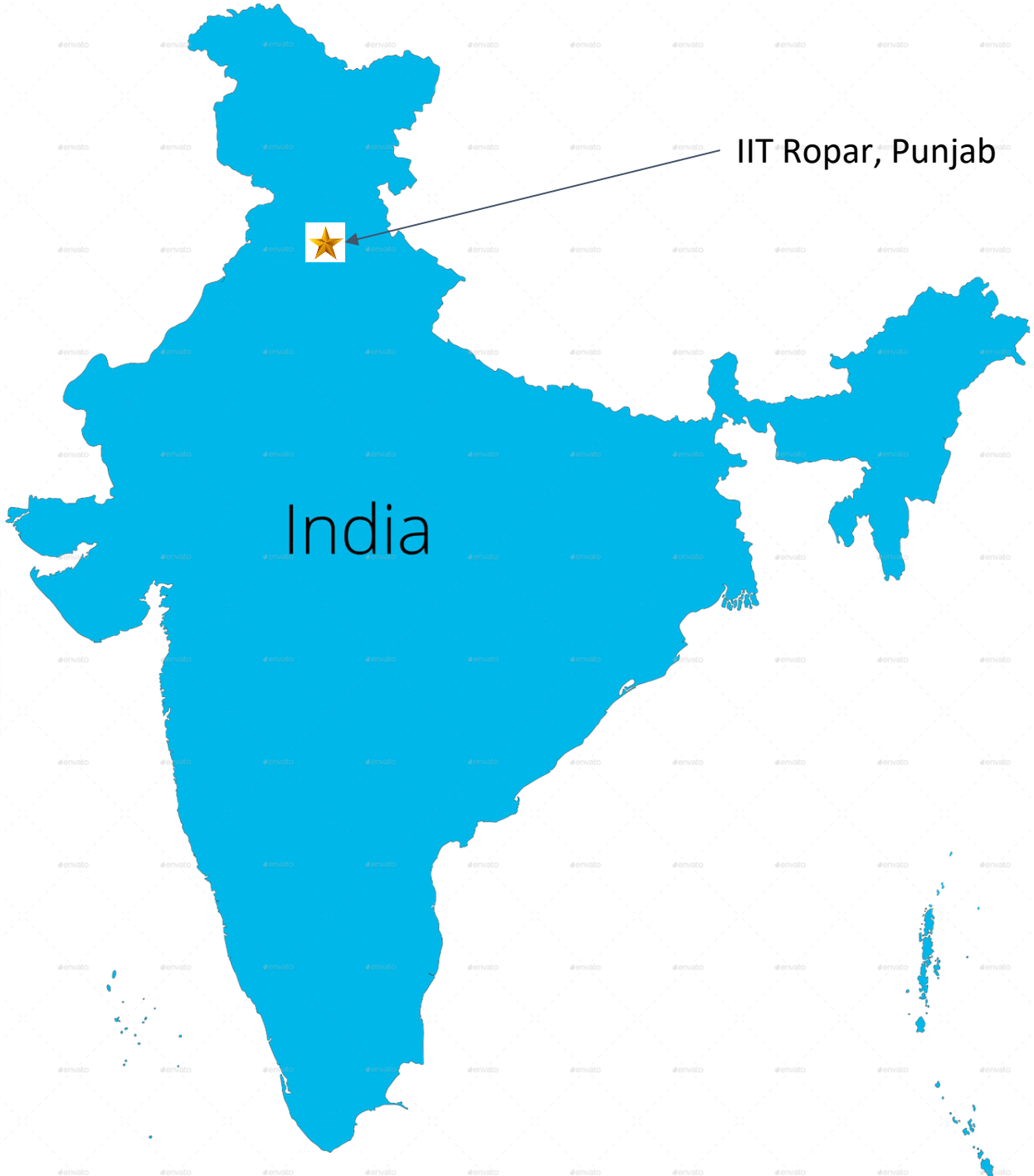
Indian Institute of Technology Ropar

(An Institute of National Importance Established by an ACT of Parliament and Funded by the Govt. of India)


IIT Ropar, Punjab
India

Departments and Centers

Departments

ENGINEERING

- Civil Engineering
- Electrical Engineering
- Computer Science
- Mechanical Engineering
- Chemical Engineering
- Metallurgy and Materials
- Biomedical Engineering
- Artificial Intelligence and Data Engineering

BASIC SCIENCES

- Chemistry
- Mathematics
- Physics
- Humanities & Social Science

Centers

- Center for advanced research in data science
- Center for Engineering Education
- Indo-taiwan Joint Research Centre on Artificial Intelligence and Machine Learning
- Center of Research for Energy Efficiency and Decarbonization

Academic Programs

B. TECH.

Civil Engineering
Computer Science and Engineering
Electrical Engineering
Mechanical Engineering
Chemical Engineering
Metallurgical & Materials Engineering
Artificial Intelligence and Data Engineering

M.TECH.

Mechanical Engineering
Electrical Engineering
Computer Science Engineering
Biomedical Engineering
Civil Engineering
Chemical Engineering
Metallurgical & Materials Engineering

Ph. D.

Ph.D. in all the departments & centers

M.Sc.

