# A Large Intelligent Surface Prototype for 5G and Beyond Wireless Communications

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5G and future generation wireless communications are expected to change our day-to-day lives by enabling the development of several applications including internet-of-things (IoT), portable virtual reality, self-driving cars, and remote medical operations. All these applications require high-connectivity and high-throughput communications to transmit and receive an enormous amount of data. Recently, 5G has been deployed in microwave frequencies (below 6 GHz), though in the upcoming years, the operating frequency is expected to increase in the millimeter-wave (mmWave) bands to leverage the available ample bandwidths enabling high throughputs. The existing sub-6 GHz 5G base stations offer broad coverage over large areas, thus much of the transmitted power is scattered leading to multi-path channels between the base station and the user. The quality of the wireless channels depends on the relative position of the user, the base station, and the surrounding environment (e.g. buildings, trees, moving vehicles, etc.). This uncontrolled multi-path propagation, deteriorates the achieved throughput, since, the received signals have arbitrary phases leading to destructive interference in the user's receiver. On the other hand, mmWave bands exhibit high propagation and scattering losses, thus base stations are expected to either offer multiple high-gain beams to carry out line-of-sight spatial-division-multiple access and/or the size of the cells will be reduced to ensure coverage. The latter option could lead to the deployment of thousands of base stations per $km^2$, especially in urban environments. For the first option, the excess losses of scattering through electrically-rough surfaces are expected to lead into shading and low coverage; thus, relays have been proposed that redirect (without scanning) the beams towards the shadowed areas offering better coverage and higher throughput.

Our goal is to use reconfigurable large intelligent surfaces (LISs) that estimate the relative position of the base station and the user and dynamically redirect the impinging waves toward the user. LISs can be deployed on external building walls and other surfaces acting as dynamically reconfigurable relays, leading to controlled multi-path propagation in the sub-6 GHz 5G (constructive interference) and/or eliminating shadowing in the mmWave 5G. As such, we have implemented a proof-of-concept sub-6 GHz LIS and evaluated the effect of controlled beam-steering on the improvement of the wireless channel. The LIS consists of 160 antenna elements, integrated with RF PIN diodes that are controlled by an Arduino microcontroller for agile beam-steering. The LIS features a simple reflect array topology with 1-bit PIN diode switches that can easily be scaled to multi-bit switching for mmWave frequencies. During the conference, the LIS design aspects and limitations will be presented alongside the theoretical background. Finally, we will present results of improved throughput exploiting LISs for 5G and beyond applications.