

RISilience: Resilience-Oriented Placement of Reflecting Surfaces Under Dynamic Blockages

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Abstract—Despite growing interest in reconfigurable intelligent surfaces (RIS) for coverage and resilience, their integration into existing wireless networks remains challenging. While most works rely on continuous phase adaptation and real-time control, we investigate statically-configured RIS (SC-RIS), which are set up once during link initialization, thereby reducing the control overhead associated with dynamically reconfigurable RIS. By strategically placing multiple SC-RIS based on expected blockage patterns in highly mobile environments, path diversity can be increased in otherwise sparse channels. Using ray-tracing simulations in *Sionna RT* to model urban environments with stochastic vehicular traffic, we formulate an outage-constrained optimization problem. The objective is to determine the minimum number and placement of SC-RIS such that the received signal to noise ratio (SNR) remains above a target threshold except a small outage probability during the communication interval. This problem is combinatorial and NP-hard, so we adopt a heuristic that evaluates candidate paths, selects weakly correlated ones in terms of blockages, and iteratively chooses the ones that minimize outage probability. In a Manhattan grid scenario at sub-6 GHz under non-line-of-sight (NLOS) conditions, our optimization selects 1, 3 and 4 surfaces to ensure an outage probability of 10^{-2} under low, moderate, and high traffic, respectively. In contrast, randomly chosen subsets of about 4 and 10 surfaces are required under low and moderate traffic, and fail to reach the target under high traffic, saturating at 4×10^{-2} even with 15 surfaces. Placement therefore matters more than count: additional surfaces yield diminishing returns once they duplicate correlated paths.

Index Terms—statically-configured reconfigurable intelligent surfaces, RIS, resilience, sub-6 GHz, mmWave, mobility.

I. INTRODUCTION

Reconfigurable intelligent surfaces (RIS) have been commonly proposed as a promising technology for shaping the wireless propagation environment, attracting significant attention from both academia and industry [1], [2]. By dynamically reconfiguring the characteristics of impinging waves, RIS could transform traditionally passive environments into adaptive communication spaces. This is typically done through many passive reflecting elements, each capable of adjusting one or more properties of the incident signal, such as phase, amplitude, polarization, and, in some designs, even frequency [3]–[5].

As wireless systems evolve toward higher carrier frequencies, channels tend to become sparser and more sensitive to blockages [6]. Highly directional beams, while beneficial for link budget and network capacity, are inherently vulnerable to blockages and mobility. In this context, RIS offer an attractive mechanism to increase multipath diversity, improve robust-

ness, and support reliable connectivity through synthesizing additional paths in dense or obstructed environments [7], [8].

However, despite extensive theoretical work showing significant performance gains, the practical integration of RIS remains limited [9]. Much of the literature focuses on optimizing isolated aspects: phase-shift design, channel estimation, or beamforming, often under simplified models with idealized assumptions of perfect channel state information (CSI), centralized coordination, and instantaneous reconfiguration. Aspects related to RIS configuration for user tracking are also extensively discussed [10]–[12]. Yet, fewer works consider RIS as part of the broader network, where they must be managed alongside scheduling, mobility, interference, hardware limitations, and practical deployment costs [13]. Implementation therefore raises additional challenges, including control signaling overhead, synchronization, and scalability in multi-user outdoor scenarios with possible strong interference [14].

Given the complexity of continuous phase control and CSI acquisition, we instead look at statically-configured RIS (SC-RIS), which are configured at the beginning of a communication period and remain fixed throughout it. Requiring no control link and no synchronization during this period, they can integrate into existing deployments at much lower cost compared to RIS, which is particularly useful for deployments with stationary users. Nevertheless, the SC-RIS paths are themselves directional and can also be affected by blockages, specifically in highly mobile environments, or under unfavorable geometry. Thus, it remains questionable whether theoretical gains reported in small-scale or simulation setups (such as [8], [15]) can be sustained in larger, more heterogeneous networks.