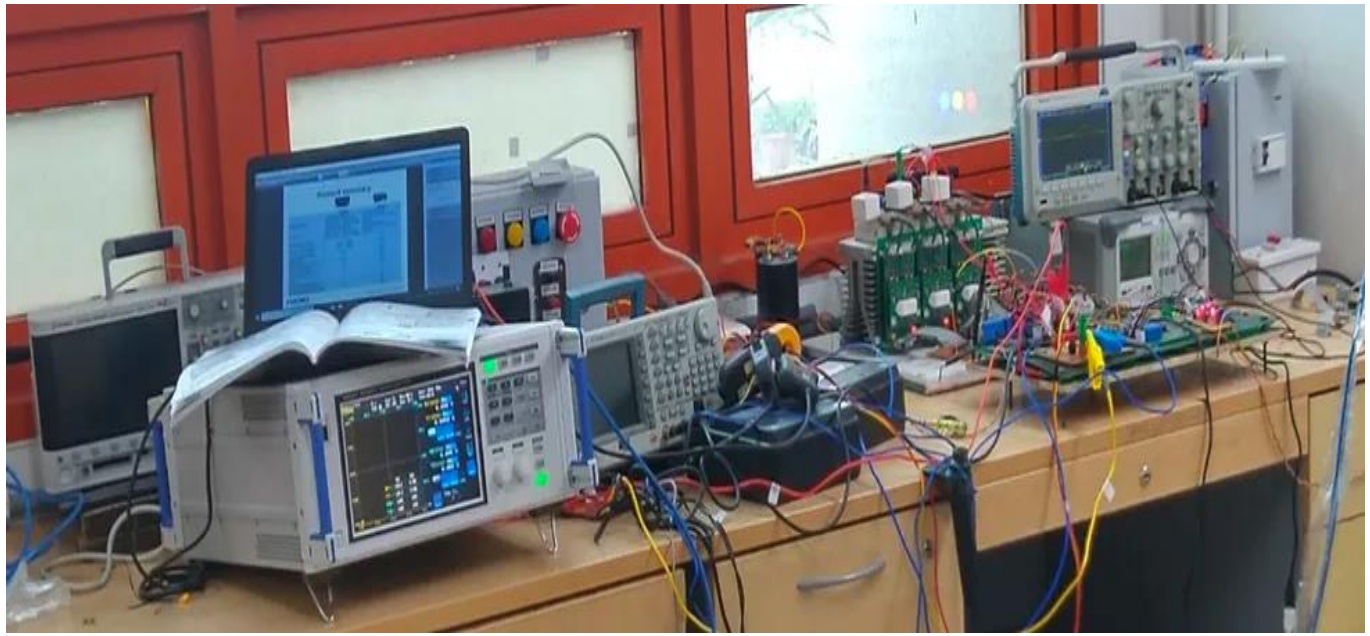
Physics
Chemistry
Mathematics

M.S. (Research)

Electrical Engineering
Computer Science and Engineering

Department of Electrical Engineering

1. 22 Faculty Members
2. Specializations
    a. Power Systems Engineering
    b. Microelectronics and VLSI
    c. Signal Processing and Communication

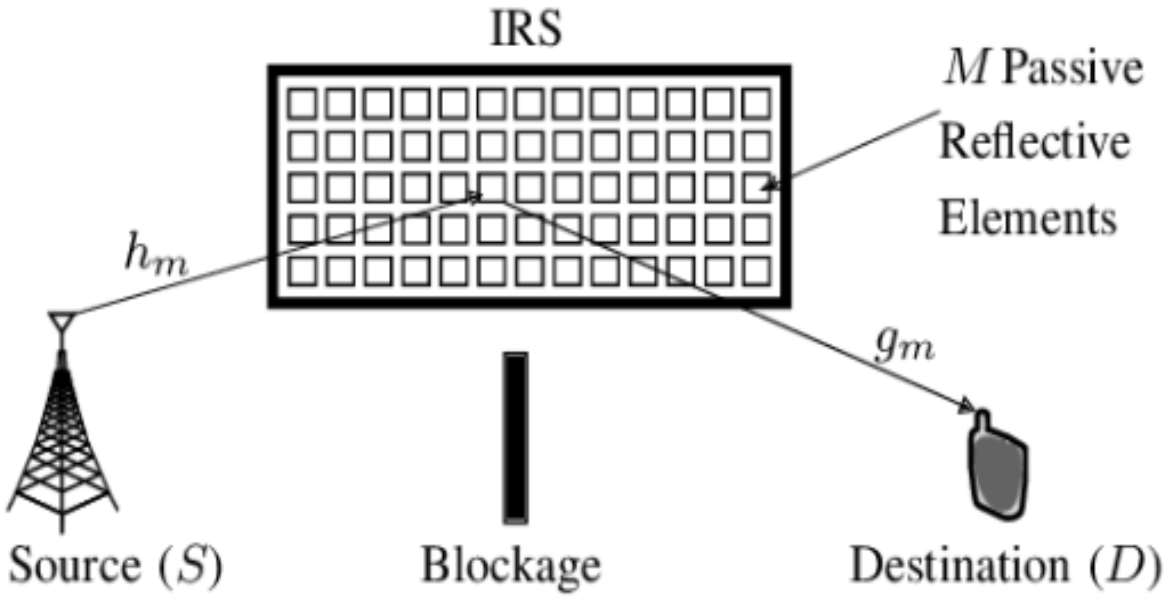


IRS Training in Multi-User Scenario

Brijesh Kumbhani
Department of Electrical Engineering
IIT Ropar, India
brijesh@iitrpr.ac.in

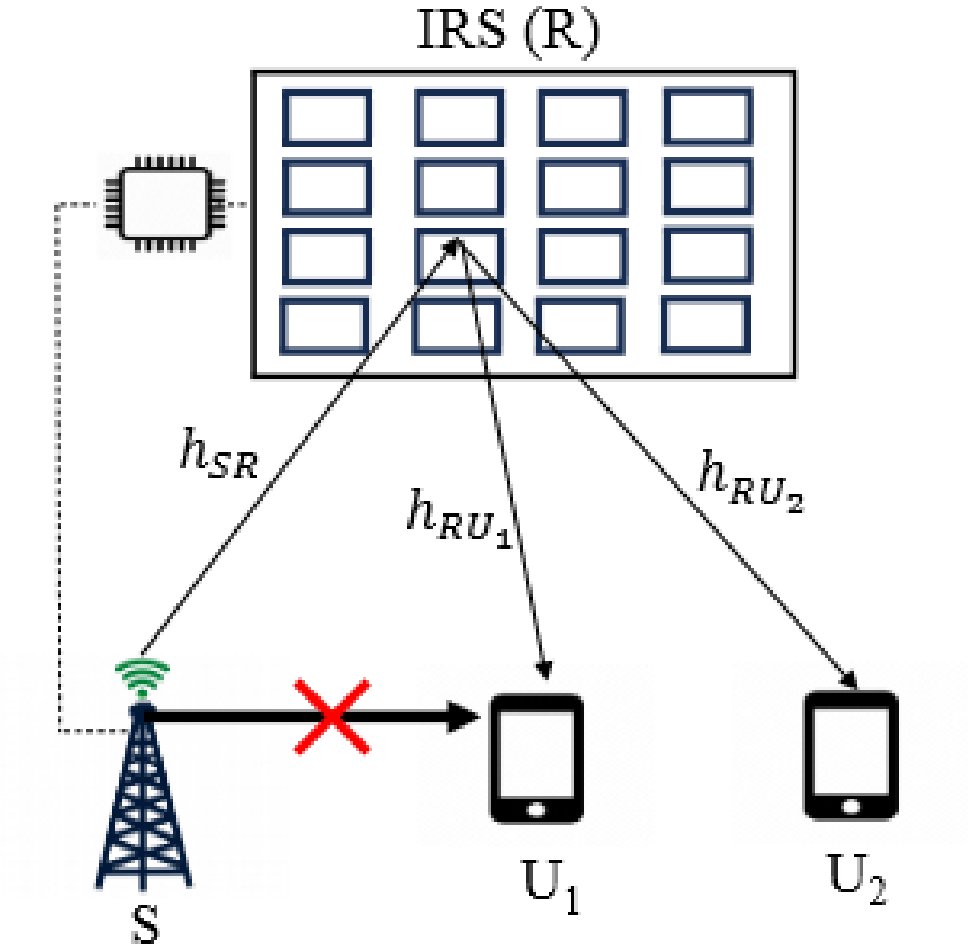
Introduction

- Passive reflecting elements
- Assist communication when source to destination link is blocked
- Two phases of operation
  - Training
  - Communication



