(SD2023-064) A programmable antenna arrays for 5G/6G networks: Flexible Directional Frequency Multiplexing for Multi-user Millimeter-wave Networks using Delay Phased Array

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ABSTRACT

Modern mmWave systems cannot scale to a large number of users because of the inflexibility in performing directional frequency multiplexing. All the frequency components in the mmWave signal are beamformed to one direction via pencil beams and cannot be streamed to other user directions.

Engineers from UC San Diego present mmFlexible, a flexible mmWave system that enables flexible directional frequency multiplexing, allowing different frequency components to radiate in multiple arbitrary directions with the same pencil beam.

OTHER INFORMATION

KEYWORDS

5G, millimeter-wave, beamforming, frequency multiplexing, delay-phased array, antenna, wireless, 6G, programmable antenna array

TECHNOLOGY DESCRIPTION

This technology makes two important contributions: 1. A novel 5G millimeter-wave (mmWave) front-end architecture called a delayphased array that uses a variable delay and variable phase element to create a desired frequency-direction response.

CATEGORIZED AS

  ▶ **Communications**
      ▶ **Wireless**

RELATED CASES

2021-Z08-1

2. A novel algorithm to estimate delay and phase values for the real-time operation of the delay-phased array. This front-end architecture creates an abstraction that allows any OFDMA scheduler to operate flexibly like sub-6 without any fixed direction constraints.

mmFlexible performs flexible directional frequency multiplexing by transmitting/receiving a sub-set of contiguous frequency resources to each user irrespective of their directions until all of the allocated resources are used (no spectrum wastage). Said differently, rather than transmitting all frequency components to one fixed direction, mmFlexible creates multiple concurrent pencil beams in different directions; Each beam carries a separate sub-set of frequency components for users in that beam direction, while other beams serve other directions with different frequency bands without compromising the beamforming gain in each direction. The set of frequency-direction pairs can be chosen arbitrarily, allowing flexibility in performing directional frequency multiplexing.

It allows packing the entire frequency band (up to 800 MHz for 5G NR and 2.3 GHz for IEEE 802.11ax bands) with data to serve multiple users concurrently, thus reducing spectrum wastage and providing low latency to access the network.

APPLICATIONS

ADVANTAGES

Evaluation with indoor and outdoor mmWave channel traces shows 1.3x throughput improvement over traditional phased array architecture and 3.9x improvement over true-time delay architecture; while providing a 72% reduction in worst-case latency.
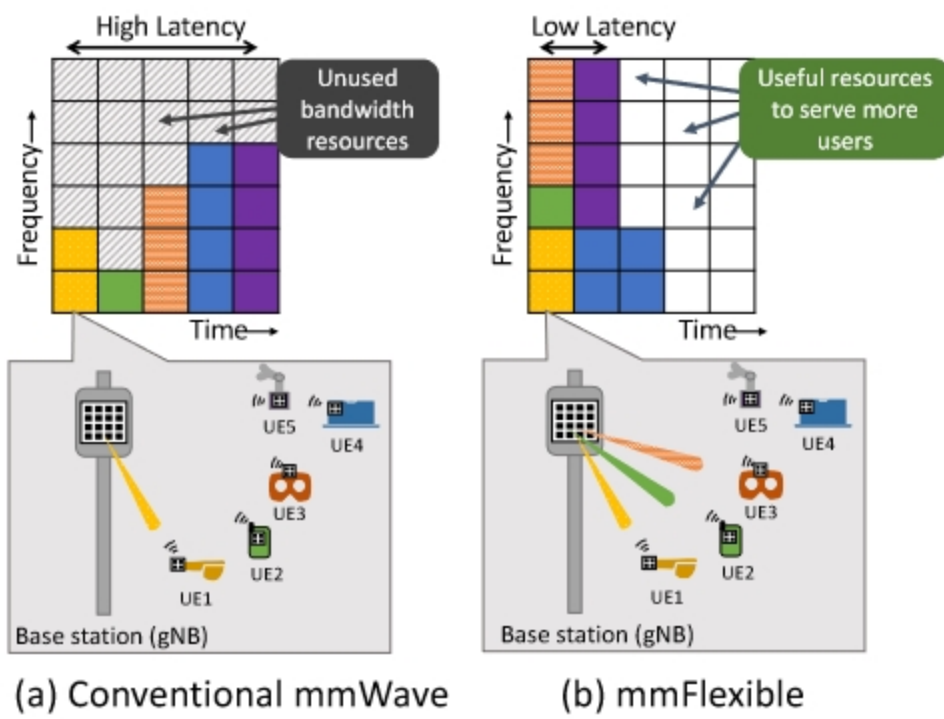
Fig. 1: mmFlexible enables efficient use of the available mmWave spectrum resources through flexible directional-frequency multiplexing, allowing multiple users to be served simultaneously with low latency and high spectrum utilization.