In order to assess the practicability of SC-RIS under the impact of blockages, we employ ray-tracing simulations using *Sionna RT* [16]. While traditional channel models often neglect the spatial and temporal correlations between different paths, *Sionna RT* provides spatially consistent channels and physically accurate modeling of propagation. Accordingly, we formulate an optimization problem that determines the smallest set of SC-RIS needed to satisfy a predefined outage constraint for a specific user. We then discuss if resilience improves monotonically, saturates due to spatial correlation or even degrades due to it. Through this study, we provide quantitative insights whether “more” surfaces necessarily translate into “less” outage when mobility is considered.

Our design philosophy is not to suppress multipath, but to

deliberately exploit it: by increasing the number of independently fading and physically distinct propagation paths that are unlikely to be simultaneously blocked, and that can be effectively combined at the receiver using typical protocols like 5G or WiFi, we enhance robustness against blockages. Our main contributions can be summarized as:

- We minimize the number of SC-RIS required to meet a target outage probability, considering varying traffic intensities and different radio spectrum.
- We propose a low-complexity heuristic combining correlation-based pre-filtering with iterative greedy selection.
- We leverage ray-tracing simulations based on *Sionna RT* to capture time-varying propagation effects induced by mobile obstacles and realistic environmental interactions.

II. BACKGROUND: MULTIPATH DIVERSITY GAIN

Multipath diversity mitigates *small-scale fading*, i.e., rapid signal fluctuations caused by constructive or destructive interference among propagation paths over spatial scales on the order of a wavelength [17]. Blockage, in contrast, is a *large-scale fading* phenomenon caused by obstructions such as buildings, vehicles, or human bodies, operating over much larger spatial scales. Despite their different physical origins, a rich multipath environment can also offer resilience against blockage: if the line-of-sight (LOS) path is obstructed, non-line-of-sight (NLOS) reflections or scattered paths can sustain the link. In rich scattering environments, many independent paths exist, so blocking a single path rarely causes outage; the channel may degrade from Rician to Rayleigh statistics but connectivity remains preserved. Sparse environments, however, are more vulnerable, and blockage of the main path can cause complete link failure.

Multipath provides propagation-domain redundancy: if L independent paths exist, each blocked with probability p , the outage probability is p^L . Adding N SC-RIS would suggest $P_{\text{out}} \sim p^{L+N}$, decreasing geometrically with N . This idealization assumes paths fail independently and that outage means that all the paths are blocked. Neither holds in practice: nearby surfaces are shadowed by the same blockages, and an unblocked path may still be too weak to meet the signal to noise ratio (SNR) target. Quantifying this gap motivates our approach, i.e., we *engineer multipath* through SC-RIS and evaluate how many of them are needed in urban scenarios.

III. RELATED WORK

A. RIS Placement for Coverage Enhancement

Several studies have addressed RIS placement, primarily focusing on coverage enhancement, often using stochastic geometry frameworks. For example, Wang et al., [18] derive a closed-form expression for the coverage probability of a typical user in a large-scale cellular network with RIS, while Ma et al. [19] consider outdoor environments with static obstacles, where RIS are mounted directly on existing obstacles to improve coverage. Similarly, Kishk and Alouini [20] use

stochastic geometry to show that converting a fraction of obstacles into RIS reduces coverage blind spots and enhances network reliability. Ghatak et al. [21] demonstrate that, in mmWave networks, deploying RIS at street intersections yields higher coverage probability than colocating them with base stations. As for indoor scenarios, Zhang and Blough [22] optimize locations and orientations of multiple RIS to serve regions where the direct LOS path is blocked using an iterative gradient-descent algorithm. Similarly, Huo et al. [23] mitigate signal attenuation and human blockage in terahertz indoor networks using distributed RIS.

B. RIS for Mobile Obstacle Mitigation

Several works also focus on using RIS for mitigating dynamic blockages. Guo et al. [7] design region-based RIS pre-selection and blockage prediction schemes for high-mobility mmWave scenarios such as in Internet of Vehicles (IoV), improving reliability and throughput, while also highlighting practical challenges related to channel acquisition and real-time control. Zhang et al. [24] propose adaptive switching for multiple RIS, using reinforcement learning to track user mobility and environmental dynamics for near-optimal ergodic rates. On the other hand, Luc et al. [25] explore cooperative sensing with spatially distributed dual-beam reflective RIS to detect and localize mobile passive blockers, improving blockage detection and positioning accuracy. Kilcioglu and Oestges [26] leverage *Sionna RT* to jointly optimize RIS position, size, and beam-steering, combining path-gain thresholding and K-means clustering for improved indoor coverage.

