Fronthual and frame structure optimization for regenerative LEO-based satellite networks

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Abstract—This paper presents a system model that extends the structure of C-RAN (Cloud Radio Access Network) utilizing functional splits to LEO (Low Earth Orbit satellite) communication to efficiently deploy the LEO satellites by sharing them. In such a non-terrestrial network (NTN), joint optimization of transmit power and inter-satellite link (ISL) fronthaul compression of data and pilots to both maximize the uplink throughput and minimize the bandwidth of ISL and feeder link is formulated and solved.

Keywords—NTN, LEO, fronthaul, compression, ISL, frame optimization

Recently, a non-terrestrial network (NTN) has been standardized to realize a three-dimensional network with the existing terrestrial network. As one of the system architectures, a gNB-DU payload scheme that is like the open radio access network (ORAN) architecture, where a gNB is divided into a radio unit (RU), distributed unit (DU), central unit (CU) and these units are connected with a fronthaul interface, has been considered. In the NTN based on LEO satellites, the CU's function is in a ground gateway (GW), and the DU's and RU's functions are implemented in the LEO satellites. Especially, the DU's functions are included in the LEO satellite which is directly connected to the ground GW as shown in Fig. 1. In this system model, the feeder link and inter-satellite link (ISL) are assumed to share the bandwidth resource, i.e., a part of bandwidth is used for the feeder link and the remaining resource is exclusively used by multiple ISLs to avoid interference among these links. If this bandwidth for the feeder link and ISLs is minimized, the remaining resource can be used by others. It means that the bandwidth for the feeder link and ISL should be minimized. On the other hand, because the DU and RU are split by a resource element (RE) (de)mapping block. In the fronthaul link, i.e., ISL, data and pilot REs are separately delivered. To reduce the fronthaul capacity, the compression of data and pilot signals is required, and this compression can degrade the quality of signals. Therefore, to increase the uplink rate from user equipments (UEs) to the GW, more bandwidth of fronthaul and feeder links is required. It means that there exists a tradeoff between uplink rate and feeder and fronthaul link bandwidth. In this study, we investigate this tradeoff and formulate an optimization problem to maximize the uplink rate and minimize the bandwidth of fronthaul and feeder links by adjusting the transmit power and compression in the fronthaul link for both data and pilot signals. The proposed optimization problem is too complicated to solve directly. Alternatively, we separate the original problem into several sub-problems with a single optimization parameter by fixing the other parameters. An alternating optimization algorithm in which the sub-problems are iteratively solved is developed. The sub-problems can be rewritten as convex problems through proper approximation and the closed-form solutions can be obtained analytically. Through numerical simulations, the analytical solutions of sub-problems are verified, and the convergence of the proposed alternating optimization algorithm is examined.

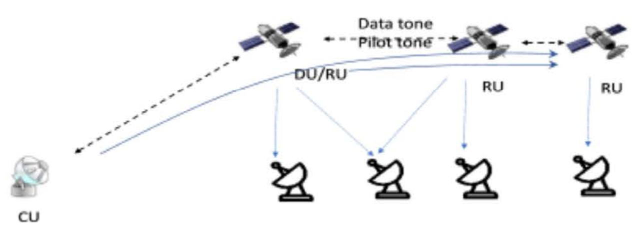

Figure 1. Regenerative ORAN-NTN system model.

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