Toward URLLC: A Full-Duplex Relay System with Self-Interference Utilization or Cancellation

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***Abstract*—Ultra-reliable and low-latency communication (URLLC) is one of the key use cases of the fifth generation (5G) wireless communications to facilitate specific application scenarios with stringent latency and reliability demands, such as industrial automation and Tactile Internet. A full-duplex (FD) relay with simultaneous transmission and reception in the same frequency band is an effective approach to enhance the reliability of cell-edge user terminals, by significantly suppressing self-interference (SI). However, the signal processing latency at FD relay due to SI cancellation, referred to as relaying latency, takes a significant part in the end-to-end latency, and therefore should be minimized, while guaranteeing high reliability. In this article, we first present an up-to-date overview of the end-to-end latency for an FD relay system, addressed on physical layer challenges. We investigate the possible solutions in the literature to achieve the goal of URLLC. The efficient solution is to allow a simple amplify-and-forward (AF) FD relay mode with low-complexity SI radio frequency and analog cancellations, and process the residual SI alongside the desired signal at base station in an adaptive manner, rather than being cancelled at relay in digital domain. Also, the residual SI can be utilized at base station to enhance the reliability and the degree of freedom in signal processing, not necessarily being cancelled as much as possible. The FD relay assisted system with adaptive SI utilization or cancellation enables extended network coverage, enhanced reliability and reduced latency, compared to the existing overview work.**

INTRODUCTION

LOW latency and high reliability have become two major challenges in the future wireless communication design. However, more and more emerging devices and applications request strict constraints of high reliability and low latency, such as industrial automation, Tactile Internet, virtual reality, Internet of vehicles, telemedicine and so on [1], as shown in Fig. 1. In the fifth generation (5G) cellular networks, ultra-reliable and low-latency communication (URLLC) is introduced to achieve reliability of 99.999 percent and latency of 1 ms. The future networks are expected to require even more stringent reliability and latency (e.g., below 1 ms).

It is very challenging to achieve such two ambitious targets for cell-edge user terminals that encounter wireless deep fading, dramatically reducing the link reliability. The application of a relay [2], as an efficient way to mitigate wireless fading, can be utilized to guarantee high reliability of a communication link highly separated by a cell-edge user and base station. However, the latency is very high for a traditional half-duplex (HD) relay system, as two time slots are required to complete a single data transmission. The source transmits data to an HD relay in the first time slot, and the HD relay forwards them to destination in the second time slot. Meanwhile, the source is not allowed to transmit data in the second time slot. Thus, the latency of the HD relay system is twice, as much as possible, that of direct transmissions with no relay and no retransmission during data transmission completion. In order to reduce the latency, a full-duplex (FD) relay, equipped with transmit antennas and receive antennas, has been widely studied in the literature, to enable simultaneous transmission and reception in the same frequency band, with theoretically doubled throughput [3]. The source and relay can successively transmit data in consecutive time slots. Thus, the FD relay system is a promising solution to provide latency lower than the HD relay system, and close to direct transmissions with no relay and no retransmission. In the literature, there is only one overview work for an HD relay-enabled URLLC system in the finite blocklength regime [2]. So far, there has been no overview work for an FD relay system from the URLLC perspective.

In an FD relay system, the reliability is limited by self-interference (SI) due to the signal leakage from transmit antennas to receive antennas at relay, seriously affecting bit error rate (BER) performance [4]. Recent breakthroughs reveal up to 120 dB SI cancellation capability [5], and facilitate the real application of FD communications at relay rather than at base station. The SI suppression is as low as approximately -97 dBm at relay with transmission power of 23 dBm, and -74 dBm at base station with transmission power of 46 dBm. The significant SI suppression at FD relay can be as low as the noise power level of -90 dBm. To guarantee high reliability, traditional works [3-6] require the FD relay to work in the decode-and-forward (DF) mode with a number of SI cancellation processes, such as radio frequency (RF) cancellation, analog cancellation and digital cancellation. However, the SI cancellation increases processing latency, referred to as relaying latency, which should be maintained at a low level as much as possible, without compromising reliability in terms of SI cancellation capability, to achieve URLLC.

To the best of the authors' knowledge, this is the first work to present an insightful investigation of reliability and latency together for an FD relay assisted URLLC system. We provide an overview of the end-to-end latency, where the relaying latency plays a significant part. This has not been presented in the existing overview works [2, 5, 7]. We discuss possible relaying latency reduction solutions. An efficient solution is to

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