C. Research Gap

Although these works demonstrate performance gains, they often assume sufficient infrastructure, controlled environments, and/or small-scale scenarios. They further share the assumption of real-time adaptation: surface selection, phase, or beam steering is updated as the environment changes. Closer to our setting, the concept of pre-configured RIS has been introduced as a solution towards fully passive operation [15], and in [27] the authors concluded that full reconfigurability is not always necessary. Our previous work experimentally showed that multiple pre-configured RIS can enhance resilience to blockages in an indoor mmWave setup, but did not systematically study how resilience scales with the number of surfaces [8].

We claim that deploying additional surfaces in a highly mobile environment can be more cost-effective than continuously tracking channel dynamics. Motivated by this and by the high overhead of fully dynamic RIS, we investigate the achievable system resilience using SC-RIS in the following sections.

IV. PROBLEM STATEMENT

A. System model

We consider a typical urban outdoor scenario with a stationary transmitter–receiver pair. Depending on their relative positions, a direct LOS path may or may not be present. It is important to emphasize that the LOS and NLOS labels refer exclusively to the direct link between the transmitter and

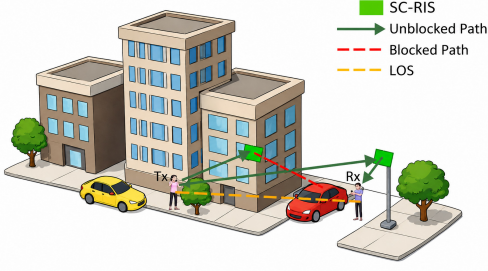


Figure 1. Urban outdoor scenario illustrating communication enabled via SC-RIS panels, despite multiple blocked paths, including the LOS and one SC-RIS path obstructed by the red car.

receiver. Under LOS, SC-RIS reflections complement the direct path and may improve the overall SNR through coherent combining. If the direct path is blocked, communication becomes fully dependent on the SC-RIS, as is inherently the case under NLOS. As a result, communication always depends on SC-RIS paths, and any additional blockage simply reduces the number of available paths in the system. There are static and mobile blockages in the environment, such as buildings and vehicles. To ensure reliable connectivity despite these obstructions, multiple SC-RIS are deployed on existing structures, including building facades and practical supports such as lamp posts, resembling realistic deployment conditions. Each SC-RIS is configured once with fixed incidence and reflection angles to direct signals from the transmitter to a specific user, thereby creating alternative paths that can bypass blockage. A simple illustration is shown in Fig. 1, where the direct LOS path is blocked, one path is temporarily obstructed by a vehicle, and another one maintains uninterrupted communication. We also provide an example from the simulated environment in Fig. 2a, where the blue-green transmitter–receiver pair operates under NLOS conditions. The orange pair is included in the same illustration to indicate a typical LOS scenario.

In practice, configuring an SC-RIS once does not imply that each surface is physically installed and removed for every user. A single panel can store a small set of precomputed phase configurations, such that the same deployed SC-RIS can be time-multiplexed across users: the relevant configuration is loaded once at the start of a communication period and held fixed throughout it. Adaptation occurs only at the coarse timescale of switching between served users.

B. Problem formulation

We consider a point-to-point orthogonal frequency-division multiplexing (OFDM) system. For a given SC-RIS j with M reflecting elements, its channel at time t and subcarrier k is:

$$h_j(t, k) = \mathbf{f}_j(t, k) \mathbf{\Theta}_j \mathbf{g}_j(t, k), \quad (1)$$

where $\mathbf{f}_j(t, k) \in \mathbb{C}^{1 \times M}$ is the transmitter-to-SC-RIS channel, $\mathbf{\Theta}_j = \text{diag}(e^{i\theta_{j,1}}, \dots, e^{i\theta_{j,M}})$ is the phase configuration of surface j , set at the start of the communication period to redirect signals from the transmitter to the receiver and held fixed afterwards, and $\mathbf{g}_j(t, k) \in \mathbb{C}^{M \times 1}$ is the SC-RIS-to-receiver channel. The index $k \in \{1, \dots, K\}$ denotes the subcarrier index, where K is the total number of subcarriers. Consider