Multi-user IRS Operation

- Multiple users are inevitable in communication networks
- Multiple phase shifts for multiple users is required
- Strategies:
  - Separate IRS for each user
  - Element Splitting
  - Time splitting



S. Zhang and R. Zhang, "Intelligent Reflecting Surface Aided Multi-User Communication: Capacity Region and Deployment Strategy," in *IEEE Transactions on Communications*, vol. 69, no. 9, pp. 5790-5806, Sept. 2021

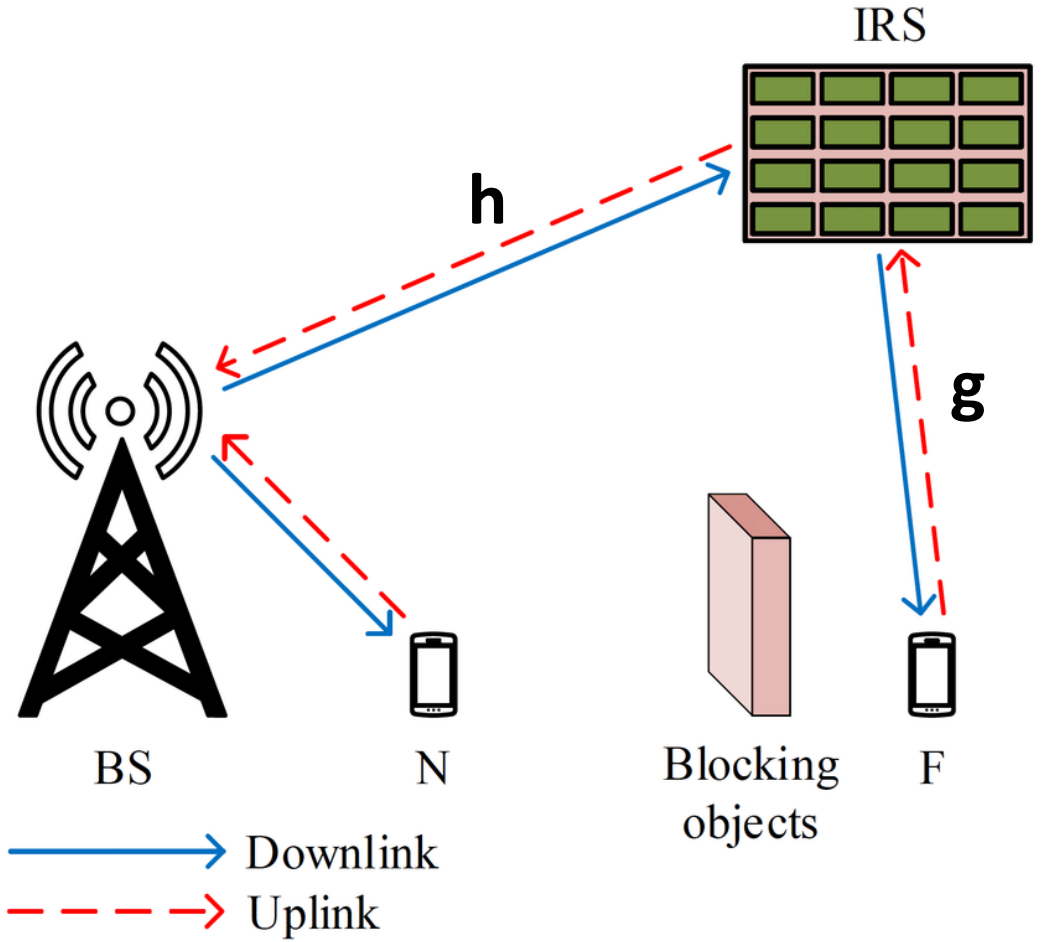
Multi-user IRS Operation - NOMA

- Began with service only for far user with IRS assistance
- Near user is served through direct link with the base station

- Received signal Equation at far user

$$r = \sum_{i=1}^{M} h_i \varphi_i g_i x + n$$

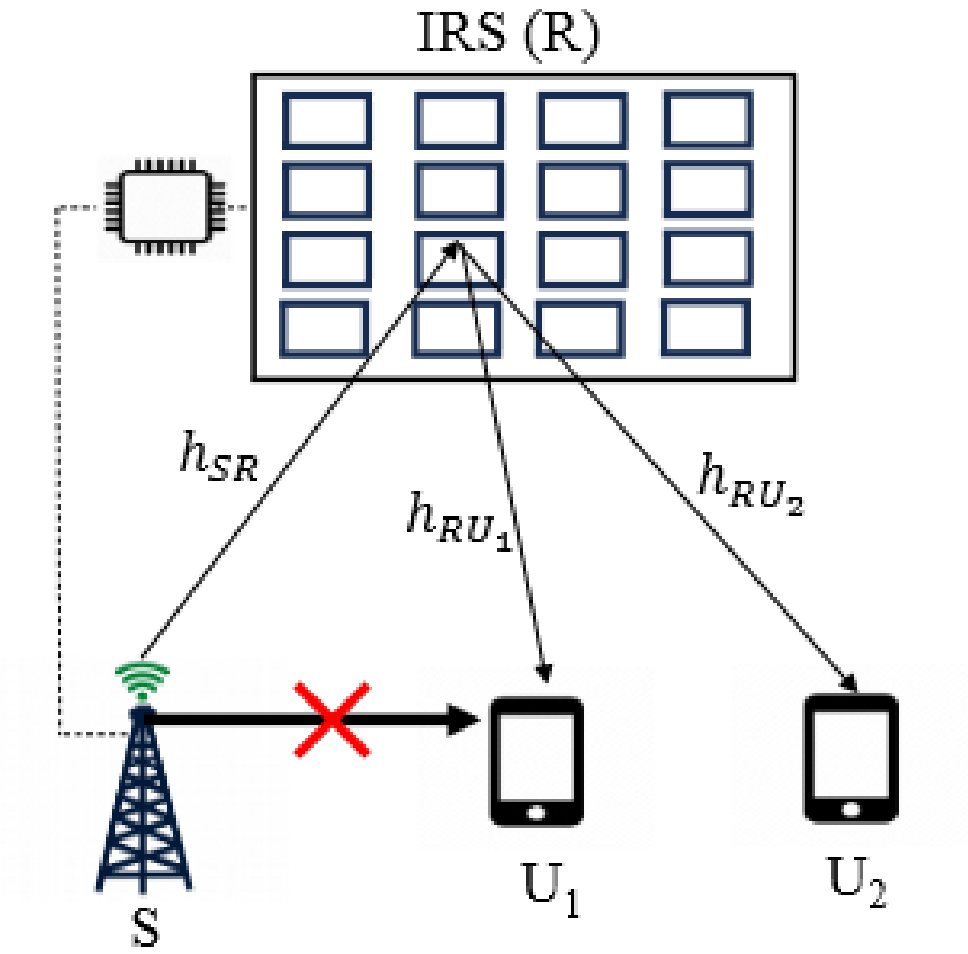
- **What if the reflected component reaches to near user?**



