MURRA: Multi-UAV-Assisted RIS-Aided Random Access

Nadhira Azizah Suwanda, I Nyoman Apraz Ramatryana, *Soo Young Shin
Department of IT Convergence Engineering, Kumoh National Institute of Technology
nadhirasuwanda@kumoh.ac.kr, ramatryana@kumoh.ac.kr, *wdragon@kumoh.ac.kr

Abstract

In this paper, multiple unmanned aerial vehicles (UAV) with reconfigurable intelligent surfaces (RIS) is exploited for random access (RA) of massive internet of things (IoT) networks in 6G ultra-massive machine-type communications (umMTC), referred to as multi-UAV-assisted RIS-aided RA (MURRA). In the proposed MURRA, Q-number of UAV with RIS (UAV-RIS) and M-number of user are considered, where decided before transmission with different preambles and two phases of medium access control (MAC). Specifically, UAV-RIS is reflected information via fixed-slots with scheduling. MURRA outperforms the conventional networks in terms of normalized throughput and normalized channel efficiency.

Ⅰ. Introduction

Ultra-massive machine-type communications (umMTC) and enhanced ultra-reliable low-latency communication (eURLLC) are the key enabler of 6G wireless networks to support massive internet-of-things (IoT) applications, where umMTC requires massive connectivity and eURLLC needs reliability with low data latency [1]. To support these requirements, random access (RA) is chosen to replace scheduling access for massive connectivity. The first attempt to reach RA was slotted ALOHA (SA) [2]. Although several RA have proposed to enhance the throughput of SA; i.e., contention resolution diversity slotted ALOHA (CRDSA) [3] and irregular repetition slotted ALOHA (IRSA) [4]. These existing RA systems utilize successive interference cancellation (SIC) and packet replicas for the throughput improvement [4].

However, two challenges remain for the existing RA systems. First, when the offered traffic in the existing RA systems increases, the throughput is no longer raised but automatically decreased or dropped [3]. Second, lower capability efficiency of the existing RA systems is achieved; that is, since the amount of replicas is increased, they need higher transmission power compared with SA to increase the probability of successful decoding [4].

In this paper, a novel RA in overload wireless networks to solve dropped throughput performance for massive internet of things (IoT) networks is proposed exploiting multiple unmanned aerial vehicles (UAV) with reconfigurable intelligent surfaces (RIS), referred to as multi-UAV-assisted RIS-aided RA (MURRA). In SA-based scheme, UAV with RIS and active users are decided at the beginning of medium access control (MAC). UAV with RIS are exploited as coding gain, where packet data from nearest active users are reflected by RIS to destination.

Ⅱ. System Model

The MURRA provides massive access to a large number of users using uncoded SA access system for packet data transmissions. Packet data is transmitted to a single base station (BS) by M users (denoted as $U_m = \{u_1, u_2, \dots, u_M\}$) with one antenna at the transmitter and receiver via one MAC frame. One frame MAC divided into two sub-MAC frames, MAC phase-1 and MAC phase-2. Fig.1 show MURRA structure with Q UAV-RIS (UR) (denoted as $P_q = \{p_1, p_2, \dots, p_Q\}$) and M users, where solid lines represent the connection between two nodes in first phase of MAC and dashed lines represent the connection of UAV-RIS to the BS in second phase of MAC.

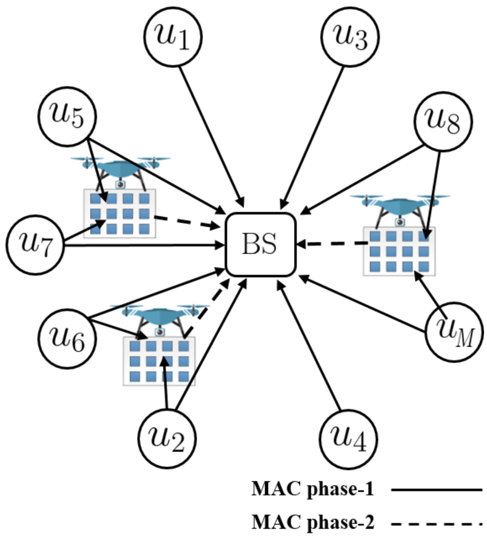

Fig.1. Block Diagram of UAV-assisted RIS-aided random access

In this paper, perfect preamble detection is assumed for the synchronization. Similar to existing SA, the BS know both large-scale fading and small scale fading coefficient hence fading is not considered in this letter. Both UN and UR transmit same length of packets to the slot in one frame without re-transmission. Due to slot synchronization, packets from different users either collide or not at all. Therefore, a single slot may contain collided packets. A singleton and a clean packet denote a slot and a packet in a slot without collision, respectively.