a system with N candidate SC-RIS, observed over a period of T seconds sampled at intervals of Δt . This yields the set of snapshots $\mathcal{T} = \{\Delta t, 2\Delta t, \dots, T\}$. We introduce binary variables $z_j \in \{0, 1\}$, where $z_j = 1$ indicates that SC-RIS j is perfectly configured for the user. Let $h_0(t, k)$ denote the direct transmitter–receiver channel. The wideband SNR at snapshot $t \in \mathcal{T}$ under deployment $\mathbf{z}$ is:

$$\bar{\gamma}(\mathbf{z}, t) = \frac{P_{\text{TX}}}{K} \sum_{k=1}^K \frac{|h_0(t, k) + \sum_{j=1}^N z_j h_j(t, k)|^2}{\sigma^2}, \quad (2)$$

where P_{TX} is the transmit power and $\sigma^2 = N_0 W / K$ is the per-subcarrier noise power, with N_0 being the noise power spectral density and W the total channel bandwidth. The objective is to minimize the number of deployed SC-RIS while ensuring that $\bar{\gamma}$ meets the threshold Γ for all but a small fraction of the snapshots. Introducing auxiliary indicators $u_t \in \{0, 1\}$, $t \in \mathcal{T}$, where $u_t = 1$ marks snapshot t as an outage, the problem is formulated as:

$$\min_{\mathbf{z} \in \{0,1\}^N, \mathbf{u} \in \{0,1\}^{|\mathcal{T}|}} \sum_{j=1}^N z_j \quad (3a)$$

$$\text{s.t. } \bar{\gamma}(\mathbf{z}, t) \geq \Gamma (1 - u_t), \quad \forall t \in \mathcal{T}, \quad (3b)$$

$$\frac{1}{|\mathcal{T}|} \sum_{t \in \mathcal{T}} u_t \leq \varepsilon. \quad (3c)$$

Constraint (3b) enforces $\bar{\gamma}(\mathbf{z}, t) \geq \Gamma$ whenever $u_t = 0$, and is trivially satisfied when $u_t = 1$; (3c) limits the admitted outages to a fraction ε of the observation period. For simplicity, the mean SNR across subcarriers is evaluated, rather than a modulation-dependent effective SNR. This problem is combinatorial, non-convex and NP-hard. The search space grows combinatorially with the number of candidate surfaces, since all possible subsets of N must in principle be evaluated, resulting in $\mathcal{O}(2^N)$ candidate configurations. Moreover, because the received power depends on $|h_0 + \sum_{i \in \mathcal{S}} h_i|^2$, where $\mathcal{S} = \{j \mid z_j = 1\}$ the complex channel coefficients may combine constructively or destructively, making the objective non-monotonic and preventing efficient pruning of the search space. This impact diminishes when bandwidth increases, due to the averaging out effect among more subcarriers [28].

C. Low complexity heuristic

To reduce the search space, highly correlated SC-RIS (for example, spatially clustered surfaces that are similarly affected by mobile obstacles), can be pre-filtered. The correlation coefficient (ρ), e.g., of their SNR, can be computed pairwise, and only one SC-RIS is to be retained from pairs satisfying $\rho > \rho_{th}$, where ρ_{th} is the predefined filtering threshold. We propose a greedy heuristic to solve the optimization problem efficiently. Let $\mathcal{S}^{(i)} = \{j \mid z_j^{(i)} = 1\}$ denote the set of selected SC-RIS at iteration i , starting with $\mathcal{S}^{(0)} = \emptyset$. The instantaneous SNR at iteration i is $\bar{\gamma}(\mathbf{z}^{(i)}, t)$, evaluated as in (2). The greedy procedure iteratively adds the candidate that minimizes the number of outage snapshots when combined with the already

