STAR-RIS: Applications and Research Issues

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***Abstract*—Simultaneously transmitting and reflecting reconfigurable intelligent surface (STAR-RIS) can serve the users in a full-space via both transmitting and reflecting signals. We present the novel application scenarios along with the research issues and future directions of the STAR-RIS-aided communications in 6G.**

I. Introduction

The same side deployment of the transmitter and receiver for the reflecting-only RIS causes performance degradation [1]. Through intelligent deployment and effective beamforming designs, simultaneous transmitting and reflecting-RIS (STAR-RIS) can overcome such a limitation and provide service coverage in a full-space [2].

II. Contribution

In the literature, the design and optimization of the conventional RIS is mainly focused [3]. Since STAR-RIS is a new wireless communication paradigm, the study and evaluation of the STAR-RIS in 6G require further investigation. As compared to the reflecting-only RIS, the potential applications and specific use cases of STAR-RIS are not limited. In this paper, we discuss the novel applications for STAR-RIS to serve users wherever their locations are with respect to the STAR-RIS. In addition, the research challenges and future directions for STAR-RIS are also presented.

III. Application scenarios of the STAR-RIS

The application scenarios of the STAR-RIS, including multi-cell communication, aerial communication, physical layer security (PLS), non-orthogonal multiple access (NOMA), and simultaneous wireless information and power transfer (SWIPT), are as follow:

A. Coverage extension

RIS/STAR-RIS can enhance the wireless connectivity and service coverage. However, RIS can provide the half-space coverage only. As shown in Fig. 1 (a), STAR-RIS can extend the coverage in a full-space supporting users inside and outside of building.

B. Multi-Cell Communications

RIS/STAR-RIS can be deployed in overlapping coverage area of adjacent cells in multi-cell indoor communication systems such that inter-cell interference can be alleviated. RIS in the overlapping coverage area of adjacent cells can only serve the user in the reflection region). Fig. 1 (b) shows that the STAR-RIS can serve users in both cells, tackle multi-cell interference, and focus the signals toward users on one side while nulling the interference to the other side.

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C. NOMA

For the RIS, the optimal selection of NOMA user pair is possible within the reflection region only. As shown in Fig. 1 (c), STAR-RIS serves NOMA user pairs in full-dimensional propagation environment and provide the channel-quality adjustments for more flexible decoding order and higher performance gain.

D. SWIPT

STAR-RIS/RIS can provide promising solutions in SWIPT systems as RF signals can be received with improved directivity and power. Fig. 1 (d) shows STAR-RIS-SWIPT systems. For example, energy splitting (ES) protocol can split the power before arriving the user to provide more flexibility and support for a more practical scenario (e.g., IoT networks with users having different requirements).

E. PLS

PLS can be enhanced using RIS only if an eavesdropper and a legitimate user are located on the same side of transmitter. As shown in Fig. 1 (e), STAR-RIS can provide novel PLS solutions, e.g., enhance (degrade) the communication links of the legitimate user (eavesdropper) located in a full-space.

F. RF sensing and localization

RF sensing and localization precision depends on the distinguished received fingerprints at two arbitrary positions. A receiver can recognize different sensing targets via different received signals. However, sensing accuracy is limited by unfavorable channel conditions. Fig. 1 (f) shows an application of the STAR-RIS supporting RF sensing and localization. STAR-RIS/RIS can actively customize the wireless channels, and provide the full-space coverage to effectively reduce the blind zones, thus improving the reliability of the system.

G. Aerial access networks (AANs)

STAR-RIS/RIS provides innovation communication solutions in AANs (e.g., can complement the path loss caused by the long coverage distance and improve the communication links). If RIS is used, flying range of aerial users must be restricted and a handover (to another RIS) is required when aerial user flies away from the reflection region. Such an operation results in signaling burden. As shown in Fig. 1 (g), STAR-RIS can provide the full-space maneuverability to the aerial users, and more flexible trajectory designs are possible for the AANs to cover the diverse requirements.

IV. Research issues and future directions

The results of the RIS do not directly apply since the STAR-RIS considers more adjustable parameters with both transmission and reflection links. The research issues and future directions for the STAR-RIS in 6G are as follow:

- The mathematical-tractable and numerically-reproducible channel models are required.

