IRSA-NOMA with Power Diversity-Based Priority for 6G

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Abstract

In this letter, a novel power diversity-based priority (PDP) scheme is introduced in non-orthogonal multiple access with irregular repetition slotted ALOHA (IRSA-NOMA), referred to as PDP-IRSA-NOMA, for different groups of devices in 6G ultra-massive machine-type communications (umMTC). Compared to conventional IRSA-NOMA with random power levels, the PDP scheme controls higher power levels for a higher priority group. The performance evaluations show that PDP-IRSA-NOMA can outperform conventional IRSA-NOMA with higher normalized throughput, lower error floor in packet loss rate (PLR), and higher normalized efficiency.

Ⅰ. Introduction

Random access (RA) is one of important factors in} wireless connectivity for ultra-massive machine-type communications (umMTC) [1]. RA is chosen because scheduling access to massive connectivity is challenging, and packet collisions are crucial to improving RA performance. In [2], contention resolution slotted ALOHA (CRDSA) proposed how to handle packet collisions relies on successive interference cancellation (SIC) and packet diversity (packet replica). Furthermore, CRDSA was improved by irregular repetition slotted ALOHA (IRSA) where a probability mass function is used to specify the packet diversity [3].

Multiple users exploit the same resource in non-orthogonal multiple access (NOMA), where multiple users are differentiated with power and successive interference cancellation (SIC) is performed in the receiver [4]. Generally, coordination with established channel state information is required to assign powers to multiple users. For this cause, NOMA is not sufficient for RA schemes that lack coordination [4]. But, the RA schemes can also take advantage of NOMA by exploiting different power levels for each replica in RA schemes [5]. A discrete transmit power diversity was introduced to enhance CRDSA, where a random power level is selected to transmit each packet replica [6]. Also, NOMA-based IRSA (IRSA-NOMA) was proposed by applying discrete power diversity [7].

In umMTC, different types of devices transmit bursty packets via a shared communication medium [8]. Prioritized access to the shared medium is needed for important information such as safety-related devices over regular information. Furthermore, coordinating all devices before each transmission is impractical. Therefore, prioritized RA protocol is required [8]. Some works introduced priority scheme for RA, i.e., access priority [9] and degree distributions priority [10]. In the literature, no priority scheme has been considered in NOMA-based RA related to power diversity.

In this letter, an IRSA-NOMA scheme using power diversity-based priority (PDP) is introduced by exploiting power access controller before transmission, referred to as PDP-IRSA-NOMA. In PDP-IRSA-NOMA, a different group of devices in umMTC are considered. The priority scheme allows higher power levels for higher priority groups and the same power level for devices in the same group.

Ⅱ. System Model

An umMTC with a single-cell uplink wireless communication system is considered, where a massive number (M) of devices transmit packets to a base station (BS) via shared medium access control (MAC). Each device can retain the TDMA slot synchronization after registering with the system. All devices transmit their packets to the slot with the same length and re-transmission is not taken into consideration. One frame is made up of N slots and the offered traffic load G is specified by $\frac{M}{N}$ [devices/slot].

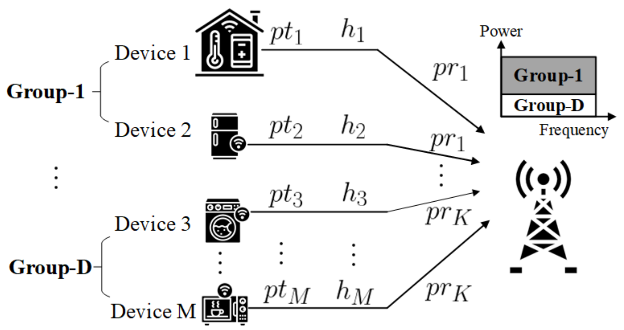

Fig.1. IRSA-NOMA with PDP in umMTC

In IRSA-NOMA scheme, replicas from one packet are transmitted with random power levels. The power level is chosen randomly according to uniform distributions. While the selected slot is chosen randomly according to a probability mass function: $\{\Lambda_l\}$, where Λ_l reflects the probability of l replicas are transmitted. The information of all replicas is known by the BS, i.e, a pointer to show the slot locations of all replicas in a frame. With this information, SIC can be performed to remove the interference in a slot with packet collisions. Different from conventional IRSA, IRSA-NOMA takes benefit from NOMA scheme to perform successful decoding for collided packets in one slot because of power differentiation.

This letter considers D different groups of devices, which are referred to as group-D devices. The group depends on access delay and the number of devices in each group. For example $D = 2$, two different devices consist of group group-1 and group-2 are considered. The system model of PDP-IRSA-NOMA is shown in Fig.1, where M devices, D groups, and K power levels are considered. And with D growing, the K levels in NOMA is from high to low.

Ⅲ. Simulation Result

This section presents normalized throughput with the simulation condition is defined as follows: the slots (N) number is 50, the iteration number of IC (N_{iter}) in the frame is 50, and the M 5-500. The duration of each simulation is 20 frames, with 10,000 simulation runs on average. Fig.2 displays throughput result for the proposed PDP-IRSA-NOMA compared to IRSA and IRSA-NOMA schemes. It can be shown that PDP-IRSA-NOMA demonstrates better throughput for all \$G\$ conditions. Compared with IRSA-NOMA, the throughput of PDP-IRSA-NOMA with low priority is decreased whereas throughput with high priority performs well under high traffic load.

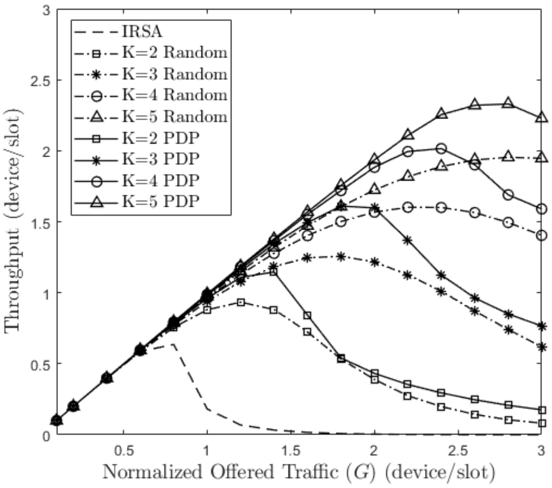

Fig.2. The normalized throughput

IV. Conclusion

In this letter, the power diversity-based priority IRSA-NOMA scheme is proposed to maximize the performance of conventional IRSA-NOMA in a high traffic load system. It is shown that, compared to IRSA and IRSA-NOMA in particular for multipacket messages, the proposed PDP-IRSA-NOMA can improve both reliability and channel efficiency. An interesting future direction is to consider an approximation for PLR using density evolution (DE) recursion to improve the error floor.

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