

**Analysis of Millimeter-Wave Multi-Hop Networks With Full-Duplex Buffered Relays**

**Abstract:**

The abundance of spectrum in the millimeter-wave (mm-wave) bands makes it an attractive alternative for future wireless communication systems. Such systems are expected to provide data transmission rates in the order of multi-gigabits per second in order to satisfy the ever-increasing demand for high rate data communication. Unfortunately, mm-wave radio is subject to severe path loss, which limits its usability for long-range outdoor communication. In this paper, we propose a multi-hop mm-wave wireless network for outdoor communication, where multiple full-duplex buffered relays are used to extend the communication range, while providing end-to-end performance guarantees to the traffic traversing the network. We provide a cumulative service process characterization for the mm-wave propagation channel with self-interference in terms of the moment generating function of its channel capacity. Then, we then use this characterization to compute probabilistic upper bounds on the overall network performance, i.e., total backlog and end-to-end delay. Furthermore, we study the effect of selfinterference on the network performance and propose an optimal power allocation scheme to mitigate its impact in order to enhance network performance. Finally, we investigate the relation between relay density and network performance under a sum power constraint. We show that increasing relay density may have adverse effects on network performance, unless the selfinterference can be kept sufficiently small.

**Existing System:**

To overcome larger distances or obstructed paths, especially in outdoor applications for high data rate transmissions, a strategically placed storeand- forward relay node may be used to form a multi-hop wireless network. Thus, it is our claim that multi-hop communications can be utilized to mitigate the effects of path loss over long distances and/or the effect of NLOS, while maintaining the traffic flows’ quality of service (QoS) requirements. In this case, an understanding of corresponding network performance in terms of end-

to-end delay and loss probability becomes the key to support real-time missions and critical applications, e.g., online banking, remote health, transportation systems operation and control, and electric power systems. Nevertheless, an analytical model for the multi-hop network in mm-wave bands does not exist, and its performance is not yet understood.

**Proposed System:**

We provide a probabilistic end-to-end delay and total backlog analysis of such networks in terms of the underlying channel parameters. This analysis can be used as a guideline for planning and operating QoS-driven multihop mm-wave network. The analysis of multi-hop wireless networks in mm-wave bands poses two main challenges: (i) the service process characterization for mm-wave fading channel, and (ii) multi-hop network performance analysis. The first challenge comes from the random nature of the mm-wave fading channel which results in time varying channel capacity, and the second challenge is a direct result of the limitations and strict assumptions of the traditional queuing theory, which is the main tool for network analysis, when applied to queuing networks. To address these two challenges, we adopt a moment generating function (MGF)-based stochastic network calculus approach for the analysis of networks of tandem queues. Then the service process, which is a function of the instantaneous channel capacity, is given in terms of the MGF of the fading channel distribution. This addresses the first challenge. Furthermore, we utilize network calculus to address the second challenge by using the service concatenation property.