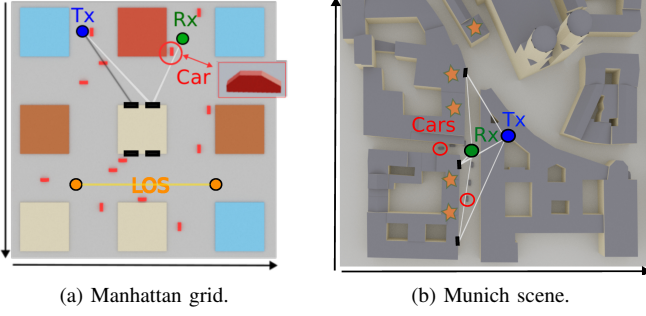


Figure 2. Example scenarios used to assess the impact of SC-RIS in outdoor environments. The transmitter–receiver pairs are shown in blue–green and orange, representing NLOS and LOS conditions, respectively. Some vehicles are highlighted with red circles. Black rectangles illustrate possible SC-RIS locations, and the arrows indicate the directions of vehicle mobility.

selected subset. Additionally, to prevent the greedy algorithm from selecting SC-RIS that yield negligible improvements, a minimum marginal improvement threshold is introduced, such that its contribution should exceed outage reduction of $\varepsilon/2$. The algorithm terminates when the fraction of time during which the instantaneous SNR falls below the threshold Γ is smaller than the allowed tolerance ε , or when all possibilities have been evaluated. In reality, the SC-RIS selection can be done offline, with the SNR traces of the candidate locations obtained before deployment from a digital twin (ray tracing combined with traffic statistics).

V. PERFORMANCE EVALUATION

A. Simulation setup

We evaluate our proposed algorithm using the RIS model in *Sionna RT* 0.19.2. *Sionna RT* is a GPU-accelerated, differentiable ray-tracing framework that provides physically, spatially and temporally consistent wireless channel modeling in realistic 3D environments [16]. The setup is designed to resemble an urban environment, where dynamic obstacles such as vehicular traffic introduce time-varying blockages. The placement and number of surfaces required to achieve resilience strongly depend on the geometry of the environment.

1) *Manhattan grid*: To systematically analyze these effects, we first consider a regular 3×3 Manhattan grid scenario (see Fig. 2a), which is modeled and rendered using Blender. This configuration provides sufficient spatial diversity to create meaningful blockage scenarios while maintaining geometric symmetry. For each building facade, four predefined candidate positions for SC-RIS are considered (36 total placements) i.e. all have potential visibility to both nodes; while denser sets would mainly add strongly correlated candidates. For readability, only four are shown in the central building, and the same layout is available in all of them. Each SC-RIS is configured once during $\mathcal{T}$ with the inbound angle towards the transmitter, and the outbound angle facing the receiver. The four traffic lanes represent streets along which mobile obstacles (cars) move. Vehicles travel along straight trajectories either from top to bottom or from left to right, maintaining a constant velocity throughout the simulation. The traffic density

Table I
SIMULATION PARAMETERS

Parameter	Value (sub-6 GHz / mmWave)
Spectrum	3.5 GHz / 28 GHz
Channel Bandwidth W	100 MHz / 400 MHz
No. Subcarriers K	1024 / 2048
No. of elements M per SC-RIS	625 / 2500
Thermal noise power	-94 dBm / -88 dBm
Transmit power P_{TX}	44 dBm
Simulation time T	100 s
Simulation update interval Δt	0.1 s
Obstacle (car) velocity v	10 m/s
Outage threshold Γ_{dB}	5 dB
Correlation coefficient threshold ρ_{th}	0.6
Target max. outage probability ε	0.01
Traffic intensity λ	0.1, 0.3, 0.7

in each lane is modeled according to a Poisson distribution with parameter λ , which defines the traffic intensity, i.e., the average number of cars entering the lane per unit time [29].

Moving vehicles may temporarily obstruct either the transmitter-to-SC-RIS path or the SC-RIS-to-receiver path. When one of them is blocked, the corresponding link becomes unavailable. A simple illustration of such a scenario is shown in Fig. 2a. Two SC-RIS on the central building establish two potential paths between the NLOS pair. However, the red car blocks the SC-RIS-to-receiver link of the leftmost SC-RIS, rendering that path unavailable at this snapshot. Communication through that path is restored only once the vehicle has moved sufficiently far so that *both* segments are simultaneously unblocked.