Y. Cheng, K. H. Li, Y. Liu, K. C. Teh and H. Vincent Poor, "Downlink and Uplink Intelligent Reflecting Surface Aided Networks: NOMA and OMA," in *IEEE Transactions on Wireless Communications*, vol. 20, no. 6, pp. 3988-4000, June 202
Ding and H. Vincent Poor, "A Simple Design of IRS-NOMA Transmission," in IEEE Communications Letters, vol. 24, no. 5, pp. 1119-1123, May 2020

Multi-user IRS Operation - NOMA

- All the elements serve to both the users in a NOMA pair
- Single phase shift to serve both users
- Phase shift matrix is designed to maximize the sum received signal power
- A Non - LOS scenario for both the users

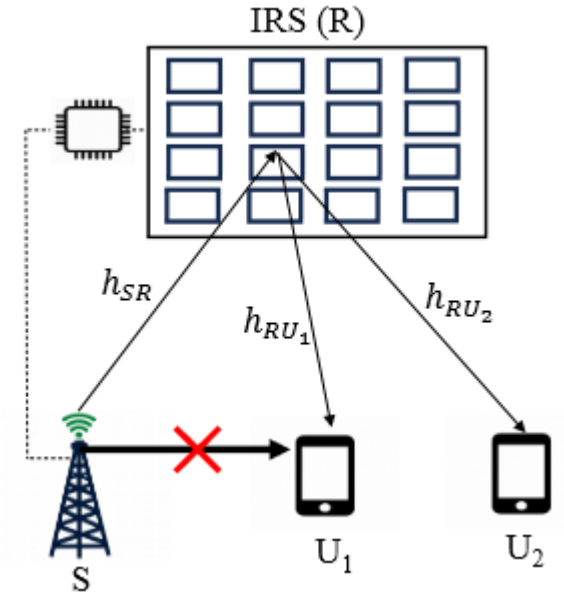


Multi-user IRS Operation - NOMA

- Received signal at user

$$y_{U_i} = \frac{1}{\sqrt{A\left(d_{SR}\right) A\left(d_{RU_i}\right)}} \left(\sum_{k=1}^{K} h_{SR_k} \Phi_k h_{R_k U_i} \right) x + n_{U_i}$$

where, $x = \sum_{i=1}^{2} \sqrt{\alpha_i P_s} x_i$.



- Sum Received power, representing cascaded channels as $\mathbf{h_1}$ and $\mathbf{h_2}$

$$\left|A_1 \mathbf{\Phi}^H \mathbf{h_1}\right|^2 + \left|A_2 \mathbf{\Phi}^H \mathbf{h_2}\right|^2$$

Multi-user IRS Operation - NOMA

- Sum received signal at user

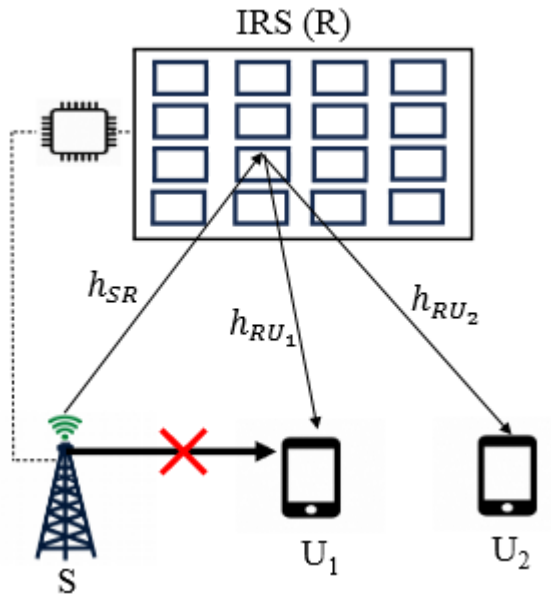
$$\left|A_1\mathbf{\Phi}^H\mathbf{h_1}\right|^2+\left|A_2\mathbf{\Phi}^H\mathbf{h_2}\right|^2\leq\left|\mathbf{\Phi}^H\left(A_1\mathbf{h_1}+A_2\mathbf{h_2}\right)\right|^2$$

