60-GHz Communications: Fundamental Limits and Practical Challenges

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Abstract

We address modeling and design of future communication systems leveraging 60-GHz technologies. Specifically, our focus is two-fold: 1) accurately characterize the fundamental limits of 60-GHz communications; 2) design and evaluate the performance of practical modulations and coding schemes with transmission and reception strategies that achieve or come close to the bounds identified in 1). A special emphasis will be on how to integrate the proposed solutions into existing microwave radio frequency (RF) communication systems and new emerging technologies such as light fidelity (Li-Fi) technologies.

Introduction

Advantages:

- Recently, 60-GHz communications has witnessed a tremendous revival due mainly to its abundant unlicensed spectrum availability.
- In US, for instance, a chunk of 7 GHz of spectrum (between 57 and 64 GHz) is available for free providing potential opportunities to overturn the spectrum crunch issue.
- According to the wireless gigabit alliance (WiGig), 60-GHz communications promise much higher rates (around Gigabit per second) than its microwave radio-frequency (RF) counterpart Wi-fi [1].
- In addition to its large bandwidth, millimeter wave (mmWave) in general and 60 GHZ particularly enjoy the property of locality allowing dense spatial frequency reuse, contrary to RF.

Those advantages make 60-GHz communications an excellent technology enabling multi-gigabits per second - applications such as uncompressed high definition television (HDTV), high-speed data transfer between devices, wireless gigabit Ethernet, and wireless gaming [2].

Challenges:

- Short range networks.
- Interference mitigations.
- Deafness due to high antenna directivity.
- Steerable beamforming.

While few aspects of the previous technical challenges have been addressed, in a form or another, there is a lack of of a thorough study that provides design guidelines for 60-GHz communication systems. .

Overview of Current Research

Existing work on mmWave may be split into three parts: a) channel modeling, b) performance limits derivation and c) practical schemes. Next, we summarize the on-going research related to each part.

Channel Modeling

- mmWave channels are generally characterized by their high path loss, sensitivity to propagation environments, vulnerability to geometry blockage in addition to their non-stationarity in time and space [3].
- Several channel models have been proposed in the literature e.g., [4, 5].

Performance Limits Derivation

- Due to the high antenna directivity in 60-GHZ communications, the LOS model is an important component to consider when deriving performance limits.
- Also, in raison of its small wavelength, future 60-GHz transceivers are more likely to be multi-antenna.
- The capacity of LOS MIMO channels has been studied by several authors, e.g., [6, 7].
- Another point of interest is to derive the maximum multiplexing gain in LOS environments, e.g., [8] .

Practical Schemes

- The small wavelengths in the millimeter wave regime has facilitated array architectures embedded into portable devices.
- Beamforming is one of the most appealing practical scheme for 60-GHz communications.
- A beamforming prototype for mmWave communications is presented in [9].
- Furthermore, in order to combat blockage due to human shadowing, several diversity techniques have been proposed

Main Goals

Our aim is to address the above shortcoming via a two-step process:

1. Establish fundamental limits of 60-GHz communications.
2. Propose interference mitigation techniques in sparse networks.
3. Drive practical schemes achieving those performance limits: Hybrid schemes that include new emerging technologies such as Li-Fi communications as relays, are of central interest to us.

Preliminary Results

Considering interference as noise, the SINR is given by:

$$\gamma = \frac{h_0\Omega_0}{\sigma^2 + \sum_{i=1}^{K} I_i h_i \Omega_i}.$$

The coverage probability is given by:

$$P_c(\beta) = \text{Prob}\left\{\gamma > \beta\right\}.$$

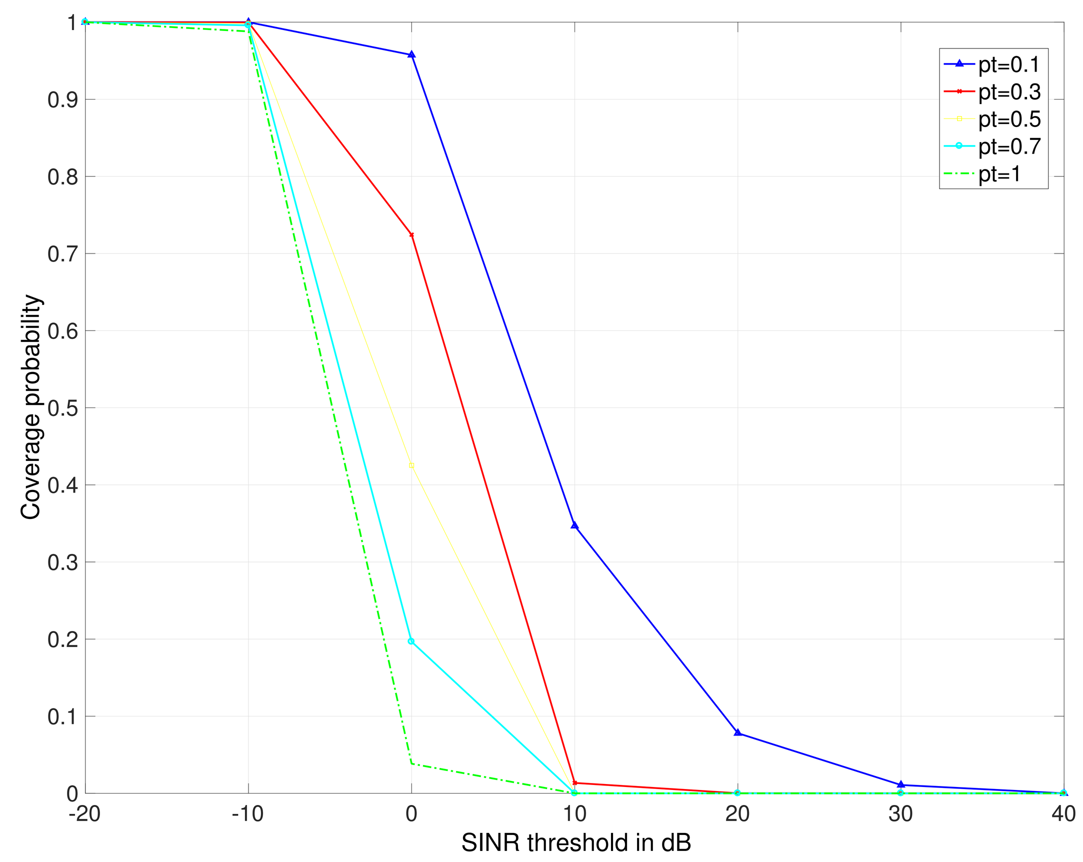

Figure 1: Figure caption

Conclusions

- Always considering interference as noise is suboptimal.
- Interference cancellation is more appealing.
- Future communication protocols are more likely to be based on multi RATs.
- Multimodal channel could be an appealing strategy to design future communication systems.

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