Double-Priority Access in NOMA-Based IRSA for Future Massive IoT

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Abstract

This paper proposes a double-priority access non-orthogonal multiple access (NOMA)-based irregular repetition slotted ALOHA (IRSA) (DPA-IRSA-NOMA) for future massive Internet of Things (IoT). In DPA-IRSA-NOMA, two groups of massive machine-type communication devices (MTDs) are considered, i.e., emergency devices (EDs) and regular devices (RDs), and the performance of the EDs is prioritized. Each MTD in the group estimates the traffic of the IoT network via traffic load estimation and adopts an adaptive traffic load (ATL) scheme to send packets. The access probability of EDs is higher than that of RDs with a higher critical traffic load, and it is demonstrated that by appropriately employing two priority access probabilities, the packet error performance and throughput are enhanced. The packet loss rate and normalized throughput are presented to demonstrate the superiority of DPA-IRSA-NOMA over the single-priority ATL (PATL-IRSA-NOMA).

Ⅰ. Introduction

A random access (RA) protocol with non-orthogonal multiple access (NOMA) was developed for improving the performance of slotted ALOHA (SA) [1]. In addition, the NOMA-based SA was improved by exploiting packet repetition on the transmitter side and successive interference cancellation (SIC) on the receiver side in a medium access control (MAC) frame, which is referred to as a NOMA-based irregular repetition SA (IRSA-NOMA) [2]. Moreover, a challenge remains in IRSA-NOMA when the network condition is overloaded (the ratio of users accessing slots in one MAC frame exceeds the critical load), which reduces the throughput after the traffic load exceeds the critical level. One solution to this problem is an adaptive traffic load (ATL) scheme with traffic load estimation (TLE) on the transmitter side. Furthermore, the exploitation of ATL and TLE in IRSA-NOMA to prioritize emergency devices (EDs) was proposed for 6G enabled massive Internet of Things (IoT) and is referred to as priority ATL in IRSA-NOMA (PATL-IRSA-NOMA) [3].

In PATL-IRSA-NOMA [3], EDs and regular devices (RDs) are considered with priority constraints, where only RDs adopt the ATL and TLE to prioritize the ED performance. In addition, the performance of the EDs is degraded owing to collisions when the number of devices in the ED exceeds the critical load of the ED. Motivated by the throughput improvement of EDs in PATL-IRSA-NOMA, this paper proposes double-priority access (DPA) in IRSA-NOMA (DPA-IRSA-NOMA) for future massive IoT. In DPA-IRSA-NOMA, both EDs and RDs perform TLE and then set an access probability using the ATL scheme. The probability of EDs is higher than the probability of RDs with a higher critical traffic load threshold. Numerical results confirmed that appropriately employing two priority access probabilities improved the packet loss rate (PLR) and normalized throughput.

Ⅱ. System Model

A 6G massive IoT communication is considered, where a base station (BS) serves D IoT massive machine-type communication devices (MTDs), as shown in Fig.1. The MTDs are categorized as EDs or RDs. The reciprocity of the uplink and downlink is exploited using preamble detection in a MAC frame for synchronization and channel state information (CSI) [4], and each MTD estimates the channel coefficient h and expects the predetermined received power to further allocate the transmit power pt for packet transmissions.

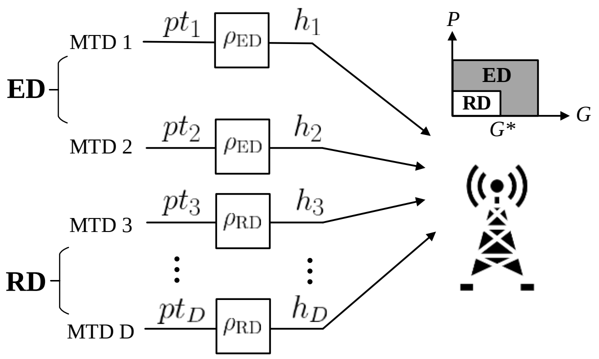

Fig.1. 6G massive IoT network using DPA-IRSA-NOMA protocol.

In many RA schemes, a normalized offered traffic load, which is defined as $G = \frac{D}{N}$ (MTDs/slot), is introduced to perform a fair comparison of a newly proposed RA protocol with other RA protocols. The numbers of MTDs in the ED and RD are denoted as αD and $(1-\alpha)D$, respectively, and the offered traffic is denoted as $G_{\text{ED}} = \alpha G$ and $G_{\text{RD}} = (1-\alpha)G$, respectively. Furthermore, the G of DPA-IRSA-NOMA is defined as $G = G_{\text{ED}} + G_{\text{RD}}$.