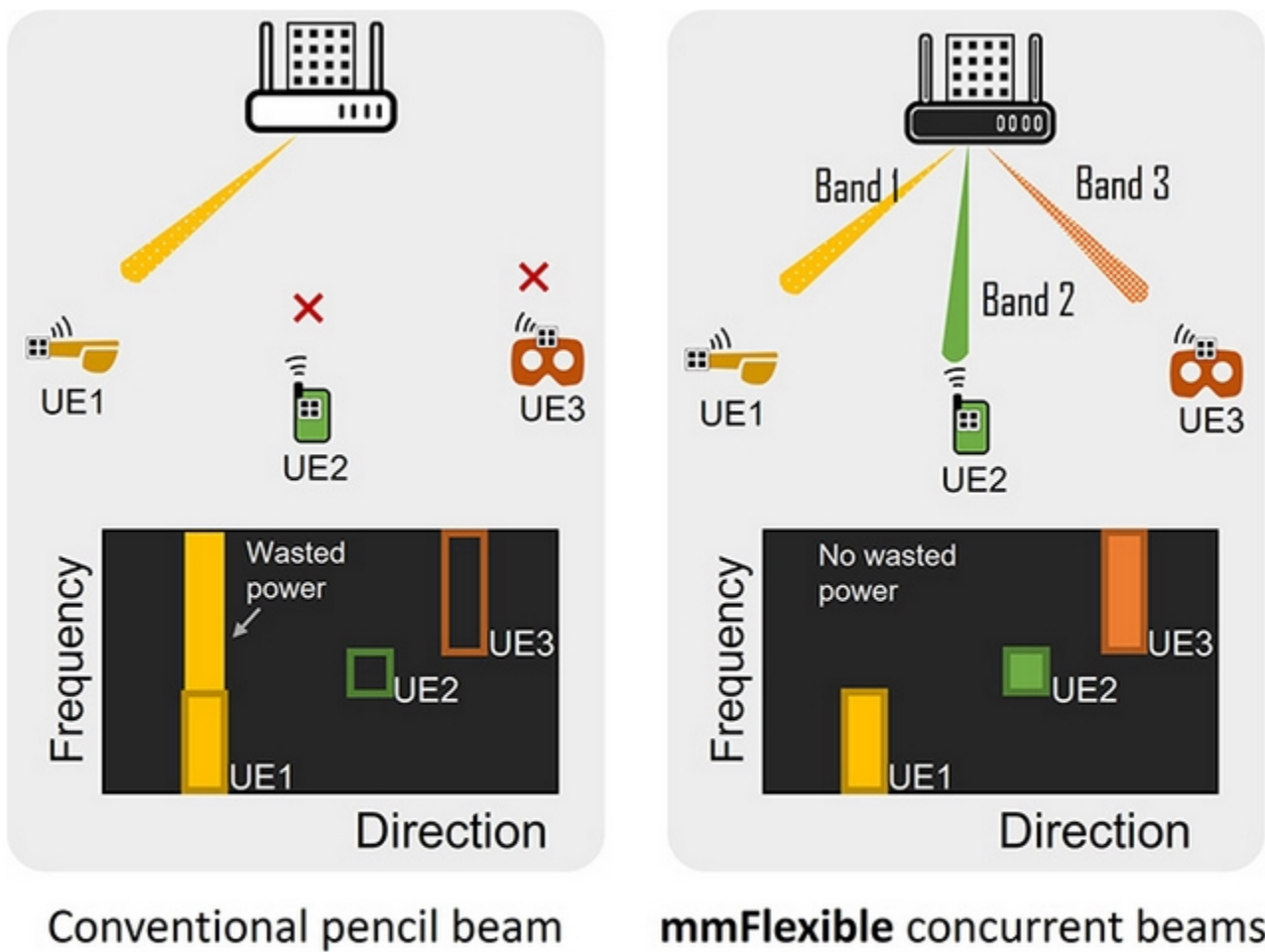Conventional pencil beam

mmFlexible concurrent beams

Diagram showing the difference in coverage attainable by a conventional base station (left) and the team's mmFlexible (right) prototype device and programmable delay-phased array. Conventional arrays can only deliver bandwidth in one direction at a time. mmFlexible splits a single frequency band into multiple "beams" of coverage, for greater range and delivery.

STATE OF DEVELOPMENT

INTELLECTUAL PROPERTY INFO

RELATED MATERIALS

▶ UC San Diego Researchers Present New Wireless System for Greater 5G Access - 05/17/2023

▶ Delay Phased Array: A programmable antenna arrays for 5G/6G networks (video and more), by Ish Kumar Jain, Rohith Reddy Vennam, Raghav Subbaraman, Dinesh Bharadia (UC San Diego) - 07/07/2022

▶ mmFlexible: Flexible Directional Frequency Multiplexing for Multi-user mmWave Networks.