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Breakout Discussion on HW-CSP Interface: Next Frontiers

Discussion Leaders: Subhanshu Gupta (Washington State U), Jeyanandh Paramesh (CMU), Greg Chance (Intel), Kate Remley (NIST).

This breakout will build on the insights from the previous workshops to identify new research frontiers at the interface of hardware (HW) design and communications and signal processing (CSP) techniques for realizing the potential of mmW technology for communication and sensing applications. Some of the important issues identified in the previous workshops include: hybrid analog-digital architectures for beamforming, novel data converter architectures for wideband signals, power amplifier efficiency, radar/imaging applications, and hardware design for secure commuincations.

Discussion Themes and Questions: The questions below are divided into five major themes (not limited):

a) <u>General Issues for 5G and Beyond</u>

1) What are the key issues at the HW-CSP interface that drive system design at the PHY layer? Specifically, techniques that drive HW-aware CSP design and CSP-aware HW design?
2) Network densification and spatial (beamspace) data multiplexing are critical mmW enablers for achieving orders-of-magnitude improvement in network throughput. What are key technical challenges at the HW-CSP interface for achieving such gains in spectral efficiency?
3) What are some persistent HW-CSP challenges that will continue beyond 5G?

b) <u>Beam management including localization, imaging and radar</u>

Digital beamforming offers the maximum flexibility at the cost of high power and complexity, analog beamforming offers low power consumption and complexity at the expense of limited operational flexibility. Hybrid beamforming enables promising intermediate configurations and opens a host of new questions:

1) What constraints limit the performance of hybrid (analog-digital) beamforming transceivers?
2) Results at 28 GHz and 73 GHz indicate noise-limited behavior with much reduced multipath issues. Highly directional beam allocation at the Base Station (BS) can mitigate much of the co-channel interference. However, network densification in urban pico-cells will result in increased interference between multiple BSs/cells. What HW-CSP design challenges are critical for beamspace interference management?
3) Automotive radar is an important application of mmW spectrum. How can radar/imaging be exploited for communication in mmW networks? (e.g., for reducing the beam management overhead by learning about the environment?)

c) Power Amplifier and Data-Converter Design:

1. Power amplifier efficiency is a critical challenge at mmW frequencies. What are some latest significant advances in this area?
2. Data-converter design is another challenging problem at mmW frequencies form the viewpoint of power efficiency. Any major recent advances?

d) <u>Role of machine-learning techniques in communication hardware</u>

1) Machine learning (ML) is attracting increasing interest in CSP techniques and at the CSP-NET interface. There is reason to believe that ML techniques could also be leveraged at HW-CSP interface? For example, the DARPA RF-MLS program focuses on the intersection of RF Signal Processing and Machine Learning. What research problems at the CSP-HW interface are ripe for leveraging ML techniques in mmW system design?
2) Can ML techniques be used for optimizing circuit design at the RF/mixed-signal level? How to establish performance bounds and metrics based design with ML techniques?

e) Physical-layer mmW Security

1) What are the key modes for exploiting physical-layer security at mmWave frequencies?
2) What is the role of HW-CSP design in realizing physical layer security?
3) Can hardware-based secure protocols be shown to be unconditionally secure in an information-theoretic sense?

f) Alternative MIMO and Beamforming Approaches

Alternative beamforming approaches may be predicated on less mature underlying technologies which in turn can spur component-level research. Are there other new approaches to beamforming beyond digital beamforming and phased-array based hybrid beamforming that are worth investigating? An example of this approach is the lens-based beamspace MIMO and its impact on energy-efficiency and wideband channels.