Intelligent reflecting surface (IRS) enabled wireless communications

CSR Group

Simultaneously Transmitting And Reflecting Surfaces (STARS) Assisted 6G [1]

❑ STARS

A tunable surface for achieving smart transmission and reflection

- Low cost/power-consumption
- Wireless extension
- Easy to deploy

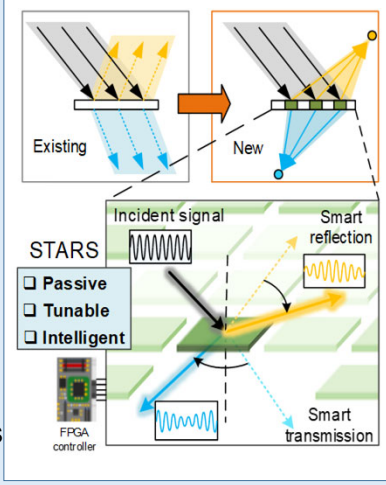
❑ Impact

- Benefit telecom users/providers
- Empower vertical industries
- Environment friendly

❑ My research

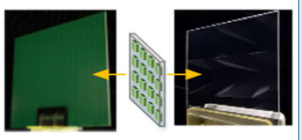
- Channel modelling
- Beamforming optimisation
- Deployment design
- Machine learning enabled STARS
- STARS with other techniques

❖STARS: a way to 360° smart propagation



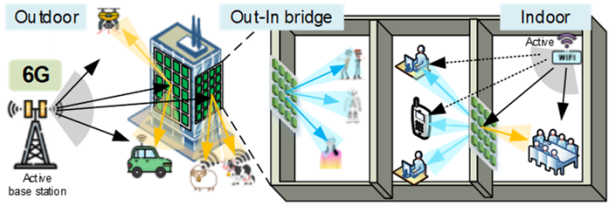
❖STARS for smart wireless

❖What STARS look like



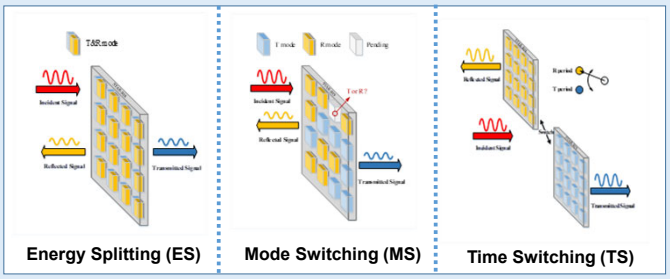
Opaque STARS (walls, ceilings,...)

Transparent STARS (windows,...)



Operating Protocol and Beamforming Design for STARS [2,3]

Research Aim: Propose practical operating protocols and the tailored beamforming approaches for employing STARS-assisted wireless communications.



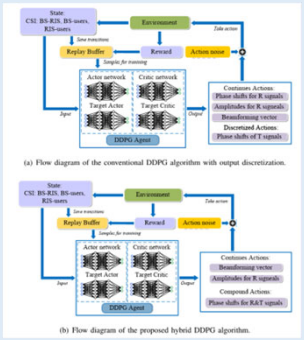
Energy Splitting (ES) | Mode Switching (MS) | Time Switching (TS)

Key research findings: TS and ES protocols are preferable for unicast and multicast, respectively; STAR-RIS significantly outperforms conventional RIS.

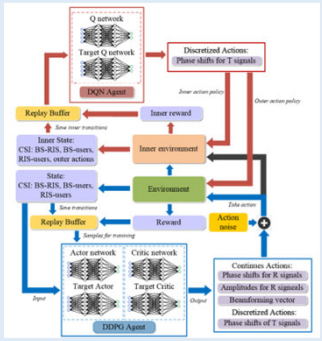
Artificial Intelligence Enabled STARS [4]

Research Aim: Proposing artificial intelligence methods for employing STARS

Optimisation variables: joint active BS beamforming and STARS passive beamforming optimisation