- Using Cauchy - Schwarz inequality,

$$\mathbf{\Phi}\propto\left(A_1\mathbf{h_1}+A_2\mathbf{h_2}\right)$$

- Thus, phase shift at each element can be given by

$$\Phi_k=\left(c_1e^{-j\phi_{U1}^k}+c_2e^{-j\phi_{U2}^k}\right)$$

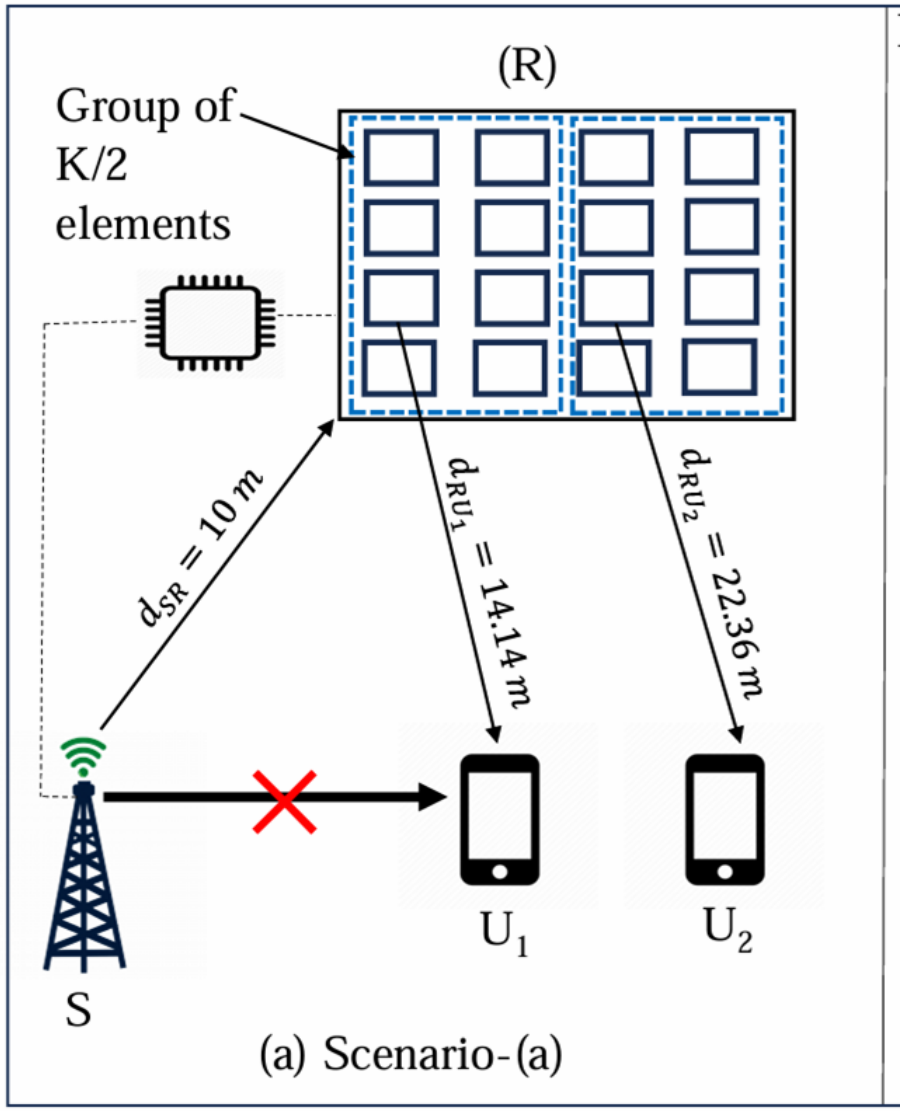


Multi-user IRS Operation - NOMA (3 cases)

❖ Scenario - (a)

- ➢ Single IRS to serve both the users in NOMA pair (Total Elements (K))
- ➢ Elements are divided into two equal parts
- ➢ Effectively half of the IRS elements (K/2) serve an user

❖ **Assumption:** No interference from the non serving elements of the IRS

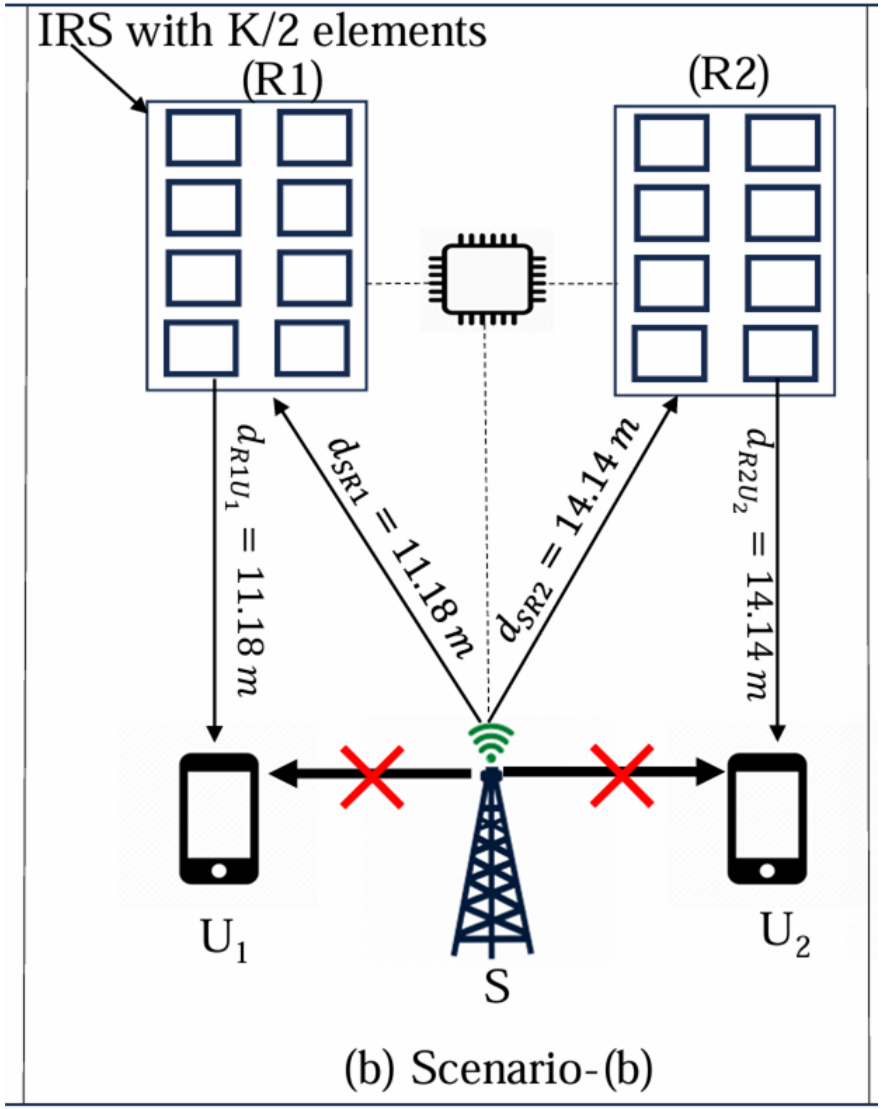


Multi-user IRS Operation - NOMA (3 cases)

❖ Scenario - (b)

- ➢ Two IRS, each with K/2 elements, to serve the users in NOMA pair
- ➢ Each IRS is kept at the same distance from Base station and the user

