Joint Optimization of Reconfigurable Intelligent Surface-assisted Task Offloading in Mobile Edge Computing for Beyond 6G Communication

Daniar Estu Widiyanti, Krisma Asmoro, *Soo Young Shin
Department of IT Convergence Engineering,
Kumoh National Institute of Technology (KIT), Gumi, South Korea
Email: {daniarestuw, krisma, *wdragon}@kumoh.ac.kr

Abstract

Beyond 6G services and application demand high and efficient processing capacity, due to the massive connectivity of users equipment (UEs). However, high computational capability and energy consumption of UEs are limited, then it becomes a main challenge to overcome. Recently, mobile edge computing (MEC) is studied widely, because of it potential to assist complex task executed at UES. The challenge in MEC is the line-of-sight (LoS) issue from UEs to base station (BS) due to blocking objects. Furthermore, it can increase offloading latency and energy consumption. Reconfigurable intelligence surfaces (RIS) are deployed to assist multiple-input-single-output (MISO) BS to overcome non-line-of-sight (nLoS) case. The main contribution of this study is to develop a low-complexity algorithm to jointly optimize offloading strategy, BS transmit and RIS reflect precoding. In addition, the uplink and downlink is considered in this study. The simulation shows that the impact of the algorithm can minimize delay for UEs.

I. Introduction

The requirement for user equipment (UEs) in beyond 6G is a powerful computation. However, high computational capability and energy consumption of UEs are the main challenge to overcome. Therefore, one of the solutions is the mobile edge computing (MEC) [1]. This technique proposes an integration of base stations (BS) and edge servers. Further, it can provide UEs with higher computation processing and storage resources, which can significantly reduce response latency and computation time[2].

Reconfigurable intelligence surfaces (RIS) is one of the strong candidate as a device to assist wireless communication in beyond 6G, which will operates at The next generation new radio (NR) standard at frequencies over 6 GHz[3]. Due to high-frequency transmissions are sensitive to an obstacles[4], it will cause a weak offloading rates. Further, it can affect UEs that has non-line-of-sight (nLoS) to the BS, which is resulting in an increasing offloading latency and energy consumption[5]. RIS that comprises of low-cost element, has been suggested as a practical way to overcome nLoS issue and improve energy efficiency.

In this study, reconfigurable intelligence surface (RIS) is deployed to assist multiple-input-single-output (MISO) base station (BS). The RIS is capable of increasing a signal-to-noise ratio (SNR) which can assist task offloading for UEs whose position is distant from the optimal transmission rate or suffering nLoS communication. The main contribution of this study, is to develop a low-complexity algorithm to jointly optimize offloading strategy, BS transmit and RIS reflect precoding.

II. Proposed System and Problem Formulation

The proposed RIS-assisted edge computing system can be seen in Fig. 1, The set of user equipments (UEs) in user clusters is denoted as $k \in \{1, \dots K\}$, where K is the total number of UEs. Due to each UEs CPU limited computational capacity, the UEs could offload the data to the computational node in the multiple-input-single-output (MISO) base station (BS). In the user cluster, K UEs are distributed at random and can be categorized as having *good* or *poor* signal reception depending on how close each device to the BS.

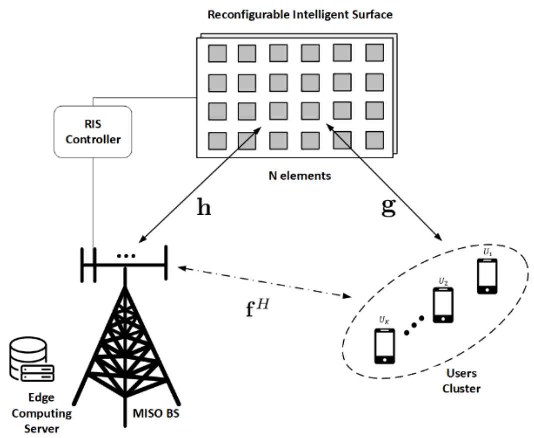

Figure 1. Proposed System

The task offloading placement decision variable for UE as $x_{i,k}$ which can be divided as: $x_{i,k} = \{0,1\}$ which is task offloaded to MISO BS or processed locally. When a task is locally processed by the UEs, the computation delay denoted as: $t^L_{i,k} = \frac{\omega_i}{f^l_k}$ where, ω_i is the computation amount of the *i*th task, f^l_k is the CPU computing capabilities of *k*th UE. If the task is offloaded to the edge server through MISO BS, the computation delay is denoted as: $t^E_{i,k} = \underbrace{\frac{D_i}{r^{UL}_{i,k}}}_{SendingData} + \underbrace{\frac{\omega_i}{1_i f^c_k}}_{Computation} + \underbrace{\frac{D_i}{r^{DL}_{i,k}}}_{RecievingData}$

