Hybrid Computational Offloading in Terrestrial Networks using Uplink NOMA

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Abstract

This paper proposes a hybrid computational offloading in terrestrial networks using Uplink Non-Orthogonal Multiple Access (NOMA). This involves determining the best offloading decision between the Mobile Edge Computing (MEC) server and the satellite. The proposed approach aims to minimize the impact of the offloading decision on user energy consumption. Simulation results demonstrate the effectiveness of the offloading decision with the Uplink NOMA approach, highlighting its potential for minimizing the energy consumption for computation offloading in terrestrial networks.

I. Introduction

Meeting the demand for substantial computational power for user equipment (UEs) poses a notable challenge, due to the high computational capability and energy consumption required. Mobile edge computing (MEC) has been proposed as a potential solution, which integrates base stations (BS) and edge servers to offer UEs increased computation processing and storage resources [1][2]. In addition to MEC, cloud computing can also assist the computation offloading, as the MEC server computation is still limited. Some previous research mentioned that cloud computing is connected through the LEO satellite network to assist more general users in remote areas and the ocean for the terrestrial networks. However, restricted by the height of LEO satellites, the transmission delay of users in the LEO satellite networks will increase correspondingly alongside the energy consumption, making it difficult to meet the real-time requirements of ground users.

To assist the communication delay, communication techniques such as NOMA can be implemented in the system to aim for lower transmission latency, higher spectral efficiency, and enhanced user fairness in the system. In this paper, Uplink NOMA is used to assist a hybrid computational offloading. Where the user must offload their task to either the MEC server or the LEO satellite to determine the best offloading decision. In addition, this paper investigates the offloading decision and the impact of the NOMA and OMA in the hybrid computation offloading scenarios in terrestrial networks.

II. Proposed System and Problem Formulation

The proposed system can be seen in Fig. 1. A set of user in user cluster is denoted as $\kappa \in \{1, \cdots M\}$. Due to each UEs CPU limited computational capacity, the UEs must offload their data to the MEC server. However, if the resource in MEC server is full, the data then can be offloaded to the cloud server in the LEO satellite. The task offloading placement decision variable for UE as $W_{\kappa,\varkappa} = \{0,1\}$ which is task offloaded to LEO satellite or offloaded to the MEC server.

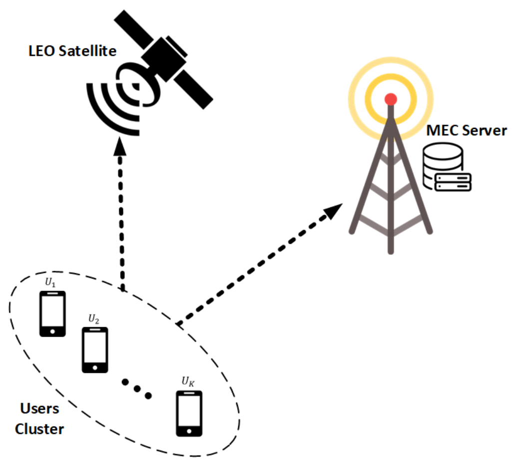

Figure 1. Proposed System

To measure the LEO satellite coverage, the formulation can be denoted as follows:

$$\beta_0 = \arccos\left(\frac{R_m}{R_m + h} \cdot \cos\varepsilon_0\right) - \varepsilon_0. \quad (1)$$

Based on the β_0 value, which is the planet center angle to the LEO satellite, the arc length of the satellite can be denoted as follows: $L = 2 \cdot (R_m + h) \cdot \beta_0$. The total available communication time between the user and the satellite is denoted as: $T = \frac{L}{v_s}$, where v_s is the satellite velocity. Furthermore, square distance between user to satellite is denoted as [3]: $s_m = \sqrt{R_m^2 + (R_m + h)^2 - 2 \cdot R_m \cdot (Rm + h) \cdot cos\beta_0}$.

The total delay caused by offloading to the satellite can be calculated as:

$$T^{S}_{\kappa,\varkappa} = \frac{s_{\kappa,\varkappa}}{c} + \frac{D_\kappa}{R_{\kappa,\varkappa}} + \frac{X_\kappa}{f^{S}_{\kappa,\varkappa}} \quad \forall \kappa, \varkappa \qquad (2)$$

While the total delay caused by offloading to the MEC can be calculated as:

$$T^{MEC}_{\kappa,\varkappa} = \frac{s_{k,\varkappa}}{c} + \frac{D_\kappa}{R_{k,\varkappa}} + \frac{X_\kappa}{f^{MEC}_{k,\varkappa}} \quad \forall \kappa, \varkappa \qquad (3)$$

Where $f^{S}_{k,\varkappa}$ is the satellite computation capability, $f^{MEC}_{k,\varkappa}$is the MEC computation capability, D_k is the input data size, and c is the velocity of light. The data rates follows NOMA Uplink, where:

$$R = \log_2\left(1 + \frac{P_i|h_i|^2}{P_I|h_I|^2 + N_o}\right). \qquad (4)$$

III. Result

The simulation parameters are as follows; $f^{S}_{k,\varkappa}$ = 10 Gcyles/s; and $f^{MEC}_{k,\varkappa}$ = 3 Gcycles/s; The result can be seen in Fig. 2, where the optimized and random offloading decisions are compared. The results indicate that employing optimized offloading decisions with OMA and NOMA strategies leads to a slight reduction in energy consumption for the user when contrasted with the outcomes of random offloading decisions.

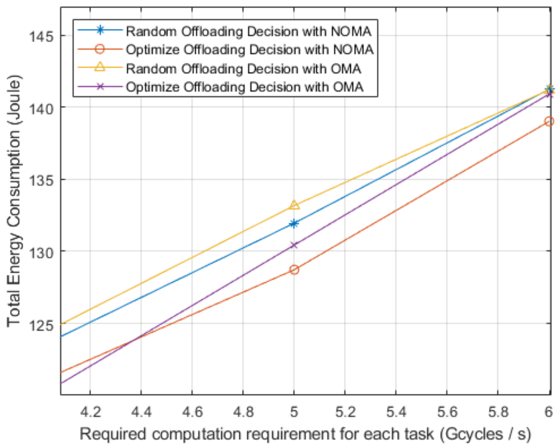

Figure 2. Result of Total Energy Consumption

IV. Conclusion

This paper proposes a hybrid computational offloading in terrestrial networks using Uplink NOMA by determining the best offloading decision between the MEC server and the satellite. The proposed approach aims to minimize the impact of the offloading decision on user energy consumption. Simulation results show the difference of the optimize and random offloading decision with the Uplink NOMA and OMA approach, highlighting its potential for minimizing the energy consumption for computation offloading in terrestrial networks. In the future, a air-relay technology can be considered to minimize the time latency for offloading to the satellite.

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REFERENCE

[1] N. Abbas, Y. Zhang, A. Taherkordi and T. Skeie, "Mobile Edge Computing: A Survey," in IEEE Internet of Things Journal, vol. 5, no. 1, pp. 450-465, Feb. 2018.

[2] C. Tang, C. Zhu, N. Zhang, M. Guizani, and J. J. P. C. Rodrigues,"SDN-assisted mobile edge computing for collaborative computation offloading in industrial internet of things," IEEE Internet of Things Journal, vol. 9, no. 23, pp. 24 253–24 263, 2022.

[3] Q. Tang, Z. Fei, B. Li and Z. Han, "Computation Offloading in LEO Satellite Networks With Hybrid Cloud and Edge Computing," in IEEE Internet of Things Journal, vol. 8, no. 11, pp. 9164-9176, 1 June1, 2021.