2) *Munich scene*: To verify the proposed algorithm in a more realistic scenario, we present results from a part of the Munich scene in *Sionna* (see Fig. 2b), where we deploy 72 different SC-RIS on the facades of buildings surrounding the nodes, at various heights. This allows us to evaluate the impact of vertical diversity and spatial distribution of the reflecting surfaces. The buildings where surfaces are added are annotated with a star, and for readability only a subset of the SC-RIS is illustrated. The transmitter and receiver are in NLOS condition. Similarly, vehicles move along the two traffic lanes visible in the figure (the almost perpendicular lanes alongside the SC-RIS markers) - and the direction is annotated by the black arrows.

3) *Simulation parameters*: Vehicles follow a Poisson process with rate λ , thus blockage events are stochastic and time-varying, constantly changing the availability of $f_j(t)$ and/or $g_j(t)$. For all the scenarios we consider three traffic intensities: low, moderate and high, with $\lambda = 0.1, 0.3, 0.7$ respectively [29], [30]. Each SC-RIS path of the NLOS case is monitored for 100 s. During the simulation, the cars move at a constant velocity of 10 m/s. The update interval (0.1 s) is chosen sufficiently small to avoid temporal undersampling of short blockage events, while keeping the simulation runtime manageable. A summary of the simulation parameters is provided in Table I.

B. Observations

First in Fig. 3 we observe the temporal availability of the individual SC-RIS paths in the sub-6 GHz spectrum. Here, each

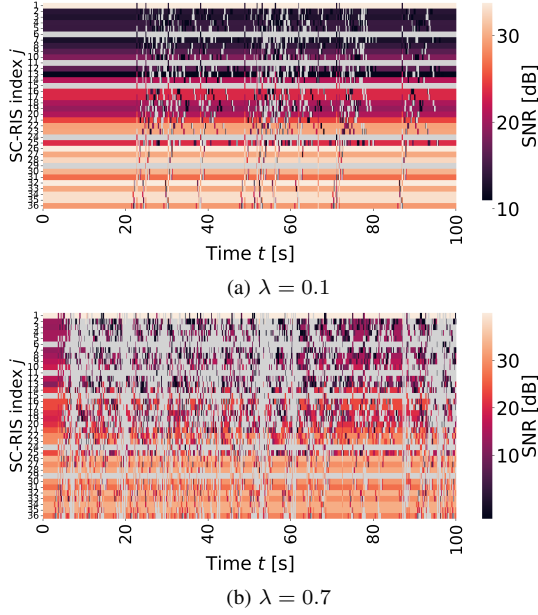


Figure 3. SNR for each SC-RIS path during 100 s for different traffic intensities: (a) $\lambda = 0.1$, and (b) $\lambda = 0.7$ at 3.5 GHz.

row represents one SC-RIS, and the corresponding SNR is plotted as a function of time. As observed, sometimes the path to the transmitter and/or receiver is not possible (e.g. SC-RIS 6) while other paths may be intermittently blocked (the gray regions in the plot) depending on vehicle positions. As traffic intensity increases, the blocked intervals become more frequent and longer. We compute ρ in terms of these path gains, and use $\rho_{th} = 0.6$ for removing highly correlated SC-RIS. For example, since SC-RIS 27 and 28 exhibit strong correlation, only the one providing the higher average SNR is retained.

C. Performance of the proposed heuristic

The results are presented for four main cases: the three configurations shown in Fig. 2 operating at sub-6 GHz, and the NLOS Manhattan grid scenario at the mmWave band. After highly correlated SC-RIS are removed from the set, the algorithm finds the minimum subset for which outage is below the threshold. In Fig. 4, the indices of the selected SC-RIS are shown for each traffic scenario across three cases: pure NLOS, the scenario in the Manhattan grid with direct LOS, and the NLOS case in the mmWave band (see Fig. 2a). As expected, as the traffic intensity increases, so does the number of required SC-RIS. More surfaces are required in the mmWave band, as beams are narrower, paths are more susceptible to blockages, and there is less scattering. In the

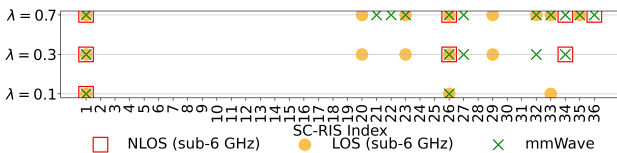


Figure 4. The minimized subset of SC-RIS that ensures an outage probability less than or equal to $\varepsilon = 0.01$.