This paper considers PATL-IRSA-NOMA [3] and propose DPA to improve the throughput of EDs. In contrast to PATL [3], which is only performed by RDs, the DPA in this study is performed by both EDs and RDs using different access probabilities with different critical load G^*. In DPA, ATL is performed to control the number of MTDs in the ED that access one MAC frame with an access probability of

$$p_{\text{ED}} = \begin{cases} 1 & \text{for } G_{\text{TLE}} \le G_{\text{ED}} \\ \frac{G^*_{\text{ED}}}{G_{\text{TEE}}} & \text{for } G_{\text{TLE}} > G_{\text{ED}}, \end{cases} \quad (1)$$

where p_{ED} represents the access probability of an ED, G^*_{ED} represents the critical G of the ED, and G_{TLE} represents the estimated G from TLE. For an RD, the access probability [3] is defined with respect to the critical G of the RD (G^*_{RD}) and the ratio of EDs in DPA-IRSA-NOMA (α), as follows:

$$p_{\text{RD}} = \begin{cases} 1 & \text{for } G_{\text{TLE}} \le G_{\text{RD}} \\ \frac{G^*_{\text{RD}}}{G_{\text{TLE}}} - \alpha & \text{for } G_{\text{TLE}} > G_{\text{RD}}. \end{cases} \quad (2)$$

Ⅲ. Simulation Result

This section presents the PLR and normalized throughput (T) results used to validate the DE analysis. The design of the repetition in IRSA-NOMA with $L = 1,2,\ldots,5$, as shown in Table 1. Each simulation consisted of 1000 frames and 10000 trials.

Table 1. IRSA-NOMA distributions.

L	$\Lambda_r(x)$	G^*
1	$0.5112x^2 + 0.266x^3 + 0.2228x^8$	0.92
2	$0.6607x^2 + 0.1605x^3 + 0.1788x^8$	1.43
3	$0.7439x^2 + 0.0906x^3 + 0.0156x^4 + 0.1499x^8$	1.78
4	$0.7947x^2 + 0.047x^3 + 0.1583x^8$	2.32
5	$0.837x^2 + 0.163x^8$	2.61

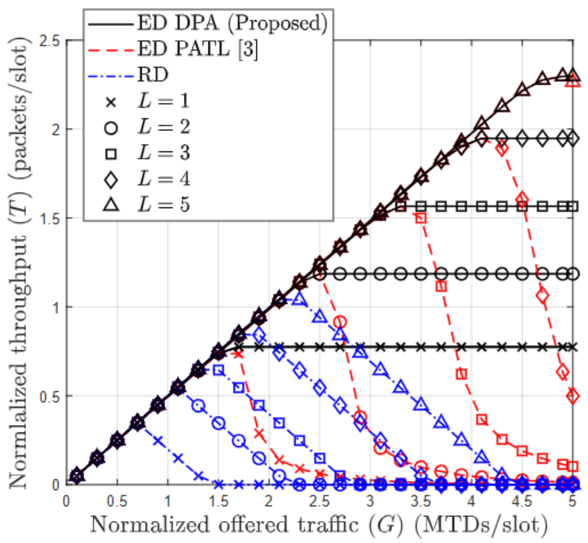

Fig.2. Throughput Result

The T results for the EDs and RDs with respect to L (Table 1) were examined, as shown in Fig.2, and the DPA was compared to the PATL in IRSA-NOMA. The simulation parameters were $\alpha = 0.5$, $N = 1000$, and G^*_{RD}, as shown in Table 1. The power level (L) and T_{ED} increased. Furthermore, the DPA controlled T_{ED} at $G > G^*_{\text{RD}}$, and it outperformed the PATL scheme [3].

Ⅳ. Conclusion

A DPA-IRSA-NOMA scheme is proposed to improve the performance of EDs in PATL-IRSA-NOMA for overload 6G massive IoT. The DE was analyzed to validate the PLR and normalized throughput performance. The numerical results confirmed that DPA outperformed the PATL scheme [3] with different settings of the power level L in IRSA-NOMA and the MTD ratio of the groups α. In the future, an investigation of multiple priorities and further improvement of IRSA-NOMA using coded slotted ALOHA [5] will be performed to improve the throughput for overload future massive IoT.

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