❖ **Assumption:** No interference from the non serving IRS to the other user



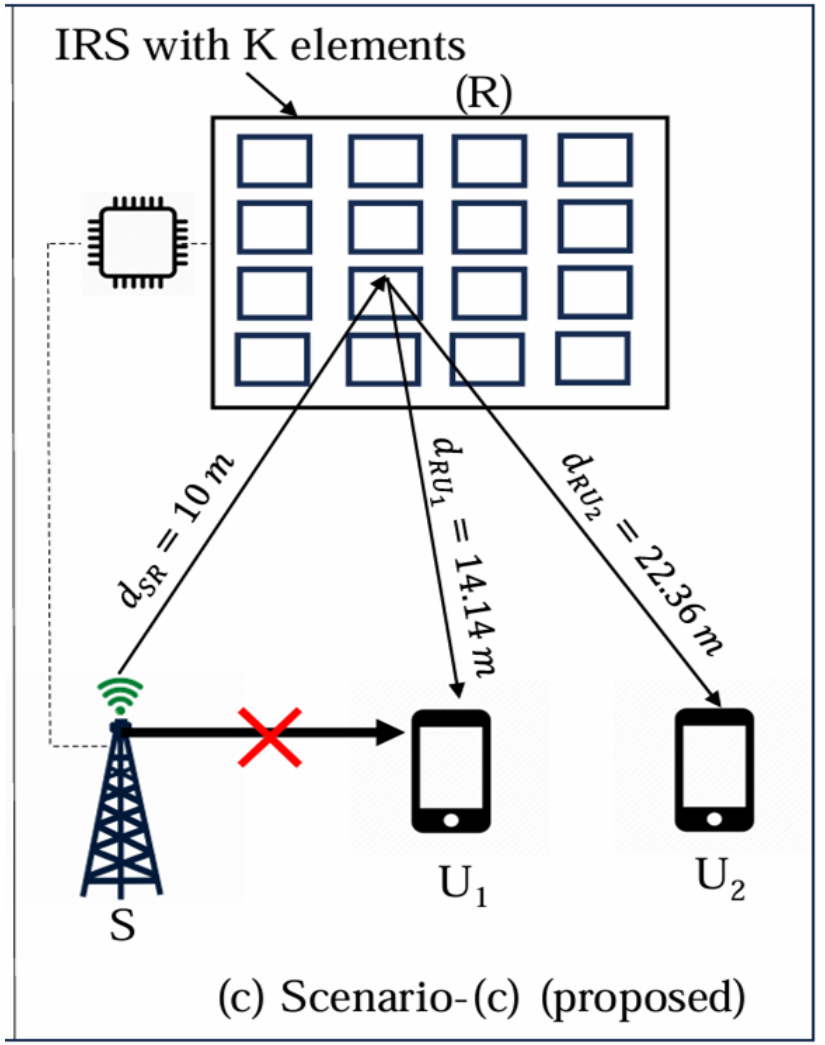
(b) Scenario-(b)

Multi-user IRS Operation - NOMA (3 cases)

❖ Scenario - (c) : Proposed in this work

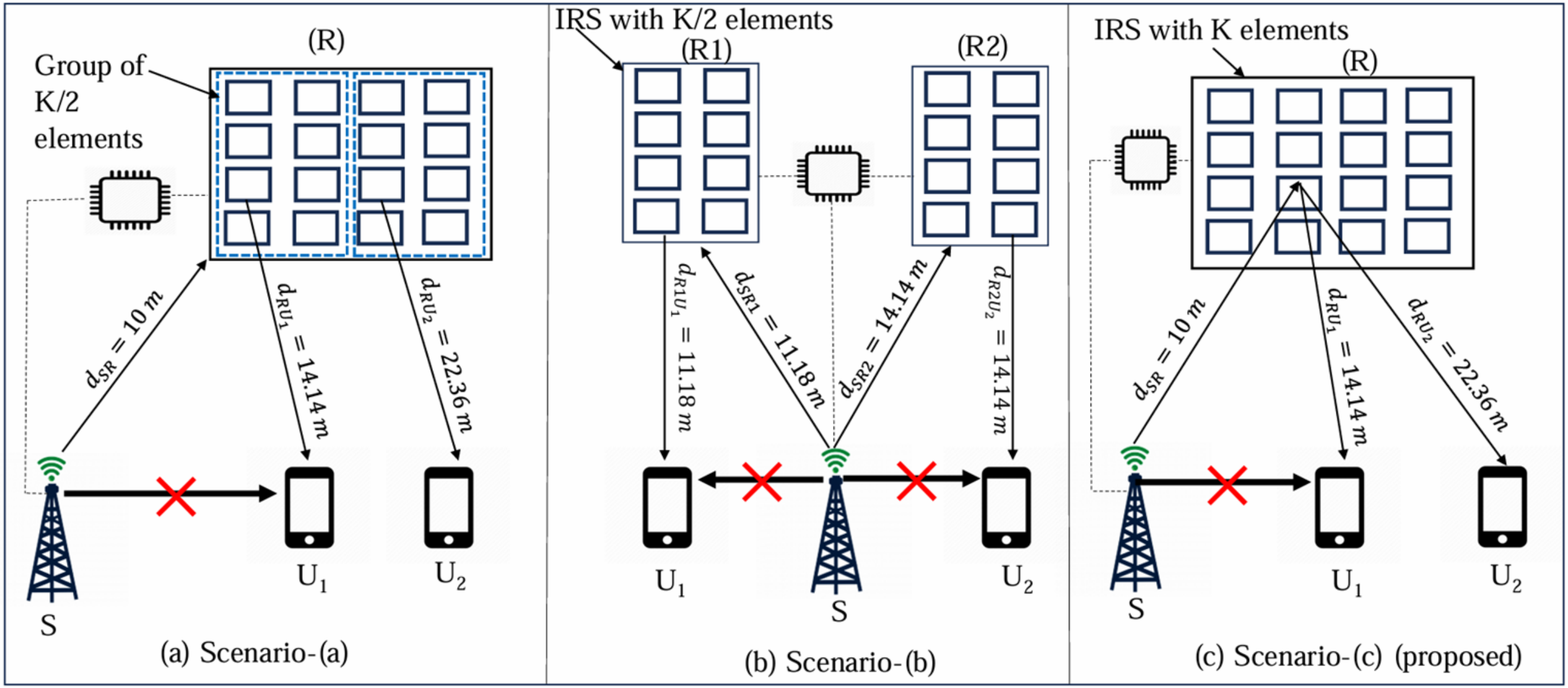
- ➢ Single IRS to serve both the users
- ➢ All the elements are trained to serve both the users
- ➢ A small amount of interference due to phase shift matrix containing phases of both the users

