Priority Access Controls in NOMA-Based Slotted ALOHA for 6G IoT Medium Access Controls

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Abstract

In this paper, novel medium access control (MAC) relies on priority access control (PAC), uplink non-orthogonal multiple access (NOMA), and slotted ALOHA (SA) (PACSA–NOMA) is proposed to solve dropped throughput performance at overload traffic condition for 6G internet of things (IoT). The main idea is to reduce collisions by controlling the number of devices at overload traffic for stable throughput performance. To evaluate the performance of PACSA–NOMA, density evolution is derived for packet loss rate in an asymptotic regime. Finally, numerical results validate PACSA–NOMA substantially increases the energy efficiency of the conventional RAs.

I. Introduction

In massive internet of things (mIoT) applications, due to low-cost and low-complexity devices which are deployed, slotted ALOHA (SA) is exploited for RA protocol (i.e. LoRa, LTE-M, and NB-IoT) where energy consumption is the critical issue [1]. Non-orthogonal multiple access-based random access (NOMA–RA) with multichannel ALOHA (NMALOHA) was proposed by applying power division multiple access (PDMA) to slotted ALOHA (SA) and expected as one of the candidates for massive machine-type communications (mMTC) [2]. Furthermore, contention resolution diversity SA with transmit power diversity (CRDSA–NOMA) [3] was proposed to improve the throughput of NOM–ALOHA.

However, existing NOM–RA are mostly based on NOMA and a challenge remains in NOMA–RAs at critical traffic loads or overload condition, e.g., ratio of the number of devices and slots is above the maximum traffic load. The throughput of the RA is decreased due to a large number of collisions and it is not feasible for mIoT due to wasted power consumption of RAs. To solve this problem, this paper proposes a way to stabilize the performance of joint NOMA and diversity SA at overload traffic loads by dynamically controlling the number of the devices according to an priority access control, referred to as priority access control (PAC) in joint NOMA and diversity SA (PACSA–NOMA). The contributions mainly consist of two aspects. First, a novel random access is proposed which relies on the combination of PAC, NOMA, and diversity SA (DSA), where OC controls the number of devices accessing the NOMA–DSA channel at overload traffic loads to reduce the collisions in mIoT network. Second, a density evolution (DE) analysis is derived, which is used to express the packet loss rate (PLR) and average throughput of the PACSA–NOMA.

II. System Model

This paper considers a 6G IoT network where D machine-type communication devices (MTDs) transmit packets to randomly selected slots following joint NOMA and SA protocol. Each device selects a slot from N total slots in one MAC frame for transmissions.

Fig.1. System model of PACSA–NOMA

Fig.1 shows a system model of mIoT with two groups, emergency device (ED) and regular device (RD), where the received signal at specific time slot in BS is defined as

\[ y_n = \sum_{m=1}^{M} h_m \sqrt{p \epsilon_m} s_{d,n} + w_n \]

where \( 1 \leq n \leq N \) denotes slot, \( d \) denotes MTD, \( h_d \) denotes channel coefficient of device \( d \), \( p \epsilon_m \) denotes transmit power of device \( d \), \( s_{d,n} \) denotes a signal of replica from device \( d \) that transmitted at slot \( n \), and \( w_n \) denotes additive white gaussian noise (AWGN) with \( w_n \sim N(0,\sigma) \). Furthermore, as shown in [4], to show the fair comparison of a new proposed RA to others RAs, the normalized offered traffic load is introduced and defined as \( G = \frac{\rho}{\pi} \) (devices/slot).
III. Simulation Result

This paper investigates high traffic load in RA or $G > G^*$, where the ratio of devices and slots or normalized offered traffic load $G = \frac{D}{N}$ (devices/slot) is the most critical variable. The target SINR is 3 dB, noise figure 1 dB, the number of MAC frame is 1000 frames, the number of SIC iteration is 10,000, and 10,000 simulation runs on average. The asymptotic analytical and simulated results are presented to evaluate the asymptotic performance of the PACSA-NOMA (denoted as Prop.) as shown in Fig.2. For performance comparison, NOMA SA [2] and NOMA SA with priority adaptive traffic load (PATL-NOMA SA) [5] are presented.

![Fig.2. The PLR](image)

Fig.2 compares PLR of asymptotic and simulated with finite number of slots $N = 200$ using 5 power level in NOMA and $G^* = 2.1$. The PLR waterfall of asymptotic with SIC iterations 300 is $G^* = 1.5$ while the Prop. restricts the growth of PLR and stable at value $10^{-2}$. It is shown that as $N$ increases, the simulated results quickly approach the asymptotic PLR.

![Fig.3. The normalized throughput](image)

Fig.3. The normalized throughput

Next, with the same setting, Fig.3 shows the throughput of asymptotic and simulated results, as $G$ grows until $G = G^*$, the throughput is perform well same as NOMA-CRDSA without PAC. While $G > G^*$, PAC stabilizes the throughput around 2.1 packets/slot and with the increase of $N$, the simulated throughput gradually approach the asymptotic approach.

IV. Conclusion

PACSA-NOMA is proposed to solve the overload traffic loads in 6G IoT and stabilize the throughput performance by dynamically controlling the number of devices accessing the RA channel according to the estimated traffic load. The asymptotic PLR of the PACSA-NOMA has been derived by using DE analysis. Both theoretical asymptotic and simulation results show that PACSA-NOMA outperforms conventional RAs in terms of PLR and normalized throughput. The proposed PACSA-NOMA can be useful for the MAC layer in massive IoT applications with lower energy consumption and stable throughput performance even the networks in an overload condition.

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References