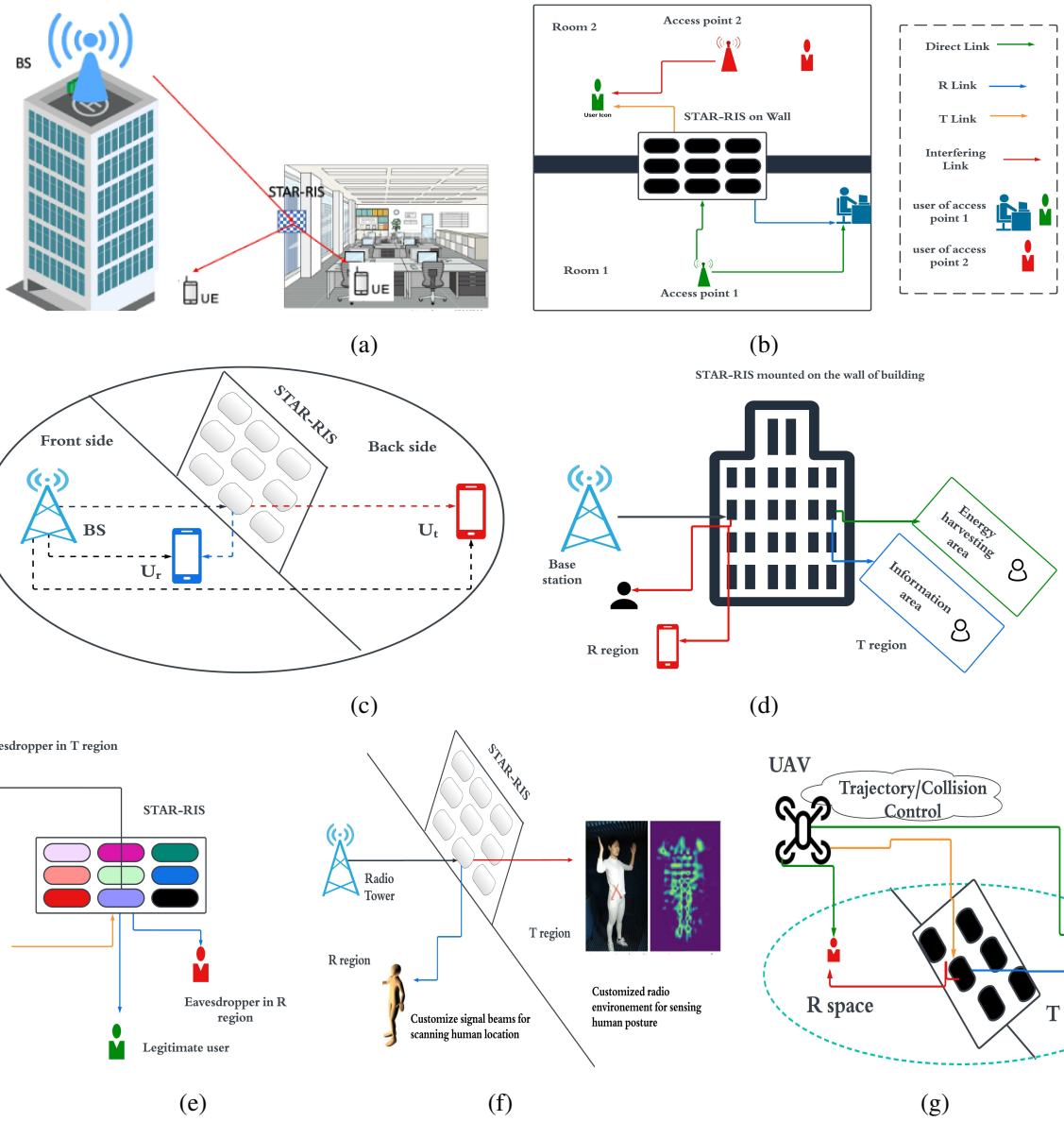

Fig. 1. Novel applications of the STAR-RIS: (a) Users inside and outside of building, (b) Multi-cell communications, (c) NOMA implementation, (d) SWIPT implementation, (e) PLS implementation, (f) RF sensing and localization, (g) AANs.

- Channel estimation depends on the hardware designs and operating protocols. The signal-processing and machine-learning-based channel estimation designs require further investigation.
- Hardware solutions (e.g., PIN diode- and metasurface-based implementations) are required for the affordable and scalable manufacturing with the efficient tuning and independent controls.
- The hardware constraints, e.g., coupled phases, phase-dependent amplitude, discrete amplitude and phase, and correlated channels, are required to be incorporated in hardware modeling.
- Efficient solutions are required for the non-convex/high-dimensional 6G STAR-RIS optimization problems.

V. Conclusion

STAR-RIS can control the wireless channels in a full-space and enable higher design flexibility with more degrees of freedom for signal manipulation. We discuss the effectiveness of STAR-RIS serving the users on both sides. We provide the representative applications and research issues of the STAR-RIS in future 6G deployments.

References

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