❖ **Assumption:** Non - LOS channels for both the users

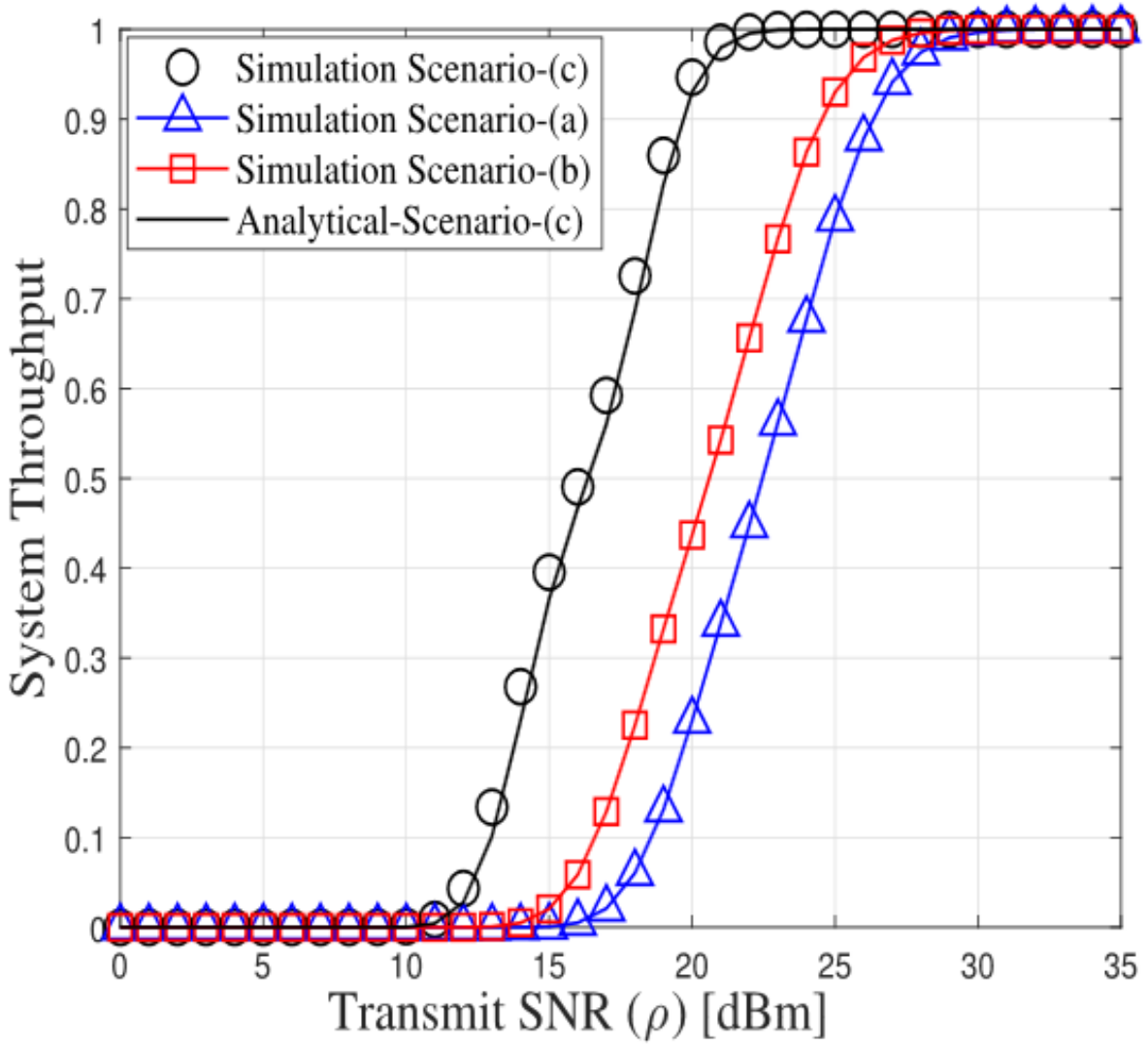


S. Kumar, R. Singh, B. Kumbhani and S. Agarwal, "A New Paradigm for IRS-NOMA Transmission," in *IEEE Transactions on Vehicular Technology*, vol. 73, no. 7, pp. 10835-10839, July 2024

Multi-user IRS Operation - NOMA (3 cases)



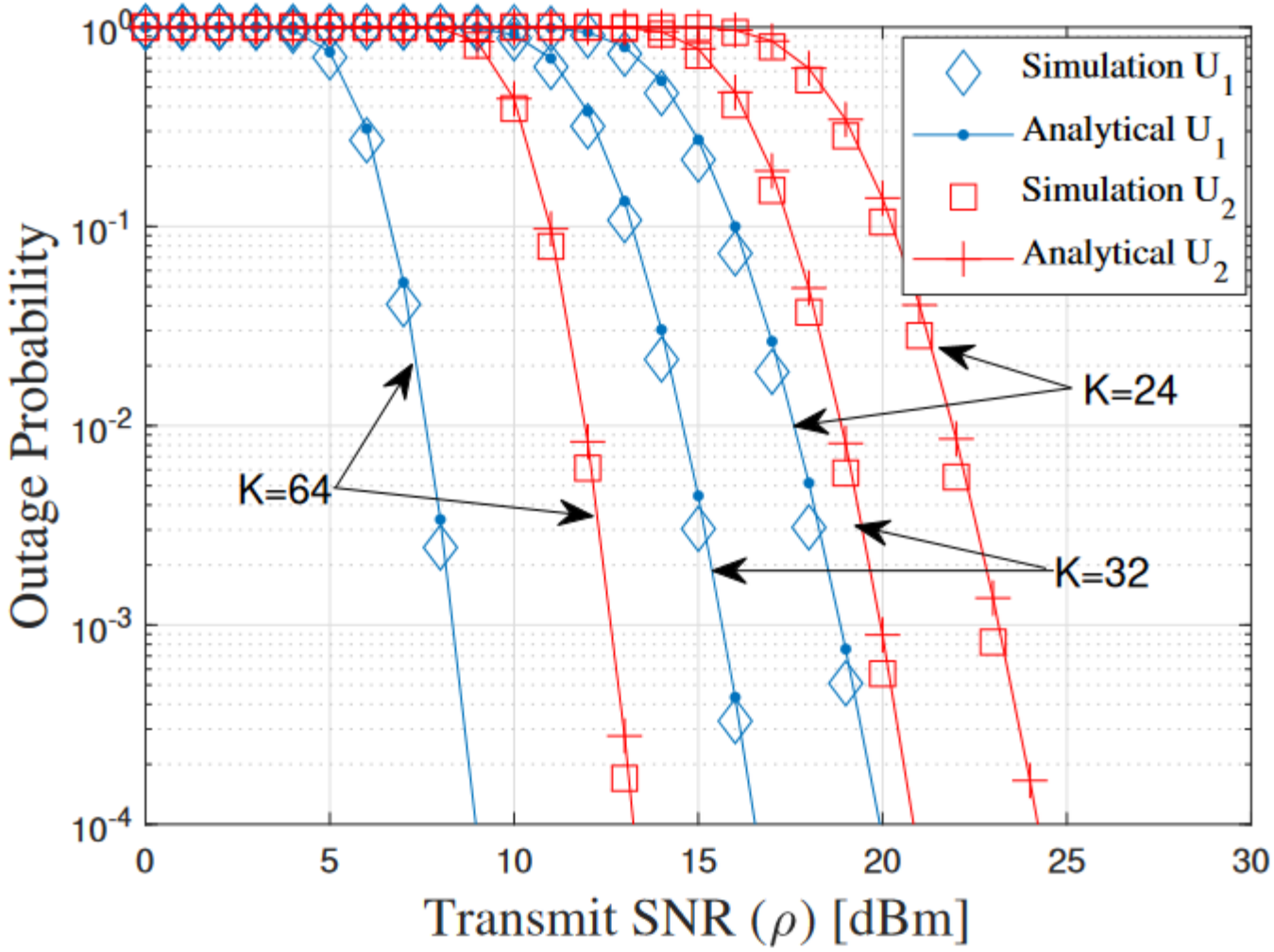
Multi-user IRS Operation - NOMA (3 cases)



- System throughput for the proposed scenario is higher than the other two.
- Scenario - b performs better than scenario - a in throughput on the account of the IRS positions.

