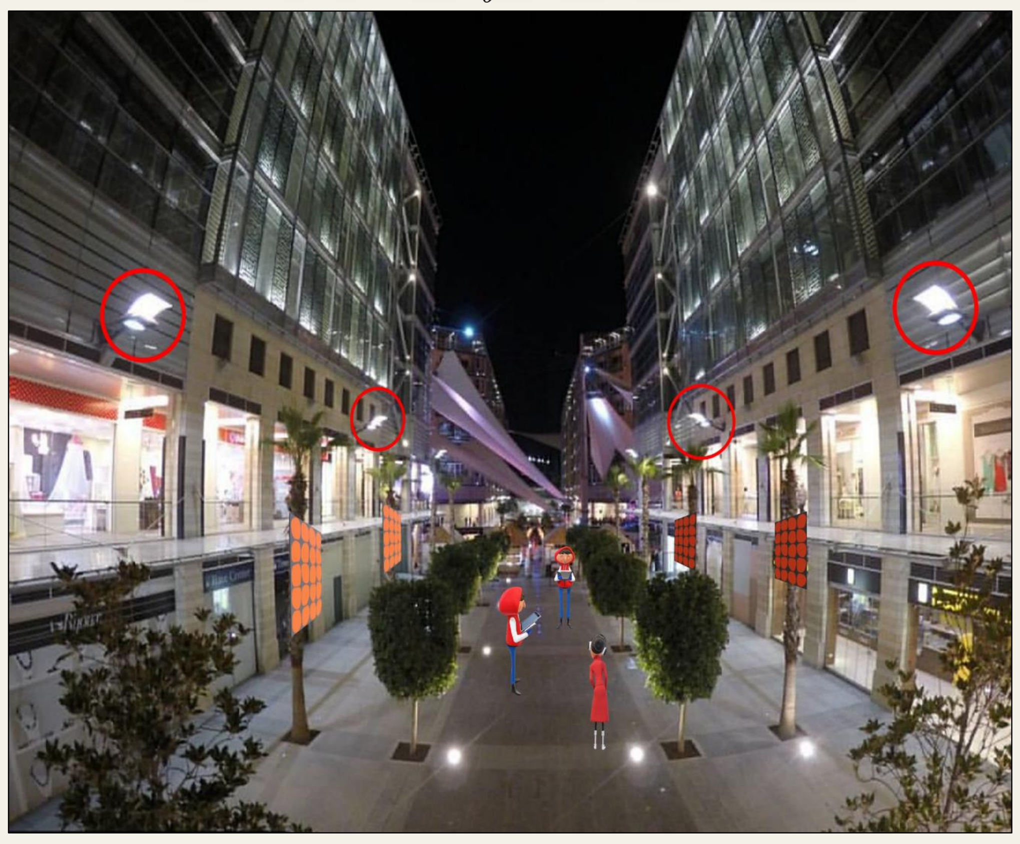
Figure 9: Walkway scenario in Boulevard-Amman, where the LEDs are utilized as VLC transmitters while RISs are used to assist the communication.

- Since random device orientation was assumed, users may experience link outages. The probability that the incident beams will lie within the receivers' FOV was considered to evaluate Outage Probability.
- Outage Probability improved due to the spatial diversity provided by the RISs, where the outage probability decreased by increasing the number of RISs.

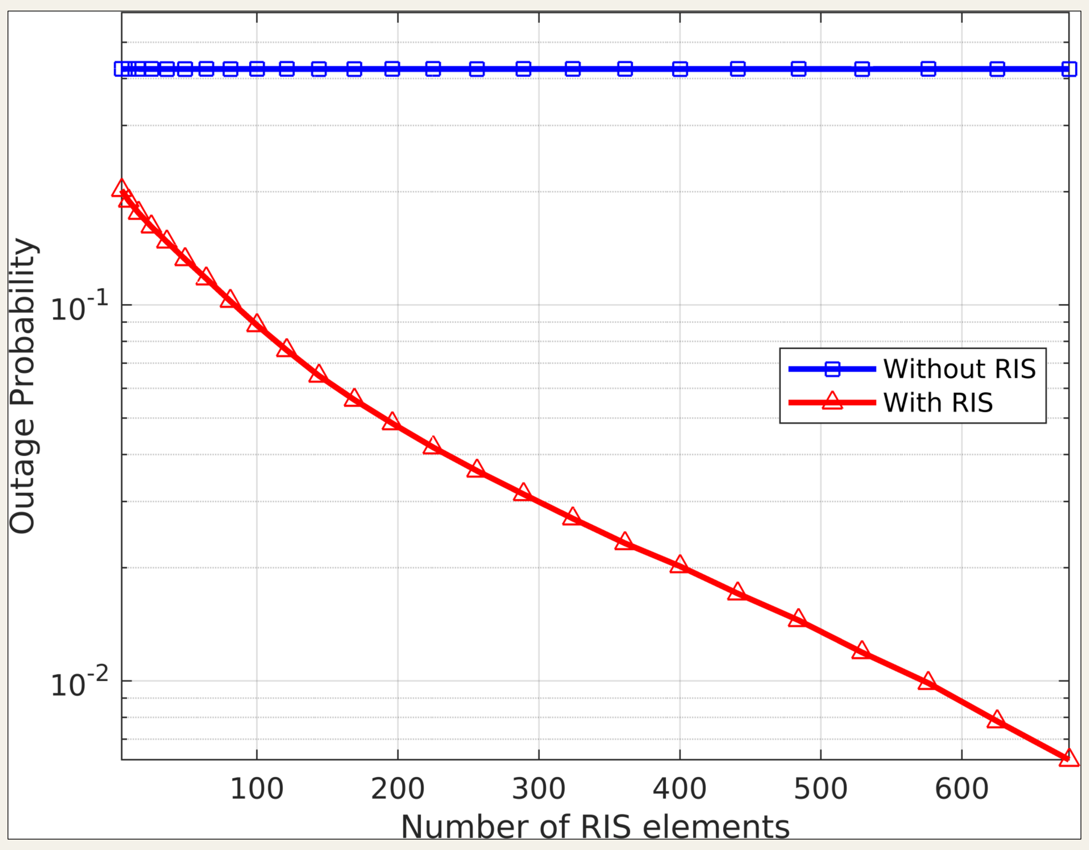

Figure 10: Outage Probability for the Walkway scenario studied in Fig. 9, where random users' location and random device orientation were assumed.

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