Three connection is considered, U-BS connection, U-UR, and UR-BS. In MURRA, UR is decided before transmission with preamble approach [5], where β is percentage users from M that are connected to each UR and Q is total UR in the network. The total slot in one frame MAC is denoted as $N = N_D + N_P$, where $N_D = N(1-\beta Q)$, $N_P = Q\beta N$, and $0 < Q\beta < 1$. Furthermore, the activation of UR is controlled by $\alpha = Q\beta$, where $\alpha = 0$ denotes no UR in the network and $\alpha = 1$ no U-BS connection in the network. With this condition, MURRA has capability to adapt the design of RA according to varying number of UN and available UR. The offered traffic of MURRA also calculated as $G = \frac{M}{N}$.

Ⅲ. Numerical Result

The performances evaluation in this section consist of normalized throughput and normalized efficiency. The SA are verified by utilizing more practical models, including burst carrier processes, magnitude differences, power transmit, and AWGN noise. The ratio between total number of users (M) and total number of slots (N) is the most critical variables. The offered traffic $M/N > 1$ denotes overload network is targeted in this paper. Therefore, the simulation conditions is defined as follows: the slots (N) number is 1000 and the UN 100-5000. The amount of UN is not explicitly listed in [3][4], which is why we have traced the required value. This can be treated as a fair benefit as the proposed MURRA is an important alternative for overload network ($M > N$). The duration of each simulation is 1,000 frames, with over 10,000 simulation runs on average.

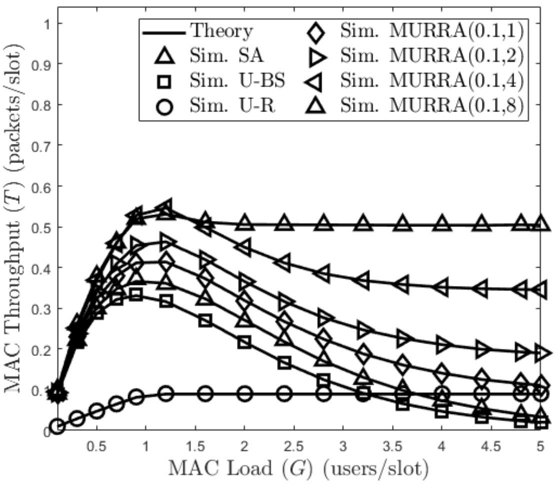

Fig.2. Throughput result of MURRA with $\beta = 0.1$

Fig.2 displays normalized throughput for MURRA denoted as prov., and SA scheme denoted as conv. SA. It can be shown that MURRA demonstrates the non-dropped throughput for $G > 1$. The MURRA($Q > 5$) can obtain improved performance with a critical point higher than conventional SA and stable throughput for $G > 1$. The greater essential factor allows it easy and effective to monitor loads in wireless networks. This also serves to maintain channel power reliability as traffic loads escalate quickly.

IV. Conclusion

The MURRA is proposed in this paper to guarantee non-dropping throughput of active users with the help of UAV-aided RIS and to maximize the performance of conventional SA in a high traffic load system. We have shown that, relative to SA in particular for multipacket messages, the proposed MURRA can increase the reliability and keep the throughput high. The MURRA is better than SA in NB-IoT, indicating that these results are a potential for future wireless access to support massive IoT applications. An interesting future direction is to consider an approximation for PLR using density evolution (DE) recursion to investigate the error floor.

ACKNOWLEDGMENT

This research was supported by the Grand Information Technology Research Center Program through the Institute of Information & Communications Technology and Planning & Evaluation (IITP) funded by the Ministry of Science and ICT (MSIT), Korea (IITP-2020-2020-0-01612)

References

[1] Z. Zhang, Y. Xiao, Z. Ma, M. Xiao, Z. Ding, X. Lei, G. K. Karagiannidis, P. Fan, 6G wireless networks: Vision, requirements, architecture, and key technologies, IEEE Vehicular Technology Magazine 14 (3) (2019) 28-41.

[2] N. Abramson, The throughput of packet broadcasting channels, IEEE Transactions on Communications 25 (1) (1977) 117-128.

[3] E. Casini, R. De Gaudenzi, O. Del Rio Herrero, Contention resolution diversity slotted ALOHA (CRDSA): An enhanced random access scheme for satellite access packet networks, IEEE Transactions on Wireless Communications 6 (4) (2007) 1408-1419.

[4] G. Liva, Graph-based analysis and optimization of contention resolution diversity slotted ALOHA, IEEE Transactions on Communications 59 (2) (2011) 477-487.

[5] J. Choi, Random access with layered preambles based on NOMA for two different types of devices in MTC, IEEE Transactions on Wireless Communications (2020).