Affordable Rural Cellular Coverage for 5G and Beyond

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In urban areas, the network operators deploy small-cell sites and install many base stations to support densely populated cellular users. A similar small-cell deployment in rural areas is not feasible for the operators, as it will significantly increase the CapEx costs, and the return on the investment will also be comparatively lower. In developing countries like India, most of the population is in rural areas. To improve broadband connectivity in rural areas, the Government of India has initiated a significant optical fiber deployment.

A feasible solution to achieve last-mile rural connectivity is to install a base station at each of those optical drop-points and serve the neighbouring rural areas. This ensures an interconnection between the base stations and reduces the CapEx costs for the network operators. Even with such an optical fibre infrastructure in India, the minimum feasible inter-site distance is close to 12 Km.

However, the technology developed for IMT-advanced (4G-LTE) was evaluated for an inter-site distance of 1.732 Km, making the large-cell connectivity required for rural areas an afterthought. For cellular last-mile rural connectivity to be a reality through IMT-2020 (5G-NR), the key is to have future technologies supporting large cells. In large-cell sites, the users experience comparatively more path loss and have poor signal coverage.

Further, compared to the downlink, the transmission power in the uplink is limited, and therefore, uplink transmissions define the coverage of the communication system. Motivated by this, at our communications laboratory (A-621), we evaluated various coverage solutions for uplink, considering an extremely large-cell site scenario. We have proposed several enhancements related to the waveform, modulation and coding schemes, resource allocation, and power control mechanisms. We have shown that the proposed solutions achieve close to 2 times improvement in network capacity when compared to the currently available Release-15 5G systems.

5G-like Performance from the Existing 4G Deployments

Full Dimension-Multi Input Multi-Output (FD-MIMO) is a technology where a two-dimensional antenna array structure is used to beamform the data along with both elevation and azimuth directions. With this kind of beamforming, an enhanced multi-user MIMO transmission can be done at the base station to achieve a multi-fold enhancement in the network throughput. The 3GPP specifications for 5G support beamforming of all the physical layer channels in both the azimuth and elevation directions.

However, this is not the case in 4G systems, where only the data channel supports beamforming. Typically, the base station transmits the actual user-intended payload in the data channel. All the information required to decode this data is transmitted in a payload in the control channel. Hence, first, a user has to decode the control-payload, and only then it can decode the data payload.

Thus, even though the beamformed data channel has improved capacity, the control channel still has a limited capacity and has become a bottleneck in achieving larger network throughput. To address this issue, we have proposed a beamformed downlink control channel design for existing 4G deployments, which strictly adheres to the current 4G specifications, and yet achieves 5G-like system performance.

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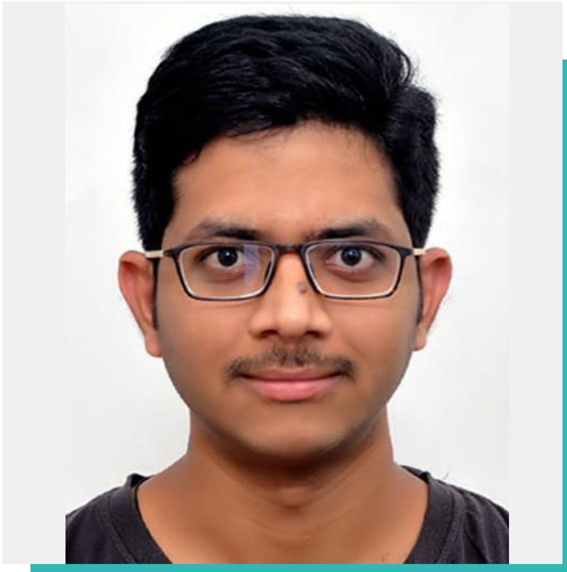
We have evaluated the proposed design using a system-level simulator and compared the performance against the existing algorithms. We have shown that the proposed design achieves significant improvement in the network capacity as compared to the state-of-the-art algorithms. Our proposed design has won the **"Best Paper Award Honourable Mention"** at the COMSNETS-2020 conference.



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