where D_i is the data size of each task, $f_k{}^c$ is the CPU computing capabilities in edge server and $r^{UL}_{i,k}$, $r^{DL}_{i,k}$ is the data rate for uplink and downlink transmission. The problem formulation for minimizing average task duration:

$$min_{x,\ell} \sum_{i=1}^{k} \left[x_{i,k} \frac{\omega_{i,k}}{f^l_i}\left(1 - x_{i,k}\right) + \left(\frac{D_i}{r^{UL}_{i,k}} + \frac{\omega_i}{1_i f^c_k} + \frac{D_i}{r^{DL}_{i,k}} \right) \right] \quad (1)$$

Subject to:

$C1: \sum_{i\epsilon o} \ell_k \leq 1$, (2)

The problem (1) is a mixed integer non-linear optimization problem, as can be seen. As a result, alternative optimization algorithms for resource allocation problems (ℓ_i) are considered in the paper. By using Karush-Kuhn Tucker (KKT) conditions, we can get the optimal value as: $l_i^* = \frac{\sqrt{\omega_i}}{\sum_{i\epsilon o_j}\sqrt{\omega_i}}$. In this study, we propose a joint optimization precoding and RIS phase shifter. Suppose the set of precoding vector of K user is denoted as $W = [W_1^T, \ldots, W_K^T]^T$ and the RIS phase is $\theta = diag\{e^{j\theta 1}, \ldots, e^{j\theta N}\}$. Problem formulation for energy-efficient RIS-aided MISO task offloading can be written as:

$$\max_{W,\Theta} \eta = \frac{R}{P} \quad (3)$$

Subject to:

$$C1: \xi \sum_{k=1}^{K} ||w_k||^2 + W_{BS} \leq P_{BS}^{max}, \quad (4)$$

$$C2: |\theta_n| \leq 1, \forall_n \in [N] \quad , (5)$$

where $C_1$and C_2 are the maximum power consumption of BS and passive RIS. C_3denotes the feasible sets of N RIS phase shifter. In addition, we consider that there is no amplification factor at the RIS. However, solving the problem (3) is very hard due its non-convexity. Therefore, the problem is reformulated by utilizing fractional programming (Dinklebach Algorithms) and solving η^*.

III. Result

Offloading schemes simulation setups are divided into two different offloading strategies: random offloading scheme and uniform offloading scheme. Where a Random offloading scheme places the task computation randomly, either offloaded to the edge cloud for processing or processed locally and a Uniform offloading scheme is dividing all the tasks into two parts depending on UEs battery capacity. Each parameters are set as follows: Data size D_i is random, following Normal Distribution with mean 25 MB; f_k^c = 25 GHz;

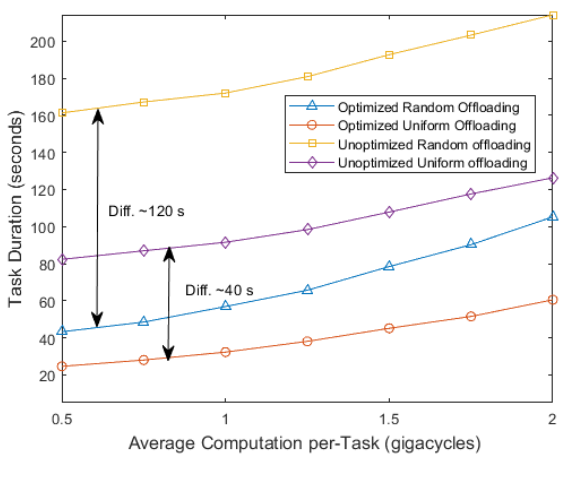

Figure 2. Result (Average Computation per-Task)

f_k^l= 10 GHz; total task i = 500; P_{BS} = 9dB; W_{BS} = 6dB; W_{UE} = W_{PS} = −20dB; N_t = 6. The coordinate location (x,y) of BS and RIS are (0, -20) and (100, 5), respectively (in meters). The location of UEs are following uniformly distributed pseudo-random integers, ranging from 50 to 100. Figure 2 depicts that our proposed system is perform better with optimal BS precoding. In term of random offloading scenario, the proposed system perform 120 s faster.

IV. Conclusion

RIS-assisted task offloading shows that the RIS can assist UEs whose position is categorized as poor signal based on their distance from BS. Result show that the impact of the RIS-assisted task offloading can enhance spectral efficiency (SE) and minimize delay for the number of UEs. The implementation of UAV-relay aided network is interesting for future research direction. Moreover, users movement and multiple cluster can be considered for future research.

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