Hybrid DDPG algorithm

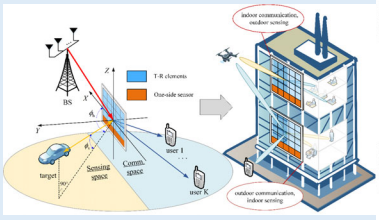


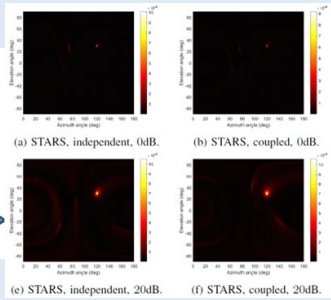
Joint DDPG-DQN algorithm

STARS enabled Integrated Sensing and Communications (ISAC) [5]

Sensing-at-STARS: install low-cost active sensors at the STARS.

2D Sensing: Estimating both azimuth and elevation Directions-of-Arrival (DOAs).





(a) STARS, independent, 0dB. (b) STARS, coupled, 0dB. (e) STARS, independent, 20dB. (f) STARS, coupled, 20dB.

Key research findings: Installing more passive elements is more appealing than installing more active sensors.

Research grants on STARS and other topics

❑ Ongoing Grants (over £700k)

- **EPSRC**, "Towards Sustainable ICT: Sparse Ubiquitous Networks based on Reconfigurable Intelligent SurfacEs", £350k
- **UK-South Korea Collaborative R&D**, "AI for Reconfigurable Intelligent Surfaces", £100k
- **British Council Hubert Curien project**, "RT-RIS for Integrated Signal Enhancement and Information Transfer in Wireless Communication System", £3.8k
- **Industry Fund**, "Next Generation Multiple Acces", £176k (Contract exchange)
- **A*STAR (Singapore) PhD Scholarships**, £100k

❑ Completed Grants (over £700k)

- **Royal Society**, "Prototype Design for Reconfigurable Refracting and Reflecting Intelligent Surfaces (R3ISs)", £15.15k
- **Royal Society-NSFC**, "Intelligent Unmanned Aerial Vehicle Communications over Cellular Networks", £12k
- **Industry Fund**, "Intelligent Reflecting and Refracting Surface (IR2S)", £345k
- **Industry Fund**, "Reinforcement Learning for Multi-Objective Optimization in Wireless Networks", £239k
- **Industry Fund**, "Multi-Cell NOMA", £130k

Engineering and Physical Sciences Research Council | Innovate UK | The Royal Society | British Council

[1] **Y. Liu**, *et al*, "STAR: Simultaneous Transmission And Reflection for 360 Coverage by Intelligent Surfaces", IEEE Wireless Communications; vol. 28, no. 6, pp. 102-109, December 2021. (***Popular article on IEEE WCM***)
[2] **Y. Liu**, *et al*, "Simultaneously Transmitting and Reflecting (STAR)-RISs: A Coupled Phase-Shift Model", ICC 2022 -IEEE International Conference on Communications, 2022, pp. 2840-2845. (***2022 IEEE SPCC TC Best Paper Award***)
[3] X. Mu, **Y. Liu**, *et al*, "Simultaneously Transmitting And Reflecting (STAR) RIS Aided Wireless Communications", IEEE Transactions on Wireless Communications; vol. 21, no. 5, pp. 3083-3098, May 2022. (***ESI Highly Cited Paper, <1%***)
[4] R. Zhong, **Y. Liu**, *et al*, "Hybrid Reinforcement Learning for STAR-RISs: A Coupled Phase-Shift Model Based Beamformer", IEEE Journal on Selected Areas in Communications; vol. 40, no. 9, pp. 2556-2569, Sept. 2022.
[5] Z. Wang, X. Mu, **Y. Liu**, "STARS Enabled Integrated Sensing and Communications: A CRB Optimization Perspective", 2022 IEEE 96th Vehicular Technology Conference (VTC2022-Fall), London, United Kingdom, 2022, pp. 1-6. (***IEEE VTC2022-Fall Best Student Paper Award***)