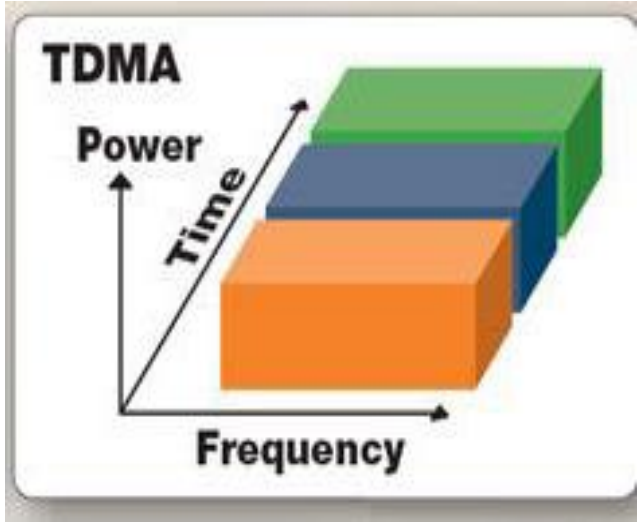
Multi-user IRS Operation - NOMA (3 cases)

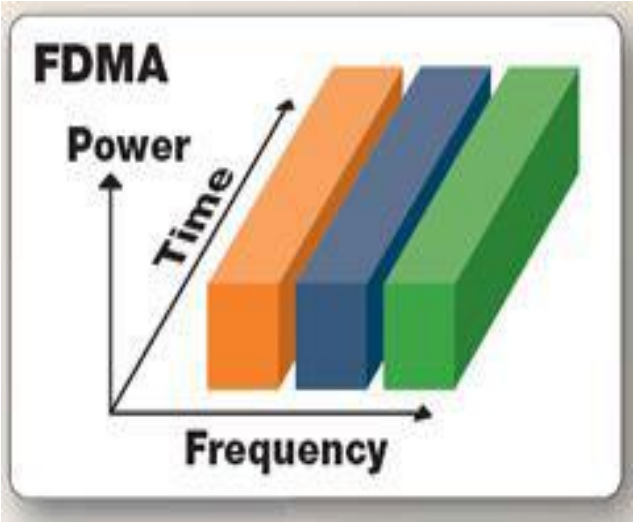
- Outage probability for both users (Scenario - c) with different number of IRS elements
- User 1 performance is better being at nearer position from the base station (Total distance from user to base station)



Multiple access in IRS Operation

- Single IRS to serve multiple users in orthogonal fashion
- TDMA: Time variation in the phase shifts for different users
- FDMA: Phase variation in different frequency channels
- CDMA: multiple users served at same time - frequency slot however, wideband training is necessary





https://www.polytechnichub.com/difference-fdma-tdma/

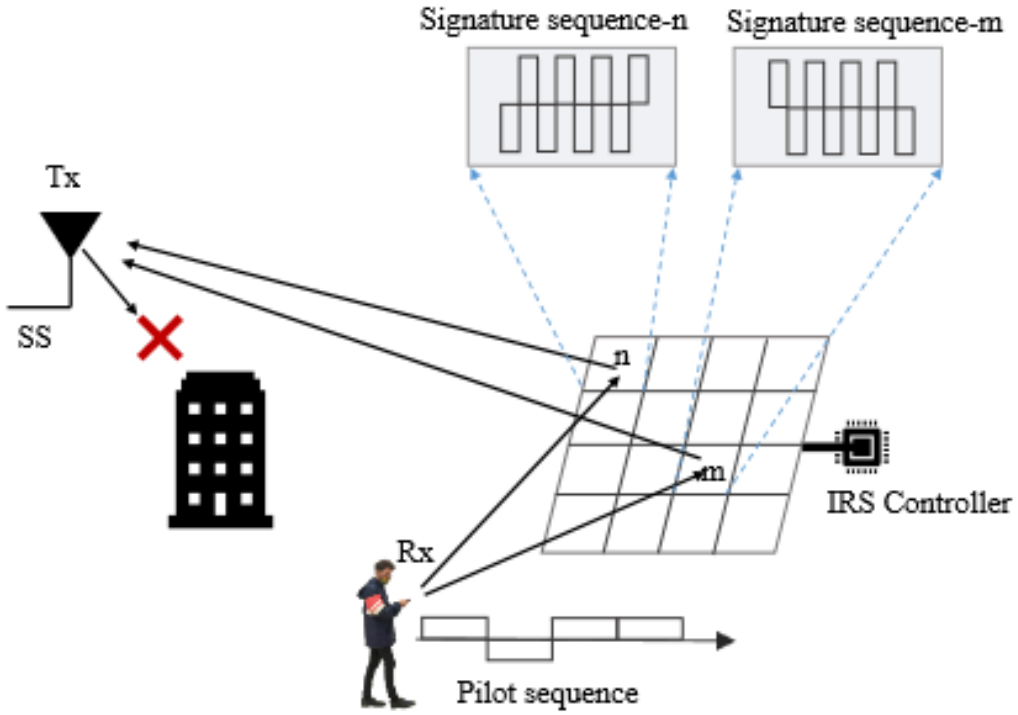
Parallel training

- CDMA Approach for wideband training with orthogonal pilot transmission

  For multiple users

  For multiple elements

- IRS bandwidth considerations are the limiting factor



More readings

- S. Kumar, R. Singh, B. Kumbhani and S. Agarwal, "A New Paradigm for IRS-NOMA Transmission," in *IEEE Transactions on Vehicular Technology*, vol. 73, no. 7, pp. 10835-10839, July 2024
- V. C. Thirumavalavan and T. S. Jayaraman, "BER analysis of reconfigurable intelligent surface assisted downlink power domain NOMA system", *Proc. Int. Conf. Commun. Syst. Netw.*, pp. 519-522, 2020.
- Z. Ding and H. V. Poor, "A simple design of IRS-NOMA transmission", *IEEE Commun. Lett.*, vol. 24, no. 5, pp. 1119-1123, May 2020.
- Y. Cheng, K. H. Li, Y. Liu, K. C. Teh and G. K. Karagiannidis, "Non-orthogonal multiple access (NOMA) with multiple intelligent reflecting surfaces", *IEEE Trans. Wireless Commun.*, vol. 20, no. 11, pp. 7184-7195, Nov. 2021.


Thank
You