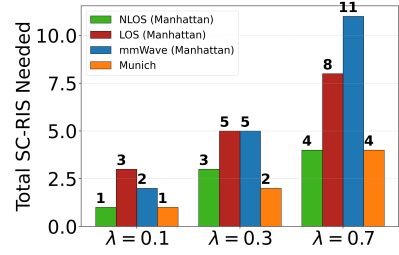


Figure 5. Total number of required SC-RIS to ensure an outage probability smaller or equal to $\varepsilon = 0.01$ in the Manhattan grid and Munich scenarios for three different traffic intensity levels.

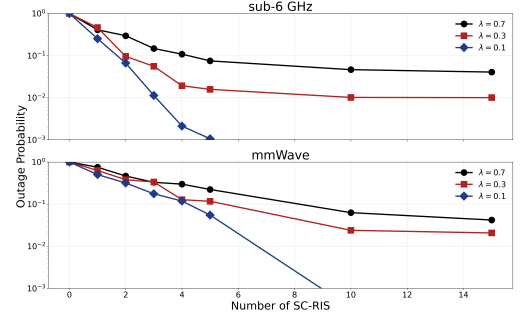


Figure 6. Outage probability (log scale) vs. number of SC-RIS for different traffic intensities; top: sub-6 GHz, bottom: mmWave.

LOS scenario, more SC-RIS are needed to satisfy the constraint. This is due to intermittent blockage from the cars, which causes strong channel fluctuations. As a result, the SC-RIS must both compensate for blocked LOS and coherently combine with it if available. In contrast, in the NLOS case, the SC-RIS provide the dominant and more stable paths. The same conclusion can be drawn from Fig. 5, where the total number of needed SC-RIS is shown. Overall, fewer SC-RIS are required in the Munich scene, since the transmitter is mounted on the roof of the building, making the transmitter–SC-RIS link largely immune to obstructions by the cars. For $\lambda = 0.1$, exhaustive search confirms that the greedy selection is optimal in the NLOS, mmWave and Munich cases, and needs one additional surface in the LOS one, while avoiding the combinatorial complexity.

The outage probability is shown in logarithmic scale as a function of the number of SC-RIS for the NLOS case of Fig. 2a, for sub-6 GHz (top) and mmWave (bottom). Specifically, for each SC-RIS count, outage performance is estimated by averaging over multiple Monte Carlo trials, where random different SC-RIS groups are selected. For example, for the two SC-RIS case, 20 random subsets are sampled from the 36 available candidates. It is evident that increasing the number of SC-RIS in the system improves the outage performance; however, the performance gain gradually saturates. The plots also show that, for the same number of deployed surfaces, sub-6 GHz achieves lower outage probabilities compared to mmWave, as discussed in Fig. 4.

VI. CONCLUSION

One of the main operational advantages of RIS is enabling communication under NLOS conditions. However, in large-

scale, multi-user, and dynamic environments, many current solutions remain impractical. In scenarios where channel variations are driven primarily by mobile obstacles, continuously tracking environmental changes with a fully adaptive RIS may introduce unnecessary cost and complexity. We argue that deploying multiple SC-RIS, whose inbound and outbound angles are configured once per communication interval and remain fixed throughout it, can provide a simpler and more cost-effective alternative. Accordingly, this work investigates the use of SC-RIS to mitigate communication outages caused by mobile obstacles. Using a low-complexity heuristic, we solve an optimization problem to determine the minimum subset of SC-RIS required for reliable connectivity. Results show that higher traffic intensity requires more, but gains are not linear; performance gradually saturates once enough surfaces are deployed. This analysis provides a starting point for understanding trade-offs between infrastructure deployment and reliability in practical, low-complexity networks. Future work will include evaluation in multi-user scenarios and validate the framework using end-to-end indoor deployments with mmWave and 5G technologies (e.g., srsRAN, software defined radio (SDR) platforms, and TMYTEK XRifle Reflectors).

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